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BEHAVIOUR OF COLD FORM STEEL SECTION UNDER PURE TORSION

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ABSTRACT

The advances in the construction have lead to light weight construction that has improved the importance of the light gauge steel sections in the construction industry. The sections are open in nature but the load carrying capacity is enhanced using less thickness of the steel. The steel sheets of .8 to 3 mm are rolled and the sections are prepared. This improves the section modulus of the section which ultimately improves the load carrying capacity of the section. Due to its open in nature the shear centre and the centroid of the section does not match which leads to the development of the torque forces in the section even under flexural loading. The eccentricity develops torsional moments in the section and these results in the distortional buckling in progression with the flexural failure. In this dissertation work we have studied the effect of the torsional loading on the light gauge channel section. Five different specimens of the channel section where considered with and without lip, v-stiffeners and rectangular stiffeners for deriving the ultimate moment carrying capacity and angle of rotation of the section. The analysis and design of the channel section was done using code is 801-1975 while the analytical work was carried out using finite element method with ABAQUS software. Further the experimental validation was done using true length specimen and setup was prepared for the pure torsion loading. The results of this experimental investigation indicated that the torsional capacity of the light gauge channel section is enhanced by using different stiffener and lips. The light gauge steel section should be provided with stiffener even in the regular flexural loading case so as to minimise the eccentric loading due to the difference between shear centre and centroid of the section. Thus from the study it is concluded that the use of stiffeners minimizes the torsional failure of the light gauge steel section.

I. INTRODUCTION

In recent decades the interest of the building sector is tending towards the lightweight construction so as to overcome the faults of the last decades. The light weight and faster construction is the demand of the era. This has led to the increase in the use of the cold form steel structure as they satisfy the demand of the light weight and faster construction. Though there are several advantages of the light gauge steel section they are partially obtained due to the unawareness of the designer about the behaviour of the section. Therefore it is necessary to study the behaviour of the light gauge section under loading which will help in achieving the good performance of the structure. The important points to be noted by the designer are that:

i) The section is open in nature and as the shear center lies out of the section it is difficult to match the centroid and the shear center which lead to the torque in the section.

ii) The torsion factor of the section is directly proportional to the cube of the thickness of the section.

iii) The torque generated will induce the longitudinal stress additive to the primary stress.

This lead the scope to understand the torsional behavior of the cold form steel sections its behavior and capacity to sustain the eccentric loading. In this we will study the channel section with and without stiffener under pure torsion condition. This will help in understanding the behaviour of the cold form channel section with different stiffeners and its reduction the twisting moment. It is important in case of the overhang portion of the beams these parts of the beam undergo the same behavior. Most cold-formed steel members display very slender thin walled open cross sections, making them highly susceptible to several instability phenomena as local, distortional and global (flexural or flexural-torsional) buckling depending on the member length and cross-section shape, dimensions, any of these buckling modes may be critical. Since commonly used cold formed steel member geometries may lead to similar local, distortional and or global buckling stresses, the associated post-buckling behaviour, ultimate strength and collapse mode are likely to be strongly affected by the coupling between these three buckling modes. It is well known that thin walled member's exhibits table local and global post buckling behaviors with high and low post critical strength reserve. On the other hand, recent studies showed that the distortional post-buckling behaviour fits in between the previous two and exhibits a negligible symmetry with respect to the flange lip motion. Concerning the mode interaction phenomena affecting the column post buckling behaviour, those stemming from the nearly simultaneous occurrence of local and global buckling are better understood, as attested by their inclusion in virtually all current hot rolled and cold formed steel design codes.

The Major advantage of CFS beams over hot rolled beams is to be found in the relative thickness of the material from which the sections are formed. This will lead to having highly effective in terms of weight and efficient member and structures. However, the promising advantages of the thin walls can only be partially obtained. To obtain these advantages, the designer must be aware of the importance associated with thin-walled members and their effects on analysis and design. The most important of these phenomena is local buckling.

In thin walled members, the role played by torsion is enhanced in comparison to hot-rolled sections. The reasons for this are listed below:

1. Application of load through the shear centre in an open cross-section which has shear centre outside the section is difficult to achieve. Hence, CFS beams are subjected to an applied torque so that twisting of the section is bound to occur if it is not restrained against torsion.

2. The torsion constant J, for open cross sections, which is directly related to the resistance to twist, is proportional to the material thickness raised to the third power.

3. Restraining this torsion induces longitudinal stresses which may be of the same order of magnitude as the primary bending stresses and additive to them.

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In most frequent applications purlins, floor joists and wall studs, the loading and restraint are both continuous, both of which are self-equilibrating to some extent so that the tendency to twist is greatly reduced. Rational methods of analysis in these situations are exceedingly complicated and design usually proceeds on the basis of test results. In this study, continuous restraint is not considered and attention is confined to cases where light gauge steel members are free to twist between discrete points of restraint.

II. EXPERIMENTAL WORK

The experimental work was carried out for five different channel sections with different stiffeners. The setup for the torsion was prepared using plates welded on the either side of the section with the extra length of flange of I section. The loading was done on the extended length of plate to exactly produce the torsional moment in the section. The load at the failure where noted with the angular deflection on both side of section.

Properties of Steel material:

Poisson's Ratio (μ) : 0.3.

Density (δ) : 0.000000785 N/mm3

Young's Modulus (E) : 203395.33Mpa

Maximum Yield stress (fy) : 250Mpa

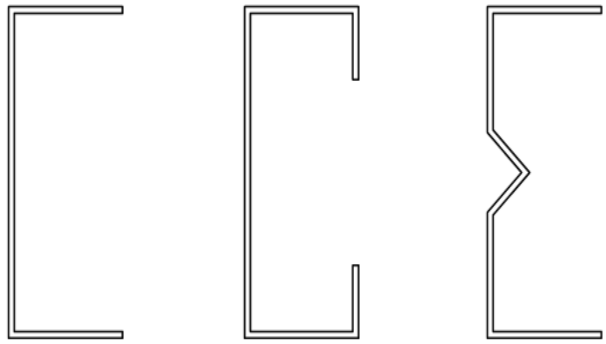

Fig 1 Specimens of cold formed steel channel section for the experimental work

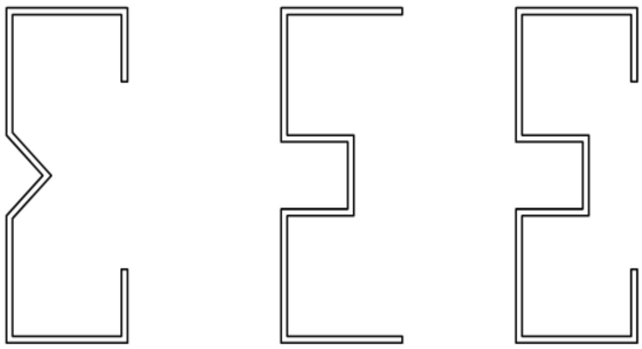

Fig 2 Specimens of cold formed steel channel section for the experimental work

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Fig 3 Specimens of cold formed steel channel section for the experimental work

Fig 4 Experimental Work Set Up

Five different beams are considered for the experimental investigation for the torsional capacity of the beam. The different stiffeners and lips are introduced to the beam to compare the increase in the torsional capacity of the beam The loading was done using plates of the 10mm thickness on the either side of the opening as shown in the image further Pure torsion was developed as seen in the arrangements of the experimental work.

Fig 5 Experimental specimen after Testing

III. ANALYSIS BY USING ABAQUS

The finite element program ABAQUS is a computational tool for modelling structures with material and nonlinear behaviour. ABAQUS version 6.13 was used to simulate the model and find buckling mode and strength of cold-formed steel beams under flexure a parametric analysis was performed, in order to investigate the influence of the width and height on the flexure behaviour of the beams.

IV. ANALYTICAL RESULTS

For the study the channel section are considered with the different stiffeners. The size of the channel section is 100x40x2 mm of the galvanized steel material Fe245. Five different cases are studied using the ABAQUS software for the torsional capacity of the section. The channel sections are compared with the moment carrying capacity and the angle of the rotation. The angle of the rotation is measured on both the side of the section. The loading is done on the cantilever part of the section as shown in fig due to this type of loading the twisting moment is generated.

Table 1 Comparison of moment carrying capacity and Angle of Rotation

Description	Moment Carrying Capacity (KNm)	Angle Of Rotation (Degree)
C without lip	16.29	21
C with lip	19.63	17
C with V stiffener	24.28	13.28
C with V stiffener and lip	23.63	10.65
C with Rectangular stiffener	32.6	6.56
C with Rectangular stiffener and lip	39.65	6.5

It was observed that the moment carrying capacity is increased by the 20.50% only using channel section with the lips of 20mm. The difference of the moment carrying capacity of the beam with the v stiffener and v stiffener with lips was seen to be only 2.67% while using the rectangular stiffener the enhancement of the moment carrying capacity than channel section was 58.91%. This shows the beam with the lips in the stiffened beam is not as important as in the un-stiffened beam as the increase in the capacity is relatively small.

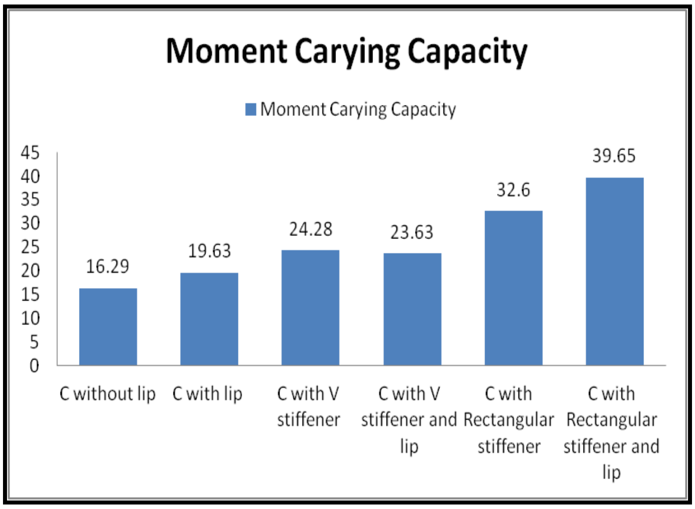

Fig 6 Comparison of Moment Carrying Capacity with different types of stiffener

It was observed that the angle of rotation is increased by the 19.04 % only using channel section with the lips of 20mm. The difference of the angle of rotation of the beam with the v stiffener and v stiffener with lips was seen to be only 19.80% while using the rectangular stiffener the enhancement of the moment carrying capacity than channel section was 69.04%.

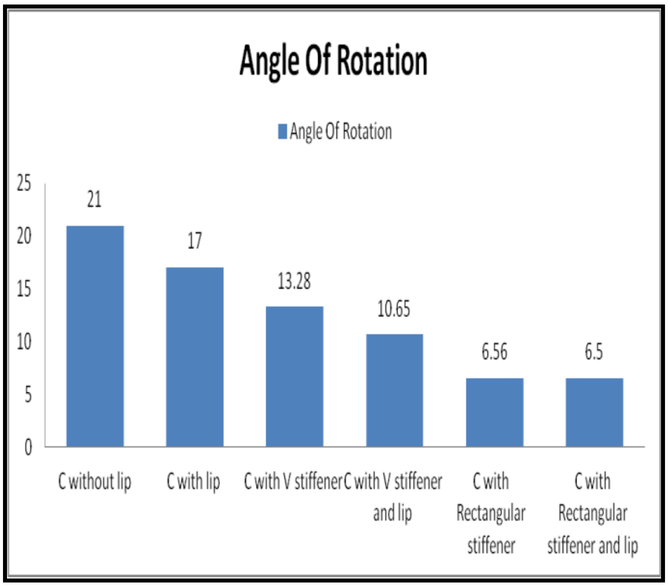

Fig 7Comparison of angle of rotation with different type's stiffener

This shows the beam with the lips in the stiffened beam reduces the angle of rotation considerably though the moment carrying capacity is not increased. this shows the angle of rotation is dependent on the lip we provide as it reduces the difference of the shear centre and centroid.

V. EXPERIMENTAL RESULTS

It was observed that the moment carrying capacity is increased by the 17.09% only using channel section with the lips of 20mm. The difference of the moment carrying capacity of the beam with the v stiffener and v stiffener with lips was seen to be only 4.55% while using the rectangular stiffener the enhancement of the moment carrying capacity than channel section was 49.21%. This shows the beam with the lips in the stiffened beam is not as important as in the un-stiffened beam as the increase in the capacity is relatively small.

Table 2 Comparison of moment carrying capacity and Angle of Rotation

Description	Moment Carrying Capacity (KNm)	Angle Of Rotation (Degree)
C with lip	18.43	29
C with V stiffener and lip	27.45	9
C with Rectangular stiffener	36.29	19
C with V stiffener	26.2	16
C without lip	14.91	28

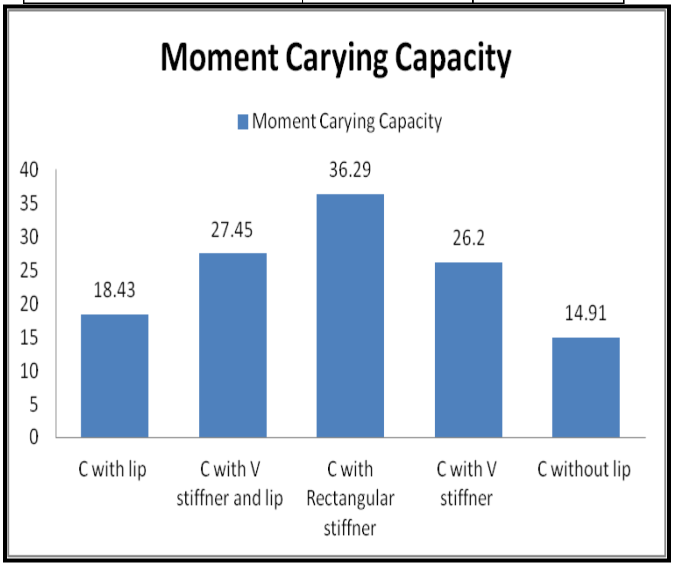

Fig 7 Comparison of Moment Carrying Capacity

It was observed that the angle of rotation is increased by the 3.44 % only using channel section with the lips of 20mm. The difference of the angle of rotation of the beam with the v stiffener and v stiffener with lips was seen to be only 32.50% while using the rectangular stiffener the enhancement of the moment carrying capacity than channel section was 34.48%. This shows the beam with the lips in the stiffened beam reduces the angle of rotation considerably though the moment carrying capacity is not increased. This shows the angle of rotation is dependent on the lip we provide as it reduces the difference of the shear centre and centroid.

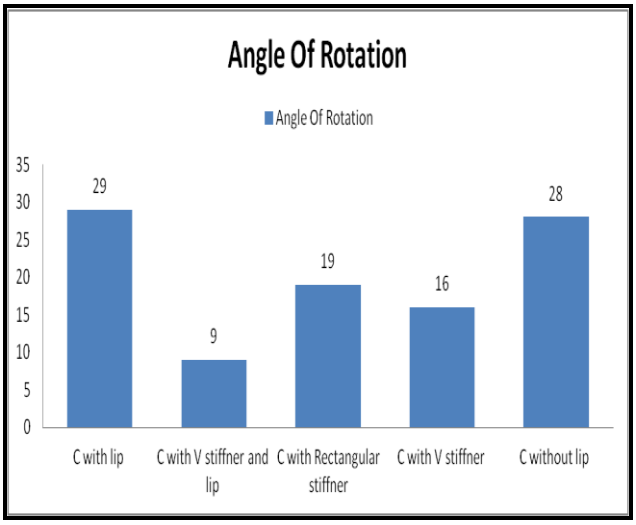

Fig 8 Comparison of Angle of Rotation

VI. MOMENT CARRYING CAPACITY AND DEFLECTION

It was observed that there was sudden change in the deflection in sample without stiffener and lips. There is far difference in deflection between beam with the v stiffener and v stiffener with lips while using the rectangular stiffener the enhancement of the moment carrying capacity is seen but with the least deflection. This shows the beam with the lips in the stiffened beam reduces the deflection considerably. This shows the deflection is dependent on the stiffeners we provide as it reduces the difference of the shear centre and centroid.

Table No.5.3 Comparison of moment carrying capacity and Deflection

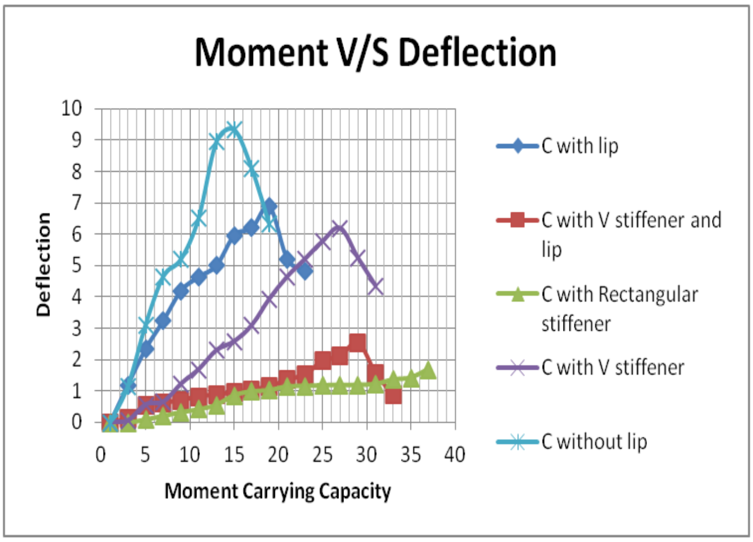

Fig 9 Comparison of moment carrying capacity and Deflection

VII. VALIDATION

The validation of the analytical work was done using the experimental test on the true scale specimen under pure torsion. it was observed that the results of abacus and experimental work are good in agreement as the percentage difference of the both the results is in permissible limit 15%. This shows the actual analysis of the beam element can be done using the finite element analysis and no need of every time going for the experimental investigation.

Table 3 Comparison Results of Experimental and Analytical Procedures

Description	Analytical Results	Experimental Results
C with lip	19.63	18.43
C with V stiffener and lip	23.63	27.45
C with Rectangular stiffener	32.6	36.29
C with V stiffener	24.28	26.2
C without lip	16.29	14.91

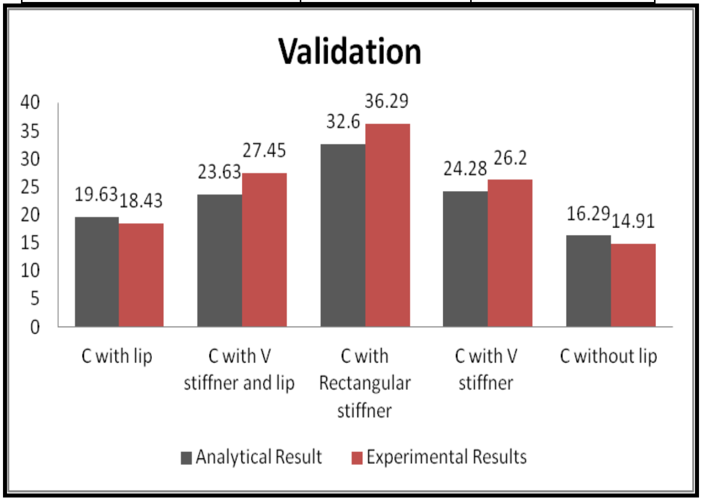

Fig 10 Comparison Results of Experimental and Analytical Procedures

Table 4 Comparison of Ultimate Deflection and Load Carrying Capacity

Description	Moment Carrying Capacity (KNm)	Deflection In mm	Load VS Deflection
C with lip	18.43	6.78	2.72
C with V stiffener and lip	27.45	2.33	11.78
C with Rectangular stiffener	36.29	1.43	25.38
C with V stiffener	26.2	6.20	4.23
C without lip	14.91	9.21	1.62

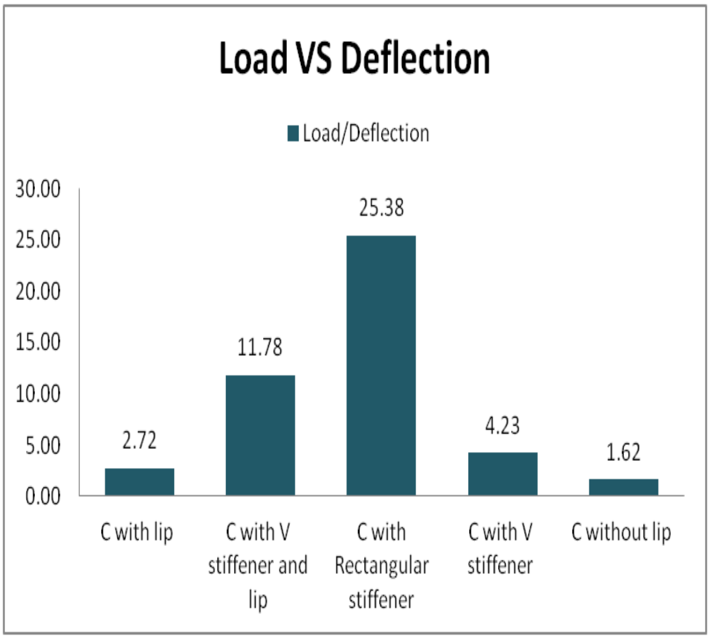

Fig 11 Comparison of Ultimate Deflection and Load Carrying Capacity

VIII. CONCLUSION

1. From this experimental work it concludes that as the shear center and the centroid of the cold form steel channel section is never intersecting so there is induction of the torque under any flexure loading.
2. The torsion capacity of the cold form is considerably increased up to 58% with different stiffeners.
3. By adding different stiffness agents the angle of rotation can be considerably reduced by 69%.
4. The moment carrying capacity of cold formed steel channel section is increasing as the stiffeners are introduced but simultaneously the angle of the rotation is reduced.
5. The experimental and the analytical results show the good agreement as the percentage error is within the limit less than 15%.

REFERENCES

[1.] A. Andrade, P. Providência, D. Camotim," Elastic lateral-torsional buckling of restrained web-tapered I-beams", Computers and Structures, vol. 88, pp. 1179–1196, 2010.

[2.] B.P. Gotluru, B.W. Schafer and T. Pekoz, " Torsion in thin-walled cold-formed steel beams", Thin-Walled Structures, Vol- 37, pp-127–145, 2000.

[3.] Bogdan, M. Put, Yong-Lin Pi, and. Trahair N.S (1999), "Lateral Buckling Tests on Cold-Formed Channel Beams, " Journal of Structural Division, ASCE, Vol. 125, No. 5, pp 532 – 539.

[4.] Chi-Ling Pan, and Wei-Wen Yu (2001), "Yield moment of cold-formed steel beams under different strain rates, "Journal of Structural Engineering, Vol.127, No.3, pp264-270.

[5.] Chong, K.P., and D.M. Mosier (1975) "Non linear behavior of continuous cold-formed beams" Proceedings of the 3rdinternational specialty conference on cold-formed steel structures, W.W.Yu and J.H. Senne Eds, University of Missouri-Rolla, pp 227-250.

[6.] Chong Ren, Xianzhong Zhao and Yiyi Chen, " Buckling behaviour of partially restrained cold-formed steel zed purlins subjected to transverse distributed uplift loading", Engineering Structures, vol. 114, pp. 14–24, 2016.

[7.] Cyrilus, W.K, and Mahen Mahendran (2009),“Lateral buckling strength of simply supported lite steel beams subject to moment gradient effects, “Journal of Structural Engineering,Vol.135, No.9, pp 1058-1066.

[8.] D. S. Yerudkar and G. R. Vesmawala," Strength and Behavior of Cold Formed Steel Stiffened Sections under Interaction of Local, Distortional and Lateral Torsional Buckling: A Review", International Journal of Civil and Structural Engineering Research, Vol. 3, pp-234-250, 2015.

[9.] Feng Zhou and Lu Li, "Experimental study on hysteretic behavior of structural stainless steels under cyclic loading", Journal of Constructional Steel Research, Vol. 122, pp-94–109, 2016.

[10.] Hancock. G.J.,.Kwon. Y.B, and. Stephen Bemard E (1994), “Strength design curves for thin-walled sections undergoing distortional buckling”, Journal of Constructional steel and Research, Vol.31(2-3), pp 169-186.

[11.] Hong-Xia Wana and Mahen Mahendran," Bending and torsion of hollow flange channel beams", Engineering Structures, Vol. 84, pp-300–312,2015

[12.] Murat Pala," Genetic programming-based formulation for distortional buckling stress of cold-formed steel members" , Journal of Constructional Steel Research, Vol- 64, pp-1495–1504, 2008.

[13.] Maria. E. Moreya and Pekoz T. (1994), “Experiments on lipped channel flexural members”, Proceeding of 12thinternational specialty conference on cold-formed steel structures , St. Louis, Missouri, USA Oct 18-19, pp 41-56.

[14.] Mohammed H. Serror, Emad M. Hassan and Sherif A. Mourad," Experimental study on the rotation capacity of cold-formed steel beams", Journal of Constructional Steel Research, vol. 121, pp. 216–228,2016.

[15.] Paul Bezkorovainy, Tim Burns and Kim Rasmussen J. R. (2003), “Strength curves for metals plates in compression”, Journal of Structural Engineering, ASCE, 129 (11), Vol pp 1433-1440.

[16.] Pedro B. Dinis and Dinar Camotim," Post-buckling behaviour and strength of cold-formed steel lipped channel columns experiencing distortional/global interaction", Computers and Structures, Vol- 89, pp-422–434, 2011.

[17.] R. Kandasamy , R. Thenmozhi, and L.S.Jeyagopal," Flexural -Torsional Buckling Tests of Cold-Formed Lipped Channel Beams Under Restrained Boundary Conditions ", International Journal of Engineering and Technology

[18.] Reck, H.P.,.Pekoz T, and.Winter G (1975), “ Inelastic strength of cold-formed steel beams” Journal of the Structural Division, ASCE Proceedings, Vol.101, No. 11, pp2193 – 2203

[19.] Rhodes, J" Design of Cold Formed Steel Members ", Elsevier Applied Science, London and New York.

[20.] Wang, S.T., and Yeh S.S. (1974), “Post-local buckling behavior of continuous beams,” Journal of the Structural Division, ASCE Proceedings, Vol.100, pp 1178-1187.

[21.] Wei-Wen Yu, and Roger LaBoube, “Cold-Formed Steel Design”, Fourth Edition, WILEY, John Wiley & Sons, Inc.

[22.] Yener, M., and Pekoz T. (1980), “Inelastic load carrying capacity of Cold-Formed Steel Beams,”. Proceedings of the 5thinternational speciality conference on Cold-Formed Structures, W.W. Yu and J.H. Senne, Eds., University of Missouri-Rolla, pp 145 – 174.

[23.] Yener, M., and Pekoz T. (1985), “Partial stress redistribution in cold-formed steel, “Journal of structural Engineering, ASCE, Vol.111, No.6, pp 1169-1186.

[24.] Yener, M., and Pekoz T. (1985), “ Partial moment redistribution in cold-formed steel, “ Journal of Structural Engineering, Vol.111, No.6, pp 1187-1203.

[25.] Zhao, X.L., Hancock. G.J., and. Trahair N.S (1995), “Lateral buckling tests of cold-formed RHS beams”, Journal of Structural Engineering, ASCE, Vol.121, No.11,pp 1656-1673.

[26.] Is Codes IS:801