DESIGN OF PILE CAP FOR FOUR (04) PILE

A column of size 230 x 700 mm subjected to a factored load of 5900 KN. The ultimate pile capacity of each individual end bearing pile is 1900 KN. Where the diameter for pile is 500 mm. Materials to be used as M30 and Fe 500. Design and detail suitable pile cap.

Step-01: Determination Pile Cap Dimensions (As per IS 2911)

Column Size, b x D = 230 x 700 mm……(Given)

Factored Load, Pu = 5900 KN ……(Given)

Capacity of each individual pile = 1900 KN……(Given)

Diameter of pile, D_p = 500 mm……(Given)

Materials: M30 and Fe 500……(Given)

Number of pile required, $N = \frac{5900}{1900} = 3.105 \cong 4$ No.s

C-C distance between pile (IS 2911, Page. 04, Cl. 6.6.1,) Lc-c = 2.5 x D_p = 2.5 x 500 = 1250 mm

Clear Edge distance (IS 2911, Page. 06, Cl. 6.6.1,) E_{clear} = 250 mm

Effective Edge distance, $E_{eff} = 250 + \frac{D_p}{2} = 250 + \frac{500}{2} = 500$ mm

Reaction at under each pile, $R = \frac{5900}{4} = 1475.00$ KN

downloaded from StudentSuvidha.com

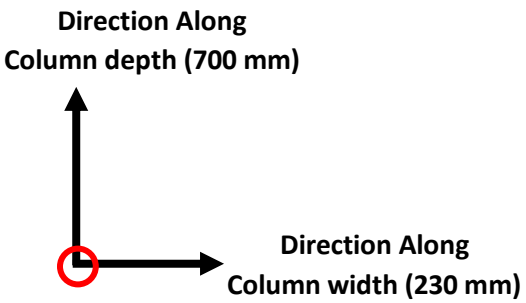


Fig.(a) Direction Consideration

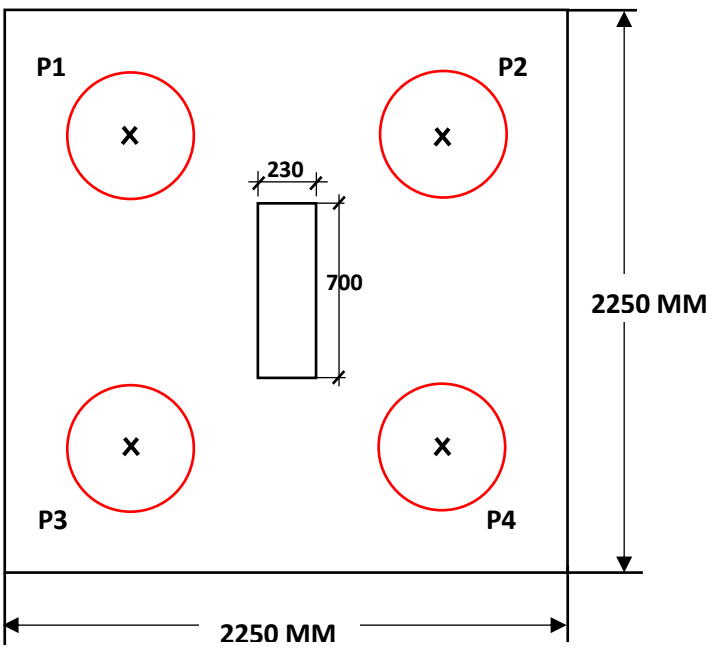


Fig. (b) In-Plan Dimensions of Pile Cap

STEP-02 TRIAL DEPTH OF PILE CAP

As per the Varghese* empirical expression the thickness of the pile cap will be as a function of pile diameter i.e.

1. $D_{pile-cap} = 2\,D_p + 100$ ..... When D_p is less than 550 mm
2. $D_{pile-cap} = (1/3)\,(8D_p + 600)$ ..... When D_p is equal to or greater than 550 mm

As in proposed example, the diameter of the pile is 500 mm, hence the empirical formula number 1 is needed to adopt for finding trial depth.

$D_{pile-cap} = 2 \text{ x } Dp + 100 = 2 \text{ x } 500 + 100 = 1100 \text{ mm}$

Now adopting trail depth as, $D_{pile-cap} = 1200$ mm

Note: The depth of the pile cap usually should not be less than of 600 mm.

Now, assuming clear cover as 60 mm and diameter of bar as 20 mm.

Effective depth of pile cap, $d_{eff} = D - \text{Clear cover} - \emptyset/2 = 1200 - 60 - 20/2 = 1130$ mm

STEP-03 DESING FOR FLEXURE

(a) Bottom reinforcement along width of column

$$M_u = 2 \text{ x } R \text{ x } \left[\frac{L_{c-c}}{2} - \frac{B_{column}}{2} \right] = 2 \text{ x } 1475 \text{ x } \left[\frac{1.25}{2} - \frac{0.23}{2} \right] = 1504.5 \text{ KN} - \text{m}$$

b = 1000 mm, d_{cap} = 1130 mm, F_{ck} = 30 MPa, F_y = 500 MPa

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

$$A_{st} = \frac{0.5 \text{ x } 30}{500} \left[1 - \sqrt{1 - {}^{4.6 \text{ x } 1504.5 \text{ x } 10^6}/_{30 \text{ x } 1000 \text{ x } 1130^2}} \right] \text{x } 1000 \text{ x } 1130 = 3214.67 \text{ mm}^2$$

$A_{st} = 3214.67$ mm² (Design Requirement)

$A_{st\text{-}min} = 0.12\ \%$ x b x D = 0.12 % x 1000 x 1200 = 1440 mm² (Minimum Requirement)

Providing T25 mm, Unit area of bar = 490.87 mm²

$$\text{Spacing Required, } S_{req} = \frac{490.87}{3214.67} \text{ x } 1000 = 152.696 \text{ mm}$$

Hence provide the spacing as 125 mm c/c

Downloaded from StudentSuvidha.com

Provide T25 @ 125 mm c/c along width of column.

Area of steel provided, A_{st} = (490.87/125) x 1000 = 3926.96 mm²

$$P_t = \frac{Ast}{b \times d_{cap}} = \frac{3926.96}{1000 \times 1130} \times 100 = 0.3475\ \%$$

(b) Bottom reinforcement along depth of column

$$M_u = 2 \times R \times \left[\frac{L_{c-c}}{2} - \frac{D_{column}}{2} \right] = 2 \times 1475 \times \left[\frac{1.25}{2} - \frac{0.70}{2} \right] = 811.25\ KN - m$$

b = 1000 mm, d_{cap} = 1130 mm, F_{ck} = 30 MPa, F_y = 500 MPa

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

$$A_{st} = \frac{0.5 \times 30}{500} \left[1 - \sqrt{1 - {}^{4.6 \times 811.25 \times 10^6}/_{30 \times 1000 \times 1130^2}} \right] \times 1000 \times 1130 = 1693.52\ mm^2$$

A_{st} = 1693.52 mm² (Design Requirement)

$A_{st\text{-}min}$ = 0.12 % x b x D = 0.12 % x 1000 x 1200 = 1440 mm² (Minimum Requirement)

Providing T25 mm, Unit area of bar = 490.87 mm²

Spacing required over width,

$$S_{req} = \frac{490.87}{1693.52} \times 1000 = 289.85\ mm$$

Hence provide the spacing as 275 mm c/c

Provide T25 @ 275 mm c/c along depth of column.

Area of steel provided, A_{st} = (490.87/275) x 1000 = 1784.98 mm²

$$P_t = \frac{Ast}{b \times d_{cap}} = \frac{1784.98}{1000 \times 1130} \times 100 = 0.158\ \%$$

(c) Top reinforcement along width and depth of column (i.e. both direction)

There is no tensile force or hogging moment, hence minimum percentage of reinforcement is needed to provide.

$A_{st\text{-}min}$ = 0.06 % x b x D = 0.06 % x 1000 x 1200 = 720 mm²

Providing T12 mm, Unit area of bar = 113.09 mm²

downloaded from StudentSuvidha.com

Spacing required over length,

$$S_{req} = \frac{113.09}{720} \text{x } 1000 = 157.06 \text{ mm}$$

Therefore, **T12 @ 150 mm c/c** along both directions.

Area of steel provided, A_{st} = (113.09/150) x 1000 = 753.93 mm^2

$$P_t = \frac{Ast}{b \text{ x } d_{cap}} = \frac{753.93}{1000 \text{ x } 1130} \text{x } 100 = 0.067 \text{ \%}$$

SUMMARY FOR FLEXURAL DESIGN

Sr. No.	Location	Direction	Reinforcement	Percentage (%)
1	Bottom	Along width of column	T25 @ 125 mm	0.3475
		Along depth of column	T25 @ 275 mm	0.158
2	Top	Along width of column	T12 @ 150 mm	0.067
		Along depth of column	T12 @ 150 mm	0.067

STEP-03 DESING CHECKS FOR SHEARS

(a) Check for punching shear around column

Considering critical section at a distance of $d_{cap}/2$ from column face.

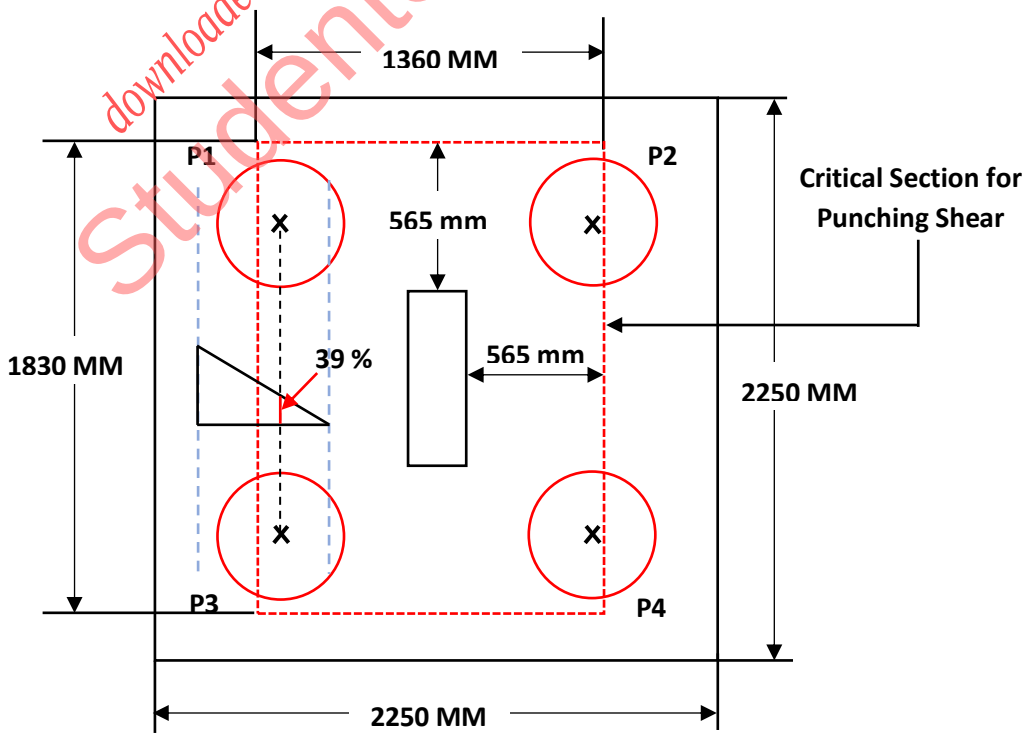


Fig. (c) Punching shear at (d/2) around column

downloaded from StudentSuvidha.com

Now as per IS 456-2000, Cl.34.2.4.2, Pg. No. 65 and by following Fig.(a)

Pile Number	Reaction	% To be considered	Shear Reaction
P1	1475.00	39	575.25
P2	1475.00	39	575.25
P3	1475.00	39	575.25
P4	1475.00	39	575.25

Total Factored shear force around column,

Vu = P1 + P2 + P3 + P4 = 4 x 575.25 = 2301.00 KN

Total perimeter length of shear area, $= (d_{cap} + B_{column}) \times 2 + (d_{cap} + D_{column}) \times 2$

$= 2 \times (1130 + 230) + 2 \times (1130 + 700) = 6380$ mm

Nominal shear at critical section, $T_v = \frac{V_u}{b' \times d} = \frac{2301.00 \times 10^3}{6380 \times 1130} = 0.319$ MPa

IS 456-2000, Pg. 58, Cl.31.6.3…… Shear at critical section = $T_c \times K_s$

$K_s = 0.5 + \beta_c$ where β_c = shorter side of column / Longer side of column

Therefore, $\beta_c = 230/700 = 0.3285$ Therefore, Ks = 0.5 +0.3285 = 0.8285 < 1

$Tc = Ks \times 0.25\sqrt{f_{ck}} = 0.8285 \times 0.25 \times \sqrt{30} = 1.1345$ MPa

Punching shear ratio, $= \frac{T_v}{T_c} = \frac{0.319}{1.1345} = 0.2812 < 1$ Hence design is safe in punching shear.

(b) Check for punching shear around pile

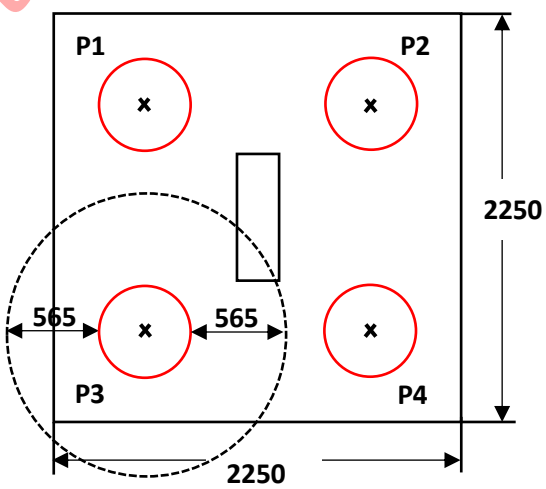


Fig. (c) Punching shear at (d/2) around Pile

downloaded from StudentSuvidha.com

Over all perimeter length around pile $b' = \pi \times \left(\frac{d_{cap}}{2} + D_{pile} + \frac{d_{cap}}{2}\right)$

Perimeter length around pile, $b' = 3.1416 \times \left(\frac{1130}{2} + 500 + \frac{1130}{2}\right) = 5120.808$ mm

Effective perimeter length, $b_{effective} = 0.25 \times 5120.808 = 1280.202$ mm

Punching shear section around the pile at d/2 from pile face,

Factored Shear force, $V_u = 1475.00$ KN

Nominal Shear at critical section, $T_v = \frac{V_u}{b' \times d} = \frac{1475.00 \times 10^3}{1280.202 \times 1130} = 1.0196$ MPa

IS 456-2000, Pg. 58, Cl.31.6.3

Shear at critical section = $T_c \times K_s$

$K_s = 0.5 + \beta_c$ where β_c = Shorter side of column/Longer side of column

Therefore, $\beta_c = 500/500 = 1.0$ Therefore, $K_s = 0.5 + 1.00 = 1.50$ limiting to 1.0

$Tc = Ks \times 0.25\sqrt{f_{ck}} = 1.0 \times 0.25 \times \sqrt{30} = 1.3693$ MPa

Punching shear capacity ration, $= \frac{T_v}{T_c} = \frac{1.0196}{1.3693} = 0.7446 < 1$

Hence the provided depth is safe in punching shear around pile.

(C) Check for one – way shear (along width of column)

Considering critical section for one way shear at a distance of $d_{cap}/2$ from the face of the column along its width.

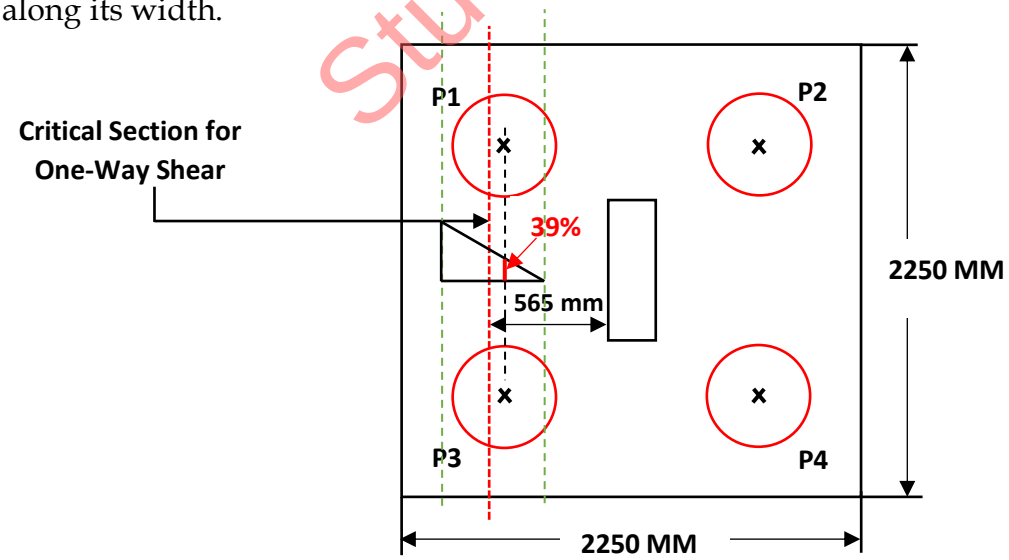


Fig. (e) One-way shear at (d/2) along width of column

StudentSuvidha.com
downloaded from

Pile Number	Reaction	% To be Considered	Shear Reaction
P1	1475.00	39	575.250
P2	1475.00	39	575.250
P3	1475.00	39	575.250
P4	1475.00	39	575.250

Design shear force, V_u = Maximum of (P1+P3, P2+P4) = 1150.5 KN

Effective depth of pile cap, d_{eff} = 1130 mm and

width of pile cap available at critical section, B_{eff} = 2250 mm

Nominal shear at critical section, $T_v = \frac{V_u}{B_{eff} \times d_{eff}} = \frac{1150.5 \times 10^3}{2250 \times 1130} = 0.4525$ MPa

At a proposed critical section, the available % of reinforcement is 0.3475%. Therefore, as per IS 456-2000, Table.19……Tc = 0.4209 MPa

As per IS 456-2000, Clause 40.5, Page. No. 74

$$a_v = \frac{d_{cap}}{2} - \frac{(L_{c-c} - B_{column})}{2} = \frac{1130}{2} - \frac{(1250 - 230)}{2} = 55 \text{ mm}$$

Now, position of critical section from centre of the pile, a_v = 55 mm

Shear enhancemnet factor, $S_{fact} = \frac{2 \times d_{eff}}{a_v} = \frac{2 \times 1130}{55} = 41.09$

Now enhanced shear strength, $Tc = 0.4209 \times S_{fact} = 0.4209 \times 41.09 = 17.295$ MPa

Now, Tv < Tc …… Hence safe in design.

downloaded from StudentSuvidha.com

Download all NOTES and PAPERS at StudentSuvidha.com

(D) Check for one – way shear (along depth of column)

Considering critical section for one way shear at a distance of $d_{cap}/2$ from the face of the column along its depth.

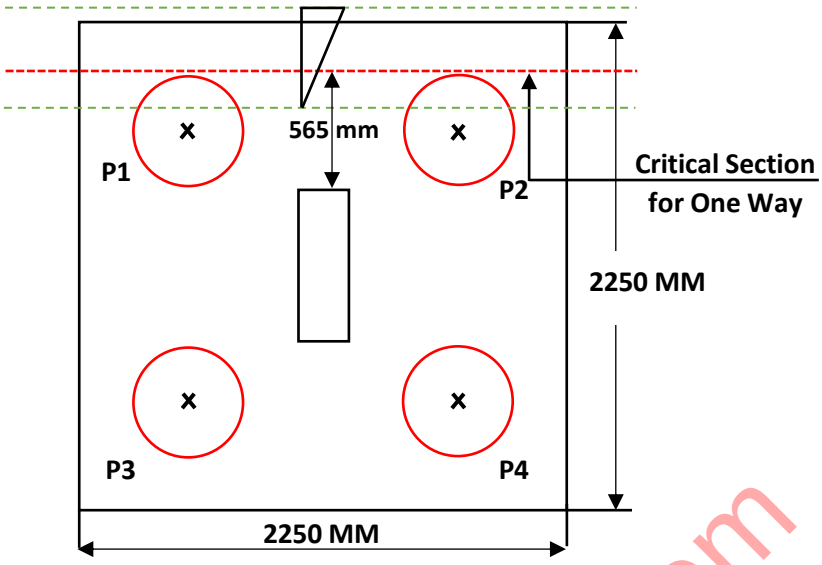


Fig. (e) One-Way Shear at (d/2) Along Depth of Column

Pile Number	Reaction	% To be Considered	Shear Reaction
P1	1475.00	0	0
P2	1475.00	0	0
P3	1475.00	0	0
P4	1475.00	0	0

Note: One – way shear check along depth of column is not applicable.

downloaded from StudentSuvidha.com

STEP-05: IN-PLAN AND SECTIONAL DETAIL OF R/F FOR DESIGN RESULTS

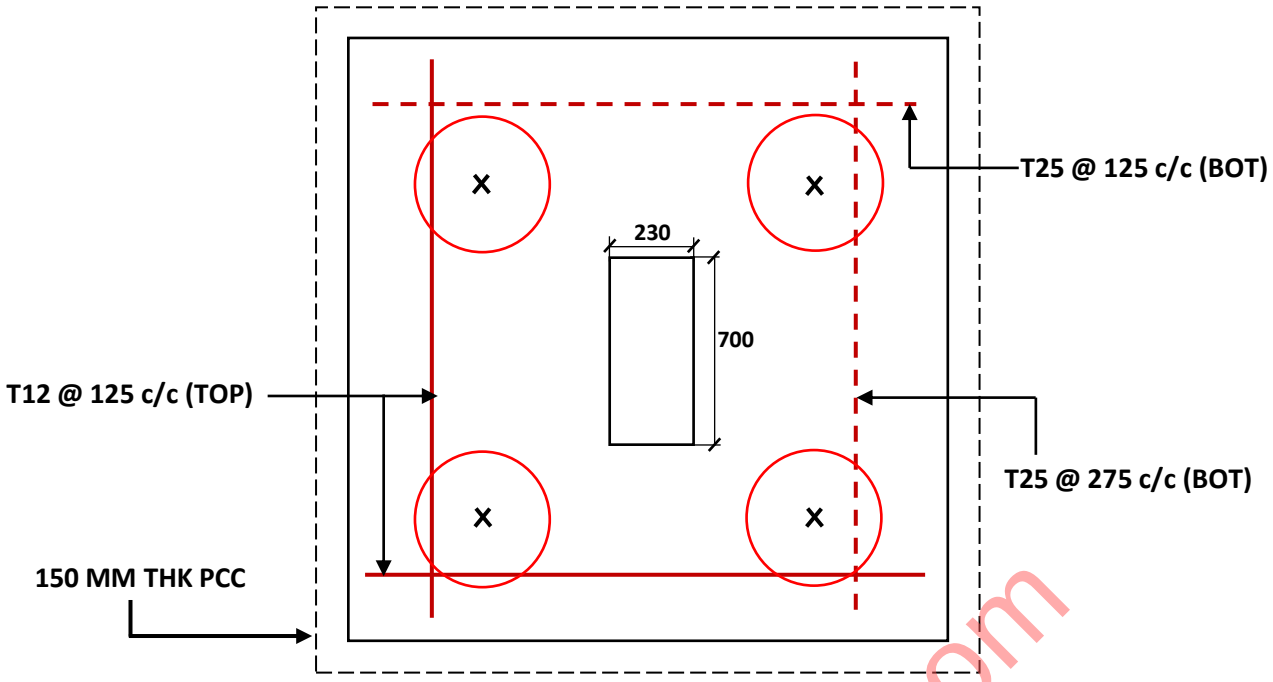


Fig. (f) Pile Cap R/F Design Detail (In-Plan View)

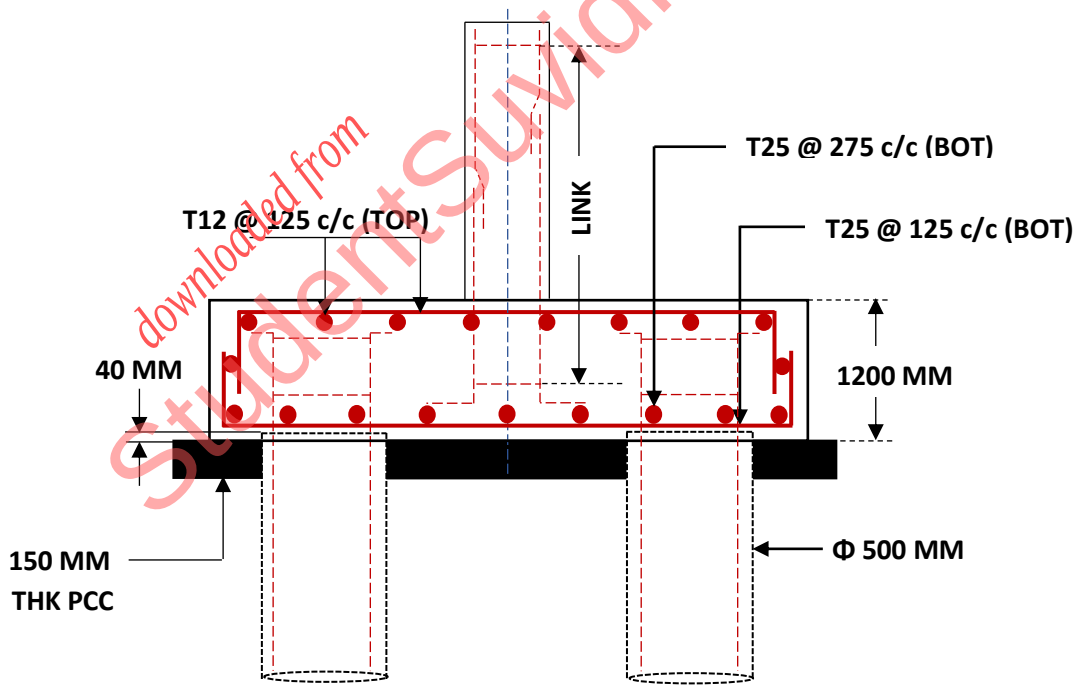


Fig. (g) Pile Cap R/F Design Detail (Sectional Elevation)

downloaded from StudentSuvidha.com