



**NEPAL ENGINEERING COUNCIL  
LICENSE EXAM PREPARATION COURSE  
FOR  
CIVIL ENGINEERS**

# 5. Design of Structure

## 5.3 RCC structure-1

# Sub topics

- Working stress and limit state methods;
- design of beams and slabs;
- analysis of RC beams and slabs in bending, shear, deflection, bond and end anchorage;
- RCC; NS & IS codes.



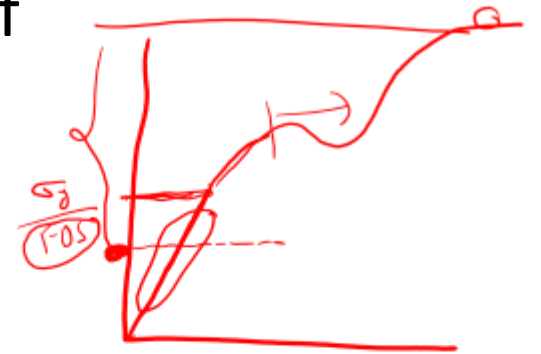
# WSM and LSM

Working stress method is based on elastic region of material and load interaction. The section are less economical and method is rarely used now.

One factor of safety based on stress at failure.

Stress method.

stress are linear



The factor of Safety is the ratio of the yield stress of the steel reinforcement or the concrete cube strength to the corresponding permissible or working stress.

{ For steel-1.8, for concrete-3

# WSM and LSM

$5000 \sqrt{f_{ck}}$



Modular ratio: Ratio of modulus of elasticity of steel and concrete.

$$m = \frac{E_s}{E_c} \rightarrow \frac{200 \times 10^3 \text{ N/mm}^2}{5700 \sqrt{f_{ck}}}$$
$$m = \frac{280}{3\sigma_{cbc}}$$

$\sigma_{cbc}$  is permissible compressive stress in concrete due to bending

In modular ratio, the long term effect of creep and shrinkage partly taken into account.

# WSM

## Modular ratio

Taken 1.5 times for steel in compression

$$\frac{20}{f_{0.5}} = \frac{20}{3} = \underline{6.66}$$

$1.5 m_{Asf}$

$m_{Asf}$

Grade of Concrete	Permissible Stress in Compression	
	Bending $\sigma_{cbc}$ (N/m <sup>2</sup> )	Direct $\sigma_{cc}$ (N/mm <sup>2</sup> )
M15	5.0	4.0
<b>M20</b>	<b>7.0</b>	5.0
M25	8.5	6.0
M30	10.0	8.0
M35	11.5	9.0
M40	13.0	10.0
M45	14.5	11.0

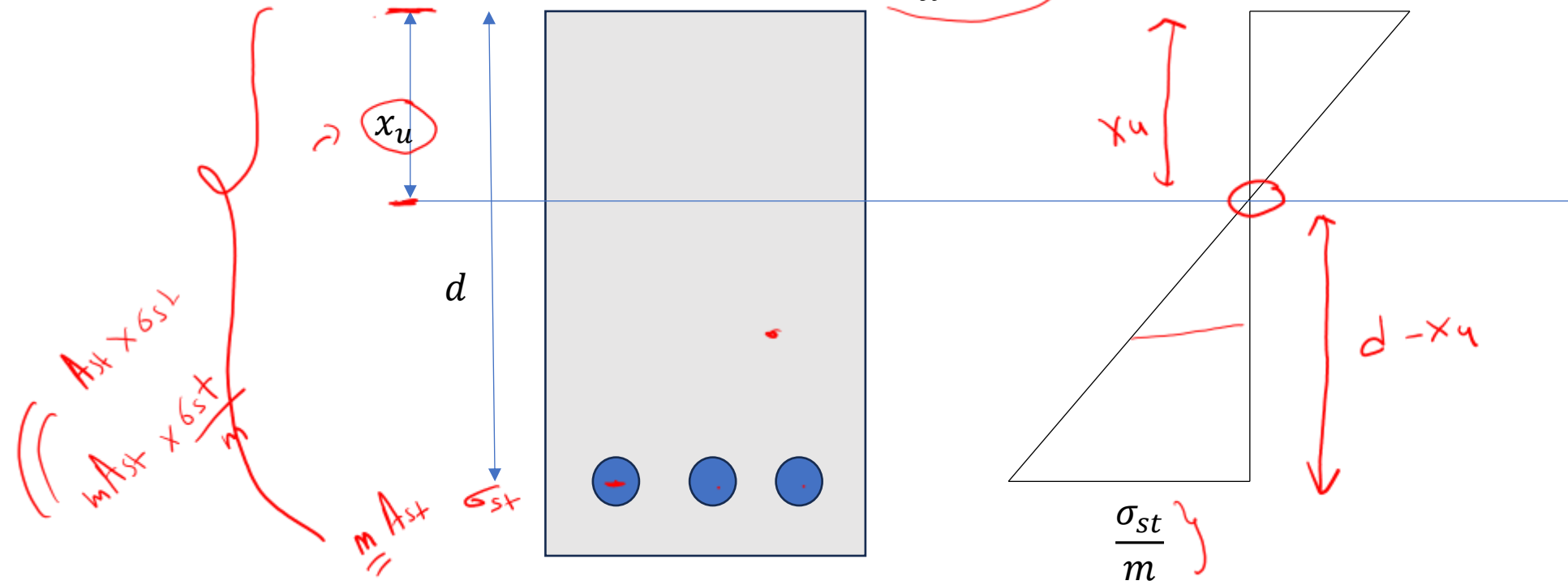
$$m = \frac{280}{3 \sigma_{cbc}}$$

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

# WSM

$$\frac{x_u}{d} = \frac{m \sigma_{cbc}}{\sigma_{st} + m \sigma_{cbc}} = \frac{280/3}{\sigma_{st} + 280/3}$$

Neutral axis Depth factor :  $\frac{x_u}{d}$



$$k = \frac{280}{3\sigma_{st} + 280}$$

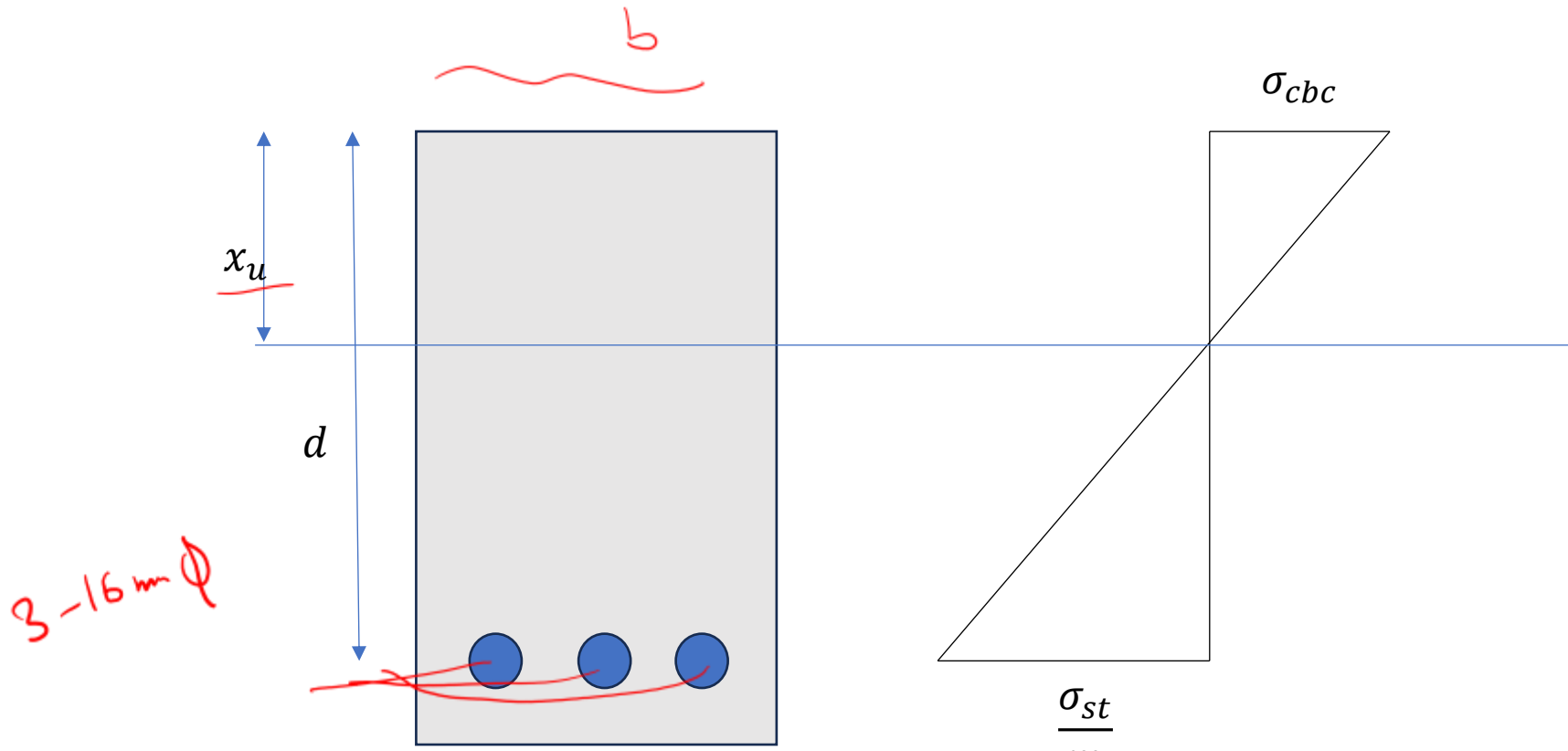
$$\frac{d - x_u}{x_u} = \frac{\sigma_{st}/m}{\sigma_{cbc}}$$

$$\frac{d}{x_u} - 1 = \frac{\sigma_{st}}{m \sigma_{cbc}}$$

$$\frac{d}{x_u} = \frac{\sigma_{st} + m \sigma_{cbc}}{m \sigma_{cbc}}$$

The lever arm is the perpendicular distance between the line of action of the couple forming compressive and tensile force in a Reinforced concrete section.

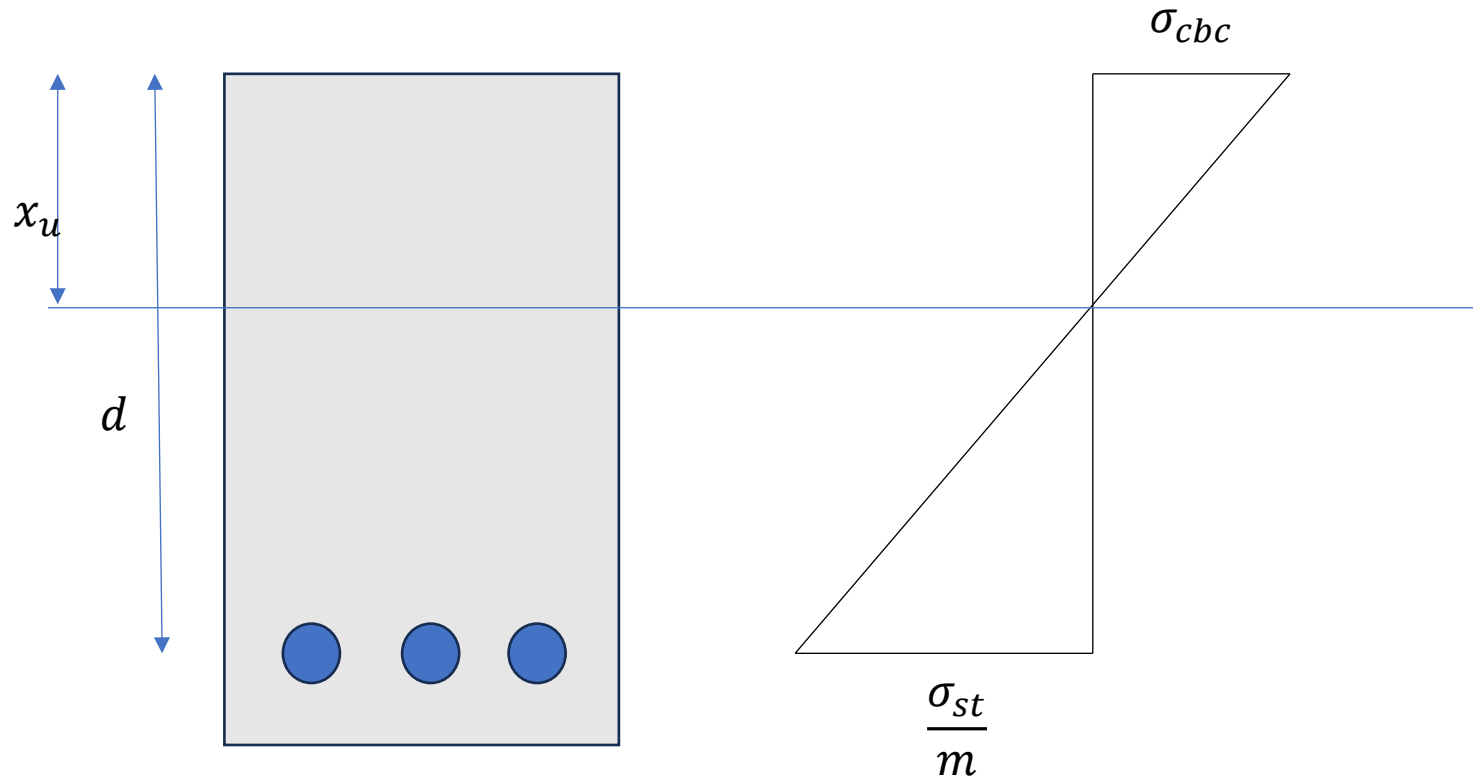
# WSM



$$k = \frac{280}{3\sigma_{st} + 280}$$

$$\text{Actual depth}(x_a): \frac{Bx_a^2}{2} = mA_{st}(d - x_a)$$

# WSM



$$k = \frac{280}{3\sigma_{st} + 280}$$

# WSM and LSM



Limit state stress method is based on plastic region of material and load interaction. The section are economical and method is commonly used.


It has factor of safety for loads as well as material

For steel-1.15, for concrete-1.5

Strain method

Limit state of collapse

Limit state of serviveability


$$\left. \begin{array}{l} 0.87 f_y \\ \frac{f_y}{1.15} = 0.87 f_y \end{array} \right\}$$

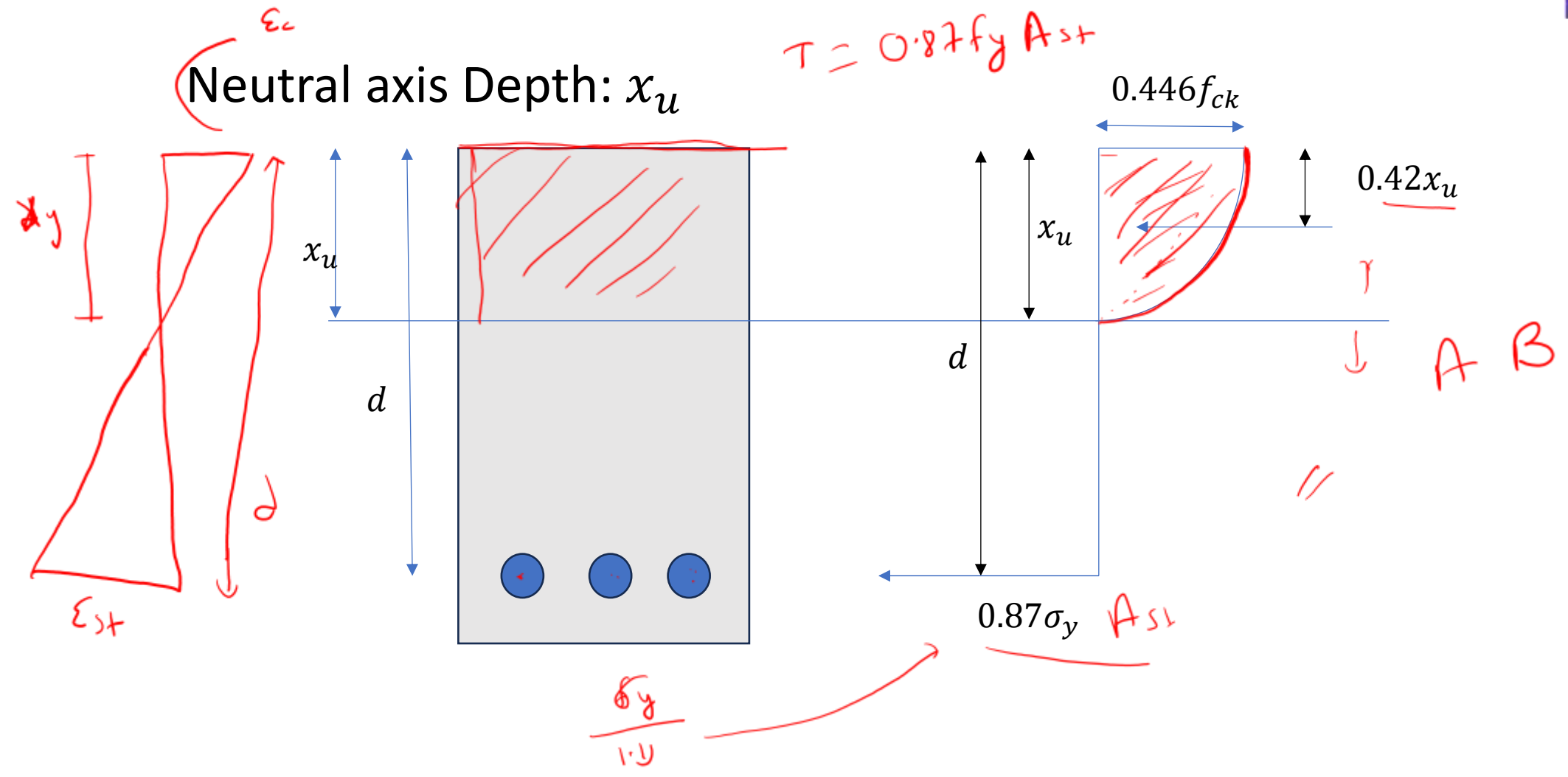


# LSM

$$C = 0.36 f_{ck} x_u b$$

$$T = 0.87 f_y A_{st}$$

Neutral axis Depth:  $x_u$



# Design of beam

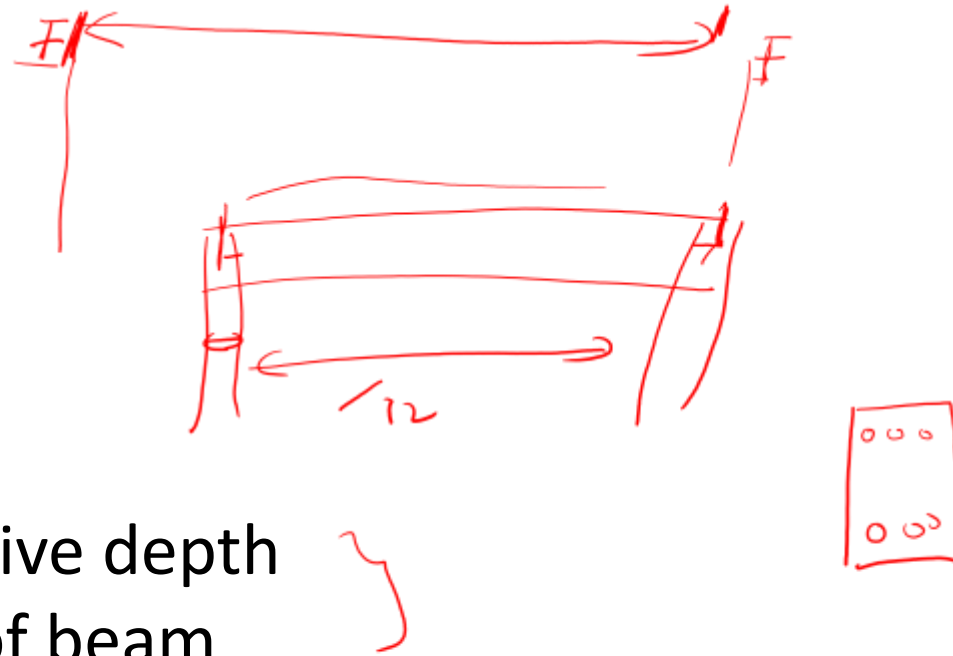
Effective span

Simply supported beam

Least of:

- Clear span + effective depth
- Centre to centre of beam

*clear +  $b/2$  +  $b/2$*

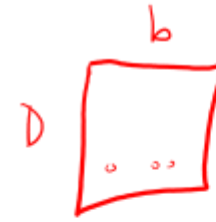


Continuous beam of support width less than clear span / 12 same formula is used.

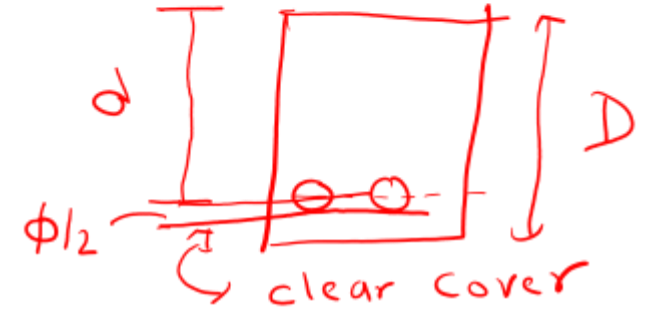
# Design of beam

CC → 25 mm  
20 mm

$L/d = 20$   
 $d =$



Beam type	Span to effective depth
Cantilever	7
Simply supported	20
Continuous	26



For spans above 10m, values may be multiplied by  $10/\text{span}$  except for cantilever

20mm

$$D = d + (cc + \phi/2)$$

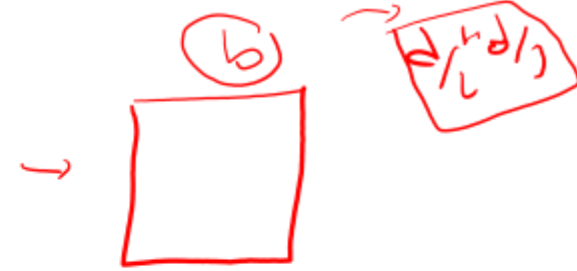
$= 285$

It is modified based on percent of tensile and compressive steel.

$$D = 300 \text{ mm}$$

$$\rightarrow d = D - cc - \phi/2$$

# Design of beam



Continuous  
SISO

For lateral stability, clear distance between support should not exceed

$$\underline{60b} \text{ or } \frac{250b^2}{\underline{d}}$$

For cantilever clear distance between support should not exceed

$$25b \text{ or } \frac{100b^2}{d}$$



# Singly and doubly reinforced beam

Based on reinforcement provided on tension and compression

Over reinforced, under reinforced and balanced section

~~Balanced~~ section fails both on compression and tension

Under reinforced section fails on tension part

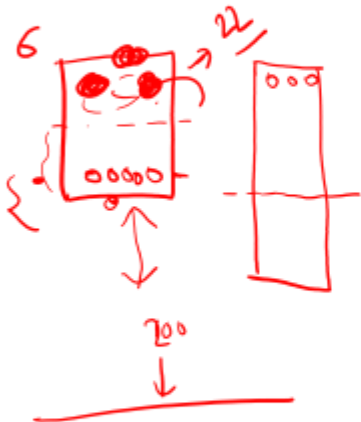
Failure is gradual elastic

Over reinforced section fails on compression part

Failure is brittle

gradual  
elastic

MLO



# LSM

$$0.36 f_{ck} x_u b = 0.87 f_y A_{st}$$

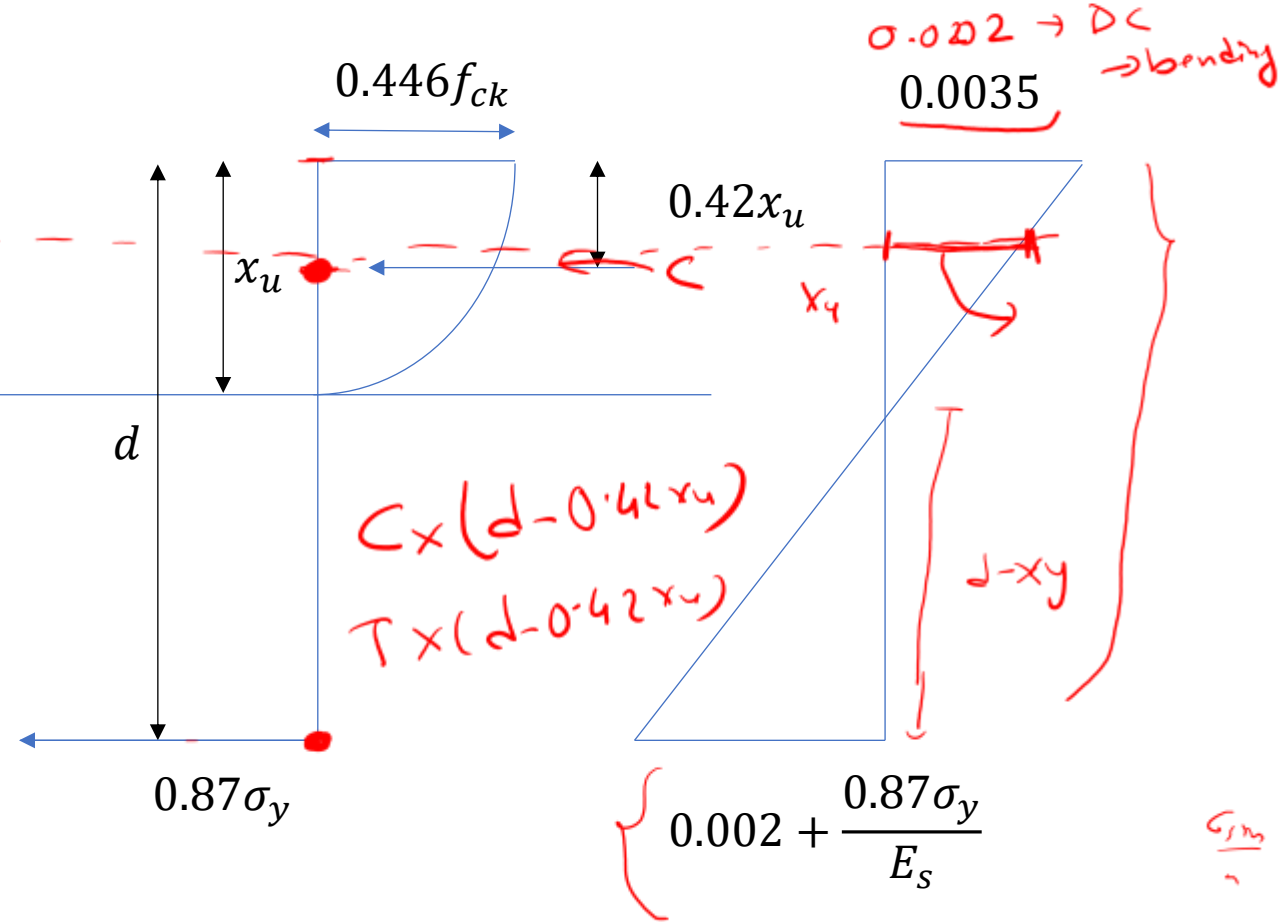
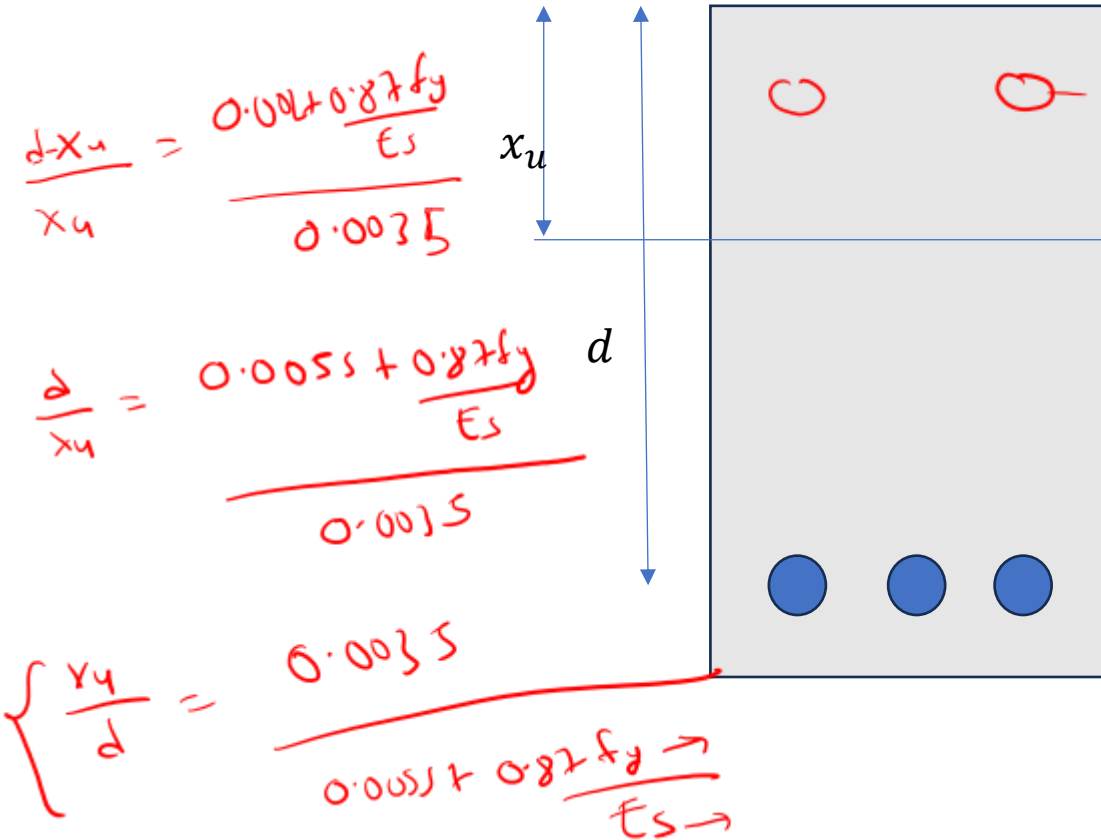
$$\frac{x_u}{d} = \frac{0.87 f_y A_{st}}{0.36 f_{ck} b d}$$

6.10.1



PANA ACADEMY

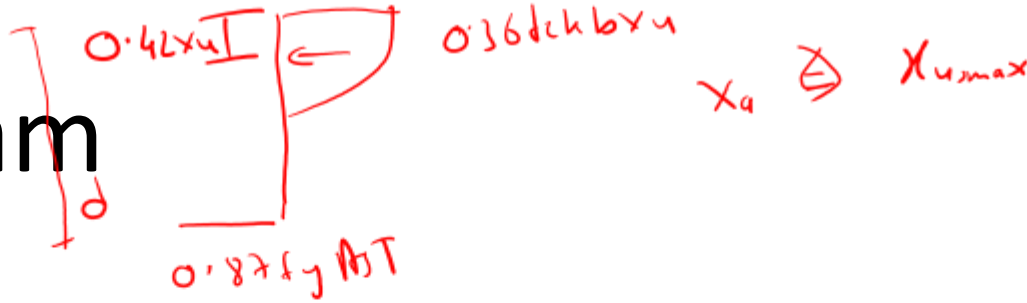
Neutral axis Depth:  $x_u$



$\frac{\sigma_y}{E_s}$

$\frac{wl^2}{8} = 120 \text{ kNm}$

# Design of beam



20mm  $f_{c415}$



## Moment of resistance for balanced section

$M_u = 0.36 f_{ck} b d^2 \frac{x_u}{d} \left( 1 - 0.42 \frac{x_u}{d} \right)$

$M_u = 0.87 f_y A_{st} d \left( 1 - \frac{A_{st} f_y}{b d f_{ck}} \right)$

$0.42 \frac{x_u}{d} = \frac{A_{st} f_y}{b d f_{ck}}$

mild steel

$f_y$	$\frac{x_{u,max}}{d}$
250	0.53
415	0.48
500	0.46

$\frac{\pi 20^2}{4} \Rightarrow \frac{A_{st}}{A} = \text{no of rei.} \rightarrow 3.1 \rightarrow 4 \text{ nos of bar}$



# Design of beam

flexural member  
Bending ST design  
Shear ST check



$$C = f_{sc} \times A_{sc}$$

Moment of resistance for over reinforced section

Contains extra MOR due to compression

$$A_{st1} + A_{st2} = \frac{A_{st}}{A}$$

$$M_2 = \frac{f_{sc} A_{sc}}{0.87 f_y} (d - d') = 0.87 f_y A_{st2} (d - d')$$

$$M_u = M_1 + M_2$$

$$A_{sc}/A = \text{not cr}$$

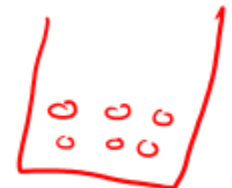
$f_{sc}$  = stress in compression reinforcement

due to strain of  $\frac{0.0035(x_{u,max} - d')}{x_{u,max}}$

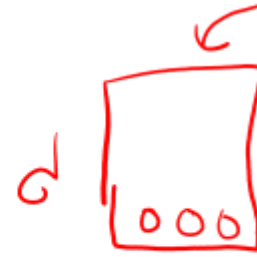


$$T = 0.87 f_y A_{st2}$$

$$130 - 110 = 20 =$$



# Design of beam



Tension reinforcement:

→ i) Minimum reinforcement:

$$\rightarrow \left\{ \frac{A_s}{bd} = \frac{0.85}{f_y} \right\} \rightarrow$$

min % of  $b$  for  $F_e 415$

$$\frac{A_s}{bd} \times 100\% = \frac{0.85}{415} \times 100 = 0.2\%$$

$b$  is breadth of web for T and I beam

→ ii) Maximum reinforcement:

$$\underline{0.04bD} \quad 4\%$$

Compression reinforcement:

Maximum reinforcement:

$$\underline{0.04bD} \quad 4\%$$

# Design of beam



$$\underline{20} + 5 = 25$$

Minimum distance between bars in same row : Greater of:

i) Diameter of larger bar

20

ii) 5mm more than nominal size  
of max aggregate

In different row the distance should be greater of

i) Diameter of larger bar

ii) 2/3 nominal size  
of max aggregate

iii) 15mm



# Design of beam



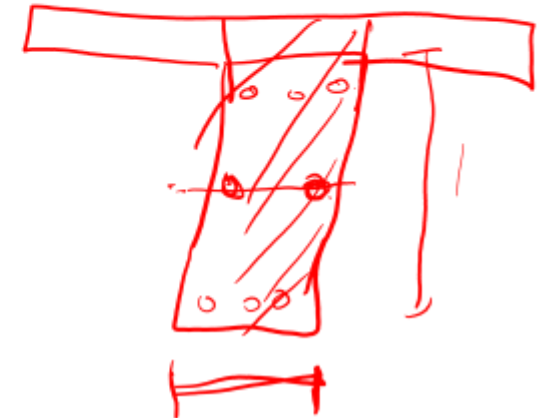
Maximum distance between bars in tension:

Fy	Spacing (mm)
250	<u>300</u> }
415	<u>180</u>
500	<u>150</u>

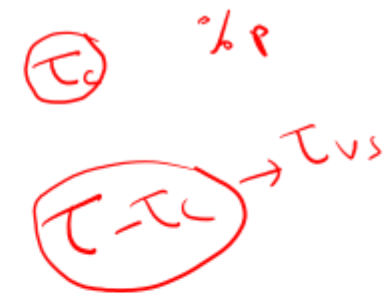
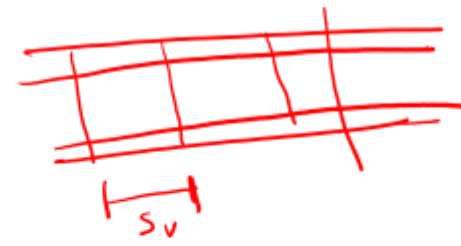


For web exceeding 750 mm side reinforcement not less than 0.1% of web area should be provided.

Spacing least of 300mm or web thickness



# Design of beam

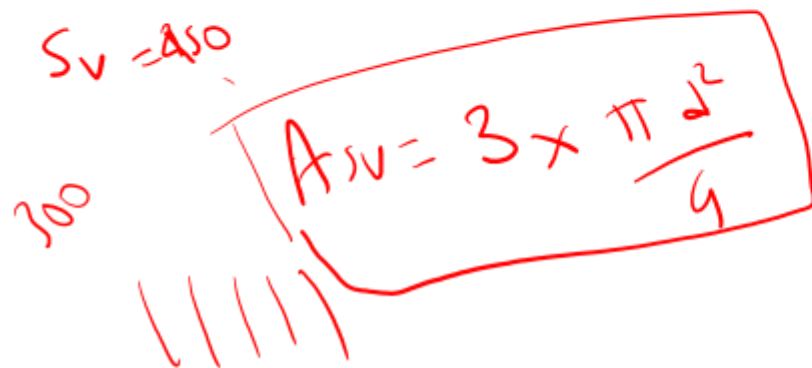
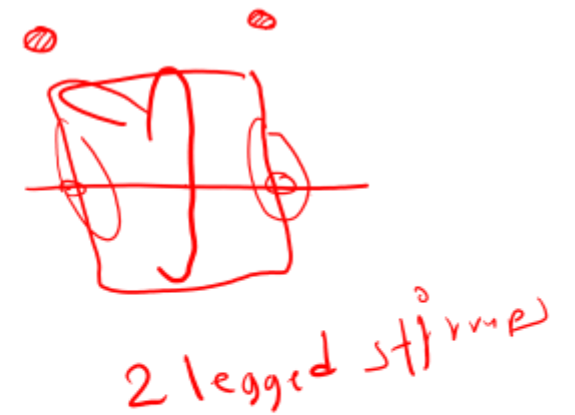
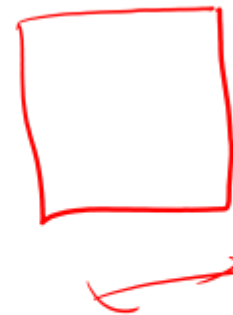


$d = 360$   
 $0.75 \times 480$

Maximum spacing between bars in shear :  
0.75d for vertical and d for inclined  
 No case should be more than 300mm

## Minimum shear reinforcement

$$\frac{A_{sv}}{b s_v} \geq \frac{0.4}{0.87 f_y}$$





# Design of beam

$$\tau_c < \tau_v \quad \tau_v < \tau_c$$

Beam should be designed for shear if shear due to load is more than shear capacity of concrete

$$\tau_c < \tau_v < \tau_{cmax}$$

Where,

$$\tau_v = \frac{V_u}{bd}$$

$$\tau_v < \tau_c$$
$$\tau_v < \tau_{cmax}$$

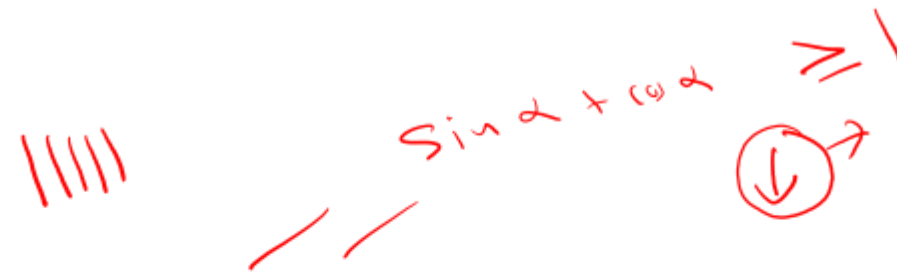
Grade	M15	M20	M25	M30	M35	M40 AND MORE
$\tau_{cmax}$	2.5	2.8	3.1	3.5	3.7	4.0



**Table 19 Design Shear Strength of Concrete,  $\tau_c$ , N/mm<sup>2</sup>**  
*(Clauses 40.2.1, 40.2.2, 40.3, 40.4, 40.5.3, 41.3.2, 41.3.3 and 41.4.3)*

$100 \frac{A_s}{bd}$	Concrete Grade						
	M 15	M 20	M 25	M 30	M 35	M 40 and above	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	
≤ 0.15	0.28	0.28	0.29	0.29	0.29	0.30	
0.25	0.35	0.36	0.36	0.37	0.37	0.38	
0.50	0.46	0.48	0.49	0.50	0.50	0.51	
0.75	0.54	0.56	0.57	0.59	0.59	0.60	
1.00	0.60	0.62	0.64	0.66	0.67	0.68	
1.25	0.64	0.67	0.70	0.71	0.73	0.74	
1.50	0.68	0.72	0.74	0.76	0.78	0.79	
1.75	0.71	0.75	0.78	0.80	0.82	0.84	
2.00	0.71	0.79	0.82	0.84	0.86	0.88	
2.25	0.71	0.81	0.85	0.88	0.90	0.92	
2.50	0.71	0.82	0.88	0.91	0.93	0.95	
2.75	0.71	0.82	0.90	0.94	0.96	0.98	
3.00 and above	0.71	0.82	0.92	0.96	0.99	1.01	

# Design of beam



Beam should be designed for shear if shear due to load is more than shear capacity of concrete

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

$$\tau_v = \frac{V_u}{b d}$$

Handwritten notes:

$$\tau_{us} = \tau_v - \tau_c$$

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

$$= V - \tau_c b d$$

For vertical stirrups:

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

inclined

For ~~vertical~~ stirrups:

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



# Bond and end anchorage

Development length for tension

$$L_d = \frac{\phi \sigma_s}{4 \tau_{bd}}$$

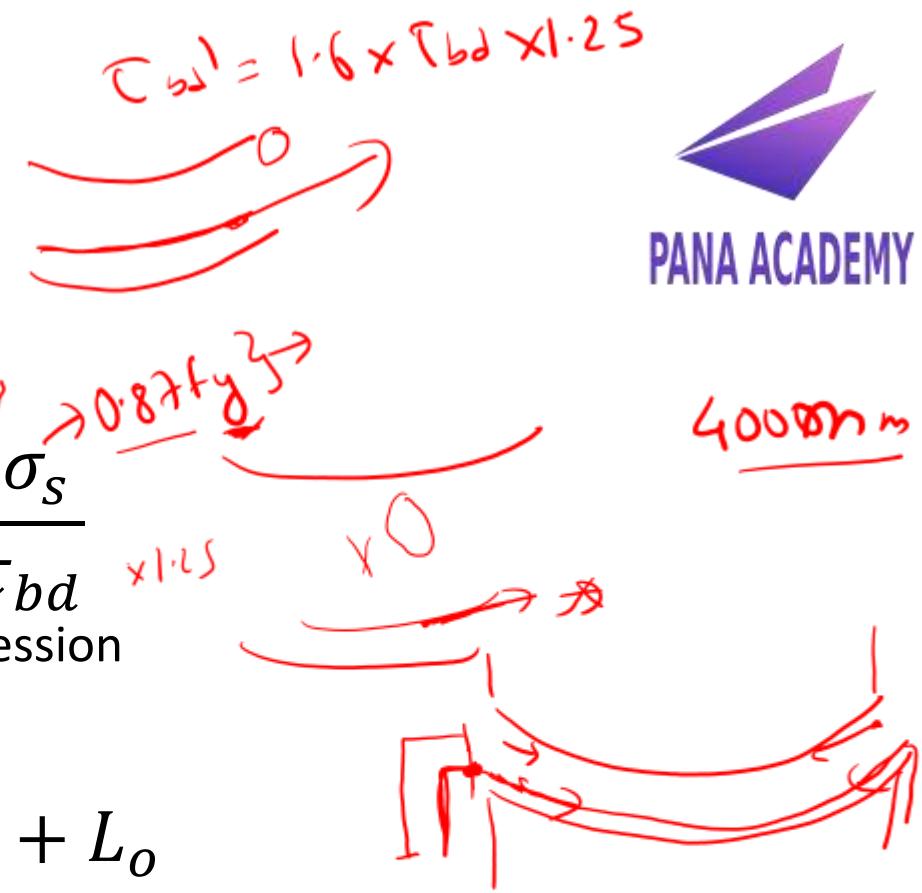
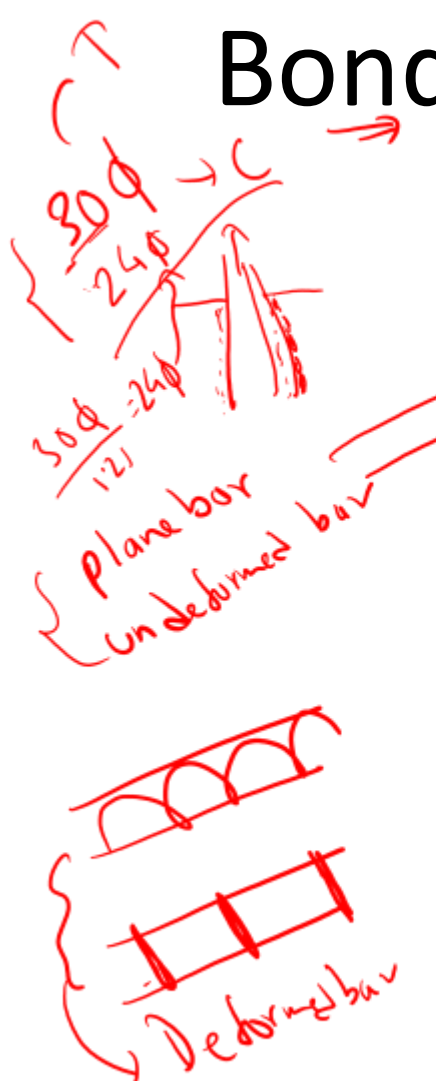
$\sigma_s$  is  $0.87 f_y$ ,  $\tau_{bd}$  is increased by 25% for compression  
 $\tau_{bd}$  is increased by 60% for deformed bar

$$L_d \leq \left( \frac{M}{V} \right) + L_o$$

30% increment in value of  $M/V$  for bars confined by compressive reinforcement

Grade	M20	M25	M30	M35	M40 AND MORE
$\tau_{bd}$	1.2	1.4	1.5	1.7	1.9

Bar in bundle	2 bars	3 bars	4 bars
Increase in $L_d$	10%	20%	33%



# Bond and end anchorage



Anchorage in tension

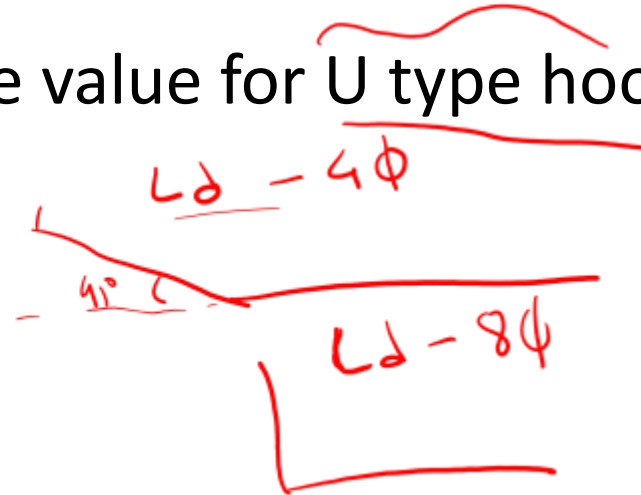
Deformed bar do not need end anchorage



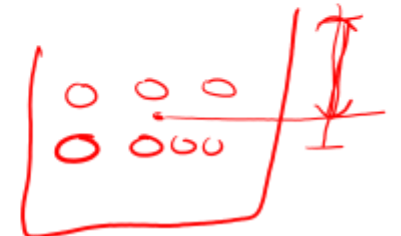
Bend having 45 degree bend is taken as having anchorage value 4  $\phi$  for each and total not more than 16  $\phi$



Anchorage value for U type hooks is taken 16  $\phi$



4x4 $\phi$

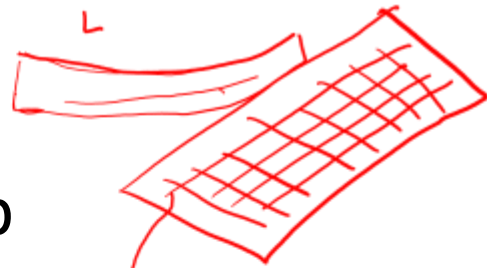




# Slab

①

One way slab



BM design → Shear design  
 $\tau_v < \tau_{c1}$   
 $\tau_c < \tau_v < \tau_{cmax}$   
 $\tau_v > \tau_{cmax}$

$$\frac{L}{b} \geq 2$$



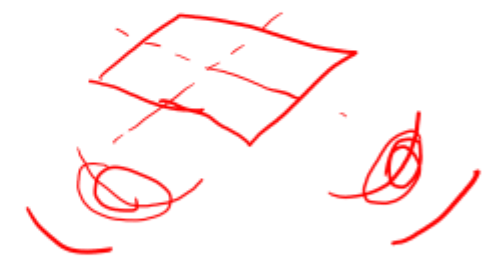
Bending occurs in one axis and load is taken in one direction

②

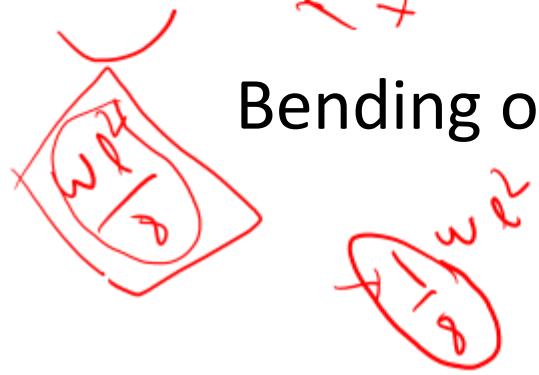
Two way slab

$$\frac{A_{st}}{A} = 3.05$$

$$\frac{L}{b} < 2$$



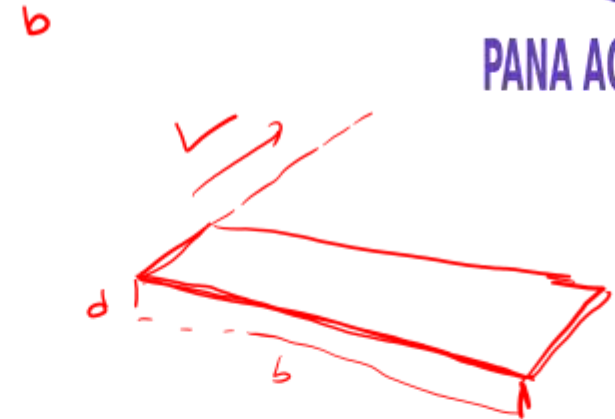
Bending occurs in two axis and load is taken in two direction



# One way Slab


Slab type	Span to effective depth
Simply supported	20
Continuous	26

beam →



Least of:

- a) Clear span + effective depth
- b) Centre to centre of beam

$187.5$   
 $200$   
 $D = d + \phi/2 + CC \rightarrow 20mm$   
 min  $\rightarrow 15mm$  or  $\phi$  or max  
 effective length  
 $1000mm$       $n = 3.05$   
 $\frac{1000}{3.05} = S$   


Total depth (D) = d + clear cover + dia of bar/2

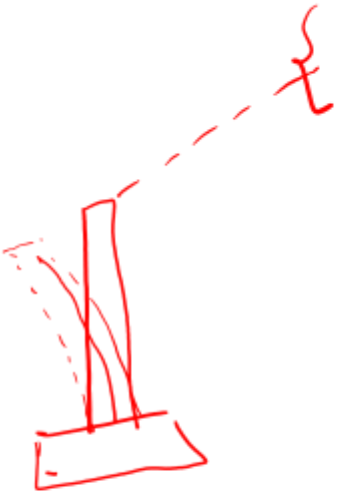
# Two way Slab

For shorter span upto 3.5m

Slab type	Span to effective depth
Simply supported	35 x 0.8
Continuous	40 x 0.8

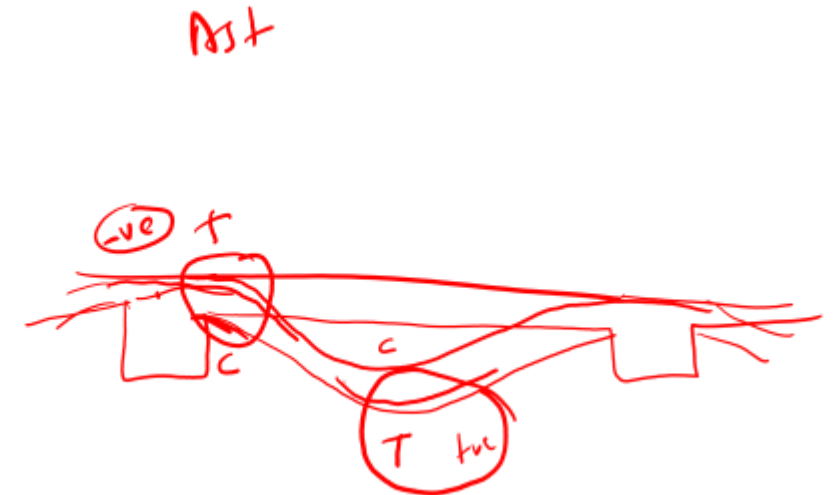
Thickness of slab  $l_e$   
 $\frac{l}{d} = 35$   
 $d = \frac{l}{35}$   
 $d = \frac{l}{40}$

For bar of high strength above values should be multiplied by 0.8.



$$M_x = \alpha_x w l_x^2$$

$$M_y = \alpha_y w l_y^2$$



**Table 26 Bending Moment Coefficients for Rectangular Panels Supported on Four Sides with Provision for Torsion at Corners**

*(Clauses D-1.1 and 24.4.1)*



**PANA ACADEMY**

Case No.	Type of Panel and Moments Considered	Short Span Coefficients $\alpha_x$ (Values of $l_y/l_x$ )									Long Span Coefficients $\alpha_y$ for All Values of $l_y/l_x$
		1.0	1.1	1.2	1.3	1.4	1.5	1.75	2.0		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	
1	<i>Interior Panels:</i>										
	Negative moment at continuous edge	0.032	0.037	0.043	0.047	0.051	0.053	0.060	0.065	0.032	
	Positive moment at mid-span	0.024	0.028	0.032	0.036	0.039	0.041	0.045	0.049	0.024	
2	<i>One Short Edge Continuous:</i>										
	Negative moment at continuous edge	0.037	0.043	0.048	0.051	0.055	0.057	0.064	0.068	0.037	
	Positive moment at mid-span	0.028	0.032	0.036	0.039	0.041	0.044	0.048	0.052	0.028	
3	<i>One Long Edge Discontinuous:</i>										
	Negative moment at continuous edge	0.037	0.044	0.052	0.057	0.063	0.067	0.077	0.085	0.037	
	Positive moment at mid-span	0.028	0.033	0.039	0.044	0.047	0.051	0.059	0.065	0.028	
4	<i>Two Adjacent Edges Discontinuous:</i>										
	Negative moment at continuous edge	0.047	0.053	0.060	0.065	0.071	0.075	0.084	0.091	0.047	
	Positive moment at mid-span	0.035	0.040	0.045	0.049	0.053	0.056	0.063	0.069	0.035	
5	<i>Two Short Edges Discontinuous:</i>										
	Negative moment at continuous edge	0.045	0.049	0.052	0.056	0.059	0.060	0.065	0.069	—	
	Positive moment at mid-span	0.035	0.037	0.040	0.043	0.044	0.045	0.049	0.052	0.035	



# Slab design

Call  
seve

$A_{st}$

$b = 1000\text{mm}$   
 $D = 125\text{mm}$

$0.15 \times 1000 \times 125$

$A_{st_{min}}$

Minimum reinforcement is 0.15% of total cross section for mild steel ( $f_y = f_e 250$ )  $\rightarrow$

Minimum reinforcement is 0.12% of total cross section is high strength

$0.12 \times 1000 \times 125$

slab

Designed as Beam in both direction.

Deflection has limiting value  $L/250$

$L/250$

When effect of temperature, creep and shrinkage is considered deflection has limiting value  $L/350$

# Slab design



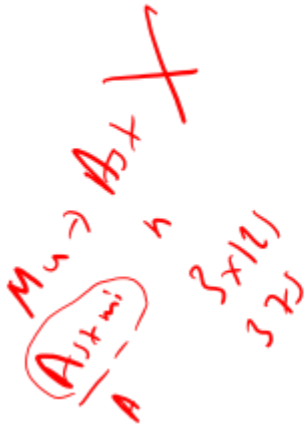
Spacing of bars : The maximum spacing of bars shall not exceed

- Main Steel – 3d or 300 mm whichever is smaller
- Distribution steel – 5d or 450 mm whichever is smaller

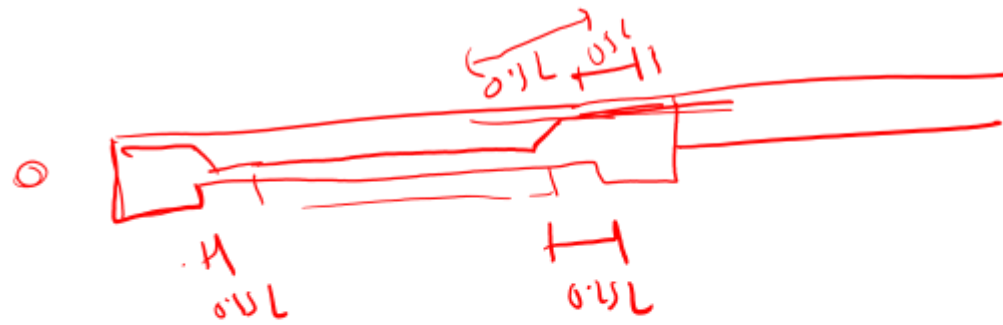
Where, 'd' is the effective depth of slab.

Minimum clear spacing of bars is not kept less than 75 mm }  
though code do not recommend any value.

Maximum diameter of bar: The maximum diameter of bar in slab, shall not exceed D/8, where D is the total thickness of slab.



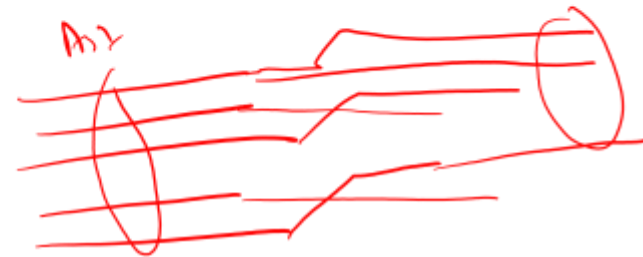
# Slab design



Tension reinforcement:

Slab is divided into midstrip which is three fourth of total span and remaining is edge strip, equal in either sides.

Reinforcement at mid span shall extend lower part of slab within 0.25l of a continuous or 0.15l of discontinuous edge from midpoint of support.



# Slab design



Over continuous edge, reinforcement at mid span shall extend upper part of slab within  $0.15l$  of a support and at least 50% shall extend  $0.3l$  from face of support.

Over discontinuous edge, reinforcement at mid span shall extend upper part of slab at least 50% shall extend  $0.1l$  from face of support.

# Slab design



✓ Torsion reinforcement:

Reinforcement should extend to one fifth of length of shorter span.

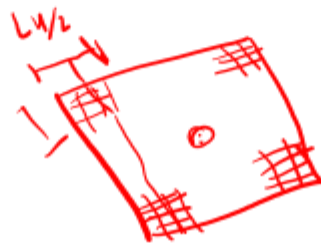


0.2l<sub>x</sub>,  $\frac{l_x}{5}$ , l<sub>y</sub>

Reinforcement should be 0.75A<sub>st</sub> (minimum required area for midspan positive moment)

Half reinforcement is provided if corner is over one edge continuous

37.5%  
0.375A<sub>st</sub>



# Slab design



If a beam fails in bond, then its bond strength can be increased most economically by

- a) Increasing the depth of beam
- ~~b) Using thinner bars but more in number~~
- c) Using thicker bars but less in number
- d) Providing vertical stirrups

# Slab design

The percentage of reinforcement in case of slab, when high strength deformed bars are used is not less than

- a) 0.15
  - b) 0.12
  - c) 0.30
  - d) 1.00
- Mild steel*

# Slab design

When shear stress exceeds the permissible limit in a slab, then it is reduced by

- ~~a)~~ Increasing the depth
- b) Providing shear reinforcement
- c) Using high strength steel
- d) Using thinner bars but more in number



# Slab design

$$\frac{L}{d} = 20$$
$$\frac{8000}{20} = d$$

For simply supported beam of span 8 m, the minimum effective depth to satisfy the vertical deflection limits should be

$$\frac{L}{d}$$

- a) ~~400 mm~~
- b) 500 mm
- c) 700 mm
- d) More than 1 m

# Slab design

For simply supported beam of span 15 m, the minimum effective depth to satisfy the vertical deflection limits should be

- a) 600 mm
- b) 750 mm
- c) 900 mm
- d) More than 1 m

$$\frac{L}{d} = 20 \times \frac{10}{15}$$

# Slab design

→ 1.6 →

The average permissible stress in bond for plain bars in tension is

- a) Increased by 10% for bars in compression
- ~~b) Increased by 25% for bars in compression~~
- c) Decreased by 10% for bars in compression
- d) Decreased by 25% for bars in compression

# Slab design

Minimum cover in a slab should neither be less than the diameter of bar nor less than

- a) 10 mm
- b) 15 mm
- c) 25 mm
- d) 13 mm

Slab: 15 20<sup>-5</sup> 12mm  $\phi$   
beam: 20 25-5m

# Slab design



The maximum depth of neutral axis for beam of effective depth 500 mm

- a) 260 mm
- b) 265 mm
- c) 200 mm
- d) 245 mm

$$\begin{aligned} f_y & \rightarrow 250 \\ x_u/d & \underline{\underline{0.53}} \\ 0.53 \times 500 & \quad x_{u,max} \end{aligned}$$

# Slab design

The maximum depth of stress block in a balanced RCC beam section of depth 'd' is.....

- a) 0.3 d
- b) 0.43 d
- ~~c) 0.53 d~~ →
- d) 0.60 d

Thank YOU !!!

# Slab design

Workability of concrete is inversely proportional to

- a) Time of transit
- b) Water cement ratio
- c) Air content
- d) Size of aggregate