Design of welded joint :

1. Fillet welds :

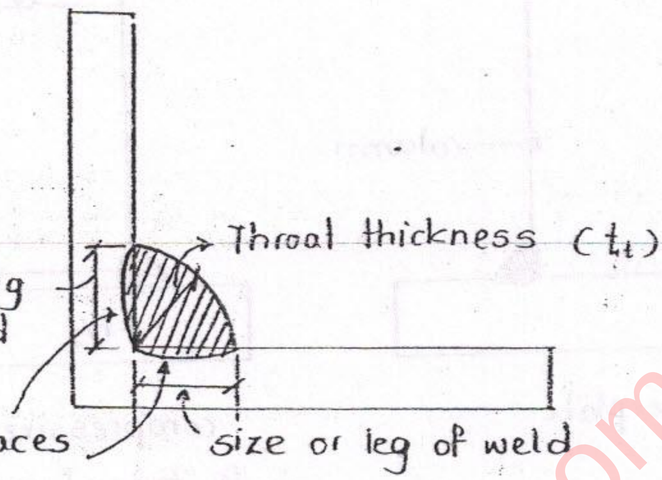


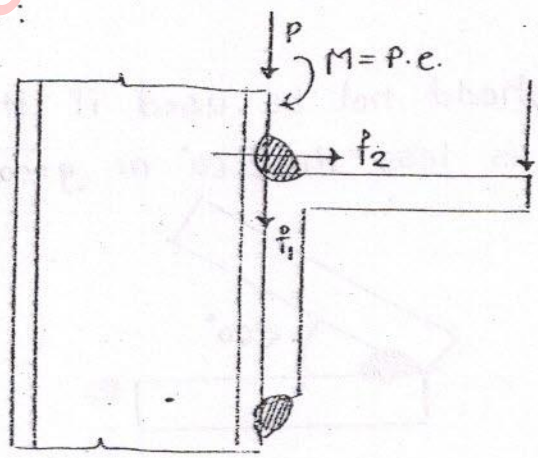
Fig. Fillet weld.

(i) The part of the weld which is assumed to be effective in transfering the stress is called 'Throat'.

(ii) Throat thickness (t_t) is minimum dimension in fillet weld.

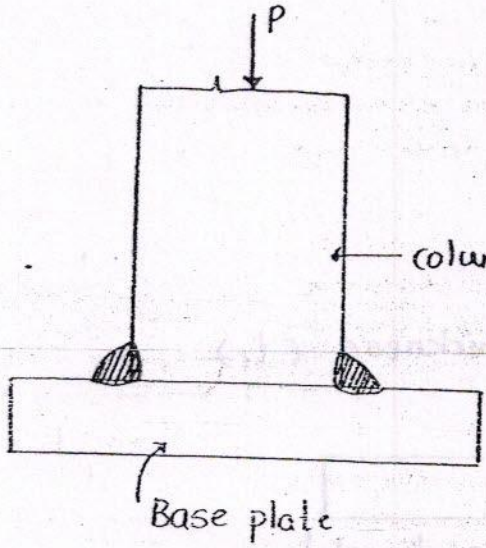
(iii) It is assumed that fillet weld always offers resistance in the form of shear.

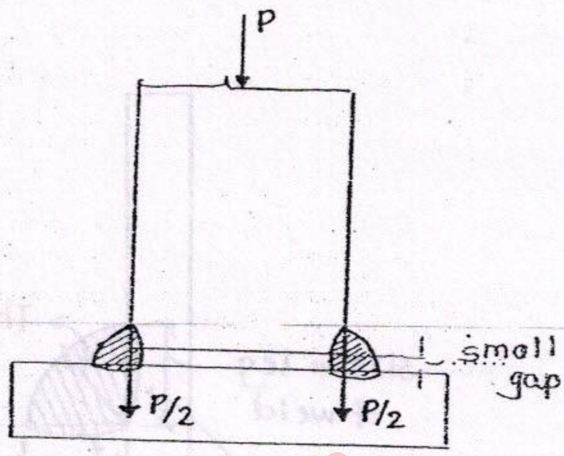
Example : 1 :



- Bending tensile stress is transfered as horizontal shear stress (f_2) and direct load is transfered as vertical shear stress (f_1) in weld.

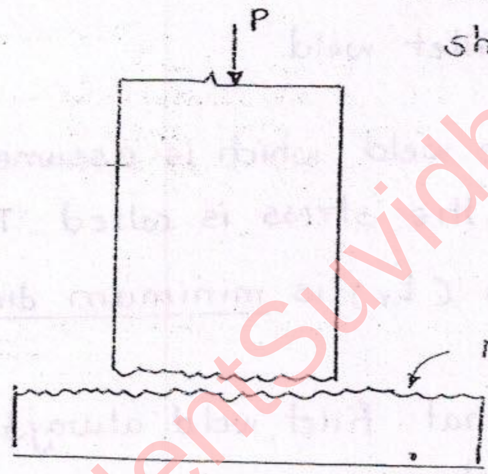
Example 2:





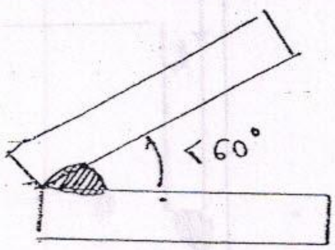
compressive force in column is transfered as vetical shear in weld

Ideal condition.



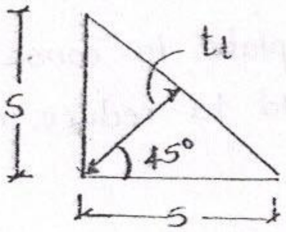
Actual condition

(iv) Filled weld should not be used if the angle between fusion faces is less than 60° or greater than 120°



(v) Throat thickness of weld (t_t) = k×size of weld

where k is the constant depending upon angle between fusion faces.



$t_t = s \cos 45°$

$= 0.707\, s$

$= 0.7\, s$

Angle between fusion faces	k
60 - 90°	0.70
91 - 100°	0.65
101 - 106°	0.66
107 - 113°	0.55
114 - 120°	0.50

Q. Two plates whose angle of inclination is 105° is welded by using 8 mm size fillet weld. Throat thickness is ___

$t_t = k \times size$

$= 0.6 \times 8$

$= 4.8$ mm

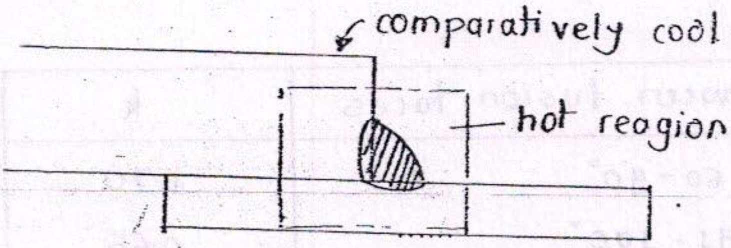
(vi) Minimum size of weld :

It depends on thickness of thicker plate being connected.

Thickness of thicker plate (mm)	Minimum size of weld (mm
upto 10	3
11 - 20	5
21 - 32	6
> 32	8

Note:

Thickness of thicker plate is considered while fixing minimum size of weld to reduce residual tensile stresses in welded.

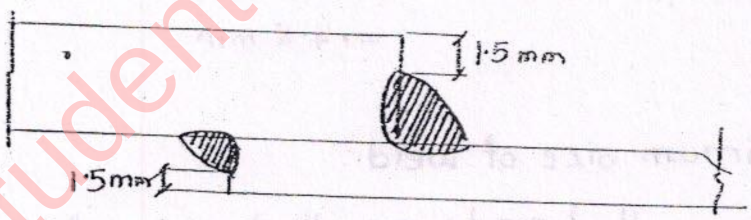


while cooling, the tensile stress will be developed in weld due to temperature difference between weld & thicker plate. (Becouse thicker plate has cold surface being larger and away from hot weld)

(vii) Maximum size of weld:

ⓐ For a square plate:

max. size = thickness of plate − 1.5 mm

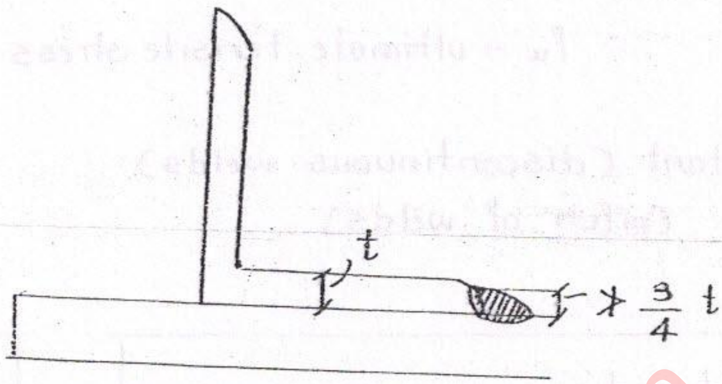


Note:

If we want to provide uniform size of weld everywhere, thickness of inner plate is considered while fixing max. size.

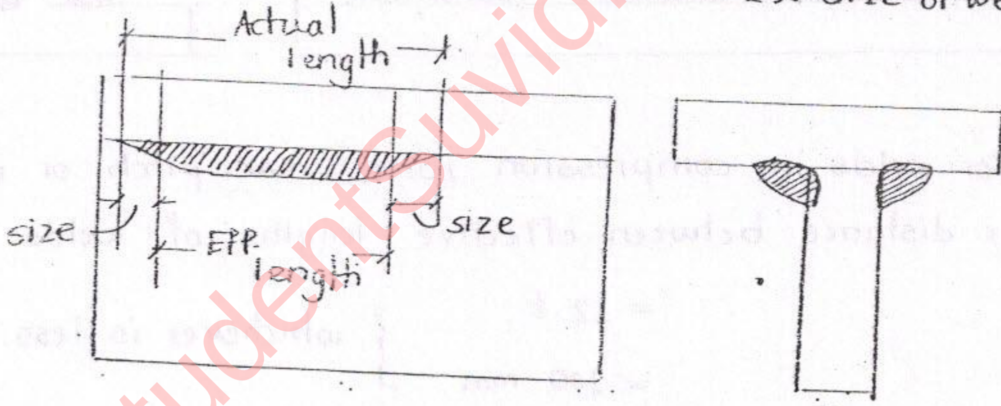
(b) At rounded edge.

Maximum size of weld $= \frac{3}{4} \times$ thickness of the element.



(viii) Effective length of weld:

Effective length = Actual length of weld − 2 × size of weld



(ix) Effective c/s area of weld

Eff. c/s area = Throat area

= eff length of weld × throat thickness

(x) Load carrying capacity of weld / shear strength of weld:

P = permissible shear stress in weld × effective area of weld

$P = f_s \times l_{eff} \times t_t$

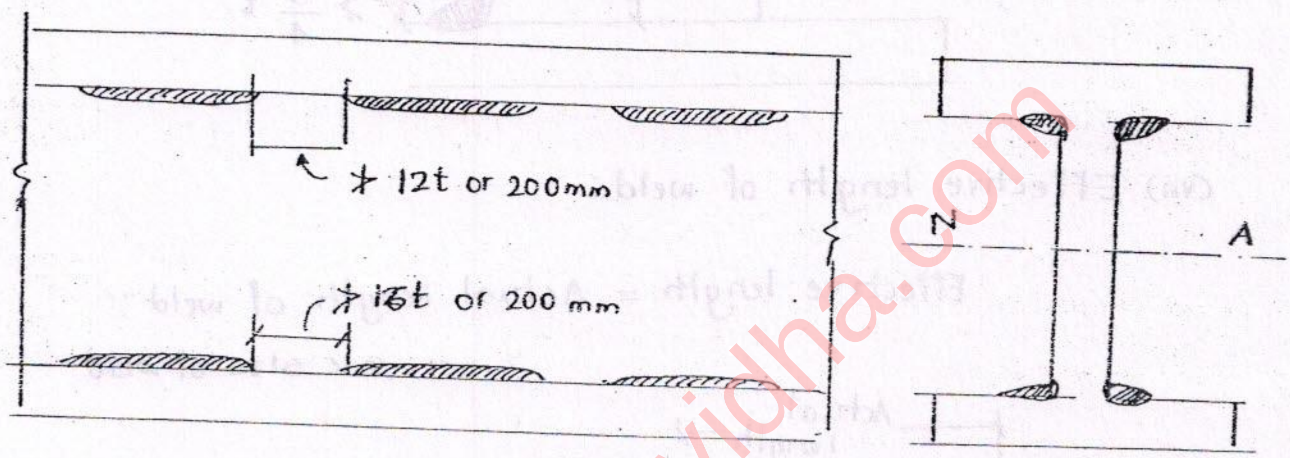
where,

f_s - 110 MPa (In WSM)

$$= \frac{f_u}{\sqrt{3} \times 1.25} \quad \text{(in LSM)}$$

f_u - ultimate tensile stress in weld metal.

(xi) Intermittant (discontinuous welds)
(pitch of welds)



ⓐ For welds in compression zone, max. pitch or max. clear distance between effective lengths of welds is

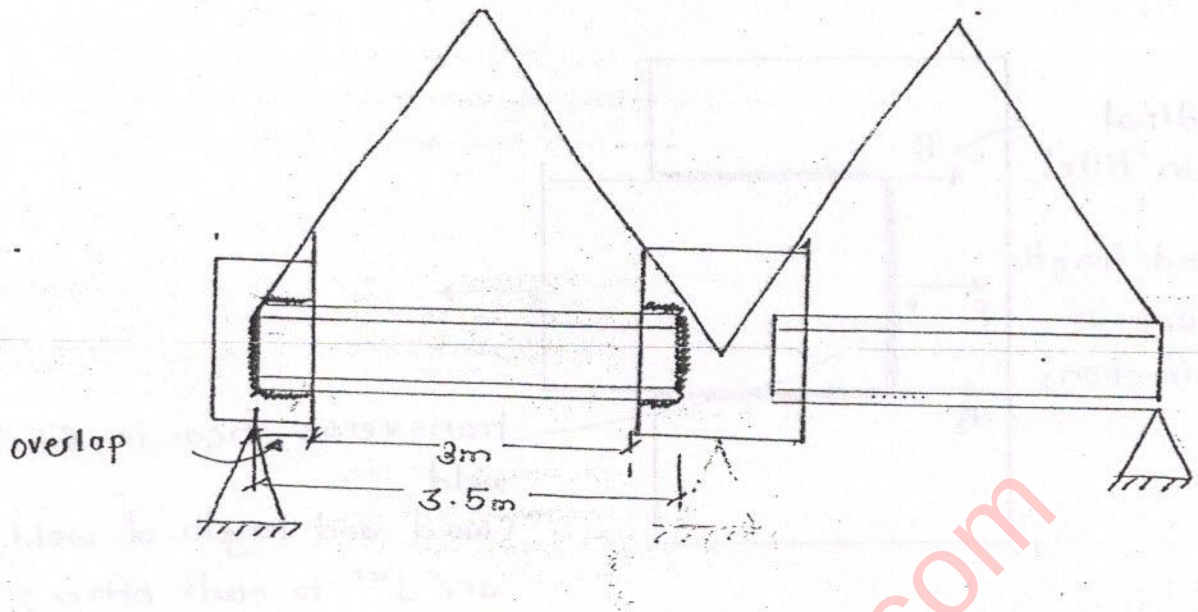
$$\left.\begin{aligned} &= 12\,t \\ &= 200 \text{ mm} \end{aligned}\right\} \text{whichever is less.}$$

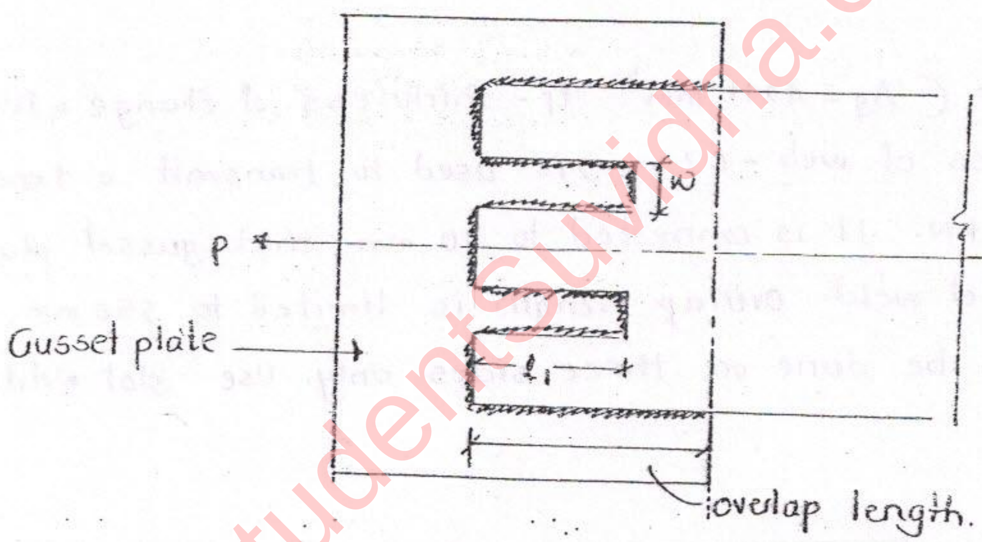
t - thickness of thinner plate.

ⓑ For welds in tension zone :

$$\left.\begin{aligned} \text{max. pitch} &= 16\,t \\ &= 200 \text{ mm} \end{aligned}\right\} \text{whichere is less.}$$

(xii) Slot welding :





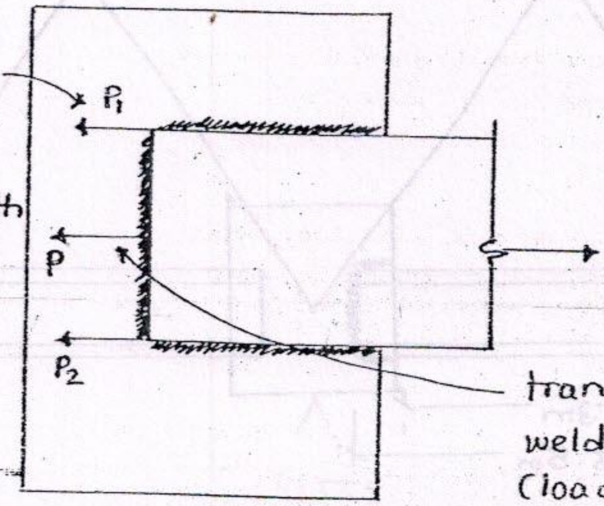
If overlap length is limited then slot welding is done by making slots in the connecting plate as shown in fig.

w - width of slot $\nless 3t$

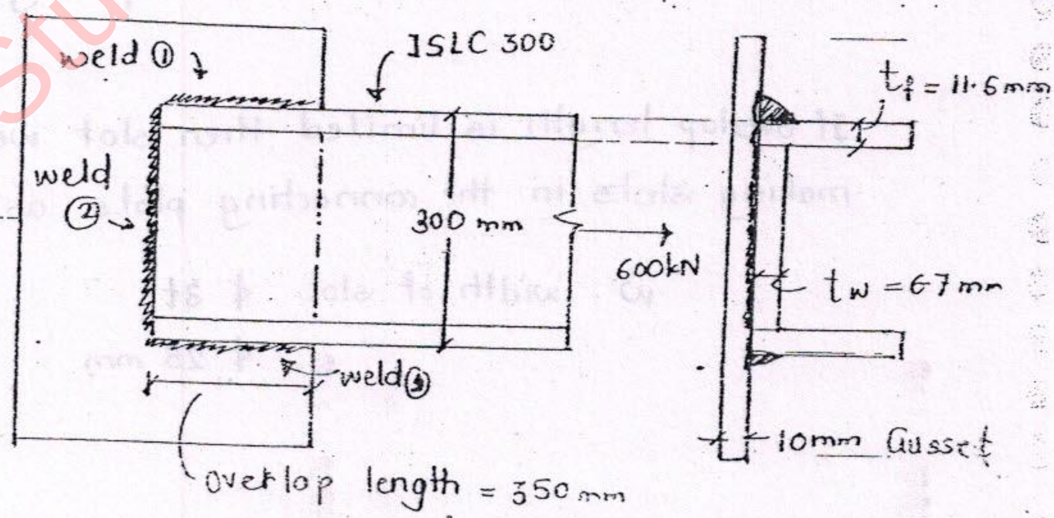
$\nless 25$ mm

(xiii) Longitudinal and transverse shear :

Saturday
12th October 2013



Q. As ISLC 300 (A_g = 4211 mm^3 t_f - thickness of flange = 11·6mm) tw - thickness of web - 6·7 mm) is used to transmit a tensile force of 600 kN. It is connected to 10 mm thick gussel plate. Design a fillet weld. Overlap length is limited to 350 mm. & welding can be done on three sides only. Use slot welding if required.



Note:

Design of a weld means fixing the size of weld and finding length of the weld.

(i) Size of the weld (S):

(a) At weld ① (connecting 10 mm gussel and 11.5 mm flange

Minimum size - (based on thickness of thicker plate - 11.6 mm thick)

= 5m $\because t > 10$ mm

Maximum size = (Thickness of thiner plate) -1.5

$= 10 - 1.5$

$= 8.5$ mm

(b) At weld ②. (connecting 10 mm gussel and 6.7 mm web.

Minimum size -- for thicker plate of 10 mm

= 3mm $\because$ (upto 10mm - 3m, 11-20 mm - 5m

Maximum size $= 6.7 - 1.5$

$= 5.2$ mm

Provide uniform size of weld of 5mm at all weld locations.

(ii) Length of weld:

Shear strength of weld = applied load = $f_s \times l_{eff} \times t_t$

$\therefore \; 600 \times 10^3 = 108 \times l_{eff} \times (0.7 \times 5)$

$l_{eff} = 1587.5$ mm

Weld length that can be accomodated in channel

$= 350 + 350 + 300$

$= 1000$ mm

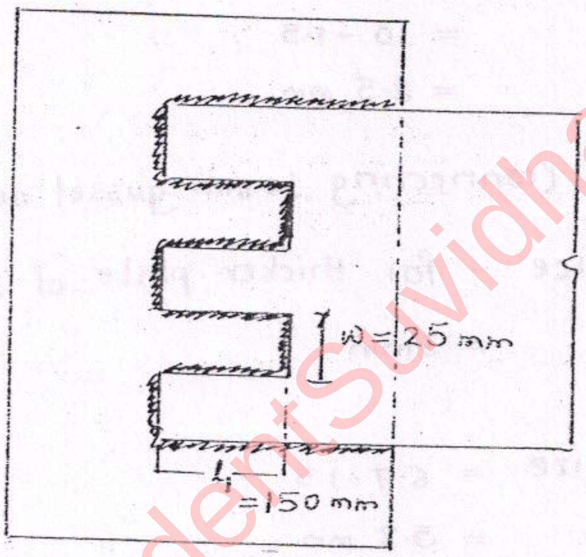
For the remaining length, i.e. $1587.5 - 1000 = 587.5$ mm provide slot welding.

Provide two slots, symmetrical to centreline of channel section.

$\therefore$ length of slot $= l_1 = \frac{587.5}{4} = 146.8$ mm ≈ 150 mm

$\therefore$ Width of slot $\nless 3t = 3 \times 6.7 = 20.1$ mm
$\nless 25$ mm

provide width of 25 mm.



Q. In the above problem is factored tensile load is 900 kN and ultimate tensile stress in weld metal is 410 MPa. Find the length of weld required.

$$P_u = f_s \times l_{eff} \times (t_t)$$

$$f_s = \frac{f_u}{\sqrt{3} \cdot 1.25} = \frac{410}{\sqrt{3} \times 1.25} = 189.67 \text{ mm}$$

$$\therefore \quad 900 \times 10^3 = 189.67 \times l_{eff} (0.7 \times 5)$$

$$l_{eff} = 1357.8 \text{ mm}$$

Note:

(i) Channel section is symmetrical about x-x axis so line of action of load and and C.G. of weld group lie on same line. So no moments are developed therefore is called as moment free connection.

(ii) If angle section are connected to gusset plate we have to ensure that moments are not developed in welded joints. The lengths of welds are so adjusted that it should be a moment free connection.

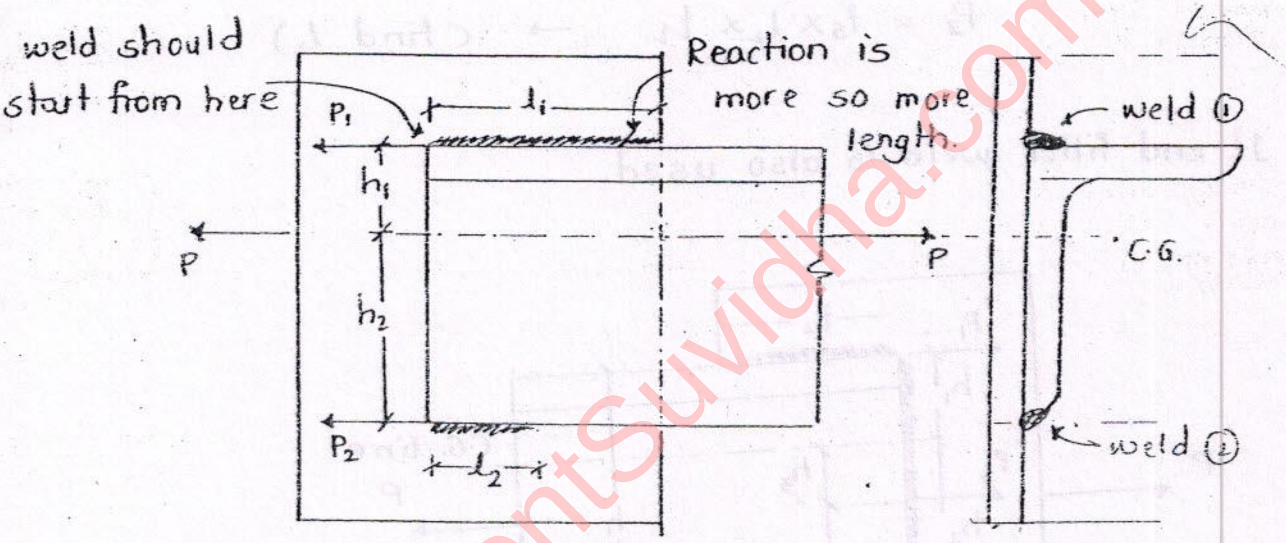


Fig. welded connection in angle sections

If a load is nearer to support the reaction at that suppo[r]t is maximum. In this case load is nearer to weld ①. so the reaction at weld ① is more.

Analysis:

(To find forces P_1 and P_2)

No. of unknowns = 2.

∴ We require 2 equations.

$$\Sigma Fx = 0.$$

$\rightarrow$ +ve
$\leftarrow$ -ve

$$-P_1 - P_2 + P = 0$$

$$P_1 + P_2 = P \quad \text{---- (i)}$$

Σ Mo C.G. = 0

$$-P_1 \times h_1 + P_2 \cdot h_2 = 0 \qquad \curvearrowright +ve \quad \curvearrowleft -ve$$

$$P_2 = \frac{P_1 \cdot h_1}{h_2} \qquad \text{---- (ii)}$$

from ---- (i) and ---- (ii)

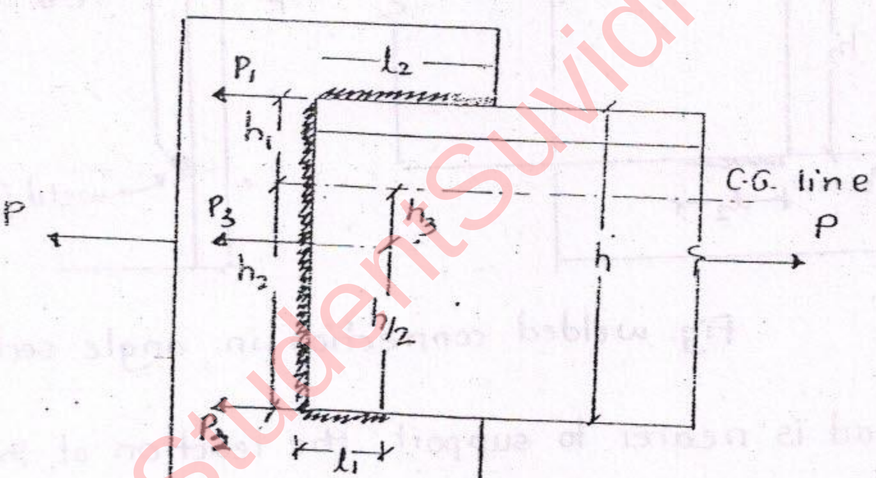
find forces P_1 and P_2

Design: (finding lengths l_1 and l_2)

$$\because \quad P_1 = f_s \times l_1 \times t_t \rightarrow (\text{find } l_1)$$

$$P_2 = f_s \times l_2 \times t_t \rightarrow (\text{find } l_2)$$

If end fillet weld is also used.



Analysis:

$\Sigma X = 0$

$$-P_1 - P_2 - P_3 = P$$

$$P_1 + P_2 + P_3 = P \qquad \text{---- (i)}$$

$\because$ P_3 is not unknown

$$P_3 = f_s \times h \times t_t$$

$\Sigma M = 0$

$$-P_1 \times h_1 + P_2 \cdot h_2 + P_3 \cdot h_3 = 0 \qquad \text{---- (ii)}$$

from —— (i) & —— (ii) find P_1 and P_2

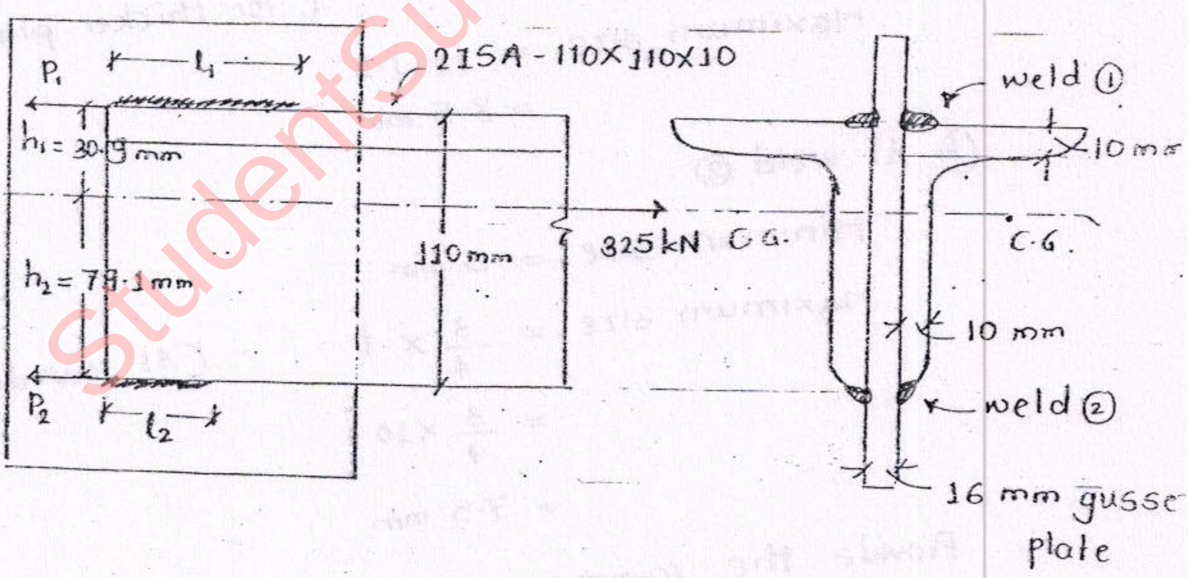
Design: (finding l_1 and l_2)

$$P_1 = f_s \times l_1 \times t_t \rightarrow \text{find } l_1$$
$$P_2 = f_s \times l_2 \times t_t \rightarrow \text{find } l_2$$

When compar with previou l_1 & l_2 thes. values are less b $h/2$.

It means that, as long as total length of weld is same the orientation of weld does not matter.

Q. In a shed a member consisting 2 ISA 110 × 110 × 10 is connected to a 16 mm gusset plate to resist a tensile force of 650 kN. Design a moment free connection. Distance between C.G. of angle and heel = $C_{xx} = C_{yy}$ = 30.9 mm. f_s = 76 MPa (in we



(i) Since overlap length is unlimited (not mentioned) avoid end fillet to reduce unnecessary calculations.

(ii) The applied load 650 kN is shared by 2 angles. So the load taken by each angle is P = 325 kN.

Analysis : (finding P_1 and P_2)

$\Sigma X = 0.$

$$-P_1 - P_2 = P$$

$$P_1 + P_2 = P$$

$$P_1 + P_2 = 325 \text{ kN} \quad \text{——— (i)}$$

ΣM_{O} C.G. $= 0$

$$-P_1 \times 30.9 + P_2 \times 79.1 = 0$$

$$P_2 = \frac{30.9 \times P_1}{79.1} \quad \text{——— (ii)}$$

from —(i) & —(ii)

$$P_1 = 233.7 \text{ kN}$$

$$P_2 = 91.3 \text{ kN}$$

Design : (size of weld)

(a) At weld ①,

Minimum size = 5mm (for thicker plate 16mm)

Maximum size = 10 − 1.5

= 8.5 mm

(b) At weld ②

Minimum size = 5 mm

Maximum size $= \frac{3}{4} \times t$ — (At rounded edge)*

$= \frac{3}{4} \times 10$

= 7.5 mm

Provide the minimum size of weld as 5 mm.

Note: As far as possible select minimum size of weld, so that for a given force, volume of a belt metal (wel required will be less.

length of weld:

$$P_1 = f_{s_1} \times l_1 \times t_t$$

$$233.7 \times 10^3 = 76 \times l_1 \times (0.7 \times 5)$$

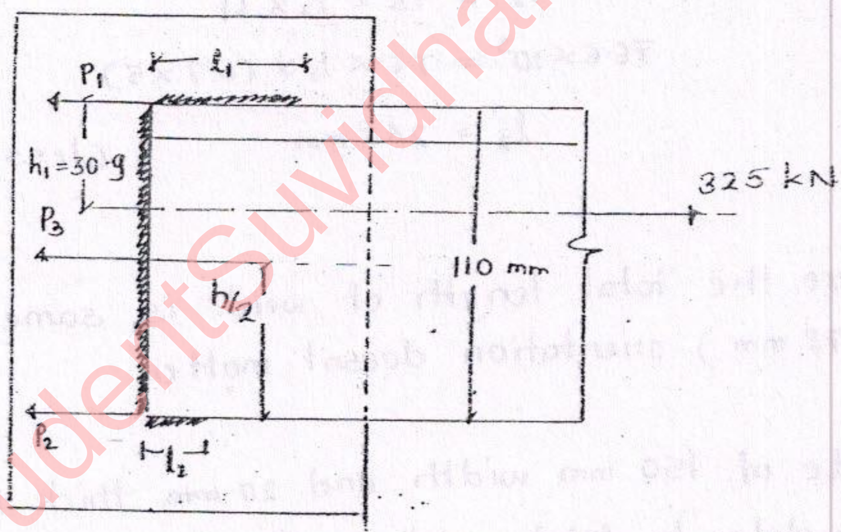
$$l_1 = 87.8 \text{ mm}$$

$$P_2 = f_{s_2} \times l_2 \times t_t$$

$$91.5 \times 10^3 = 76 \times l_2 \times (0.7 \times 5)$$

$$l_2 = 343 \text{ mm}$$

In above problem, if end fillet weld is also used, then the design of moment free connection is done as follow:



Analysis:

$$\Sigma F_x = 0$$

$$-P_1 - P_3 - P_2 = 325$$

$$P_1 + P_2 + P_3 = 325$$

$$P_3 = f_s \times l_3 \times t_t$$

$$= 76 \times 110 \times (0.7 \times 5)$$

$$= 29.26 \text{ kN}$$

$$P_1 + P_2 = (325 - 29.26) \qquad \text{—— (1)}$$

$\Sigma M_o\ C.G. = 0$

$$-P_1 \times 30.9 + 29.26 \times (79.1 - 55) + P_2 \times 79.1 = 0 \quad \text{——— (ii)}$$

from ——— (i) and ——— (ii)

$$P_1 = 219.1 \text{ kN}$$

$$P_2 = 76.6 \text{ kN}$$

Design:

$$P_1 = f_s \times l_1 \times t_t$$

$$219 \times 10^3 = 76 \times l_1 \times (0.7 \times 5)$$

$$l_1 = 823 \text{ mm}$$ (less by 55 mm than 878 mm)

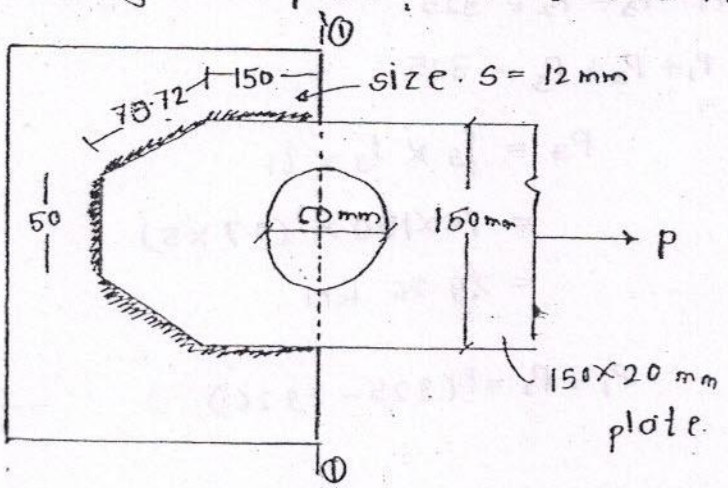
$$P_2 = f_s \times l_2 \times t_t$$

$$76.6 \times 10^3 = 76 \times l_2 \times (0.7 \times 5)$$

$$l_2 = 288 \text{ mm}$$ (less by 55 mm than 343 mm)

Here, the total length of weld is same in both case (i.e. 878 mm) orientation doesn't matter.

Q. A plate of 150 mm width and 20 mm thick is welded to another plate by fillet weld as shown in fig. The size of weld is 12 mm. Find the average shear stress produced in weld for full strength of plate? If $f_t = 150$ MPa.



Criticall section for plate is at section ①-①

$$P_t = (B-d) \cdot t \cdot f_t$$

$$= (150-60) \times 20 \times 150$$ dia. of hole

$$= 270 \text{ kN}$$

$\therefore$ $$P_t = f_s \times l_{eff} \cdot t_t$$

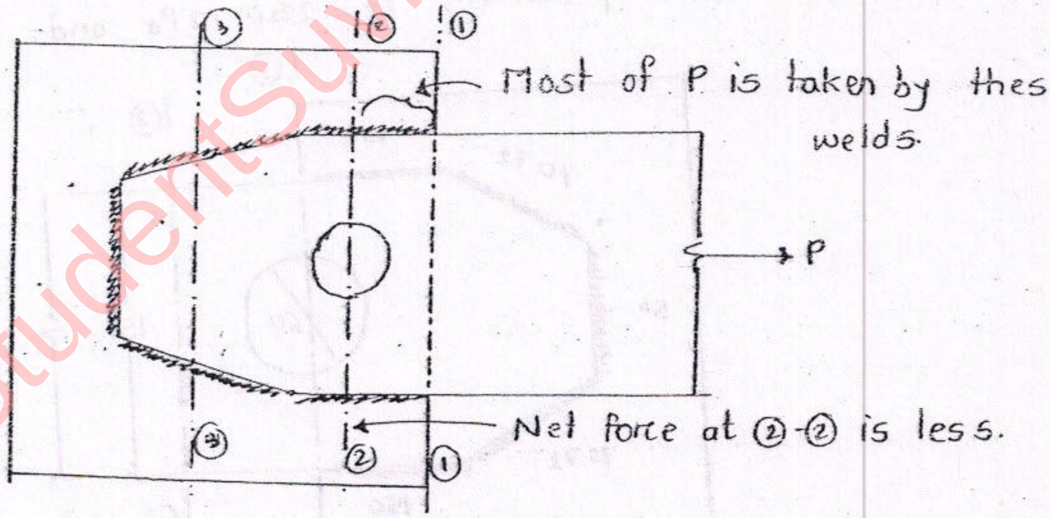
$$270 \times 10^3 = f_s \times (150 + 70.72 + 50 + 70.72 + 150) \times (0.7 \times 12)$$

$$f_s = 65.4 \text{ MPa.}$$

$\therefore$ Average shear stress in weld = 65.4 MPa.

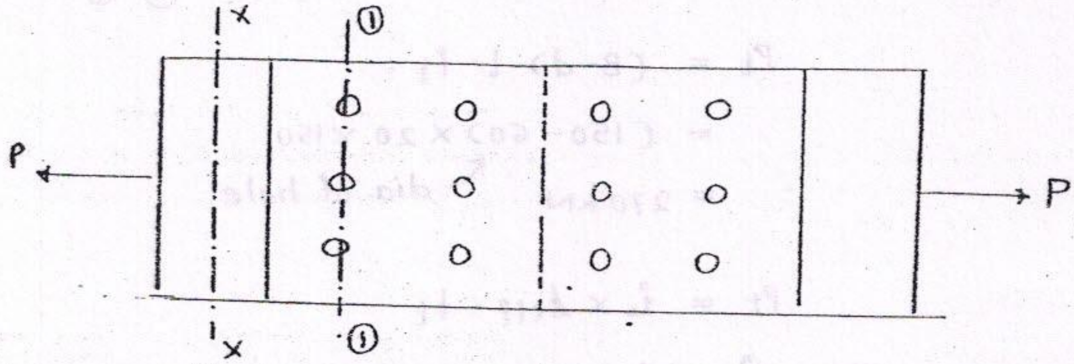
Note:

(i) If the hole is made in the plate within welded zone then dia is not deducted to find P_t.



In the above diagram critical section for main plate is at ①-① but not at ②-② or ③-③ because tensile force in the plate at ②-② or ③-③ will be very less. Because most of the tension in the plate is taken by the welds before the section ②-②

(ii) In Limit state method:

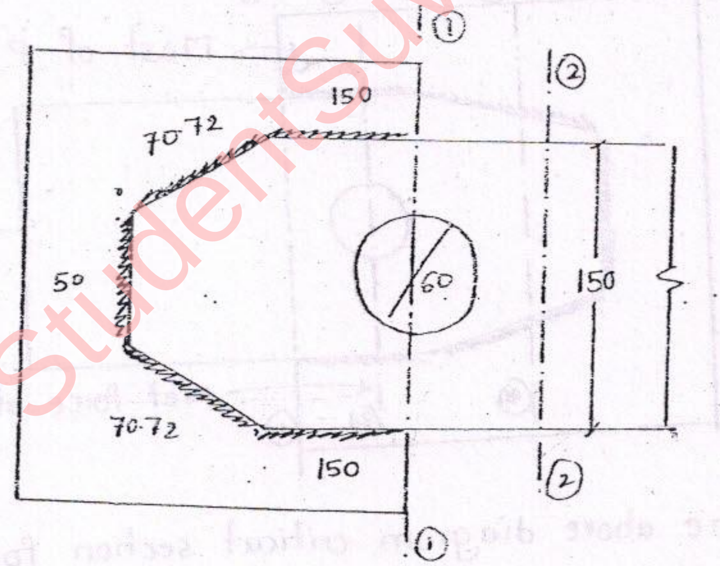


$$(P_t)_{x-x} = A_g \times \frac{f_y}{1.1} \quad \text{(when yielding of plate is considered)}$$

$$(P_t)_{①-①} = A_{net} \times \left[\frac{0.9 \cdot f_u}{\sqrt{3} \cdot 1.25}\right] \quad \text{(when } f_u \text{ is considered ior. rupture of plate considered)}$$

The smaller of the above two values is taken as Tensile strength of plate.

(iii) If for earlier problem, $f_y = 250$ MPa and $f_u = 410$ MPa.



P_{T_1} - tensile strength of plate at ① - ①

(at ① - ① plate will crack because of A_{net})

$$P_{T_1} = A_{net} \times \left[\frac{0.9\ f_u}{1.25}\right]$$

$$= (B - d) \times t \times \left[\frac{0.9 \times f_u}{1.25}\right]$$

$$= (150-60)\times 20\left[\frac{0.9\times 410}{1.25}\right]$$

$$= 531.3 \text{ kN}$$

P_T - tensile strength of plate at ②-②

(at ②-② plate will yield due to f_y)

$$\therefore \quad P_{T_1} = A_g \times \frac{f_y}{1.1}$$

$$= (150\times 20)\times \frac{250}{1.1}$$

$$= 681 \text{ kN}$$

So, before plate yields, it cracks at ①-①.

$\therefore$ Tensile strength of plate $= P_T = 531.3$ kN.

$$\therefore \quad P_t = f_s \times l_{eff} \times t_t$$

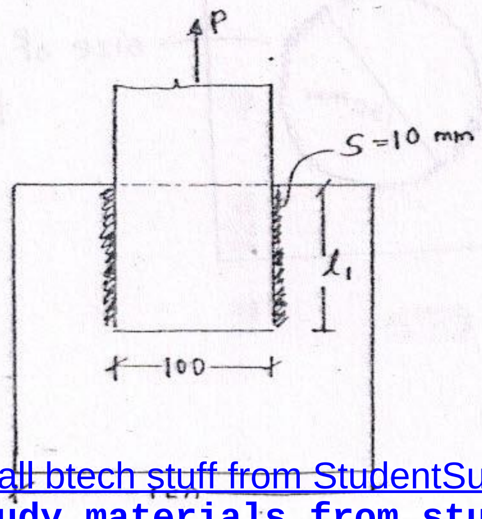
$$531.3\times 10^3 = f_s \times (350 + 2\times 70.72)\times(0.7\times 12)$$

$$f_s = 128.7 \text{ N/mm}^2$$

- Calculated avg. shear stress in plate $= 128.7$ N/mm²

Q. Two plates are connected by fillet weld of size 10 mm and subjected to tension. The thickness of each plate is 12 mm $f_y = 250$ MPa. $f_u = 410$ MPa. $\gamma_m = 1.25$. Use L.S.M. Minimum length of each weld to transmit the force P.

2 Marks



Since there are no holes in the plate, yielding will govern the strength of plate.

$$P_t = A_g \times \frac{f_y}{1.1}$$

$$= (100 \times 12) \times \frac{250}{1.1}$$

$$= 272.73 \text{ kN}$$

$$P_t = f_s \cdot l_{eff} \cdot t_t$$

$$272.73 \times 10^3 = \left[\frac{410}{\sqrt{3} \times 1.25}\right] \times l_{eff} \times (0.7 \times 10)$$

$$l_{eff} = 205.7 \text{ mm} \qquad f_s = \frac{f_u}{\sqrt{3} \times 1.25} \text{ Always}$$

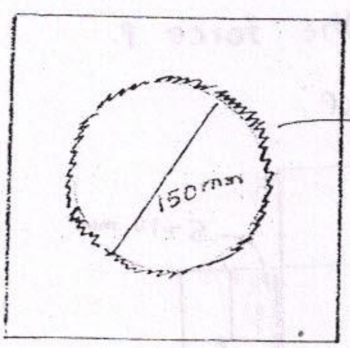
So, length of weld on each side $= \frac{205.7}{2} = 102.8$ mm

$$\frac{f_y}{1.1} = \frac{250}{1.1} = 227 \text{ N/mm}^2$$

$$\frac{0.9 f_u}{1.25} = \frac{0.9 \times 410}{1.25} = 295 \text{ N/mm}^2 \leftarrow \text{More, Thus yielding governs.}$$

Q. A circular shaft of dia. 150 mm is welded to rigid plate by an external all round fillet weld of size 10 mm. If a torque of 10 kN/m is applied to shaft. Find max. shear stress developed in weld.

Marks



size of weld = 10 mm

$t = 0.7 \times 10$

$= 7$ mm

Note:

(i) Torque is the twisting moment - Couse

Torsion is the twist generated - Effect.

(ii) Torsion formula.

$$\frac{T}{J} = \frac{f_s}{r} = \frac{C \cdot \theta}{l}.$$

where. f_s - shear stress.

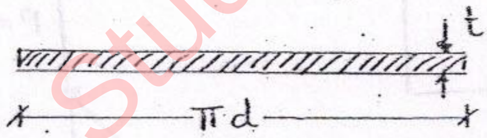
$$= \frac{T}{J} \times r$$

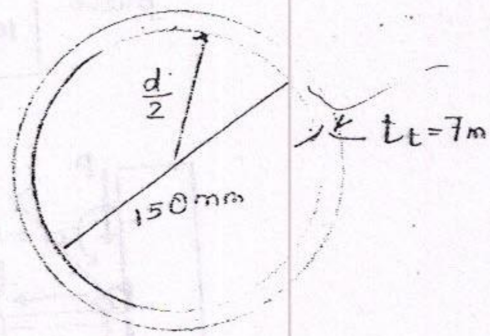
$$= \frac{T}{Z_P}$$

where. Z_P - polar modulus (also called torsional strength parameter)

$Z_P = \frac{J}{r}$ (weld area is treated as line area. It means t^2, t^3 terms ar neglected in calculations)

$T = 10 \text{ kNm} = 10 \times 10^6 \text{ Nmm}$





$A = \pi \cdot d \cdot t.$

$\therefore J = A r^2 = I_{zz}$

$= \pi \cdot d \cdot t \cdot \left(\frac{d}{2}\right)^2$

$= \frac{\pi d^3 . t}{4}$

Eff. c/s area of weld not shaft

$Z_P = \frac{J}{r} = \frac{\pi d^3 t}{4 \times \left(\frac{d}{2}\right)}$

$= \frac{\pi \cdot d^2 \cdot t}{2}$

$$\therefore\ f_s = \frac{T}{Z_P}$$

$$= \frac{10\times10^6}{\frac{\pi d^2 t}{2}}$$

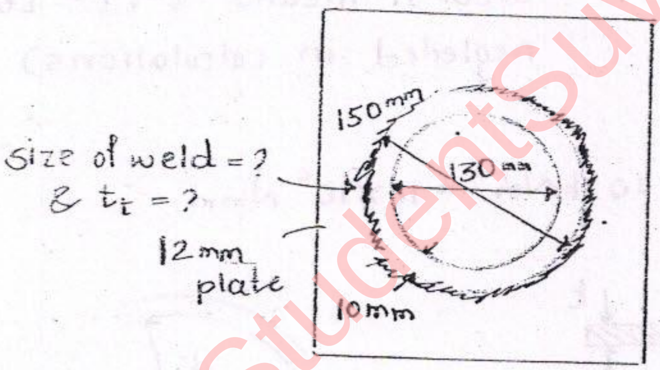
$$= \frac{10\times10^6}{\frac{\pi\times150^2\times7}{2}}$$

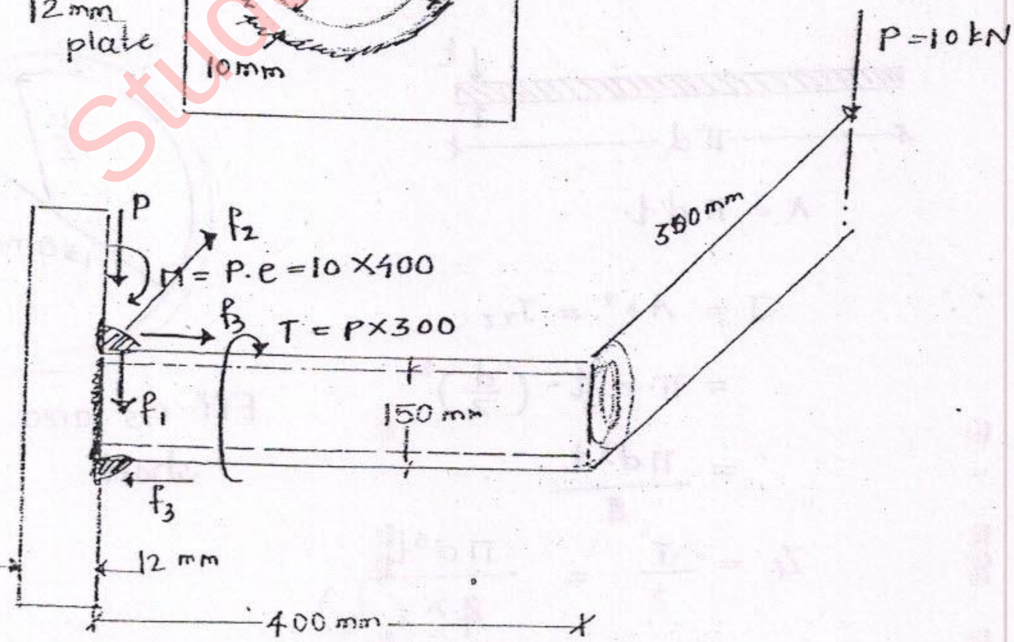
$$(f_s)_{max.} = 40.44\ N/mm^2$$

......

Q. A circular steel pipe of 150 mm dia and 10 mm thick. is welded to a rectangular plate of 12 mm thick by fillet weld. around the pipe. A vertical load of 10 kN is acting on the pipe at a distance of 400 mm from the weld. in the longitudinal direction and 300 mm from the centre of pipe. transvusly. Design the weld. (Means to find size of welds)

0 Marks





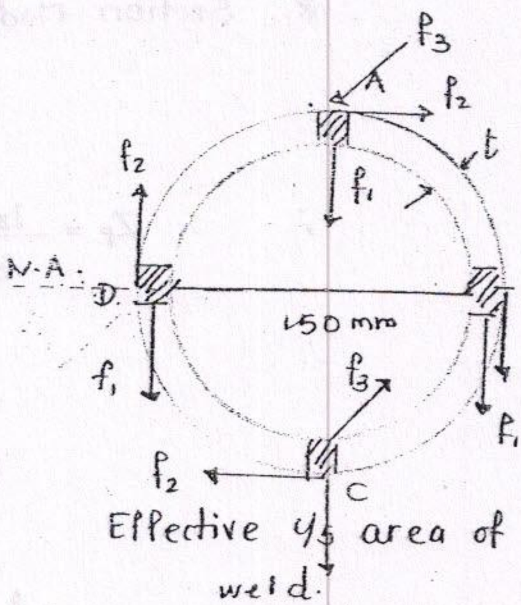
(i) The effect of eccentric load P at the weld location is a direct force, P, twisting moment T. (= P×300 kNmm) and a bending moment M (P×400 kNmm)

(ii) Due to direct force P, vertical shear stress f_1 is developed in the weld. Due to twisting moment the horizontal shear stress F_2 is developed in weld.
Due to B.M., bending tensile stress is developed. This bending tensile stress converted to horizontal shear stress F_3. Since these three stresses are shear stress we can calculate Resultant shear stress F_r:

$$f_r = \sqrt{f_1^2 + f_2^2 + f_3^2}$$

This resultant shear stress should not exceed max. shear stress permissible value of shear stress.

Analysis:



Effective 1/5 area of weld.

(i) f_1 - vertical shear stress in weld due to load 'P'.

$$f_1 = \frac{P}{\text{Area of weld}}$$

$$= \frac{10\times10^3}{\pi\, d\cdot t} = \frac{10\times10^3}{\pi\times150\times t}$$

$$f_1 = \frac{21.22}{t} \quad N/mm^2$$

(ii) f_2 - horizontal shear stress in weld due to twisting moment (T)

$$f_2 = \frac{T}{Z_p}$$

$$Z_p = \frac{\pi d^2 \cdot t}{2} \quad \text{- (Because of line area)}$$

$$T = P \times 300 \text{ kN mm}$$

$$= 10 \times 10^3 \times 300$$

$$= 300 \times 10^4$$

$$f_2 = \frac{300 \times 10^4 \text{ N·mm}}{\left(\frac{\pi \times 150^2 \times t}{2}\right)}$$

$$= \frac{84.88}{t} \text{ N/mm}^2$$

The locations of f_1 and f_2 are shown in fig. at A,B,C,D.

(iii) f_3 - horizontal shear stress in weld due to B.M. M

= Bending tensile stress in weld.

$$f_3 = \frac{M}{Z}$$

$\therefore$ $M = P \times 400 = 10 \times 10^3 \times 400$ Nmm

$\therefore$ * Section Modulus, $Z = \frac{Z_P}{2} = \left(\frac{\pi d^2 t}{2}\right) \times \frac{1}{2}$

$$= \frac{\pi d^2 t}{4}$$

$\therefore$ $Z_P = \frac{I_{zz}}{r} = \frac{(I_{xx} + I_{yy})}{r} = 2\frac{I_{xx}}{r}$

$\therefore$ $Z_P = 2\left(\frac{I_{xx}}{r}\right)$

$\therefore$ $Z_P = 2Z$ $\quad \because Z = \frac{I_{xx}}{r}$

$\therefore$ $$f_3 = \frac{10 \times 10^3 \times 400}{\left(\frac{\pi \times 150^2 \times t}{4}\right)}$$

$$f_3 = \frac{226.35}{t} \text{ N/mm}^2$$

f_3 is zero at locations B and D. and from F.B.D we find that shear stress is maximum at A and C.

Max. shear stress at A

$$f_R = \sqrt{f_1^2 + f_2^2 + f_3^2} \not> f_s \text{ i.e. } 110$$

$$= \sqrt{\left(\frac{21.22}{t}\right)^2 + \left(\frac{84.88}{t}\right)^2 + \left(\frac{226.85}{t}\right)^2}$$

$$= 110 \text{ MPa.}$$

$$t = 2.21 \text{ mm}$$

$\therefore$ Size of weld $= \frac{t}{0.7} = \frac{2.21}{0.7} = 3.16$ mm

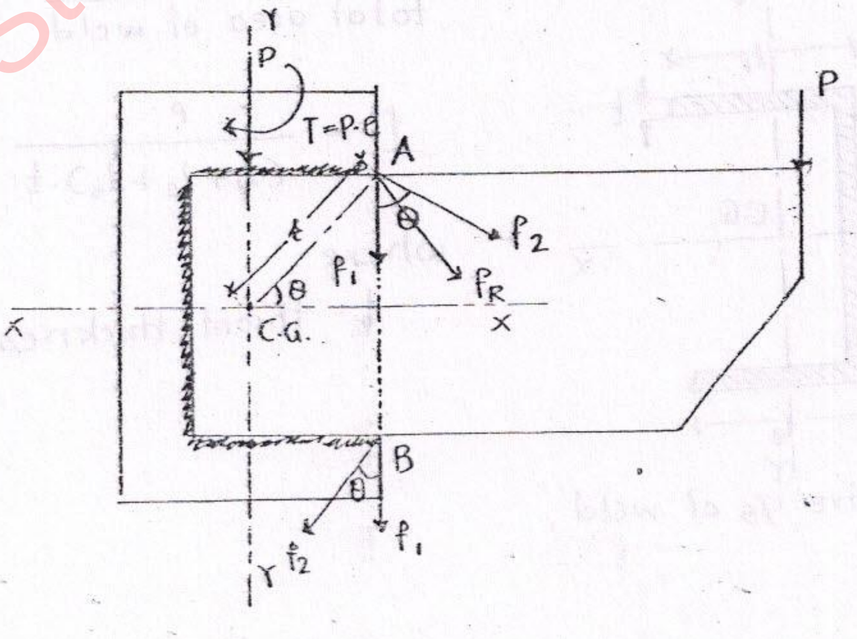
But minimum size of weld for a thicker plate (i.e. 12 mm) is 5 mm.

$\therefore$ So provide size of weld as 5 mm.

Sunday
13th October 2013

Eccentrically welded connections:

(I) In plane eccentric connection:



(i) The effect of eccentric load at the C.G. of weld group will be a direct load P and twisting moment ($T = P \cdot e$) where e is measured from C.G. of weld group.

(ii) Due to direct load P, direct shear stress f_1 is developed at A. Due to twisting moment torsional shear stress f_2 is developed at A. Since these two stresses are shear stresses, we can find resultant shear stress f_R.

$$f_R = \sqrt{f_1^2 + f_2^2 + 2 f_1 \cdot f_2 \cdot \cos\theta}$$

$$f_R \ngtr f_s = 110 \text{ MPa.} \quad \text{(in WSM)}$$

or

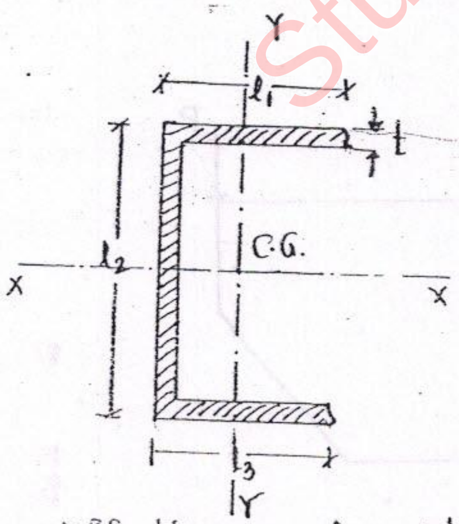
$$f_s = \frac{f_u}{\sqrt{3} \times 1.25} \quad \text{(in LSM)}$$

(iii) Torsion formula is applicable to circular shafts only. In this case, weld area is in the shape of 'C' but we assume that it is a circular shape and apply torsion formula. It is only an approximation.

Analysis:

(i) Direct shear stress in the weld at A due to P.

$$f_1 = \frac{P}{\text{total area of weld}}$$



Effective c/s of weld

$$f_1 = \frac{P}{(l_1 + l_2 + l_3) \cdot t}$$

where

t - throat thickness.

(ii) Torsional shear stress at A

$$f_2 = \frac{T}{J} \times r_A$$

where,

J - polar moment of inertia.

$J = J_{xx} + J_{yy}$ (from $\perp^{ar}$ axis theorem)

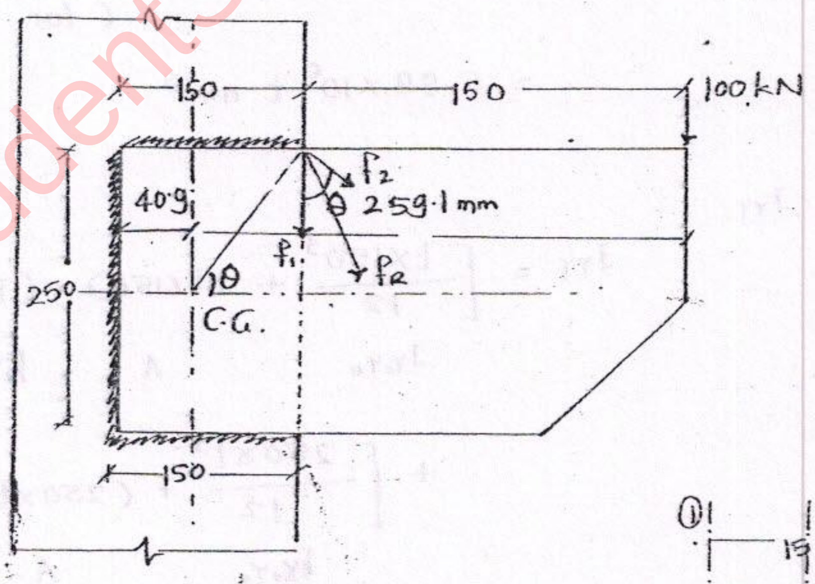
r_A - radial distance of 'A' from C.G. of weld group.

(iii) Resultant shear stress:

$$f_R = \sqrt{f_1^2 + f_2^2 + 2 f_1 f_2 \cdot \cos\theta}$$

$$f_R \leq f_s$$

Q. A bracket is connected to column flange as shown in fig. Find the size of the weld if allowable shear stress in the weld is 110 MPa.

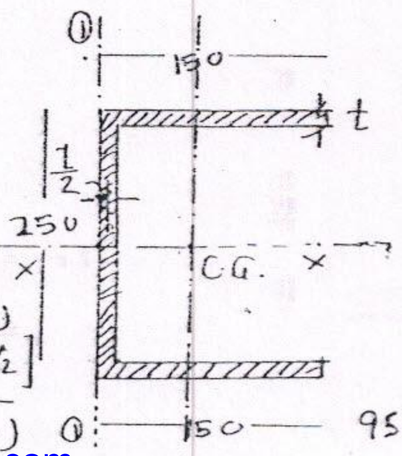


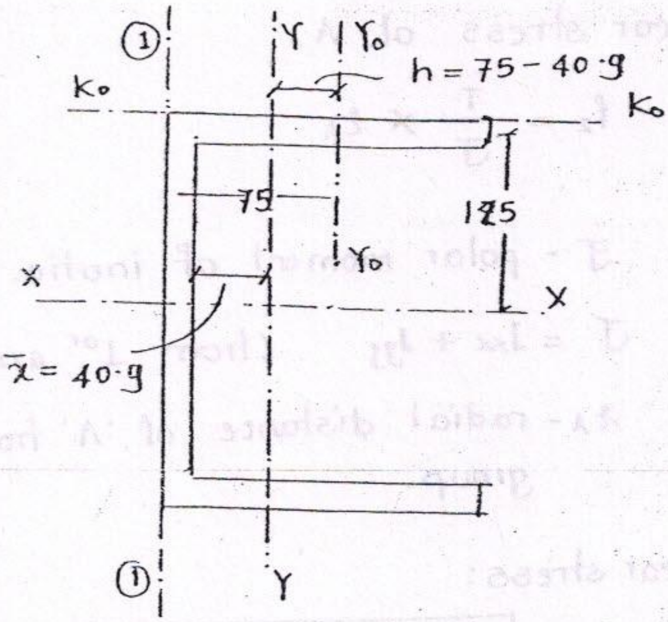
(a) Find C.G. of weld area:

$$A\bar{x} = a_1 x_1 + a_2 x_2$$

$t^2 \approx 0$

$$\bar{x} = \frac{[((150 \times t) \times 75)] \times 2 + [(250 \times t) \times t/2]}{(150 \times t) \times 2 + (250 \times t)}$$





(It is taken as line area)

$\bar{x} = 40.9$ mm.

(b) I_{xx}.

$$I_{xx} = \Big[\underbrace{\frac{150 \times t^3}{12}}_{I_{k_0 \cdot k_0}} + \underbrace{(150 \times t)}_{A} \times \underbrace{125^2}_{h^2}\Big] \times 2 \quad \text{(for horizontal rectangle)}$$

$$+ \left[\frac{t \times 250^3}{12}\right] \quad \text{(for vertical rectangle)}$$

$$= 5.99 \times 10^6 \, t \ \text{mm}^4$$

(c) I_{YY}.

$$I_{YY} = \Big[\underbrace{\frac{t \times 150^3}{12}}_{I_{Y_0 Y_0}} + \underbrace{(t \times 150)}_{A} \times \underbrace{(75 - 40.9)^2}_{h^2}\Big] \times 2$$

$$+ \Big[\underbrace{\frac{250 \times t^3}{12}}_{I_{Y_0 Y_0}} + \underbrace{(250 \times t)}_{A} \times \underbrace{40.9^2}_{h^2}\Big]$$

$$= 1.329 \times 10^6 \, t \ \text{mm}^4$$

$$I_{zz} = I_{xx} + I_{YY}$$

$$= 7.319 \times 10^6 \cdot t \ \text{mm}^4.$$

Analysis :

(i) Direct shear stress at A due to P.

$$f_1 = \frac{P}{A}$$

$$= \frac{100 \times 10^3 \text{ N}}{(150 + 250 + 150) \times t}$$

$$= \frac{181.8}{t} \text{ N/mm}^2$$

(ii) Torsional shear stress at A due to P.

$$f_2 = \frac{T}{J} \times r_A$$

$$\because \quad T = P \cdot e$$

$$= 100 \times 10^3 \times 259.1$$

$$r_A = \sqrt{(109.1)^2 + (125)^2}$$

$$= 165.9 \text{ mm}$$

$$\therefore \quad f_2 = \frac{100 \times 10^3 \times 259.1}{7.319 \times 10^6 \cdot t} \times 165.9$$

$$= \frac{587.43}{t} \text{ N/mm}^2$$

(iii) Resultant shear stress :

$$\tan\theta = \frac{125}{109.1}$$

$$\theta = 48.9^\circ$$

$$\therefore \quad f_R = \sqrt{\left(\frac{181.8}{t}\right)^2 + \left(\frac{587.43}{t}\right)^2} \quad \leq 150 \text{ MPa}$$

$$150 = \left(\frac{181.8}{t}\right)^2 + \left(\frac{587.43}{t}\right)^2$$

$$t = 6.54 \text{ mm}$$

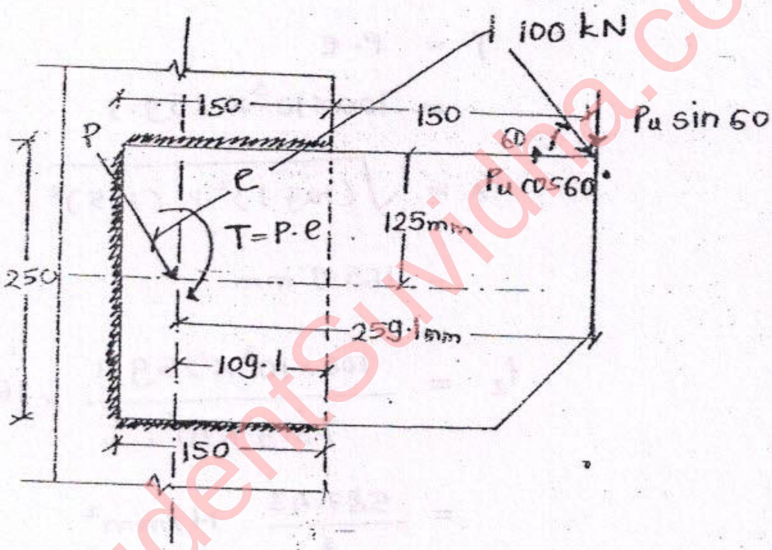
$\therefore$ Size of the weld $s = \dfrac{t}{0.7}$

$$= \frac{6.54}{0.7}$$

$$= 9.32 \simeq 10 \text{ mm}$$

$\therefore$ Provide size of weld $(s) = 10$ mm

Q. A bracket connection is subjected to a factored load of 100 kN as shown in fig. If ultimate tensile stress in the weld metal is 410 MPa, Design the weld. Use Limit state method.



ⓐ C.G. of the weld area :

$$\bar{x} = 40.9 \text{ mm}$$

$$I_{zz} = 7.319 \times 10^6 \, t \text{ mm}^4$$

ⓑ Replace P_u to C.G. of weld group as shown in fig

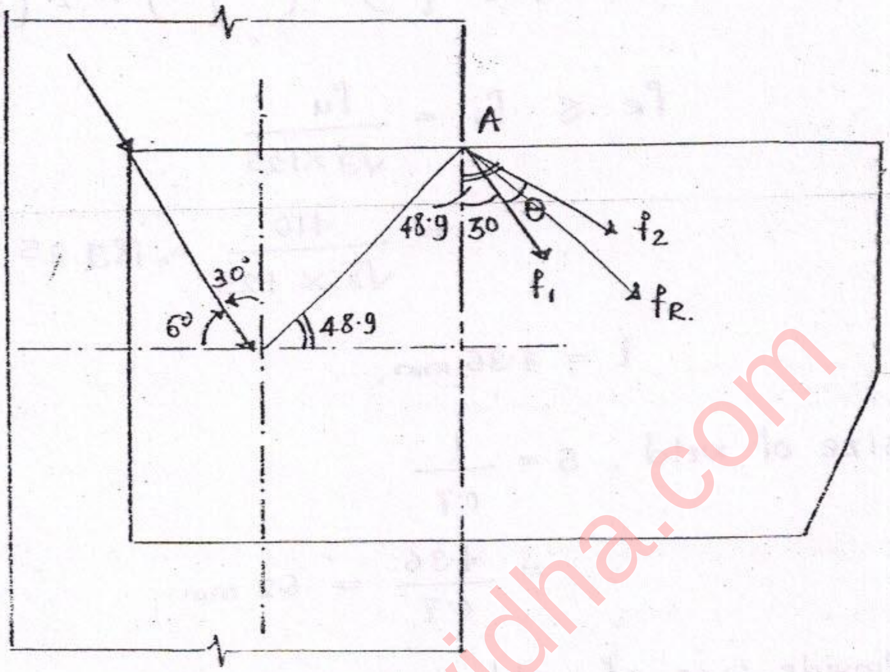
$$T = P_u \cdot e$$

$$= (P_u \cdot \cos 60) \times 125 + (P_u \cdot \sin 60) \times 259.1$$

(from varignon's theorem i.e. moment of force about any point = moment summation of components)

$\therefore \quad T = (100 \cos 60^\circ) \times 125 + (100 \sin 60^\circ) \times 259.1$

$= 28.68 \times 10^6$ Nmm



$\theta =$ Angle between f_1 and f_2

$\theta = 48.9 - 30 = 18.9^\circ$

Analysis:

(i) $\quad f_1 = \dfrac{P}{\text{Area of weld}}$

$= \dfrac{181.8}{t}$ N/mm² (orientation of we doesn't matter)

(f_1 is inclined to vertical by 30°)

(ii) $\quad f_2 = \dfrac{T}{J} \times r_A$ (J and r_A are same as earlier) - WSM

$= \dfrac{28.68 \times 10^6 \text{ N·mm}}{7.319 \times 10^6 \cdot t} \times 165.9$ mm

$= \dfrac{650.5}{t}$ N/mm².

(f_2 is inclined to vertical by 48.9°)

(iii) Resultant shear stress:

$$f_R = \sqrt{f_1^2 + f_2^2 + 2 f_1 \cdot f_2 \cdot \cos\theta}$$

$$= \sqrt{\left(\frac{181.8}{t}\right)^2 + \left(\frac{650.5}{t}\right)^2 + 2\left(\frac{181.8}{t}\right)\left(\frac{650.5}{t}\right)^2}$$

cos 18.9

θ - angle between f_1 & f_2.

$$f_R \leq f_s = \frac{f_u}{\sqrt{3} \times 1.25}$$

$$= \frac{410}{\sqrt{3} \times 1.25} = 189.25$$

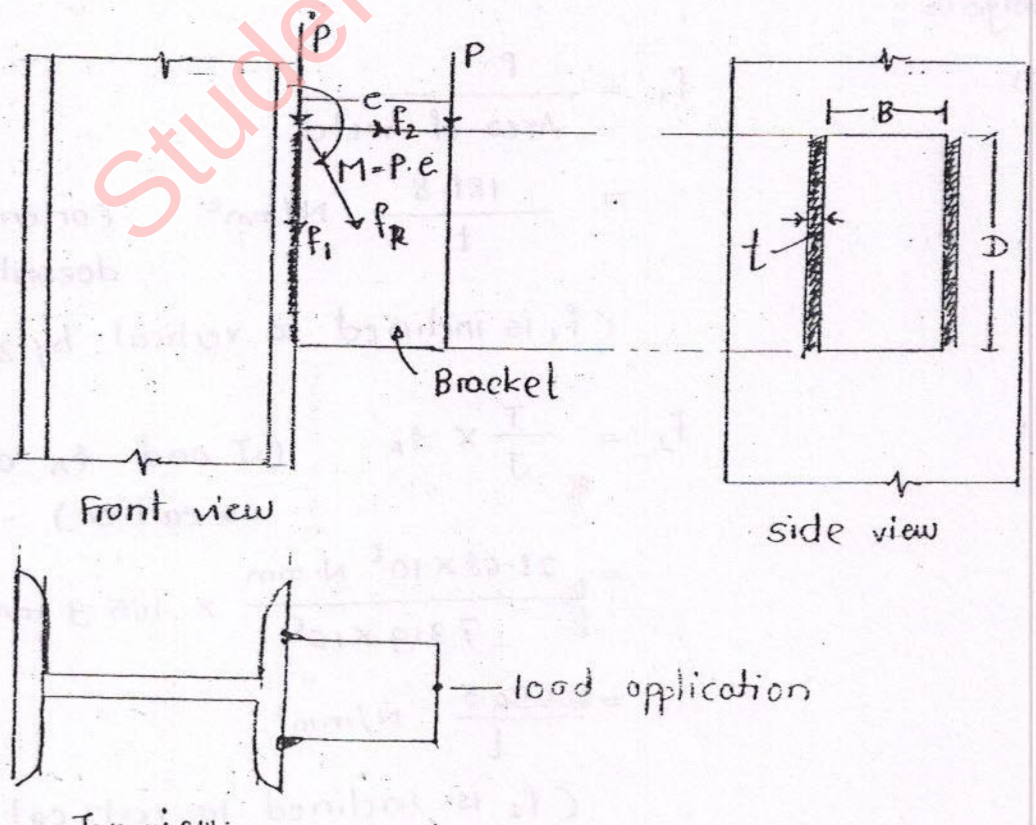
$t = 4.36$ mm.

so size of weld, $s = \frac{t}{0.7}$

$$= \frac{4.36}{0.7} = 6.2 \text{ mm}$$

Provide size of weld = 7 mm.

(II) Out of plane eccentric welded connection:



(i) The effect of eccentric load at the C.G. of weld group will be a direct load P. and a B.M ($M = P \cdot e$)

(ii) Due to direct load P. vertical shear stress f_1 is developed at A. Due to B.M., bending tensile stress is developed in the bracket. This bending tensile stress is transferred as horizontal shear stress in the weld at A. (f_2 - as shown in Fig.). Since these two stresses are shear stresses, we can find resultant shear stress.

$$f_R = \sqrt{f_1^2 + f_2^2}$$

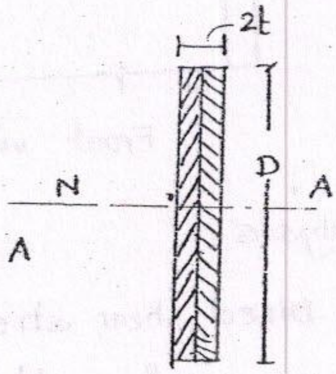
$$f_R \leq 110 \text{ MPa} \quad \text{(WSM)}$$

$$\leq \frac{f_u}{\sqrt{3} \times 1.25} \quad \text{(LSM)}$$

Analysis :

(i) Vertical shear stress at A

$$f_1 = \frac{P}{2(t \times D)}$$



(ii) Horizontal shear stress in weld at A

f_2 = bending tensile stress at A

$$= \frac{M}{Z}$$

$$= \frac{M}{\left(\frac{(2t) \cdot D^2}{6}\right)}$$

Effective area of weld (taken as line area)

* Consider weld as beam

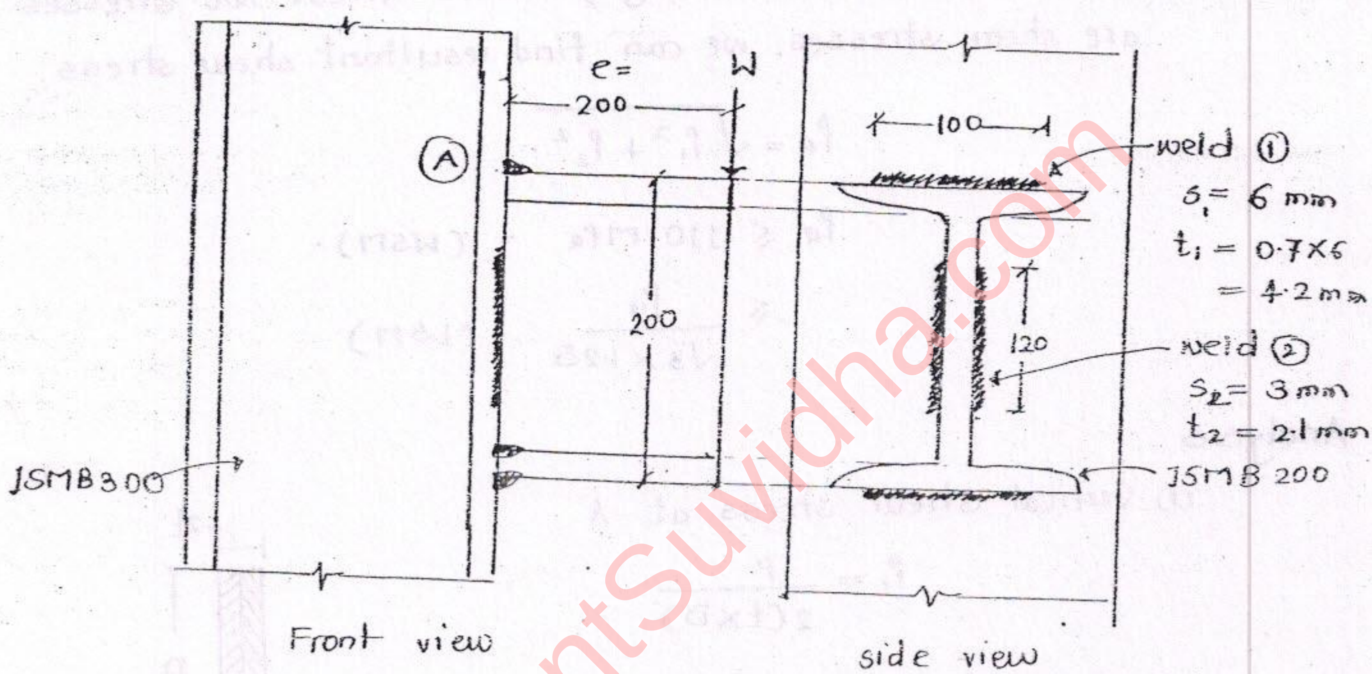
(iii) Resultant shear stress at A

$$f_R = \sqrt{f_1^2 + f_2^2}$$

$f_R \leq f_s$ (permissible shear stress in weld)

Q. A stub (a small piece of J-Section) of JSMB-200 is welded to the flange of JSMB-300 by a fillet welding. Effecting length of weld is 100 mm and its size is 6 mm. Web is welded on either sides by 3mm fillet weld whose effective length is 120 mm on either side. Find safe load W that can act at an eccentricity of 200 mm from the flange. ($f_s \not> 100$ MPa)

20 Marks



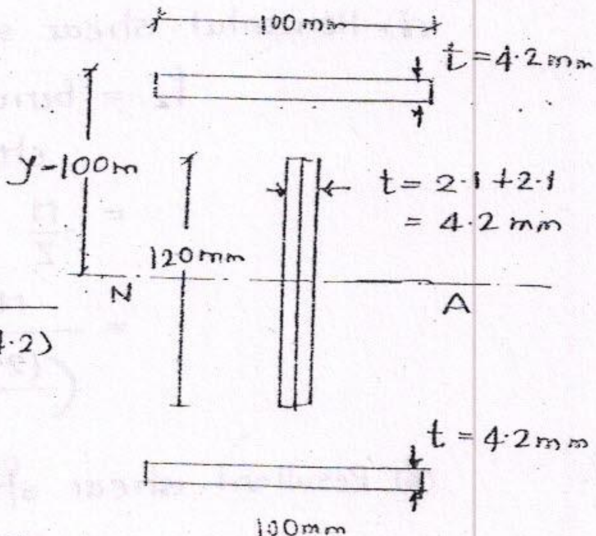
Analysis:

(i) Direct shear stress at A.

$$f_1 = \frac{W}{A}$$

$$= \frac{W}{(100 \times 4.2) \times 2 + (120 \times 4.2)}$$

$$= \frac{W}{1344} \text{ N/mm}^2$$



(ii) Horizontal shear stress in weld at A
=
bending tensile stress at A

Effective c/s of weld.
(taken as line area)

$$= \frac{M}{I_{xx}} \times y.$$

$$M = W \times e$$
$$= W \times 200$$

$\therefore$ I_{xx} of weld area $\frac{Bt^3}{12} = 0$

$$= \left[\cancel{\frac{100 \times 4.2^3}{12}} + (100 \times 4.2) \times 100^2\right] \times 2$$

I_{koko} A. h^2

$$+ \left[\frac{4.2 \times 120^3}{12}\right]$$

for vertical rectangle.

$$I_{xx} = 9.09 \times 10^6 \ mm^4$$

y - distance from N.A. to extreme fibre
= 100 mm

$$\therefore \quad f_2 = \frac{W \times 200}{9.09 \times 10^6} \times 100$$
$$= \frac{W}{454.8} \ N/mm^2$$

(iii) Resultant shear stress at A

$$f_R = \sqrt{f_1^2 + f_2^2} \ngtr f_s = 100 \ MPa$$

$$= \sqrt{\left(\frac{W}{1344}\right)^2 + \left(\frac{W}{454.8}\right)^2}$$

$$W = 43.1 \ kN.$$

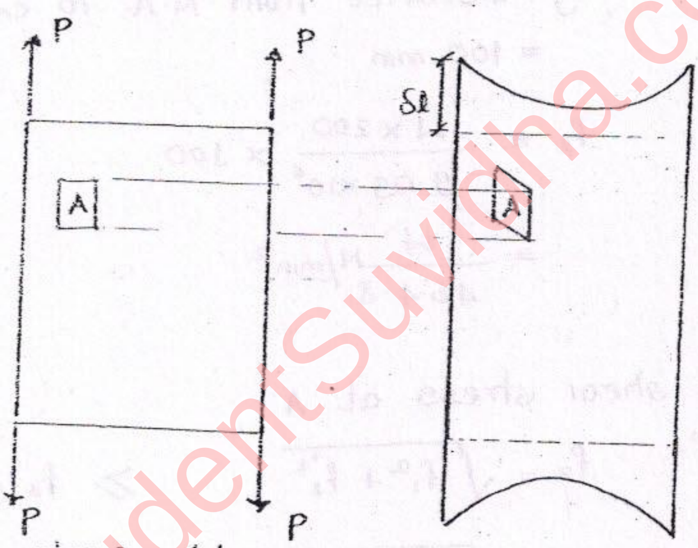
Q. In the above problem, find factored load W_u, if ultimate tensile stress in weld metal $f_u = 410$ MPa & $\gamma_m = 1.25$.

$$f_R = \sqrt{\left(\frac{W_u}{1344}\right)^2 + \left(\frac{W_u}{454.8}\right)^2} \leq \frac{f_u}{\sqrt{3} \times 1.25}$$

$W_u = 81.61$ kN.

Design of tension members:

(1) Shear lag:



plane rubber plate. Loded rubber (deformed shape)

(i) Non-uniform straining of a member due to tension is called shear lag. Shear lag reduces the efficiency of the tension member components that are not connected directly to the gusset plate.

(ii) To strain the member uniformly the section will be cracked at the connected part (where the δl is already more)