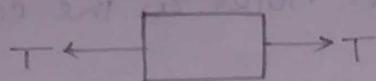


Design of Tension member:-

→ Types of failure:-

A tension member may fail in any of the following modes

- ① Gross section yielding
- ② Net section rupture
- ③ Block shear failure.



We know $\sigma = \frac{T}{A} = f_y$

$$\Rightarrow T = \sigma \cdot A = \left(\frac{f_y}{\gamma_{M0}} \right) \cdot A \quad \text{or } T = f_y A$$

Gross section - yielding:-

As per Pg. 32 Cl. 6.2

$$T_{dg} = A_g \left(\frac{f_y}{\gamma_{M0}} \right)$$

Where f_y = yield stress of material

A_g = Gross area of section

γ_{M0} = Partial safety factor for failure in tension by yielding. (Table-5)

Net section rupture:-

As per Pg-32 Cl 6.3.1

For plates

$$T_{dn} = 0.9 A_n \left(\frac{f_u}{\gamma_{M1}} \right)$$

Where γ_{M1} = Partial safety factor for failure in tension at ultimate stress (Table-5).

f_u = ultimate stress of material

A_n = net effective area of member

$$A_n = \left[b - n d_h + \sum \frac{P_s i^2}{4 g_i} \right] t$$

Where 'b' and 't' are width and thickness of the plate
 d_h - Dia of hole

g - Gauge length between the holes

P_s - Staggered pitch length between line of bolt hole

n = number of bolt holes in the critical sec.

For threaded end

-As per Pg 33, Cl 6.3.2

$$T_{dn} = 0.9 A_n \left(\frac{f_u}{V_{m1}} \right)$$

A_n = Net cont area at the threaded section.

For single angle

-As per Pg-33, Cl 6.3.3

$$T_{dn} = 0.9 A_{nc} \left(\frac{f_u}{V_{m1}} \right) + \beta A_{go} \cdot \left(\frac{f_y}{V_{m0}} \right)$$

Where $\beta = 1.0 - 0.076 \left(\frac{w}{t} \right) \left(\frac{f_y}{f_u} \right) \left(\frac{b_s}{L_c} \right)$

$$\frac{f_u}{V_{m0}} \frac{f_y V_{m0}}{f_y V_{m1}} > 0.7$$

Where w = outstanding leg width

b_s = shear lag width

L_c = length of end connection.

For preliminary sizing the roughage strength of net section may be approximately taken as

$$T_{dn} = d A_n f_u$$

Where A_n = net area of total connection

A_{nc} = net area of connected leg

A_{go} = Gross area of outstanding leg

t = thickness of the leg.

Design Strength due to block shear :-

$$T_{db} = \frac{A_{ug} t_y}{\sqrt{3} V_{mo}} + \frac{0.9 A_{tn} t_u}{V_{mo}}$$

or

$$T_{db} = \frac{0.9 A_{vn} t_u}{\sqrt{3} V_{mo}} + \frac{A_{tg} t_y}{V_{mo}}$$

which ever is minimum from above value.

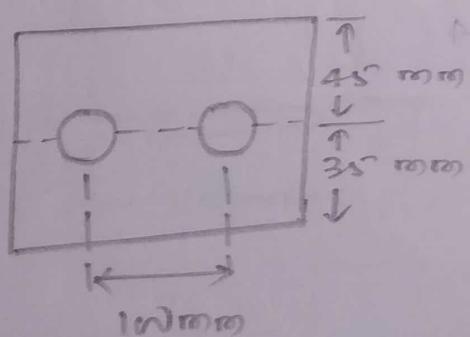
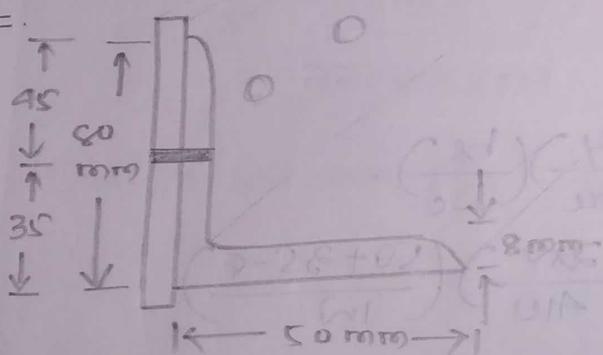
Where

T_{db} = Block shear strength.

A_{ug} , A_{vn} - minimum gross and net area in shear along bolt line parallel to external force.

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 line of force.

Q :-



Let us consider
bolt dia = 16 mm
hole dia = $16 + 2 = 18$ mm.

Design strength due to yielding of gross section

$$T_{dy} = \frac{A_g b_y}{V_{m0}}$$

$$A_g = \left(80 - \frac{8}{2}\right) \times 8 + \left(50 - \frac{8}{2}\right) \times 8 \\ = 976 \text{ mm}^2$$

Let us consider Fe 415 Steel

$$b_y = 250 \text{ N/mm}^2$$

$$V_{m0} = 1.10$$

$$T_{dy} = \frac{976 \times 250}{1.1} = 221.818 \text{ KN}$$

Design strength due to rupture of critical section

$$T_{dr} = \frac{0.9 A_{nc} f_{ue}}{V_{m0}} + B A_g b_y$$

$$\text{Hence } f_{ue} = 410 \text{ N/mm}^2$$

$$V_{m0} = 1.25$$

$$b_y = 250 \text{ N/mm}^2$$

$$V_{m0} = 1.10$$

$$B = 1.4 - 0.076 \times \left(\frac{\omega}{t}\right) \left(\frac{b_y}{f_{ue}}\right) \left(\frac{b_s}{L_c}\right) \\ = 1.4 - 0.076 \times \left(\frac{50}{8}\right) \left(\frac{250}{410}\right) \left(\frac{50+35-8}{100}\right) \\ = 1.177$$

$$\frac{f_{ue} \cdot V_{m0}}{V_{m0} b_y} = \frac{410 \times 1.10}{250 \times 1.25} = 1.044$$

$$1.177 < 1.044 \text{ (not valid)}$$

$$> 0.7$$

$$\beta = 1.177$$

$$A_{nc} = \left(80 - \frac{8}{2} - 18\right) \times 8$$

$$= 164 \text{ mm}^2$$

$$A_n = A_{nc} + A_{go}$$

$$= 164 + 368 = 532 \text{ mm}^2$$

$$A_{go} = \left(50 - \frac{8}{2}\right) \times 8 = 368 \text{ mm}^2.$$

$$T_{dn} = \frac{0.9 \times 464 \times 410}{1.25} + \frac{1.177 \times 368 \times 250}{1.01}$$

$$= 225.412 \text{ kN.}$$

Design strength due to block shear

$$A_{vg} = (100 + 50) \times 8 = 1200 \text{ mm}^2$$

$$A_{vd} = \left(150 - 18 - \frac{18}{2}\right) \times 8 = 984 \text{ mm}^2$$

$$A_{tg} = 150 \times (25 \times 8) = 280 \text{ mm}^2$$

$$A_{tn} = \left(35 - \frac{18}{2}\right) \times 8 = 208 \text{ mm}^2$$

$$(T_{db})_1 = \frac{1200 \times 250}{\sqrt{3} \times 1.10} + \frac{0.9 \times 208 \times 410}{1.25} = 354$$

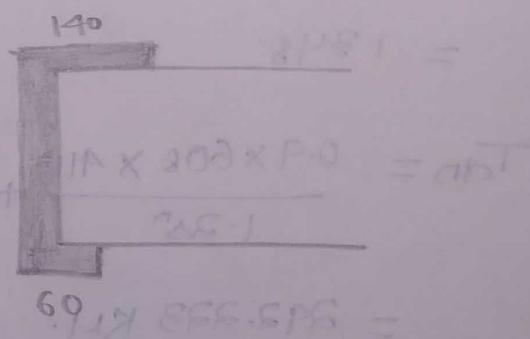
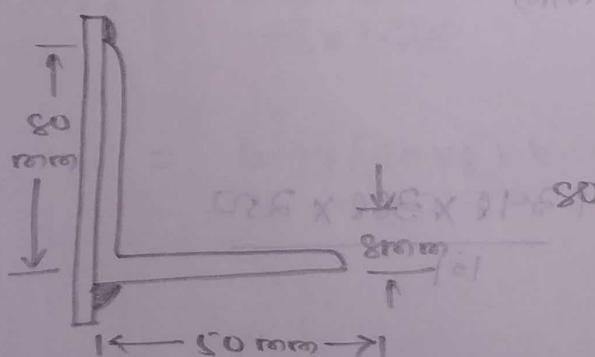
$$= 218.860 \text{ kN} \quad \leftarrow \text{lowest one}$$

$$(T_{db})_2 = \frac{0.9 \times 984 \times 410}{\sqrt{3} \times 1.25} + \frac{280 \times 250}{1.10}$$

$$= 221.243 \text{ kN.}$$

Design strength is 218.860 kN.

Ans:-



Design Strength due to yielding of gross-section

$$T_{dg} = \frac{A_g t_y}{V_{m0}}$$

$$A_g = \left(80 - \frac{8}{2}\right) \times 8 + \left(50 - \frac{8}{2}\right) \times 8 \\ = 976 \text{ mm}^2$$

$$t_y = 250 \text{ N/mm}^2$$

$$V_{m0} = 1010.$$

$$T_{dg} = \frac{976 \times 250}{1010} = 221.818 \text{ kN.} \leftarrow \text{Design Strength}$$

Design Strength Due to rupture of critical section

$$T_{dr} = \frac{0.9 A_{nc} t_y}{V_{m0}} + \beta \frac{A_{so} \cdot t_y}{V_{m0}}$$

$$A_{nc} = \left(80 - \frac{8}{2}\right) \times 8 = 608 \text{ mm}^2$$

$$A_{so} = \left(80 - \frac{8}{2}\right) \times 8 = 368 \text{ mm}^2.$$

$$\boxed{A_g > A_{nc} + A_{so}} \quad (\text{DFT})$$

$$B = 1.04 - 0.076 \times \frac{\omega}{t} \times \frac{t_y}{t_u} \times \frac{b_s}{L_c}$$

$$= 1.04 - 0.076 \times \frac{50}{8} \times \frac{250}{410} \times \frac{50}{280}$$

$$L_c = 140 + 60 + 80 = 280 \text{ mm}$$

$$= 1.348$$

$$T_{dr} = \frac{0.9 \times 608 \times 410}{1.25} + \frac{1.348 \times 368 \times 250}{101}$$

$$= 292.223 \text{ kN.}$$

Design strength due to block shear

$$A_{vg} = (140 + 60) \times 8 = 1600 \text{ mm}^2.$$

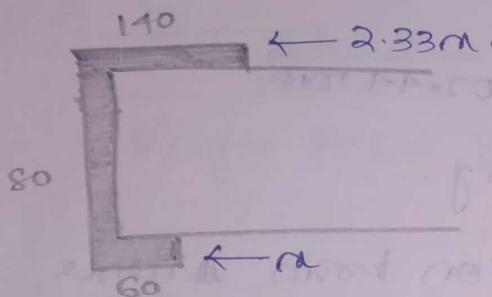
$$A_{tn} = 80 \times 8 = 640 \text{ mm}^2$$

$$A_{vn} = (140 + 60) \times 8 = 1600 \text{ mm}^2$$

$$A_{tg} = 640 \text{ mm}^2.$$

$$(T_{db})_1 = \frac{1600 \times 200}{\sqrt{3} \times 1.01} + \frac{0.9 \times 640 \times 410}{1.25^2} = 398.873 \text{ kN}$$

$$(T_{db})_2 = \frac{0.9 \times 1600 \times 410}{\sqrt{3} \times 1.25} + \frac{640 \times 200}{1.01} = 418.15 \text{ kN.}$$



Let us consider $(T_{db})_1 = 219 \text{ kN.}$

$$219 = \frac{(3.3\alpha \times 8) \times 200}{\sqrt{3} \times 1.01} + \left(\frac{0.9 \times 640 \times 410}{1.25^2} \right)$$

$$\alpha = 9 \text{ mm}$$

$$2.3\alpha = 21 \text{ mm.}$$

$$(T_{db})_2 = \frac{0.9 \times A_{vn} \times b_{ue}}{\sqrt{3} \times 1.25} + \frac{A_{tg} \cdot t_y}{V_m}$$

$$= \frac{0.9 \times (110 \times 8) \times 410}{\sqrt{3} \times 1.25}$$

S.Q.:- Design an angle section of factored load 230 kN.

$$\frac{T_{dg}}{V_{mo}} = \frac{A_g b_y}{V_{mo}}$$

$$\Rightarrow 230 = \frac{A_g \cdot 250}{1.10} = 1012 \text{ mm}^2$$

$$T_{dn} = \frac{d \cdot A_n \cdot f_u}{V_{mo}}$$

$$\Rightarrow 230 = \frac{0.6 \times A_n \times 410}{1.25} = 1168.7 \text{ mm}^2$$

From problem (3) $\frac{A_g}{A_n} = \frac{976}{832} = 1.17$

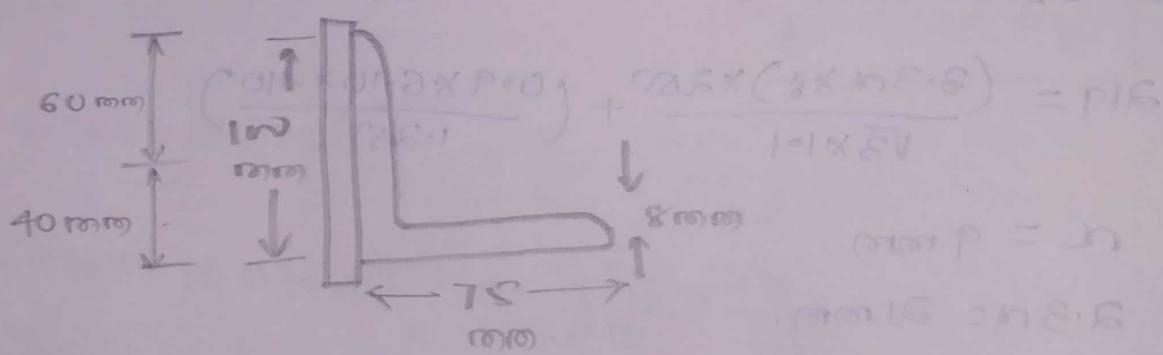
Let us take ratio = 1.20.

Now $A_n = 1168.7 \times 1.20 = 1402.44 \text{ mm}^2$.

Let us take $1402 \text{ mm}^2 = A_g$.

Now Select an angle section from Table

ISA 1Wx75x8



$$A_g = 1236 \text{ mm}^2$$

$$\frac{T_{dg}}{V_{mo}} = \frac{A_g b_y}{V_{mo}}$$

$$= \frac{1236 \times 250}{1.10}$$

$$= 303.636 \text{ kN.}$$

Hinged :-

1. Tension members.

2. compression.

1. Tension Member:-

→ Definition.

→ Type of section.

→ Net area

→ Net effective sections for angles and the tie in tension.

→ Use for lug angle.

→ Design of tension splice.

→ Concept of shear lag.

Definition:-

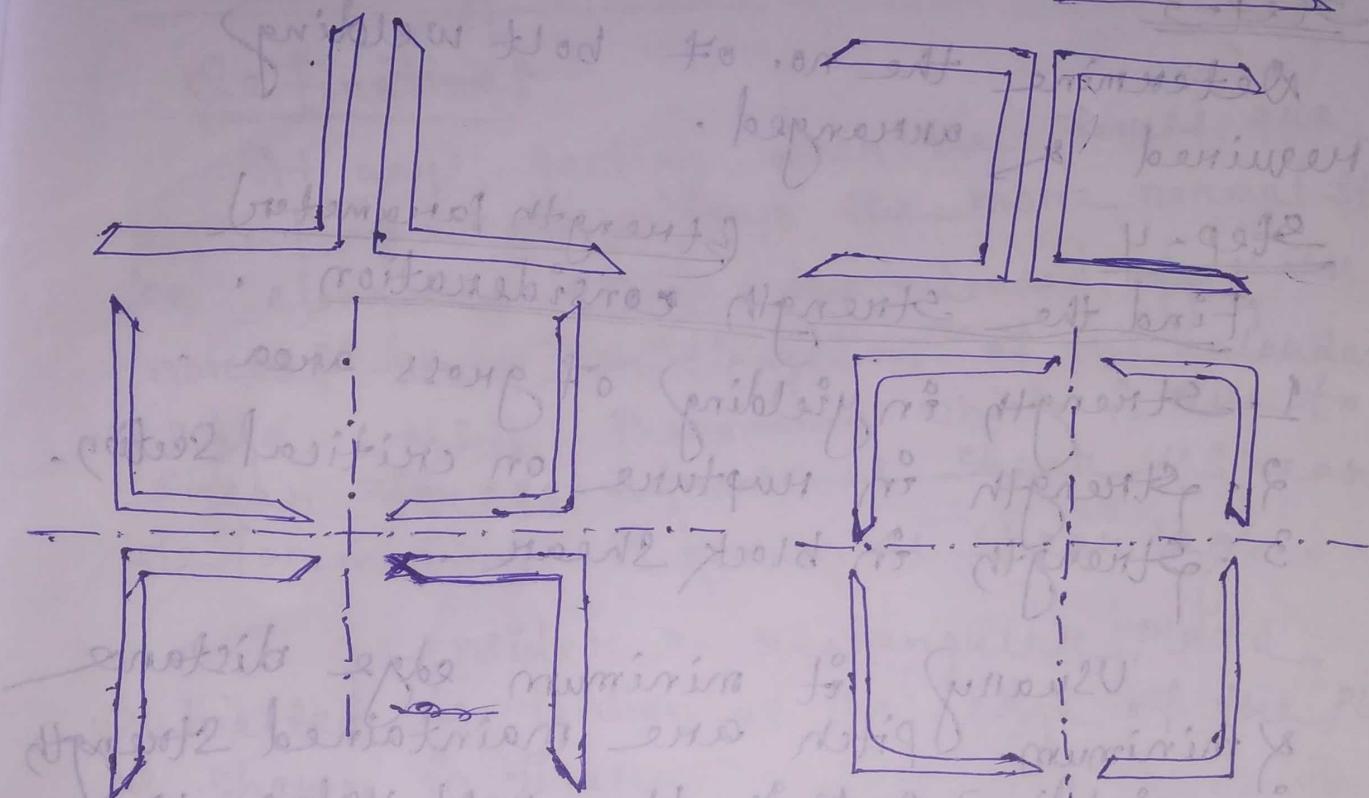
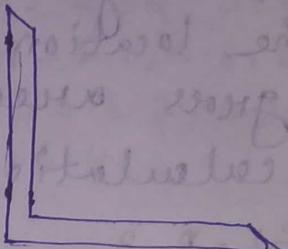
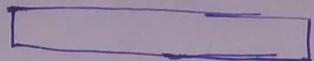
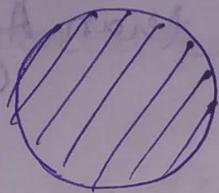
→ Tension members are also known as tie members.

→ The section should be compact and in order to minimize stress concentration.

It should be so arranged that as a large portion of it as possible is connected to the gusset plate.

→ A structural member is subjected to two pulling forces applied at its ends is called tension member.

Various types of shape / shape of tension member :-



Design procedure:-

Step-1

Find the required gross area to carry the factored load considering the strength is yield.

$$A_g = \frac{F_u}{f_y/\gamma_{mo}} = \frac{1.1 T_u}{f_y}$$

$$\gamma_{mo} = 1.1$$

where, A_g = gross area.

f_y = Factored tensile force.

Step-2

Select suitable shape of the section depending upon the type of structures & the location of the member such that gross area is 25 to 50% more than Ag calculation.

Step-3

Determine the no. of bolt welding required & arranged.

Step-4

(Strength parameter)
Find the strength consideration.

1. Strength in yielding of gross area.

2. Strength in rupture on critical section.

3. Strength in block shear.

Usually if minimum edge distance & minimum pitch are maintained strength in yielding is the rest value, hence design is safe if A_g provided $> A_g$ required.

Step-5

The strength obtained should be more than factored tension, if it is too much higher side 'or' the strength is less than factored tension, the section may be suitably changed & checked.

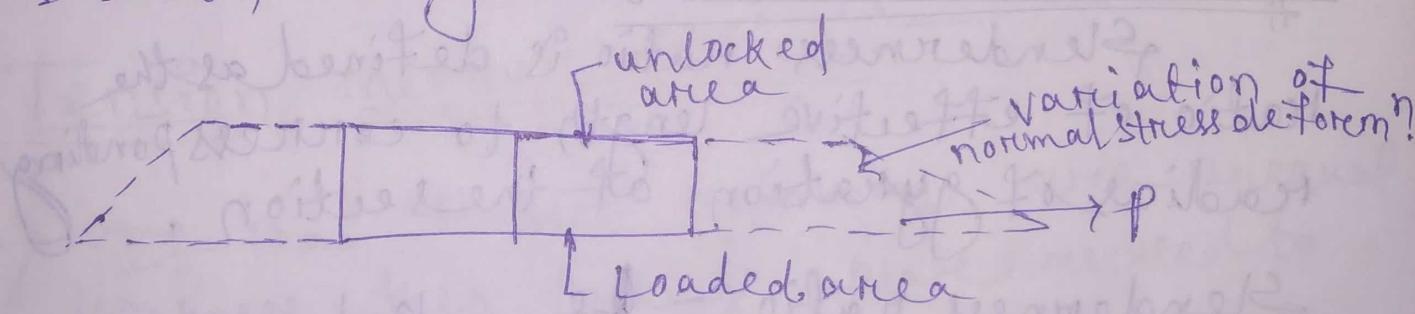
Step-6 ~~use~~ IS 800, 2007 also recommends to check
Torsion Slenderness ratio of tension member as
Per table-3, IS 800, 2007 (Page = 32-33)
~~Serial no:~~ CL No - 6.1, 6.2, 6.3,
6.3.1, 6.3.2, 6.3.3,
6.8.4, 6.4, 6.4.1, 6.4.2)

Shear lag concept:-

Definitions

At any section when the forces are applied is non-uniform the more normal stress or elongation along the loaded edge & less normal stress or elongation of the unloaded edge, this phenomenon which is due to shear forces is known as shear lag.

Consider a rectangular plate subjected to tension at the edge of the plate as shown in figure:



→ Normal stress distribution & deformation in the flat near the end where the forces applied is non-uniform which more normal stress, the loaded edge & the less normal stress, the unloaded edge.

→ The distribution of normal stress & deformation of the flat becomes uniform at the section away from the end i.e. in the middle of the plate.

→ The design of steel such as angles, channels & ties & they are connected to a gusset through one leg, ~~cocks~~ or flange when used as tension 'or' compression member.

→ The connecting element of section are more stressed than unconnected elements of the section as the load is transferred.

→ For example - In the case of single angle the connected angle is more stressed than the outstanding leg near the loaded area.

Slenderness Ratio :-

Slenderness ratio is defined as the ratio of effective length to corresponding radius of gyration of the section.

$$\text{Slenderness ratio} = \frac{l_e}{r_e} = k \cdot L$$

Where,

L = Actual length

l_e = Effective length = $k \cdot L$

r_e = Radius of gyration.

* Maximum value of effective slenderness ratio: (From Table No: 03, IS 800, 2007)

1. A tension member in which reversal of direct stress occurs due to loads other than wind or seismic load.

$$\boxed{\text{Effective Slenderness Ratio} = \frac{l}{r_e} = 180}$$

2. A member normally acting as a tie in a roof truss or a bracing system not consider effective when subjected to possible reversal of stress into compression resulting from the action of wind or earthquake forces. ($\frac{l}{r_e} = 350$)

3. Member always under tension other than free tension member ($\frac{l}{r_e} = 400$).

Tension member splice:

- If the tension members are unequal thickness then packing plate are used to surface of the tension member splice.
- The strength of the splice plates & bolt or weld connecting them should have strength at least equal to design load when tension members of different thickness are spliced.

to be connected filler plates may be used to bring the member in level.

→ The design shear capacity of bolt carrying shear through packing plate in excess of 6mm shall be decreased as a factor.

$$\beta_{PK} = 1 - 0.0125 \cdot t_{PK}$$

Where, t_{PK} = Thickness of the thicker packing plate.

Lag Angle:

Length of the end connection of a heavily loaded tension member may be reduced by using lag angles. By using lag angles there will be saving in gusset plate.

IS Specification per lag angle:

1. The effective connection of the lag angles shall as far as possible terminate at the end of the member.

2. The connection of lag angles to main member shall preferably start in advance of the member at the gusset plate.

3. Minimum two bolts weld equivalent welds are used for attaching the lag plate from the gusset plate.

4. If the member is an angle:

(a) the whole area of the members shall be taken as the effective rather than net effective section. the whole area of the ~~is~~ the whole member is the gross area less reduction per whole.

(b) the strength of lag angles & transfer connecting lag angles to gusset plate should be atleast 20% more than the force in outstanding leg.

(c) the strength of the lag angle & main member shall be atleast 40% more than the force carried by the outstanding leg.

Design Strength of tension member —

1. Design strength due to yielding gross section.
(T_{dg}) .

$$T_{dg} = A_g \cdot f_y \cdot Y_m$$

Where, f_y = yield stress of the material

A_g = gross area of cb.

Y_m = partial safety factor for failure in tension by yielding = 1.1

2. Design strength due to rupture of critical section (T_{dn}) .

$T_{dn} = \alpha A_f f_y$

$$T_{dn} = \frac{0.9 A_f f_u}{Y_m}$$

Where, A_n = Net effective area of the critical section.

$$A_n = [b - n d_o + \sum_i \frac{P_i g_i^2}{4 g_i}] t$$

* For threaded bolt & bolt, $T_{dn} = \frac{0.9 A_f f_u}{Y_m}$

$A_n = 0.78 \frac{\pi}{4} d^2$ For IS of thread force single angle.

$$T_{dn} = \frac{0.9 A_f f_u}{Y_m} + \frac{\beta A_g f_y}{Y_m}$$

Where, A_n = Net area of the connected length.

A_n = Net area of the connected length.

A_g = Gross area of the outstanding leg.

→ For Preliminary design IS code recommended the following formula,

$$T_{dn} = \frac{\chi A_f f_u}{Y_m}$$

$\chi = 0.6$ for one or two bolt,

0.7 for V bolt & 0.8 for 4

or more than 4 bolt.

$$T_{db} = \frac{A_{vg} f_y}{V_b Y_m} + 0.9 A_{tn} f_u$$

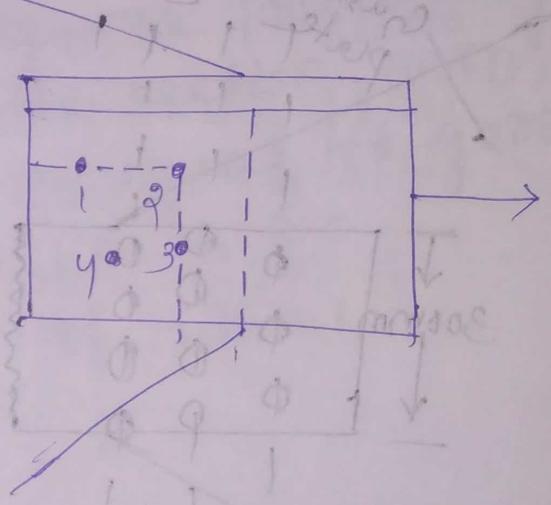
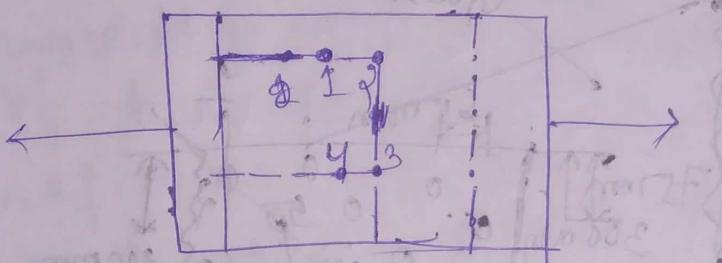
(Note: A_{vg} is the gross area of the column, V_b is the bond stress, Y_m is the yield stress of the reinforcement, and A_{tn} is the tensile area of the reinforcement.)

$$T_{db} = \frac{0.9 A_{vn} f_u}{V_b Y_m} + \frac{A_{tg} f_y}{Y_m}$$

(Note: A_{vn} is the net area of the column, A_{tg} is the transverse gross area of the column, and f_y is the yield stress of the reinforcement.)

→ Avg. of A_{vn} minimum gross or net area of shear 1 to 2, 3 - y in fig: a & 1-2 in fig: b)

→ A_{tn} (one) A_{tg} minimum gross or net area in tension (2-3 in fig: a & b)



Types of Failure:-

1. Gross section yielding. (limit state of yielding in gross section).
2. Net section rupture. (limit section of rupture or fracture)
3. Block shear failure.

(Note: Block shear failure occurs when a crack propagates from one corner of a column to another, creating a large block of concrete that falls off.)

* Net sectional area :-

→ The net sectional area of a tension member is the gross sectional area of the member — the sectional area of the max^m no. of hole.

i.e. $A_n = A_g - \text{Sectional areas of holes}$

→ The reserves considering the net section in the calculation of stresses is the failure of section with holes.

Plate :-

→ As shown in Fig-1 subjected to a pull (T) and provided with chain bolting. The possibility of failure can be along the section ABCD, net area of the section is equal to gross area — The area of bolt hole B P C.

$$A_n = A_g - \text{Sectional area of holes.}$$

$$\Rightarrow A_n = b_t - n (\text{d}_h \cdot t)$$

$$\Rightarrow A_n = (b - n \cdot d_h) t$$

Where,

A_n = net sectional area of plate

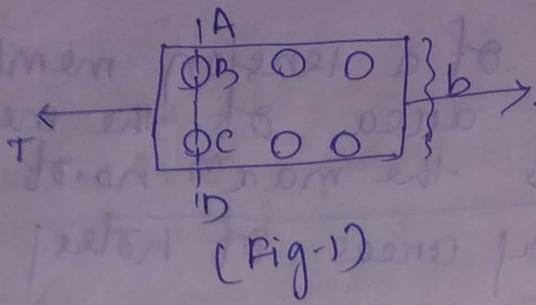
A_g = gross sectional area of plate.

b = width of plate

n = no. of bolts (on this fig. $n = 2$)

d_h = diameter of bolt hole

t = thickness of plate.



(b) As shown in fig. subjected to a pull 'T' and provided with a zigzag bolting.

To determine the critical length area of might seem logical to complete the area of a section ABC less the area of one bolt hole and then the area of a section ABDF less two bolt holes. The lgt of the two values obtained would be the critical value.

$$A_n = A_g - \left[\frac{\text{Sectional Area of hole}}{A_{g_1}} - \left(\frac{P_1^2 t}{A_{g_1}} + \frac{P_2^2 t}{A_{g_2}} \right) \right]$$

$$= bt - n dh + \frac{P_1^2 t}{A_{g_1}} + \frac{P_2^2 t}{A_{g_2}}$$

$$= \left[b - ndh + \frac{P_1^2}{A_{g_1}} + \frac{P_2^2}{A_{g_2}} \right] t$$

Where, $P_1 = P_2$

$$A_n = \left(b - ndh + n' \frac{P^2}{A_g} \right) t$$

Where P = Staggered pitch,
 g = Gauge distance

n = no. of holes in the zigzag lines

n' = no. of staggered pitches.

SOP :- Data given
for Fe410 grade of steel,
 $f_u = 410 \text{ MPa}$
 $f_y = 250 \text{ MPa}$

Thickness (t) = 12 mm

diameter of bolt (d) = 18 mm

" " hole (d_h) = 20 mm

(a) In chain bolting the critical section will be = 1-1
Net effective area

$$A_n = (B - n d_h) t$$

$$= (300 - 4 \times 20) 8 \\ = 1760 \text{ mm}^2$$

table no = 4.1
ekdugal
book
page no. 148

(b) in zig-zag bolting the section may fail along 1-2-3-4, 1-2-5-6-7, 1-2-5-3-4 or 1-2-5-8-9-10.

The effective net area is calculated and the min^m is considered to be critical.
Effective net area along section 1-2-3-4,

$$\text{Here } n = 2,$$

$$A_n = (B - n d_h) t$$

$$= (300 - 2 \times 20) 8$$

$$= 2080 \text{ mm}^2$$

Effective net area along section 1-2-5-6-7

$$n = 3, n' = 1$$

$$p = 65 \text{ mm}$$

$$g = 75 \text{ mm}$$

$$A_n = \left(B - n d_h + n' \frac{P^2}{4g_i} \right) t$$

$$= \left(300 - 3 \times 20 + \frac{1 \times 65^2}{4 \times 75} \right) 8$$

$$= 2032.66 \text{ mm}^2$$

(n' = No. of staggered pitches)

Effective net area of 1-2-5-3-4

$$n = 3, n' = 2$$

n = No. of hole in a zigzag line

$$A_n = \left[b - n d_o + \sum_i \frac{P s_i^2}{4 g_i} \right] t$$

$$\mu = \left\{ 300 - 3 \times 20 + \frac{2 \times 65^2}{4 \times 75} \right\} \times 8$$

$$= 2145.33 \text{ mm}^2$$

1-2-5-8-9-10

$$n = 4, n' = 3$$

$$A_n = \left[b - n d_o + \sum_i \frac{P s_i^2}{4 g_i} \right] t$$

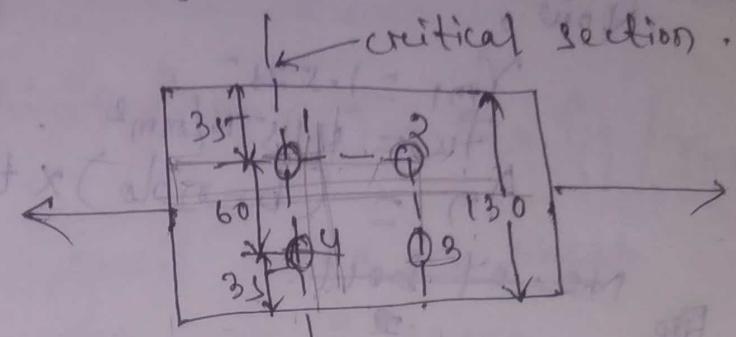
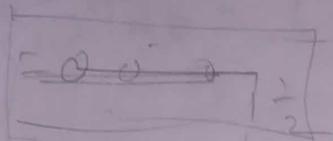
$$= \left(300 - 4 \times 20 + \frac{3 \times 65^2}{4 \times 75} \right) \times 8$$

$$= 2098 \text{ mm}^2$$

The min^m net effective area in a section 1-2-5-8-7 is 2032.66 mm².

Date - 13/09/2019

~~Q1~~ :- Determine the design tensile strength of the plate $130\text{mm} \times 12\text{mm}$ with the holes of 16mm diameter bolt as shown in figure. Steel used is of Fe45 grade quality.



Solⁿ

Strength of the plate is the least of :-

(a) Yielding of gross section

(b) Rupture of critical section

(c) Block shear strength

(a) Yielding of gross section :- (32-33)

$$T_{dg} = A_g f_y / \gamma_m o$$

Now, $f_y = 250 \text{ N/mm}^2$.

$$A_g = 130 \times 12 = 1560 \text{ mm}^2$$

$$\gamma_m o = 1.1$$

$$T_{dg} = \frac{1560 \times 250}{1.1}$$

$$= 354545.45 \text{ N}$$

$$= 354.54 \text{ kN}$$

(b) Rupture of critical section

$$T_{dn} = 0.9 A_n f_u / \gamma_m$$

Now,

$$\gamma_m = 1.525$$

$$f_u = 415 \text{ N/mm}^2$$

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

~~No. of bolt~~

~~For~~

From the consideration of rupture along the critical section, critical is having two holes.

$$d = 16 \text{ mm}$$

$$\text{diameter of hole } d_o = 16 + 2 = 18 \text{ mm}$$

$$A_n = (130 - 2 \times 18) \times 12 = 1128 \text{ mm}^2$$

Strength of member from the consideration of rupture,

• of rupture,

$$T_{dn} = \frac{0.9 \times 1128 \times 415}{1.525}$$

$$= 337046.4 \text{ N}$$

$$= 337.04 \text{ kN}$$

(c) The block shear strength is —

The block shear strength is the least of the following two:

$$(i) T_{db} = [A_{vg} f_y / (\sqrt{3} \gamma_m) + 0.9 A_{tn} f_u / \gamma_m]$$

$$(ii) T_{db} = (0.9 A_{vn} f_u / (\sqrt{3} \gamma_m) + A_{tg} f_y / \gamma_m)$$

A_{vg} = minimum gross area in shear.

A_{vn} = Minimum net area in shear.

A_{tg} = Minimum gross area in tension.

A_{tn} = Minimum net area in tension.

A_{vg} = $(60+35) \times 12$

$$= (60+35) \times 12$$

$$A_{vg} = 12 \times (35+60) \times 12$$
$$= 1860 \text{ mm}^2$$

$$A_{tg} = 60 \times 12 = 720 \text{ mm}^2$$

$$A_{vn} = \{(35+60 - 1.5 \times 18) \times 12\} \times 2$$

$$= 1632 \text{ mm}^2$$

$$A_{tn} = (60 - 18) \times 12$$

$$= 504 \text{ mm}^2$$

$$(i) T_{ab} = \left[\frac{2280 \times 280}{B \times 1.1} + \frac{0.9 \times 504 \times 415}{1.25} \right]$$

$$= 449767.61 \text{ N}$$

$$[\text{Com. of } f_t \text{ at p. o.} + (\text{Com. of } f_t \text{ at g. o.})] = abT(1)$$

$$= 449.76 \text{ kN}$$

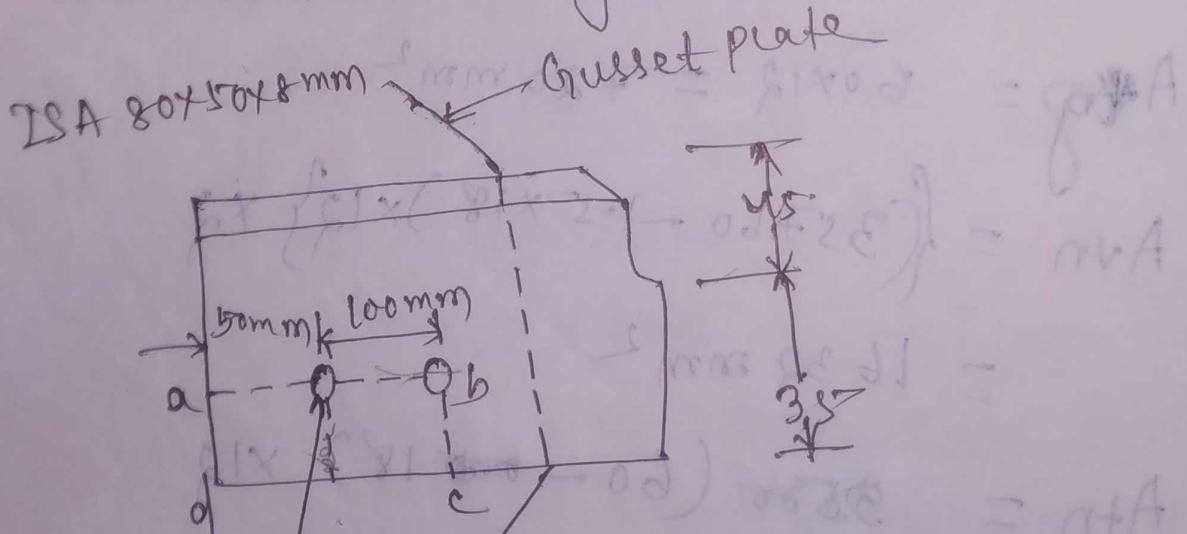
$$(ii) T_{ab} = \left[\frac{0.9 \times 1635 \times 415}{B \times 1.25} + \frac{720 \times 280}{1.1} \right]$$

$$= 445176.37 \text{ N}$$

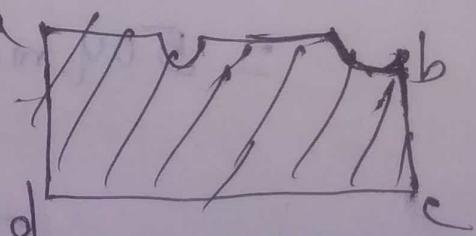
$$= 445.17 \text{ kN}$$

So the ~~desi~~ strength of the plate = 337.04 kN.

Q:- Determine the block shear strength of tension member as shown in figure. The steel is of grade Fe410.



18 mm diameter bolt hole.



Soln

$$\text{Given data} \quad \frac{0.1 \times 8 \times 8 \times 10^3}{1000} + \frac{0.2 \times 8 \times 10^3}{1000} = 1467$$

For Fe410 grade of Steel

$$f_u = 410 \text{ MPa}$$

$$f_y = 250 \text{ MPa}$$

Partial safety factors for material

$$\gamma_{m0} = 1.1$$

$$\gamma_{m1} = 1.25$$

The block shear strength will be minimum of T_{db1} & T_{db2} .

$$T_{db1} = \left[\text{Avg } f_y / (V_b \gamma_{m0}) + 0.9 A_{tn} f_u / \gamma_{m1} \right]$$

$$T_{db2} = \left[\frac{0.9 A_{tn} f_u}{V_b \gamma_{m1}} + \frac{\text{Avg } f_y}{\gamma_{m0}} \right]$$

$$\text{Avg } = 1 \times (50 + 100) \times 8 \\ = 1200 \text{ mm}^2$$

$$A_{tn} = 1 \times (100 + 50 - 1.5 \times 18) \times 8$$

$$= 984 \text{ mm}^2$$

$$A_{tg} = 35 \times 8 = 280 \text{ mm}^2$$

$$A_{tn} = (35 - \frac{1}{2} \times 18) \times 8 = 208 \text{ mm}^2$$

$$T_{db1} = \frac{1200 \times 250}{V_b \times 1.1} + \frac{0.9 \times 208 \times 410}{1.25}$$

Take to abutment not

$$= 218860.76 \text{ N}$$

$$= 218.86 \text{ kN}$$

$$T_{db2} = \frac{0.9 \times 984 \times 410}{V_b \times 1.25} + \frac{280 \times 250}{1.1}$$

28.1 = part

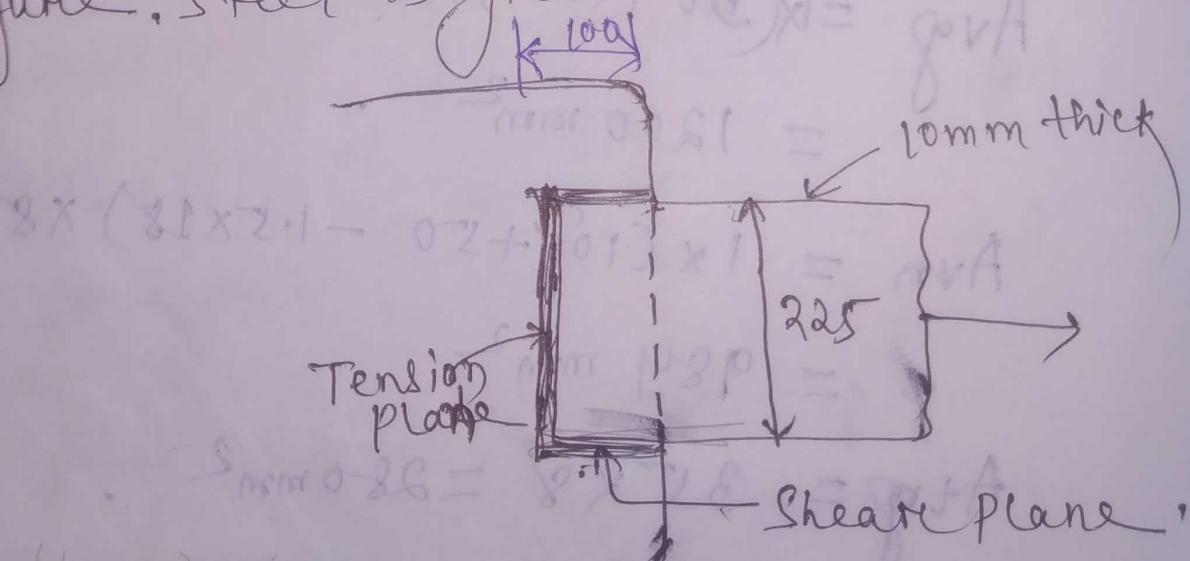
$$= 231343.22 \text{ N}$$

$$= 231.34 \text{ kN}$$

not part to minimum

Hence the block shear strength of the tension member is 218.86 kN , which is less than T_{db2} .

Q: Determine the block shear strength of the welded tension member shown in figure. Steel is grade of Fe410.



$$8 \times (80 \times 21 - 0.2 \times 0.9 \times 21) = 8 \times 178.78 = 1429.6 \text{ mm}^2$$

or or or

Sol

Given data
For Fe410 grade steel

$$f_u = 410 \text{ MPa}$$

$$f_y = 250 \text{ MPa}$$

$$\gamma_m = 1.1$$

$$\gamma_m = 1.25$$

The shaded area will be shear out.

$$A_{ng} = 2 \times 100 \times 10 = 2000 \text{ mm}^2$$

$$A_{vn} = 2 \times 100 \times 10 = 2000 \text{ mm}^2$$

$$A_{tg} = 225 \times 10 = 2250 \text{ mm}^2$$

$$A_{tn} = 225 \times 10 = 2250 \text{ mm}^2$$

Block shear strength will be minimum of T_{db1} & T_{db2} .

$$T_{db1} = \frac{A_{ng} f_y}{\gamma_3 \gamma_m} + \frac{0.9 A_{tn} f_u}{\gamma_m}$$
$$= \frac{2000 \times 250}{\gamma_3 \times 1.1} + \frac{0.9 \times 2250 \times 410}{1.25}$$

$$= 926631.94 \text{ N}$$

$$= 926.63 \text{ kN}$$

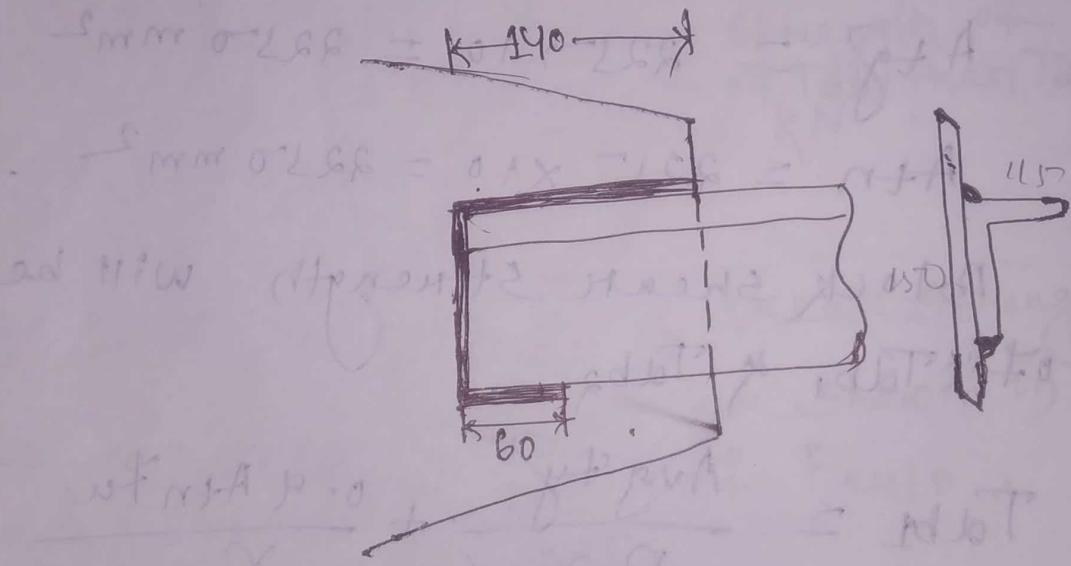
$$T_{db2} = \frac{0.9 A_{vn} f_u}{\gamma_3 \gamma_m} + \frac{A_{tg} f_y}{\gamma_m}$$
$$= \frac{0.9 \times 2000 \times 410}{\gamma_3 \times 1.25} + \frac{2250 \times 250}{1.1} = 859.93 \text{ kN}$$

The block shear strength of the

The block shear strength of the welded tension member is the minimum of T_{db_2} than T_{db} , $= 852.23 \text{ kN}$.

Q:- compute the tensile strength of an angle section ISA ($150 \times 115 \times 8$)mm of Fe 410 grade of steel connected with a gusset plate as shown in figure for the following cases :-

- (a) Gross section yielding
(b) Net section capacity.



~~501~~

For 410 grade of steel,

$$f_u = 410 \text{ MPa}$$

$$f_y = 250 \text{ MPa}$$

Partial safety factor

$$\gamma_m = 1.1$$

$$\gamma_m = 1.25$$

For ISA (150x115x8) mm

$$A_g = 20.58 \text{ cm}^2 = 2058 \text{ mm}^2$$

(a) Tensile strength due to gross section yielding.

$$T_{dg} = \frac{A_g f_y}{\gamma_m}$$

$$= \frac{2058 \times 250}{\gamma_m}$$

$$= 467.73 \text{ KN}$$

Date - 14/09/2019

(b) Net section rupture:-

$$T_{dn} = \frac{\alpha_1 A_n e_f u + \beta A_g o f_y}{\gamma_m}$$

(c) Tensile strength due to net section rupture.

The section is a single angle section ISA (150x115x8) mm with a longer end length welded to the gusset plate.

The short length will be the outstanding length.

Length of gusset plate = 31. peak ext

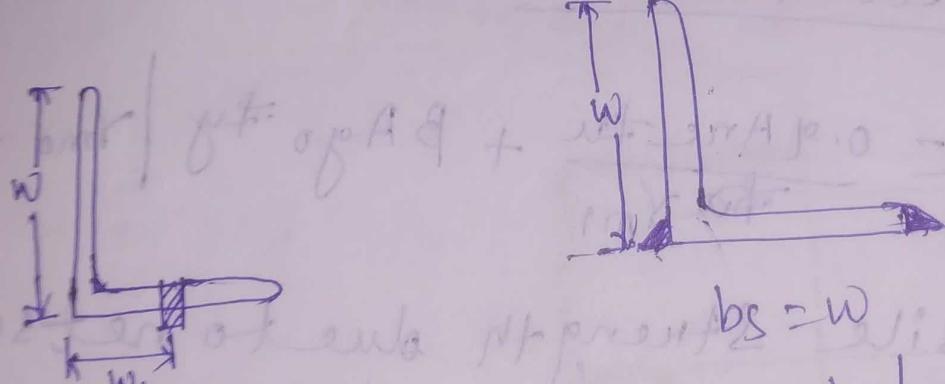
For single angle section the design

Strength,

$$T_{dn} = \frac{0.9 A_{nc} f_u}{\gamma_m} + \beta A_g \frac{f_y}{\gamma_m}$$

where, $\beta = 1.4 - 0.076 (w/t) (f_y/f_u) C_{bL}$
 $\leq \frac{f_y}{f_u} \geq 0.7$
where, w & b_s are indicated in figure.

L_c is the length of end connection
i.e. the distance between the outer
most bolt in the joint along the
length of the weld along the
load direction.



$b_s = w + w_1 - t$
(Bolted connection)

$b_s = w$
(Welded connection)

Length of the outstanding length,

$$w = 115 \text{ mm}$$

Shear lag width, $b_s = w = 115 \text{ mm}$,
weld length along the direction of
the load, $L_c = 140 \text{ mm}$.

thickness $t = 8 \text{ mm}$

$$\beta = 1.4 - 0.076 \left(\frac{115}{8} \right) \left(\frac{250}{410} \right) \left(\frac{115}{140} \right)$$
$$= 0.85 < 1.44 \Rightarrow \text{safe}$$

Hence, $\beta = 0.85$

A_{nc} tends to net area of the connected leg & $A_{go} = \text{gross area of the outstanding leg}$

t = thickness of the angle leg,

Net area of the connected leg,

$$A_{nc} = \left(150 - \frac{8}{2} \right) \times 8 = 1168 \text{ mm}^2.$$

Gross area of the outstanding length,

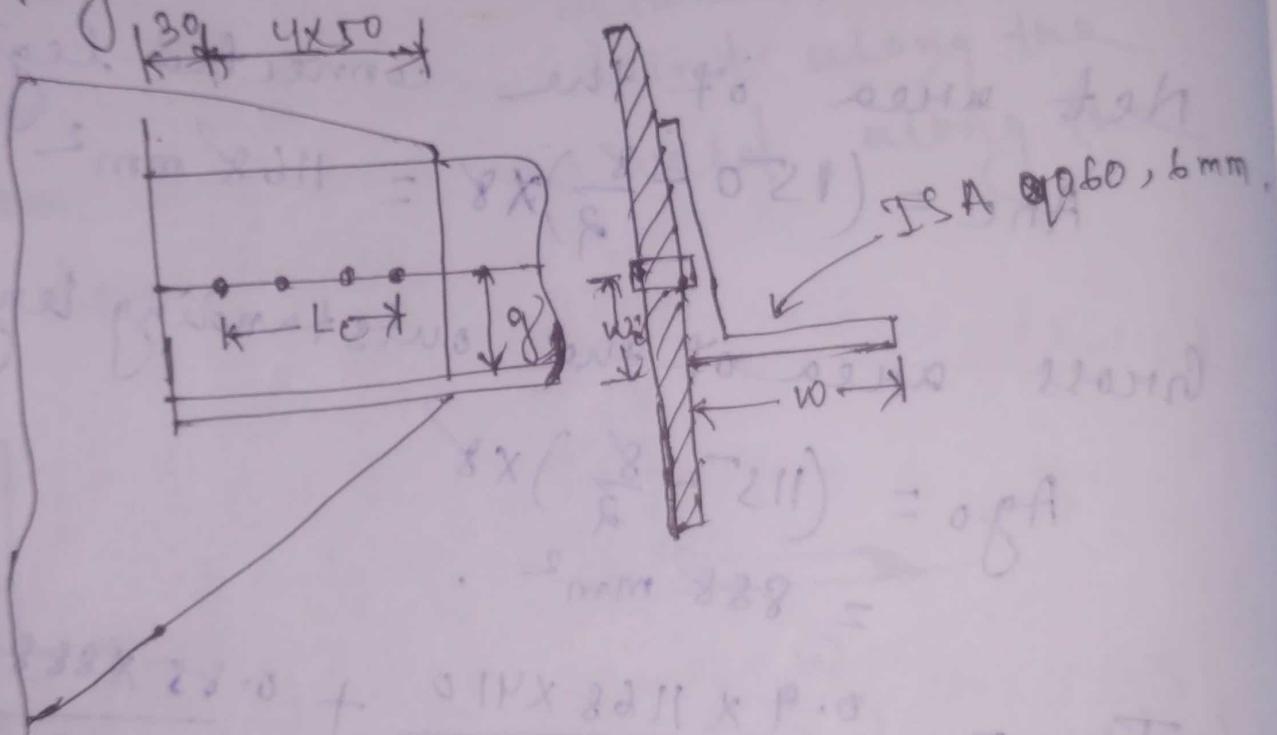
$$A_{go} = \left(115 - \frac{8}{2} \right) \times 8$$
$$= 888 \text{ mm}^2.$$

$$T_{dn} = \frac{0.9 \times 1168 \times 410}{1.25} + \frac{0.85 \times 888 \times 250}{1.1}$$

$$= 516.34 \text{ kN}$$

Q1: A single unequal angle ISA 9060,6mm is connected to a gusset plate at the ends with 15nos. of 16mm bolt to transfer tensile tension. Determine the design tensile strength of the angle.

- (a) If the gusset is connected to 90mm leg.
 (b) if the gusset is connected to 60mm leg.



~~Given data:~~, type d 171
 Given $g = 250\text{ mm}$ if 90mm leg is connected
 $g = 30\text{ mm}$ if 60mm leg is connected.

Date - 20/09/2019

Q17

Given data,

Angle = ISA 9060, 6mm

Gusset plate thickness = 10mm

Dia of bolt = 16mm
 $F_y = 250 \text{ MPa}$

(a) 90mm leg is connected to gusset : -

(i) Strength as governed by yielding of gross section,

$$T_{dg} = \frac{A_g F_y}{\gamma_m o}$$

$$A_g = 865 \text{ mm}^2$$

$$\begin{aligned} T_{dg} &= \frac{865 \times 250}{1.1} \\ &= 196364 \text{ N} \\ &= 196.36 \text{ kN} \end{aligned}$$

(ii) Strength as governed by tearing at critical section,

$$T_{dn} = \frac{0.9 A_{nc} F_y}{\gamma_m d} + \frac{\beta A_{go} F_y}{\gamma_m o}$$

$$\beta = 1.4 - 0.076 \times \frac{w}{t} \times \frac{F_y}{F_u} \times \frac{b_s}{L_c}$$

$$w = 60 \text{ mm}$$

$$w_i = 50 \text{ mm}$$

$$b_s = w + w_i - t = 60 + 50 - 6 = 104 \text{ mm}$$

$$b_s L_c = 4 \times 50 = 200 \text{ mm}$$

Ans:

$$\beta = 1.4 - 0.076 \times \frac{60}{6} \times \frac{250}{410} \times \frac{1.04}{200}$$

$$= 1.159$$

$$\leq \frac{f_u}{f_y} \times \frac{\gamma_{m0}}{\gamma_{m1}} = \frac{410}{250} \times \frac{1.1}{1.25} = 1.44 \geq 0.7$$

$$A_{nc} = (90 - \frac{6}{2}) \times 6 = 522 \text{ mm}^2$$

$$A_{go} = (60 - \frac{6}{2}) \times 6 = 342 \text{ mm}^2$$

$$T_{dn} = \frac{0.9 \times 522 \times 410}{1.25} + \frac{1.159 \times 342 \times 250}{1.1}$$

$$= 244.180 \text{ kN}$$

(iii) Block Shear strength:

$$T_{db} = \frac{Avg f_y}{\sqrt{3} \gamma_{m0}} + \frac{0.9 A_{tn} f_u}{\gamma_{m1}}$$

or/

$$T_{db} = \frac{0.9 A_{vn} f_u}{\gamma_{m1}} + \frac{Avg f_y}{\gamma_{m0}}$$

$$d_0 = 16 + 2 = 18 \text{ mm}$$

Tearing length in tension = $90 - 50 = 40 \text{ mm}$

$$Avg = 230 \times 6 = 1380 \text{ mm}^2$$

$$Avn = (230 - 4.5 \times 18) \times 6 = 894 \text{ mm}^2$$

$$Atg = 40 \times 6 = 240 \text{ mm}^2$$

$$Atn = (40 - 0.5 \times 18) \times 6 = 186 \text{ mm}^2$$

$$T_{ab} = \frac{1380 \times 250}{B_3 \times 1.1} + \frac{0.9 \times 186 \times 410}{1.25} = 235.98 \text{ kN}$$

$$\text{or } T_{ab} = \frac{0.9 \times 894 \times 410}{1.25} + \frac{240 \times 250}{1.1} = 318.45 \text{ kN}$$

When 90mm leg is connected to gusset the strength of the plate is least of 3 parameter i.e. Strength of the plate is 196.364 kN.

(b) 60 mm leg connected to gusset plate:-

Design strength due to yielding of gross section:

$$T_{dy} = A_g f_y / r_{mo} = 865 \times 250 / 1.1 = 1960.59 \text{ kN}$$

Design strength due to rupture of critical sections:

$$T_{dn} = \frac{0.9 A_{nc} f_u b}{r_{m1}} + \frac{\beta A_{go} f_y}{r_{mo}}$$

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

$$= 1.4 - 0.076 (90/6) (250/410) (114/200)$$

$$= 1.003 \leq \frac{410 \times 1.1}{280 \times 1.25} = 1.44 > 0.7$$

$$b_s = 90 + 60 - 6 = 124$$

$$L_c = 49 \times 50 = 200 \text{ mm}$$

$$A_{nc} = \frac{60 \times 60}{1000} \times (60 - \frac{6}{2}) \times 6 = 234 \text{ mm}^2$$

$$A_{go} = \left(90 - \frac{6}{2}\right) \times 6 = 522 \text{ mm}^2$$

$$T_{dn} = \frac{0.9 \times 234 \times 410}{1.25} + \frac{1.003 \times 522 \times 250}{1.1}$$

$$= 188.07 \text{ kN}$$

Design strength due to Block Shear

Tearing length = $60 - 30 = 30 \text{ mm}$

Avg = $230 \times 6 = 1380 \text{ mm}^2$

Avn = $(230 - 4.5 \times 18) \times 6 = 894 \text{ mm}^2$

Atg = $30 \times 6 = 180 \text{ mm}^2$

Atn = $(30 - 0.5 \times 18) \times 6 = 126 \text{ mm}^2$

$$T_{db} = \left[\frac{\text{Avg } f_y}{\sqrt{3} \gamma_m} + \frac{0.9 \text{ Atn } f_u}{\gamma_m} \right]$$

$$= \frac{1380 \times 250}{\sqrt{3} \times 1.1} + \frac{0.9 \times 126 \times 410}{1.25}$$

$$= 218.27 \text{ kN}$$

$$T_{db} = \frac{0.9 \text{ Avn } f_u}{\sqrt{3} \gamma_m} + \frac{\text{Atg } f_y}{\gamma_m}$$

$$= \frac{0.9 \times 894 \times 410}{\sqrt{3} \times 1.25} + \frac{180 \times 250}{1.1}$$

$$= 193.27 \text{ kN}$$

When 60 mm leg is connected to gusset
the strength of the plate is the
least of 3 parameters i.e.
Strength of the plate is 188.07 kN.