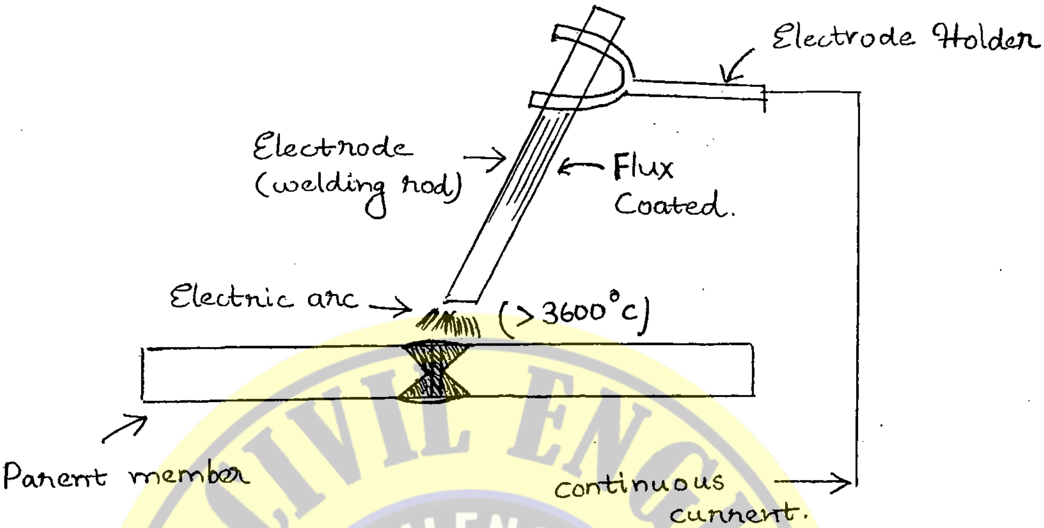
3. WELDED CONNECTIONS



MP of steel = 1450°

→ Welding Classification :

a) Fusion Process
- Electric arc welding or Metal arc welding.
- Gas welding.

b) Pressure Process
- Electric resistance welding.
- Forge welding.

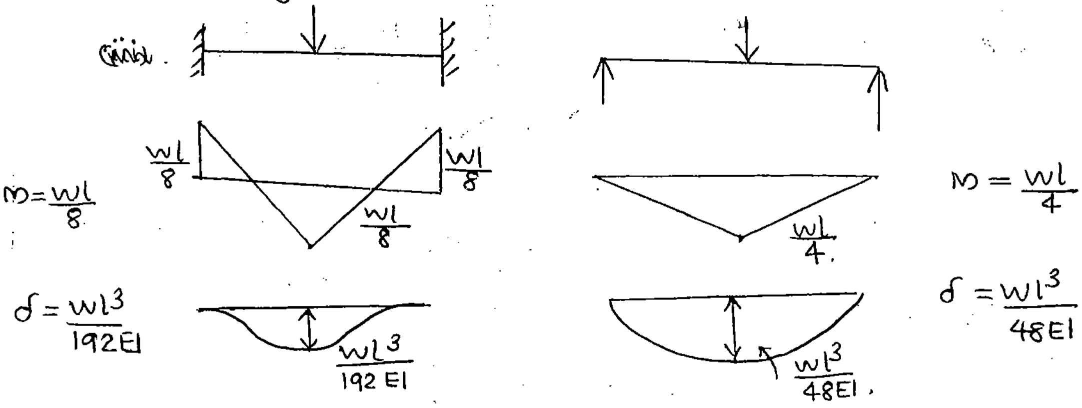
• Flux coating controls the melting of electrode. By adding some elements to the flux, mechanical properties of the joint can be enhanced.

→ Advantages :

(i) Weld joints are more efficient and stronger. Max. efficiency of bolted connection is 85%. But min. efficiency of welded connection is 95%. Bolt holes reduces η.

$$\eta = \left(\frac{B - n d_0}{B}\right) \times 100.$$

(ii) Moments and deflections are less due to rigid nature of welded joints.



Lesser the design moment, lesser depth of c/s can be used.

4th Sept, THURSDAY

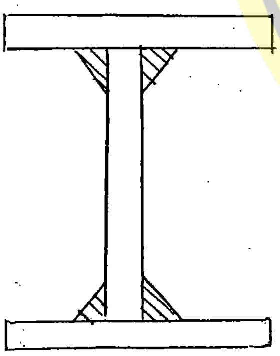
→ Types of Welds

(i) Fillet Welds or Lap welds.

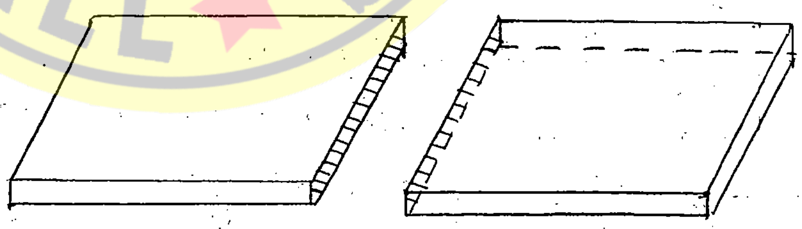
(ii) Butt or Groove welds.

(iii) Slot welds.

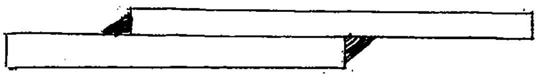
(iv) Plug welds etc.



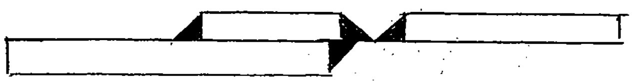
Joints two ⊥r planes.



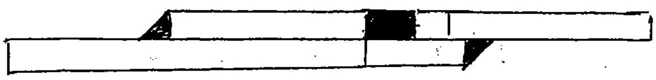
Butt weld. (Joints two // planes)



Fillet Weld.



Slot Weld

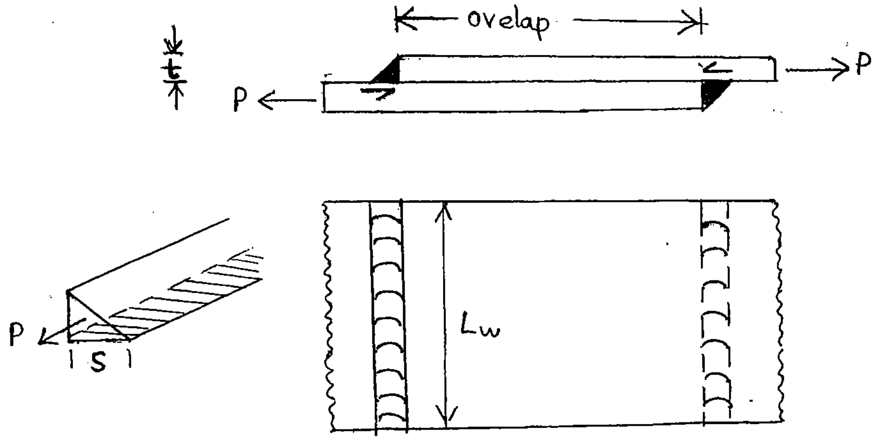


Plug Weld.

Slot weld & plug weld are the supporting welds.

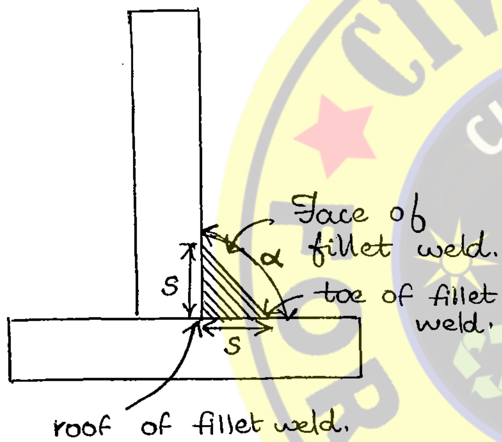
When the unsupported length b/w fillet welds ~~or butt~~ are mo moments may be induced. To avoid that slot welds or plug welds are used.

→ Design of Fillet or Lap Weld

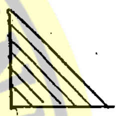


t → thickness of thinner connected member.

Minimum overlap required as per IS 800: 2007, ≮ 4t or 40 mm whichever is more.

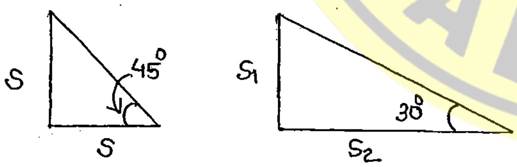


Fillet weld symbol:



⊙ Standard c/s fillet weld – Right angle triangle.

⊙ Standard angle of fillet weld – 45°



S = minimum of S_1 & S_2

For 45° standard fillet, $S_1 = S_2 = S$

Shearing area of fillet weld $= S \times L_w$.

So minimum of S_1 & S_2 is selected to design shear stress on safer side.

* Size of Fillet Weld (S)

– Distance b/w corner of fillet to the toe of fillet we[ld]

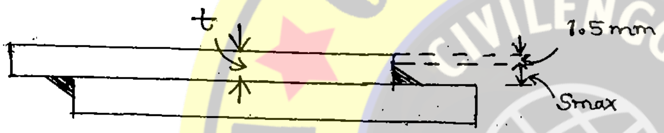
* Min. size of Fillet weld (S_{min}).

– Depends on thickness of thicker connected member.

Thickness of thicker connected member (mm)		S_{min} (mm)
over	upto & including	
0	10	3
10	20	5
20	32	6
32	50	8

* Maximum size of fillet of weld (S_{max})

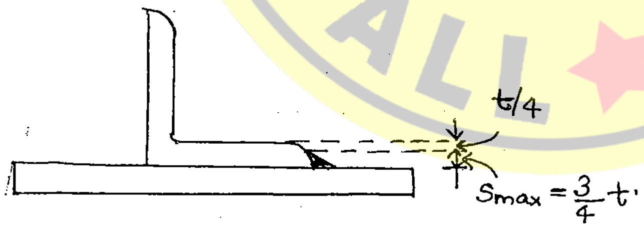
– For square edge (like plates or flat sections)



$t \rightarrow$ thickness of thinner connected member

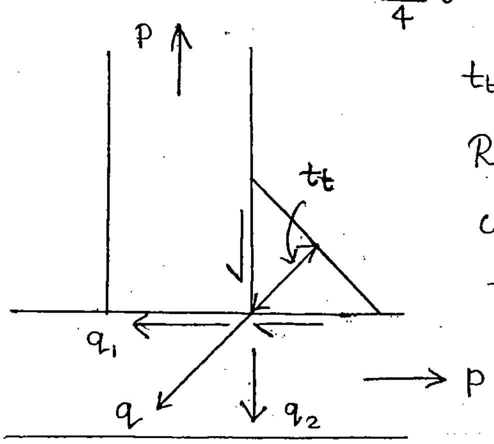
$$S_{max} = t - 1.5 \text{ mm}$$

– For round edges (like flange of an angle or flange of channel or leg of an angle etc)



$t \rightarrow$ thickness of round edge at toe.

$$S_{max} = \frac{3}{4} t$$



$t_t \rightarrow$ thickness of throat.

Resultant shear act along throat fo critical combination of loads and $t_t < S$.

So failure will occur along the the throat of fillet weld.

$t_t \rightarrow$ min dimension in c/s of fillet weld.

$$t_{t(max)} = \frac{S}{\sqrt{2}} = 0.707 S \quad (\text{for } 45^\circ)$$

→ Effective Throat Thickness (t_t):

– It is the distance b/w corner of fillet weld to the face of fillet weld.

– t_t = k × size of fillet weld.

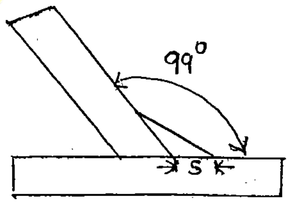
$t_t = k \cdot s$; $t_t \not< 3$ mm

where k → constant which depends on angle b/w welds or fusion faces (α).

Angle b/w weld faces (α)	Values of k ($\alpha = 90$; $k = \frac{1}{\sqrt{2}}$)
$60^\circ - 90^\circ$	0.70
$91 - 100^\circ$	0.65
$101^\circ - 106^\circ$	0.60
$107^\circ - 113^\circ$	0.55
$114 - 120^\circ$	0.50

Q. The Effective throat thickness of fillet weld shown is: (GATE 2011)

a) 0.70 s
b) 0.65 s
c) 0.50 s
d) 0.55 s



Ans: 0.65 s

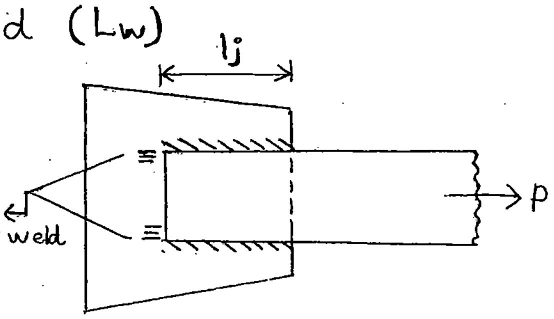
● For $\alpha < 60^\circ$ & $\alpha > 120^\circ$, code does not recommend fillet weld. t_t will be very less when $\alpha > 120^\circ$ and it is very difficult to connect by fillet weld, when $\alpha < 60^\circ$.

→ Effective Length of Fillet Weld (L_w)

l_j = length of side fillet weld parallel to direction of load.

L_w = eff. length of fillet weld = $2 \cdot l_j$

End returns $\not< 2 \times$ size of fillet weld (2.s)



- It is actual length of fillet weld shown on drawing.
- End returns are provided to minimise the stress concentration due to non-uniform deformations along the length of weld.

when $l_j < 150\, t_t$, uniform shear of $\frac{P}{L_w \cdot t_t}$ occurs

But when $l_j > 150\, t_t$, stress concentration occurs near the end. So end returns are provided.

∴ in usual practise,

- Length of weld = eff. length of fillet weld + end returns

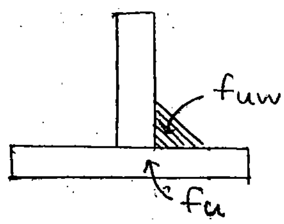
ie $L = L_w + 2s$; $s \rightarrow$ size of fillet weld.

- $L_w \nless 4s$ or 40 mm, whichever is more.

→ Design shear strength of Fillet weld (P_{dw})

P_{dw} = effective sectional area * design shear capacity of fillet weld (f_{wd}).

$$f_{wd} = \frac{\text{Nominal shear capacity of fillet } (f_{wn})}{\text{Partial safety factor}}$$



$$f_{wd} = \frac{f_{wn}}{\gamma_{mw}}$$

$$f_{wn} = \frac{f_{u1}}{\sqrt{3}} \quad ; \quad f_{u1} = \min \text{ of } \begin{cases} f_u \\ f_{uw} \end{cases}$$

$$\Rightarrow \boxed{f_{wd} = \frac{f_{u1}}{\sqrt{3}\,\gamma_{mw}}}$$

$$P_{dw} = L_w \cdot t_t \cdot \frac{f_{u1}}{\sqrt{3}\,\gamma_{mw}}$$

$\gamma_{mw} = 1.25$ (workshop welding)
$= 1.5$ (site or field welding)

$$\boxed{P_{dw} = L_w \cdot K s \cdot \frac{f_{u1}}{\sqrt{3}\,\gamma_{mw}}}$$

– For safety criteria:

Design action (P) ≤ Design shear strength of Fillet weld (P_{dw})

→ Reduction factor for Long Joint (β_{lw}) {when $l_j > 150 t_t$}

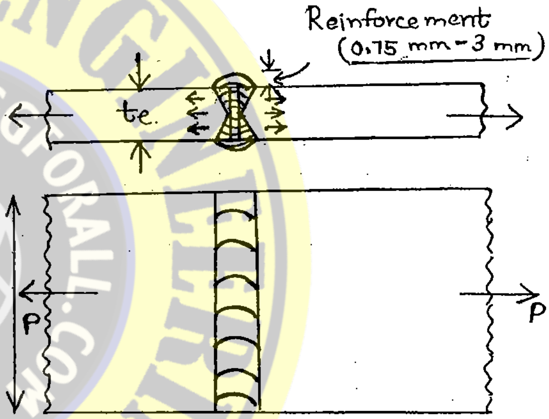
$$\beta_{lw} = \left[1.2 - \frac{0.2\, l_j}{150\, t_t}\right] \leq 1$$

→ Design of Butt or Groove Welds.

– Types of Butt Welds

1. Partially Penetrated or Single butt welds.

Eg: Single 'V' Butt welds.
Single 'U' Butt welds.
Single 'J' Butt welds.

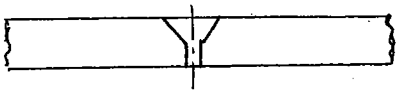
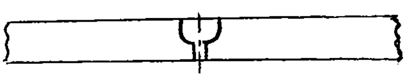
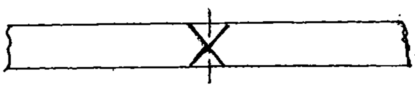
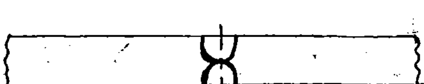


Butt Welds

2. Fully Penetrated or Double Butt Welds.

Eg: Double 'V' Butt welds.
Double 'U' Butt welds.
Double 'J' Butt welds.

▪ Reinforcement is provided by the welder at the site. It's not part of the design.

Type of Butt weld	Symbolic Representation	Symbol	te
– single V butt weld.			$\frac{5}{8}t$
– single U butt weld.			$\frac{5}{8}t$
– double V butt weld.			t
– double U butt weld.			t.

→ Design Axial Strength of Butt Weld (T_{dw})

T_{dw} = Effective sectional area × design axial stress

$$T_{dw} = L_w \cdot t_e \cdot \frac{f_{y1}}{\gamma_{mw}}$$

t_e → effective throat thickness of butt weld.

$t_e = \frac{5}{8} t$ (for single butt welds)

$= t$ (for double butt welds)

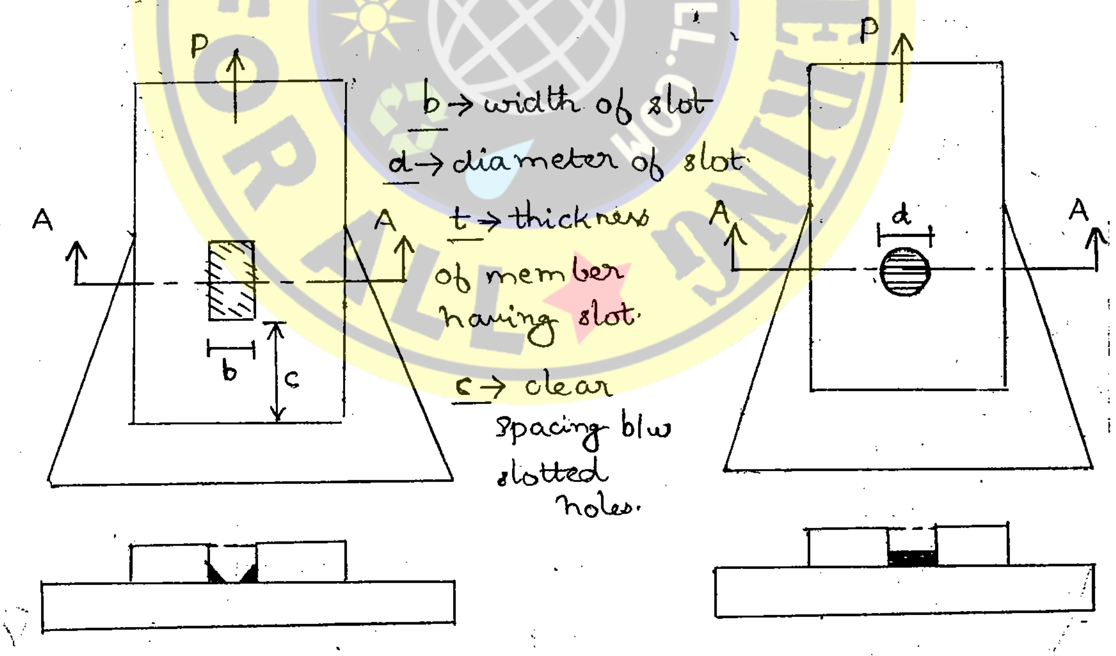
t : thickness of thinner connected member

L_w : effective length of butt weld.

f_{y1} : minimum of f_y & f_{yw}

th Sept, SATURDAY

→ Slot & Plug Welds



Section A-A (slot welds)

Section A-A (Plug welds)

- Width of slot or Diameter of slot ≥ 3t & 25 mm
- Clear spacing b/w slots ≥ 2t & 25 mm
- Corner radius of slotted hole, R ≥ 1.5t & 25mm

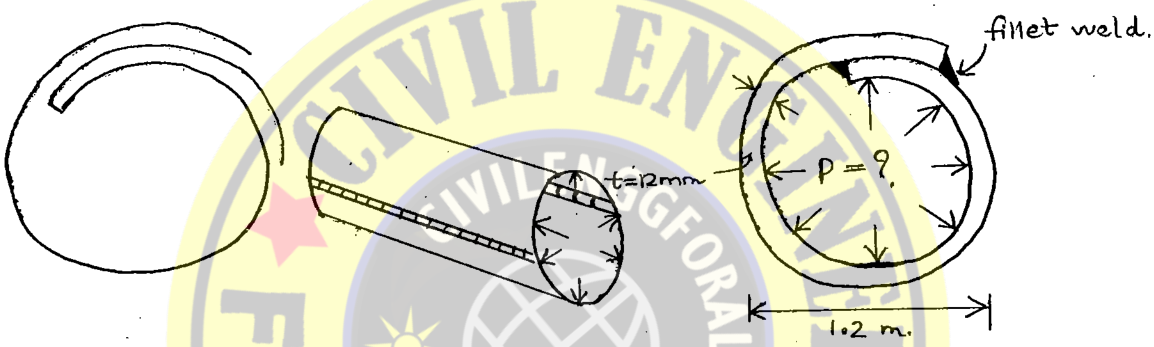
Q.1. Design shear capacity $= f_{wd} = \frac{f_{wn}}{\gamma_{mw}} = \frac{f_u}{\sqrt{3}\cdot\gamma_{mw}}$

$$= \frac{410}{\sqrt{3}\times 1.25} = \underline{189.37} \text{ N/mm}^2$$

Q.2 Size of weld, $s = 8$ mm.

For grade Fe 410, $f_y = 250$ MPa, $f_u = 410$ MPa.

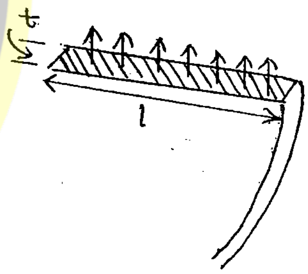
For workshop weld, $\gamma_{mw} = 1.25$



Design hoop stress, $f_h = \frac{Pd}{2t}$

Design hoop force, $F_h = f_h \times$ area

$$= \frac{Pd}{2t} \times l \times t = \frac{Pdl}{2}$$



where P → design internal fluid pressure

$= \gamma_L \times$ safe internal fluid pressure

Design shear strength of fillet weld ; $P_{dw} = \left(L_w \cdot t_t \cdot \frac{f_u}{\sqrt{3}\,\gamma_{mw}}\right)$

$$F_h = P_{dw}$$

$$\frac{Pd}{2} = t_t \cdot \frac{f_u}{\sqrt{3}\cdot\gamma_{mw}} \times 2$$

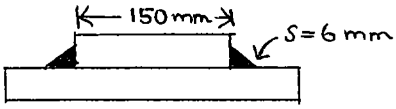
$$\frac{P \times 1200}{2} = 0.7 \times 8 \times \frac{410}{\sqrt{3} \times 1.25} \times 2$$

$$P = 3.55 \text{ N/mm}^2$$

Safe internal fluid pressure (working internal fluid pressure

$$= \frac{3.55}{\gamma_L} = \frac{3.55}{1.5} = 2.36 \text{ N/mm}^2$$

03.



For Fe 410 grade steel, $f_u = 410$ MPa

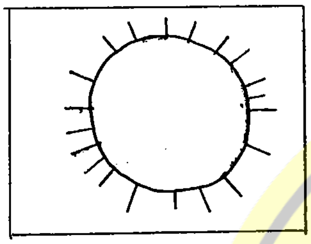
For workshop welding, $\gamma_{mw} = 1.25$

Size of fillet weld, $S = 6$ mm

Eff. throat thickness, $t_t = KS$

$= 0.7 \times 6$

$= 4.2$ mm.



$L_w = \pi d$

Design shear strength of fillet, $P_{dw} = L_w \cdot t_t \cdot \frac{f_u}{\sqrt{3}\,\gamma_{mw}}$

Ultimate twisting moment resistance, $T_u = P_{dw} \cdot \frac{d}{2}$

$$= L_w \cdot t_t \cdot \frac{f_u}{\sqrt{3}\,\gamma_{mw}} \cdot \frac{d}{2}$$

$$= \frac{\pi \times 150 \times 4.2 \times 410}{\sqrt{3} \times 1.25} \times \frac{150}{2}$$

$$= 28.11 \text{ kNm}$$

04 Single butt weld, $t_e = \frac{5}{8} t$.

$$= \frac{5}{8} \times 12 = 7.5 \text{ mm}$$

Design strength of butt weld, $T_{dw} = (L_w t_e) \cdot \frac{f_y}{\gamma_{mw}}$

$$= L_w \times 7.5 \times \frac{250}{1.25}$$

$$= 330 \text{ kN}$$

5 . For Fe 410 grade steel, $f_u = 410$ MPa, $f_y = 250$ MPa, $\gamma_{mw} = 1.25$

Design load or Factored load $= \gamma_L \times$ Service load

$= \gamma_L \times$ working load

$= \gamma_L \times$ characteristic load.

Size of weld = 3 mm.

Effective throat thickness, $t_t = K \cdot S = 0.7 \times 3$

$= 2.1$ mm $\not< 3$ mm

Design load (P) = Design strength of fillet weld. (P_{dw})

$$= L_w \cdot t_t \cdot \frac{f_u}{\sqrt{3}\gamma_{mw}} = \frac{3 \times 150 \times 3 \times 410}{\sqrt{3} \times 1.25}$$

$= 255$ kN

Service load $= \frac{P}{\gamma_L} = \frac{255}{1.5} = \underline{\underline{170.43}}$ kN

7 $f_y = 250$ MPa,

$f_u = 410$ MPa, $\gamma_{mw} = 1.25$

$T \leq T_{dw}$

Design load, P = Design axial strength of butt weld (T_{dw})

$$T_{dw} = t_e \times L_w \times \frac{f_y}{\gamma_{mw}}$$

$$= T \times L_w \times \frac{f_y}{\gamma_{mw}}$$

$$= 10 \times 300 \times \frac{250}{1.25} = 600 \text{ kN}$$

Safe load allowed, $P_s = \frac{P}{\gamma_L} = \frac{600}{1.5} = \underline{\underline{400 \text{ kN}}}$

8.

	S_{min}
0–10 mm	3 mm
10–20 mm	5mm

∴ Min. size of weld, $S_{min} = 5$ mm.

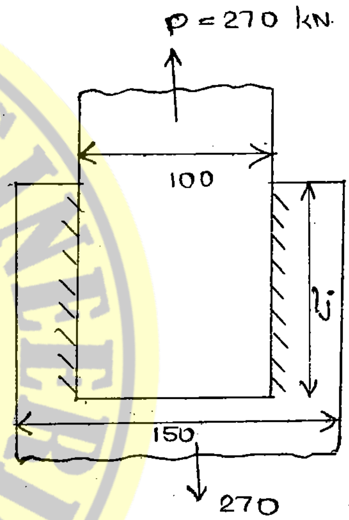
$t_t = 0.7 \times 5 = 3.5$ mm > 3 mm.

By equating $P = P_{dw}$

$$10^3 \times 300 = L_w t_t \cdot \frac{f_u}{\sqrt{3}\,\gamma_{mw}}$$

$$L_w = \frac{300 \times 10^3 \times \sqrt{3} \times 1.25}{3.5 \times 410} = \underline{452.62} \text{ mm}$$

9. Two plates are connected by fillet weld of size 10 mm and subj. to tension as shown in the fig. Thickness of each plate is 12 mm. fy & fu of steel are 250 MPa & 410 MPa resptly. The weld is done in workshop ($\gamma_{mw} = 1.25$). As per limit state method of IS 800:2007, the min length (rounded off to nearest higher multiple of 5mm) of each weld to transmit a load of P = 270 kN



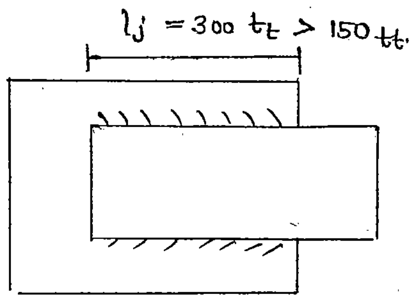
$s = 10$ mm

$P = P_{dw}$

$$270 \times 10^3 = L_w \cdot t_t \cdot \frac{f_u}{\sqrt{3}\,\gamma_{mw}}$$

$$= 2 \times l_j \times 0.7 \times 10 \times \frac{410}{\sqrt{3} \times 1.25}$$

$$\therefore l_j = 101.8 \text{ mm} \approx \underline{105 \text{ mm}}$$



10. Long joint, $l_j > 150 t_t$.

So $$\beta_{lw} = \left(1.2 - \frac{0.2\, l_j}{150 t_t}\right)$$

$$= \left(1.2 - \frac{0.2 \times 300 t_t}{150\, t_t}\right) = \underline{0.8}$$

Design shear capacity reduced by 20%.

11 $P \leq P_{dw}$

$$P_{dw} = L_w \cdot t_t \cdot \frac{f_u}{\sqrt{3} \cdot \gamma_{mw}} \times \beta_{lw}$$

$$= 1200 \times 3.5 \times \frac{410}{\sqrt{3} \cdot \gamma_{mw}} \times \beta_{lw}$$

$$= 771.49 \text{ kN}$$

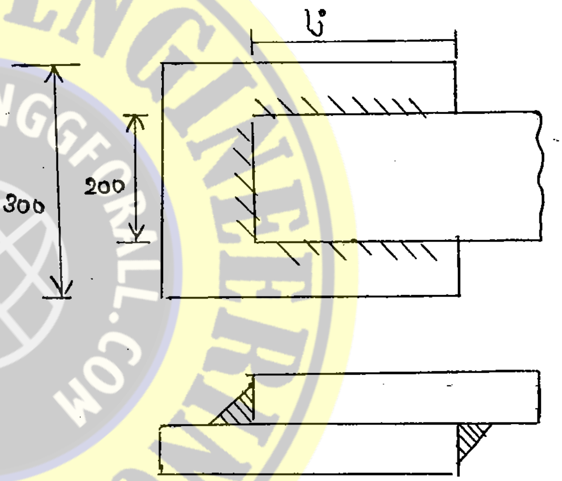
$l_j = 600$

$150 t_t = 150 \times 3.5 = 525$

$l_j > 150 t_t$.

$$\beta_{lw} = 1.2 - \frac{0.2 l_j}{150 t_t}$$

$$= 1.2 - \frac{0.2 \times 600}{525} = 0.971$$



12. $P = P_{dw}$

$$600 \times 10^3 = L_w \times K \cdot S_{max} \frac{f_u}{\sqrt{3}\, \gamma_{mw}}$$

Max size of fillet weld,

$S_{max} = 10 - 1.5 = 8.5$ mm.

$$\Rightarrow 600 \times 10^3 = L_w \times 0.7 \times 8.5 \times \frac{410}{\sqrt{3} \times 1.25}$$

$L_w = 532.502$ mm

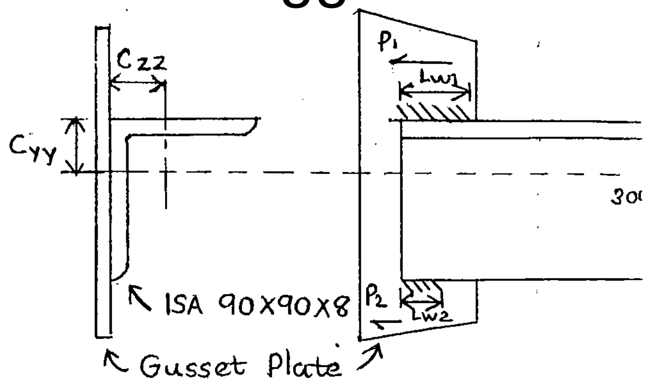
$L_w = 2 \times 200 + 2 l_j$

$l_j = 66.25 \approx 70$ mm $>$ 40mm (min. overlap)

Sept,
DAY

13 Fe 410 grade steel : $f_u = 410$ MPa, $f_y = 250$ MPa

For site welding, $\gamma_{mw} = 1.5$



Max size of fillet weld for round edges, $S_{max} = \frac{3}{4} t$.

$= \frac{3}{4} \times 8 = \underline{6\ mm}$

Effective throat thickness,

$t_t = K.S.$

$= 0.7 \times 6 = 4.2$ mm.

$P = P_{dw}$

$300 \times 10^3 = L_w . t_t . \frac{f_u}{\sqrt{3}\ \gamma_{mw}}$

$= L_w . 4.2 . \frac{410}{\sqrt{3} \times 1.50}$

$L_w = 452.6$ mm.

Let L_{w1} & L_{w2} are lengths of top weld and bottom weld respectively.

$L_{w1} + L_{w2} = 452.6$ mm $\rightarrow$ ①

Consider moments of strength of weld and loads on top edge of an angle.

$P_2 \times 90 + P_1 \times 0 - 300 \times 25.1 = 0.$

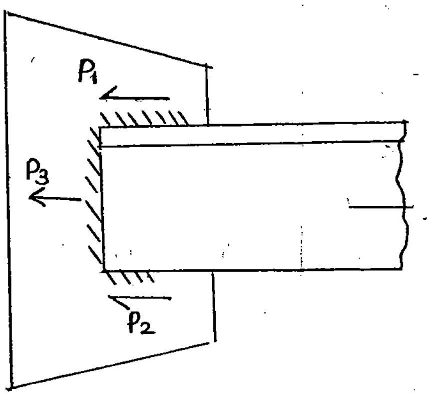
$L_{w2}\ t_t . \frac{f_u}{\sqrt{3}\ \gamma_{mw}} \times 90 + 0 - 300 \times 10^3 \times 25.1 = 0.$

$L_{w2} = 126.23$ mm

$\therefore L_{w1} = \underline{326.37}$ mm.

14. $L_{w1} + L_{w2} + 90 = 452.66$

$L_{w1} + L_{w2} = 362.6 \rightarrow$ ①



$P_2 \times 90 + P_3 \times \frac{90}{2} + P_1 \times 0 = 300 \times 10^3 \times 25.1$

$L_{w2} . 4.2 \times \frac{410}{\sqrt{3} . 1.5} + 90 \times 4.2 \times \frac{410}{\sqrt{3} \times 1.5} \times \frac{90}{2} + 0$

$= 300 \times 10^3 \times 25.1$

$L_{w2} = 81.2$ mm

$L_{w1} = 362.6 - 81.2 = 281.4$ mm