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COMPARATIVE STUDY OF EXPERIMENTAL ANALYSIS OF COLD-FORMED STEEL IN TENSION MEMBERS

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ABSTRACT

Cold formed steel is a basic components in the construction of lightweight prefabricated structures like stud frame panels, trusses and prefabricated structures. This research work deals with the details of an Experimental of shear lag on cold-formed steel sections subjected to tension load. This analysis carries single angle sections of 2mm & 3mm and double angles sections of above members where under plain (without Lipped) and with Lipped conditions subjected to tension. The papers describes the load carrying capacity of single angles lipped section increases by 23% and double angles by 26% compare with plain angles of 2mm & 3mm section. Analyses were carried out for thirty six numbers of angle sections under condition such as Lipped were connected same side to gusset plate and connected to opposite side.

Keywords: tension members, cold-formed angles, net section, block shear, shear, bucking behavior.

INTRODUCTION

Cold formed steel products are made by bending a flat sheet of steel at room temperature into a shape that will support more loads the flat sheet itself. Cold formed steel members are manufactures by cold rolling or press bracking and the plain angle sections are generally made by bending a plain sheet. Generally there are four types of buckling such as local buckling, flexural buckling, torsional buckling and distortional bucking. Global bucking is a bucking mode where the member deforms with no deformation in its cross sectional shape, consistent with classical beam theory. Torsional buckling causes the element to twist parallel to the loading. Distortional bucking is a mode with cross- sectional that involves the translation the some of fold lines (intersection lines of adjacent plate elements).

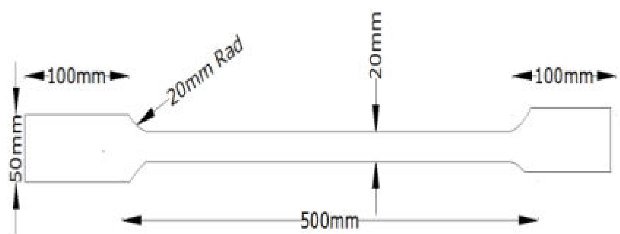

Figure-1. Tensile coupon test specimen.

Table-1. Properties of cold forms steel.

Thickness of steel sheet	2mm	3mm
Yield stress in MPa (f_y)	**220N/mm^2**	**232N/mm^2**
Ultimate Stress in MPa (fu)	252N/mm^2	263N/mm^2
Modulus of Elasticity	2.03x10^5 N/mm^2	2.07x10^5 N/mm^2
f_u/f_y	1.14	1.13
Percentage elongation	10 %	11 %

REVIEW OF LITERATURE

Experiments on cold formed angle tension members were initiated by Holcomb *et al* Chi-Ling Pan [1] (2004) carried experimental work on cold form channel section to study the effect of connection length, bolt arrangement and tested a series of bolted cold-formed channel sections to study the shear lag effect. Pan concluded that the ratio of connection eccentricity to [2] at the University of Missouri- Rolla. They conducted 27 tests consisting of equal and unequal, angle thickness and connection eccentricity. [3] Schafer (2014) characterized geometric imperfections and residual stresses in the numerical analysis, found the moment capacity of laterally braced cold-formed steel flexural members with edge stiffened flanges which were affected by local or distortional buckling. They presented a new procedure for buckling stress in local and distortional mode. [4] Gotloru *et al*. (2013) studied the behavior of cold formed steel beams having open sections, which were subjected to torsion. They focused only on beams subjected to bending and torsion. They conducted a series of experimental study on angle sections and compared the result with simple geometric analysis, finite element analysis and finite strip analysis results. [5] This paper presents the effect of shear lag on the tensile capacities of cold formed angles. Practically angles are connected with gusset plates through one leg and due to this there will be non- uniform stress distribution due to eccentrically applied load.

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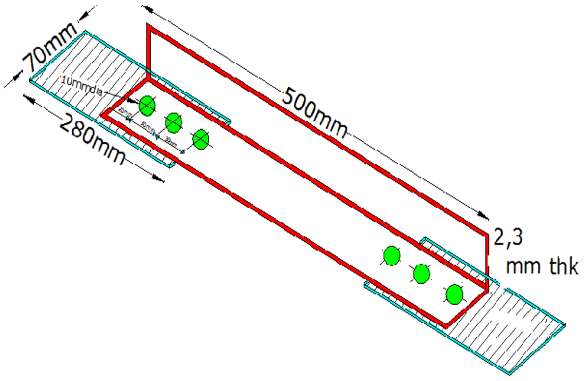

Figure-2.a. Single angle without lip.

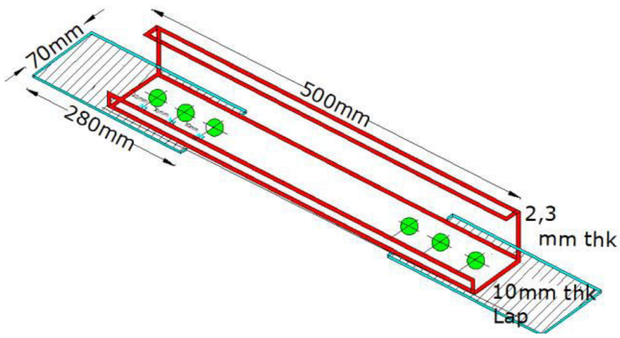

Figure-2.b. Single angle with lip.

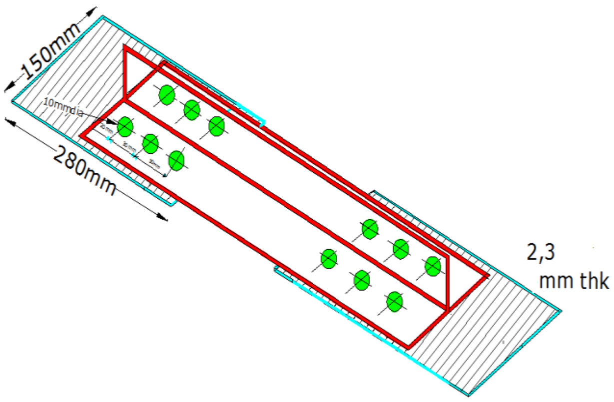

Figure-2.c. Double angle on same side without lip.

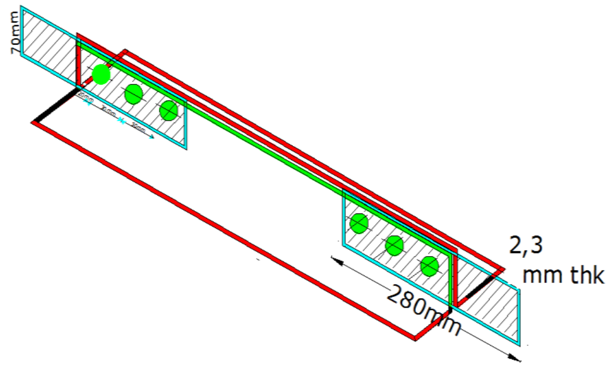

Figure-2.d. Double angle on opposite side without lip.

Figure-3. Cold formed steel sheet.

Figure-4. Angles fixed in universal testing machine (UTM).

RESULT AND DISCUSSIONS

ULTIMATE LOAD-CARRYING CAPACITY

A total of thirty six specimens have been tested by varying the angle sizes, number of bolts and the bolt pitch distance. All the specimens have been designed to undergo net section rupture failure. The specimens are equal angles of dimensions 50x50mm, 60x60mm and 70x70 mm and they have equal length 500mm and thickness 2 and 3 mm and unequal angle of 50x25mm, 60x30mm and 70x35 mm and they have equal length 500mm and thickness 2 and 3 mm respectively. The experimental ultimate loads for all the cold-formed steel single angles are presented in Table-2. It is observed that in the case of single equal lipped angles the average increase in ultimate load is 1.20 times greater than that of single equal plain angles.

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Table-2. Ultimate load-carrying capacity.

S. No	Description	Size of specimen	Ultimate load (P_{Ul}) kN		Yield load (P_{yl}) kN		Design strength ((P_{DS})	
			2mm	3mm	2mm	3mm	2mm	3mm
1	Single angle without Lip	50x50	55.98	96.28	46.65	77.64	31.10	46.59
		60x60	70.32	119.48	57.87	96.35	38.13	57.81
		70x70	83.43	140.54	68.91	113.34	45.26	68.00
		50x25	39.6	67.68	33.15	54.58	22.00	32.75
		60x30	46.26	84.06	38.54	67.79	25.70	40.67
		70x35	55.32	101.35	46.13	81.73	30.70	49.04
6	Single angle with Lip	50x50	67.43	112.96	56.12	91.09	37.32	54.66
		60x60	84.3	136.11	70.25	109.77	46.17	65.86
		70x70	97.34	149.69	82.35	120.72	54.37	72.43
		50x25	48.34	85.93	40.21	69.30	26.80	41.58
		60x30	56.43	102.45	47.32	82.62	31.34	49.57
		70x35	66.31	118.98	55.18	95.95	36.78	57.57
3	Double angle on opposite side without Lip	50x50	105.23	182.14	87.24	146.89	58.63	88.13
		60x60	127.32	224.02	108.32	180.66	72.11	108.40
		70x70	154.25	265.89	129.43	214.43	85.59	128.66
		50x25	75.43	136.60	62.65	110.16	41.78	66.10
		60x30	90.31	169.65	75.42	136.82	50.05	82.09
		70x35	107.76	202.70	89.65	163.47	59.79	98.08
4	Double angle on opposite side with Lip	50x50	128.35	215.64	106.31	173.91	71.02	104.34
		60x60	162.37	257.51	134.26	207.67	88.88	124.60
		70x70	185.32	299.39	155.34	241.44	103.37	144.86
		50x25	92.56	171.86	76.94	138.59	51.15	83.16
		60x30	109.32	204.91	90.54	165.25	60.59	99.15
		70x35	129.34	237.95	108.65	191.90	72.12	115.14
5	Double angle on same side without Lip	50x50	107.43	182.14	90.31	146.89	59.76	88.13
		60x60	133.32	224.02	110.43	180.66	73.70	108.40
		70x70	157.42	265.89	132.32	214.43	87.81	128.66
		50x25	75.86	136.60	62.15	110.16	41.98	66.10
		60x30	89.32	169.65	75.23	136.82	49.95	82.09
		70x35	107.93	202.70	90.54	163.47	59.85	98.08
6	Double angle on same side with Lip	50x50	130.36	215.64	108.32	173.91	72.37	104.34
		60x60	163.25	268.55	135.78	216.57	89.34	129.94
		70x70	196.26	312.22	162.87	251.79	106.35	151.07
		50x25	91.56	171.86	76.15	138.59	50.66	83.16
		60x30	109.38	215.92	92.43	174.13	60.77	104.48
		70x35	129.04	237.95	108.26	191.90	71.68	115.14

Load vs deflection

The typical load versus deflection has shown in Figure-5.a to Figure-5.d. From the graphs, it is observed that the ultimate load carrying capacity increases as the cross-sectional area and number of bolts in the connection increases. It is also observed that when the rigidity of the connection increases the stiffness of the member also increases.

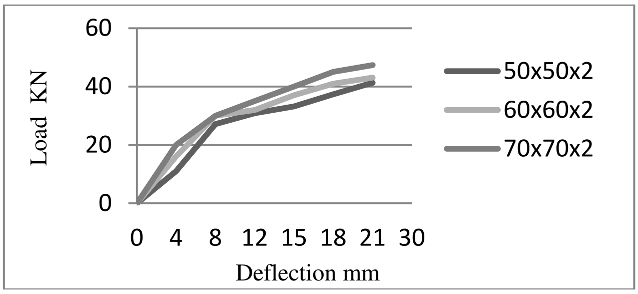

Figure-5.a. Single plain angle specimen without lip 2mm).

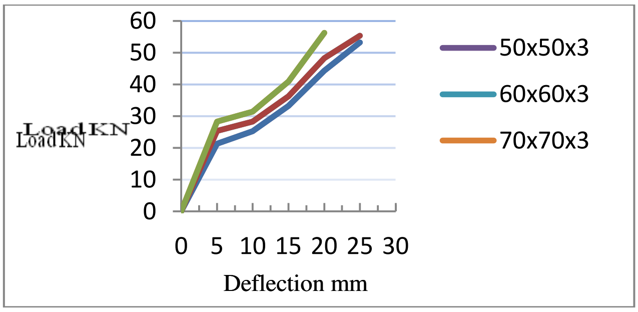

Figure-5.b. Double plain angle specimen opposite without lip (3mm).

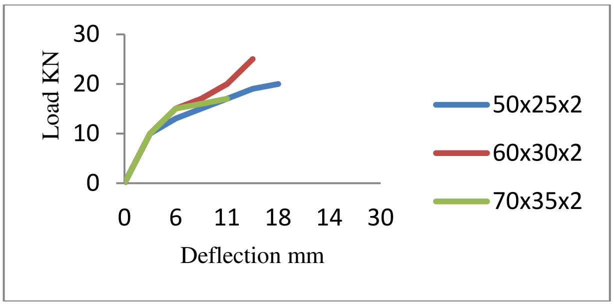

Figure-5.c. Single plain unequal angle specimen without lip (2mm).

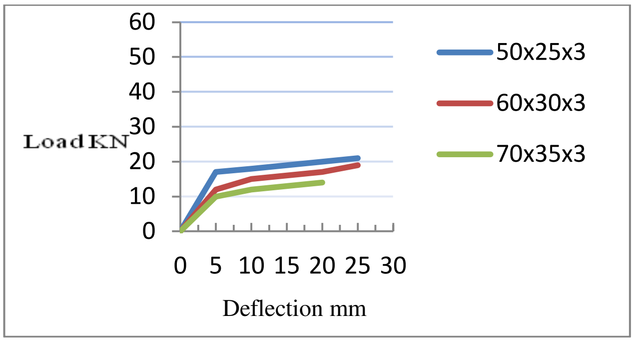

Figure-5.d. Double unequal angle specimen same side with lip (3mm).

MODES OF FAILURE

The modes of failure of all single and double angle specimens were noticed during testing. Generally tearing failure, block shear failure, net section fracture failure was observed as in Figure-6(a) to 6(c). Thus, a gap was formed between the corner of the connected leg and the gusset plate. This is referred as local bending. The mode of failure depends upon the cross section and rigidity of connection. During the loading process, the gusset plates of double angle members remained straight. However, in the case of single angles the gusset plate and the angles bent during loading. This is due to eccentrically applied load. This kind of bending is referred as global bending. As the load is applied, the angle and plate can be seen deforming; the plate edges bend over and the bolt hole undergo plastic deformation. Finally, the plate tears along a horizontal line that is coincident with the widest point of the bolt hole in tearing failure.

The design strength of tension members are not always controlled by factor of safety or by the strength of the bolts or welds with which they are connected. After necking, the critical cross-section was torn out from the edge of the connected leg to the hole then to the corner of the angle. The specimens carried some amount of load beyond the ultimate load and until failure. It was noted that all the bolts were still tight after completion of the tests. This indicates that the bolts were not highly stressed during the tests. The outstanding leg which is subjected to compression experiences, local buckling nearer to the supports. Mode of failure as shown in Table-3.

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Table-3. Mode of failure.

S. No	Specimens	Size/Mode of failure angles (2mm)	Size/Mode of failure angles (3mm)	Size/Mode of failure angles (2mm)	Size/Mode of failure angles (b)
1	Size	Single angle without Lip		Single angle with Lip	
	50x50	Net Section	Net Section	Block Shear	Net Section
	60x60	Block Shear	Block Shear	Net Section	Block Shear
	70x70	Net Section	Net Section	Net Section	Net Section
	50x25	Net Section	Block Shear	Net Section	Block Shear
	60x30	Block Shear	Block Shear	Block Shear	Block Shear
	70x35	Block Shear	Block Shear	Net Section	Block Shear
2	Size	Double angle on opposite side without Lip		Double angle on opposite side with Lip	
	50x50	Block Shear	Net Section	Block Shear	Net Section
	60x60	Block Shear	Block Shear	Block Shear	Block Shear
	70x70	Net Section	Net section	Net Section	Net Section
	50x25	Net Section	BlockShear	Net Section	Block Shear
	60x30	Block Shear	Block Shear	Net Section	Block Shear
	70x35	Net Section	BlockShear	Net Section	Block Shear
3	Size	Double angle on same side without Lip		Double angle on same side with Lip	
	50x50	Block Shear	Net Section	Net Section	Net Section
	60x60	Net Section	Block Shear	Block Shear	Block Shear
	70x70	Block Shear	Net Section	Net Section	Net Section
	50x25	Block Shear	Block Shear	Block Shear	Block Shear
	60x30	Net Section	Block Shear	Net Section	Block Shear
	70x35	Block Shear	Block Shear	Block Shear	Block Shear

Figure-6.a. Single plain angle without lip (2mm).

Figure-6.b. Double angle on same side with out lip (3mm).

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CONCLUSIONS

Based on the experimental, and analytical results were concluded. The experimental studies describes the load carrying capacity of single angles lipped section increases by 23% and double angles by 26% compare with plain angles of 2mm and 3mm section. The load carrying capacity of single angles lipped section increases by 26% in 2mm and double angles by 29% in 3mm compare with plain angles in 4mm. Results were recorded as the load carrying capacity increases for connected to the opposite side of the gusset than the connected to same side

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