TOPIC : TENSION MEMBERS

6.3 Block shear failure

Block shear failure is considered as a potential failure mode at the ends of an axially loaded tension member. In this failure mode, the failure of the member occurs along a path involving tension on one plane and shear on a perpendicular plane along the fasteners. A typical block shear failure of a gusset plate is shown in Fig. 5. Here plane B-C is under tension whereas planes A-B and C-D are in shear.

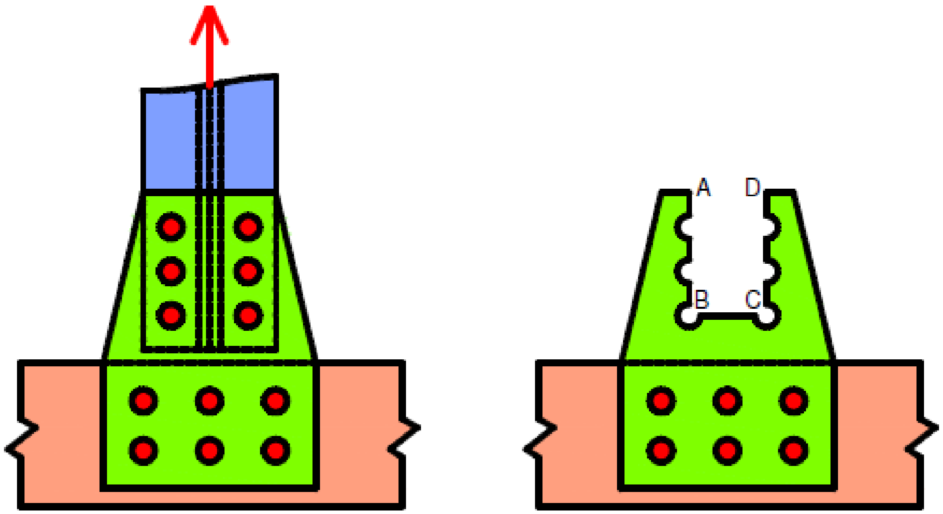


Fig. 5 Block shear failure in gusset plate

Typical block shear failure of angles in a bolted connection is shown in Fig. 6. Here plane 1-2 is in shear and plane 2-3 is in tension.

The block shear failure is also seen in welded connections. A typical failure of a gusset in the welded connection is shown in Fig. 7. The planes of failure are chosen around the weld. Here plane B-C is under tension and planes A-B and C-D are in shear.

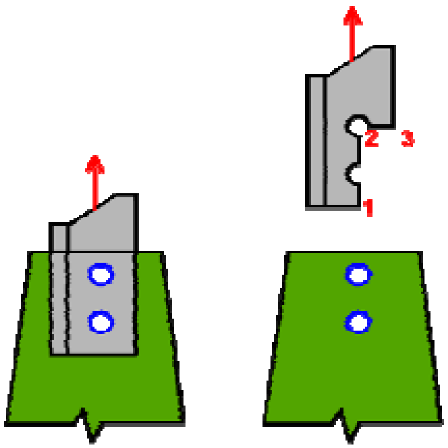


Fig. 6 Block shear failure in angle with bolted connection

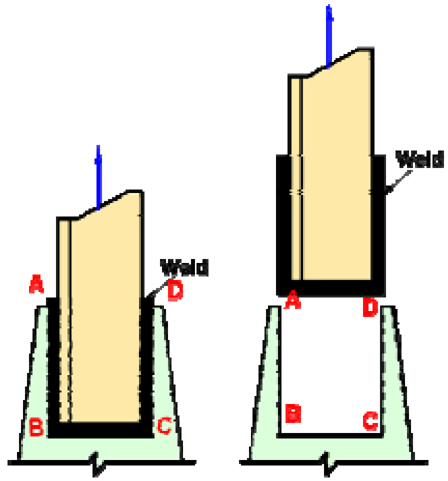


Fig. 7 Block shear failure of gusset plate in welded connections

6.3.1 Design strength due to block shear in bolted connections............................*IS 800-2007 ; Cl. 6.4.1 ; Pg. 33*

The block shear strength, T_{db}, of connection shall be taken as the smaller of

$$T_{db} = [\,A_{vg}\, f_y/(\sqrt{3}\,\gamma_{m0}) + 0.9A_{tn} f_u /\gamma_{m1}\,]$$

or

$$T_{db} = (0.9A_{vn}\, f_u/(\sqrt{3}\,\gamma_{m1}) + A_{tg}\, f_y /\gamma_{m0})$$

Where

A_{vg}, A_{vn} = minimum gross and net area in shear along a line of transmitted force, respectively (1-2 and 3–4 as shown in Fig. 8 and 1-2 as shown in Fig. 9)

A_{tg}, A_{tn} = minimum gross and net area in tension from the bolt hole to the toe of the angle, end bolt line, perpendicular to the line of force (2-3 as shown in Figs. 8 and 9)

f_u, f_y = ultimate and yield stress of the material respectively

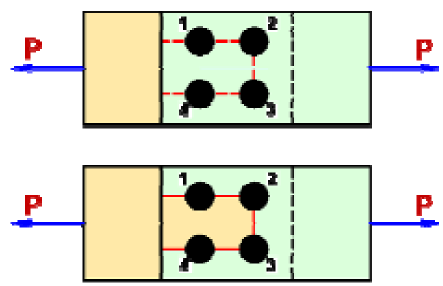


Fig. 8 Block shear failure in plate

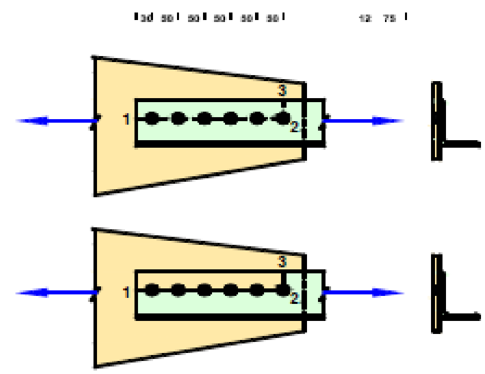


Fig. 9 Block shear failure in angle

7.0 Lug Angles

Lug angles are short angles used to connect the gusset and the outstanding leg of the main member as shown in Fig. 10. The lug angles help to increase the

efficiency of the outstanding leg of angles or channels. They are normally provided when the tension member carries a very large load. Higher load results in a larger end connection which can be reduced by providing lug angles. It is ideal to place the lug angle at the beginning of the connection than at any other position.

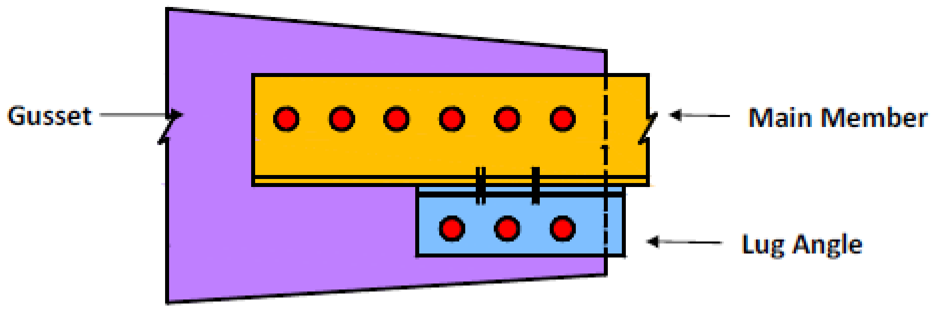


Fig. 10 Lug angle connecting Main member with Gusset

Problem

A single unequal angle 125 x 75 x 8 mm is connected to a 10 mm thick gusset plate at the ends with 4 numbers of 16 mm diameter bolts to transfer tension as shown in Fig. Determine the design tensile strength of the angle if the gusset is connected to the 100 mm leg. The yield strength and ultimate strength of the steel used are 250 MPa and 400 MPa.

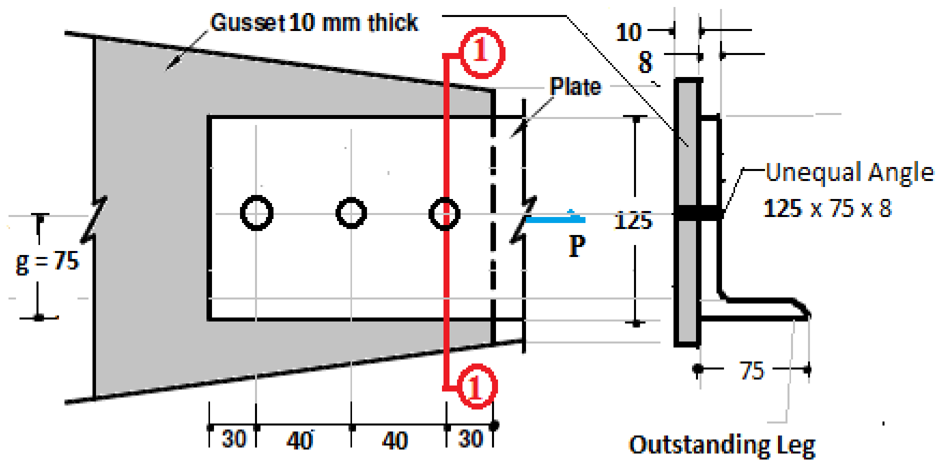


Fig. 11 Details of end connection

Solution

The design tensile strength Td of the plate is calculated based on the following criteria.

(i) Gross section yielding :

$T_{dg} = 1/\gamma\ (A_g\ F_y)$ …………. ....*IS 800-2007; cl. 6.2 ; pg. 32*

Where, A_g = Gross Area Of plate S/c

$= ((125 \times 8) + (75 - 8) \times 8) = 1536\ mm^2$

F_y = Yield Stress Of the plate = 250 N/mm^2

γ = Partial Safety Factor for failure by Yielding = 1.10

………………………………………………………………… *IS 800-2007 ; Table 5 ; pg. 30*

$\therefore \boldsymbol{T_{dg}}$ **= 349.09 KN**

(ii) Net section rupture

Design strength in Rupture for single angle ;

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

where

$$\beta = 1.4 - 0.076\,(w/t)\,(f_y/f_u)\,(b_s/L_c) \le (f_u\gamma_{m0}/f_y\gamma_{m1})$$
$$\ge 0.7$$

…………………...................................*IS 800-2007; cl. 6.3.3 ; pg. 33*

Here ; $\gamma_{m_0} = 1.10$; $\gamma_{m_1} = 1.25$

……………………………………………….....*IS 800-2007 ; Table 5 ; pg. 30*

W = outstand leg width = 75 mm

b_S = shear leg width = outstand + Guage distance – thickness

= (75 + 75 – 8) = 142 mm

L_c = Length of the end connection

= Distance between the outermost bolt holes

= (2 x 40) = 80 mm

$$\therefore\ \beta = 1.4 - (0.076 \times \frac{75}{8} \times \frac{250}{410} \times \frac{142}{80})$$

$$= 0.628 \le 0.9 \times \frac{410}{250} \times \frac{1.10}{1.25} = 1.3$$

$\ge$ 0.7 ; Ok ; Safe

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

Where ; $F_u = f_{u_{plate}}$ = Ultimate stress of plate material = 410 N/mm^2

diameter of bolt hole (d_o) = 16 + 2 = 18 mm

A_n = Net effective area of the connected leg

$= ((b) - (n\ d_o)) \times t$

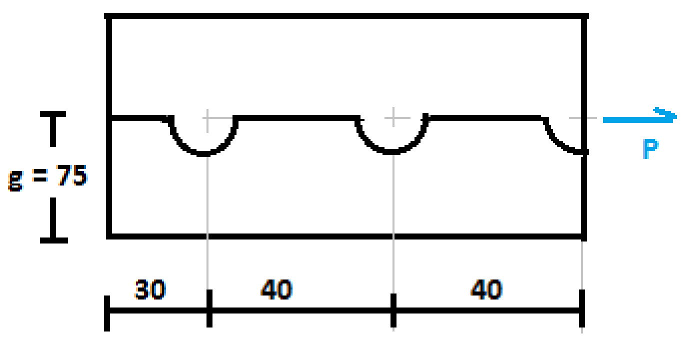
$= ((125) - (1 \times 18)) \times 8 = 880\ mm^2$

A_{go} = Gross area of outstanding leg = (75 – 8) x 8 = 536 mm^2

$$\therefore\ T_{dn} = \frac{0.9 \times 410 \times 880}{1.25} + \frac{0.628 \times 250 \times 536}{1.10} = 336.27\ \text{KN}$$

$$\therefore\ T_{dn} = 336.27\ \text{KN}$$

(i) Block shear failure



As per IS 800-2007 ; Cl. 6.4.1 ; Pg. 33

The block shear strength shall be smaller of following ;

$$T_{db_1} = [\,A_{vg}\, f_y /(\sqrt{3}\,\gamma_{m0}) + 0.9A_{tn} f_u /\gamma_{m1}\,]$$

or

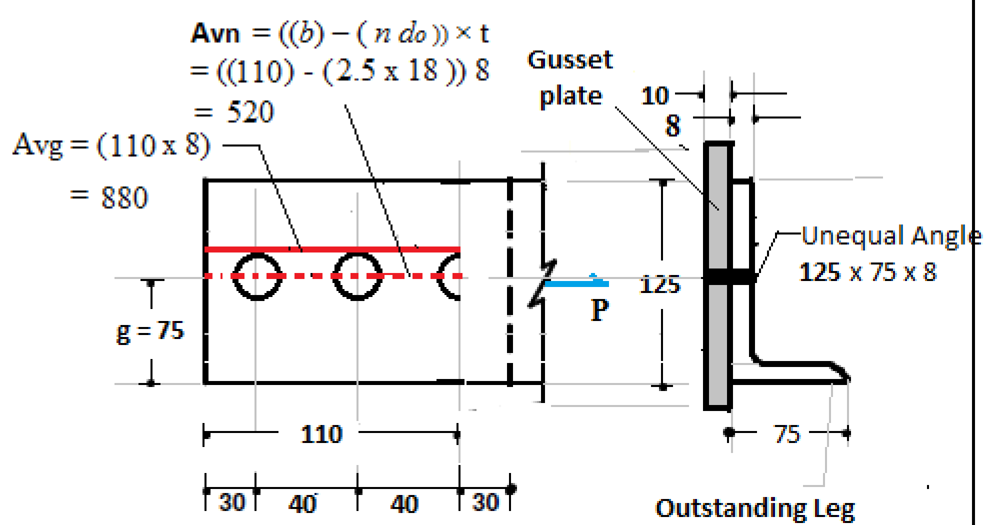
$$T_{db_2} = (0.9A_{vn}\, f_u /(\sqrt{3}\,\gamma_{m1}) + A_{tg}\, f_y /\gamma_{m0}\,)$$

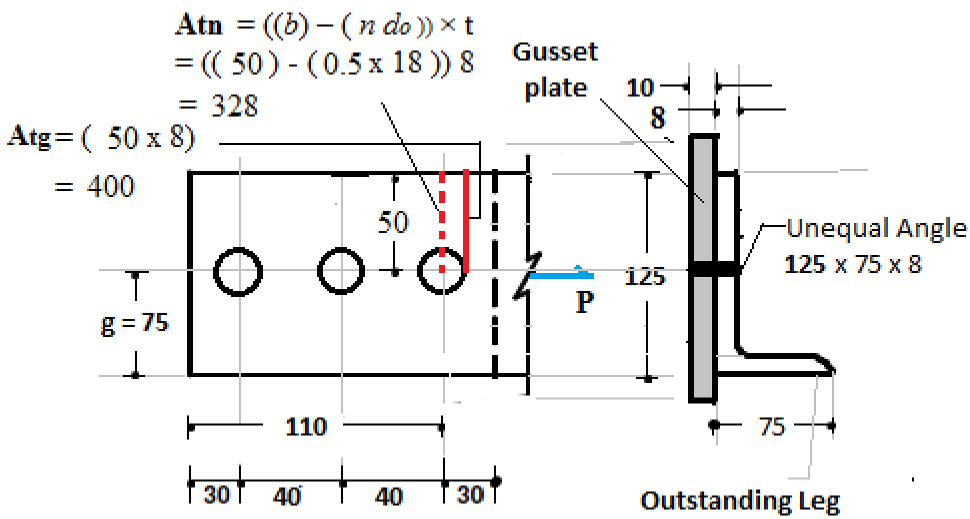
where, Avg = Minimum gross area to shear parallel to the line of action of force = (110 x 8) = 880 mm^2,

Avn = Minimum net area to shear parallel to the line of action of force ; Avn = [(110 – 2.5 x 18) x 8]

= 520 mm^2,

&





Here ; Tdb2 < Tdb1

$\therefore$ **block shear strength =** Tdb2 = 107.11 kN

(iv) Design tensile strength :

We have ;

Tdb2 = 107.11 kN < $\therefore T_{dn}$ = 336.27 KN < $\therefore T_{dg}$ = 349.09 KN

Tdb2 = 107.11 kN **…. Answer**

Atg = Minimum gross area to shear perpandicular to the line of action of force

= (50 x 8) = 400 mm^2,

Atn = Minimum net area to shear perpandicular to the line of action of force ;

= [(50 – (0.5 x 18) x 8] = 328 mm^2,

Therefore, Tdb1 = 212.30 kN and Tdb2 = 107.11 kN

Problem

A single unequal angle 100 x 75 x 8 mm is connected to a 12 mm thick gusset plate at the ends with 3 numbers of 18 mm diameter bolts to transfer tension as shown in Fig. Determine the design tensile strength of the angle if the gusset is connected to the 100 mm leg. The yield strength and ultimate strength of the steel used are 250 MPa and 400 MPa.

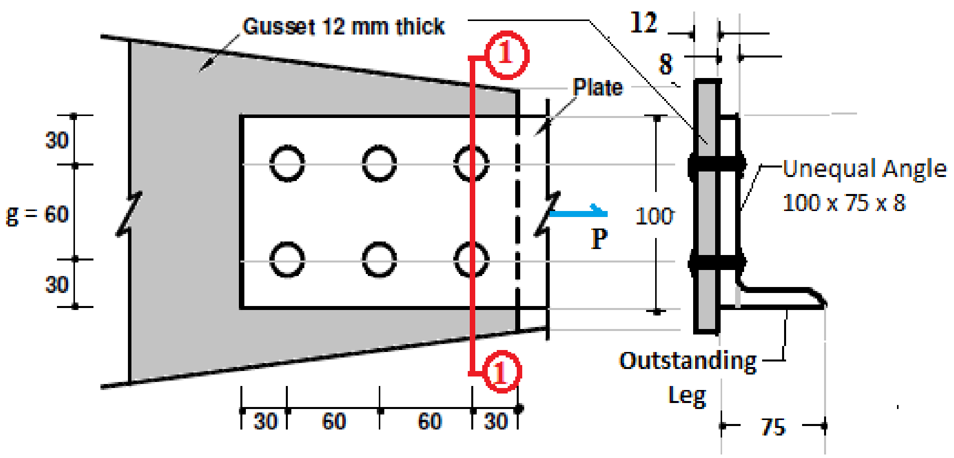


Fig. 11 Details of end connection

Solution

The design tensile strength Td of the plate is calculated based on the following criteria.

(i) Gross section yielding :

$T_{dg} = 1/\gamma\ (A_g\ F_y)$ .... IS 800-2007; cl. 6.2 ; pg. 32

Where, A_g = Gross Area Of plate S/c

$= ((100 \times 8) + (75 - 8) \times 8) = 1336\ mm^2$

F_y = Yield Stress Of the plate = $250\ N/mm^2$

γ = Partial Safety Factor for failure by Yielding = 1.10

.... IS 800-2007 ; Table 5 ; pg. 30

$\therefore T_{dg} = 303.63$ **KN**

(ii) Net section rupture

Design strength in Rupture for single angle ;

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

where

$$\beta = 1.4 - 0.076\,(w/t)\,(f_y/f_u)\,(b_s/L_c) \le (f_u \gamma_{m0} / f_y \gamma_{m1})$$
$$\ge 0.7$$

....IS 800-2007; cl. 6.3.3 ; pg. 33

Here ; $\gamma_{m_0} = 1.10$; $\gamma_{m_1} = 1.25$

....IS 800-2007 ; Table 5 ; pg. 30

W = outstand leg width = 75 mm

b_S = shear leg width = outstand + Guage distance – thickness

= (75 + 60 – 8) = 127 mm

L_c = Length of the end connection

= Distance between the outermost bolt holes

= (2 x 60) = 120 mm

$\therefore\ \beta = 1.4 - (0.076 \times \frac{75}{8} \times \frac{250}{410} \times \frac{127}{120}) = 0.940$

$= 0.940 \le 0.9 \times \frac{410}{250} \times \frac{1.10}{1.25} = 1.3$

≥ 0.7 ; Ok ; Safe

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

Where ; $F_u = f_{u_{plate}}$ = Ultimate stress of plate material = 410 N/mm^2

diameter of bolt hole (d_o) = 20 + 2 = 22 mm

A_n = Net effective area of the connected leg

$= ((b) - (n\, d_o)) \times t$

$= ((100) - (2 \times 22)) \times 8 = 448\ mm^2$

A_{go} = Gross area of outstanding leg = (75 – 8) x 8 = 536 mm^2

$\therefore\ T_{dn} = \frac{0.9 \times 410 \times 448}{1.25} + \frac{0.940 \times 250 \times 536}{1.10} = 246.75\ KN$

$\therefore\ T_{dn} = 246.75$ **K**

(iii) Block shear failure

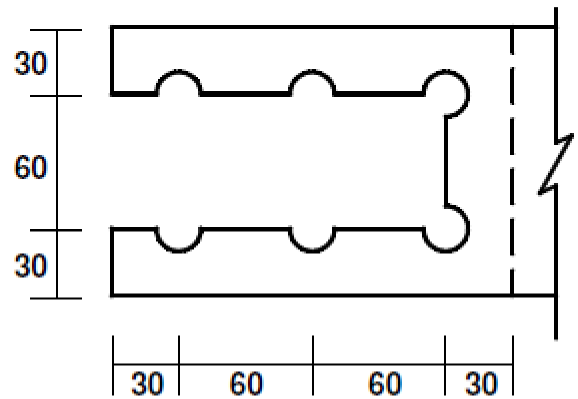


Fig. 12 Failure of plate in block shear

As per IS 800-2007 ; Cl. 6.4.1 ; Pg. 33

The block shear strength shall be smaller of following ;

$$T_{db_1} = [A_{vg} f_y / (\sqrt{3}\, \gamma_{m0}) + 0.9 A_{tn} f_u / \gamma_{m1}]$$

or

$$T_{db_2} = (0.9 A_{vn} f_u / (\sqrt{3}\, \gamma_{m1}) + A_{tg} f_y / \gamma_{m0})$$

where, Avg = Minimum gross area to shear parallel to the line of action of force = (150 x 8) 2 = 2400 mm^2,

Avn = Minimum net area to shear parallel to the line of action of force ; Avn = [(150 – 2.5 x 18) x 8] 2

Avn = 1680 mm^2,

&

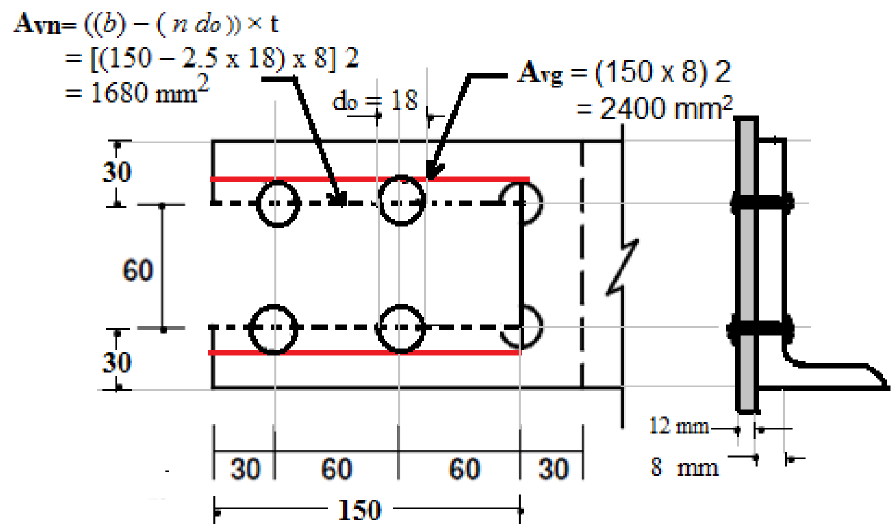
Atg = Minimum gross area to shear perpendicular to the line of action of force

= (60 x 8) = 480 mm^2,

Atn = Minimum net area to shear <u>perpandicular</u> to the line of action of force ;

= [(60 – 1.0 x 18) x 8] = 336 mm^2,

$\therefore T_{dn} = 246.75$ KN **…….. Answer**



Therefore, Tdb1 = 411.69 kN and Tdb2 = 388.44 kN

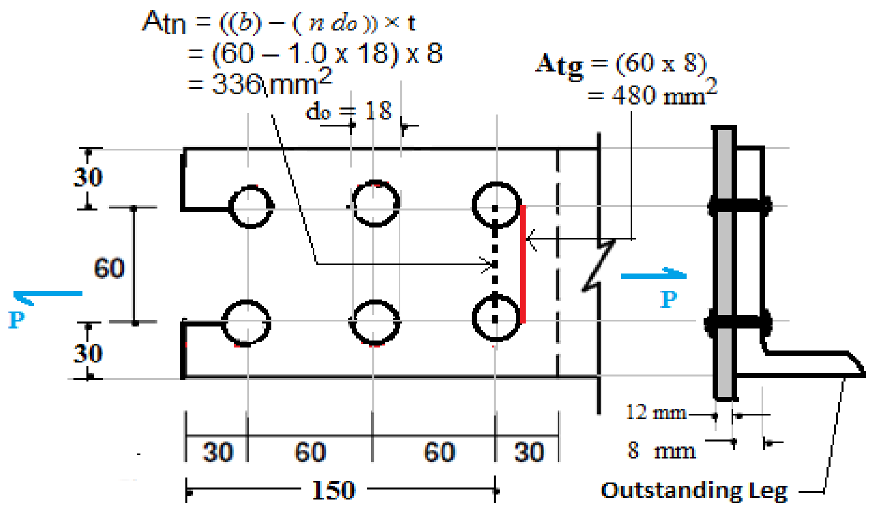
Here ; Tdb2 < Tdb1

$\therefore$ **block shear strength** = Tdb2 = 388.44 kN

(iv) <u>Design tensile strength :</u>

We have ;

$\therefore T_{dn} = 246.75$ KN < $\therefore T_{dg} = 303.63$ KN < Tdb2 = 388.44 kN


Atn = ((b) – (n do)) × t
= (60 – 1.0 x 18) x 8
= 336 mm2
do = 18
Atg = (60 x 8)
= 480 mm2
30
60
30
P
P
12 mm
8 mm
30
60
60
30
150
Outstanding Leg