DISTORTIONAL BUCKLING STUDY OF COLD FORMED COLUMNS UNDER AXIAL LOADING

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Abstract - *Cold-formed steel sections are commonly used in civil construction as both secondary and primary structural members. The stainless steel has a wide range of applications starting from truss, wall claddings, roof sheeting, canopies, storage tanks and steel rebar. Most cold-formed steel members exhibit slender cross-sections, a feature making them highly prone to several individual local , distortional , global or coupled buckling phenomena. In fact, depending upon the member geometry and loading, any of these instability phenomena may be critical. Distortional buckling governs the structural response of members with "intermediate lengths". In this project the distortional buckling of CFS channel section s studied. The influence of circular rings and spacers are studied.*

Key Words: **Cold-formed steel, Distortion, Buckling stress, Edge Rod stiffener, Flange rod stiffener, Mid Flange ring stiffener, Flange rod stiffener**

1. INTRODUCTION

In steel construction, there are primarily two types of structural members as hot-rolled steel shapes and cold-formed steel shapes. Hot-rolled steel shapes are formed at elevated temperatures while cold-formed steel shapes are formed at room temperature, thus the name cold-formed steel.

Cold-formed steel (CFS) as we know it today is one of the newest structural systems used in residential and nonresidential construction, but in a few short decades has grown into one of the most commonly used materials in developed economies around the world. Countries experiencing rapid economic and industrial development, including China, India, and throughout the Middle East, South America, and Africa, are increasingly looking to CFS because it allows builders to erect new homes and offices in a fraction of the time compared with traditional construction materials. Cold-formed steel members are made from structural quality sheet steel and formed into shape, either through press-braking blanks sheared from sheets or coils, or more commonly, by roll forming the steel through a series of dies. Fig 1 (a, b)

1.1 Buckling In Cold Formed Steel Section

CFS members invariably display very slender thin-walled open cross-sections, a feature making them highly susceptible to several instability phenomena, namely local (L), distortional (D), and global (Flexural or flexural torsional) buckling. The overall structural response and ultimate strength are affected by these instability phenomena, which explains why they must necessarily be incorporated in CFS specifications.

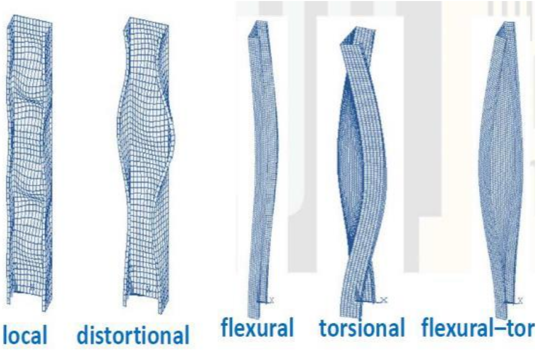
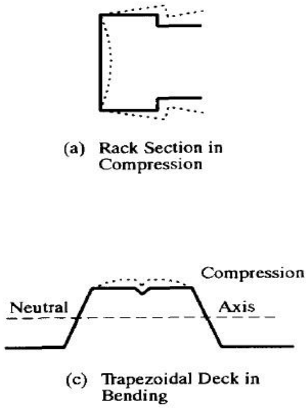


Fig -1: Different forms of Buckling in cold formed steel sections [1]

1.2 Distortional Buckling In Cold Formed Steel Sections

A mode of failure of thin-walled sections in compression and bending, in which edge-stiffened flange elements of the sections deform by rotation of the flange about the flange-web junction ,or where the intermediate stiffener in a flange moves normal to the flange, may occur in sections composed of high-strength steel. This mode of failure has been called distortional buckling. The distortional mode of buckling occurs at longer wavelengths than local buckling and involves membrane displacements of the edge or intermediate stiffeners forming the section. The distortional buckling modes are shown for a rack section in compression, a channel section in compression, a trapezoidal deck in bending and a Z-section in bending in Figs l (a), (b), (c) and (d) respectively.



(a) Rack Section in Compression

(b) Channel Section in Compression

(c) Trapezoidal Deck in Bending

(d) Z-Section in Bending

Fig -2: Distortional buckling in different sections [1]

Importance of distortional buckling is generally not recognized, because the distortional buckling was not addressed in existing BS5950-PART 5 for cold formed steel sections and because most section profiles made by UK manufacturers were designed based on old steel grade (S275)for which the section is dominated by local buckling and/or material yield. However in recent times due to improvement in CFS yield strength can reach 550MPa leading to distortional buckling becoming critical as local buckling. Also the design formulas provided in code is too complicated and involves many parameters

2. ANALYTICAL STUDIES

Numerical modeling was carried out using ANSYS APDL 16.0, a finite element software for mathematical modeling and analysis. Material property for the SLC model was selected from engineering data section of the software, where all the available materials are pre-assigned with a default value for various properties. Geometry of the SLC section was sketched in the APDL window. The SLC section was formed by drawing the key points of column and were extruded along the line. Stiffeners of different pattern are provided at various locations

2.1 Specifications of Numerical Model

Stiffened Lipped channel column section of size 140x140x5mm was investigated. Cold formed steel SLC section dimensions are tabulated in Table. Geometric dimension of stiffeners are provided. Beam section of higher strength is provided at two edges so as to apply the load.

Table -1: Geometric dimension of control section

Lip depth (d)	5.13 mm
Web height (h)	137.70 mm
Flange width (b)	139.81 mm
Thickness (t)	1.44 mm
Length (L)	1.220 mm
Length of Flange stiffeners (S_{1f})	30.5 mm

2.2 Steel column Stiffener - Specification and Patter

Model was analyzed with and without stiffeners. Stiffeners were provided around the section in order to prevent the distortional buckling effectively. Distortional buckling increasingly affect the flange section. All the possible distortional buckling modes are identified and external stiffeners are provided. Stiffeners provided are Type-1 Edge Rod stiffener (ERS), Type- 2 Flange rod stiffener (FRS), Type - 3 Mid Flange ring stiffener (MFRS), Type-4 Flange rod stiffener (RS).

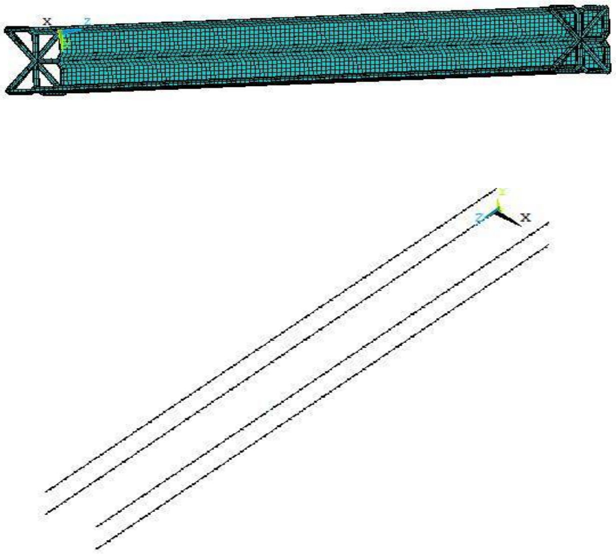


Fig -1: Type-1 stiffener and its location

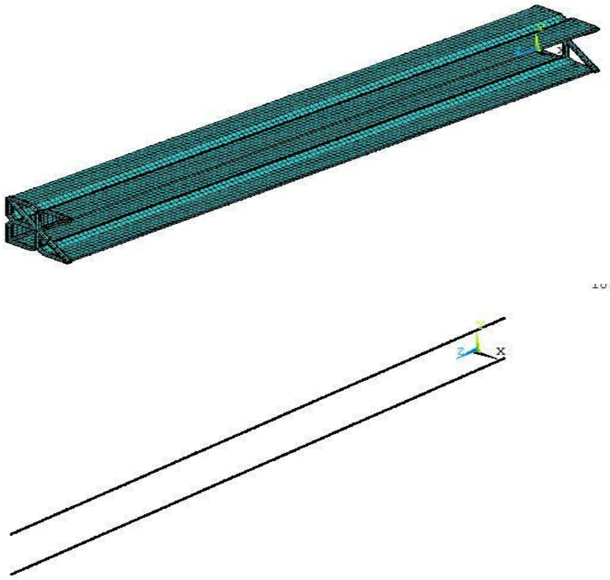


Fig -2: Type-2 stiffener and its location

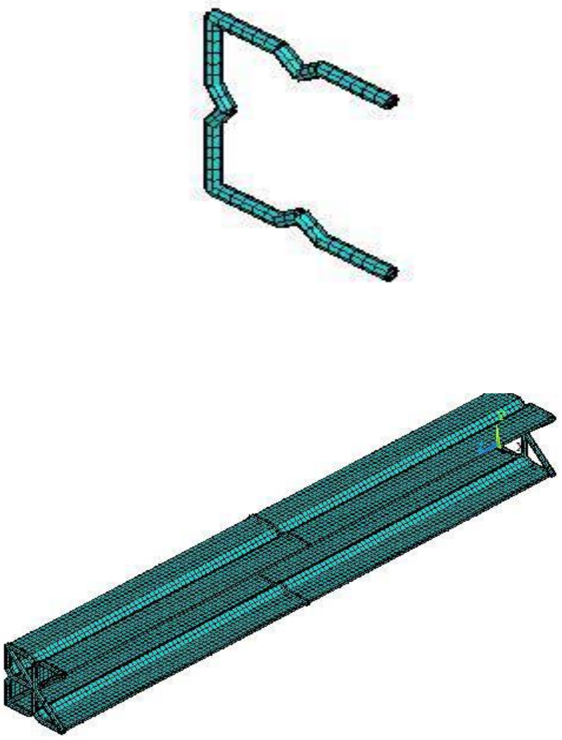


Fig -3: Type-3 stiffener and its location

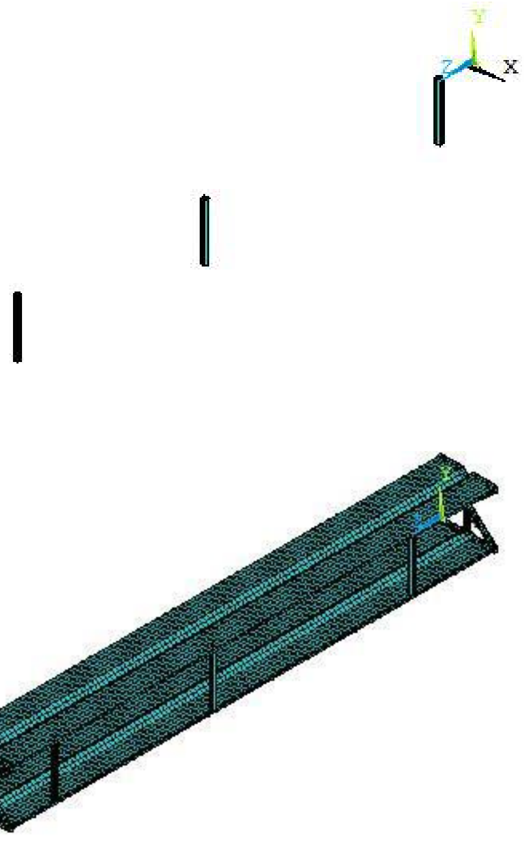


Fig -4: Type-4 stiffener and its location

2.3 Meshing and Loading conditions

Meshing is an integral part of the Computer-Aided Engineering (CAE) simulation process. The mesh influences the accuracy, convergence and speed of the solution. Furthermore, the time it takes to create and mesh a model is often a significant portion of the time it takes to get results from a CAE solution. Therefore, the better and more automated the meshing tools, the better the solution. Proper connection between various parts of the geometry also needs to be ensured before meshing. From easy, automatic meshing to a highly crafted mesh, ANSYS provides the ultimate solution. Powerful automation capabilities ease the initial meshing of a new geometry by keying off physics preferences and using smart defaults so a mesh can be obtained upon first try. Additionally, a user can update immediately to a parameter change, making the handoff from CAD to CAE seamless and aiding in upfront design. Once the best design is found, meshing technologies from ANSYS. Do not use abbreviations in the title or heads unless they are unavoidable. provide the flexibility to produce meshes that range in complexity from pure hex to highly detailed hybrid; a user can put the right mesh in the right place and ensure that a simulation will accurately validate the physical model. For solid models, meshing technologies from ANSYS provide robust, well-shaped quadratic tetrahedral meshing on even the most complicated geometries. ANSYS meshing technologies provide physics preferences that help to automate the meshing process. For an initial design, a mesh can often be generated in batch with an initial solution run to locate regions of interest. Further refinement can then be made to the mesh to improve the accuracy of the solution. By setting physics preferences, the software adapts to more logical defaults in the meshing process for better solution accuracy. For the present work, meshing was done by keeping advanced size function fixed. A uniform mesh of fine relevance and high smoothing was used for having a more defined mesh, so that obtained solution is of highest accuracy. The size of mesh was a 0.01 m. Automatic mesh based disfeaturing option was turned off.

Support condition of the column was adopted by carefully analyzing the behavior of column against buckling during static condition. If the structure is provided with hinged or point support the column may experience the effect of other buckling types such as the elastic local buckling and the torsional buckling. In order to simulate distortional buckling in the structure support condition is provided as fixed at the bottom edge with restraining all the movements and rotations. A load of 120 kN was applied as axial load to the compression member along the z direction. The load is applied gradually to obtain the effect of each time step of loading.

2.4 Analytical Results

Static non-linear analysis of cold formed steel channel section with and without stiffeners was carried out using

ANSYS16.0 APDL. The axial and lateral deformation, buckling stress were obtained from the numerical study. Different patterns are compared and the load carrying capacity was noted. A comparative study was made with the control column and the stiffened columns based on the position of stiffening and the diameter of the stiffener.

Table -1: Axial deformation and peak load of different pattern stiffeners

Type of stiffener	Radius of stiffener (mm)	Maximum axial deformation (mm)	Ultimate Load (kN)
TYPE-1 Four Edge stiffener (ERS)	2	1.631	107
	3	1.544	107
	4	1.56	107
	5	1.56	107
	6	1.55	107
	7	1.52	107
	8	1.32	107
	10	1.8	107
TYPE-2 Flange rod stiffener (FRS)	2	1.632	107
	3	1.631	107
	4	1.58	107
	5	1.537	107
	6	1.332	107
	7	1.351	107
	8	1.21	108
	9	1.6	107
	10	1.63	107
TYPE-3 Mid Flange ring stiffener (MFRS)	2	1.632	107
	3	1.62	107
	4	1.43	107
	5	1.398	107
	6	1.375	109
	7	1.78	106
	8	1.82	106
TYPE-4 Flange rod stiffener (RS)	2	1.631	107
	3	1.54	107
	4	1.559	107
	5	1.12	112
	6	1.76	105.5
	7	1.79	106.45

Table -2: Buckling stress for Type-1 stiffeners

Stiffener type	Radius (mm)	Buckling stress (kN/m2)
Type-1 Edge Rod stiffener	2	148.21
	3	150.245
	4	140.21
	5	140.23
	6	142.85
	7	140.112
	8	120.235
	9	330.12

Table -3: Buckling stress for Type-3 stiffeners

Stiffener type	Radius (mm)	Buckling stress (kN/m2)
Type -3 Mid flange ring stiffener	2	143.211
	3	140.21
	4	120.45
	5	110.555
	6	104.899
	7	110.226
	8	135

Table -4: Buckling stress for Type-4 stiffeners

Stiffener type	Radius (mm)	Buckling stress (kN/m2)
Type -4 Rod stiffener	2	148.02
	3	140.8
	4	110.343
	5	107.23
	6	142
	7	143

3. CONCLUSIONS

Ultimate strength of columns under distortional buckling failure mode should be given prior importance. Columns that fail under distortional buckling shows lower post buckling capacity of section. Cold formed channel section where studied for distortional buckling behavior and a 3D finite element model was developed. From the study the following conclusions were made. In order to prevent the effect of distortion under axial loading, stiffeners are used to strengthen the section. Material of section can be displaced far from the neutral axis to enhance the load carrying. Cold formity of steel section helps in employing the production of almost any desired shape to any desired length. The region of maximum buckling was found to be the flange region. Distortional buckling was found predominant in L/3 length from both ends as well as the mid length of the columns .Two parameters studied, the position and diameter of the stiffener type From the present study it was concluded that for Type-1, stiffener there was about 19% decrease in maximum deformation from that of unstiffened section when the section is stiffened by an 8 mm radius stiffener. For Type-2 stiffener,25% decrease in the maximum deformation is obtained when radius is about 8 mm with an increase in ultimate load by 0.93% .For Type-3,6 mm stiffeners provide reduction in maximum deformation by 15% from that of unstiffened column with 2% increase in ultimate load. From present study Type-4 stiffeners at a radius of about 5 mm provides 31% decrease in the maximum axial deformation and about 5 % increase in ultimate load. From the study an order for stiffener position was obtained as Type-4 > Type-2 > Type-1 > Type-3 .Type-4 stiffeners were found to bring better reduction in the distortional buckling as they strengthen the section from the buckling inward or outward. The effective range of stiffener radius was found to be about

5 mm to 8 mm that brings a better reduction in buckling stress by stress redistribution. When ring and rod stiffeners are compared rod stiffeners show better strengthening.

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