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DIRECT STRENGTH METHOD APPROCH FOR INDIAN COLD FORMED STEEL SECTIONS WITH AND WITHOUT PERFORATION

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ABSTRACT

Cold-formed steel section are extensively used in industry and many other non-industry constructions worldwide, it is relatively a new concept in India. Cold-formed steel sections have been developed as more economical building solutions to the alternative heavier hot-rolled sections in the commercial and residential markets. Cold-formed steel (CFS) structural members are commonly manufactured with perforations to accommodate plumbing, electrical, and heating conduits in the walls and ceilings of buildings. Current design methods available to engineers for predicting the strength of CFS members with perforations are prescriptive and limited to specific perforation locations, spacing, and sizes. The Direct Strength Method (DSM), a relatively new design method for CFS members validated for members with and without perforations, predicts the ultimate strength of general CFS members with the elastic buckling properties of the member cross section. The design compression strength of Indian (IS 811-1987) standard sections is calculated as per NAS (AISI-S100 2007, Appendix 1)

Key Words: Cold formed sections-CFS, direct strength method, elastic buckling, compression strength, holes, CUFSM.

1. INTRODUCTION

In steel construction, there are primarily two types of structural members: 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 as cold-formed steel. Cold-formed steel is a popular engineered material in residential and commercial construction because it is available in a wide range of prefabricated geometries to suit specific project demands. The thin walled structural steel members are manufactured at a roll-forming plant, where steel sheet is cold-bent into an open cross-section, for Example a C-section or Z-section. Near the end of the assembly line, holes are punched with a hydraulic die to accommodate the passage of conduits; Web holes also serve as intermediate brace connection Points in structural stud walls. Recent advances by roll forming manufacturers are leading to custom structural members with complex hole shapes, sizes and patterns. Cold –formed joists are a popular structural component in the floor systems of low and midrise buildings. These thin-walled structural steel flexural members are manufactured by cold bending steel sheet into an open cross-section, most commonly a C-section. The joists are provided with evenly spaced web holes to accommodate the passage of electrical conduits, plumbing pipes, and HVAC ducts. Hole sizes and shapes vary by manufacturer, and the hole edges can be either unstiffened or stiffened.

The Direct Strength Method (DSM), a relatively new design method for CFS members validated for members with and without holes, predicts the ultimate strength of a general CFS section with the elastic buckling properties of the member cross-section (e.g., plate buckling) and the Euler buckling load (e.g., flexural buckling). Design expressions for DSM with and without hole are based on the North American Specification (AISI-S100 2007, Appendix 1). DSM represents an important advancement in cold-formed steel design because it provides engineers and cold-formed steel manufacturers with the tools to predict member strength for a general cross-section. With the design approach summarized herein, DSM can now safely predict the strength of cold-formed steel flexural members with the ever expanding range of cross-section types, hole sizes, shapes and spacing’s common in industry.

In the present study the cold formed steel sections are analysed by using CUFSM software

2. COMPRESSION STRENGTH PREDICTION FOR CFS SECTIONS WITH AND WITHOUT PERFORATION

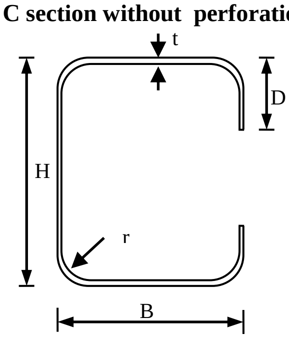
Compression Strength:

Gross and net section properties

The gross section and net section properties are calculated with the section property calculator in CUFSM. To determine the net section properties in CUFSM, assign a thickness of zero to the elements at the location of the perforations.

In accordance with DSM the nominal strength, P_n, is the minimum of nominal strength due to global buckling (P_{nc}), local buckling (P_{nl}) and distortional buckling (P_{nd}). The corresponding buckling strengths are calculated as follows:

Lipped C section without perforation: **80x50x10x1.6 mm**



C/S of lipped C-section

Where, H = Height of section, B =Width of the section, D =Height of the lip, t =Thickness of the section, r =Inner root radius

Section properties, H = 80 mm, B = 50 mm, D = 10 mm, t= 1.6 mm, r= 2.4 mm

Modulus of elasticity (E) = $2\times10^5 N/mm^2$, Poisson's ratio (ν) = 0.3, Modulus of rigidity (G), Yield stress (f_y) = $280 N/mm^2$, A=332.4527 mm^2, I_x = 405257.4505 mm^4, I_y = 133726.831 mm^4, Z_s = 41.6 mm, C_w = 205274834.8594 mm^6, J = 283.693 mm^4

From CUFSM,

Squash load: P_y = 93.08676 Kn, Local buckling in web: P_{crl} =1.28P_y, Distortional buckling: P_{crd} =1.27P_y, Global buckling: P_{cre} =0.28487P_y

Flexural, Torsional, or Torsional-flexural Buckling nominal axial strength,

$$\lambda_c = \left(\frac{P_y}{P_{cre}}\right)^{0.5} = 1.874$$

$$P_{ne} = \left(0.658^{\lambda^2_c}\right) P_Y \quad \text{for } \lambda_c \le 1.5$$

$$P_{ne} = \left(\frac{0.877}{\lambda^2_c}\right) P_Y \quad \text{for } \lambda_c > 1.5$$

P_{ne} = 23.256 kN

Local buckling nominal axial strength,

$$\lambda_l = \left(\frac{P_{ne}}{P_{cre}}\right)^{0.5} = 0.44$$

$$P_{ne} = \left(0.658^{\lambda^2_c}\right) P_Y \quad \text{for } \lambda_l \le 1.5$$

$$P_{ne} = \left(\frac{0.877}{\lambda^2_c}\right) P_Y \quad \text{for } \lambda_l > 1.5$$

P_{ne} = 23.300 Kn

Distortional buckling nominal axial strength,

$$\lambda_d = \left(\frac{P_Y}{P_{crd}}\right)^{0.5} = 0.89$$

$$P_{nd} = P_y \quad \text{for } \lambda_d \le 0.561$$

$$P_{nd} = \left(1 - 0.25\left(\frac{P_{crd}}{P_Y}\right)^{0.6}\left(\frac{P_{crd}}{P_Y}\right)^{0.6}\right) P_Y \quad \text{for } \lambda_d > 0.561$$

P_{nd} = 76.4 kN

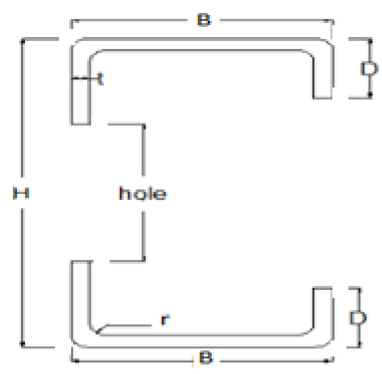
The predicted compression strength in accordance with DSM , Pn = minimum (P_{ne} P_{nl} P_{nd}) =23.256 kN

This section meets the prequalified limits as per NAS.

Resistance factor and safety factor for compression are, $\Phi = 0.85$ and $\Omega = 1.8$

Design strength $\Phi P_n = 19.76756$ kN and Allowable design strength $\frac{P_n}{\Omega} = 12.9199$ kN.

Lipped C section with perforation: **80x50x10x1.6mm**



C/S of lipped C section with perforation

h_{hole} is centered in the CFS sections. The hole depth (diameter) is varied, i.e. h_{hole}/h=0.10, 0.30, 0.50, 0.70.In all CFS section h_{hole}/h =0.5 is taken.

Section properties: H = 80 mm, B = 50 mm, D = 10 mm, t= 1.6 mm, r= 2.4 mm

Modulus of elasticity (E) = $2\times10^{5}\,N/mm^{2}$,Poisson's ratio (ν) = 0.3, Modulus of rigidity (G) = $80\times10^{3}\,N/mm^{2}$ Yield stress (f_y) = $280N/mm^{2}$, A=269.7327 mm^{2} , I_x =397225.9455 mm^{4} , I_y = 106472.284 mm^{4} , Z_s = 41.6 mm , C_w = 199574069.406 mm^{6} , J = 230.1719 mm^{4}

From CUFSM:

Squash load: P_y = 93.08676 kN (lipped C section), Squash load: P_{ynet} = 75.5251 kN, Local buckling in web: P_{crl} =1.28P_y, Distortional buckling: P_{crd} =1.22P_y, Global buckling: member is fully braced against lateral-torsional buckling P_{cre} =P_y

Flexural, Torsional, or Torsional-flexural Buckling nominal axial strength,

$$\lambda_c=\left(\frac{P_y}{P_{cre}}\right)^{0.5}=1$$

$$P_{ne}=\left(0.658^{\lambda^2{}_c}\right)P_Y \qquad \text{for } \lambda_c\le1.5$$

$$P_{ne}=\left(\frac{0.877}{\lambda^2{}_c}\right)P_Y \qquad \text{for } \lambda_c>1.5$$

P_{ne} = 61.2511 kN

Local buckling nominal axial strength,

$$\lambda_l=\left(\frac{P_{ne}}{P_{cre}}\right)^{0.5}=0.72$$

$$P_{ne}=\left(0.658^{\lambda^2{}_c}\right)P_Y \qquad \text{for } \lambda_l\le1.5$$

$$P_{ne}=\left(\frac{0.877}{\lambda^2{}_c}\right)P_Y \qquad \text{for } \lambda_l>1.5$$

P_{ne} = 61.2511 kN

Distortional buckling nominal axial strength,

$$\lambda_d=\left(\frac{P_Y}{P_{crd}}\right)^{0.5}=0.92$$

$$P_{nd}=P_y \quad \text{for } \lambda_d\le0.561$$

$$P_{nd}=\left(1-0.25\left(\frac{P_{crd}}{P_Y}\right)^{0.6}\left(\frac{P_{crd}}{P_Y}\right)^{0.6}\right)P_Y \quad \text{for } \lambda_d>0.561$$

P_{nd} = 74.653 kN

The predicted compression strength in accordance with DSM,

P_n = minimum (P_{ne} P_{nl} P_{nd}) =61.2511 kN

This section meets the prequalified limits as per NAS.

Resistance factor and safety factor for compression are,

$$\Phi=0.85 \text{ and } \Omega=1.8$$

Design strength $\Phi P_n=52.0634$ kN

Allowable design strength $\frac{P_n}{\Omega}=34.0283$ kN

From the above result it is observed that nominal axial strength of CFS section 80x50x10x1.6 with perforation increase by about 2.64% than the section without perforation.

3. RESULTS AND DISCUSSION

In the present study the compression strength is predicted for Indian standard (IS 811-1987) lipped C cold formed steel sections with and without perforations. h_{hole} is centered in the cold formed steel sections. h_{hole}/h =0.5 is considered. The elastic buckling behaviours of different cold formed sections are obtained with CUFSM software and North American Specification direct strength method is used to predict the compression strength of the Indian cold formed sections.

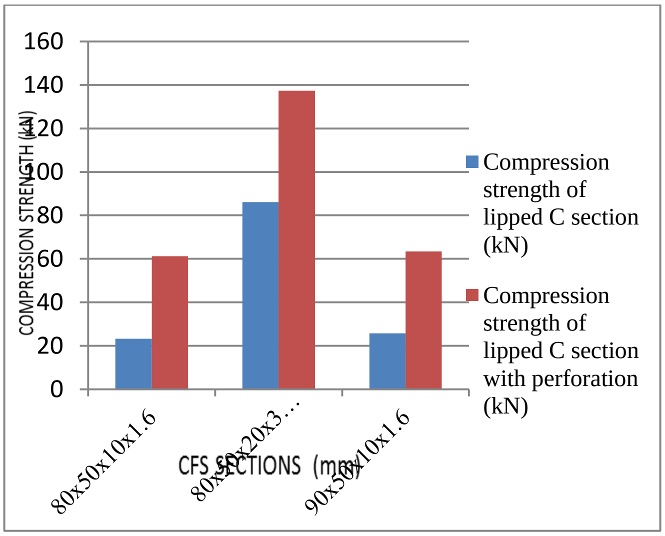
The compression strength of lipped C section with and without perforation is given below in Table 1 and graphs.

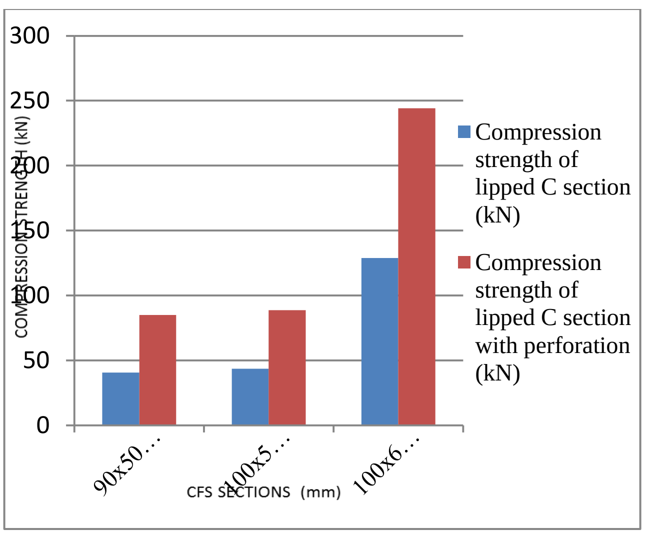
Table 1 Nominal compression strength comparison for lipped C section with and without perforation

Sl.no	Indian standard (IS 811-1987) Sections (mm)	Compression strength of lipped C section without perforation (kN)	Compression strength of lipped C section with perforation (kN)	Increase in strength (%)

1	80x50x10x1.6	23.2559	61.2511	2.64
2	80x50x20x3.15	86.0725	137.3943	1.60
3	90x50x10x1.6	25.7521	63.4427	2.47
4	90x50x15x2	40.7391	85.0188	2.09
5	100x50x15x2	43.7284	88.7036	2.03
6	100x60x20x3.15	128.8739	244.0859	1.90
7	100x65x15x2	62.1441	99.7580	1.61
8	120x60x20x3.15	153.0709	172.2157	1.13
9	120x50x15x2	71.7591	91.9433	1.29
10	140x65x15x2	70.5508	99.7821	1.42

From the above Table 1 it is concluded that there is an increase in compression strength for the lipped C sections with perforation than the lipped C section without perforation. The results graph for nominal strength comparison of CFS sections with and without perforation is given below.





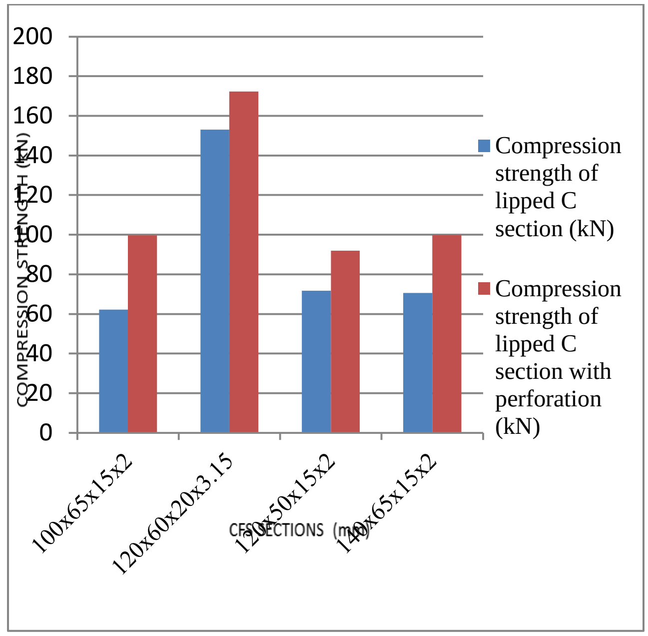


Fig 1: Nominal compression strength comparison for lipped C section with and without perforation

4. CONCLUSION

DSM represents an important advancement in cold-formed steel design because it provides engineers and cold-formed steel manufacturers with the tools to predict member strength for a general cross-section. With the design approach summarized herein, DSM can now safely predict the strength of cold-formed steel flexural members with the ever expanding range of cross-section types, hole sizes, shapes and spacing's common in industry. The AISI direct strength method for cold formed steel section with perforation utilizes the critical load load of a section, including the influence of perforation, to predict strength. The elastic buckling predictions are obtained with CUFSM software. The nominal compression strength for Indian cold formed sections with perforation increases than the cold formed sections without perforation.

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