Ultimate Strength of Various International Codes Using Cold Formed Steel Angle Sections under Tension Members

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***Abstract*: Cold formed steel is a basic components in construction of lightweight prefabricated structures like stud frame panels, trusses and prefabricated structures. Typically columns, beams and angles etc. are different globally. This research work deals with the details of an ultimate strength of various international codes using cold-formed steel angle section subjected to tension load. This analysis carries single angle sections thickness of1.5mm, 1.6mm and 2mm. A comparative study between the experimentally observed ultimate loads of the specimen tested with the tensile load carrying capacity of equations of the following codes is made to review the procedures recommended. All codal values give good relationship with experimental ultimate loads of single angle sections and double angles sections. To review the procedures recommended by the various codes , the observed load carrying capacities of angle tested are compared with the predicted valves suggested by the following codes.Bereou of Indian standard BIS 800:2007, British Standard BS: 5950 - 1998 (Part 5), American Iron and Steel Institute AISI: 2001 (manual)and Australian and New Zealand standards, AS/NZS: 4600 – 2005.**

***IndexTerms*: CFS, BIS, AS/NZS, BS, AISI, Tension, Angle**

I.INTRODUCTION

The design of commercial building is ruled primarily by useful necessities and therefore the want for economy of construction. In cross-sections these buildings can vary from single or multi bay structures of larger span. Once supposed to be used as warehouses or craft hangers to smaller span buildings for factories, assembly plants, maintenance facilities, packing plants etc. The most dimensions can nearly invariably be settled by the actual operational activities concerned, however the structural designer's input on optimum spans and therefore the choice of appropriate cross-sections profile will have a crucial pertaining to achieving overall economy.

II.STUDIES OF LITERATURE REVIEW

Prabha P and Saravanan M (2011) reported with the shear lag phenomenon in cold formed angles under tension, which are connected on one leg. A new expression for shear lag factor which represents the net section reduction coefficient has been suggested in the present paper. The proposed expression based on the regression analysis of 108 experimental results reported in the literature is validated by experiments involving net section failure in angles under tension. Totally 18 experiments were carried out on single angles fastened with bolts to the gusset plates under tension loaded upto net section rupture mode of failure. The experimental test parameters considered are number of bolts, pitch and shear lag distances and ratio of connected leg length to unconnected leg length. The tensile capacities are evaluated by various specifications such as AS/NZS:4600:2005, NAS:2001, AISC:2005, BS:5950-Part5:1998, IS:800-2007 and the proposed equation.
Rogers C.A and Hancock G.J. (2000) investigated the failure modes of bolted sheet steel connections loaded in shear. The load capacity formulations presented in the American Iron and Steel Institute specification could not accurately predict the failure modes of these connections when loaded in shear. A modification to the bearing coefficient provisions to account for the reduced bearing resistance of the materials was necessary and was suggested. A revision of the net section fracture design method was also required.
Salokhe S and Patil P (2015) investigates the cold-formed steel is used in large number of products. The Comparison of cold formed steel section and Hot rolled steel section of equal cross sectional area is done in this research paper. Sections were experimentally tested under axial compression in universal testing machine. Simultaneously, ultimate compressive strength of cold formed members and hot rolled members has been investigated. The validation of results is done by preparing finite element model in ABAQUS software. From experimental work it is observed that cold formed steel sections has more load carrying capacity as compared to hot rolled steel section.
Schiff raw and Schafer (2007) studied the inelastic bending capacity in cold formed steel members. Generally the inelastic bending capacity is dealt mainly on Hot Rolled Steel Sections, where as the authors made the first attempt to study the inelastic bending capacity of Cold Formed Steel sections. Demonstrated that the inelastic reserve strength exists in common CFS beams from the experimental observations made over 500 specimens in flexure. Examination of the test results, the demand for average strain in inelastic distortional buckling was much higher than in inelastic local buckling at an equivalent slenderness.

III. EXPERIMENTAL PROGRAMME

This programme includes testing of 54 specimens of single and double angle sections. The angle sections are using varying stages namely as equal angles. The thickness of sheet varies from 1.5mm, 1.6mm and 2mm. The cold formed steel sheets were bent in the form of angle sections of required sizes of plain angles and lipped angle sections. These specimens were arranged with the span of 500mm. The size of gusset plates are 70mm x 280mm for single angles specimen and double angles specimen on opposite side, similarly the size of gusset plates are 150mm x 280mm for double angle specimen on same side. Pitch distance and end distance are 30mm and 20mm respectively.

Angle sections are the simplest and the most commonly rolled shapes were tested as tension members. One leg of the angle section is connected while the other leg is outstandanding. In cases, where the load is applied to one leg only, it will not cause uniform stress in the section as a whole because of the shear lag. The stress distribution is non-uniform near or at the connection because of shear lag due to the eccentricity of load (assumed to be applied at the centroid of sections) with respect to the connection. The eccentric force produces bending in the member. Therefore, the connection should be designed so as to reduce the effect of bending to a minimum and the sections which are symmetrical about one or both axes. The gauge length is obtained by developing the cross section into a equivalent plate.

IV. ULTIMATE LOAD CARRYING CAPACITY

The following codal provisions are used to predict the capacity of the members of the single and double angle members of the American Iron and Steel Institute, the Australian / New Zealand and British standards.

Indian Standards, IS: 800 - 2007

Steel members can sustain loads up to the ultimate load without failure. However, the members will elongate considerably at this load, and hence make the structure unserviceable. The design strength T_{dg} is limited to the yielding of gross cross section which is given by

$T_{dg} = f_y A_g / \gamma_{m0}$

where,

f_y = yield strength of the material in MPa, A_g = gross area of cross section in mm^2.

γ_{m0}= 1.10 partial safety factor for failure at yielding.

Australian and New Zealand standards, AS/NZS: 4600 – 2005

The nominal section capacity of a member in tension shall be taken as the lesser of

$N_t = A_g f_y$ (1), $N_t = A_n 0.85\ K_t A_n f_u$ (2)

where Ag= gross cross sectional area of the member, mm^2

f_y= yield stress of the material, N/mm^2

K_t= correction factor for distribution of forces = 0.85

A_n= net area of the cross-section, obtained by deducting from the gross area of the cross section, the sectional area of all penetrations and holes, including fastener holes mm^2

f_u= tensile strength used in the design, N/mm^2

American Iron and Steel Institute, AISI: 2001 (manual)

The tensile capacity P_n, of a member should be determined from

$P_n = A_n A_e f_u$

Where f_u= tensile strength of the connected part of a member, N/mm^2

$A_e = U A_n$ and $U = 1.0 - 0.36 X / L < 0.9$ and $U > 0.5$

A_n= effective net sectional area of the member, mm^2

X = distance from shear plane to centroid of the cross section, mm

L= length of the end connection i.e. distance between the outermost bolts in the joint along the length direction mm

British Standard, BS: 5950 - 1998 (Part 5)

The tensile capacity Pt, of a member

$P_t = A_e * p_y$

Single angles

$A_e = a_1 (3a_1+4a_2) / (3a_1+a_2)$

Double angles

$A_e = a_1 (5a_1+6a_2) / (5a_1+a_2)$

For double angles connected to the same side of gusset plate the effective area can be determined as that of single angles. A_e = effective area of the section.

a_1 = the net sectional area of the connected leg.

a_2 = the gross sectional area of the unconnected leg.

V.TENSION MEMBERS

Tension members consisting of single and double angles are frequently used for lateral bracing and as truss elements. Tests performed in cold formed steel angles, connected by bolts and submitted to tensile loads are presented. A comparative study between the experimentally observed ultimate loads of the specimen tested with the tensile load carrying capacity of equations of the following codes is made to review the procedures recommended. The tensile capacity equation of the international codes take it into account the effect of shear lag and incorporates the capacity reduction factor in addition to net effective area of the section.

All angles section values predicted by the international codes IS,AISI, AS/NZS and BS. All codal values give good relationship with experimental ultimate loads of single angle sections and double angles sections. To review the procedures recommended by the various codes , the observed load carrying capacities of angle tested are compared with the predicted valves suggested by the following codes

- Bereou of Indian standard BIS 800;2007
- British Standard BS: 5950 - 1998 (Part 5)
- American Iron and Steel Institute, AISI: 2001 (manual)
- Australian and New Zealand standards, AS/NZS: 4600 – 2005.

Tables 1 shows the experimental and ultimate loads obtained by various international codes of thickness 1.5mm . The single equal angle without lip ultimate loads are 1.15 times lower than the experimental load values using IS 800:2007, the same as the ultimate loads are 1.21 times higher than the experimental load values using AISI manual- 2001. In the case of single equal plain angles, the ultimate loads are 1.30 times lesser than the experimental load values using AS / NZS: 4600- 2005. In the case of single equal angles, the ultimate load values are 1.23 times higher than the experimental values using BS: 5950- 1998(Part 5).

VI.Comparison of Predicted Ultimate Loads by various international codes

The comparison of predicted ultimate loads by the three various codes for single and double angles tested are shown in Fig 1 to 5. The tensile capacity equation of the international codes take it into account the effect of shear lag and incorporates the capacity reduction factor in addition to net effective area of the section. In case of single angles the values predicted by AISI and AS/NZS are nearly 10% lower than the ultimate loads irrespective of whether the angle is equal or unequal and provided with or without lip. BS code underestimates the values by 16% with respect to experimental ultimate loads.

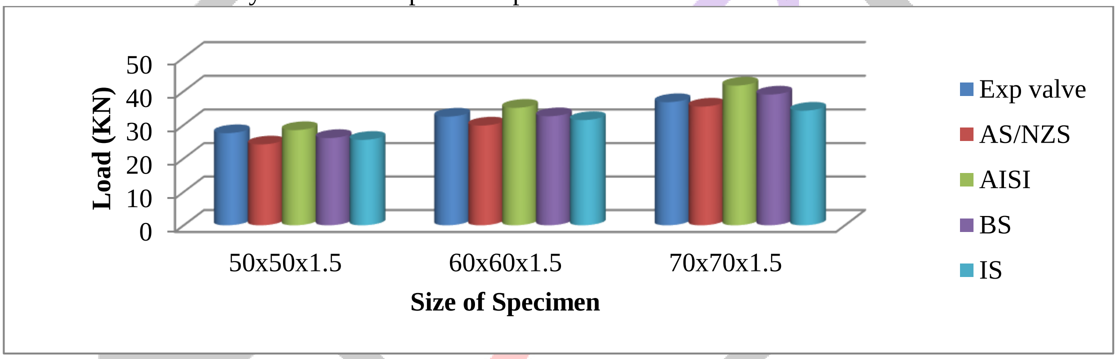

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Fig 1 Ultimate load with load based on codal provision for single plane angles (1.5mm)

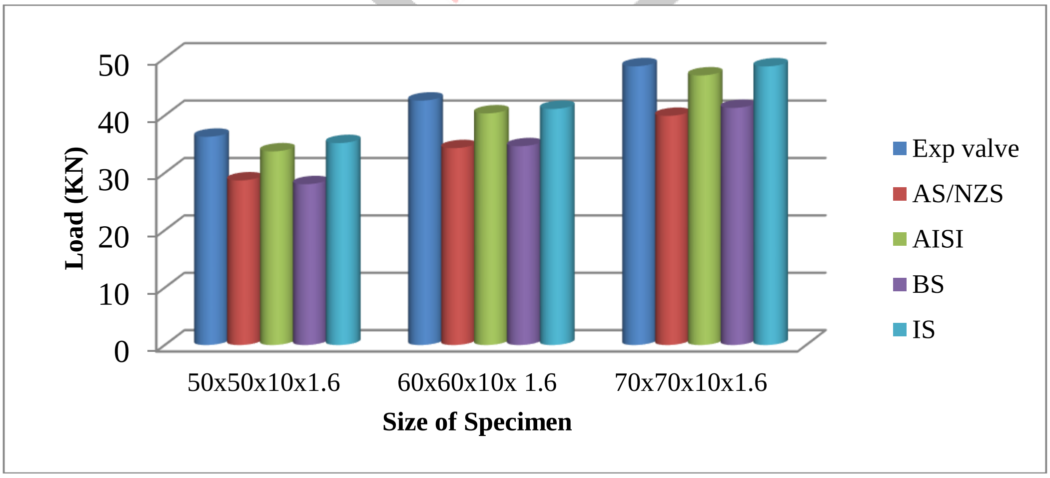

Fig 2 Ultimate load with load on codal provision for double angles connected to opposite side with lip (1.6mm)

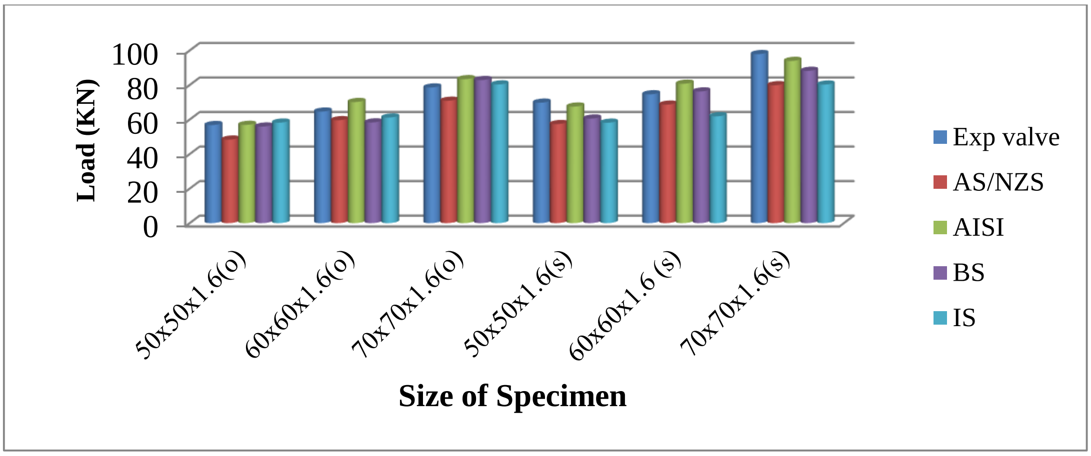

Fig 3 Ultimate load with load based on codal provision for single plane angles with Lip (1.6mm)

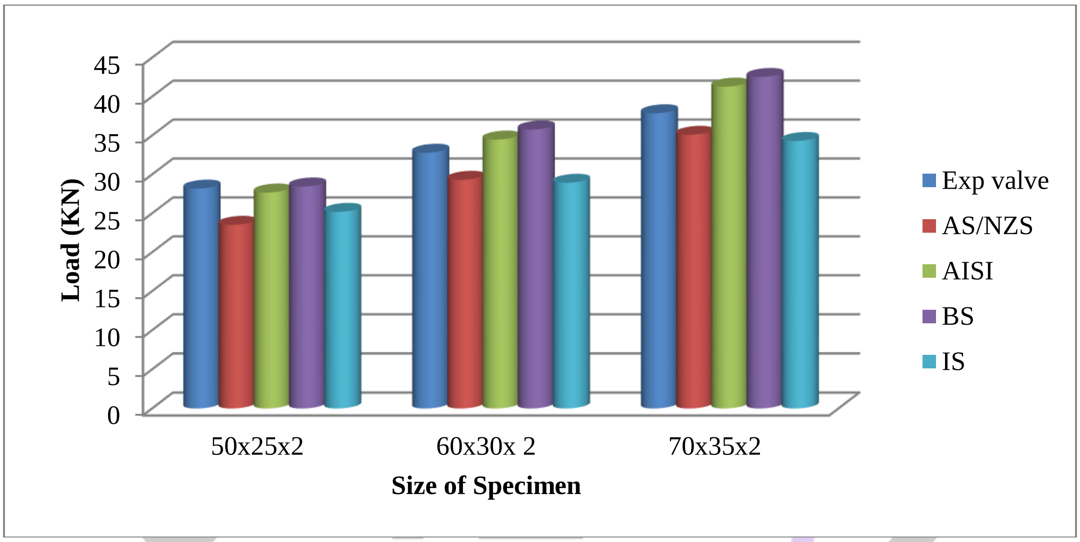

Fig 4 Ultimate load with load based on codal provision for single plane unequal angles (2mm)

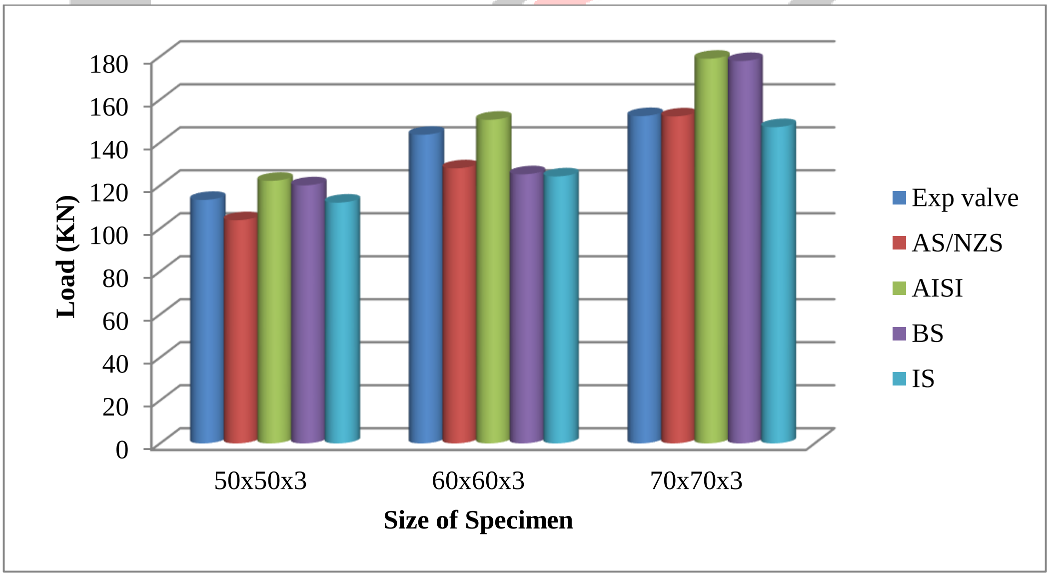

Fig 5 Ultimate load with load on codal provision for Double equal angles connected to same side of the gusset plate(2mm)

VII.Comparison of ultimate load of various international codes

Table 1 Comparison of predicted ultimate load obtained by various international codes(1.5mm thick)

S.No	Size of specimen (mm)	Exp valve (KN)	IS 800:2007 (KN)	AS/NZS/Exp	AS/NZS 4600: 2005 (KN)	AS/NZS/Exp	AISI:2007 (KN)	AISI/Exp	BS:5950 (Part 5) -1998 (KN)	BS/Exp
1	50x50	27.54	25.54	0.93	24.18	0.88	28.44	1.03	26.09	0.95
2	60x60	32.45	31.42	0.97	29.80	0.92	35.06	1.08	32.56	1.00
3	70x70	36.75	34.21	0.93	35.42	0.96	41.67	1.13	39.01	1.06
4	50x50x10	36.28	35.12	0.97	28.68	0.79	33.74	0.93	28.02	0.77
5	60x60x10	42.58	38.18	0.90	34.30	0.81	40.35	0.95	34.63	0.81
6	70x70x10	48.56	42.28	0.87	39.92	0.82	46.97	0.97	41.31	0.85
7	50x50(o)	59.78	53.16	0.89	48.36	0.81	56.89	0.95	55.91	0.94
8	60x60(o)	64.58	61.28	0.95	59.60	0.92	70.12	1.09	58.30	0.90
9	70x70(o)	79.86	74.25	0.93	70.85	0.89	83.35	1.04	82.85	1.04
10	50x50(s)	56.78	53.01	0.93	48.36	0.85	56.89	1.00	55.91	0.98
11	60x60(s)	64.58	61.12	0.95	59.60	0.92	70.12	1.09	58.30	0.90
12	70x70 (s)	78.54	73.97	0.94	70.85	0.90	83.35	1.06	82.85	1.05
13	50x50x10(o)	69.74	61.45	0.88	57.35	0.82	67.47	0.97	60.54	0.87
14	60x60x10(o)	74.58	68.12	0.91	68.60	0.92	80.70	1.08	76.24	1.02
15	70x70x10(o)	97.87	90.47	0.92	79.84	0.82	93.93	0.96	88.17	0.90
16	50x50x10(s)	68.74	67.51	0.98	57.35	0.83	67.47	0.98	60.54	0.88
17	60x60x10(s)	80.47	68.13	0.85	68.60	0.85	80.70	1.00	76.24	0.95
18	70x70x10(s)	96.47	91.16	0.94	79.84	0.83	93.93	0.97	88.17	0.91

Table 2 Comparison of predicted ultimate load obtained by various international codes(1.6mm thick)

1	50x50	29.45	24.28	0.82	26.11	0.89	30.71	1.04	28.17	0.96
2	60x60	34.56	30.48	0.88	32.18	0.93	37.85	1.10	35.15	1.02
3	70x70	40.58	36.18	0.89	38.25	0.94	45.00	1.11	42.12	1.04
4	50x50x10	39.15	35.18	0.90	30.96	0.79	36.43	0.93	30.25	0.77
5	60x60x10	46.78	41.13	0.88	37.03	0.79	43.57	0.93	37.39	0.80
6	70x70x10	52.58	48.54	0.92	43.10	0.82	50.71	0.96	44.60	0.85
7	50x50(o)	62.58	58.18	0.93	52.21	0.83	61.42	0.98	60.37	0.96
8	60x60(o)	68.41	61.13	0.89	64.35	0.94	75.71	1.11	62.95	0.92
9	70x70(o)	84.59	80.29	0.95	76.50	0.90	89.99	1.06	89.46	1.06
10	50x50(s)	62.58	58.13	0.93	52.21	0.83	61.42	0.98	60.37	0.96
11	60x60(s)	76.24	61.85	0.81	64.35	0.84	75.71	0.99	62.95	0.83
12	70x70 (s)	84.25	80.22	0.95	76.50	0.91	89.99	1.07	89.46	1.06
13	50x50x10(o)	76.28	71.92	0.94	61.92	0.81	72.85	0.96	65.37	0.86
14	60x60x10(o)	82.58	78.28	0.95	74.07	0.90	87.14	1.06	82.31	1.00
15	70x70x10(o)	103.5	96.24	0.93	86.21	0.83	101.4	0.98	95.20	0.92
16	50x50x10(s)	76.42	71.84	0.94	61.92	0.81	72.85	0.95	65.37	0.86
17	60x60x10(s)	88.48	77.21	0.87	74.07	0.84	87.14	0.98	82.31	0.93
18	70x70x10(s)	106.5	95.23	0.89	86.21	0.81	101.4`	0.95	95.20	0.89

Table 3 Comparison of predicted ultimate load obtained by various international codes(2 mm thick)

1	50x50	54.28	50.12	0.92	51.91	0.96	61.07	1.13	56.01	1.03
2	60x60	68.45	61.85	0.90	63.98	0.93	75.27	1.10	69.90	1.02
3	70x70	82.45	78.43	0.95	76.05	0.92	89.47	1.09	83.76	1.02
4	50x50x10	78.25	72.58	0.93	61.57	0.79	72.43	0.93	60.15	0.77
5	60x60x10	94.28	89.75	0.95	73.64	0.78	86.63	0.92	74.36	0.79
6	70x70x10	102.5	96.13	0.94	85.71	0.84	100.8	0.98	88.69	0.86
7	50x50(o)	124.2	113.2	0.91	103.8	0.84	122.1	0.98	120.0	0.97
8	60x60(o)	154.2	123.8	0.80	127.9	0.83	150.5	0.98	125.1	0.81
9	70x70(o)	168.2	146.2	0.87	152.1	0.90	178.9	1.06	177.8	1.06
10	50x50(s)	113.2	112.0	0.99	103.8	0.92	122.1	1.08	120.0	1.06
11	60x60(s)	143.5	124.2	0.87	127.9	0.89	150.5	1.05	125.1	0.87
12	70x70 (s)	152.2	147.1	0.97	152.1	1.00	178.9	1.18	177.8	1.17
13	50x50x10(o)	105.2	101.2	0.96	123.1	1.17	144.8	1.38	129.9	1.23
14	60x60x10(o)	131.2	125.2	0.95	147.2	1.12	173.2	1.32	163.6	1.25
15	70x70x10(o)	168.2	161.2	0.96	171.4	1.02	201.6	1.20	189.3	1.12
16	50x50x10(s)	122.4	102.4	0.84	123.1	1.01	144.8	1.18	129.9	1.06
17	60x60x10(s)	142.5	127.8	0.90	147.2	1.03	173.2	1.22	163.6	1.15
18	70x70x10(s)	169.2	162.2	0.96	171.4	1.01	201.6	1.19	189.3	1.12

VIII. CONCLUSION

Tables1 shows the experimental and ultimate loads obtained by various international codes of thickness 1.5mm . The single equal angle without lip ultimate loads are 1.15 times lower than the experimental load values using IS 800:2007, the same as the ultimate loads are 1.21 times higher than the experimental load values using AISI manual- 2001. In the case of single equal plain angles, the ultimate loads are 1.30 times lesser than the experimental load values using AS / NZS: 4600- 2005. In the case of single equal angles, the ultimate load values are 1.23 times higher than the experimental values using BS: 5950- 1998(Part 5).

Tables 2 shows the experimental and ultimate loads obtained by various international codes of thickness 1.6mm . Single unequal angle ultimate loads are 1.18 times lower than the experimental load values using IS 800:2007, the same as the ultimate loads are 1.25 times higher than the experimental load values using AISI manual- 2001. In the case of single unequal angles, the ultimate loads are 1.28 times lesser than the experimental load values using AS / NZS: 4600- 2005. In the case of single unequal angles, the ultimate load values are 1.27 times higher than the experimental values using BS: 5950- 1998(Part 5).

Tables 3 shows the experimental and ultimate loads obtained by various international codes of thickness 2 mm . Double angle connected to same side are 1.20 times lower than the experimental load values using IS 800:2007, the same as the ultimate loads are 1.28 times higher than the experimental load values using AISI manual- 2001. In the case of Double angle connected to same side , the ultimate loads are 1.32 times lesser than the experimental load values using AS / NZS: 4600- 2005. In the case of Double angle connected to same side, the ultimate load values are 1.33 times higher than the experimental values using BS: 5950- 1998(Part 5).

References:

[1] Abdul Bari, J & Easwaran, P 2017, 'A General Study of Light Gauge Steel Structures – A Review', International Journal of Advanced Research Methodology in Engineering & Technology, vol. 1, no.4, pp.1-4

[2] Bayan, A & Sariffuddin, S 2011, 'Cold formed steel joints and structures - A review', International Journal Of Civil and Structural Engineering, vol. 2,. 2, pp. 621-634

[3]Beulah & Palani, GS 2015, 'Numerical and Theoretical Studies on Cold-Formed Steel Unlipped Channels Subjected to Axial Compression' ,Latin American Journal of Solids and Structures,vol. 12, no. 1, pp.1-17

[4] Beulah Gnana & Ananthi, G 2017, 'A Study on Cold-Formed Steel Compound Angle Section Subjected to Axial Compression', KSCE Journal of Civil Engineering, vol. 22, no. 5, pp.1803-1815

[5]Ben Young 2005, 'Experimental Investigation of Cold-Formed Steel Lipped Angle Concentrically Loaded Compression Members', Journal of Structural Engineering, vol. 131, no. 9, pp. 1390-1396

[6] Ben Young & Ehab Ellobody 2006, 'Buckling Analysis of Cold-Formed Steel Lipped Angle Columns', Journal of Structural Engineering, vol. 131,no. 10, pp. 1570-1576

[7]Bhavitha, E & Rosemol, K 2015, 'Comparative study on moment connections in cold formed steel sections with and without perforations', International journal of Innovative science, Engineering & Technology, vol. 2, no. 11, pp. 478-481