Unit - III Design of Temporary & Permanent Joints

2 Marks

① Define : Pitch and lead of a screw.

Pitch : It is the axial distance from a point on one thread to corresponding point on the next thread.

Lead : It is the distance moved by the screw in one turn.

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② How is bolt designated ? Give example.

A thread is designated with letter M followed by Nominal diameter in mm and pitch in mm [for fine pitches only]. If coarse pitches are used then P value is omitted.

Thus M20 × 2.5 means, Nominal diameter is 20mm 2.5 mm pitch, fine thread. M20 means, 20 mm nominal diameter with coarse threads.

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③ Why are ACME threads preferred over square thread for power screw ?

- ACME threads is easier to machine, and it is stronger than square threads. ACME threads are thicker and wider and operate better in environments with dirt and debris.

(4) What is gib? Why it is provided in a cotter joint?

- Gib is an element made of mild steel with thickness equal to the cotter. A gib is used in combination with the cotter to provide the following advantages.
  - Reduces bending of socket &
  - Increase the bearing area of contact b/w the matting surfaces.

(5) What are the different types of cotter joints?

- Socket & Spigot cotter joint
- Sleeve and cotter joint
- Gip and cotter joint.

(6) State the two types of eccentric welded connection?

- Welded connections subjected to moment in a plane of the weld.
- Welded connections subjected to moment in a plane normal to the plane of the weld.

(7) What are the various initial stresses developed due to screwing up in bolted joints?

- Tensile stresses.
- Torsional stresses
- Shear stress
- Compressive and bending stress

8. Under what force, the big end bolts and caps are designed.

The big end bolts and caps are designed for inertia force due to reciprocating parts.

9. Name the possible modes of failure of riveting joint.

1. Crushing of rivets
2. Shear of rivets
3. Tearing of the plate at the edge
4. Tearing of the plate b/w rivets

10. What is meant by efficiency of the riveted joint?

The efficiency of a riveted joint is defined as the ratio of the strength of riveted joint to the strength of the un-riveted or solid plate.

$$\eta = \frac{\text{Least of Tearing Resistance, Shearing resistance \& Crushing resistance}}{P \times t \times \sigma_t}$$

P = pitch of rivets

t = thickness of plate

σ_t = Permissible Tensile stress of the plate material.

Part - B

1) A rectangular steel plate is welded as a Cantileaver to a vertical column & supports a single concentrated load P. as shown in fig. Determine the weld size if shear stress in the same is not to exceed 80 N/mm².

G.V. $P = 40kN = 40 \times 10^3 N$; $b = 150mm$; $d = 200mm$

$[\tau] = 80 \; N/mm^2$

To find: weld ~~strength~~ size, h.

Sln:

I. Location of the Centroid:

From DDB. P.g.no. 11.5

$$\bar{x} = N_y = \frac{b^2}{2b+d} = \frac{150^2}{2 \times 150 + 200} \Rightarrow 45 \; mm$$

$$\bar{y} = \frac{200}{2} \Rightarrow 100 \; mm$$

$$\text{Centroid} = (\bar{x}, \bar{y}) = (45, 100)$$

[Refer: Fig: 1]

II. Polar moment of Inertia:

J_o = Unit Polar moment of Inertia

$$= \frac{(2b+d)^3}{12} - \frac{b^2(b+d)^2}{(2b+d)} \quad \text{[D.D.B Pg no. 11.5]}$$

$$J_o = \frac{(2 \times 150 + 200)^3}{12} - \frac{150^2(150+200)^2}{(2 \times 150 + 200)}$$

$$\boxed{J_o = 4.904 \times 10^6 \; mm^3}$$

$J = J_u \times t$

$= 4.904 \times 10^6 \times t \ mm^4$

III. Secondary shear stress (τ_s):

$$\tau_s = \frac{T \times R}{J}$$

T = Torque = $P \times l$

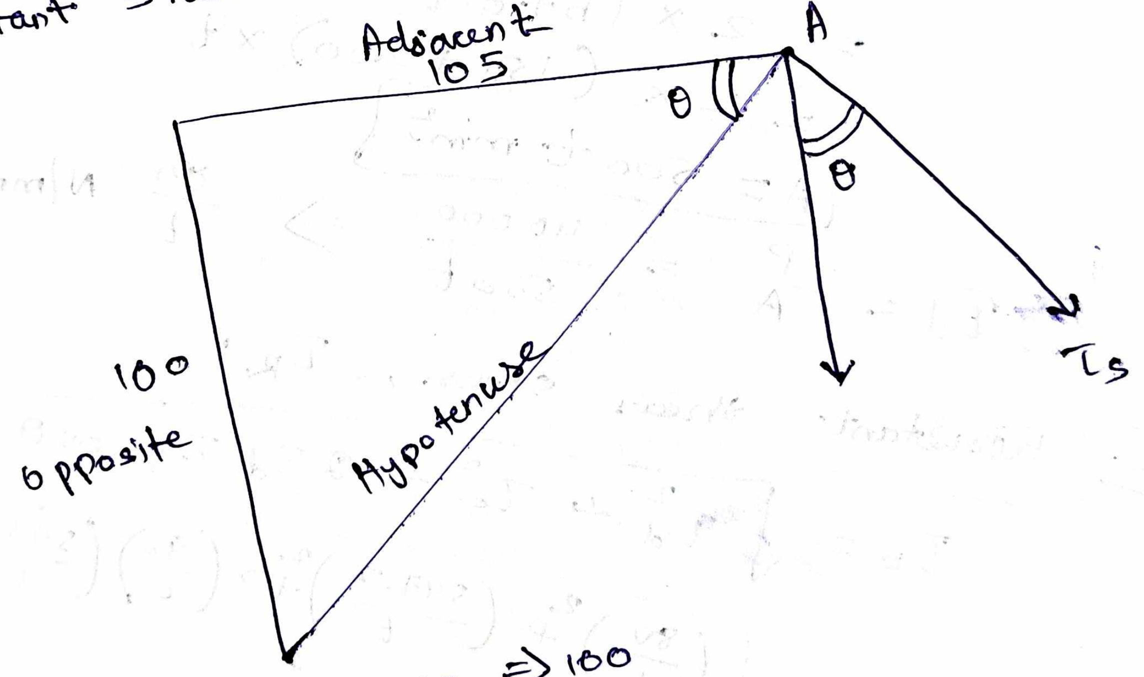
where l = Distance b/w line of action of load and centroid.

$l = (550 - 45)$

$= 505 \ mm$

$T = 40 \times 10^3 \times 505 \Rightarrow 20200000 \ N\text{-}mm$

Resultant shear stress (τ_R):



$opp = 200 - 100 \Rightarrow 100$

$Adj = 150 - 45 = 105$

$$\tan\theta = \frac{opp}{Adj} = \frac{100}{105}$$

$\boxed{\theta = 43.6^\circ}$

III. Secondary Shear Stress

$$R = GA = \sqrt{(x-\bar{x})^2 + (y-\bar{y})^2}$$

$$= \sqrt{(150-45)^2 + (200-100)^2}$$

$$\boxed{R = 145 \text{ mm}}$$

$$\tau_s = \frac{TR}{J}$$

$$= \frac{20200000 \times 145}{4.904 \times 10^6}$$

$$\boxed{\tau_s = 597.26 \text{ N/mm}^2}$$

IV. Primary shear stress, τ_d:

A = Total Throat Area,

$$= 2 \times (b+d)t$$

$$= 2 \times (150+200) \times t$$

$$\boxed{A = 500t \text{ mm}^2}$$

$$\therefore \tau_d = \frac{P}{A} = \frac{40000}{500t} \Rightarrow \frac{80}{t} \text{ N/mm}^2$$

V. Resultant shear stress, τ_R:

$$\tau_R = \sqrt{\tau_d^2 + \tau_s^2 + 2\tau_d\tau_s\cos\theta}$$

$$= \sqrt{\left(\frac{80}{t}\right)^2 + \left(\frac{597.2}{t}\right)^2 + 2\left(\frac{80}{t}\right)\left(\frac{597.2}{t}\right)\cos 43.6^\circ}$$

$$= \frac{657.45}{t}$$

VI. Weld size:

$$\frac{657.45}{t} \le [\tau] \qquad ([\tau] = 80) \quad (t = 0.707 \times h)$$

$$\therefore h \ge 11.62 \text{ mm}$$

$$\boxed{h = 12 \text{ mm}}$$

(2) A knuckle joint is to transmit a force of 140KN. Allowable stresses in tension, shear and compression are 75 N/sq.mm, 65 N/sq.mm & 140 N/sq.mm respectively. Design the joint.

(2)

G.V:

Force, $P = 140KN = 140 \times 10^3$ N

$\sigma_t = 75$ N/mm^2

$\tau = 65$ N/mm^2

$\sigma_c = 140$ N/mm^2

S/n:

Failure of soild rod in tension is

$$P = \frac{\pi}{4} d^2 \sigma_t$$

$$140 \times 10^3 = \frac{\pi}{4} \times d^2 \times 75$$

$$\boxed{d = 50mm}$$

Various standard proportions of the knuckle joint:

$d_1 = d = 50$ mm

$d_2 = 2d = 100$ mm

$d_3 = 1.5d = 75$mm

$t = 1.25d = 62.5$mm

$t_1 = 0.75d = 37.5$ m

$t_2 = 0.5d = 25$ mm

Check for τ:

1. Failure of knuckle pin by double shear

$$P = 2 \times \frac{\pi}{4} \times d_1^2 \times \tau$$

$$\boxed{\tau = 35.65 \ N/mm^2}$$

It is less than Permissible Shear Stress ($65 \ N/mm^2$)

Hence the design is safe.

2. Failure of single eye or rod end in double shear

$$P = (d_2 - d_1) \times t \times \tau$$

$$\boxed{\tau = 44.8 \ N/mm^2}$$

$\therefore$ less than Permissible, the design is safe

3. Failure of forked ends in double shear:

$$P = (d_2 - d_1) t_1 \times 2 \times \tau$$

$$\boxed{\tau = 37.3 \ N/mm^2}$$

$\therefore$ it is less than Permissible, The design is safe.

Check for σ_t:

4. Failure of the single eye or rod end in tension

$$P = (d_2 - d_1) t \ \sigma_t$$

$$\boxed{\sigma_t = 44.8 \ N/mm^2}$$

$\because$ less than Permissible ($75 \ N/mm^2$), design is safe.

5. Failure of forked end in tension:

$$P = (d_2 - d_1) \times t_1 \times 2 \times \sigma_t$$

$$\boxed{\sigma_t = 37.33\ N/mm^2}$$

less than Permissible, Design is safe.

Check for σ_c:

6. Failure of single eye or rod end in crushing:

$$P = d_1 \times t \times \sigma_c$$

$$\boxed{\sigma_c = 44.8\ N/mm^2}$$

less than Permissible (140 N/mm^2), design is safe.

7. Failure of forked end in crushing.

$$P = d_1 t_1 \times 2 \times \sigma_c$$

$$\boxed{\sigma_c = 37.33\ N/mm^2}$$

∴ less than Permissible, Design is safe.

(3) Design a cotter joint to support a completely reversed axial load of 25 KN. Use steel for all components. Allowable stresses for steel are in tension 50 N/mm^2, in compression 60 N/mm^2 and in shear 35 N/mm^2.

GV :

$$F = \pm 25 kN$$

$$(\sigma_t)_{all} = 50 N/mm^2$$

$$(\sigma_c)_{all} = 60 N/mm^2$$

$$(\tau)_{all} = 35 N/mm^2$$

sl: $\because$ Joint has to be designed for a completely reverse load, both tensile & compressive loads of 25 kN should be considered.

(i) Failure of rod in tension:

$$F = \frac{\pi}{4} d^2 (\sigma_t)_{all}$$

$$\therefore \boxed{d = 26 mm}$$

(ii) Failure of rod end at the cotter hole:

$$F = \left[\frac{\pi}{4} d_1^2 - d_1 t\right] (\sigma_t)_{all}$$

assume, $t = 0.4 \times d \Rightarrow 11 mm$ (or)

$$25 \times 10^3 = \left[\frac{\pi}{4} d_1^2 - d_1 \times 11\right] \times 50$$

$$\therefore \boxed{d_1 = 33.4 mm}$$

(iii) Tension failure of Socket end at cotter hole:

$$F = \left[\frac{\pi}{4} d_2^2 - \frac{\pi}{4} d_1^2 - (d_2 - d_1) t\right] (\sigma_t)_{all}$$

$$25 \times 10^3 = \left[\frac{\pi}{4} d_2^2 - \frac{\pi}{4} \times 34^2 - (d_2 - 34) \times 11\right] \times 50$$

$$\therefore \boxed{d_2 = 43.96 \text{ mm}}$$ ← solving above eq we get

(iv) Crushing failure at the end:

$$F = (d_2 - d_1) t (\sigma_c)_{all}$$

$$25 \times 10^3 = (44 - 34) \times 11 (\sigma_c)_{all}$$

$$\boxed{(\sigma_c)_{all} = 227.27 \text{ N/mm}^2}$$

But the allowable stress in compression is 60 N/mm². $\sigma_c > (\sigma_c)_{all}$, design is not safe.

Hence d_2 - increased.

$$F = (d_2 - d_1) t (\sigma_c)_{all}$$

$$25 \times 10^3 = (d_2 - 34) \times 11 \times 60$$

$$\boxed{d_2 = 72 \text{ mm}}$$

(v) Shear failure of cotter:

$$F = 2bt \tau_{all}$$

$$25 \times 10^3 = 2 \times b \times 11 \times 35$$

$$\boxed{b = 33 \text{ mm}}$$

(vi) Crushing failure of Cotter:

$$F = \frac{\pi}{4}\left[d_3^2 - d_1^2\right](\sigma_c)_{all}$$

$$25 \times 10^3 = \frac{\pi}{4}\left[d_3^2 - 34^2\right] \times 60$$

$$\boxed{d_3 = 42\ mm}$$

(vii) Other Parameters:

$L_1 = l_2 = 0.75d \Rightarrow \underline{20\ mm}$

$l_{13} = 0.45d = \underline{12\ mm}$

Cotter length, $l = 4d = \underline{104\ mm}$

Assuming, taper is $1:25$,

$$\tan\alpha = \frac{b_2 - b_1}{l}$$

$$\frac{1}{25} = \frac{b_2 - b_1}{104}$$

$$b_2 - b_1 = 4.16\ mm$$

$$b_2 = b + \left(\frac{b_2 - b_1}{2}\right) = \underline{36\ mm}$$

$$b_1 = b - \left(\frac{b_2 - b_1}{2}\right) = \underline{31\ mm}$$

4) Design a Cotter Joint with one gib to transmit a force of 50 kN along a rod of square section. Assume that the gib, rod & Cotter are made of Same material with the following available stresses

Under tension = 20 MPa

Compression = 50 MPa

Shear = 15 MPa

Gv:

$F = 50\ kN = 50000\ N$

$(\sigma_t)_{all} = 20\ MPa$

$(\sigma_c)_{all} = 50\ MPa$

$(\tau)_{all} = 15\ MPa$

sln:

(i) Failure of rod in tension:

$F = h^2 \cdot (\sigma_t)_{all}$

$5000 = h^2 \times 20$

$\boxed{h = 50\ mm}$

Thickness of Cotter, $t = 0.3h = 15mm$

(ii) Shearing of gibs & Cotter:

$F = 2Bt\tau_{all}$

$5000 = 2B \times 15 \times 15$

$\boxed{B \approx 111.11\ mm}$

Width of gib, $= 0.55B \Rightarrow 62\ mm$

Width of Cotter, $= 0.45B \Rightarrow 51\ mm$

(iii) Failure of strap end in tension:

$$F = 2(w.t_1 - t.t_1)(\sigma_t)_{all}$$

$$5000 = 2(50t_1 - 15t_1) \times 20$$

$$\boxed{t_1 = 36\text{ mm}}$$

(iv) Crushing of gib or strap at the strap hole:

$$F = 2.t.t_1.\sigma_c$$

$$5000 = 2 \times 15 \times 36 \times \sigma_c$$

$$\boxed{\sigma_c = 46.29\ N/mm^2}$$

$\therefore \sigma_c$ is found, $\sigma_c < (\sigma_c)_{all}$, design is safe.

(v) Shearing of strap end:

$$F = 2 \times 2 \times l_3 \times t_1 \times \tau_{all}$$

$$5000 = 2 \times 2 \times l_3 \times 36 \times 15$$

$$\boxed{l_3 = 23.15\text{ mm}}$$

(vi) Shearing of rod end:

$$F = 2 \times l_2 \times h \times \tau_{all}$$

$$5000 = 2 \times l_2 \times 50 \times 15$$

$$\boxed{l_2 = 34\text{ mm}}$$

(vii) Other Parameters:

Dimensions, $l_1 = t = 15$ mm

$l_4 = \frac{2}{3}h = 34$ mm

$t_2 = 1.3t \Rightarrow 20\,mm$

Overall gib length $= h + 2(t_1 + t_2)$

$= 50 + 2(36+20) \Rightarrow \underline{162\,mm}$

Cotter length $= 4h \Rightarrow \underline{200\,mm}$

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(5) A plate of 200mm width and 600 mm long is welded to a vertical plate by placing it on the vertical plate to form a cantilever with projecting length of 480 mm and overlap b/w plates as 120mm. A vertical fillet weld is done on all three sides. A vertical load 30 kN is applied at the free end of the cantilever plate parallel to its width of 200mm. If the allowable weld stress is 95 MPa, determine the weld size.

GV: Width of the steel plate, $d = 200\,mm$

length, $l = 600\,mm$

Projecting length $= 480\,mm$

Overlap b/w the plate $= 120\,mm$

Vertical load, $P = 30\,kN = 30 \times 10^3\,N$

$\sigma = 95\,N/mm^2$

$r = \sqrt{(120-33)^2 + 100^2}$

$\boxed{r = 132.55 \text{ mm}}$

$\cos\theta = \frac{GB}{r} = \frac{120-33}{132.55} = 0.656$

From table 3.7 (or) PSG DB pg 11.5, & considering the thickness of weld 't', the polar moments of inertia,

$$J_w = \frac{(2b+d)^3}{12} - \frac{b^2(b+d)^2}{2b+d} \times t$$

$$J_w = \frac{(2\times120+200)^3}{12} - \frac{120^2(120+200)^2}{2\times120+200} \times 0.7\times h$$

$$\boxed{J_w = 2649407.52h}$$

Secondary stress, $\tau_2 = \frac{M_t \times r}{J_w}$

$$= \frac{17010000 \times 132.55}{2649407.52h}$$

$$\tau_2 = \frac{851.01}{h} \text{ N/mm}^2$$

Resultant stress, $\tau = \sqrt{\tau_1^2 + \tau_2^2 + 2\tau_1\tau_2\cos\theta}$

$$95 = \sqrt{\left(\frac{96.44}{h}\right)^2 + \left(\frac{851.01}{h}\right)^2 + 2\left(\frac{96.44}{h}\right)\left(\frac{851.01}{h}\right) \times 0.656}$$

$$95 = \frac{917.17}{h}$$

$$\boxed{h = 9.65 \simeq 10 \text{ mm}}$$

(6) Two 15 mm thick plate are to be joined by a triple riveted double cover strap butt joint. The rivet pitch is to be the same in all rows and chain riveting is to be used. Determine rivet diameter, rivet pitch distance b/w rows of rivets, strap thickness & efficiency of the joint.

Tensile stress in steel plate = 84 N/mm^2

Shear stress in steel rivets = 63 N/mm^2

GV:

Thickness of the plate, $t = 15$ mm

Tensile stress in steel plate $= \sigma_t = 84$ N/mm^2

Shear stress in steel rivets, $\tau = 63$ N/mm^2

S/n.

i. Diameter of the rivet, d:

$$d = 6\sqrt{t} = 23.24 \text{ mm}$$

ii. Pitch of the rivet, P:

Tearing strength of the rivet joint,

$$F_t = (P-d) \times t \times \sigma_t$$

$$= (P - 24) \times 1260 \quad -(1)$$

Shearing strength of the rivet, $F_s = i \times n \times \frac{\pi d^2}{4} \times \tau$

$$= 3 \times 1.875 \times \frac{\pi \times 24^2}{4} \times 63$$

$$\boxed{F_s = 160315.47N} \quad - (2)$$

equating (1) & (2)

$$(P - 24) \times 1260 = 160315.47$$

$$\boxed{P = 152 \text{ mm}}$$

Max. pitch, $P_{max} = Ct + 41$

Factor C for triple riveted butt joint is 4.63

from table 3.14.

$$P_{max} = 4.63 \times 15 + 41$$

$$= 111 \text{ mm}$$

actual pitch of the rivet, $P > P_{max}$

$$P = P_{max} = \underline{111 \text{ mm}}$$

(iii) Distance b/w two rows, P_b:

$$P_b = 3d = \underline{72 \text{ mm}}$$

(iv) Strap thickness, t_1:

$$t_1 = 0.625 \times t$$

$$\boxed{t_1 = 9.37 \text{ mm}}$$

(vi) Efficiency of the joint, η:

$$F_t = (111 - 24) \times 1260$$

$$= 109620 \text{ N}$$

least F_t & F_s is, $\Rightarrow F_t = 109620$ N

$$\eta = \frac{\text{least of } F_t \text{ and } F_s}{p \times t \times \sigma_t} = \frac{F_t}{p \times t \times \sigma_t}$$

$$\eta = 0.78 \Rightarrow \underline{78\ \%}$$

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(9) Two length of mild steel tie rod having width 200 mm are to be connected by means of Lozenge joint with two cover plates to withstand a tensile load of 180 KN. Completely design the joint if the permissible stresses are 80 MPa in tension, 65 MPa in shear and 160 MPa in crushing. Draw a neat sketch of the joint.

<u>GV:</u> width, $b = 200$ mm

Joint type = Lozenge joint

$P = 180$ KN $= 180000$ N

$\sigma_t = 80$ N/mm^2

$\tau = 65$ N/mm^2

$\sigma_c = 160$ N/mm^2.

Sln:

Lozenge joint is a special joint of double cover plate butt joint. Mainly used in bridges, girders etc.

$$\sigma \cancel{P} = \frac{L}{A}$$

Area of mild steel, $A = \frac{P}{\sigma_t} = \frac{180000}{80}$

$$\boxed{A = 2250 \ mm^2}$$

$$A = W \times T$$

$$\therefore T = \frac{A}{W} = \frac{2250}{200} \Rightarrow 11.25 mm$$

11.25 mm - min. thickness, to withstand the ~~th~~ load of 18 kN. By the std. thickness including the F.O.S.

$$\boxed{t = 12.5 \ mm}$$

(i) Diameter of the rivet, d:

$$d = 6\sqrt{t} = \underline{21.2 \ mm}$$

(ii) Thickness of the butt strap, t_1:

$$t_1 = 0.75 t$$

$$\boxed{t_1 = 10 mm}$$

(iii) Number of rivets, N:

$$F_s = n \times \frac{\pi d^2}{4} \times \tau$$

$$= 1.875 \times \frac{\pi \times 22^2}{4} \times 65$$

$$\boxed{F_s = 46328.6\,N}$$

$$F_c = d \times t \times \sigma_c = 44000\,N$$

Tearing strength, $F_t = (b - d) \times t \times \sigma_t$

$$\boxed{F_t = 178000\,N}$$

Min. number of rivets required, n

$$n = \frac{\text{Tearing strength of the plate}}{\text{Lowest strength of one plate}}$$

$$= \frac{178000}{44000} \Rightarrow \underline{5 \text{ rivets}}.$$

(iv) Pitch of the rivet, P

$$P = \frac{b}{2} \Rightarrow 100\,mm$$

(v) Margin of the rivet, m

$$m = 1.5\,d$$

$$\boxed{m = 33\,mm}$$

(Vi) Transverse pitch, P_b:

Pitch of the rivet along section B-B & C-C.

$$P_b = 2.5d = \underline{55\,mm}$$

(Vii) Efficiency of the rivet joint, η:

Tearing of plate A-A,

$$F_{t_1} = (b-d) \times t \times \sigma_t = 178000\,N$$

Tearing of plate along section B-B + Tearing of one rivet at section A-A.

$$F_{t_2} = (b-2d) \times t \times \sigma_t + 1.875 \times \frac{\pi d^2}{4} \times \tau$$

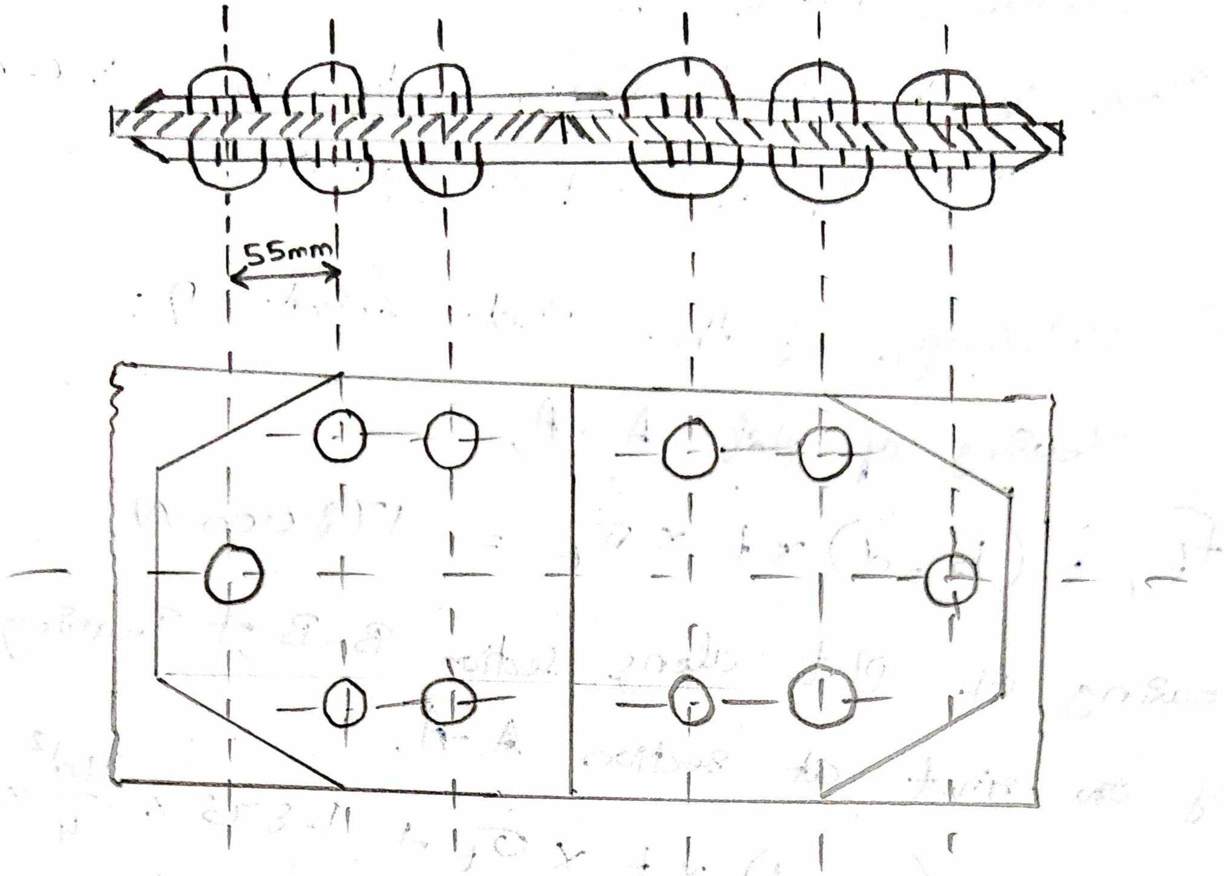
$$= (200 - 2 \times 22) \times 12.5 \times 80 + 1.875 \times \frac{\pi \times 22^2}{4} \times 65$$

$$\boxed{F_{t_2} = 202328.67\,N}$$

Tearing strength of plate along section C-C + Shearing of three rivets.

$$F_{t_3} = (b-2d) \times t \times \sigma_t + 3 \times 1.875 \times \frac{\pi d^2}{4} \times \tau$$

$$\boxed{F_{t_3} = 294986.02\,N}$$



Shearing strength of all the rivets,

$$F_s = 5 \times 1.875 \times \frac{\pi d^2}{4} \times \tau$$

$$\boxed{F_s = 231643.37\,N}$$

Crushing strength of all the rivets,

$$F_c = 5 \times d \times t \times \sigma_c$$

$$\boxed{F_c = 220000\,N}$$

Least F_c, F_s, F_{t_1}, F_{t_2} & F_{t_3} is $F_{t_1} = 178000N$

$$\eta = \frac{\text{least of } F_s, F_c, F_{t_1} \text{ \& } F_{t_3}}{b \times t \times \sigma_t}$$

$$= \frac{F_{t_1}}{P \times t \times \sigma_t}$$

$$= \frac{178000}{200 \times 12.5 \times 80}$$

$$= 0.89$$

$$\boxed{\eta = 89\%}$$

B.Bh

Prepared By

Approved By

17/8/23

Verified By