EXPERIMENTAL STUDY ON COLD FORMED STEEL MEMBERS

[1] Jay M. Padariya, [2] Dr. Vishal A. Arekar, [3] Prof. Vimlesh V. Agrawal
[1]PG Research Scholar, [2]Assistant Professor, [3]Assistant Professor
[1]Structural Engineering Department,
[1] BVM Engineering College, Anand, India

ABSTRACT: Cold formed steel is basic component in the construction of lightweight prefabricated structures like stud frame panels, trusses and prefabricated structures. This thesis work deals with the details of an experiment on cold formed steel section subjected to compression and flexure. The main aim of the research work is to find out the effect of the l5 mm,20 mm and 25 mm lip in cold formed angle and cold formed channel section. This analysis carries an angle and channel section of thickness 2 mm and 3 mm with different sizes. Total 32 experiment are carried out and for flexure testing two-point loading is applied to cold formed member. The experimental results show that the effect of the lip in in case of channel section size 100x50x3 lip help to increase compressive strength up to 30% to 50. While in case of square channel section size 100x100x2, lip is not much effective because the unstiffened portion of member buckle easily. In case of angle section size 85x50x3 lip help to increase compressive strength up to 20% to 47%. While in case of angle section size 100x85x2 lip help to increase strength up to 25% to 42%. During flexure testing bending consistently occurred towards the web in the plain channels and towards the lips in the lipped channels. During compression test buckling of member occurs first in unstiffened member and then towards stiffened member. The effect of the lip in square channel section is more effective. lip portion enhance the flexure strength of member up to 262 % but in case of channel section lip help to increase strength about 20% to 50%.

***Keywords* – cold formed channel, cold formed angle, crippling, Two-point loading test, local buckling.**

➢ Introduction

Cold formed member is produced by bending a flat sheet of steel at room temperature into shape that will support more loads the flat sheet itself. Cold formed steel members are manufactures by cold rolling or press braking and the plain angle sections and channel section are generally made by bending a plain sheet. Thus, the original strip is converted into two different regions, one of which is corner portion and another region is of a flat portion. Thin sheet steel products are extensively used in building industry, and range from purlins to roof sheeting and floor decking.

Generally, these are available for use as basic building elements for assembly at site or as prefabricated frames or panels. These thin steel sections are cold-formed, i.e. their manufacturing process involves forming steel sections in a cold state (i.e. without application of heat) from steel sheets of uniform thickness. These are given the generic title Cold Formed Steel Sections. Sometimes they are also called Light Gauge Steel Sections or Cold Rolled Steel Sections. The thickness of steel sheet used in cold formed construction is usually 1 to 3 mm. Much thicker material up to 8 mm can be formed if pre-galvanized material is not required for the particular application.

The method of manufacturing is important as it differentiates these products from hot rolled steel sections. Normally, the yield strength of steel sheets used in cold-formed sections is at least 280 N/mm2, although there is a trend to use steels of higher strengths, and sometimes as low as 230 N/mm2. Galvanizing (or zinc coating) of the preformed coil provides very satisfactory protection against corrosion in internal environments. Although the cold rolled products were developed during the First World War, their extensive use worldwide has grown only during the last 20 years because of their versatility and suitability for a range of lighter load bearing applications. Thus, the wide range of available products has extended their use to primary beams, floor units, roof trusses and building frames. Indeed, it is difficult to think of any industry in which Cold Rolled Steel products do not exist in one form or the other. Besides building industry, they are employed in motor vehicles, railways, aircrafts, ships, agricultural machinery, electrical equipment, storage racks, house hold appliances and so on.

In recent years, with the evolution of attractive coatings and the distinctive profiles that can be manufactured, cold formed steel construction has been used for highly pleasing designs in practically every sector of building construction. In this chapter, the background theory governing the design of cold formed steel elements is presented in a summary form. Design of cold formed steel sections are dealt with in IS: 801-1975 which is currently due under revision.

➢ MANUFACTURES OF CFS

In building construction there are basically two type of structural steel: hot rolled steel shapes and cold formed steel shapes. The hot rolled steel shapes are formed at elevated temperature while the cold formed steel shapes are formed at room temperature. Cold formed steel structural members are shapes commonly manufactured from steel plate, sheet metal or strip material. The manufacturing process involves forming the material by either press braking or cold roll forming to achieve the desired shape.

Manufacturers of cold formed steel sections is may be done by cold rolling in which a steel coils of 1.0 to 1.25 m width is placed longitudinally to the correct width appropriate to the section required and then feed them into a series of roll forms. These rolls, containing male and female dies, are arranged in pairs, moving in opposite direction so that as the sheet is fed through them its shape is gradually altered to the required profile.

The number of pairs of rolls depends on the complexity of the cross-sectional shape and varies from 5 to 15. At the end of the rolling stage a flying shearing machine cuts the member into the desired lengths. An alternative method of forming is by press - braking which is limited to short lengths of around 6 m and for relatively simple shapes. In this process short lengths of strip are pressed between a male and a female die to fabricate one-fold at a time and obtain the final required shape of the section. Cold rolling is used when large volume of long products is required and press breaking is used when small volumes of short length products are produced. Galvanizing (or zinc coating) of the preformed coil provides very satisfactory protection against corrosion in internal environments.

➢ EFFECTIVE WIDTH CONCEPT

The effects of local buckling can be evaluated by using the concept of effective width. Lightly stressed regions at centre are ignored, as these are least effective in resisting the applied stresses. Regions near the supports are far more effective and are taken to be fully effective. The section behaviour is modelled on the basis of the effective width (beff) sketched in Fig. 1. The effective width, (beff) multiplied by the edge stress is the same as the mean stress across the section multiplied by the total width (b) of the compression member. The effective width of an element under compression is dependent on the magnitude of the applied stress fc, the width/thickness ratio of the element and the edge support conditions.

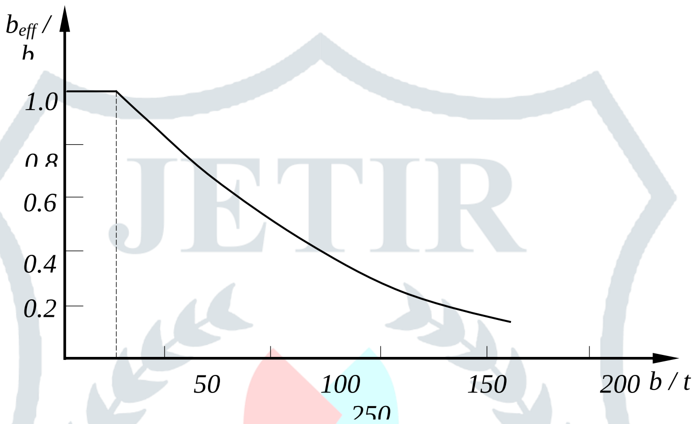


Fig. 1 Ratio of effective width to flat width (fy = 280 N/mm2) of compression plate with simple edge supports

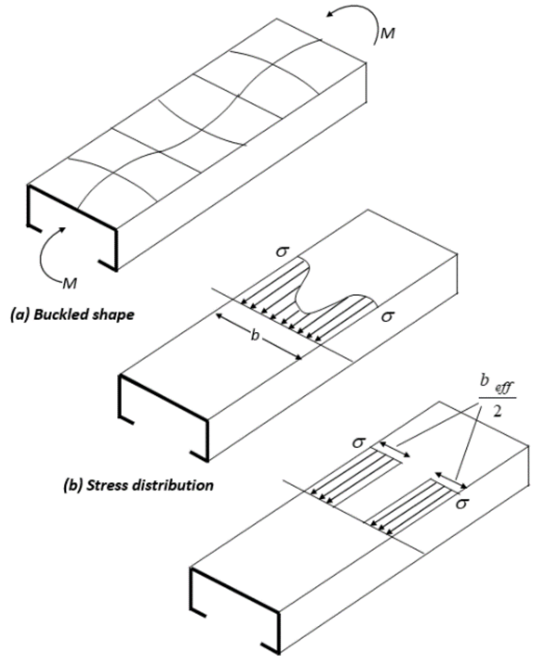


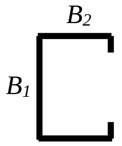
Fig 2. local buckling

It is emphasized that in employing the value of K (to compute pcr) could be 4.0 for a stiffened element or 0.425 for an unstiffened element. BS5950, part 5 provides for a modification for an unstiffened element under uniform compression (Refer clause 4.5.1).

The code also provides modifications for elements under combined bending and axial load (ref. Clause 4.5.2). Typical formula given in BS 5950, Part 5 for computing K values for a channel element is given below for illustration. (see BS 5950, Part 5 for a complete list of buckling coefficients).

1. Lipped channel.

The buckling coefficient K1 for the member having a width of B1 and B2 in a lipped channel is given by:



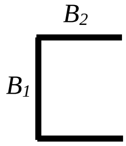
$$K_1 = 7 - \frac{1.8h}{0.15+h} - 1.43h^3 \qquad K_2 = K_1 h^2 \left(\frac{t_1}{t_2}\right)^2$$

where $h = B2 / B1$

where t1 and t2 are the thicknesses of element width B1 and B2 respectively. (Note: normally t1 and t2 will be equal). The computed values of K2 should not be less than 4.0 or 0.425 as the case may be.

2. Plain channel (without lips)

The buckling coefficient K1 for the element of width B1 is given by



$$K_1 = \frac{2}{(1+15h^3)^{0.5}} + \frac{2+4.8h}{(1+15h^3)} \qquad K_2 = K_1 h^2 \left(\frac{t_1}{t_2}\right)^2$$

➢ MAXIMUM WIDTH TO THICKNESS RATIOS

IS: 801 and BS 5950, Part 5 limit the maximum ratios of (b/t) for compression elements as follows:

- Stiffened elements with one longitudinal edge connected to a flange or web element and the other stiffened by a simple lip 60
- Stiffened elements with both longitudinal edges connected to other stiffened elements 500
- Unstiffened compression elements 60

However, the code also warns against the elements developing very large deformations, when b/t values exceed half the values tabulated above.

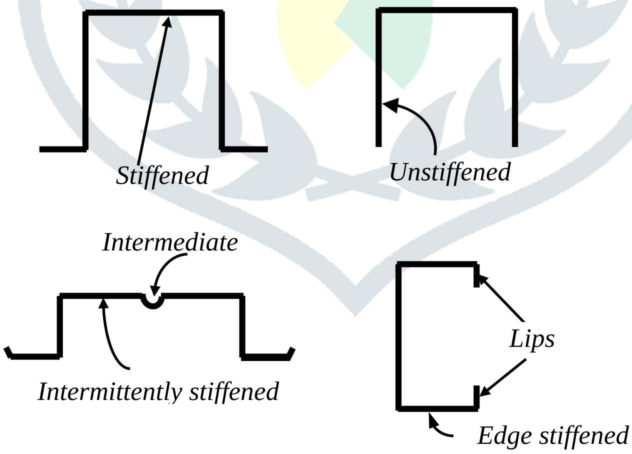


Fig. 3 Stiffened and Unstiffened elements

➢ Code Provisions on "Local Buckling of Compressed Plates"

The effective width concept is usually modified to take into account the effects of yielding and imperfection. For example, BS5950: Part 5 provides a semi-empirical formula for basic effective width, beff, to conform to extensive experimental data.

When fc > 0.123 pcr, then

When fc < 0.123 pcr, then beff = b Where,

$$\frac{b_{eff}}{b} = \left[1 + 14\left\{\left[\frac{f_c}{p_{cr}}\right]^{0.5} - 0.35\right\}^4\right]^{-0.2}$$

fc = compressive stress on the effective element, N/ mm2
pcr = local buckling stress given by
pcr = 185,000 K (t / b)2 N/ mm2
K = load buckling coefficient which depends on the element type, section geometry
t = thickness of the element, in mm
b = width of the element, in mm

➢ Section properties

Table 1: Section properties

SR NO	SECTION	DIMENSION	AREA	Ix	Iy	Rx	Ry
			mm2	mm4	mm4	mm	mm
1	Unequal angle section without lip	85x50x3	388.27	286405	96017	27.159	15.726
	Unequal angle section with lip	85x50x3x15	444.82	390485	119184	29.628	16.369
		85x50x3x20	474.82	434058	137632	30.235	17.025
		85x50x3x25	504.82	474351	155427	30.654	17.547
2	Unequal angle section without lip	100x85x2	362.57	510664	129051	37.53	18.866
	Unequal angle section with lip	100x85x2x15	407.7	499363	347811	34.998	29.208
		100x85x2x20	427.7	546811	384225	35.756	29.973
		100x85x2x25	447.7	591645	418774	36.353	30.584
3	Channel section without lip	100x50x3	566.55	875511	140233	39.311	15.733
	Channel section with lip	100x50x3x15	623.1	959373	200486	39.239	17.938
		100x50x3x20	653.1	991122	228764	38.956	18.716
		100x50x3x25	683.1	1013873	254561	38.526	19.304
4	Square Channel section without lip	100x100x2	585.13	1090994	636917	43.18	32.992
	Square Channel section with lip	100x100x2x15	630.27	1164288	810602	42.98	35.86
		100x100x2x20	650.27	1185455	880126	42.7	36.79
		100x100x2x25	670.27	1200621	945500	42.32	37.56

➢ Analytical and Experimental Compressive Strength

Table 2: Compression Test Results

No	SECTION	DIMENSION	EXPERIMENTAL	ANALYTICAL
1	Unequal angle section without lip	85x50x3	46.204 kN	46.745 kN
	Unequal angle section with lip	85x50x3x15	55.704 kN	53.181 kN
		85x50x3x20	68.22 kN	64.133 kN
		85x50x3x25	66.58 kN	65.983 kN
2	(without lip)	100x85x2	53.562 kN	50.775 kN
	(with lip)	100x85x2x15	68.532 kN	65.181 kN
		100x85x2x20	76.284 kN	72.927 kN
		100x85x2x25	76.424 kN	73.237 kN
3	Channel section without lip	100x50x3	117.52 kN	109.618 kN
	Channel section with lip	100x50x3x15	161.84 kN	137.285 kN
		100x50x3x20	173.976 kN	155.762 kN
		100x50x3x25	175.976 kN	157.843 kN
4	Square Channel section without lip	100x100x2	125.79 kN	118.786 kN
	Square Channel section with lip	100x100x2x15	109.36 kN	123.78 kN
		100x100x2x20	112.808 kN	129.603 kN
		100x100x2x25	119.744 kN	136.165 kN

Table 3: Flexure Test Results

No	SECTION	DIMENSION	EXPERIMENTAL	ANALYTICAL
1	Channel section without lip	100x50x3	1.9141 kN.m	1.3306 kN.m
	Channel section with lip	100x50x3x15	2.578 kN.m	2.6426 kN.m
		100x50x3x20	3.077 kN.m	2.7300 kN.m
		100x50x3x25	3.162 kN.m	2.7927 kN.m
2	Square Channel section without lip	100x100x2	2.2 kN.m	1.5814 kN.m
	Square Channel section with lip	100x100x2x15	7.9575 kN.m	5.4416 kN.m
		100x100x2x20	7.1087 kN.m	6.6878 kN.m
		100x100x2x25	7.3209 kN.m	7.9348 kN.m

Fig 4. Cold Formed steel Sheet

Fig 5. Channel Fix in UTM

Fig
of
of

Fig 6. Digital
UTM
7. Failure Shape
Channel section
size
100x50x3x15

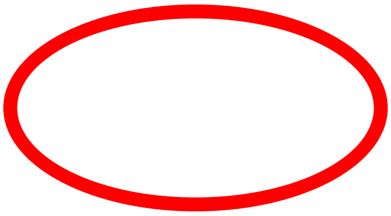


Fig 8. Failure Shape of Channel section of size 100x50x3x20

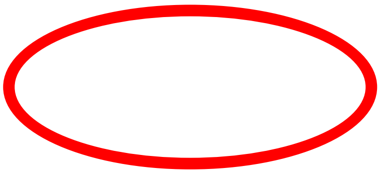


Fig 9. Failure Shape of Square Channel section of size 100x100x2x15

- **Load vs Deflection**

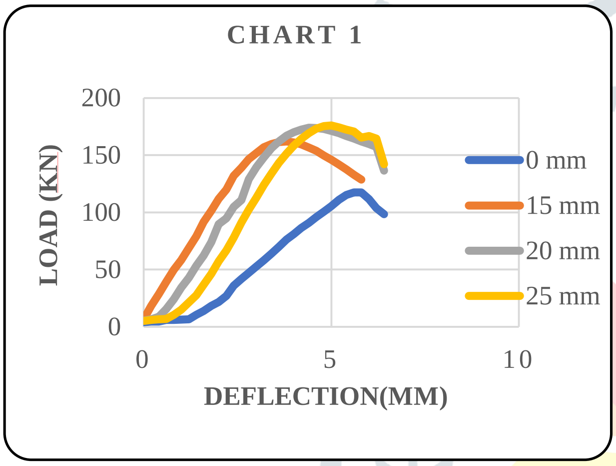


Fig 10. load vs deflection curve of channel section size 100x50x3 for compression test

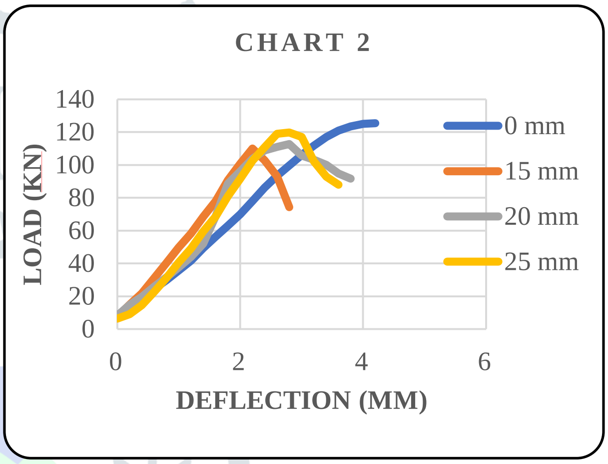


Fig 11. load vs deflection curve of channel section size 100x100x2 for compression test

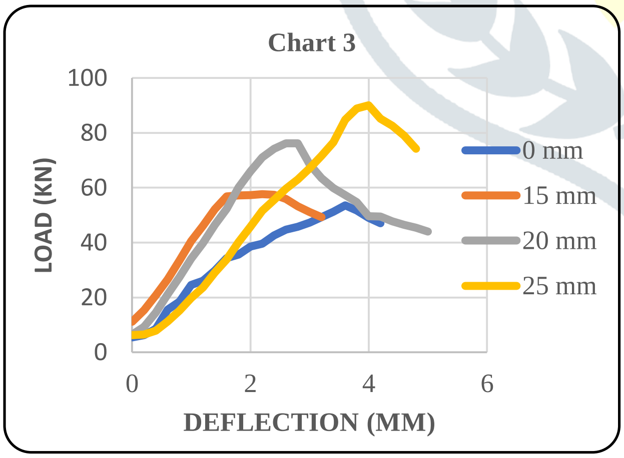


Fig 12. load vs deflection curve of channel section size 100x85x2 for compression test

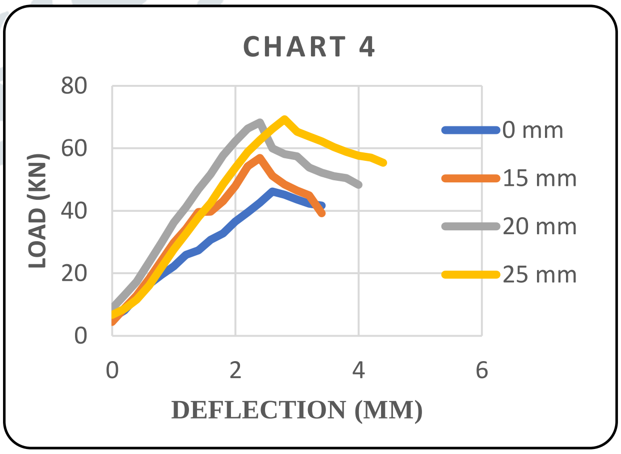


Fig 13. load vs deflection curve of channel section size 85x50x3 for compression test

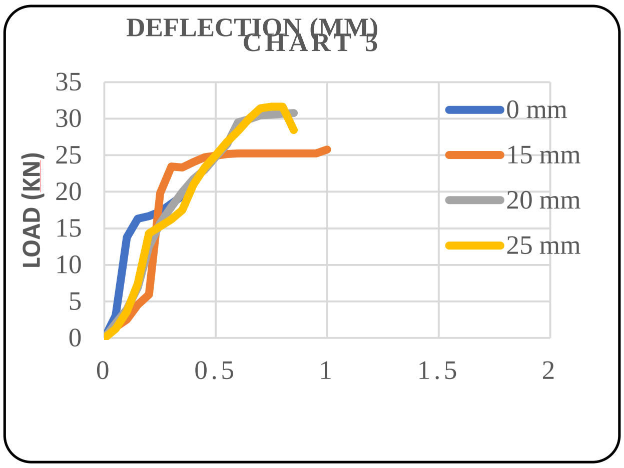


Fig 14. load vs deflection curve of channel section size 100x50x3 for flexure test

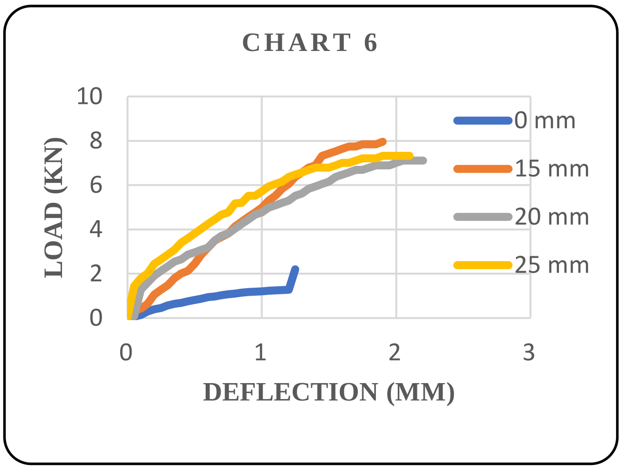


Fig 11. load vs deflection curve of channel section size 100x100x2 for flexure test

➢ CONCLUSION

A total of 32 CFS channel compression tests and 16 flexure tests are carried out, including four different cross-sectional geometries and same lengths, were carried out with the aim for (a) find out the lip effect in CFS section (b) verifying the accuracy of the relevant IS 801 design procedures. The specimens were tested under a nominally concentric load between pinned boundary conditions. Based on an analysis of the results, the following conclusions could be drawn :

- The effect of the lip in in case of channel section size 100x50x3 lip help to increase strength up to 30% to 50%. The effect of 20 mm and 25 mm lip is same in channel section size 100x50x3.
- The effect of the lip in square channel section size 100x100x2 is not much effective because the unstiffened portion of member (lip portion) is buckle easily.
- The effect of the lip in in case of channel section size 85x50x3 lip help to increase strength up to 20% to 47%. The effect of 20 mm and 25 mm lip is same in angle section size 85x50x3.
- The effect of the lip in in case of channel section size 100x85x2 lip help to increase strength up to 25% to 42%.
- Bending consistently occurred towards the web in the plain channels and towards the lips in the lipped channels. During compression test buckling of member occurs first in unstiffened member and then towards stiffened member.
- The effect of the lip in square channel section is more effective. lip enhance the flexure strength of member up to 262 % while in case channel section lip help to increase strength up to 20% to 50%.
- Experimental data shows that the lip length (15 mm, 20 mm, 25 mm) is not play any roll to enhance the flexure strength of the member while 20 mm lip length is proved more effective to enhance the compression strength.

➢ References

- AISI commentary (2007), "Design of Cold-formed Steel Structural Members, North American Specification"
- Book by : Wei-Wen Yu Roger A. LaBoube,"Cold-Formed Steel Design"
- B. Young, Design of channel columns with inclined edge stiffeners, J. Constr. Steel Res. 60 (2004) 183–197. [43]
- B. Young, G.J. Hancock, Compression tests of channels with inclined simple edge stiffeners, J. Struct. Eng., ASCE 129 (2003) 1403–1411.
- Chi - Ling pan, (2004), "Prediction of the strength of bolted cold - formed channel sections in tension", Thin walled structures, Volume 42, pp 1177 - 1198.
- D. Ungermann, B. Brune, S. Lübke, Numerical and analytical investigations on plain channels in coupled instabilities, Steel Constr. 5.4 (2012) 205–211. [34]
- D. Ungermann, S. Lübke, B. Brune, Tests and design approach for plain channels in local and coupled local-flexural buckling based on eurocode 3, Thin-walled Struct. 81 (2014) 108–120.
- G.J. Hancock, Y.B. Kwon, E.S. Bernard, Strength design curves for thin-walled sections undergoing distortional buckling, J. Constr. Steel Res. 31 (2–3) (1994) 169–186.
- Jaghan S and Padmapriya R, (2015), "Behavior of Bolted Cold Formed Steel Channel Tension Members", Asian Journal of Civil Engineering (BHRC), 17 (1), pp. 137-146.
- J.B.P. Lim, D.A. Nethercot, Finite element idealization of a cold-formed steel portal frame, J. Struct. Eng., ASCE 130 (2004) 78–94. [26]

- J. Loughlan, N. Yidris, The local-overall flexural interaction of fixed-ended plain channel columns and the influence on behaviour of local conditions at the constituent plate ends, Thin-Walled Struct. 81 (2014) 132–137.
- Lip H. Teh and Benoit Gilbert, (2014), "Net section tension capacity of equal angle braces bolted at different legs", Journal of Structural Engineering, 140 (6), pp.1943-1953. 11
- IS: 801 – 1975,"Code of practice for use of cold-formed light gauge steel structural member in general building construction"
- W. Ma, J. Becque, I. Hajirasouliha, J. Ye, Cross-sectional optimization of cold formed steel channels to Eurocode 3, Eng. Struct. 101 (2015) 641–651.