LUG ANGLE : CONCEPT AND DESIGN

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Abstract - *Steel structure has always been top choice of designers for construction over other construction methods. Various development and improvement has taken place over the period of time in steel construction. Lug Angle is one such development which can be used effectively in designing of tension member.*

1. INTRODUCTION

- Lug angle is small piece of angle used to connect outstand legs of the members to the gusset plate.
- The purpose of lug angle is to reduce the length of connection to the gusset plate and to reduce shear lag effect.
- If lug angle is used then the unconnected length of main angle behave like a connected leg and entire cross section area of the angle become effective in resisting tension. So if lug angle is used, then efficiency of the tension member increases because it reduces shear lag effect.
- If lug angle is used the resultant reaction at bolt location 1 and 2 pass through CG of cross section. Since action and reaction pass through CG of angle, stress and strain distribution are uniform hence no shear lag

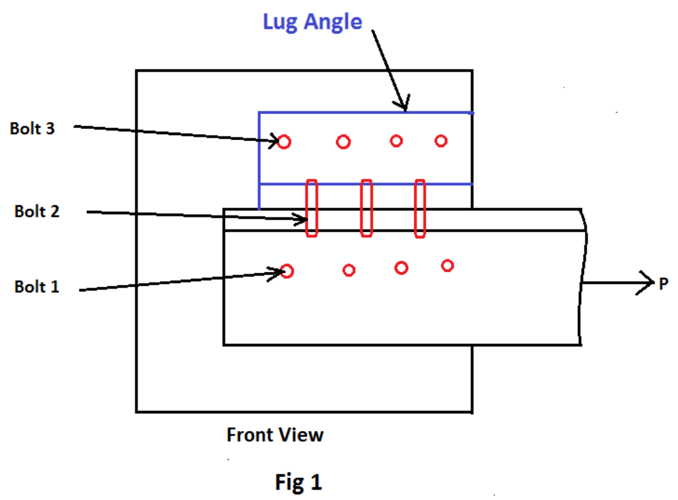

Fig -1: Front View of connection having Lug angle, Tension member connected to a Gusset plate with the help of bolts.

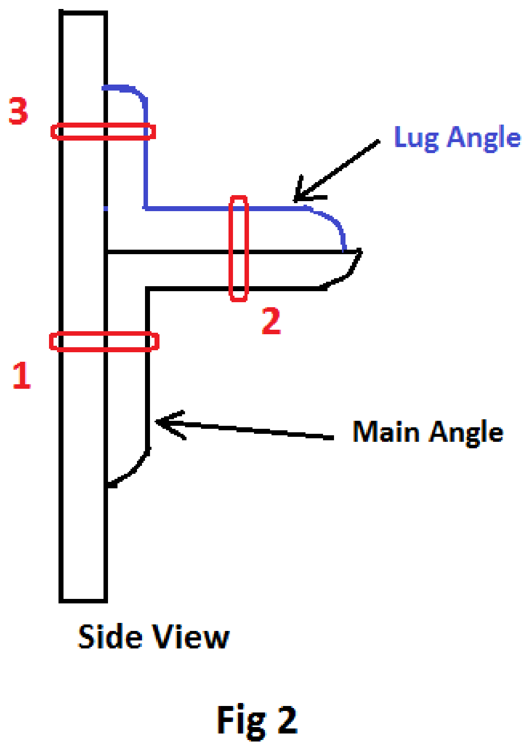

Fig -2: Side View of Connection

2. DESIGN OF LUG ANGLE

Bolt 1- bolt connecting main angle and gusset plate.
Bolt 2- bolt connecting outstand legs of main angle and lug angle.
Bolt 3- bolt connecting lug angle and gusset plate.

- Since lug angle is used, there is no shear lag effect in main angle and lug angle. Entire cross section area of lug angle is effective in resisting tension.
- The bolt connecting outstand legs of main angle and lug angle (bolt 2) must start in advance of all other bolt to ensure that outstand leg of main angle transfers the load to the lug angle effectively.
- The minimum number of bolts to be used in lug angle (bolt 3) is equal to 2

When angle section is used as main member

1. Force in connected leg = $F_{Connect} = \frac{P}{A_1+A_2} * A_1$

Where A_1= Cross sectional area of connected leg

A_2 = Cross sectional area of outstand or unconnected leg.

So applied 'P' is shared by two legs in proportion to their areas.

2. Force in outstand leg = $F_{Outstand} = \frac{P}{A_1+A_2} * A_2$

3. Design force for lug angle (to fix size of lug angle) = 1.2 * $F_{Outstand}$
4. No. of bolts at 1 = $n_1 = \frac{F_{connect}}{R_V}$
5. No. of bolts at 2 = $n_2 = \frac{1.4 * F_{outstand}}{R_v}$
6. No. of bolts at 3 = $n_3 = \frac{1.2 * F_{outstand}}{R_v}$

   Where Rv is Rivet value.

Using the above results a connection is designed with the help of lug angle in which an ISA 100 x 75 x 10 is used as tension member with longer leg connected to a 10 mm thick gusset plate. The section available for lug angle is ISA 60 x 60 x10 ($A_g = 1100\ mm^2$)

Always longer legs are connected to gusset plates because there is no shear lag effect in the connected leg. Due to shear lag effect, outstand legs are less effective in transferring the tension. So shorter legs are kept as unconnected legs.

Design of lug angle means fixing the size of lug angle and finding the no. of bolts at location 1, 2 and 3.

2.1 Analysis

(Finding P_T , $F_{Connect}$, $F_{Outstand}$)

$(P_T)_{xx}$ based on gross area yielding = $A_g * \frac{f_u}{1.1}$

(P_T) based on net area cracking = $A_{net} * \frac{0.9 f_u}{1.25}$

Take lesser value of (P_T) from above 2 equations

Assume 20 mm dia bolts.

Minimum Pitch = 2.5Ø = 2.5 * 20= 50 mm

d= dia of hole = 20+2 = 22mm

Minimum end and edge distance = 1.5 * d = 1.5 * 22 = 33 ≈ 35 mm

A_1= Gross area of connected leg

= (100-5) * 10 = 950 mm^2

A_2 = Gross area of outstand or unconnected leg.

= (75-5) * 10 = 700 mm^2

A_g = Gross area of entire angle = $A_1 + A_2$ = 1650 mm^2

A_{net} = Net area of angle to the connection (treat angle as a plate)

A_{net} along 1-2-5 = (B-d)t = (165-22) * 10 = 1430

A_{net} along 1-2-3-6 = $\left(B - 2d + \frac{S_1^2}{4g_1}\right)$ * t

$= \left(165 - 2 * 22 + \frac{25^2}{4*70}\right) * 10$

= 1232 mm^2

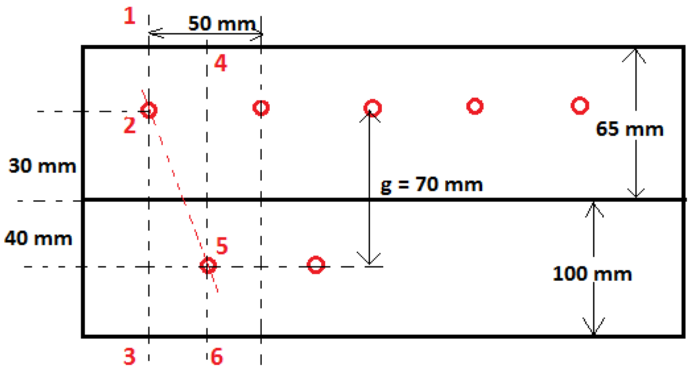

Fig 3

$(P_T)_{xx} = A_g * \frac{f_u}{1.1} = 1650 * \frac{250}{1.1} = 375$ KN

(P_T) along (1-2-5-6) = $A_{net} * \frac{0.9 f_u}{1.25}$

Taking f_u value 410 from IS 800(2007)

(P_T) along (1-2-5-6) = 363 KN

$F_{Connect} = \frac{P}{A_1+A_2} * A_1 = \frac{363}{1650} * 950 = 209.4$ KN

$F_{Outstand} = \frac{P}{A_1+A_2} * A_2 = \frac{363}{1650} * 700 = 154.6$ KN

2. 2 Design

Design force for lug angle = 1.2 * $F_{Outstand}$ = 1.2 * 154.6 = 185.15 KN

A_g required for lug angle = $\frac{1.2 * F_{Outstand}}{\frac{fu}{1.1}} = \frac{185.15 * 10^3}{\frac{250}{1.1}}$ N = 814.6 mm^2

A_{net} required for lug angle = $\frac{1.2 * F_{Outstand}}{\frac{0.9fu}{1.25}} = \frac{185.15 * 10^3}{\frac{0.9*410}{1.25}}$ = 627.26 mm^2

We have select ISA 60 x 60 x 10 as lug angle

A_{net} provided for lug angle = $\left(B - 2d + \frac{S_1^2}{4g_1}\right) * t$

$= \left(110 - 2 * 22 + \frac{25^2}{4*70}\right) * 10$

= 682 mm^2 ($>A_{net}\ req = 627.27\ mm^2$)

Hence safe

Number of bolts required at 1, 2, 3 locations

All bolts are in single shear

Ps = $\frac{\pi}{4} * d^2 *$ fs = $\frac{\pi}{4} * 20^2 * \frac{400}{\sqrt{3}*1.25}$ = 58.04 KN

Ps = d * t * fb = 20 * 10 * 2.5 * $\frac{400}{1.25}$ = 160 KN

So Rv = 58.04 KN

No. of bolts at 1 = $n_1 = \frac{F_{connect}}{R_v} = \frac{209.4\ KN}{58.04\ KN} = 3.6 \approx 4$ bolts

No. of bolts at 2 = $n_2 = \frac{1.4 * F_{outstand}}{R_v} = \frac{1.4*154.6}{58.04} = 3.72 \approx 4$ bolts

No. of bolts at 3 = $n_3 = \frac{1.2 * F_{outstand}}{R_v} = \frac{1.2*154.6}{58.04} = 3.16 \approx 4$ bolts

3. CONCLUSION

Sometimes a larger length of the tension member and the gusset plate may be required to accommodate the required number of connection rivets. But this may not be feasible and economical. To overcome this difficulty lug angles are used in conjunction with main tension members at the ends. It provides extra gauge lines for accommodating the rivets and thus enables to reduce the length of the connection. They are generally used when the members are of single angle, double angle or channel sections.