Pad footing design

1) General equation for allowable bearing capacity after Brinch Hansen

$$\text{Pad footings: } q_{\text{allowable}} = \frac{1.3cN_c + q_o'N_q + 0.4\gamma BN_\gamma}{\gamma_f}$$

where : $ˠf$ is factor of safety against bearing capacity failure (2.0 – 3.0),

q' is the effective over- burden pressure,

ˠ is the unit weight of the soil,

B is the width of the foundation,

c is the cohesion (for the drained or undrained case under consideration) and

Nc, Nq and N are shallow bearing capacity factors.

2) Preliminary sizing of pad footing

$$Area = Unfactored\ load\ /\ qallowable$$

$$Area, pad\ footing = B * l$$

where; Unfactored load, is dead load + live load; (kN)

l is length of the footing pad

b is breadth of the footing pad

3) Ultimate bearing pressure

$$ULS, q = factored\ load / Area$$

Where: factored load, is dead load * safety factor + live load * safety factor (kN);

ULS,q is ultimate bearing pressure

- ❑ Loading

Safety Factor	
SF for live load; qk	1.25,1.3, 1.4 ,1.5, 1.6
SF for dead load; gk	1.25, 1.35, 1.4, 1.5 , 1.6

Design load = Live load * $SF_{,qk}$ + Dead load * $SF_{,gk}$

where : $SF_{,qk}$ and $SF_{,gk}$ are safety factors for live load and dead load respectively.

4) Moment at the face of the column

Along x direction

$$M_{ED1} = \frac{ULS,q * l * \left[\frac{b - c\,x}{2}\right]^2}{2}$$

Along y direction

$$M_{ED2} = \frac{ULS,q * b * \left[\frac{l - cy}{2}\right]^2}{2}$$

Where : M_{ED1} , M_{ED2} is bending moment at the face of the column

b and l is breadth and length of the footing pad;

ULS,q is ultimate bearing pressure;

5) Area of steel, flexure capacity

- ❑ Effective depth, d:

$$d_1 = pad\ thickness - concrete\ cover - bar\ dia/2$$

$$d_2 = pad\ thickness - concrete\ cover - bar\ in\ the\ bottom\ layer - bar\ dia/2$$

- ❑ Determine K for respective M_{ED},

$$K_1 = M_{ED1}/\,(l * d_1^2 f_{ck})$$

$$K_2 = M_{ED}\ /\,(b * d_2^2 f_{ck})$$

where : d is effective depth

b is width of the footing pad

l is length of the footing pad

f_{ck} is characteristic compressive strength ;

M_{ED1} , M_{ED2} are bending moment at the face of the column

- Determine lever arm, z for every K

$$z_1 = \frac{d_1}{2}[\,1 + \sqrt{1 - 3.53\,K_1}] \leq 0.95 d_1$$

$$z_2 = \frac{d_2}{2}[\,1 + \sqrt{1 - 3.53\,K_2}] \leq 0.95 d_2$$

- Steel area A_s for respective $M_{ED,}$

$$\mathrm{A_{s,1}} = \frac{M_{ED1}}{\mathrm{f_{yd}} * z_1}$$

$$\mathrm{A_{s,2}} = \frac{M_{ED2}}{\mathrm{f_{yd}} * z_2}$$

where : $f_{yd} = f_{yk}/\gamma_s$

γ_{s} is material safety factor; 1.15

f_{yk} is design yield stress

- Spacing , c/c: for every section area.

$$Spacing_1 = b * \frac{as}{\mathrm{A_{s1}}} \leq \min(2D, 250); \quad \text{(mm)}$$

$$Spacing_2 = l * \frac{as}{\mathrm{A_{s2}}} \leq \min(2D, 250);$$

where : as = area of a single bar

A_s = required amount of steel area

D = slab thickness

b = section width= 1000 mm is taken;

6) Checking for shear

Beam shear

Check critical section d away from column face

$$V_{ED,1} = ULS, q * (\frac{b - c\,x}{2})$$

$\frac{V_{ED,1}}{d_1}$ gives beam shear in MPa

$$V_{ED,2} = ULS, q * (\frac{l - cy}{2})$$

where $V_{ED,1}$, $V_{ED,2}$ are beam shear at the d away from column face; ($V_{ED,1}$ is critical)

ULS,q is ultimate bearing pressure;

cx,cy are column width along x and y direction

Punching shear

Check at u_1, the basic control perimeter

$$V_{ED} = \beta \frac{v_{ED}}{u_1 d}$$

where : β is factor dealing with eccentricity;

$v_{ED,}$ is applied force minus net force within the area of the control perimeter;

v_{ED} = Applied load - ultimate bearing press [(cx x cy) + π(2d)^2 + 4d(cx + cy)]

d is mean effective depth;

u_1 is 2 (cx + cy) + 2π x 2d;

d is effective depth as the average of the effective depths in two orthogonal directions; $(d_1 + d_2)/2$

7) Section shear capacity

$$\rho_x = \frac{\mathrm{A_{s,1}}}{l * d_1}$$

$$\rho_y = \frac{\mathrm{A_{s,2}}}{b * d_2}$$

$$\rho = \left(\rho_x * \ \rho_y\right)^{\frac{1}{2}} \leq 0.02$$

$$V_{RD,c} = \ C_{Rd,c}\ k(100\rho f_{ck})^{\frac{1}{3}}\, b_w d\ \geq V_{min}$$

$$V_{min} = 0.035\ k^{1.5} f_{ck}^{0.5}$$

where : $V_{RD,c}$ is the concrete shear capacity in N

$C_{RD,c}$ is coefficient derived from test (0.18/ 1.5) ;

b_w is with of the footing pad, in mm

d is effective depth in mm = $(d_1\ +\ d_2\,)/2$

k is size factor = $1 + \sqrt{200/d} \leq 2.0$, d is effective depth in mm;

ρ is steel ratio and ρ_x, ρ_y are steel ratio along x and y direction

f_{ck} is characteristic compressive strength in MPa;