TENSION MEMBERS OF NET SECTION EFFICIENCY ON COLD FORMED STEEL ANGLE SECTIONS

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ABSTRACT

A tension part is connected by bolts to other parts or gusset plates. The sectional area is reduced by the bolt holes. These holes cause stress concentration adjacent to bolt holes. The stresses at these locations can be a high average stress on the net area at the angle sections. Due to the inherent ductility of cold formed steel this is usually neglected due to stress. The maximum elastic stress ratio adjacent to the hole to the average net cross section stress is referred to as the stress concentration factor Tests. This research work deals with the details of an Experimental investigation and net section failure on cold-formed steel section subjected to tension. This analysis carries single angle sections and double angles sections of 1.5mm and 1.6mm under plain (without Lipped) and with Lipped conditions subjected to tension. Analyses were carried out for 24 specimens of single angle sections and 48 specimens of double angles were connected same side to gusset plate and connected to opposite side. Results were recorded as the net section efficiency of the specimens failed by net section rupture.

Keyword: - *Net section rupture, Effective area, connection Eccentricity, Connection length, Ultimate strength*

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1. INTRODUTION

A definition for cold-formed steel members, as given by both the AISI and AISC design specifications: "Shapes manufactured by press-braking blanks sheared from sheets, cut lengths of coils or plates, or by roll forming cold- or hot-rolled coils or sheets; both forming operations being performed at ambient room temperature, that is, without manifest addition of heat such as would be required from hot forming." Light-gauge cold-formed steel roof purlins were first introduced to the UK construction industry in the fifties, to replace heavier hot-rolled steel angle and channel sections. The purlin transfers load from the roof cladding to the primary steel rafters. Cold-formed steel roof purlins are used on a wide range of building types including retail and leisure, industrial, warehouses and distribution, healthcare and education. 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.

2. REVIEW OF LITERATURE

Sonal Banchhor et al [1] (2016) were reported behavior of cold formed steel bolted angle tension members. The main objective of this study is to investigate the behavior of cold steel single and double angle subjected to tension. Experimental and theoretical investigations were carried out for single angle, double angle connected to opposite sides of gusset plates and double angle connected to same side of gusset plates and the whole cross-section may not be fully utilized which causes a reduction in the net section efficiency. This loss of efficiency of the section is due to shear lag.

Padma Priya [2] (2015) conducted experimental work on Sixteen single plain and lipped angle specimens and thirty two numbers of double angle specimens connected to the same side and opposite side of the gusset plate. The experimental loads are compared with ultimate load calculated using BS 5950 (Part V)-1998, and AS/NZS 4600:2005.Most of the single and double angles failed by net section fracture failure and the outstanding leg are subjected to local bend due to shear lag effect.

RajaRathinam et al.,[3](2015) examine the main objective of this research is to understand the behavior and strength of cold formed steel 'HAT' sections connected at ends only through gusset plate, causing shear lag at the end connections and thus develop a method for evaluating the net section rupture strength of such members.

3. EXPERIMENTAL INVESTUGATIONS

A totally Seventy two experiments were conducted on single and double angle specimen of 1.5 mm and 1.6mm thickness which were connected to the gusset plate under eccentric tensile loads. The specimens were tested as two different section configurations namely single angles and double angles. The single angle specimens were connected with their larger leg to end gusset plates of mild steel of 8mm thickness. Ordinary black bolts of 10mm diameter are used as connectors for specimens made from 1.5mm and 1.6mm. In case of specimens fabricated from 1.5mm and 1.6mm thickness sheet 10mm diameter bolts were used. The double angle specimens were connected with their larger leg with two mild steel gusset plates of 8mm using ordinary black bolts of 10mm diameter. All the specimens were fabricated for a length of 500mm.They are used to transfer the load of the universal test machine (UTM) with 100 T capacity to the specimens. The specimens were tested as two separate sections configurations, namely single angle sections and double angle sections.

4. DISCUSSION OF TEST RESULTS FOR NET SECTION FAILURE

In tension components with bolted end connections, the net sectional area at angle sections is equal to the gross area of the components at sections minus bolt area at angle sections. The experimental program consists of 180 specimens of single angle sections and double angle sections. Angles with connections normally Multiple linear regression analysis was carried out and the expression for net section efficiency(U) was suggested, which depended on the geometric factors such as connection eccentricity (x), connection length (L), width of connected leg of the angle (a_c), net width of connected leg of the angle(a_{cn}), width of unconnected leg (a_d), nominal bolt diameter (d) and angle thickness (t). It is therefore necessary to propose an equation to calculate the efficiency of the net section. Table 1 shows the single and double angle specimens that failed due to net fracture failure, their geometric factors and the efficiency of the net section.

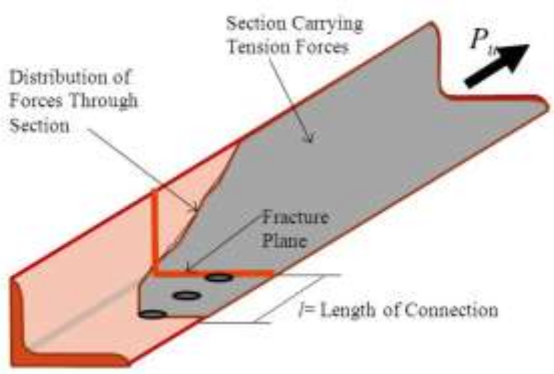

Chart-1 Net section failure on effective area

Table -1 Net section efficiency 'u' of the specimens failed by net section rupture

S.No	Size of the Specimen	X	L	X/L	A_{cn}/a_c	a_d/a_c	d/a_c	t/a_c	U
Single equal angle specimen without Lip									
1	50x50x1.5	13.24	60.00	0.22	1.118	1.000	0.200	0.030	0.90
2	60x60x1.5	15.75	60.00	0.26	1.181	1.000	0.167	0.025	0.86
3	70x70x1.5	18.25	60.00	0.30	1.227	1.000	0.143	0.021	0.82
4	50x50x1.6	13.24	60.00	0.22	1.190	1.000	0.200	0.032	0.86
5	60x60x1.6	15.75	60.00	0.26	1.259	1.000	0.167	0.027	0.82
6	70x70x1.6	18.25	60.00	0.30	1.307	1.000	0.143	0.023	0.81
Single equal angle specimen with Lip									
7	50x50x10x1.5	15.12	60.00	0.25	1.118	1.000	0.200	0.030	0.97
8	60x60x10x1.5	17.68	60.00	0.29	1.181	1.000	0.167	0.025	0.96
9	70x70x10x1.5	20.22	60.00	0.34	1.227	1.000	0.143	0.021	0.94
10	50x50x10x1.6	15.11	60.00	0.25	1.190	1.000	0.200	0.032	0.95
11	60x60x10x1.6	17.67	60.00	0.29	1.259	1.000	0.167	0.027	0.95
12	70x70x10x1.6	20.21	60.00	0.34	1.307	1.000	0.143	0.023	0.92
Single unequal angle specimen without Lip									
13	50x25x1.5	11.50	60.00	0.19	1.118	0.500	0.200	0.030	0.84
14	60x30x1.5	14.00	60.00	0.23	1.181	0.500	0.167	0.025	0.83
15	70x35x1.5	16.50	60.00	0.28	1.227	0.500	0.143	0.021	0.88
16	50x25x1.6	11.50	60.00	0.19	1.190	0.500	0.200	0.032	0.89
17	60x30x1.6	14.00	60.00	0.23	1.259	0.500	0.167	0.027	0.84
18	70x35x1.6	16.50	60.00	0.28	1.307	0.500	0.143	0.023	0.90
Single unequal angle specimen with Lip									
19	50x25x10x1.5	6.50	60.00	0.11	1.118	0.500	0.200	0.030	0.83
20	60x30x10x1.5	7.39	60.00	0.12	1.181	0.500	0.167	0.025	0.91
21	70x35x10x1.5	7.59	60.00	0.13	1.227	0.500	0.143	0.021	0.86
22	50x25x10x1.6	6.49	60.00	0.11	1.190	0.500	0.200	0.032	0.89
23	60x30x10x1.6	7.39	60.00	0.12	1.259	0.500	0.167	0.027	0.84
24	70x35x10x1.6	7.59	60.00	0.13	1.307	0.500	0.143	0.023	0.91
Double angle on opposite side without Lip									
25	50x50x1.5	26.49	60.00	0.35	1.118	1.000	0.200	0.030	0.97
26	60x60x1.5	31.49	60.00	0.42	1.181	1.000	0.167	0.025	0.85
27	70x70x1.5	36.49	60.00	0.49	1.227	1.000	0.143	0.021	0.89
28	50x50x1.6	26.49	60.00	0.35	1.190	1.000	0.200	0.032	0.92
29	60x60x1.6	31.49	60.00	0.42	1.259	1.000	0.167	0.027	0.81
30	70x70x1.6	36.49	60.00	0.49	1.307	1.000	0.143	0.023	0.85
Double angle on opposite side with Lip									
31	50x50x10x1.5	30.24	60.00	0.40	1.118	1.000	0.200	0.030	0.93
32	60x60x10x1.5	35.35	60.00	0.47	1.181	1.000	0.167	0.025	0.84
33	70x70x10x1.5	40.43	60.00	0.54	1.227	1.000	0.143	0.021	0.95
34	50x50x10x1.6	30.23	60.00	0.40	1.190	1.000	0.200	0.032	0.92
35	60x60x10x1.6	35.34	60.00	0.47	1.259	1.000	0.167	0.027	0.84
36	70x70x10x1.6	40.42	60.00	0.54	1.307	1.000	0.143	0.023	0.90
Double unequal angle on opposite side without Lip									

37	50x25x1.5	23.00	60.00	0.31	1.118	0.500	0.200	0.030	0.89
38	60x30x1.5	28.00	60.00	0.37	1.181	0.500	0.167	0.025	0.92
39	70x35x1.5	33.00	60.00	0.44	1.227	0.500	0.143	0.021	0.90
40	50x25x1.6	23.00	60.00	0.31	1.190	0.500	0.200	0.032	0.83
41	60x30x1.6	28.00	60.00	0.37	1.259	0.500	0.167	0.027	0.95
42	75x35x1.6	33.00	60.00	0.44	1.307	0.500	0.143	0.023	0.93
Double unequal angle on opposite side with Lip									
43	50x25x10x1.5	13.00	60.00	0.17	1.118	0.500	0.200	0.030	0.89
44	60x30x10x1.5	14.79	60.00	0.20	1.181	0.500	0.167	0.025	0.81
45	70x35x10x1.5	15.19	60.00	0.20	1.227	0.500	0.143	0.021	0.90
46	50x25x10x1.6	12.98	60.00	0.17	1.190	0.500	0.200	0.032	0.93
47	60x30x10x1.6	14.78	60.00	0.20	1.259	0.500	0.167	0.027	0.91
48	70x35x10x1.6	15.18	60.00	0.20	1.307	0.500	0.143	0.023	0.94

4.1 Effects of connection Eccentricity

It is easily observed that eccentricity has a direct impact on the net section efficiency of a connection. The excentricity depends on the cross- sectional area's shape. The experimental study shows that the efficiency of the net section decreases as the excentricity increases in single and double- angle sections. This is because of the induced bending moments due to the eccentricity in connection. It showed that the bending effects induced by connection eccentricity can significantly reduce the failure capacity of a section.Fig 2 to 3 shows the effect of connection eccentricity on net section efficiency for single and double angle sections.

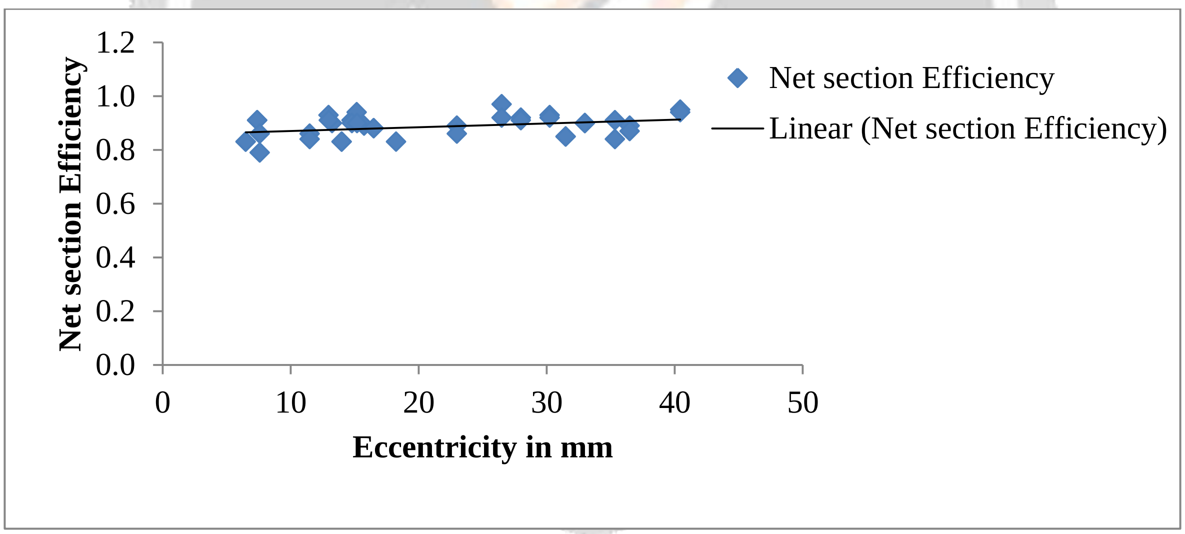

Chart-2 Effect of connection eccentricity on net section efficiency

4.2 Effect of connection length (L)

The efficiency of the net section is affected by the connection length. The length of the connection was calculated from the center of the bolt at one end to the center of the bolt at the other end using the following formula L. Fig 4 shows the effect of connection length on net section efficiency for the angle section. The graph decreases the efficiency of the net section with an increase in connection length. The effect of shear lags on angle specimens is shown by the fact that efficiency decreases with increased excentricity and connection length.

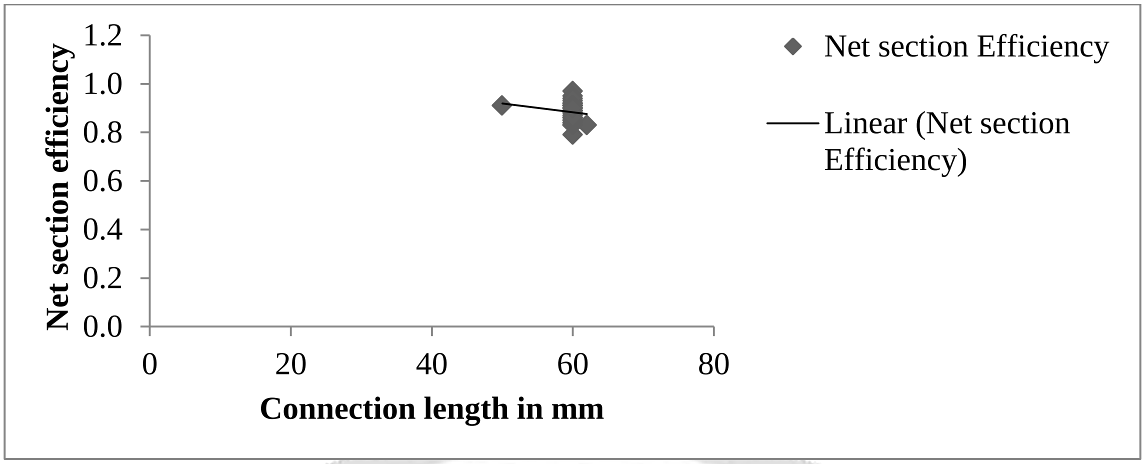

Chart-3 Effect of connection length on net section efficiency

4.3 Effect of ratio of width of unconnected leg to width of connected leg (a_d/ a_c)

Fig 5 shows the effect of ratio of width of unconnected leg to width of connected leg for the single equal angle specimens of thickness 1.5 and 1.6mm. Fig 6.55 shows the effect of ratio of width of unconnected leg to width of connected leg for the double angle specimens connected to same side of thickness 2mm, 3mm and 4mm.It is observed that the efficiency decreases with respect to the increase in value of (a_d/ a_c).

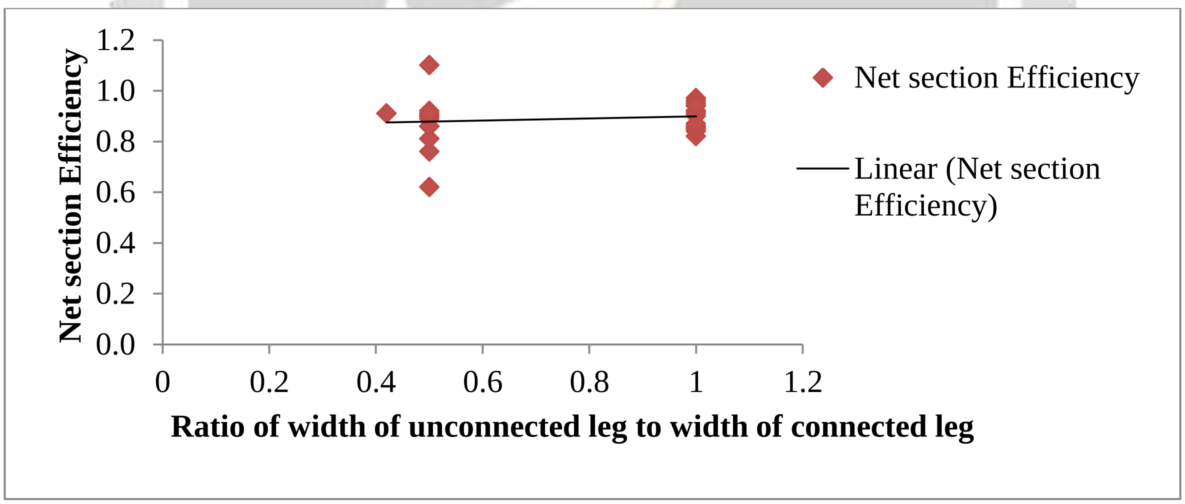

Chart- 4 Effect of ratio of width of unconnected leg to width of connected leg on net section efficiency for single angle specimens

4.4 Effect of ratio of diameter of bolt to width of connected leg (d/ a_c)

Fig 5 shows the diameter ratio of the bolt to the width of the connected leg on single angles and double angle sections. Diameter of the bolts is 10mm was used for connecters. When the diameter of the bolts is decreased for the same width of the connected leg, the ratio d/ a_c decreases and thereby the net section efficiency increases.

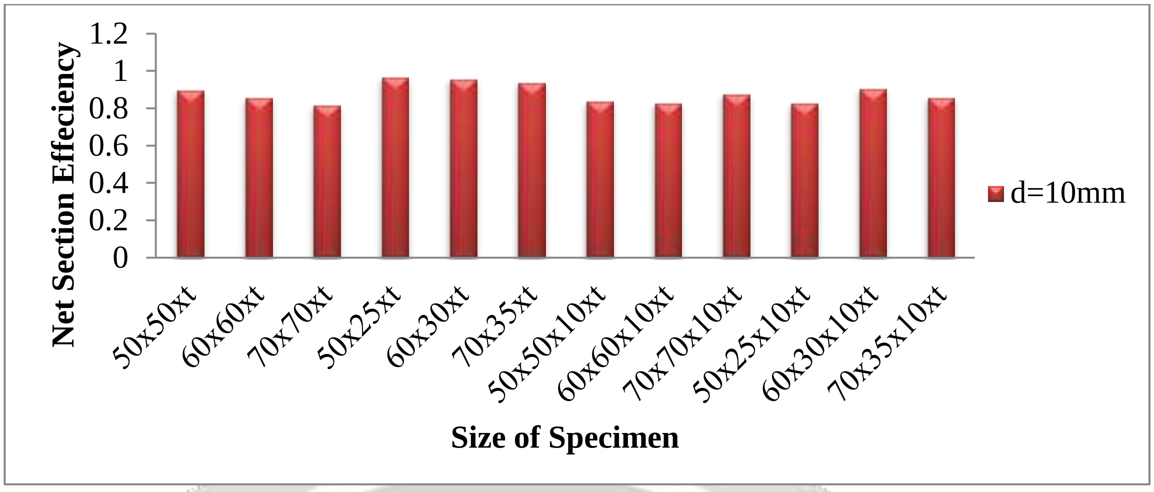

Chart- 5 Effect of ratio of diameter of bolt to width of connected leg on net section efficiency for single plain angle sections

4.5 Effect of ratio of thickness of the specimen to width of connected leg(t/ ac)

Fig 6 shows the ratio of thickness of specimen to width of connected leg on single angles and double angles of thickness 1.5mm and 1.6mm. It is observed from the graph that when the thickness increases for the same width of the connected leg, the t/a_c ratio increases the net section efficiency.

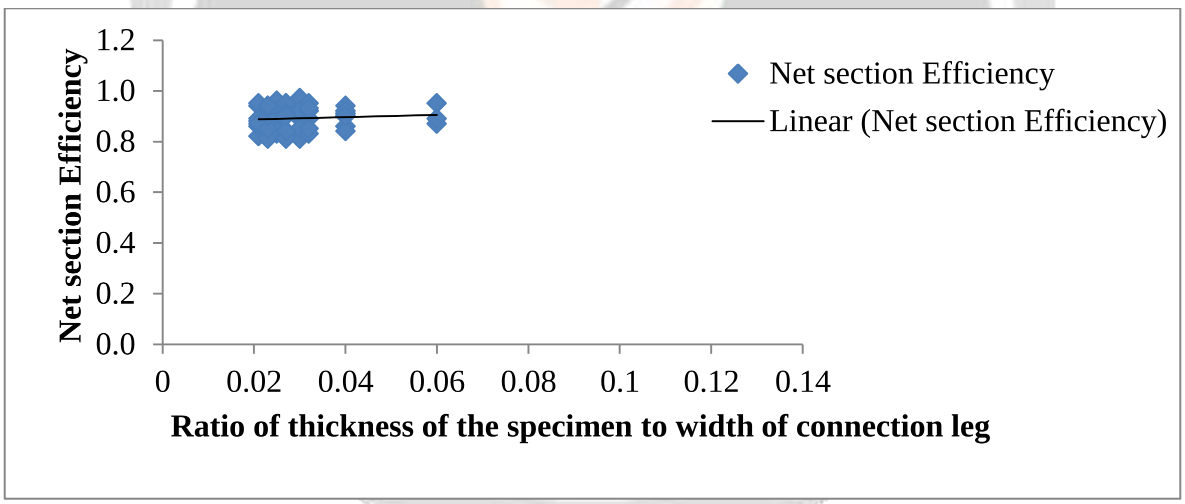

Chart - 6 Effect of ratio of thickness of the specimen to width of connected leg for single and double angle sections

5. CONCLUSIONS

In the analysis, the form of the predicted equation was first chosen and the optimal values of the unknown coefficients were then calculated. In order to establish the form of the equation, regression analysis including linear and non-linear regression analysis have been performed. The form of the predicted equation was first selected using the Excel spreadsheet and the optimal values of the unknown coefficients were then calculated. The coefficient valve was used to determine the most appropriate form of equation to describe the net section efficiency of a section. Using Excel spread sheet, the form of the predicted equation was first chosen and the optimal values of the unknown coefficients were then calculated.In order to determine the most suitable form of equation to describe the net section efficiency of a section, the coefficient valve was used. The regression model describes the data, which is the most common measure. The equation has a good description of the relationship between independent and dependent variables if the coefficient values are less than 1.The proposed equation for net section tension capacity is applicable for all the section which gives more accruable value when compared to experimental values.

6 REFERENCES:

[1] AISI commentary (2007), 'Design of Cold-formed Steel Structural Members ", North American Specification.
[2] AS/NZS: 4600 (2005), 'Cold-formed Steel Structures', Australia / New Zealand Standard.
[3] Lip H. Teh and Benoit Gilbert, (2014), “Net section tension capacity of equal angle braces bolted at different legs”, Journal of Structural Engineering, Volume 140, Issue 6,, pp.1943-1953.
[4] Jaghan S and Padmapriya R ,(2015), “Behavior of Bolted Cold Formed Steel Channel Tension Members”, Asian Journal of Civil Engineering (BHRC),Vol.17, NO. 1, pp.137-146.
[5] Kulak, G. and Wu, E. (1997). "Shear Lag in Bolted Angle Tension Members." Journal of Structural Engineering, Volume 123, Issue 9, pp. 1144-1152.
[6] Prabha P, Saravanan M, Marimuthu V And Arul Jayachandran S,(2011), “Experimental Studies on Cold-Formed Steel Angle Tension Members”, Journal of Recent Researches in Geography, Geology, Energy, Environment and Biomedicine,Vol.1, Issue. 4,pp 236-241.