ANALYSIS OF HOT ROLLED STEEL ANGLES UNDER TENSION

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Abstract - This project work includes study of commonly available angles of steel which are used as tension members. These angles have three types of design strengths – 1)

Design strength due to yielding of gross area. 2) Design strength due to rupture of critical section. 3) Design strength due to Block shear.

Provision for block shear failure in steel angles has different rules and formulae in different codes. A steel angle generally acts as tension members and can be used singly or coupled. This paper analyses the mechanisms for block shear capacity and failures of steel angle in tension postulated in the design equations specified in Working Stress Method, Limit State Method & practical analysis with the help of test specimens in Universal Testing Machine (UTM).

***Key Words*: Steel structure, Universal Testing Machine (UTM), Steel angle, Block shear, LSM, Tension members. Design capacity.**

1. INTRODUCTION

Rolled steel has many advantages over other rival materials such as concrete and wood, it has high strength to weight ratio, high ductility, uniformity, and its ability to be entirely recyclable. Ductility and toughness are very important when steel is subjected to earthquake loads or impact loads. It offers much better compressive and tensile strength than concrete.

Angles are available as equal angles and unequal angles. The legs of equal angle sections are equal and in case of unequal angle section, length of one leg is longer than the other.

Thickness of legs of equal and unequal angle sections are equal. The bulb angle consists of a web a flange and a bulb projecting from end of web.

1.1 TENSION MEMBERS

Tension members are linear members in which axial forces act so as to elongate (stretch) the member. Tension members carry loads most efficiently, since the entire cross section is subjected to uniform stress. Suspenders in suspended buildings & suspension bridge, stay cables in stayed cable in stayed bridge, bracing in bracing frame structure, tie & purlin in roof truss and a rope are examples of the tension members. Tension members are structural elements that are subjected to axial tensile forces. Examples include:

- Members in trusses.
- Cables in cable-stayed and suspension bridges.
- Bracing in frames to resist lateral forces from blast, wind, and earthquake.

1.2 Single angles

These are commonly used as tension members, for example, as bracing for carrying lateral forces due to wind or earthquake. Angle end connection is simple but eccentric to its centroidal axis. The eccentric application of tensile force produces bending stresses in members which are often ignored in design practice.

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Angles have great applications in the fabrications. The angle sections are used as independent sections consisting of one or two or four angles designed for resisting axial forces (tension and compression) and transverse forces as purlins. Angles may be used as connecting elements to connect structural elements like sheets or plates or to form a built up section. The angle sections are also used as construction elements for connecting beams to the columns and purlins to the chords of trusses in the capacity of beam seats, stiffening ribs and cleat angles. The bulb angles are used in the ship buildings. The bulb helps to stiffen the outstanding leg when the angle is under compression.

Fig. 1: Test Specimen of Tension member

1.2 BLOCK SHEAR

It is a limit state that should be accounted for during the design of steel tension members. This failure mechanism combines a tensile failure on one plane and a shear failure on a perpendicular plane.

Block shear failure commonly refers to the tearing of a block of material and it presumes a combination of tension rupture and shear yield or a combination of shear rupture and Tension yield.

Although the first failure mode is quite common, the later failure mode is Uncommon because of the small ductility in tension as compared with shear. Block shear failure is usually linked with bolted details because a reduced area is present in that case, but in principle it can also be present in welded details.

2. LITERATURE REVIEW

Hiren J. Chavda(2007) They tried to DESIGN AIDS FOR TENSION MEMBERS AS PER REVISED IS: 800-2007.He concluded that 'the revised IS 800-2007 has given number of formula for design a tension member which is time consuming'.

Lip H. Teh and Drew D. A. Clements (2012) examines the mechanisms for block shear failures of bolted connections in steel plates postulated in the design equations specified in the North American, European, and Australian steel structures codes. The active shear resistance planes of a bolted connection block are identified in this paper and are crucial for an accurate determination of the block shear capacity of a connection with multiple rows of bolts.

Mohamed Nainakkan Subuhan et. Al (AARCV 2012), studied the block shear failure of tension members and concluded that - is for positive stagger it is recommended that block shear path should follow the tension stagger line. For negative stagger it is recommended that Path 1 follow the closer result to the FE result.

Gupta et. Al (2004), examined the block shear capacity of steel angles for bolt holes in one or more rows, and with staggered and non-staggered holes. Only those specimens that follow all provisions regarding minimum pitch, edge and end distances were included in the study. The area as per their improved approach was termed as effective block gross shear area and was somewhat less than the block gross shear area, as per current practice. Their findings, have proposed that a simple equation is sufficient to give adequate results for single as well as double angles, for bolt holes in one or more rows, and with staggered and non-staggered holes.

C. Crosti & D. Duthinh (2007) tried the catastrophic failure of the I-35W Bridge in Minnesota in 2007, the Federal Highway Administration issued guidelines for the load rating of bolted and riveted gusset plates in truss bridges (FHWA, 2009). This paper develops finite-element models capable of predicting the behaviour of gusset plates in tension, resulting in possible failure by block shear.

3. METHODOLOGY & EXPERIMENTAL SETUP

The factored design tension T, in the members shall satisfy the following requirement:

$T < T_d$

Where,

T_d = Design strength of the member.

The design strength of a member under axial tension, Td, is the lowest of the design strength due to –

a) Yielding of gross section, Tdg

b) Rupture strength of critical section, Tdn

c) Block shears Tdb1 & Tdb2

Single Angles:

The design strength, Tdn, as governed by rupture at net section is given by:

$T_{dn} = 0.9\, A_{nc} \times f_u / \gamma_{m1} + \beta \times A_{go} f_y / \gamma_{m0}$

Where,

$\beta = 1.4 - 0.076\, (w/t)\, (f_y/f_u)\, (b_s/L_c)$

Where,

w = outstand leg width,

bs = shear lag width and

Lc = length of the end connection, that is the distance between the outermost bolts in the end joint measured along the load direction or length of the weld along the load direction.

Design Strength Due to Block Shear:

The block shear strength, Tdb of connection shall be taken as smaller of the following -

1. $T_{db1} = [A_{vg} \times f_y/(\sqrt{3}\, \gamma_{m0}) + 0.9\, A_{tn} \times f_u/\gamma_{m1}]$
2. $T_{db2} = (0.9 A_{vn} \times f_u / (\sqrt{3}\, \gamma_{m1}) + (A_{tg} \times f_y / \gamma_{m0})$

The design strength of a member under axial tension, Td, is the lowest of the design strength of the above four values.

Fig. 2: Specimen assembled under UTM for test

4. RESULT ANALYSIS & OBSERVATIONS

Table 1: List of studied parameters

S. No.	Type of member	Section analysed	No. of bolts	Dia of bolts
1	Tension member	ISA 50x50x6 mm	4	12 mm
2	Tension member	ISA 50x50x5 mm	3	16 mm
3	Tension member	ISA 50x50x5 mm	2	16 mm
4	Tension member	ISA 60x60x6 mm	5	16 mm
5	Tension member	ISA 65x65x6 mm	4	16 mm

Table 2: Comparison of test results on UTM & IS 800: 2007.

S. No.	Section	No. of bolts	Dia of bolts (mm)	g (mm)	p (mm)	Td by IS code	T by UTM
1	ISA 50x50x5 mm	3	16	25	50	100.843 KN	101.93 KN
2	ISA 50x50x5 mm	2	16	25	50	73.574 KN	82.568 KN
3	ISA 50x50x6 mm	4	12	25	50	129.09 KN	134.56 KN
4	ISA 65x65x6 mm	4	16	30	50	160.553 KN	167.17 KN

On observing the above tables, comparisons, & test results, we found the following results:

• Limit state method provides more accurate results for angle sections & it also proves to be economical.

• Testing of specimens in UTM proves that locally available hot rolled steel sections full fill all the criteria & end results of IS codal provisions.

• Apply connections on long leg when using Unequal sections as it gives 15% to 30% higher results.

5. CONCLUSIONS

In order to design a structural element in tension, present Indian Standard code of practice for design of steel structures, IS 800:2007 is good, as the designs by this method prove to be economical. The problems such as the failure criteria and the interface between the gusset plate and the angle are not to be considered, if the analysis is performed at design loads. Design strength by LSM method & by test in UTM is approximately equal.

Unequal angle long leg connected with single row bolted varies from 15 % to 30 % for higher sections to smaller sections. & angles generally failed in block shear.

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