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Investigation of Slenderness Ratio for Cold-Formed C-Section

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***Abstract:* -- Cold-Formed Steel (CFS) has been used as a primary & secondary structure for flexural and compression member. Cold-formed sections have various advantages such as high strength to weight ratio, high corrosion resistance, and ease of fabrication. The criteria need to be considered in improving the structural strength in the fabrication method. Fast and easy fabrication can produce an efficient structure. Design of cold formed sections has obvious complexity in view of buckling and flexure due to use of slender section. Hence to avoid Lateral & Torsional Buckling of member various investigations have been carried out by researchers. In this paper a detailed review of research carried out by researchers worldwide has been discussed. The investigation is expected to aid in finalizing configuration of cold form profiles while modeling and analysis.**

Keywords:- Cold Formed Steel, Lateral & torsional Buckling, Slenderness

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I. INTRODUCTION

A Pre Engineered Steel Building (PEB) mainly consists of a steel frame as primary framing and cold form purlins and sheeting for roof and walls as secondary framing. Purlins and girts are roll formed C or Z section. Girts are beams subjected to irregular bending. These support vertical dead load from the sliding and horizontal wind loads. To make economical design of structures, the area of great interest of the researchers to get lighter and cheaper steel sections. Cold formed sections are thin walled steel section. Cold formed sections has highly slender webs and flanges and used as a primary & secondary structure for flexural and compression member. Cold formed sections has various advantages such as high strength to weigh ratio, high corrosion resistance, and ease of fabrication. In case of cold formed sections, thickness is very less hence lateral & torsional Buckling will occurs in such Sections due to impact of loads. The strength of members made of such thin sections depends on their slenderness ratio. Higher strengths can be obtained by reducing the slenderness ratio i.e. by increasing the moment of inertia of the cross-section. Similarly, the strengths of beams can be increased, by increasing the moment of inertia of the cross-section. And for given cross-sectional area, higher moment of inertia can be obtained by making the sections thin-walled. Fig.1 Shows Local, Distortional and Global Buckling.

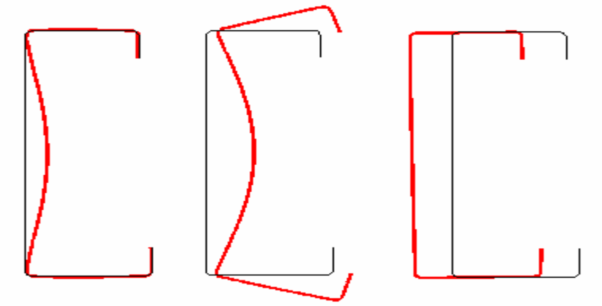

Figure 1[11]: Local, distortional and global buckling

II. LITERATURE REVIEW

Hancock et.al.[1] described, a method of inelastic buckling analysis of thin walled structural members and plates, based on finite strip method of structural analysis. Researcher analyzed Beams, Columns, and Plates. The residual stress distribution and the non-linear stress strain properties of the material were taken into account. Further researcher inelastic theory for plate buckling divided into two groups i.e. deformation theory of plasticity and flow theory of plasticity. Both flow theory and deformation theory were summarized by researcher. The buckling modes and load computed are compared with theoretical values and test results.

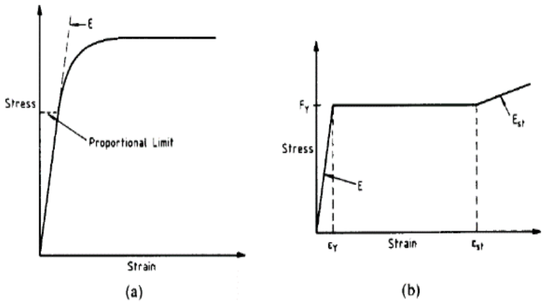

Figure 1: (a) Stress-strain curve for cold-formed steel. (b) Idealised stress-strain curve for hot rolled steel.

Khong et.al.[2] described, a theoretical and experimental study of buckling behavior of channel beams with unbraced longitudinal edge stiffener, Also described the distortional buckling failure mode and behavior of short and long beam. A semi-Analytical and semi-Numerical approached was used in theoretical analysis to predict the critical lateral torsional buckling moments of thin beams. Further Researcher described that the modes of failure were not only depend on length, geometry and material property but also on how the bending loads has been applied. Finally researcher compared the theoretical and experimental results and found that the agreements obtained were good when the effective length was taken in the range of 0.7 to 0.8 of original length.

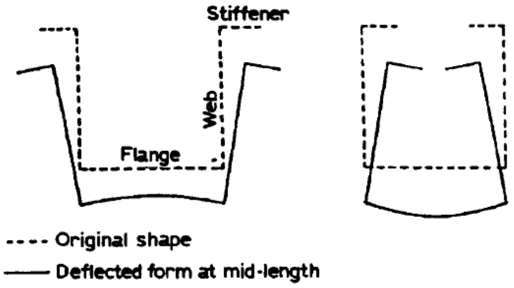

Figure 2: Deflected form for short channel beams.

Kwon et.al [3] tested two different section geometrics between fixed boundary conditions. Researcher taken two sections, a simple lipped channel section and a lipped channel section with intermediate stiffener in the web. The Distortional buckling will usually occurs in the flanges of the channel sections if the lip stiffener is inadequate to prevent movement normal to the plane of the flange it supports. In this paper, tests were described and design curves for sections undergoing distortional buckling were provided. The compression tests on lipped channel sections, with and without intermediate stiffener in the web were performed and investigated post buckling in the distortional and mixed local distortional mode, researcher proposed two design equations on extension of previous study on column buckling analysis and second modification on plate strength design approach as used for distortional buckling in the AISI specification when the lip was not adequate to fully support the flange.

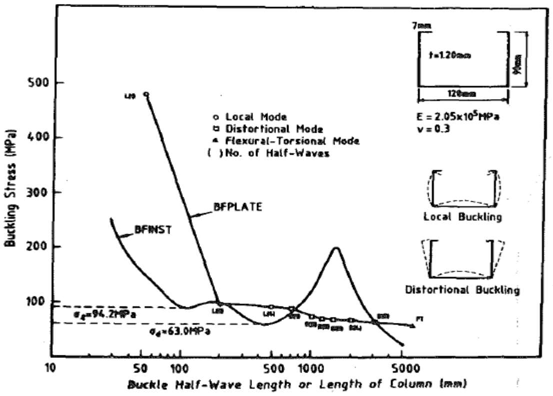

Figure 3: Buckling Analysis for Simple Lipped Channel

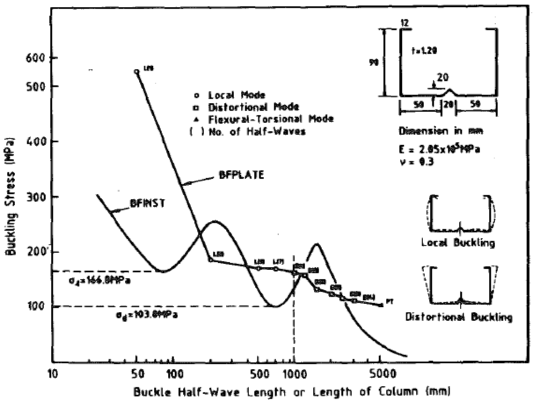

Figure 4: Buckling Analysis of Stiffened Lipped Channel

Kikidis et.al.[4] described, the influence of the slenderness ratio of a beam with a cross sectional open crack and the behaviour of the beam was investigated. The numerical results were obtained from Euler's- Bernoulli theory and compared with Timoshenko theories for different crack Depths and different slenderness ratio of the beam, also the effects of the slenderness ratio on the beam response curves and the resonant frequencies of the system were examined. In this paper, a parametric analysis of the influence of slenderness ratio and the crack depth on the vibrational behaviour of beams was investigated and concluded that the influence of the shearing deflection on the resonant frequency decreases with the increase in slenderness ratio.

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Hancock et.al [5] described, a design method for Distortional buckling of flexural members and methods for computing the elastic buckling stress. Design curves for determining the distortional buckling strength and a design method for computing the distortional buckling strength of the compression flange of C and Z- Sections under bending about an axis perpendicular to web were presented and proposed two different strength design curves.

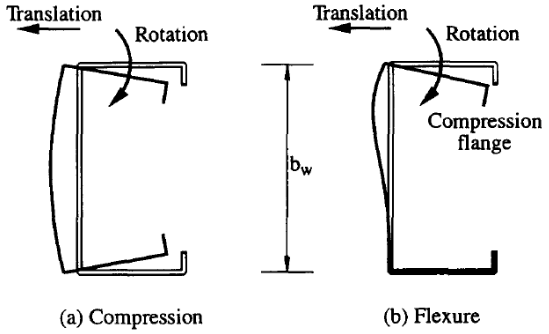

Figure 5: Distortional Buckling Modes

Dr.Varghese et.al [6] described. Cold Formed and Hot Rolled Steel Sections and advantages of Cold Formed Steel over Hot Rolled Steel Sections. Researcher analysed the Industrial Building with Cold formed Concept and also did parametric study. A comparative study between hot Roll Steel Industrial Building and Cold Formed Steel Industrial Steel Building carried out by design as per IS 801:1975 and BS 5950 Part 5-1998. Researcher concluded that the Weight of Cold Formed Steel is lighter than Hot Rolled Steel and Hence the Industrial Building designed by Cold Formed Steel is Economical and overall saving of Cost and material was around 25%.

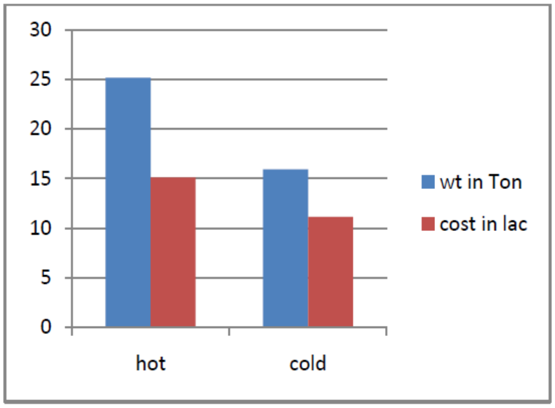

Figure 6: Comparison of cost and weight of CFS and HRS

Shivakumaran et. al[7] developed a Finite Element Model to analysed and predict the post buckling behaviour of perforated & non-perforated Cold Formed Steel members which were subjected to axial compression. A 9-Node non-linear “assumed strain” shell finite element to represent the body of CFS section model utilised and stress strain relationship, residual stress idealizations, geometric imperfection distribution, a special loading system and displacement solution algorithm derived experimentally utilised by the finite element model.

Gotluru et.al [8] The research on the behaviour of cold-formed steel beams subjected to torsion and bending is summarized in this paper. The effect of transverse loads creates torque as the loads applied away from the shear center. Finite strip analyses, Simple Geometric Analyses and finite element analyses were performed and compared with experimental results. The Beam element and Shell elements were analysed using ABAQUS.

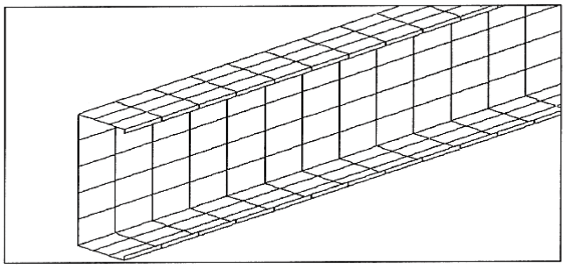

Figure 7: Analytical modeling of beams by shell elements using ABAQUS

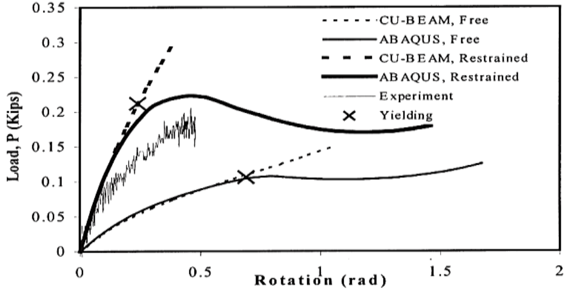

Figure 8: CU-BEAM and ABAQUS for support Free and Restrained Condition

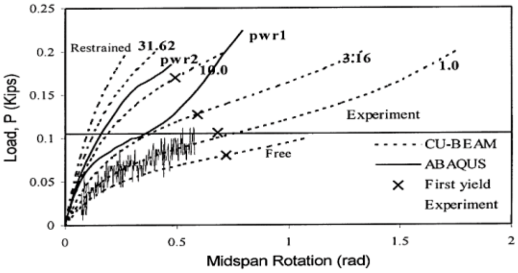

Figure 9: CU-BEAM and ABAQUS results for support warping restraints

The Load rotation curves compared to the curves obtained from ABAQUS shell Analysis as represented in Graphs. The estimation of Strength based on lateral torsional Buckling, may under or overestimate the strength as per AISI procedure. The local buckling load decreases with the rotation of the beam, and the lateral-torsional buckling load increases and beams with slender elements, local buckling influences the behaviour. Also found that the mode of failure not changed, but the strength of the beam was reduced. Therefore, for design the effective section concept may be used to calculate the strength of the beam.

K.C.Lin et.al[9] The results of 66 past experiments in Taiwan were reanalyzed by researcher, comparing connection ductility across failure modes. The failure mode and root cause identification was made for each specimen. 56 of the specimens were found to fail for the main three modes. The tests examined 5 types of specimens, connections used conventional BWWF details, increase the seismic capacity by adding cover plates and wing plates to the beam flanges, connections reduce the seismic demands by perforating the beam flanges and changing the beam sections, After conducting the tests on specimens, 43% of the connections were found to fail for flange-HAZ fracture, 27% for flange-weld fracture, and 16% for flange buckling. Then, reanalysis was made on the 56 sets of connection testing that showed that three failure modes.

Guzmán et.al.[10] conducted an experimental investigation on 48 samples (24 samples of 2 mm and 24 samples of 1.5 mm thickness) to determine comparative behaviour under compression load of box section made up of C- Section members. Members were connected by weld ranging from 100 to 900 mm Spacing. The length of member 900 mm and cross section was 100mm x100 mm with thickness 1.5 mm & 2 mm resp.

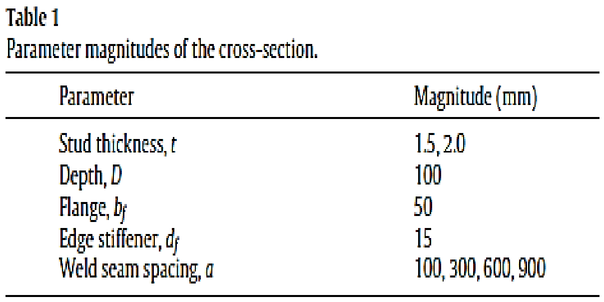
Table 1
Parameter magnitudes of the cross-section.

Parameter	Magnitude (mm)
Stud thickness, t	1.5, 2.0
Depth, D	100
Flange, b_f	50
Edge stiffener, d_f	15
Weld seam spacing, a	100, 300, 600, 900

Researcher used Fixed and Flexible support condition for experimental investigation and concluded that the actual slenderness ratio could be used to compute the ultimate load capacity for these structural members if the seam weld spacing is less than or equal to 600 mm. The values were slightly affected by the type of support as represented in Graphs.

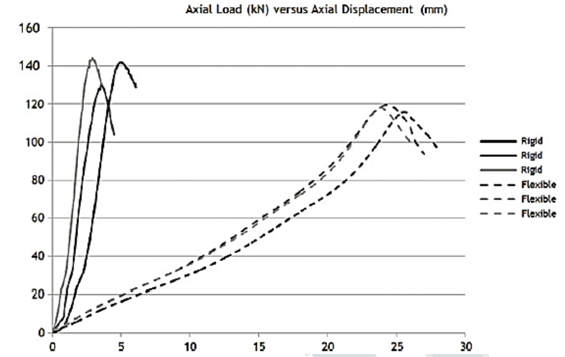

Figure 10: Comparative behaviour of samples under Rigid versus Flexible support condition for Box Members 100x100-1.5 mm and weld spacing of 900 mm.

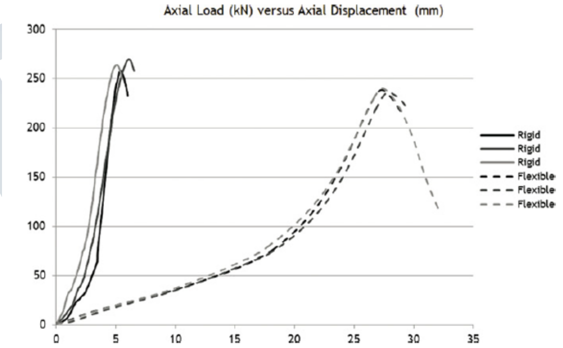

Figure 11: Comparative behaviour of samples under Rigid versus Flexible support condition for Box Members 100x100-2 mm and weld spacing of 900 mm.

III. CONCLUSION

Results of current study gives the ultimate load carrying capacity of a wide range of sections with different values of flange slenderness ratio, web slenderness ratio and unbraced length ratio which control the overall slenderness ratio of a structural member. It is also observed that use of thin walled sections with a good theoretical background knowledge and understanding of variation of local slenderness ratio with respect to overall slenderness ratio may lead to a safe and highly economical design. The use of compact flanges and webs is not advisable as in case of higher unbraced length ratios, the use of compact section even has adverse effect. It is also found that there is an interaction between the overall slenderness ratio and local slenderness ratio of built up section elements. For small unbraced length ratios the steel members with thick flanges are preferable whereas for high unbraced length ratio where overall slenderness ratio of the members governs the design, use of slender elements may lead to a good design with minimum weight of the section.

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