Tension members

- If an axial tensile force acts in a member causing elongation(stretching) of it, then such a member is called a tension member.
- Usually member will be subjected to uniform stresses over its cross section.
- Eg. -Angle (single as well as double—can be both equal or unequal) channel, Tee, I section, rods, cables, built up sections etc. $T<T_d$ (pg.32 Cl.6.1 of IS 800 : 2007)
- The factored design tension, T in the member should be < Td where Td = Design strength of tension member
- Td is least of 1. Tdg = Design strength due to yielding of gross section 2. Tdn = Design strength due to rupture of critical section and 3. Tdb = Design strength due to block shear

Case 1(yielding of gross section): $T_{dg} = \frac{A_g f_y}{\gamma_{m0}}$ [P 32 Cl.6.2]

Sometimes, gross area of cross section Ag yields over a large portion of the length of tension member before rupture load is reached. In this case member may become non-functional due to excessive elongation.

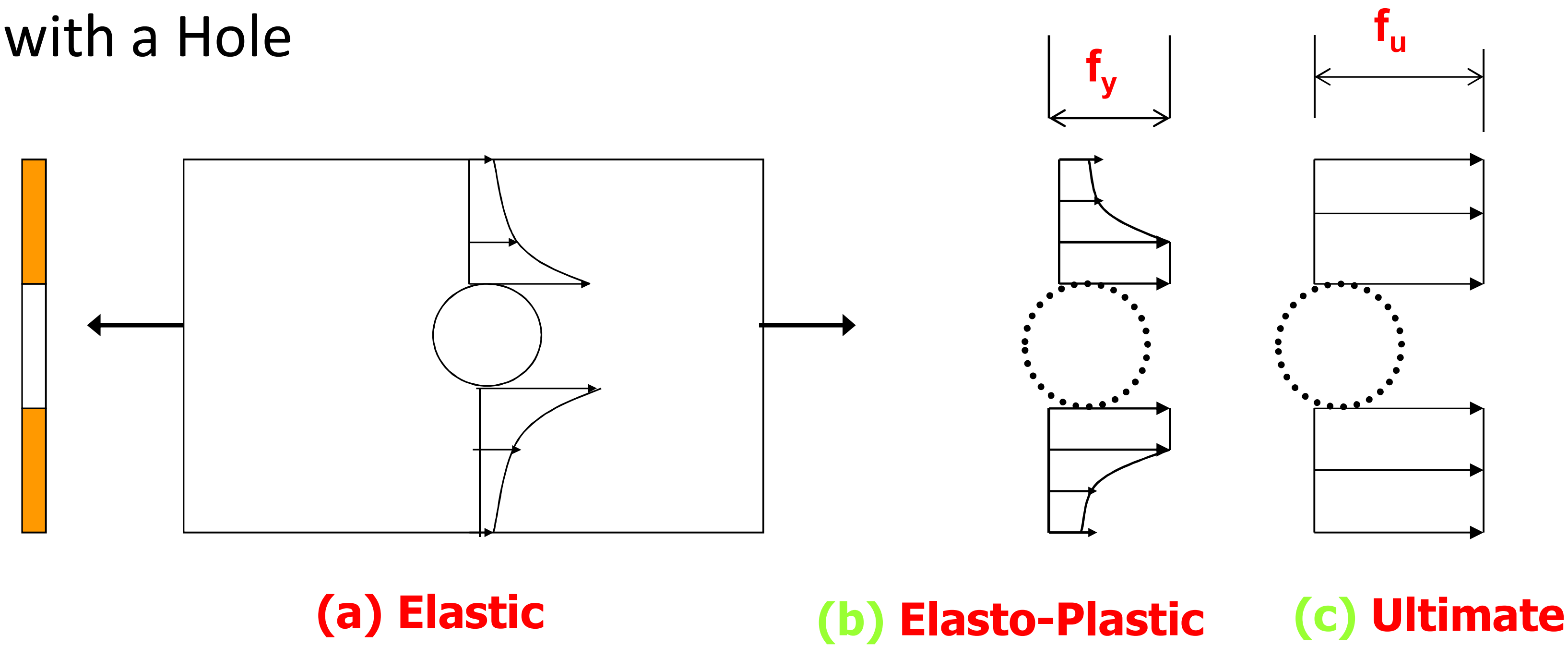
Case 2(rupture of critical section): $T_{dn} = \frac{0.9 A_n f_u}{\gamma_{m1}}$

A_n is net effective area of member.

Applicable when member is connected by bolts in which we will be providing holes in the member. These holes reduces the cross section area and produces stress concentration.

BEHAVIOUR IN TENSION

Plates with a Hole



Initially when we apply load, stress at net section becomes $f < f_y$ near the hole. As loading process is continued, at some instant of time, this $f = f_y$ near hole.

- After this stage the fibre adjacent to this layer becomes yielded and yielding will continue like this up to the edge fibre. Now the entire cross-section will get yielded.
- Even after this stage, if we increase the load, all the fibres will reach ultimate stress, $f_u > f_y$ and tension failure will take place so the strength may be greater than T_{dg} since we are considering beyond plastic range.
- Since we are dealing with the maximum stress of the material, the code has used a factor of 0.9 (which is based on experimental data) to reduce Tdn and to make safer design. This will ensure that member will not fail by rupture of critical section. P33 Fig. 5 gives the picture of plates with bolt holes in tension.

- P33 Cl. 6.3.3. Single angles

$$T_{dn} = \frac{0.9 A_{ne} f_u}{\gamma_{m1}} + \frac{\beta A_{go} f_y}{\gamma_{m0}}$$

$$\beta = 1.4 - 0.076\left(\frac{w}{t}\right)\left(\frac{f_y}{f_u}\right)\left(\frac{b_s}{L_c}\right) \leq \frac{f_u \gamma_{m0}}{f_y \gamma_{m1}}$$

$$\geq 0.7$$

This equation deals with the effect of shear lag in its second term using a factor "β". Shear lag occurs when a single angle is connected to a gusset plate through one leg. Force is transmitted from member to the gusset plate through bolt or weld during the process, the distribution of force will not be uniform since path of load gets curved and its path of passage gets shortened, those locations will be subjected to high stresses. The two legs will have very large stresses connected leg will carry more stress than outstanding leg 1^{st} term of equation gives rupture strength of connected leg and 2^{nd} term deals with unconnected leg.

Case 3. By block shear strength

- In any tension member, block shear failure can occur at the portion of the member connecting the gusset plate.
- In p34 Fig. 7 examples of block shear failure in plate and angle is shown. There will be two failure planes 1. Plane of tension perpendicular to line of force (e.g., plane 2–3 in the figure). This tension area may be subjected to either yielding or rupture. 2. Plane of shear parallel to line of force (e.g., plane 1–2 and 4–3 in Fig. 7A and plane 1–2 in Fig. 7B) the shear area may also be subjected to either yielding or rupture. IS code has used two combinations shown in Cl. 6.4.1 P33.

1. Yielding of shear plane + rupture of tension plane.
2. Rupture of shear plane + yielding of tension plane.

- least one is selected.

Block shear failure can occur in bolted as well as welded connection. But in the latter case since no holes are present, Net area = Gross Area

Block shear failure examples

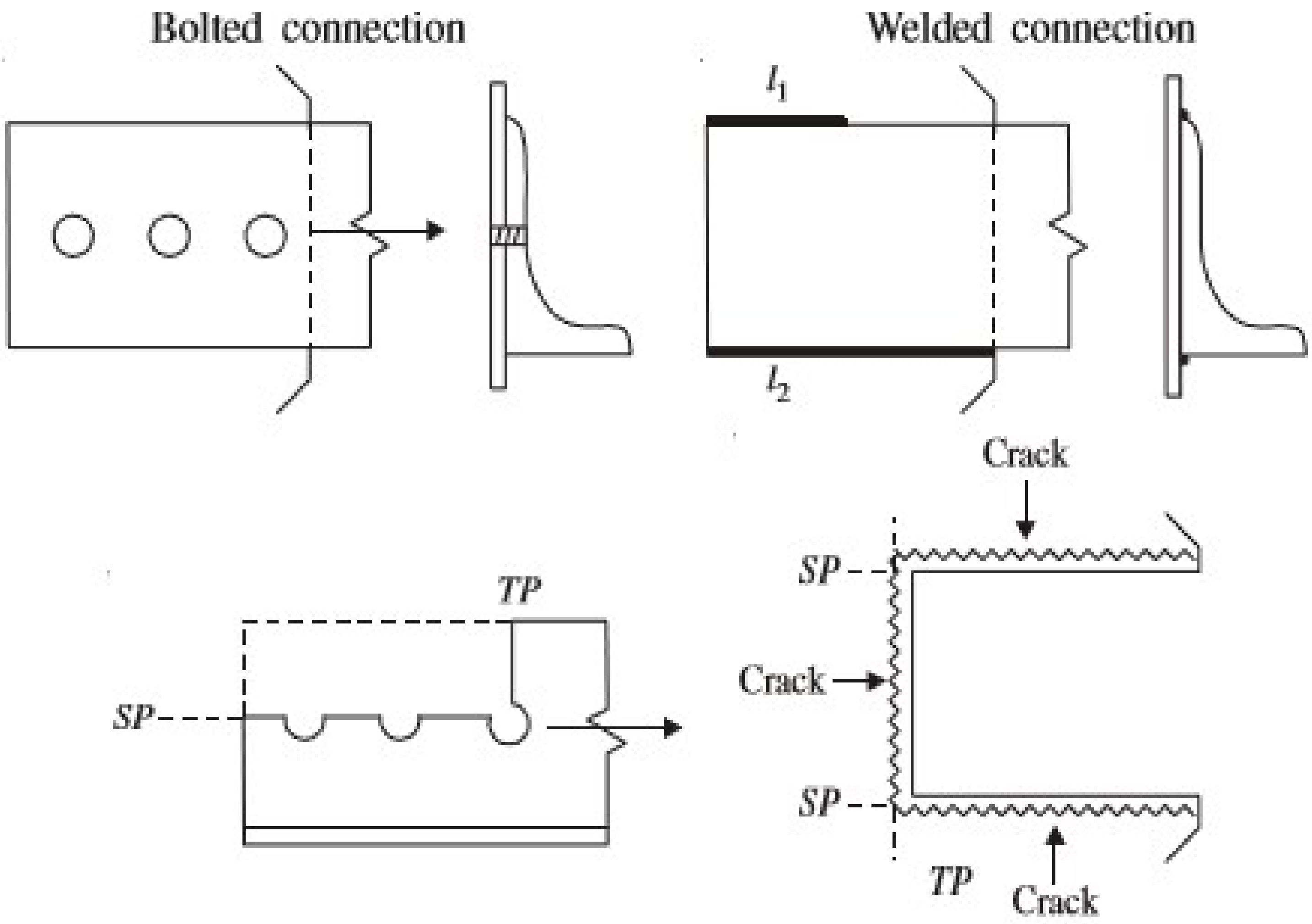
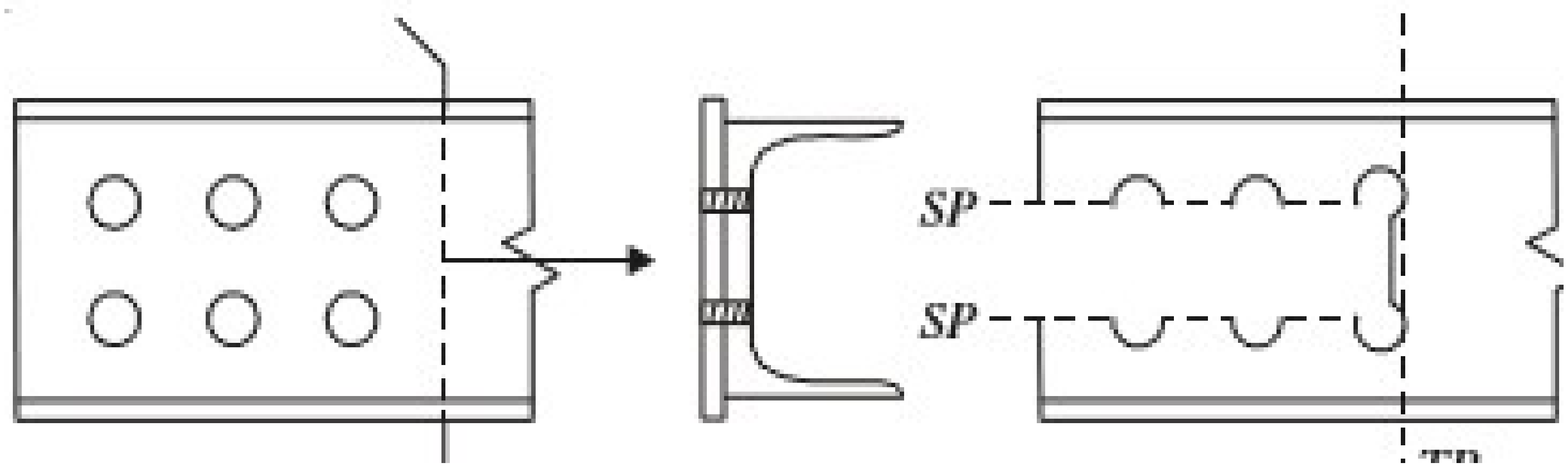


Fig. 4.3

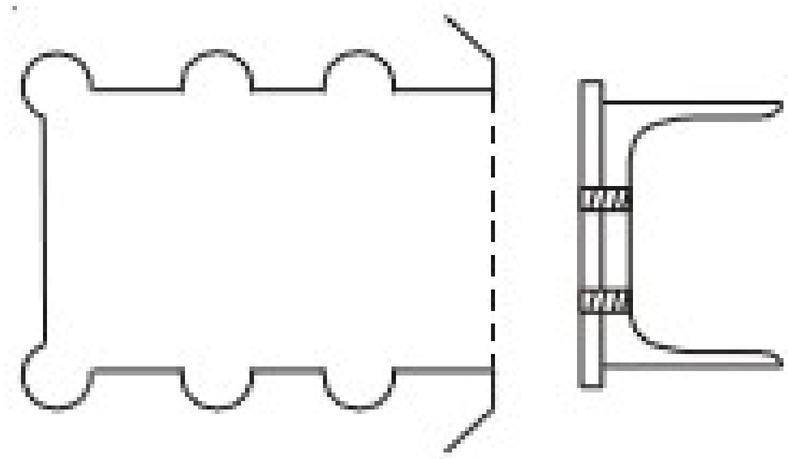
SP = Shear plane parallel to load
TP = Tension plane perpendicular to load

Block shear failure examples

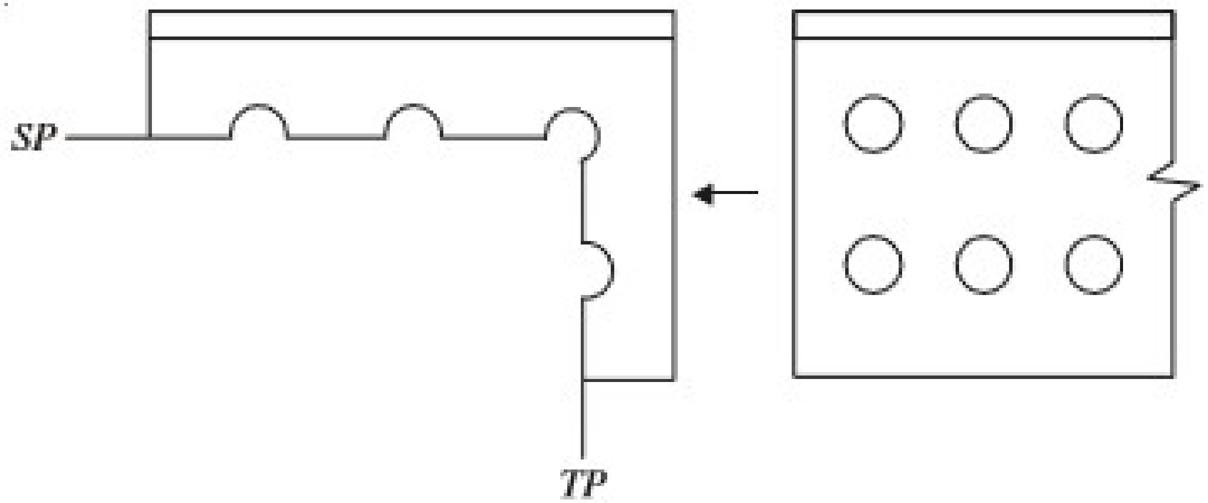


Here, gusset plate fails by block shear since crack is formed through SP by a length l_2 at top and bottom, l1 is taken = l2 for block shear calculations. In welded connection, since there are no holes, block shear failure mechanism will occur only to gusset plate along edge of connection and not inside the member as shown in the figure.

- But in bolted connection, since there are holes, crack planes will lie in the line of bolts and failure can occur either to tension member or to the gusset plate depending on their relative strengths. Figure below shows failure of gusset plate.

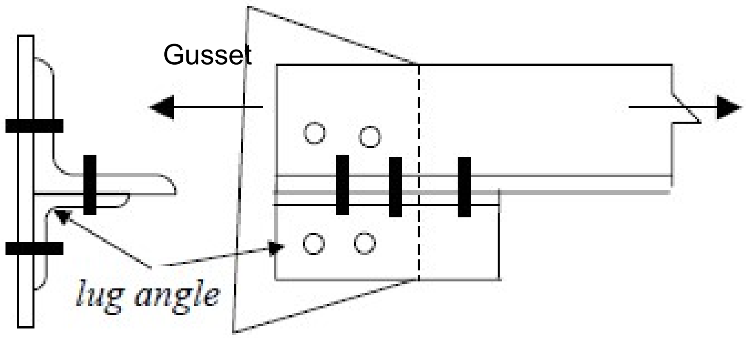


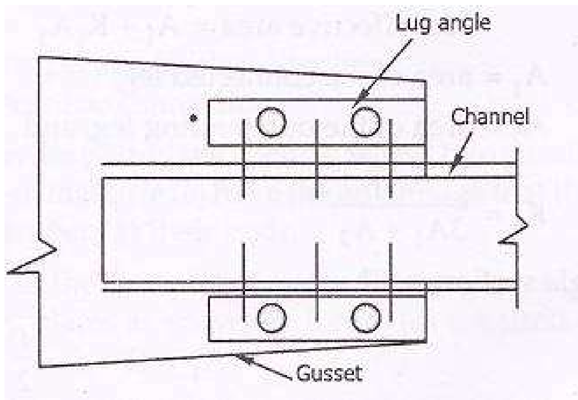
Another example in which there are two layers of bolts in one leg of angle.



LUG ANGLE (pg.83 cl.10.12)

- A short length of angle section
- Attached to the main tension member at the connecting end





- When a tension member is subjected to heavy loads, the no. of bolts/ length of the weld required for making the connection with another member will be large resulting in uneconomical size of the gusset plates. In such situations, an additional short angle is used to reduce the joint length and shear lag. Such an angle is called a lug angle.The location of lug angle is is of important. It is more effective at the beginning of the connection rather than at the ends. The use of lug angle reduces the net area of main members due to the additional bolt holes in the projected member. This reduction in net area should not be excessive. In the connection of lug angle to the member or gusset plate, more than two bolts are used.
- Lug angle may be eliminated by providing unequal angle sections with wider leg as the connected leg & using two rows of staggered bolts. In many cases, cost of providing lug angle is expensive than providing extra length of gusset plate. Hence they are not common in practice.

ADVANTAGES

- When a tension member is connected to a gusset plate at its end, a large number of bolts are required, specially when the tensile load is large, necessitating the provision of big size gusset plate
- Size of the gusset plate decreased by providing extra gauge lines for accommodating the required number of bolts.
- Increase the efficiency of the outstanding leg and to decrease the length of the end connections

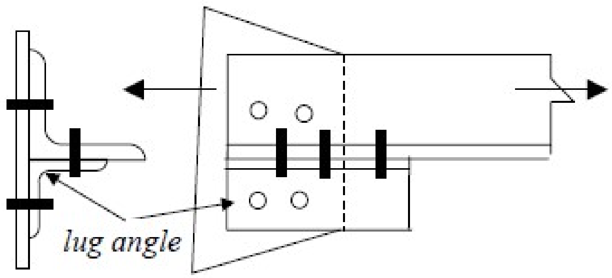
How IS 800-2007 view Lug Angle?

- Effective connection of the lug angle

  - terminate at the end of the member

  - connection start in advance of the member of the gusset plate

  - minimum of two bolts, rivets or equivalent welds



If the main member is an angle

- whole area of the member shall be taken as the effective (whole area = gross area – deduction for bolt holes)

- lug angle to gusset plate = 20% more than the force in outstanding leg

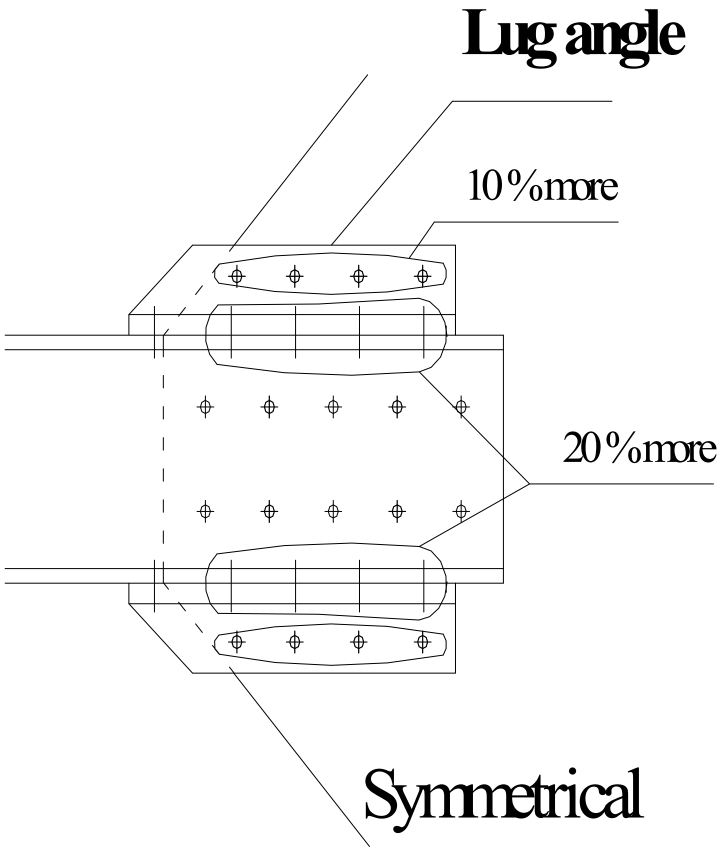
- lug angle to main member = 40% more than the force in outstanding leg of angle member

If the main member is a channel

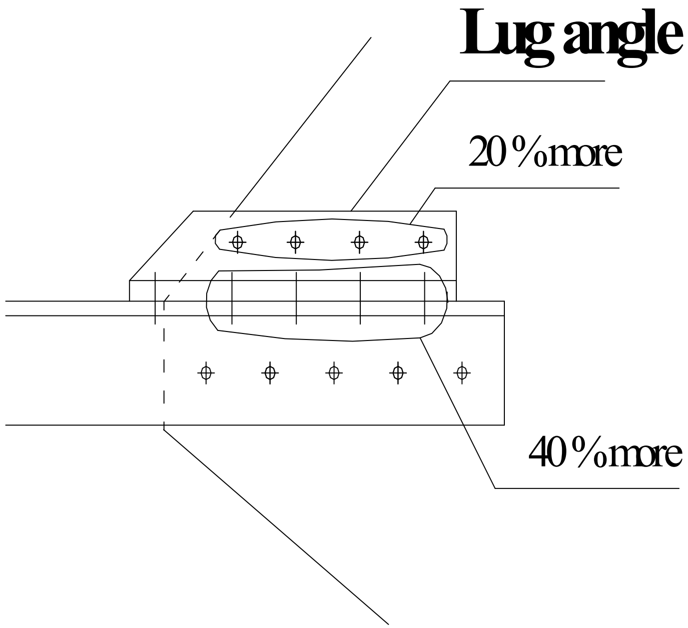
- Symmetric

- lug angle to gusset plate = 10% more than the force in outstanding leg

- lug angle to main member = 20% more than the force in outstanding leg



Symmetrical



Unsymmetrical