RCC

Self confidence → Achieve Daily Target → Multiple revision

To The Point-ByDhyanPal(ESE’17AIR-179,GATE’18AIR-93,GATE’16AIR-145)

WSM (assumption) :-

1- concrete, steel behave in linear elastic manner.

2- stress in concrete, steel is within permissible limit.

$$\text{Permissible stress} = \frac{\text{limiting strength}}{\text{FOS}}$$

in WSM FOS: concrete = 3, steel = 1.82

Grade	direct tensile strength	compression direct σ_{cc}	compression bending σ_{cbc}
M15	2	4	5
M20	2.8	5	7
M25	3.2	6	8.5
M30	3.6	8	10
M35	4	9	11.5
M40	4.4	10	13

$m = \frac{280}{3\sigma_{cbc}}$ → for tensile bars

N/mm² σ_{st}	fe250	fe415	fe500
$\phi \leq 20$	140	230	275
$\phi > 20$	130	230	275
σ_{sc}	130	190	190

Tension steel	• Shrikage reduces tensile stress ↓ • Creep produces additional tensile stress ↑
comp. steels	• shrinkage & creep causes more stresses

$m' = 1.5m$ in compression bars

↳ due to long term effect of creep & shrinkage of concrete and nonlinearity at higher strains in concrete results in much compressive stress in comp. steel.

WSM

$$x_c = \left(\frac{mc}{mc+t}\right)d$$

$$x_c = kd$$

$$M_{bal} = Qbd^2 = \left(\frac{1}{2}cjk\right)bd^2$$

$j = 1 - k/3$

$m = 280/3\sigma_{cbc}$

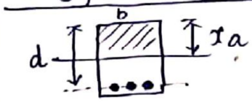
$c \rightarrow \sigma_{cbc}$

$t \rightarrow \sigma_{st}$

	$x_c = kd$ (k) WSM	$x_{ulim} = kd$ (k) LSM	M_{ulim} LSM
fe250	0.400	0.53	$0.148 f_{ck} bd^2$
fe415	0.289	0.48	$0.138 f_{ck} bd^2$
fe500	0.254	0.46	$0.133 f_{ck} bd^2$

singly reinforced section :-

take moment of area about NA

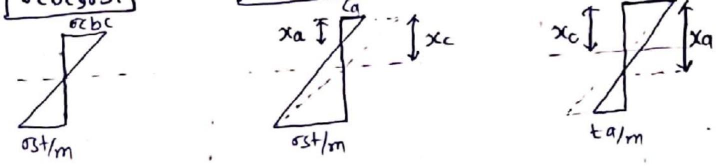


$x_a = ?$

$$(b x_a)\frac{x_a}{2} = m A_{st}(d - x_a)$$

MoR

- balanced section: $x_a = x_c$; $\sigma_{cbc}, \sigma_{st}$
- under reinforced section: $x_a < x_c$; σ_{st}, $C_a < \sigma_{cbc}$
- over reinforced section: $x_a > x_c$; σ_{cbc}, $t_a < \sigma_{st}$



Doubly reinforced section :- when provided ??

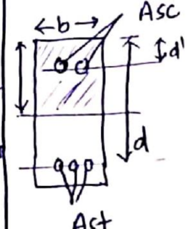
(i) where size (depth) restricted & $M > M_{balance}$

(ii) earthquake zone

use of compression steel : (i) Reduce long term Deflection

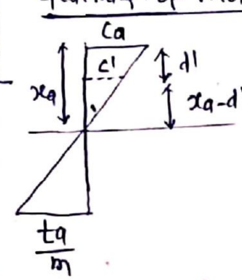
(ii) Increase ductility of beam

(iii) used as anchor bars to hold shear stirrups.



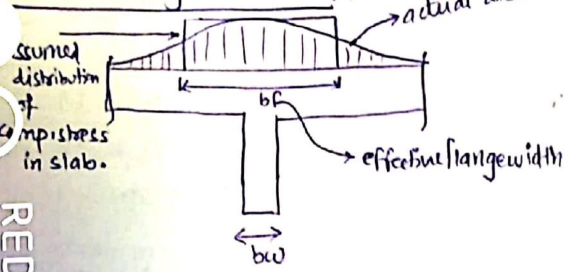
$$\frac{b x_a^2}{2} + (1.5m - 1)A_{sc}(x_a - d') = mA_{st}(d - x_a)$$

General eqn of MoR :-



$$MoR = \frac{C_a}{2}(b x_a)\left[d - \frac{x_a}{3}\right] + (1.5m - 1)c' A_{sc}(d - d')$$

effective flange width (bf) :-

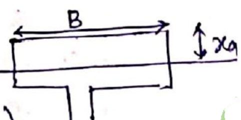


Beam casted monolithically with slab	Isolated beam
T :- $\min\left\{\begin{array}{l}\frac{l_o}{6}+b_w+6D_f\\ b_w+\frac{l_1}{2}+\frac{l_2}{2}\end{array}\right.$	$T \Rightarrow \left[\frac{l_o}{\frac{l_o}{b}+4}\right]+b_w$
L :- $\min\left\{\begin{array}{l}\frac{l_o}{12}+b_w+3D_f\\ b_w+\frac{l_1}{2}\end{array}\right.$	$L \Rightarrow \left[\frac{0.5 l_o}{\frac{l_o}{b}+4}\right]+b_w$

l_o (point of zero moment dist) :-	l_o
SSB & series of beam supported on masonary wall	l_{eff}
continuous beam	$0.7\, l_{eff}$

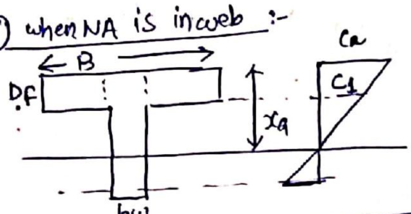
T beam :-

(i) when NA in flange :-



(Solve as single reinforced beam)

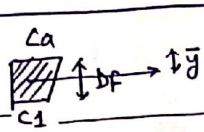
(ii) when NA is in web :-



$x_a = ?$ neutral axis calculation

$$(b_w x_a)\frac{x_a}{2} + (B-b_w)D_f\left(x_a-\frac{D_f}{2}\right) = mA_{st}(d-x_a)$$

MOR :-



$$(b_w x_a)\frac{C_a}{2}\left(d-\frac{x_a}{3}\right) + \frac{1}{2}(C_a+C_1)(D_f\times(B-b_w))\times[d-\bar{y}]$$

$$\bar{y} = \left(\frac{C_a+2C_1}{C_a+C_1}\right)\times\frac{D_f}{3}$$

IS 456 :- Admixture

mineral admixture	chemical admixture
(i) fly ash	(1) water reducing / plasticizer [calcium lignosulphate]
(ii) silica fume	(2) accelerating admixture (calcium chloride, fluo silicate's, Tri ethanolamine)
(iii) rice husk ash	(3) Retarding admixture (Sodium tartrate, Tartaric acid)
	(4) Air entraining Admixture [Aluminium powder, neutralised vinsol resin]

note :-

(i) Admixture → not increase strength

(ii) Antibleeder → $Al_2(SO_4)_3$ (Aluminium sulphate)

Grade of concrete :- Amendment no - 4, May 2013.

(3) ordinary concrete	M10, M15, M20
(8) standard concrete	M25, M30, M35, M40, M45, M50, M55, M60
(8) high strength concrete	M65, M70, M75, M80, M85, M90, M95, M100

direct tensile strength < Split tensile strength < flexural tensile strength < cylinder comp. strength < cube comp. strength

- direct tensile strength → $0.50 - 0.62\sqrt{f_{cr}}$ & $0.66 f_{cr}$; $0.7\sqrt{f_{ck}}$: $0.66\times(0.7\sqrt{f_{ck}}) = 0.462\sqrt{f_{ck}}$
- Split tensile strength: $\frac{2P}{\pi d l}$
- flexural tensile strength: $f_{cr} = 0.7\sqrt{f_{ck}}$ (modulus of rupture)
- cylinder comp. strength: $0.80 f_{ck}$
- cube comp. strength: f_{ck}

Short term modulus of elasticity: $E_c = 5000\sqrt{f_{ck}}$

long term or effective modulus of elasticity using creep coefficient: $E_{ce} = \frac{E_c}{1+\theta}$

θ → 2.2 (7 day), 1.6 (28 day), 1.1 (1 year) • Logarithm variation with time

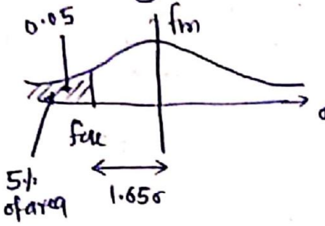
*

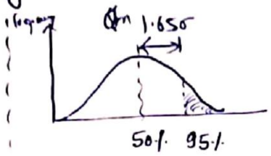
IS 456 :- max. size of coarse agg ≯ $\frac{1}{4}$th of thickness of member

Target mean strength $f_m = f_{cu} + 1.65\sigma$

characteristic strength (f_{cu}) :- below which not more than (5%) test results are expected to fall.

Characteristic load :- has a (95%) Probability of not being exceeded during life.





$f_m = f_{cu} + 1.65\sigma$ → char. strength

$Q_{cu} = Q_{mean} + 1.65\sigma$ → characteristic load; $Q_{mean} = \frac{\Sigma x_i}{n}$; $\sigma = \sqrt{\frac{\Sigma(x_i-\bar{x})^2}{n-1}}$

M	σ N/mm²
≤15	3.5
20–25	4
30–60	5

Quantity of concrete (m3)	samples
1–5	1
6–15	2
16–30	3

1 sample = 3 specimen

• compliance requirement (Acceptance criteria)

grade (> M15)

(i) mean of group of 4 nonoverlapping consecutive Test result ≥ $f_{cu} + 0.825\sigma$ or $f_{cu} + 3$ } max.

(ii) individual Test result ≥ $f_{cu} - 3$

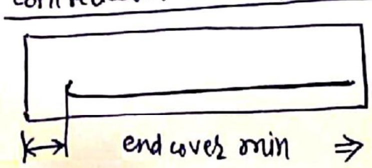
(iii) individual variation ≯ 15% of average

Probability of failure in LSM ⇒ 0.0975

failure cases			
load	X	✓	X
strength	X	X	✓

$p \Rightarrow \left(\frac{5}{100}\times\frac{5}{100}\right) + \left(\frac{95}{100}\times\frac{5}{100}\right) + \left(\frac{5}{100}\times\frac{95}{100}\right) = 0.0975$

concrete cover at end of reinforcement bars :-

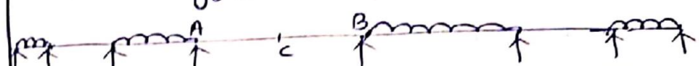


end cover min ⇒ max { 2φ, 25mm }

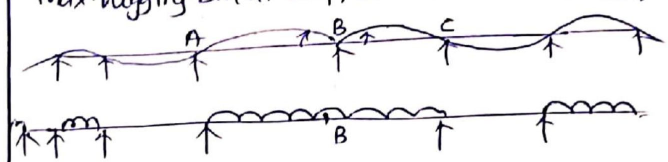
मतलब 25mm से ज्यादा होगी ।

max sagging moment b/w A & B (मतलब c)

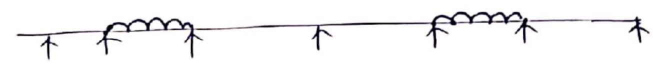
∴ max hogging moment b/w A & B (मतलब c)



max. hogging BM at support (like B)



∴ max. sagging BM at support B



Ultrasonic pulse velocity Test → NDT

• to assess quality of concrete insitu (used to obtain estimate of concrete strength of finished concrete element)

• to determine dynamic modulus of elasticity

Resonant frequency Test ⇒ vibration Technique using Ultrasonic wave

• to locate the presence of cracks in st.

Bond b/w steel & concrete → By Pull out Test acceptable limit for safety & serviceability requirement of str. before failure → limit state

limit state of collapse	limit state of serviceability
(to satisfy this, strength must be adequate to carry load)	• factors →
• Factors →	(i) Deflection
(i) Flexural (Bending)	(ii) Cracking
(ii) shear	(iii) vibration
(iii) Torsion	(iv) corrosion
(iv) compression	(v) Fire resistance
	(vi) leakage
	(vii) overturning

ILSM :- Basis of analysis of str. linear elastic theory.

note :-

• characteristic of concrete in actual structure

① strength ⇒ $0.67 f_{cu}$ or $\frac{f_{cu}}{1.5}$

[note :- this 1.5 fos → to account loading other than compressive and different shape of RCC member]

② design strength of concrete ⇒ $0.45 f_{cu}$ f_d

मतलब ⇒ $\frac{0.67 f_{cu}}{1.5}$

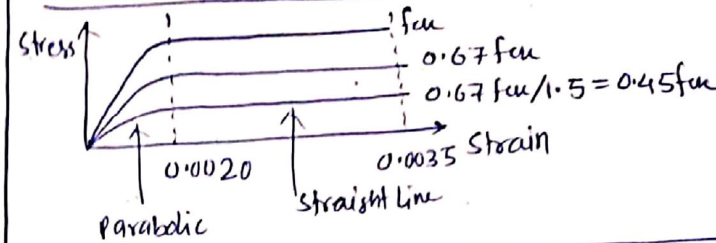
partial fos of concrete (1.5), steel (1.15)

③ design strength of steel (f_d) ⇒ $\frac{f_y}{1.15} = 0.87 f_y$

load combination	limit state of collapse			limit state of serviceability		
	DL	LL	WL	DL	LL	WL
DL + LL	1.5	1.5	_	1	1	-
DL + WL	1.5 or 0.9*	-	1.5	1	-	1
DL + LL + WL	1.2	1.2	1.2	1	0.8	0.8

[0.9* ⇒ when stability against overturning & stress reversal is critical where dead load ... gravity dam]

Stress-strain curve for concrete ..



Durability criteria :-

Exposure category	description	min RCC grade (M)	min PCC grade (M)	min nominal cover (mm)	RCC min cement (kg/m³)	max W/C ratio
mild	• normal • protect against weather or aggresive condition (except if located in coastal area)	20	-	20	300	0.55
moderate	• shelter from severe rain • continuously in water • non aggressive soil or ground water • Alternate freezing & Thawing	25	15	30	300	0.50
severe	• exposed to coastal environment (immersed in sea water) • Exposed to severe rain • Alternate drying & wetting • severe condensation	30	20	45	320	0.45
very severe	• sea water spray • contact with or buried under aggresive soil or grd. water	35	20	50	340	0.45
extreme	• tidal zone • members in direct contact with liq/solid aggresive chemical	40	25	75	360	0.40

note ① mild ⟶ if $\phi_{main} \leq 12$ mm ⟶ then cover reduced by 5mm

② severe & very severe ⟶ if $m \geq M35$ then cover reduced by 5mm

PH of water should not be less than 6 for making concrete.

(IS 456) Permissible limits for solids :- (OSCSI)

organic	sulphates (as SO_3)	chloride (as cl)	suspended solids	Inorganic solids
200	400	500 – RCC 2000 – PCC	2000	3000

type of formwork	min. period Before striking formwork
① vertical formwork (Column, wall, beam)	16 – 24 hr
② soffit formwork to (slab)	3 days
③ ———— (beam)	7 days
④ Props to (slab) span ≤ 4.5 m	7 day
span > 4.5 m	14 day
⑤ Props to (beam) & (arch) span ≤ 6 m	14 day
span > 6 m	21 day

note:- above specification valid for OPC & where temp > 15°C and adequate curing is done

- for other cements & lower temp. above time can be modified.

Bacterial concrete → (self healing concrete for crack repair)

under water concreting methods →
① Tremie pipe method (II) Direct placement with pumps (III) Drop bottom bucket (IV) Grouting

3 constituents adversely affect the concrete :-

① chlorides	• increases rate of corrosion to steel • due to this chloride content of admixture is tested separately
② sulphates (as SO_3)	• cause expansion & disruption of concrete
③ Alkali – Aggregate reaction ($Na_2O + K_2O$)	originating from cement, producing an expansive rxn which can cause cracks and disruption of concrete

Degree of workability	placing condition
very low	in highway construction
low	mass concreting, light reinforced section
medium	Heavy reinforced section & when pumping of concrete is required
High	Insitu piling
very high	Insitu piling using Tremie concrete.

note:-

	slump
vibrated concrete	12 – 25 mm
Concrete for road work	20 – 30
mass concrete	25 – 50
ordinary RCC work	50 – 100
Column, retaining wall	75 – 150

Assumption in Limit state of collapse :- flexure :-

① plain section before bending remains plain after bending (strain diagram → linear)

② max. strain in concrete at outermost compressed fibre = 0.0035 in bending.

③ Relationship b/w comp. stress distribution in concrete & steel can be assumed rectangular, trapezoidal, parabolic or any shape, which results in prediction of strength matching with test result.

④ Tensile strength of concrete is ignored.

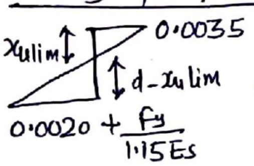
⑤ for design purpose partial safety of factor of steel = 1.15 & stress in steel are derived from stress strain curve.

⑥ max. strain in tension reinforcement $\nless$ $0.0020 + \frac{f_y}{1.15 E_s}$

note: # under reinforced section → deeper & undergo larger deflection than Balanced & over rein. section.

over reinforced section → stiffer than under reinforced section

limiting depth of NA : ($x_{u\,lim}$) → corresponds to Balanced section.



→ solve by similar Δ

v.v.v.v.Imp

	$x_{u\,lim}$	$M_{u\,lim}$	$P_{t\,lim}$ ($\frac{A_{st\,lim} \times 100}{bd}$)	$0.002 + \frac{0.87 f_y}{E_s}$ Strain in tension reinforcement
Fe250	0.53d	$0.148 f_{ck} b d^2$	$0.088 f_{ck}$	0.0031
Fe415	0.48d	$0.138 f_{ck} b d^2$	$0.048 f_{ck}$	0.0038
Fe500	0.46d	$0.133 f_{ck} b d^2$	$0.038 f_{ck}$	0.0042

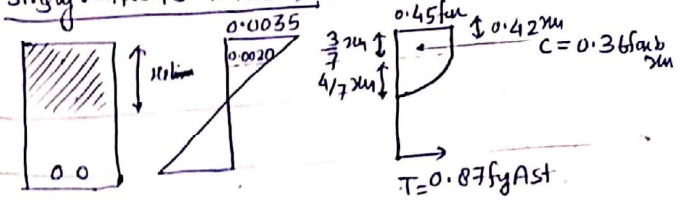
note:- Tensile reinforcement

$$\frac{A_{st\,min}}{bd} = \frac{0.85}{f_y}$$

$A_{st\,max}$ = 4% of gross → to avoid compression failure of concrete before tension failure of steel.

$A_{sc\,max}$ Compressive reinforcement = 4% of gross

Singly reinforced section (LSM) :-



C_1 = compressive force of rectangular portion
= area of stress dia × width of section
$= \left[0.45 f_{ck} \times \frac{3}{7} x_u\right] \times b = 0.193 f_{ck} b x_u$

C_2 (Parabolic) $= \left[\frac{2}{3} \times 0.45 f_{ck} \times \frac{4}{7} x_u\right] \times b = 0.171 f_{ck} b x_u$

$C = C_1 + C_2 = 0.36 f_{ck} b x_u$ | $T = 0.87 f_y A_{st}$

$y_1 = \frac{3}{14} x_u$ from top $y_2 = \frac{3}{7} x_u + \frac{3}{8}\left(\frac{4}{7} x_u\right)$ from top

$$\bar{y} = \frac{C_1 y_1 + C_2 y_2}{C_1 + C_2} = 0.42 x_u$$

∴ lever arm $= d - 0.42 x_u$

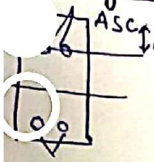
$$M_u = 0.36 f_{ck} b x_u (d - 0.42 x_u) = 0.87 f_y A_{st} (d - 0.42 x_u)$$

$$A_{st} = \frac{0.5 f_{ck} bd}{f_y}\left[1 - \sqrt{1 - \frac{4.6 M_u}{f_{ck} b d^2}}\right]$$

V. Imp :- if concrete partial fos = 1.5 is not considered then stress in compressed fibre = $0.67 f_{ck}$

hence $C = 1.5 \times (0.36 f_{ck} b x_u) = 0.54 f_{ck} b x_u$

Doubly reinforced section (LSM) :-



$A_{st} = A_{st1} + A_{st2}$

to know $x_u = ?$

$$(0.36 f_{ck} b x_u - 0.45 f_{ck} A_{sc}) + f_{sc} A_{sc} = 0.87 f_y A_{st}$$

'or'

$$0.36 f_{ck} b x_u + (f_{sc} - 0.45 f_{ck}) A_{sc} = 0.87 f_y A_{st}$$

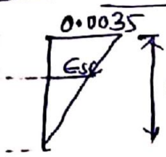
$$\therefore M_u = 0.36 f_{ck} b x_u (d - 0.42 x_u) + (f_{sc} - 0.45 f_{ck}) A_{sc} \times (d - d')$$

Design :- (M > Mbal or Mu > Mulim)	LSM ($M_u > M_{ulim}$)	WSM ($M > M_{bal}$)
A_{st1} =	$\frac{M_{ulim}}{0.87 f_y (d - 0.42 x_{ulim})}$	$A_{st1} = \frac{M_{bal}}{\sigma_{st}(d - \frac{x_c}{3})}$
A_{st2} =	$\frac{M_u - M_{ulim}}{0.87 f_y (d - d')}$	$A_{st2} = \frac{M - M_{bal}}{\sigma_{st}(d - d')}$
A_{sc} =	$\frac{M_u - M_{ulim}}{(f_{sc} - 0.45 f_{ck})(d - d')}$	$A_{sc} = \frac{M - M_{bal}}{(1.5m - 1) c'(d - d')}$

imp
note:- if in question it is written → neglect the reduction of comp. force due to removal of concrete for placing compressive steel (A_{sc})
मतलब eqn में से $0.45 f_{ck} A_{sc}$ वाला term हटादे

$$\Rightarrow 0.36 f_{ck} b x_u + f_{sc} A_{sc} = 0.87 f_y A_{st}$$

note:- How to calculate $\varepsilon_{sc} = ?$



$$\varepsilon_{sc} = 0.0035 \left(\frac{x_{u\,lim} - d'}{x_{ulim}} \right)$$

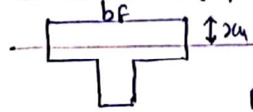
$\therefore$ yield strain $= \frac{0.87 f_y}{E_s}$

$\therefore f_{sc} = 0.87 \times f_y$ (f_y 250) ✓

note:- In doubly, strain in compressive reinforcement is higher than the strain in adjoining concrete.

T-beam (LSM) :-

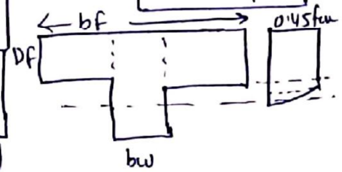
① when $x_u < D_f$



$$x_u = \frac{0.87 f_y A_{st}}{0.36 f_{ck} b_f} < D_f$$

$$M_u = 0.36 f_{ck} b_f x_u (d - 0.42 x_u)$$
$$M_u = 0.87 f_y A_{st} (d - 0.42 x_u)$$

② when $D_f < 3/7\, x_u$



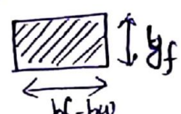
$$0.36 f_{ck} b_w x_u + 0.45 f_{ck} (b_f - b_w) D_f = 0.87 f_y A_{st}$$

$$M_u = 0.36 f_{ck} b_w x_u (d - 0.42 x_u) + 0.45 f_{ck} (b_f - b_w) D_f \left[d - \frac{D_f}{2}\right]$$

$$M_u = 0.87 f_y A_{st1} (d - 0.42 f_{ck}) + 0.87 f_y A_{st2} \left(d - \frac{D_f}{2}\right)$$

③ when $D_f > 3/7\, x_u$

convert $(b_f - b_w) D_f \longrightarrow (b_f - b_w) y_f$

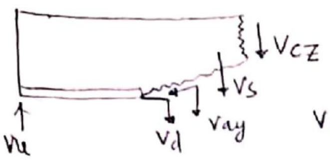


$$y_f = 0.15 x_u + 0.65 D_f$$ then solve.

note:- An Inverted T beam design as rect. beam over intermediate support of a continuous beam when BM is negative.

Shear span ⇒ span where shear force is constant

mechanism of shear resistance :-



$V_u = V_{cz} + V_{ay} + V_d + V_s$
(1) (2) (3)

V_{cz} ⇒ shear resistance by uncracked portion of concrete

V_{ay} → vertical component of aggregate interlock force
V_d → dowel force in tension bar

V_s → shear resisted by stirrups

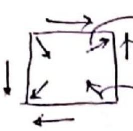
Steps :- (I) prior to flexural crack → all shear resisted by V_{cz} (uncracked portion)

(II) At commencement of crack ⇒ $(V_{ay} + V_d)$ developed

(III) at dia. tension crack V_s develops and all 4 mechanism exist.

diagonal Tension failure :- occures due to diagonal tension under large SF and Less BM.

- normally occures at 45° from horizontal.
- for diagonal tension → bent up bars, inclined stirrups & vertical stirrups used
- diagonal tension max at N.A and decreases above & below N.A (N.A → neutral axis)



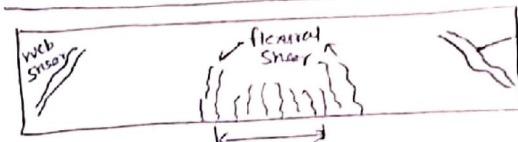
diagonal compression failure :- under large SF → Brittle failure

- It is characterised by crushing of concrete, normally it occures in beam which are reinforced against heavy shear.

note: $\tau_{cmax} = 0.62\sqrt{f_{ck}}$
for Ex. M_{20} $\tau_{cmax} = 2.8\ N/mm^2$
note :- for $\geq M40$ $\tau_{cmax} = 4\ N/mm^2$

Imp. By this provision failure of beam by diagonal compression can be prevented.

Shear cracks in structural concrete member :-

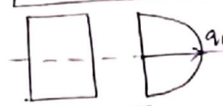


flexural shear crack → forms under large BM & less SF.

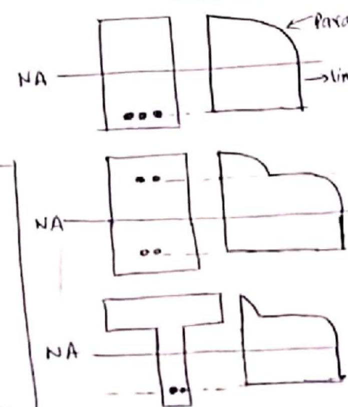
- occures normally at about (90°) with horizontal.

shear stress distribution

Homogeneous beam (as in 'SOM') | Reinforced concrete beam



$q = \frac{SA\bar{y}}{Ib}$

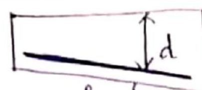


nominal or Avg. shear stress

$\tau_v = \frac{V_u}{bd} < \frac{V}{b \cdot jd}$ (based on elastic theory)

$b = b_w$ in case of flange section

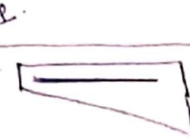
Beam of varying depth :- (But Reinforcement should be inclined)



$\tau_v = \frac{V_u - \frac{M_u}{d}\tan\beta}{bd}$

(−) ve sign if d↑ ⇒ BM↑) otherwise plus.

V. Imp. if



→ $\tau_v = V_u/bd$ {∵ β = 0}

τ_c → depend < Grade of concrete; Pt (% of tensile reinforcement only $\frac{A_{st} \times 100}{bd}$)

note :- if $P_t \geq 3$ then design shear strength will be constant

overall slab depth (mm)	≥ 300	- - - -	≤ 150
k	1		1.30

Shear strength of member under axial compression.

WSM - $S = 1 + \frac{5P}{A_g \cdot f_{ck}} \not> 1.5$ factors

LSM - $S = 1 + \frac{3P_u}{A_g \cdot f_{ck}} \not> 1.5$

min. shear reinforcement :-

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

v.imp: $f_y \not> 415$ { even if fe500 bar used but while calculation min shear reinforcement in this formula put 415 only. }

why needed →

① Sudden failure of beam prevented if — concrete cover burst; — Bond to tension steel is lost.

② Brittle shear failure arrested which would have occured without shear reinforcement therefore improves ductility.

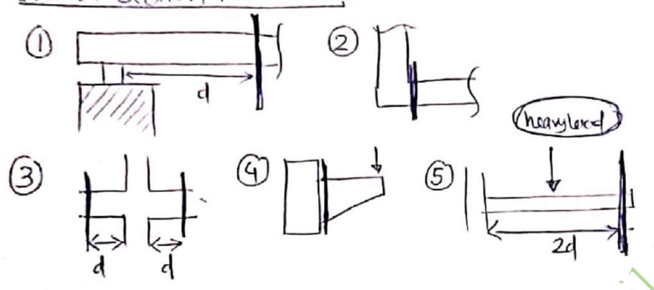
③ Tension failure prevented due to shrinkage, thermal stresses, internal cracking in beam.

④ to hold to reinforcement in place when concrete is poured.

⑤ to improve dowel action of longitudinal tension bars.

⑥ Section becomes effective with the effect of comp. steel

Critical section for shear :-



Shear reinforcement spacing max. min { $0.75d$ → vertical stirup; d → inclined; 300mm }

note :- stirups will not be able to resist shear unless an inclined crack cross them.

Shear reinforcement can be provided in the form of

① **vertical stirupps :-** *

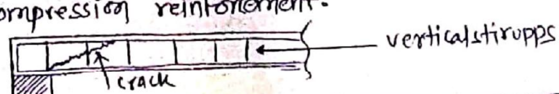
$$V_{us} = [(0.87 f_y)(A_{sv})]\left(\frac{d}{s_v}\right)$$

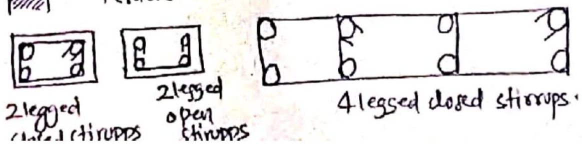
→ most effective form because →

- cracks intercepts • improve dowel action of long. reinforcement

Imp → Best for load reversal cases.

- Closed stirrups are better because it resist torsion & helps in confining the compression reinforcement in doubly-reinforced section and reduces the chances of buckling of compression reinforcement.





② **Inclined stirupps :** *

$$V_{us} = [(0.87 f_y)(A_{sv})]\left[\frac{d}{s_v}(\cos\alpha + \sin\alpha)\right]$$

- Ineffective in load reversal • most effective in reducing width of inclined cracks.
- can be provided in member having axial tension resulting in full depth of inclined cracks
- $\alpha \not< 45°$ because if $\alpha < 45° \Rightarrow$ there is a possibility of inclined stirupps sliping along the longitudinal bars.

③ **Bentup bars :-**

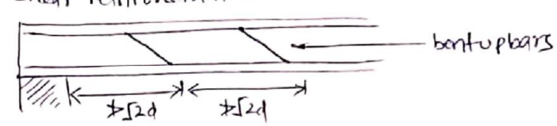
$$V_{us} = (0.87 f_y)(A_{sv}) \sin\alpha$$

(→ जितने बार (bars) Bent किए उनका area)

- These are main tensile bars bend at appropriate locations.
- don't enhance dowel action.

Imp: It is always provided with vertical stirupps

Imp: ∘ when Bentup bars are provided there shear resistance contribution $\not> 50\%$ of total shear to be resisted throuh shear reinforcement.



Example :- $V_{concrete} = 63$ $V_{stirups} = 46$ $V_{bentup} = 102$

here Bentup % $= \frac{102}{102+46} \times 100 = 68\%$ ($\not> 50\%$) As per IS

∴ $V_{u\,permitted} = \underset{c}{63} + \underset{s}{46} + \underset{Bentup}{46}$

v.v.imp

$\tau_v > \tau_c$	shear reinforcement for $(\tau_v - \tau_c)\, bd$
$\tau_v < \tau_c$	→ $\tau_v < 0.5\tau_c$ → * no shear Reinforcement → $0.5\tau_c \leq \tau_v \leq \tau_c$ → Provide min shear reinforcement *
$\tau_v > \tau_{c\,max}$ ↓ $0.62\sqrt{f_{ck}}$	• concrete failure in diagonal compression. (Brittle failure) • in such case either adopt concrete higher grade or dimension of section is need to be increased.