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Behavior of Bolted Steel Angles underTension: A Study

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Abstract:*The tension members basically take axial load. There is a wide range of usage in the construction of steel structures. In the literature it is found that the analysis is carried out on strengths of various sections by considering shear lag effect using Australia / New Zealand, British and North American standards. They developed analog beam method to analyze shear lag effect and in some literature they used ANSYS for design and analysis. The tensile strength of members found by varying gauge distance, edge distance, end distance, pitch, and thickness of angle. In this project work the tensile strength of various sections with Australia / New Zealand, British and Indian standards are presented. Angle and plate sections are being used to find the tensile strength in this study. The procedures involved in the Australia/ New Zealand and Indian codal standards for the analysis of tension members is studied. Codal provisions given by different countries have different specification for analysis of angle sections. Due to this, the strength obtained by the different codes may vary. Therefore, the interest is to study the variation of strength obtained by the codal provisions given by Australia / New Zealand, British and Indian standards. To obtain this different angle sections are taken up for analysis using IS 800:2007, BS5950 and AS/ NZS 4600:2000. The strength of the tension member depends upon the factors such as length of connection, size of spacing of fasteners, net area of cross section, distance of connection from root radius. Therefore angle sections with varying gauge length, length of connection, thickness, net area and distance of connection is taken up to study the variation of strength. The results obtained shows that there is a decrease in strength from plate to angle section. The change in strength may be reduced by decreasing the gauge distance and increasing the angle thickness and by connecting longer leg. It is concluded that angle sections can be effective and economical as tension member with some considerations at the time of design.*

Keywords-Bolted Steel Angles, Tension, axial load

I. INTRODUCTION

Problem Description: The problem taken up in the present study is to study the behaviour of angle sectionsunder tension. Angle sections are considered to be as efficient and economical when thestresses are uniformly distributed in the section. When angle sections are connected byboth legs to the other sections or gusset plate the stresses distributed in both legs areuniform but when these legs are connected to the gusset plate or other sections only byone leg, there is a non- uniform stress distribution in the outstanding leg i.e. unconnectedleg. This results in the reduction of strength of angle section due to lag in shear strength.This effect is known as shear lag. The shear lag effect reduces with increase inconnection length because as the length of the connection increases, the outstanding leg isavailable to develop an average stress equal to the yield stress while the average stress inconnected leg reaches the ultimate strength of material. But when members are withshorter connection, the average stress in the outstanding leg may not reach the yieldstrength.The strength of angle sections in tension is affected by the length of connection,size and spacing of fasteners and gauge distance. The codal provisions provided bydifferent countries specified different specifications for analysis of tension member. Dueto this design strength obtained by different codes may vary.

II. RELATED WORKS

Padmapriya (2015) explains the behaviour of bolted cold formed steel angle membersunder tension. L-shaped specimens are tested by using single-line bolted connection bytaking different dimensions etc. Cold formed steel is developed gradually more thanrolled steel section; Angles are most basic and widely used sections in nowadays. Whenangles are connected to the gusset plates by only one leg it results in the development ofnon-uniform stress distribution due to eccentrically applied load. Due to this phenomenoncalled shear lag effect, there is a reduction in load carrying capacity. Also explained thedistribution and concentration of VON MISES stresses indicated that block shear failuremight occur in three and four bolts connections. The factor of safety for angles undertension in the limit state format giving due considerations to block shear failure and yieldof gross section was obtained. Single line connections were connected with two mildgusset plates of thickness 8mm at ends.

Chi-Ling Pan (2006) explains the shear lag effect on bolted L-shaped cold-formedsteel tension members. L-shaped specimens are tested by using one-line or two line boltedconnections by taking different dimensions. Here found that there are quite discrepancybetween the test results and the predicted values for the specimens with larger size ofnon-connected elements. Here the experiments shows the tensile strength of thespecimens is predicted by the AISI code (1999) where the shear lag effect is underestimated. Conclusions made here are AISI specifications (1996) & AS/NZS 4600 code(1996) seem to be overestimated based on the results, according to 2001 AISIspecifications gives a better results for L-shaped tension members. Due to the variety ofcross sectional shape for cold form steel members, it is not possible to connect eachelement to the end connection.

Geoffrey et al (1997) explains tension members which are affected by shear lagwhen one leg is connected. Net section efficiency depends upon the net sectional area.North America design standards are used in the analysis of tension member. It explainsthe effective area depends upon ductility factor, geometric factor hole spacing, holeforming method factor and shear lag factor. Shear lag factor upper limit is 0.9 anddepends upon no of bolts in the section. They have conducted physical testing on singleand double angle tension members to obtain the net section strength and examined theshear lag effect. Comparison of the ultimate load carrying capacity of the single anddouble angle tension members is taken up in this paper. For the analysis of tensionmember 16mm thick gusset plate used for connecting single angle tension members and18mm for connecting double angle.

Singh and Nagpal (1994) explains that in column there will be positive shear lag andnegative shear lag which intern results axial force. The overall bending behaviour of atubular building is similar to that of a box girder. In box girder the stresses are maximumat web and less at flanges. There will be positive shear lag at top and negative shear lag atbottom for box girder. Positive shear lag results negative shear lag. Shear lag effect inframed tube buildings varies with height and changes its direction at certain level.Positive and negative shear lag occur in the bottom and top portions of the building.

Agereskov and Hansen (1985) explains the bolted connections in round bar, andmainly concentrated on prying action. Prying action develops when bolts subjected totension. Bolted connections used for erection considerations make bolting necessary. Aimis to study strength is to study and stiffness characteristics of bolted end plateconnections. A study is considered by varying round bar diameter and end plate thicknessand the stresses in the end plate and the bolt forces are obtained. The test show that theprying ratio will generally decreases with a load increase beyond the yield load,indicating that elastic deformations take place. The figure 2.1 shows the failure of roundbar failure at end plate connection. The failure caused due to the rupture failure of endplate connection.

III. METHODOLOGY OF SYSTEM

The strengths of various section using British, Australia/ New Zealand, Indian codes arecalculated and compared. By using Indian code, the angle and equivalent plate strengthsare calculated. Change in the strength due to change in thickness, radius of root and grossarea are compared.

Tensile strength of Angle sections: By taking the codal provisions provided by IS 800:2007, BS 5950 and AS/NZS4600:2000, analysis of various sections is carried out.

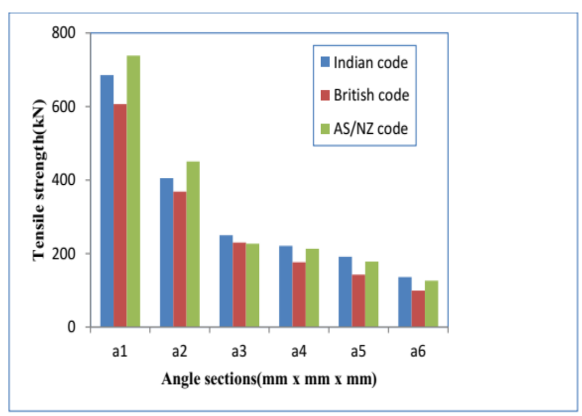

Figure.1 Tensile strength when longer leg connected

By using sections200mm x150mmx10mm,150mm x115mm x8mm,100mm x75mm x 6mm,90mm x 60mm x 6mm and80mm x 50mm x 5mm connecting longer leg, strength is obtained from three codes are tabulated in

Table.1 and variation in strength is represented graphically in Figure.1.

Table .1: Tensile strength by various codes

S.No.	Section (mm x mm x mm)	leg a (mm)	leg b (mm)	Thickness (mm)	Ag (mm^2)	Strength when Longer leg connected(kN)		
						IS 800:2007	BS 5950	AS/NZS 4600:2000
1	200x150x10	200	150	10	3400	699.403	668.75	765
2	150x115x8	150	115	8	2058	474.068	463.3	463.054
3	125x95x6	125	95	6	1286	322.91	252.3	289.35
4	100x75x6	100	75	6	1014	258.757	195.2	228.15
5	90x60x6	90	60	6	865	221.315	165.3	194.625
6	80x50x5	80	50	5	627	157.577	117.7	141.075

By using various sections and by connecting shorter leg, strength is obtained from variouscodes are tabulated in Table .2 and variation in strength obtained by various codes isrepresented graphically in Figure.2.

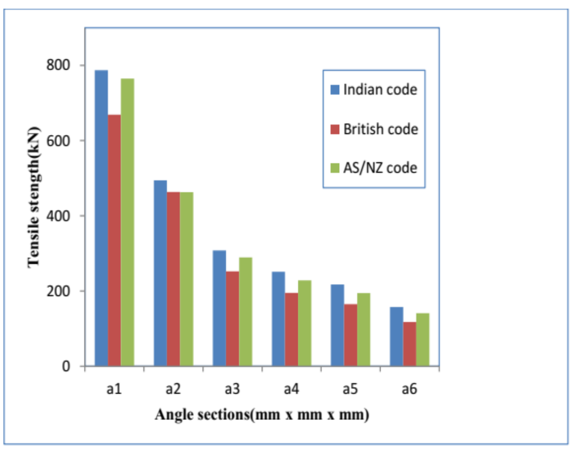

Figure .2 Tensile strength when shorter leg connected

Influence of length of connected leg: Variation of strength of various sections by varying the connected length is given in Table4.3 and Figure.3. The table and graph shows the variation in the rupture strength of thegiven section by changing the connected length as longer leg and equivalent area plate.

Table.2 Tensile strength by various codes when shorter leg connected

Sr.No.	Section (mm x mm x mm)	Leg a (mm)	Leg b (mm)	T (mm)	Strength (kN)		
					IS 800:2007	BS 5950:2000	AS/NZS 4600:2000
1	200x150x10	200	150	10	606.25	738.6	685.13
2	150x115x8	150	115	8	368.3	450.24	405.44
3	12x95x6	125	95	6	229.8	227.1	249.54
4	100x75x6	100	75	6	176.4	213.12	221.12
5	90x60x6	90	60	6	142.8	178.07	191.52
6	80x50x5	80	50	5	98.99	126.32	135.68

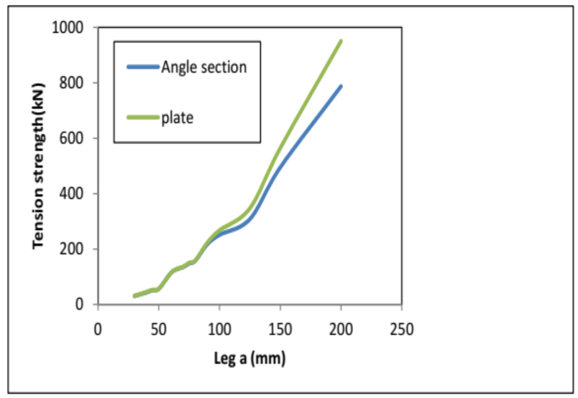

Figure.3 Variation of strength with connected leg

From the table it is observed that the strength obtained by the equivalent area plate ismore as compared to the other lengths. The strength obtained using the connected lengthas shorter leg is less and strength obtained by the longer leg, equivalent area plate isalmost near to each other.

Influence of pitch distance: The tensile strength of the tension member may depend on the pitch distance. Therefore,to study the variation of the strength of the member is taken up by using a section 200mmx 150mm x 10mm due to the change in the pitch distance of the bolts. In this analysisdiameter of bolt is taken as 16mm and number of bolts are taken as 6. The pitch distanceis taken as 2.5d, 3d, 3.5d … and 7d, where d is the diameter of bolt.

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Table .3 Influence of length of connected leg

S. No.	section (mm x mm x mm)	leg a (mm)	leg b (mm)	T (mm)	Ag (mm^2)	Strength of Angle section		Plate strength (kN)
						Longer leg (kN)	Shorter leg (kN)	
1	200x150x10	200	150	10	3400	787.341	685.13	950.544
2	150x115x8	150	115	8	2058	494.64	405.44	564.42
3	125x95x6	125	95	6	1286	308.13	249.54	347.15
4	100x75x6	100	75	6	1014	251.3	221.12	267.45
5	90x60x6	90	60	6	865	217.42	191.52	223.17
6	80x50x5	80	50	5	627	157.57	135.68	157.93
7	75x50x5	75	50	5	602	147.93	133.14	150.5
8	70x45x5	70	45	5	552	134.68	122.73	135.79
9	65x45x5	65	45	5	526	127.35	118.62	128.412
10	60x40x5	60	40	5	476	113.7	106.76	113.65
11	50x30x3	50	30	3	234	56.16	49.53	56.67
12	45x30x3	45	30	3	218	51.76	47.54	52.25
13	40x25x3	40	25	3	188	43.54	40.53	45.39
14	30x20x3	30	20	3	141	30.6	29.65	30.11

Strength obtained bychanging pitch distance is tabulated below in Table.4 and variation of the strength of thesection with variation of pitch distance is represented graphically in figure.4. From thegraphical representation, it is understood that the strength of the section increases withincrease in the pitch distance.

Table. 4 Variation of strength with pitch distance

Pitch(mm)	Length of connection(mm)	Strength(kN)
40	280	843.491
48	336	866.887
56	392	883.599
64	448	896.133
72	504	905.881
80	560	913.68
88	616	920.06
96	672	925.378
104	728	929.877
112	784	933.733

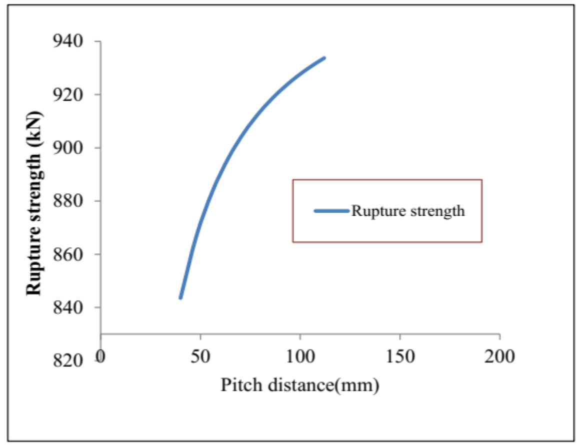

Figure .4 Influence of pitch distance

V. CONCLUSION

From the analytical results obtained, the following conclusions are framed.

i. When longer leg and smaller leg of an angle section is connected to gusset plate, itwas found that for small length of connected leg all codes gives almost similar valuesbut for longer lengths of connected length, AS/NZS 4600:2000 gives higher valuesof tensile strength than IS 800:2007 and BS 5950.

ii. In Indian code, rupture strength obtained by varying connected leg length of an anglesection and equivalent area plate, shows that strength difference between plate andlonger leg connected angle was less than shorter leg connected.

iii. In Indian code, by varying the thickness of angle it is found that strength differencebetween plate and longer leg connected angle is less than shorter leg connected.

iv. The increase of thickness of an angle the rupture strength is increased as per Indiancode

v. With the increase of bolt diameter the rupture strength is decreased due to decreasein net area.

vi. With the increase in gauge length, strength of an angle is decreased.

vii. By increasing the root radius of an angle section tensile strength is increased.

viii. By increasing the no. of bolts, the block strength is increased.

ix. By comparing the rupture strength with root radius, the difference in the rupturestrength of longer leg connected angle and plate is smaller than strength difference ofshorter leg connected and longer leg connected.

x. With increase in gross area, the rupture strength of an angle section is increased.

xi. By comparing three codes, it is found out that only Indian code has considered blockshear failure

Future Scope

i. Same study on welded connections can also be carried out for tension members.

ii. Study on double line bolting and with different bolted patterns can be done.

iii. By using software or experimental results, comparison can be done with theoreticalresults.

iv. Study on behavior of strength of built up angle sections.

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