GOVERNMENT

POLYTECHNIC

VAISHALI

Sub: Design of structures (1615604)

Unit - 5 Shear, Bond & Development Length (LSM)

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UNIT-5 Shear Design; BOND AND DEVELOPMENT LENGTH

⇒ 1st find ultimate S.F (V_u) = $1.5 V$

V = Working S.F due to applied loads.

* Nominal shear stress $(\tau_v) = \left(\frac{V_u}{bd}\right)$, Rectangular section

and $(\tau_v) = \frac{V_u}{b_w \times d}$ ⇒ for flanged section

$\tau_{c(max)}$ is taken from IS: 456:2K Table 20.

Grade of Concrete	M15	M20	M25	M30	M35	M40 and above
$\tau_{c(max)}$	2.5	2.8	3.1	3.5	3.7	4.0

* Codal provisions ($\tau_v > \tau_{c(max)}$)

If $\tau_v > \tau_{c(max)}$ ⇒ then Diagonal comp. failure occurs.

(i) In this case, increase grade of concrete (but practically Not possible.)

(ii) depth 'd' can be ~~decreased~~ increase

∵ $\boxed{\tau_v \propto \frac{1}{d}}$

τ_c ⇒ for Grade of concrete with % of steel.

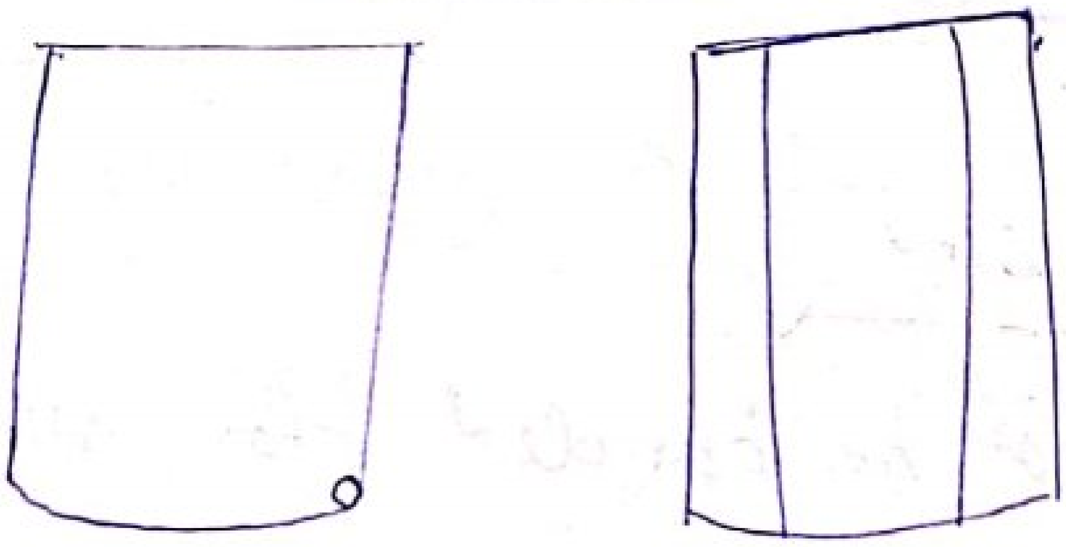
* ⇒ If $\tau_v < 0.5 \tau_c$ ⇒ No need of shear Reinforcement.

⇒ If $0.5 \tau_c < \tau_v < \tau_{c}$ ⇒ Min shear Reinforcement is to be provided.

$$\frac{A_{sv}}{b \cdot s_v} \geq \frac{0.40}{0.87 f_y}$$

A_{sv} = Area of stirrups
s_v = spacing of stirrups.

$$B \cdot S_v = 2.175 A_{sv} \cdot f_y$$



2-Legged 4-Legged

$\hookrightarrow A_{sv} = 2 \times \frac{\pi}{4} \times 8^2$

$= 100 \text{ mm}^2$

Note: Mild steel (M.S) or plain bars have to be provided as stirrups.
HYSD bars should not be used as stirrups, because they are brittle in Nature.

* If $\tau_v > \tau_c \Rightarrow$ provide shear reinforcement for V_{us}

$V_{us} = (\tau_v - \tau_c) \times bd$ in the form of

a) vertical stirrups

~~$S_v = \left[\frac{0.87 f_y A_{sv}}{V_{us}}\right]$~~

$$S_v = \frac{0.87 f_y \cdot A_{sv} \cdot d}{V_{us}}$$

b) for inclined stirrups.

$$S_v = \frac{0.87 f_y \cdot A_{sv}\, d\,(\cos\alpha + \sin\alpha)}{V_{us}}, \quad \alpha = 45^\circ$$

c) Bent up bars

$$V_{us} = 0.87 f_y \cdot A_{sv} \cdot \sin\alpha$$

Note
Bent-up-bars should not be provided for more than 50% of V_{us}.

* Shear Reinforcement must be in the combination of vertical stirrups + inclined stirrups

OR

vertical stirrups + Bent up bars

spacing of stirrups

(I) Vertical stirrups

min {
a) calculate value of S_v
b) 0.75d
c) 300 mm
}
take which ever is less.

(II) For inclined stirrups

a) calculated value of S_v
b) d
c) 300 MM

Take which ever is less.

Excercise (1) 300 mm x 450 mm (eff)

given $V_u = 80$ KN, M20, $\tau_c = 0.75$ MPa, $\tau_{c,max} = 2.5$ MPa

What is the specing 2-legged 8 mm vertical stirrups.

(a) 240 mm c/c (b) 180 mm c/c ✓ (c) 280 mm c/c (d) 300 mm

soln $\tau_v = \frac{V_u}{bd} = \frac{80 \times 10^3}{300 \times 450} = 0.59$ N/mm²

$\because \tau_v < \tau_c \Rightarrow$ so provide min shear reinforcement.

$\therefore \frac{A_{sv}}{b \cdot S_v} = \frac{0.40}{0.87 f_y} \Rightarrow S_v = \frac{A_{sv} \times 0.87 f_y}{0.40 \times b}$

$\Rightarrow S_v = \frac{2 \times \frac{\pi}{4} \times 8^2 \times 0.87 \times 250}{0.40 \times 300} = 182.1$ mm

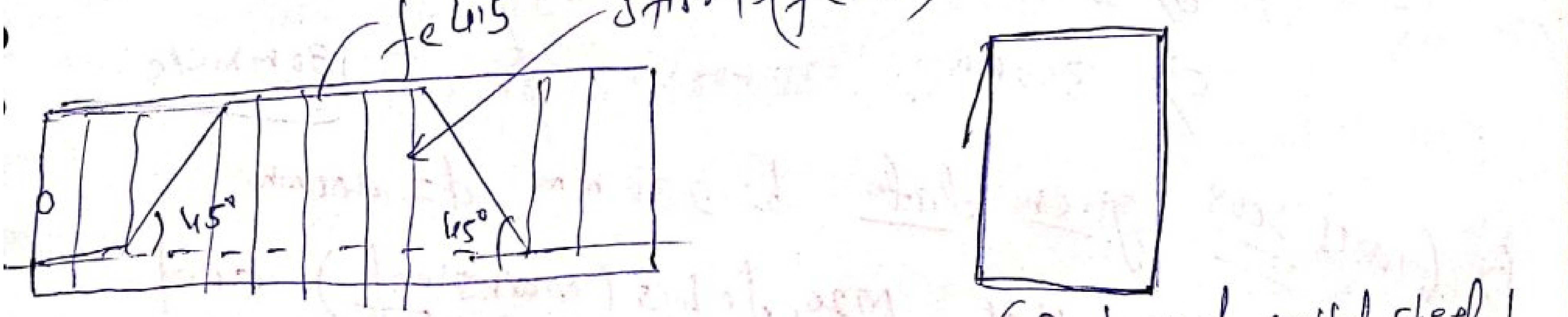
Also a) 182.1 mm

b) $0.75d = 0.75 \times 400 = 337.5$ mm

c) 300 mm

$= 182.1$ mm $\simeq 180$ mm

(II) for above question of $V_u = 250$ kN, 2-16 mm φ fe415 grade bent up with 45° Angle provided then what is the specing of (S_v) of vertical stirrups.



a) 180 mm c/c

b) 200 mm c/c

c) 300 mm c/c

d) 130 mm c/c ✓

$\therefore \tau_v = \frac{V_u}{bd} = \frac{250 \times 10^3}{300 \times 450} = 1.85$ N/mm²

If $\tau_v > \tau_{c,max} \Rightarrow$ it ~~must be~~ Redesign. but $\tau_v \not> \tau_{c,max}$

If $\tau_v > \tau_c \Rightarrow$ It is the case of min reinforcement provided.

$\frac{V_{us}}{\phi} = (\tau_v - \tau_c) bd = V_u - \tau_c bd$

shear taken by steel $= 250 - (0.75 \times 300 \times 450) \times 10^{-3} = 148.75 \text{ kN}$.

V_{us} of bent up bars $= 0.87 f_y A_{st} \sin 45°$

$= [0.87 \times 415 \times 2 \times \frac{\pi}{4} \times 16^2 \times \sin 45°] \times 10^{-3}$

$= 102.6 \text{ kN}$

V_{us} by vertical stirrups $= 148.75$ (as per above)

✓ Now as per code 50% of V_{us} is taken by bent up bars $= \frac{148.75}{2} = 74.38 \text{ kN} = V_{us2}$

and remaining 50% is taken by vertical stirrups.

$\therefore S_v = \frac{0.87 f_y A_{sv} \times d}{V_{us2}} = \frac{0.87 \times 250 \times 100 \times 450}{74.38 \times 10^3}$

$S_v = 132.3 \text{ mm}$

Also a) $= 132.3 \text{ mm}$

b) $0.75d = 0.75 \times 450 = 337.5$

c) 300 mm

$= 132.3 \text{ mm}$

$= 130 \text{ mm c/c}$

Q GATE 2008 given data $b = 230 \text{ mm}$, $d = 400 \text{ mm}$

$V_u = 120 \text{ kN}$, M20, fe415 (main steel) and fe250 stirrups and $\tau_c = 0.48 \text{ N/mm}^2$.

calculate spacing of 2-8mm stirrups (two-legged)

(a) 40 (b) 115 (c) 250 (d) 400

soln ∴ $V_{us} = 120 - (0.48 \times 230 \times 400) \times 10^{-3} = 75.84$ kN.

$$S_v = \frac{0.87 f_y A_{sv} d}{V_{us}} = \frac{0.87 \times 250 \times 2 \times \frac{\pi}{4} \times 8^2 \times 400}{75.84 \times 10^3}$$

$S_v = 115.32$ mm c/c

Q GATE-2011 Two R.C.C beams P and Q

c/s 400 × 750 mm (eff) for both. $\tau_{c,max} = 2.1$ N/mm²

$\tau_c = 0.75$ N/mm², V_u for P = 400 kN

V_u for Q = 750 kN

then which one of the followings are correct.

a) $V_{us} = 175$ kN for P, Q should be redesigned.

b) ~~V_{us}~~ Nominal shear reinforcement for P, $V_{us} = 120$ kN for Q

c) $V_{us} = 175$ kN for P, $V_{us} = 525$ kN for Q

d) P & Q should be revised.

soln for beam P

$V_{us} = V_u - \tau_c b d$

$= 400 - (0.75 \times 400 \times 750) \times 10^{-3}$

$= 175$ kN.

$$\tau_v = \frac{400 \times 10^3}{400 \times 750} = \frac{4}{3} = 1.25$$

$\tau_v > \tau_c$ only

∴ $\tau_{c,max} = 2.1$ N/mm²

for Beam Q

$$\tau_v = \frac{V_u}{bd} = \frac{750 \times 10^3}{400 \times 750}$$

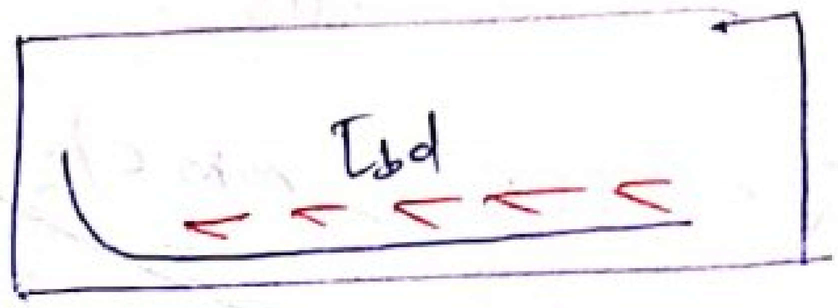
$= 2.5$ N/mm²

∴ $\tau_v > \tau_{c,max}$ so,

It should be redesigned

Topic 6 Pg^n for Bond and Anchorage

(I) **Bond** → It is the stress transfer media from concrete to steel.



τ_{bd} = Bond stress.

⇒ Bond is nothing but it is shear-resistance.

Factor affecting Bond stress (τ_{bd})

(I) pure adhesion.
(II) frictional resistance → it is due to friction b/w concrete and steel.
(III) Mechanical Resistance ⇒ provided hooks.

⇒ In case of M.S bond is due to frictional resistance only but in case of TOR steel (focus) not only due to friction but also due to Mechanical Resistance.

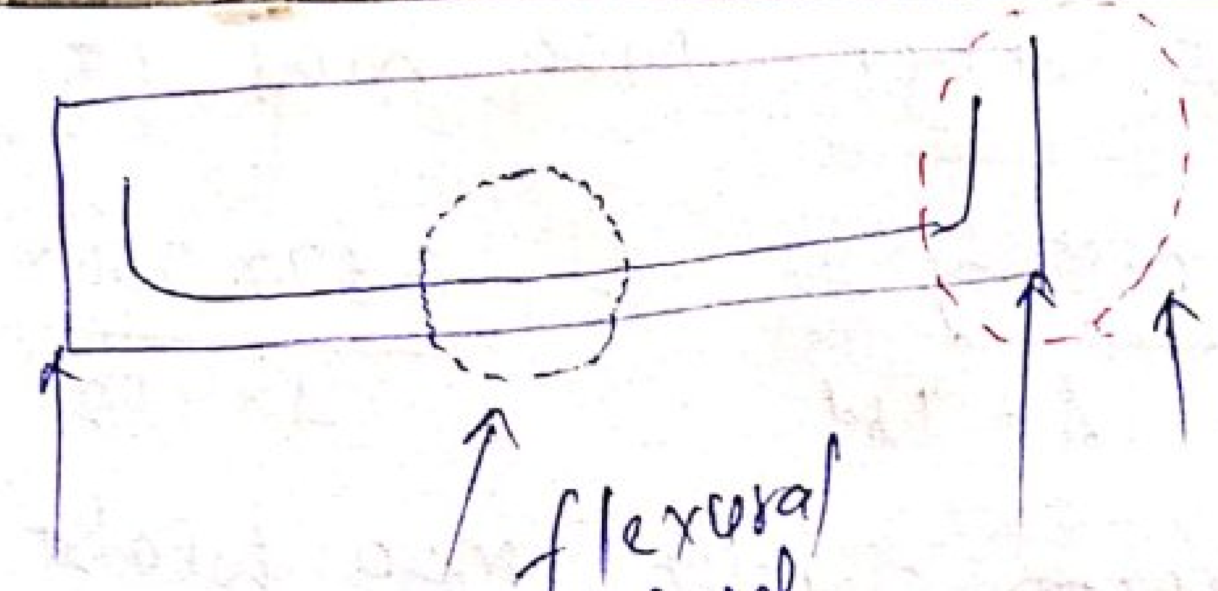
Note → Bond length in HYSD bars is more than M.S bars.

Critical section for bond:

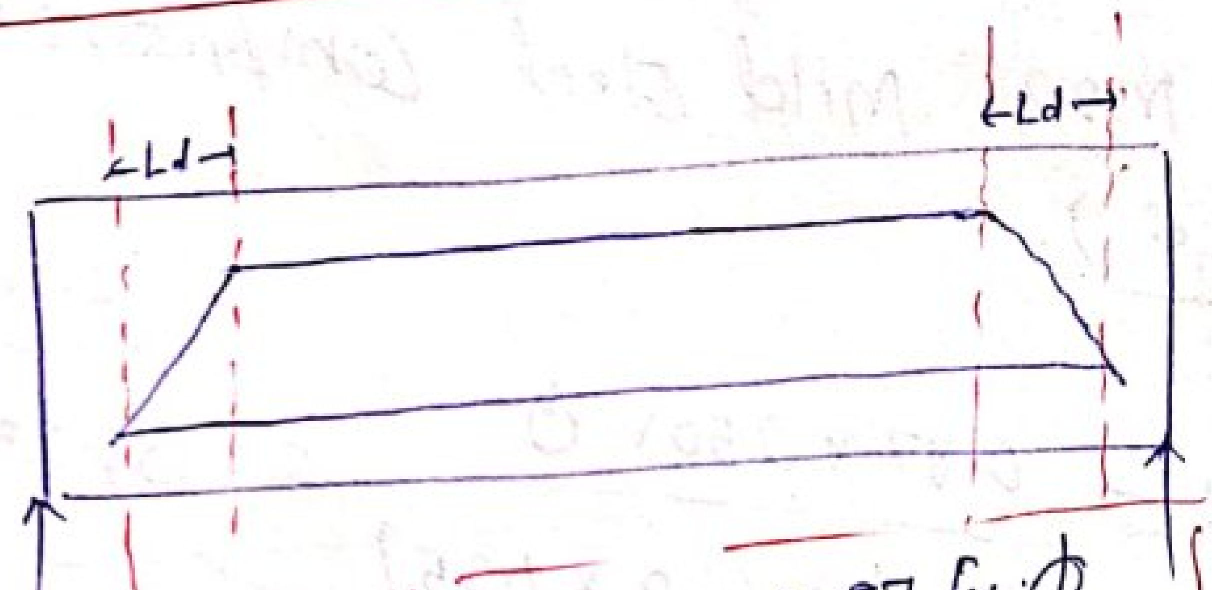
(I) At the face of support.
(II) At the section of max stress.
(III) At point of contra-flexure.

Types of Bond

(I) Flexural bond and (II) Anchorage bond



☆ Developement Length (Ld)



As per IS 456 $L_d = \frac{0.87 f_y \phi}{4 \tau_{bd}}$ ⇒ This formula is valid for plain bars or mild steel bars in tension.

τ_{bd} values

Grade of Concrete	M20	M25	M30	M35	M40 and above
τ_{bd} (N/mm²)	1.2	1.4	1.5	1.7	1.9

Note (i) for HYSD bars τ_{bd} values should be increased by 60% due to additional Mechanical Resistance. i.e 1.6 time of τ_{bd}

VVI (ii) for bars in Compression τ_{bd} value should be increased by another 25%

i.e 1.25 times of τ_{bd} due to Comp.

Ex ① for M.S, Tension, M20 What is Ld.

$$Ld = \frac{0.87 f_y \times \phi}{4 \times \tau_{bd}} = \frac{0.87 \times 250 \times \phi}{4 \times 1.2} = 45.3\phi$$

Ex ⑪ for HYSD, Tension, M20 What is Ld ?

$$Ld = \frac{0.87 \times 415 \times \phi}{4 \times (1.2 \times 1.6)} = 47\phi \quad \tau_{bd} = 1.2$$

Ex ③ for M20, Mild steel compression what is Ld ?

$$\therefore Ld = \frac{0.87 \times 250 \times \phi}{4 \times (1.2 \times 1.25)} = 36.25\phi$$

Ex ④ for M20, HYSD in Comp the Ld =

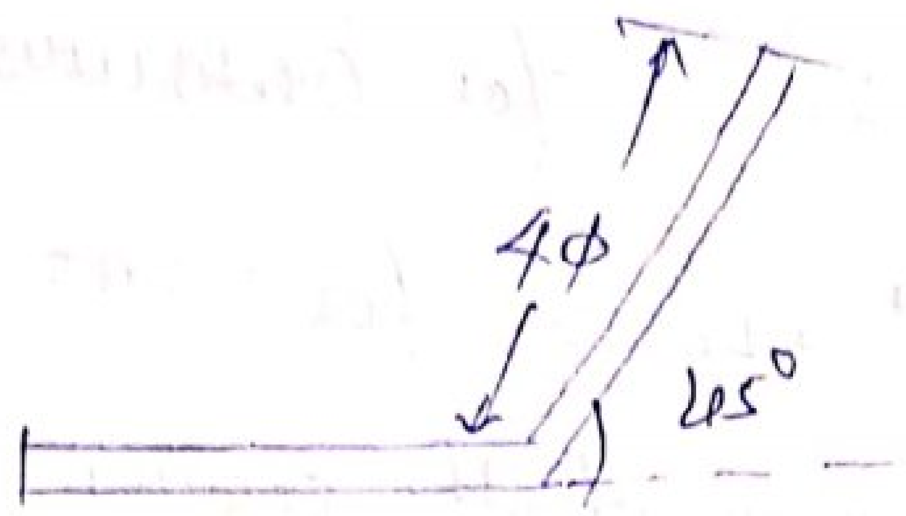
$$Ld = \frac{0.87 \times 415 \times \phi}{4 \times (1.2 \times 1.6 \times 1.25)}$$

1.2 ← τ_{bd}, 1.6 ← Due to HYSD, 1.25 ← (Due to Comp)

$$\therefore Ld = 31.34\phi$$

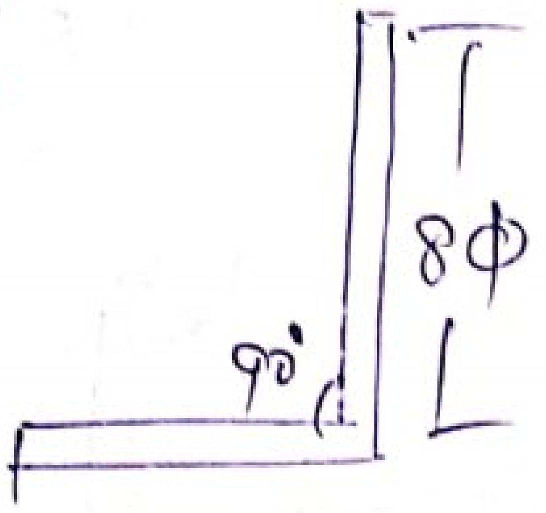
Bends and Hooks

(i) 45° Bent



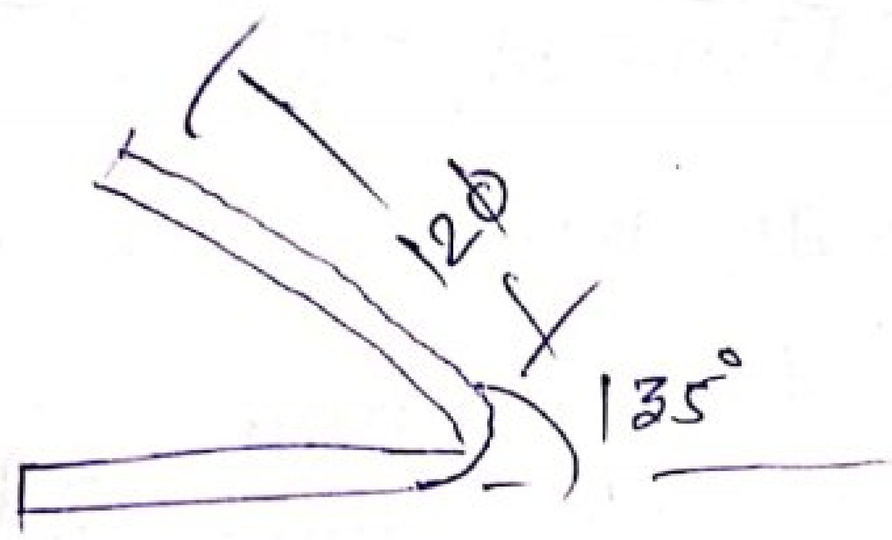
In this case $L_d = L_d(\text{calculated}) - 4\phi$

(ii) 90° Bend



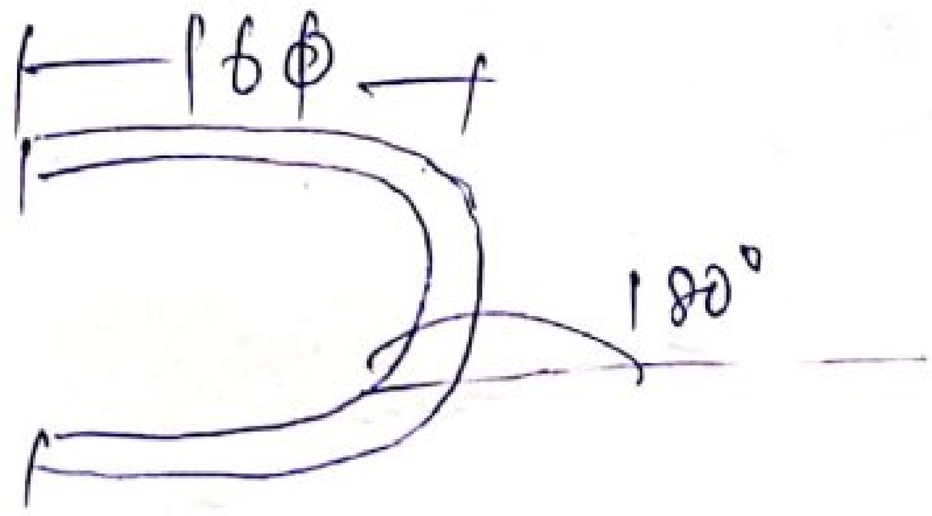
⇒ In this case $L_d(\text{req}) = L_d(\text{calculated}) - 8\phi$

(iii) 135° Bent



$L_d(\text{req}) = L_d(\text{calculated}) - 12\phi$

(iv) 180° Bent



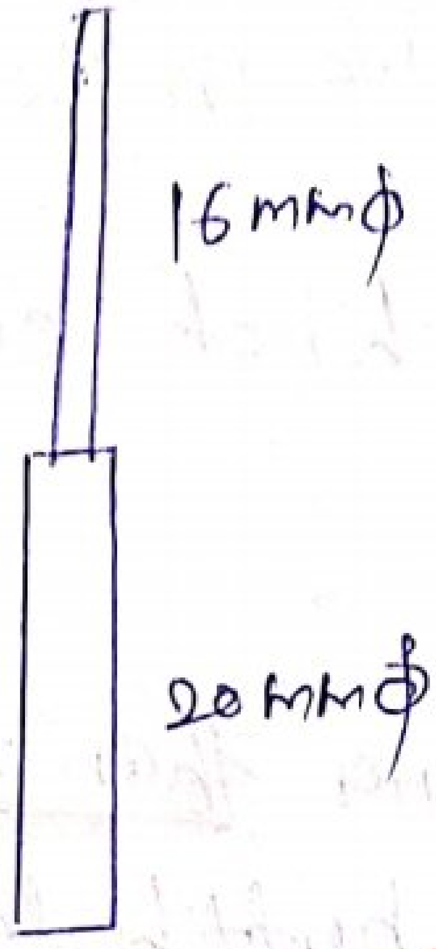
$L_{d,\text{req}} = L_d(\text{cal}) - 16\phi$

In All $L_d(\text{cal}) = \dfrac{0.87 f_y \phi}{4 \tau_{bd}}$

Note → Hooks are made ~~of~~ with M.S bars, but not HYSD since, HYSD is brittle in Nature.

So it fails

splicings ⇒ Joints in the bars are called splicings



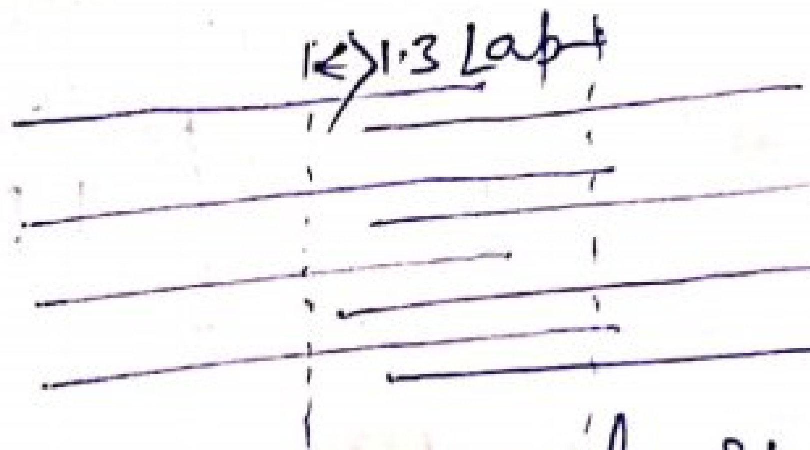
⇒ Why splicing provided

(I) If length required > Length available (12m)

(II) To change the diameter of the bars.

✱ Methods of splicings

(I) Lap splicings



(staggered splicings)

⇒ B.M due to external load should not be greater than M.R then bars can be spliced.

⇒ Not more than 50% of bars are placed.

⇒ Lap in Comp member should not be less than Developement length OR 24ϕ which ever is more.

i.e. Lap in Column
{ ≮ Ld
≮ 24ϕ } which ever is more

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