NEPAL ENGINEERING COUNCIL
LICENSE EXAM PREPARATION COURSE

FOR

CIVIL ENGINEERS

5. Design of Structure

5.4 RCC structure-2

Sub topics

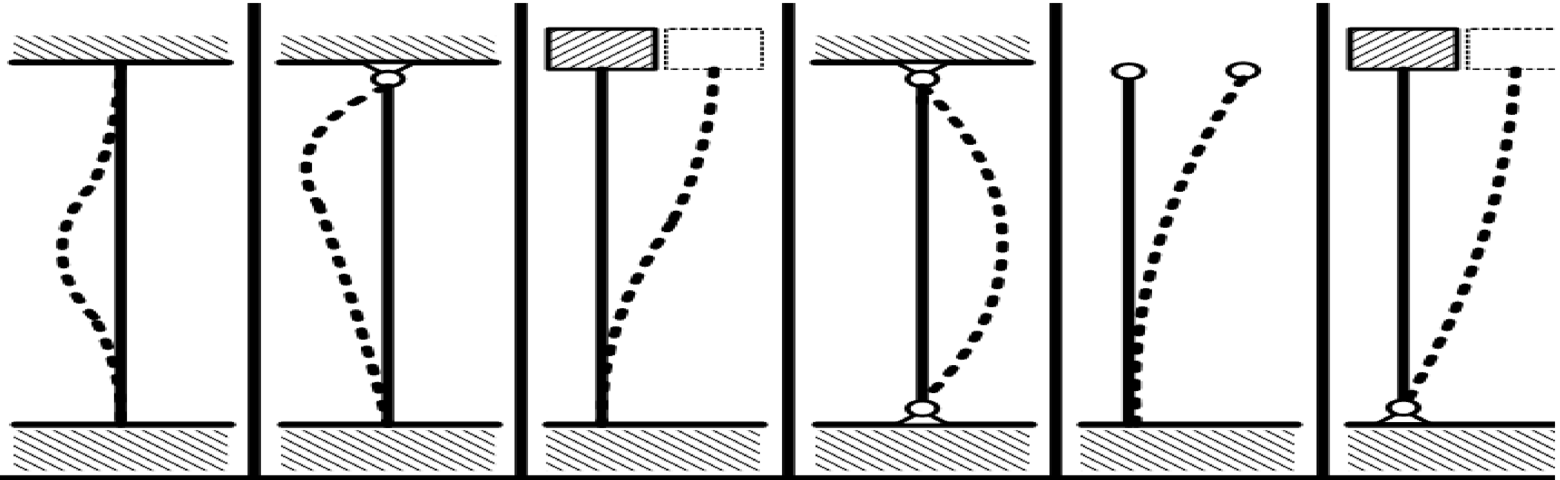
- Design of column
- Design of isolated/combined footing
- Prestress concrete
- NS & IS codes.

Design of column

PANA ACADEMY

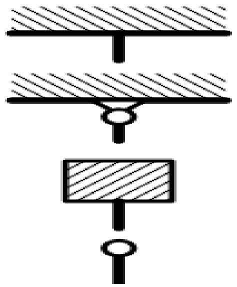
Effective length

Buckled shape of column shown by dashed line



Theoretical K value	0.5	0.7	1.0	1.0	2.0	2.0
Recommended design value K	0.65	0.80	1.2	1.0	2.10	2.0

End condition key



Rotation fixed and translation fixed

Rotation free and translation fixed

Rotation fixed and translation free

Rotation free and translation free

Design of Column

Pedestal $\frac{l}{D} < 3$ Lx

M = Pe

Ly

$\frac{P}{A} = 20+3$

Short column = $\frac{l_{ex}}{D} < 12\ and\ \frac{l_{ey}}{b} < 12$

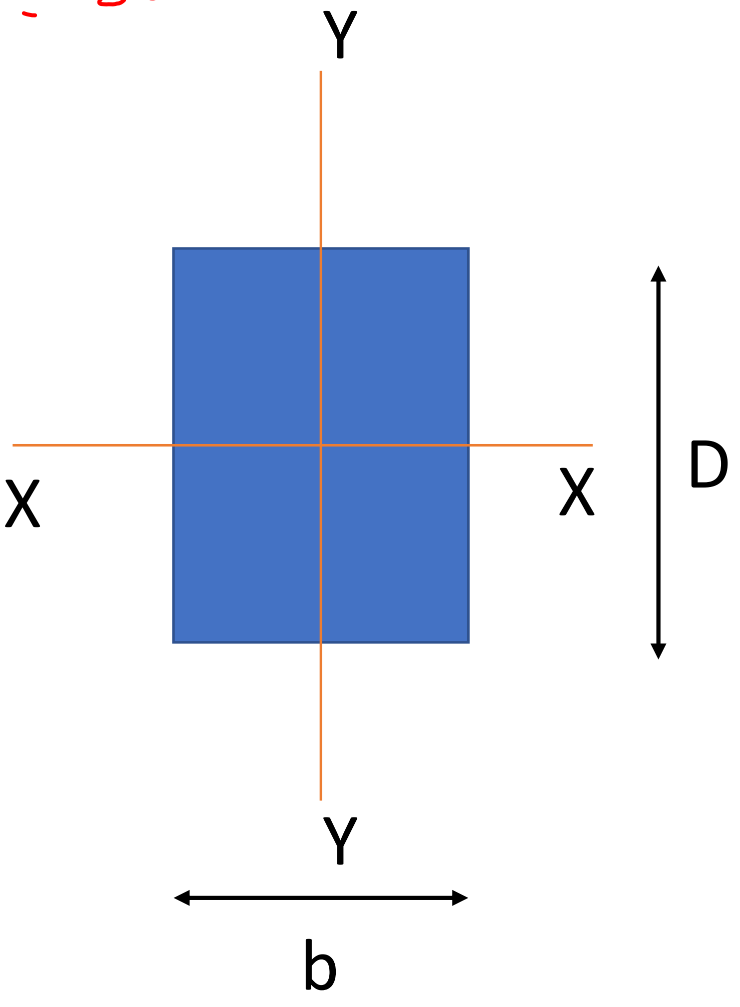
Slender column = $\frac{l_{ex}}{D} \geq 12\ and\ \frac{l_{ey}}{b} \geq 12$

(4) Lx

Ly K

l_{ex} and l_{ey} are effective length

b and D are overall dimension of column



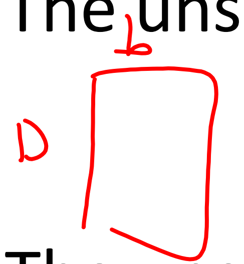
Design of ~~beam~~ Column

PANA ACADEMY

Slenderness limits:

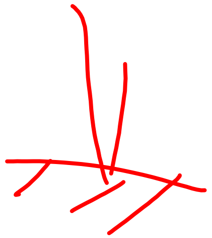
$L_{ex} = K \times L_x$

The unsupported length between end resteaints shall not exceed



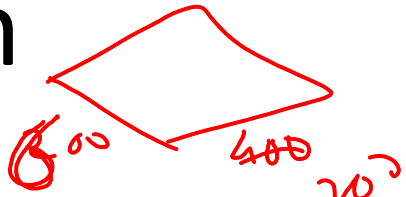
$$60b$$

The unsupported length if one end is unrestrained shall not exceed



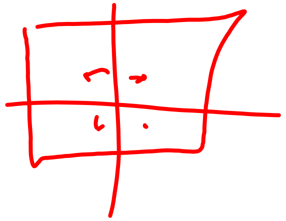
$$\frac{100b^2}{d}$$

Design of beam



PANA ACADEMY

Minimum Eccentricity: Maximum of



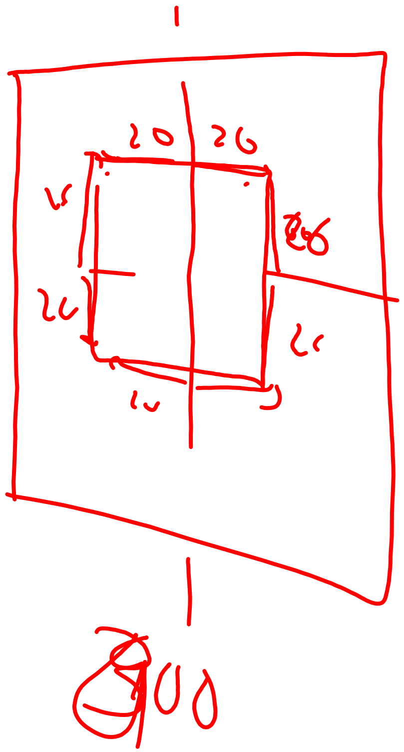
3000mm

$$\frac{3000}{500} + \frac{600}{30} = \cancel{19.71}\ \ 26.0$$

$$\frac{L}{500} + \frac{D}{30}\ or\ 20\ mm$$

Also called accidental eccentricity.

Usually cover of 40 mm is provided on column



$$\frac{L}{500} + \frac{b}{30}\ \text{or}\ 20\text{mm}$$

20mm

Axially loaded, Uniaxial and Biaxial bending

$e_x = 26$
$e_y = 20$ $\quad e_x = 32, e_y = 10$

Based on moment column has to experience

Probable failure pattern

Difference in process of design.

$M_x \quad e_x = M/P = 32$ $\quad$ 5% of
$M_y \quad e_y = M/P = 15$

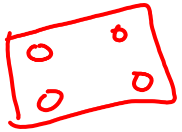
- Axially loaded: minimum eccentricity within 0.05 lateral size
- Uniaxial Bending: eccentricity exceeds 0.05 lateral size in one direction
- Biaxial Bending: eccentricity exceeds 0.05 lateral size in both direction

Design of Axially loaded column

PANA ACADEMY

400×400

4bar 16m



$\frac{A_c}{A_{sc}} + A_g = b \times D$

Minimum eccentricity is less than 0.05D

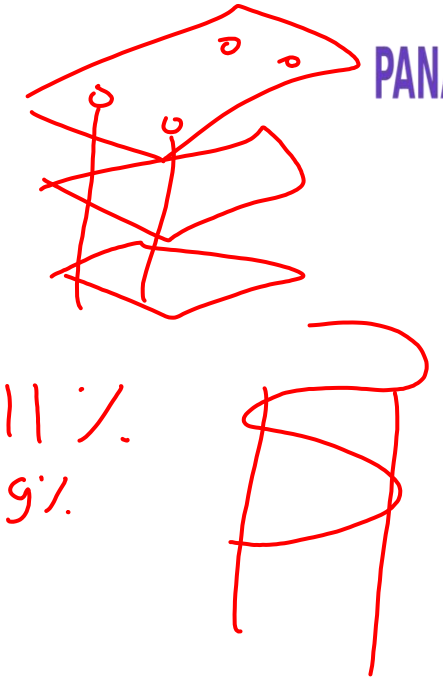
1.5×1084kN

0.988 A_g 0.012 A_g

$$P_u = 0.4 f_{ck}.A_c + 0.67 f_y.A_{sc}$$

11%

$(P_{uz} = 0.45 f_{ck} A_c + 0.75 f_y A_{sc}) \times 89\%$



P_u is axial load

$\frac{0.4}{0.45}$ $\frac{0.67}{0.75}$

0.8% — 4 → 6%

$A_g \rightarrow$ 1.2%

Strength increases by 5% when helical reinforcement is in place of ties

98.8%

$\frac{A_{sc}}{A_c}$ /

$\sqrt{A_g} = 323 \simeq 330$

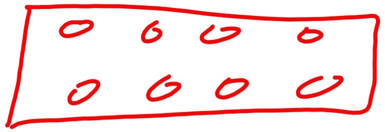
1.1%

1.05 P_u

Design of Uniaxial bending column

divisible by 2

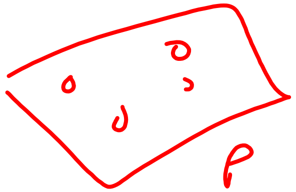
PANA ACADEMY



Designed basically using SP16 design aid for IS 456:2016

$$\boxed{\frac{p}{f_{ck}}, \frac{P_u}{f_{ck}bD}, \frac{M_u}{f_{ck}bD^2}}$$

exp



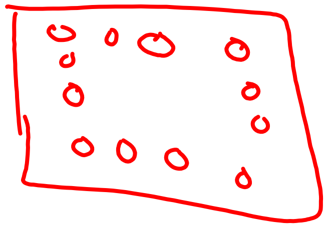
$\frac{p}{f_{ck}} = 0.28$

20

52%

p is percentage of longitudinal reinforcement

0.8% → 6%



Different chart are made based on d'/D ratio and f_y.

divisible by 4

3.2% bD 4%

6 = 8

4, 8, 12, 16

Chart 44 COMPRESSION WITH BENDING — Rectangular Section — Reinforcement Distributed Equally on Four Sides

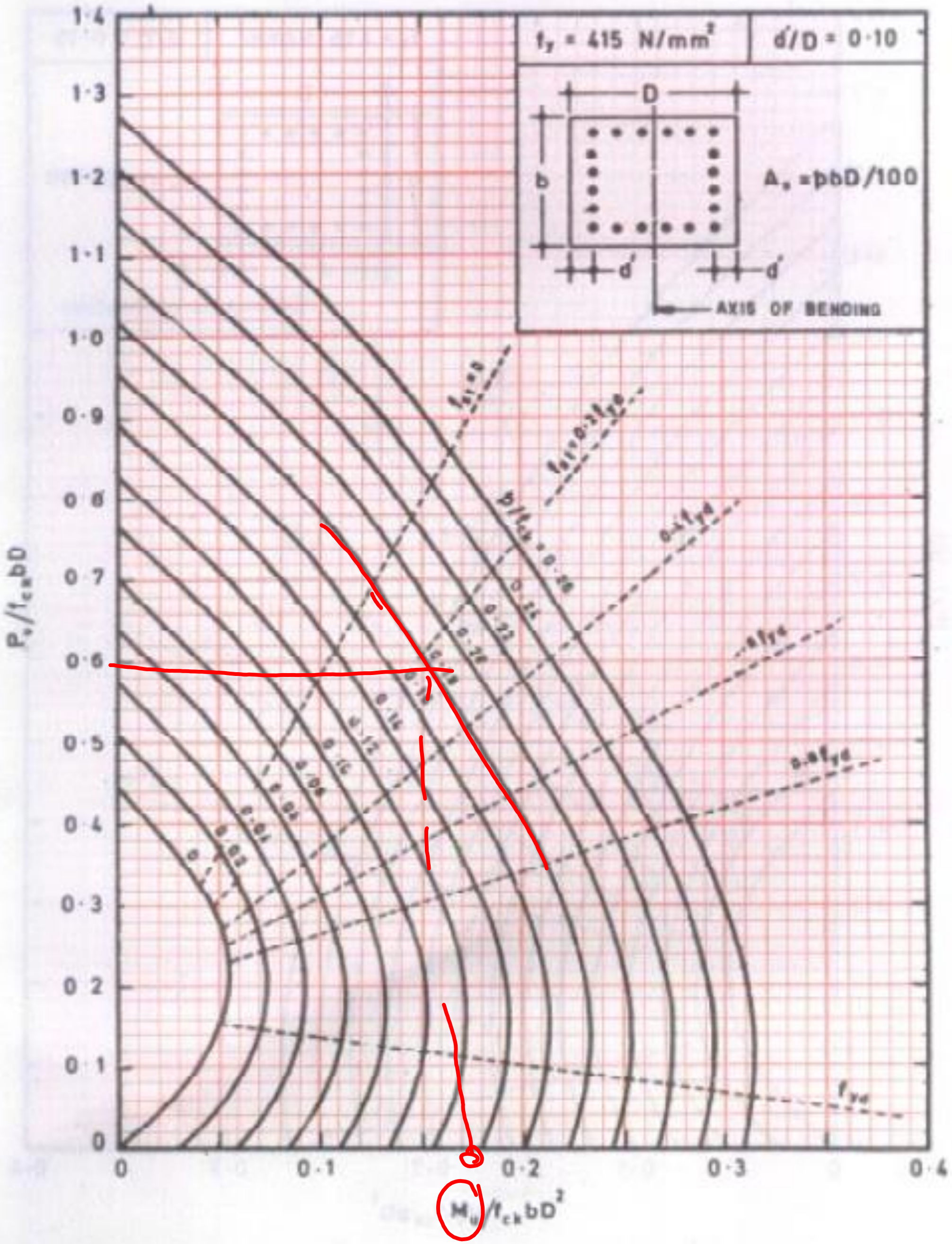
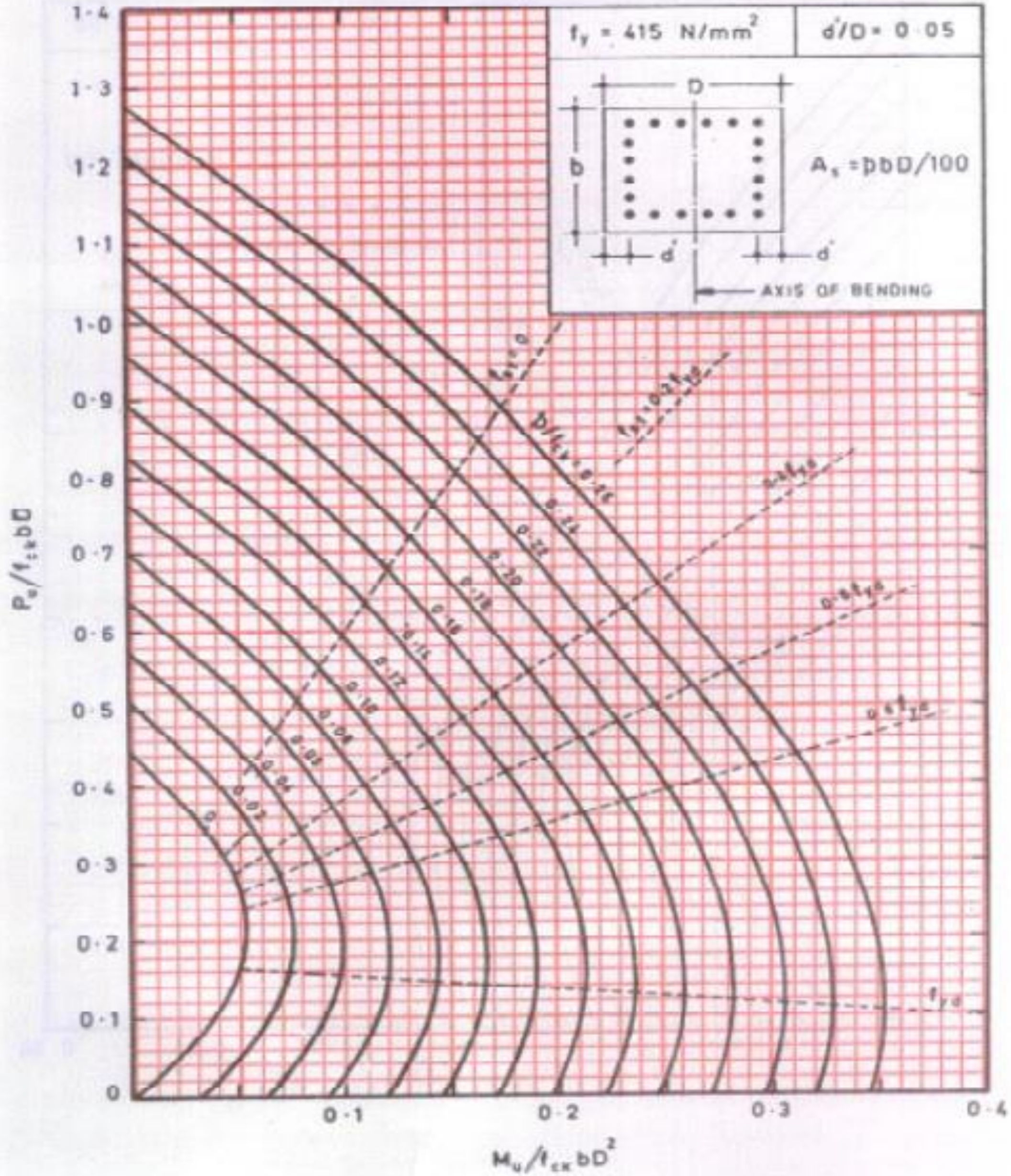


Chart 43 COMPRESSION WITH BENDING — Rectangular Section — Reinforcement Distributed Equally on Four Sides



Design of Uniaxial bending column

Section is assumed and calculation for A_{sc} is done using charts

$\frac{P_u}{f_{ck}bD}, \frac{M_u}{f_{ck}bD^2}$ are calculated, they are the strength parameter for column against compression due to axial load and uniaxial bending respectively.

$\frac{p}{f_{ck}}$ are found from graph

Design of Biaxial bending column

Designed basically using SP16 design aid for IS 456:2016

$$\left(\frac{M_{ux}}{M_{ux1}}\right)^{\alpha} + \left(\frac{M_{uy}}{M_{uy1}}\right)^{\alpha} \leq 1.0$$

$P \times e_x$

$P \times e_y$

M_{ux} *and* M_{uy} is moment about x and y axes

M_{ux1} *and* M_{uy2} is moment capacity about x and y axes

Design of Biaxial bending column

PANA ACADEMY

$I_x = \frac{bd^3}{12}$ $I_y = \frac{db^3}{12}$

p is percentage of longitudinal reinforcement (assumed)

1.2

Different chart are made based on d'/D ratio and f_y

$\frac{p}{f_{ck}}, \frac{P_u}{f_{ck}bD}$ are calculated

$\frac{M_{ux1}}{f_{ck}bD^2}$ is computed from graph, thus calculating moment resisting strength about x axis. Similar is repeated for y axis

Design of Biaxial bending column

The value of α depend upon P_u/P_{uz}

$$P_{uz} = 0.45 f_{ck}.A_c + 0.75 f_y.A_{sc}$$

P_u is axial load

P_{uz} is ultimate load capacity

P_u/P_{uz}	α
≤ 0.2	1.0
≥ 0.8	2.0

0.8

$$\frac{2-1}{0.8-0.2} \times (0.8-0.2) + 1 \quad 1.667$$

Reinforcement in column

PANA ACADEMY

Longitudinal reinforcement

12 × 12

14 × 14

- Minimum : 0.8%
- Maximum : 6%
- Practically noy more than 4%

Minimum 4 bars needs to be provided in rectangular and 6 in circular, not less than 12 mm diameter

For helical reinforcement provided number of bars required is 6

Spacing should not be more than 300 mm

Reinforcement in column

Traverse reinforcement

Pitch: should not be more than least of

- Least dimension of column (b)
- 16ϕ where ϕ is diameter of longitudinal reinforcement
- 300 mm

Diameter: Should not be less than

- $\phi/4$
- 6mm

Reinforcement in column

Traverse helical reinforcement

- Pitch:

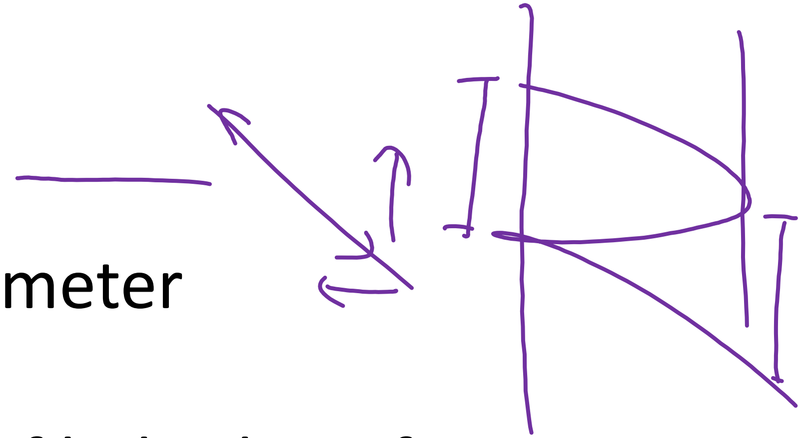
  should not be more than

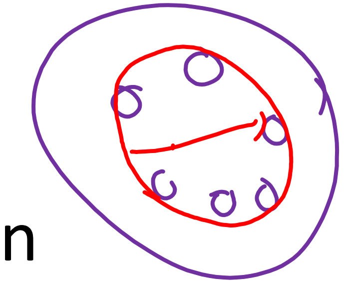
  75 mm, one sixth core diameter

  should not be less than

  $3\phi'$ where ϕ' is diameter of helical reinforcement

  25 mm





Diameter: Should not be less than

$\phi/4$ where ϕ is diameter of longitudinal reinforcement

6mm

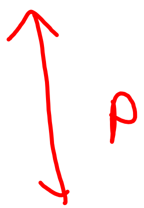
Reinforcement in column

Helical reinforcement

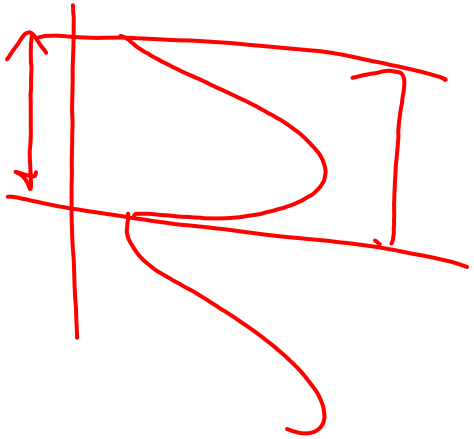
The ratio of volume of helical reinforcement to core volume shall not be less than $0.36\left(\frac{A_g}{A_c}-1\right) f_{ck}/f_y$

A_c is area of core

A_g is gross area of column



$A \ \frac{\pi \phi^2}{4} \times l$



Design of Slender column

PANA ACADEMY

Additional moments

$$M_{ax} = \frac{P_u D}{2000}\left(\frac{l_{ex}}{D}\right)^2$$

$$M_{ay} = \frac{P_u b}{2000}\left(\frac{l_{ey}}{b}\right)^2$$

Reduction factor

$$k = \frac{P_{uz} - P_u}{P_{uz} - P_b}$$

P_b is computed from values in table 60 in SP 16 which is axial load corresponding to the condition of maximum compressive strain of 0.0035 in concrete and tensile strain of 0.002 in outermost layer of tension steel.

Design of Slender column

PANA ACADEMY

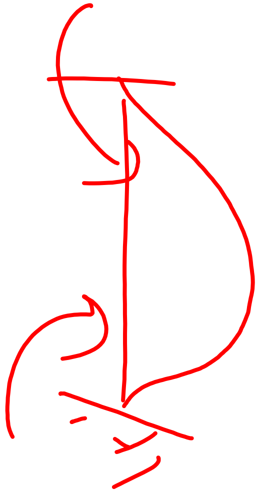
In case of braced column

Single curvature

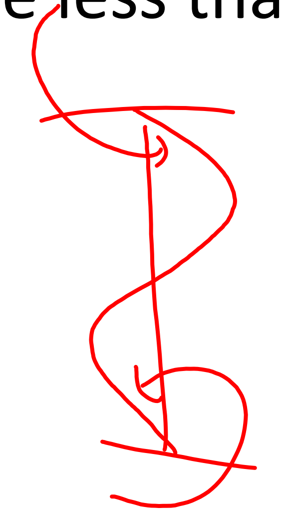
Additional moment = $0.4\,M_{u1} + 0.6M_{u2} \geq 0.4M_{u2}$

In case of bending by double curvature

Additional moment = $0.6M_{u2} - 0.4\,M_{u1} \geq 0.4M_{u2}$



Total moment should not be less than M_{u2}



Design of Slender column

PANA ACADEMY

$$P_b/f_{ck}bD = k_1 + k_2p/f_{ck}$$

Values of k_1

Section	d'/D 0·05	0·10	0·15	0·20
Rectangular	0·219	0·207	0·196	0·184
Circular	0·172	0·160	0·149	0·138

Values of k_2

Section	f_y N/mm²	d'/D 0·05	0·10	0·15	0·20
Rectangular; equal reinforcement on two opposite sides	250	−0·045	−0·045	−0·045	−0·045
	415	0·096	0·082	0·046	−0·022
	500	0·213	0·173	0·104	−0·001
Rectangular; equal reinforcement on four sides	250	0·215	0·146	0·061	−0·011
	415	0·424	0·328	0·203	0·028
	500	0·545	0·425	0·256	0·040
Circular	250	0·193	0·148	0·077	−0·020
	415	0·410	0·323	0·201	0·036
	500	0·543	0·443	0·291	0·056

Column base

PANA ACADEMY

maximum bearing stress at base is found by multiplying permissible bearing stress and $\sqrt{\frac{A_1}{A_2}}$ *but not more than* 2

$\boxed{\sigma_b \times \sqrt{\frac{A_1}{A_2}}}$

A_1 is area made having slope one vertical to two horizontal
A_2 is area of column base
Permisible bearing stress is 0.25fck for working stress and 0.45fck for limit state method

P/A

If it is exceeded dowels are provided

Design of footing

6%

Minimum thickness of edge of footing

150mm on soil

300mm above top of pile

Cover 50 mm is provided.

Designed almost as a flat slab.

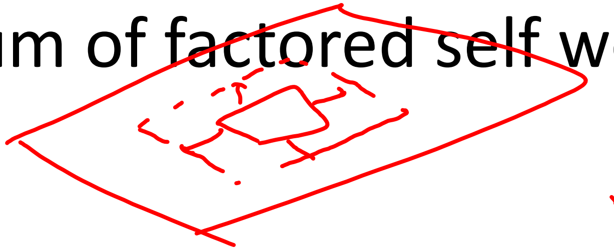
Depth of footing depend on bending moment and shear, Usually shear is detrimental for thickness of footing.

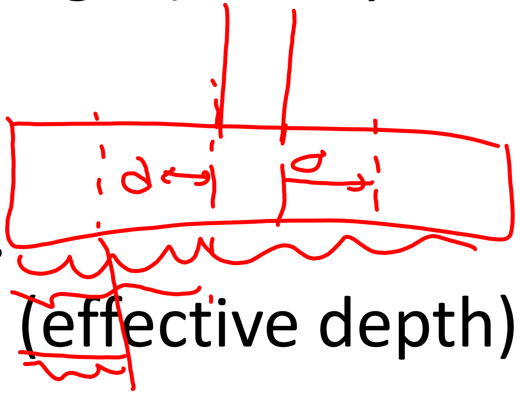
Factored load/footing area should be less than bearing capacity of soil, thus dimension of footing is found.

Design of footing

PANA ACADEMY

Design load is sum of factored self weight(usually 10%) and load from column



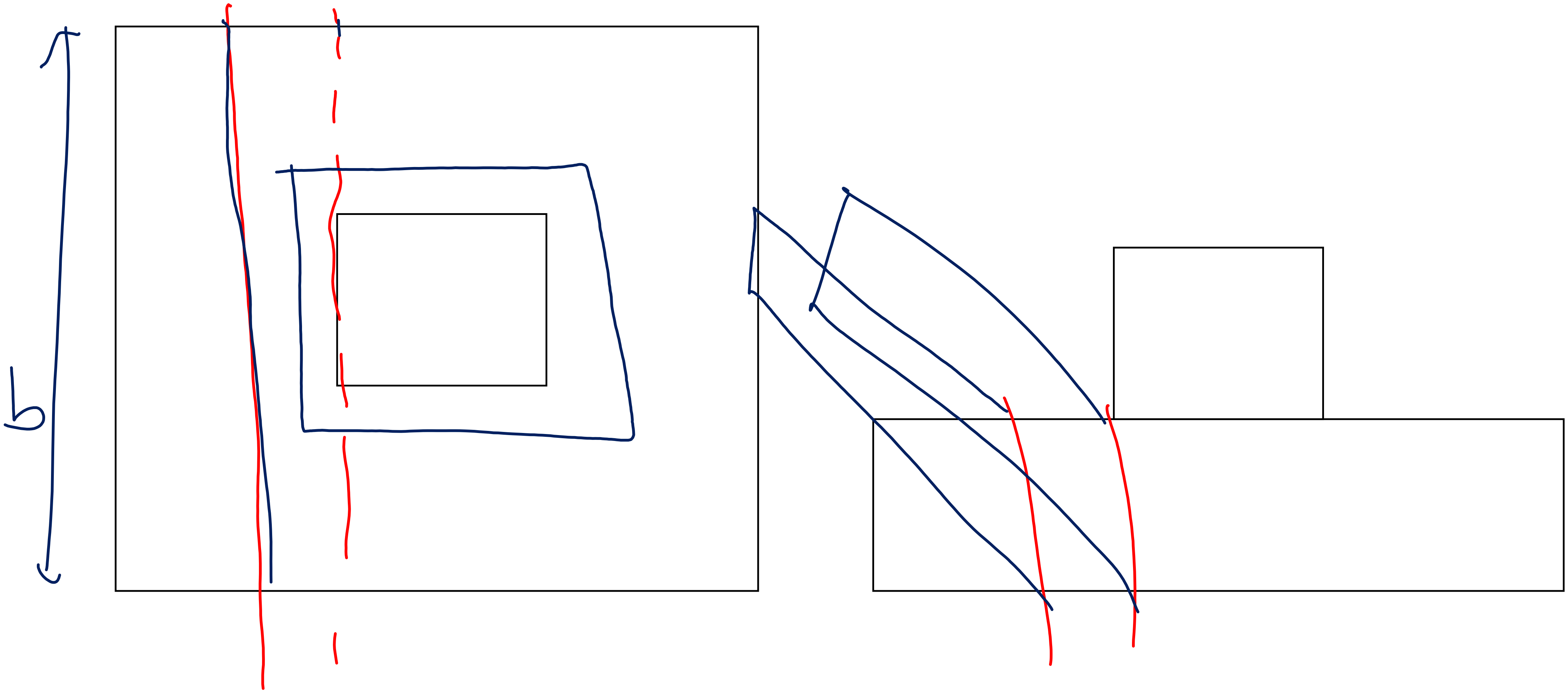


Moment is critical at face of column.

One way shear is critical at section d (effective depth) from column face.

Two way shear is critical at section d/2 (half of effective depth) from column face all around.

Design of footing



Design of footing for moment

PANA ACADEMY

$x_u = x_{u,lim}$

Moment of resistance for balanced section

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

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

$M_u = 0.138 f_{ck} b d^2$

face of column

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

$B \to 1000\,mm$

$\frac{B}{no}$

Space = $\frac{1000}{no.\ of}$

3d or 300 mm

0.15%

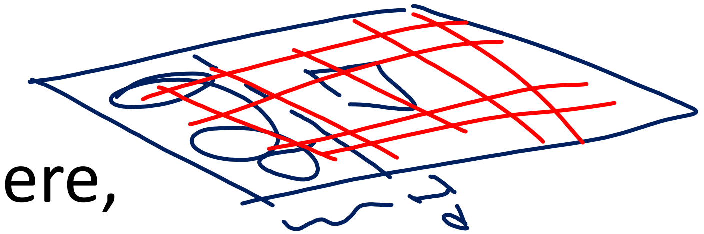
0.12%

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

Design of footing one way shear

Footing is designed such that shear is carried out such that no shear reinforcement is required.

Where,



$$\tau_v \leq \tau_c = \frac{V_u}{Bd}$$

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

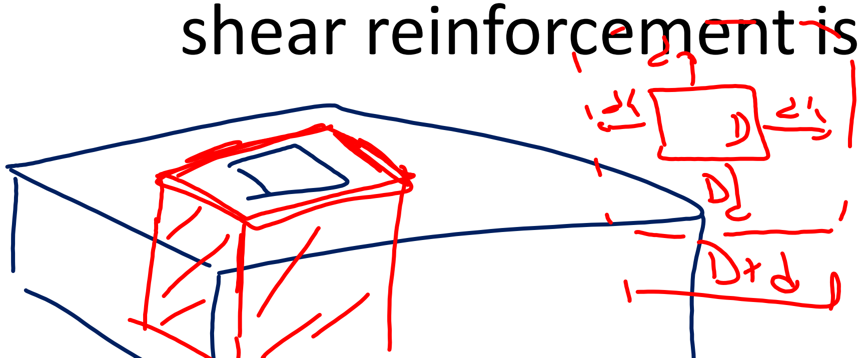
Table 19 Design Shear Strength of Concrete, τ_c, N/mm²

(*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

Footing two way shear (punching)

Footing is designed such that shear is carried out such that no shear reinforcement is required.



$$\tau_v = \frac{V_u}{4(D+d)d}$$

$$\tau_v < k_s \tau_c$$

Clause 31.6.3 Is 456

$$k_s = 0.5 + \beta_c \leq 1$$

β_c is ratio of shorter side to longer side

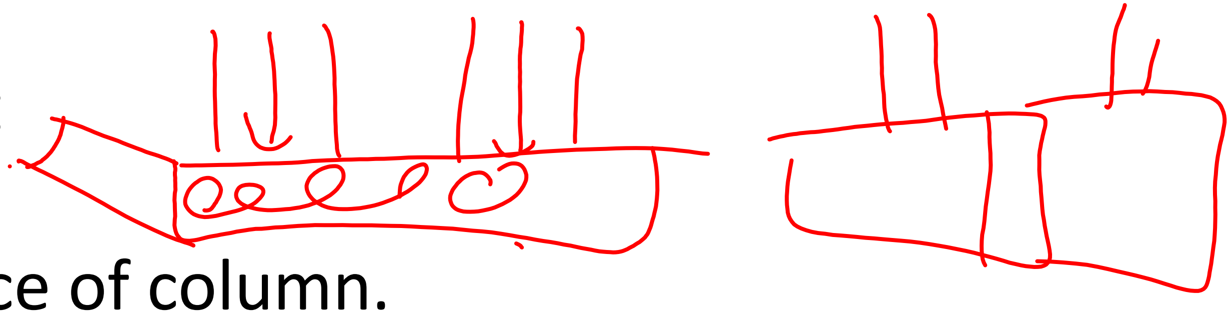
$$\tau_c = 0.25\sqrt{f_{ck}}$$

Design of Combined footing

PANA ACADEMY

Design load is sum of factored self weight(usually 10%) and load from column

W=W1+W2+self weight



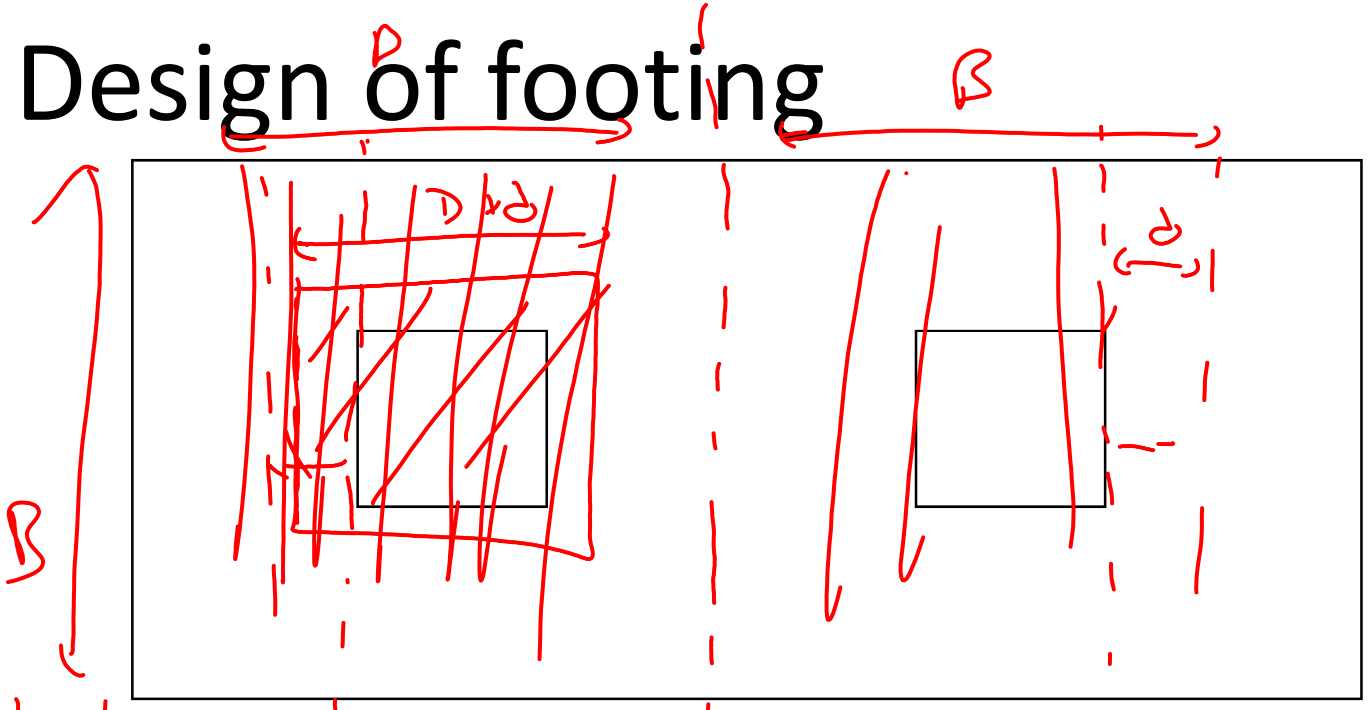
Moment is critical at face of column.

Need to design for hogging moment which arrises between two columns.

One way shear is critical at section d (effective depth) from column face between two column.

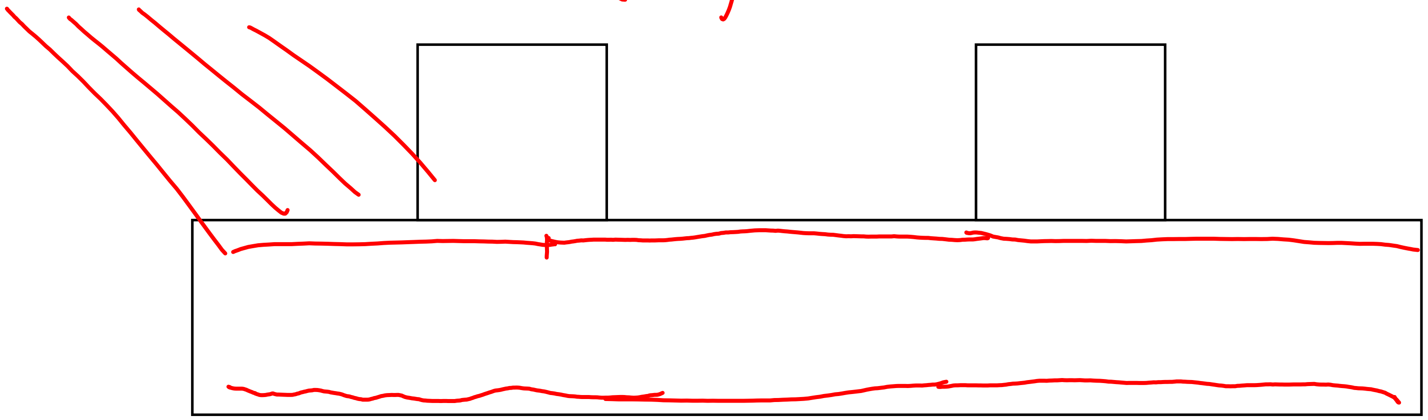
Two way shear is critical at section d/2 (half of effective depth) from column face all around the column taking heavier load.

Design of footing



d $V_s = W_1 - w \times (D+d)^2$

A_{st}



Design of footing for moment

PANA ACADEMY

Moment of resistance for balanced section

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

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

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

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

Design of footing one way shear (beam)

PANA ACADEMY

Footing is designed such that shear is carried out such that no shear reinforcement is required.

$$\tau_v < \tau_c$$

Where,

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

Table 19 Design Shear Strength of Concrete, τ_c, N/mm²

(*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

Footing two way shear (punching)

PANA ACADEMY

Footing is designed such that shear is carried out such that no shear reinforcement is required.

$$\tau_v = \frac{V_u}{4(D+d)d}$$

$$\tau_v < k_s \tau_c$$

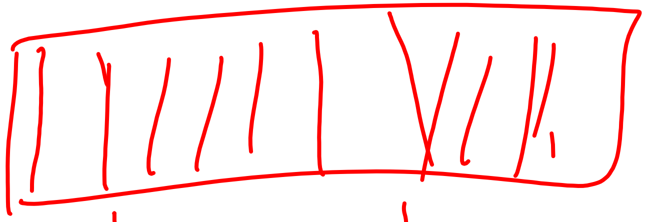
Clause 31.6.3 Is 456

$$k_s = 0.5 + \beta_c \leq 1$$

β_c is ratio of shorter side to longer side

$$\tau_c = 0.25\sqrt{f_{ck}}$$

Reinforcement



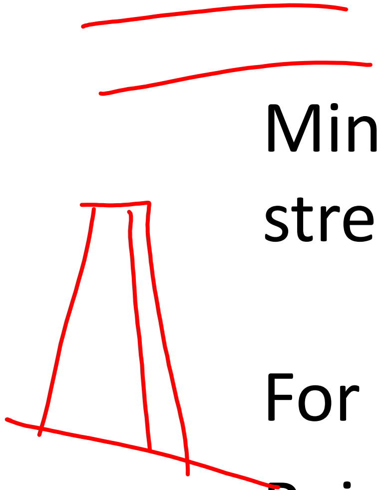
Minimum reinforcement is 0.15% of total cross section for mild steel

3m x 5m combined footing

5/3

2B / n

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



B= longer/shorter

$Ast / \frac{\pi \phi^2}{4}$

For rectangular footing

Reinforcement in central band= $\frac{2}{\beta+1}$ Total reinforcement

β is ratio of long side to short

$\frac{2}{5/3+1}$ = 75%

Footing design

PANA ACADEMY

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.

Prestress Concrete

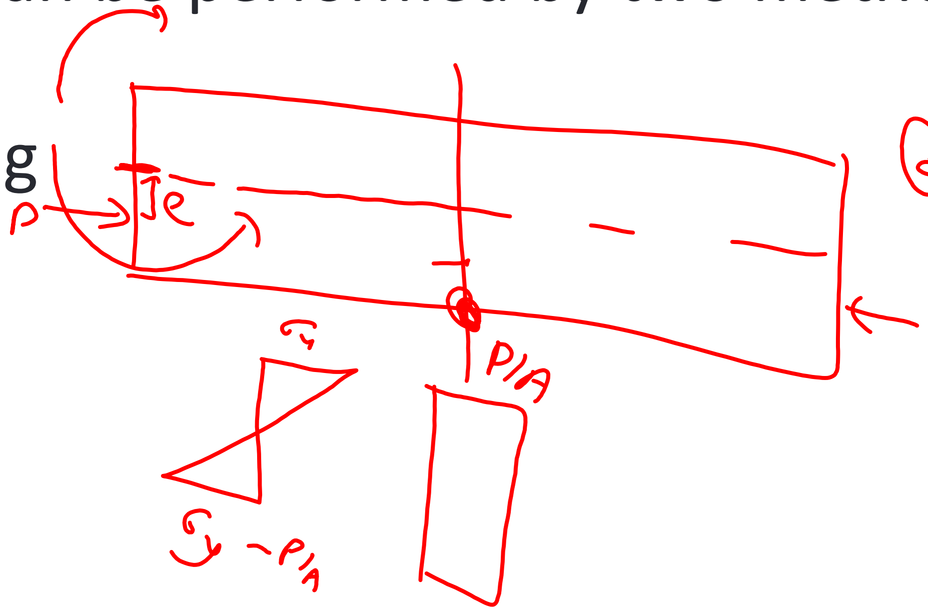
PANA ACADEMY

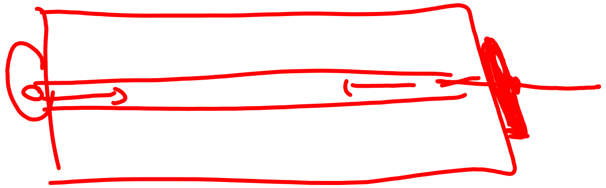
The concrete structure is stresses before service load acts on it by the use of tensioned tendons.

$M = \frac{wl^2}{8}$ $\quad \frac{M}{I} = \frac{\sigma}{y}$

The prestressing can be performed by two methods:

1. Pretensioning
2. Post-Tensioning





4m → 120kNm

8m → 4×120

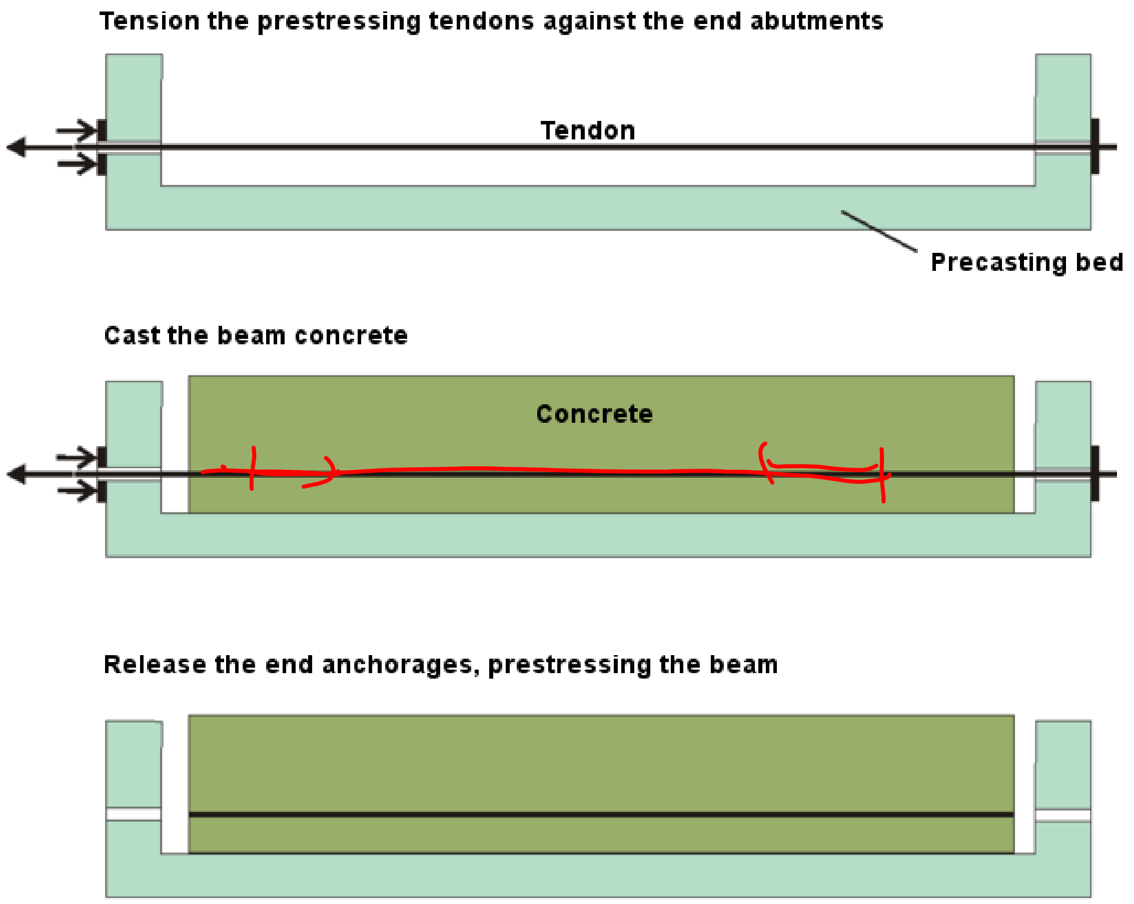
Pretensioned Prestress Concrete

40 MPa

PANA ACADEMY

Used for small structure

Tendons are tensioned before pouring concrete.



Post tensioned Prestress Concrete

Used for large structure

Tendons are tensioned after concrete is set.
Tension may be cast insitu or introduced after concrete is set.

Bonded and unbonded

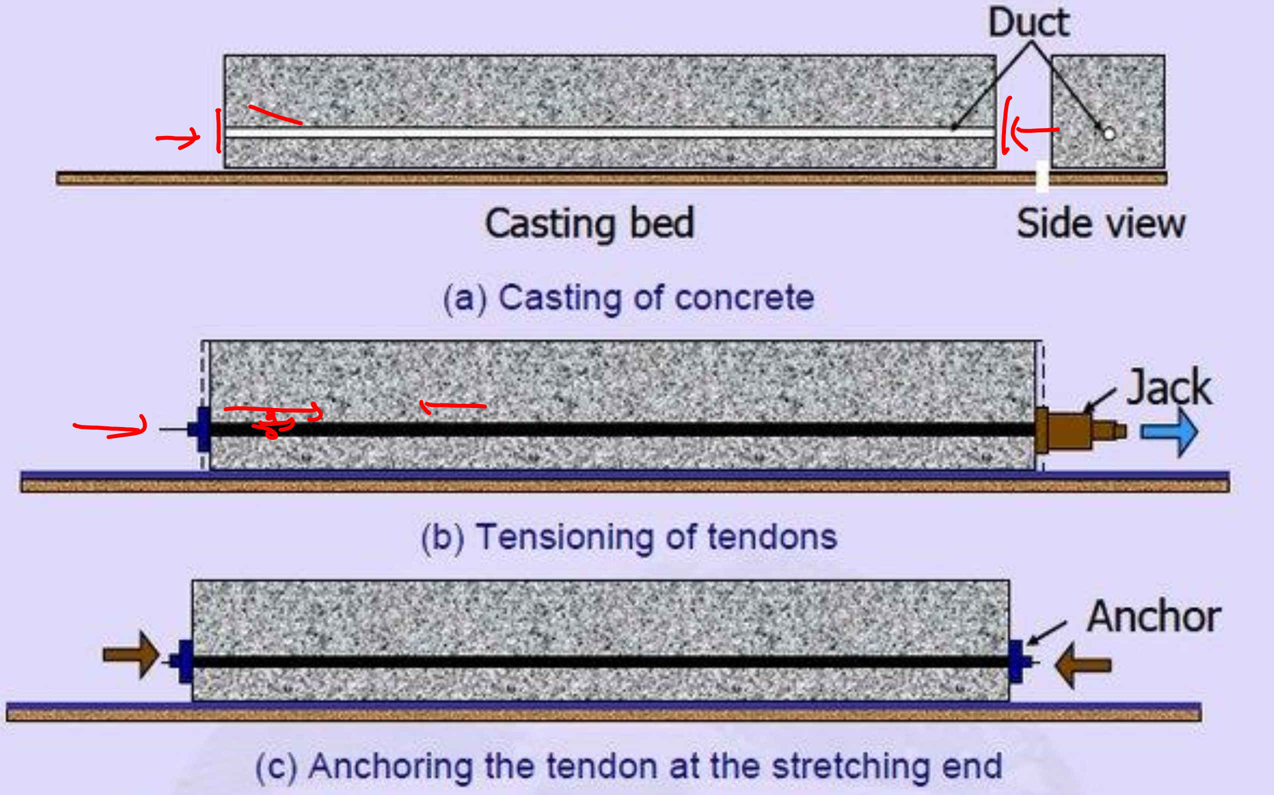
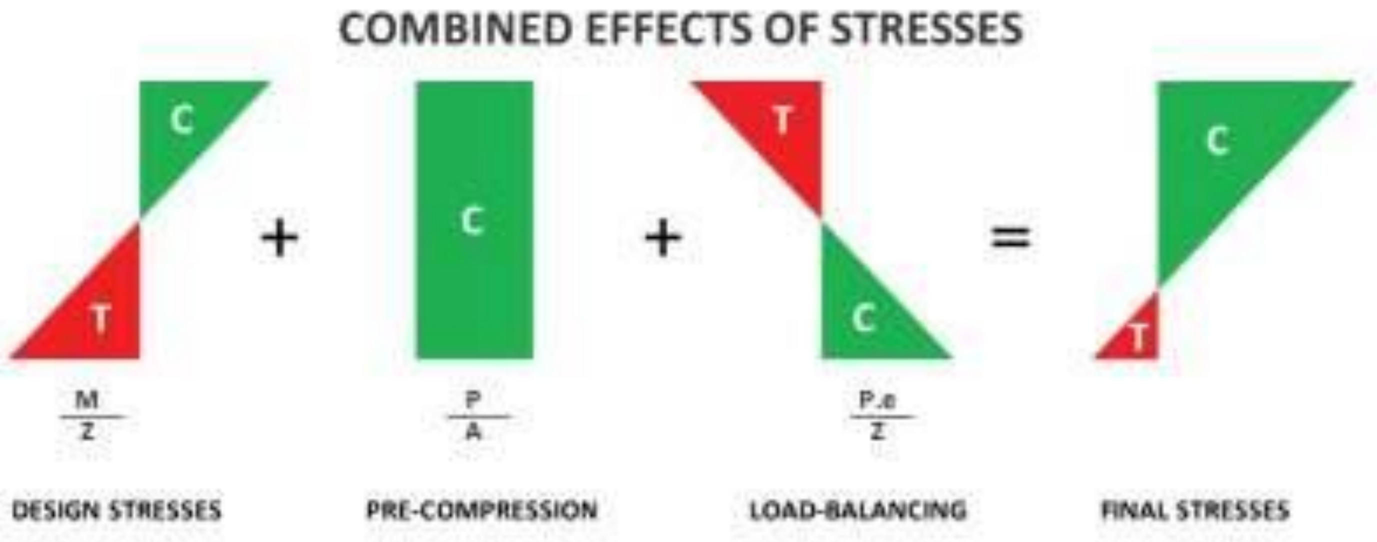


Figure 1-4.4 Stages of post-tensioning (shown in elevation)

Prestress Concrete

Effect of prestress on RCC



Prestress Concrete

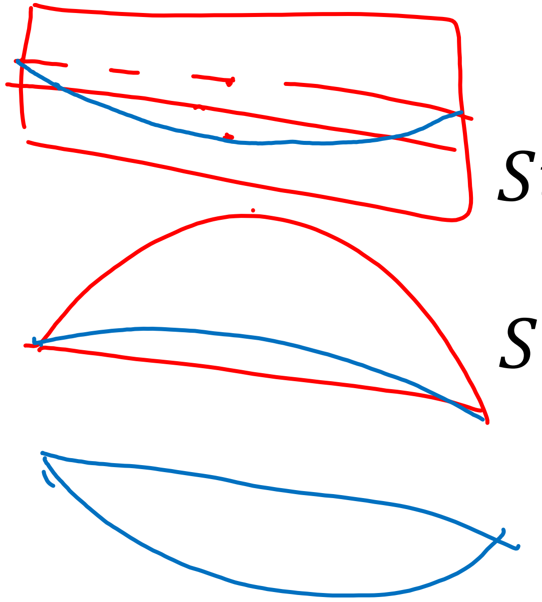
PANA ACADEMY

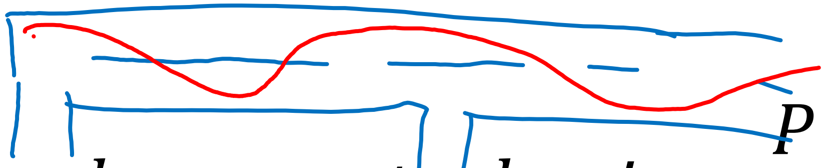
Profile of tendon cable can be straight , parabolic or any other based on usefulness.

Strengthens the structure, makes sizes small

Concrete and tendons should be of high strength

$\frac{P}{A} + \frac{Pe}{Z}$





$$Stress\ above\ neutral\ axis = \frac{P}{A} - \frac{Pey}{I} + \frac{My}{I}$$

$$Stress\ below\ neutral\ axis = \frac{P}{A} + \frac{Pey}{I} - \frac{My}{I}$$

MCQS

PANA ACADEMY

When minimum eccentricity in columns does not exceed 0.05 times the lateral dimension, the axial load carrying capacity is reduced by ________.

a) 9%
b) 10%
c) 11%
d) 15%

MCQS

Minimum eccentricity to be considered for axially loaded RCC column of size 400 mm x 400 mm with unsupported length of 5 m is:

a) 15.6 mm
b) 20.5 mm
c) 23.3 mm
d) 30.6 mm

MCQS

Minimum number of longitudinal bars in rectangular column is

a) 4
b) 6
c) 8
d) none

MCQS

PANA ACADEMY

A reinforced concrete column of size 400 mm x 400 mm is having the diameter of longitudinal bar as 20 mm. The pitch of lateral ties in such a case should be:

a) 320 mm
b) 400 mm
c) 300 mm
d) 250 mm

MCQS

PANA ACADEMY

The minimum area of longitudinal reinforcement in a RCC column 400 mm x 400 mm, shall not be less than ……… .

a) 600 mm^2
b) 640 mm^2
c) 800 mm^2
d) 1280 mm^2

MCQS

PANA ACADEMY

If the independent spread footing of two columns are connected by a beam, it is called ____________

a) Isolated footing
b) Combined footing
c) Strap footing
d) Raft footing

MCQS

PANA ACADEMY

The type of footing if two column have unequal loading

a) Rectangular combined
b) Trapezoidal combined
c) Raft footing
d) Strip footing

MCQS

PANA ACADEMY

Depth of footing for isolated column is governed by

a) Maximum bending moment
b) Shear force
c) Punching shear
d) All of these

MCQS

PANA ACADEMY

Reinforcement on combined footing is placed at

a) Bottom only
b) Top only
c) Top and bottom
d) None

MCQS

Given size of column as 200 mm x 400 mm carrying 330kN load and soil bearing capacity 150kN/m^2. Calculate footing area in square meter.

a) 2.42
b) 3.42
c) 4.24
d) 3.06

MCQS

PANA ACADEMY

For RC footing ratio of long side to short side 1.5, the ratio of reinforcement in central band width to total reinforcement in short direction is:

a) 0.6
b) 0.8
c) 1.2
d) 1.5

MCQS

PANA ACADEMY

Cube strength of concrete to be used for pre-tensioned and post- tensioned work should not be less than

a) 30 MPa and 40 MPa
b) 40 MPa and 30 MPa
c) 40 MPa and 60 MPa
d) 60 MPa and 40 MPa

MCQS

PANA ACADEMY

Which of the following influence the deflections of prestressed concrete members?

a) Wall profile
b) Type of aggregates
c) Type of cement
d) Cable profile

MCQS

PANA ACADEMY

If the direct stresses are compressive, then the magnitude of principal stresses in prestressed concrete member gets __________

a) Zero
b) Increased
c) Decreased
d) Constant

MCQS

PANA ACADEMY

The soffit of the beam after the transfer of prestress to concrete will be under ____________

a) Bondage
b) Breakage
c) Compression
d) Tension

PANA ACADEMY

Thank YOU !!!