DESIGN OF COMBINED RECTANGULAR FOOTING FOR TWO COLUMNS

Whenever two or more columns in a straight line are carried on a single spread footing, it is called a combined footing. Isolated footings for each column are generally the economical. Combined footings are provided only when it is absolutely necessary, as

1.When two columns are close together, causing overlap of adjacent isolated footings

2.Where soil bearing capacity is low, causing overlap of adjacent isolated footings

3. Proximity of building line or existing building or sewer, adjacent to a building column.

Problem

Two interior columns A and B carry 700 kN and 1000 kN loads respectively. Column A is 350 mm x 350 mm and column B is 400 mm X 400 mm in section. The centre to centre spacing between columns is 4.6 m. The soil on which the footing rests is capable of providing resistance of 130 kN/m². Design a combined footing by providing a central beam joining the two columns. Use concrete grade M25 and mild steel reinforcement.

Solution: Data

f_{ck} = 25 N/mm2,

f_y= 250 N/mm2,

f_b = l30 kN/m2 (SBC),

Column A = 350 mm x 350 mm,

Column B = 400 mm x 400 mm,

c/c spacing of columns = 4.6 m, P_A = 700 kN and P_B = 1000 kN

Ultimate loads

P_{ua} = 1.5 x 700 = 1050 kN,

P_{ub} = 1.5 x 1000 = 1500 kN

Working load carried by column A = P_A = 700 kN

Working load carried by column B = P_B = 1000 kN

Self weight of footing 10 % x (P_A + P_B) = 170 kN Total working load = 1870 kN

Required area of footing = A_f = Total load /SBC

=1870/130 = 14.38 m²

Let the width of the footing $= B_f = 2m$

Required length of footing $= L_f = A_f / B_f = 14.38/2 = 7.19m$

Provide footing of size 7.2m X 2m, $A_f = 7.2$ x $2 = 14.4$ m^2

For uniform pressure distribution the C.G. of the footing should coincide with the C.G. of column loads. Let x be the distance of C.G. from the centre line of column A
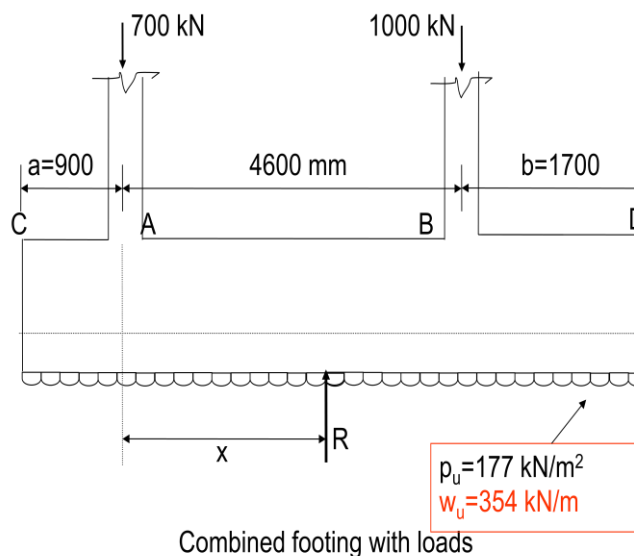
Then x $= (P_B$ x $4.6)/(P_A + P_B) = (1000$ x $4.6)/(1000 + 700)$

$= 2.7$ m from column A.

If the cantilever projection of footing beyond column A is 'a'

then, a $+ 2.7 = L_f /2 = 7.2/2$, Therefore a $= 0.9$ m

Similarly if the cantilever projection of footing beyond B is 'b'

then, b $+ (4.6-2.7) = L_f /2 = 3.6$ m,

Therefore b $= 3.6 - 1.9 = 1.7$ m

The details are shown in Figure

Combined footing with loads

Rectangular Footing with Central Beam:-Design of Bottom slab

Total ultimate load from columns $= P_u = 1.5(700 + 1000) = 2550$ kN.

Upward intensity of soil pressure $w_u = P/A_f = 2550/14.4 = 177$ kN/m^2

Design of slab

Intensity of Upward pressure = w_u =177 kN/m^2

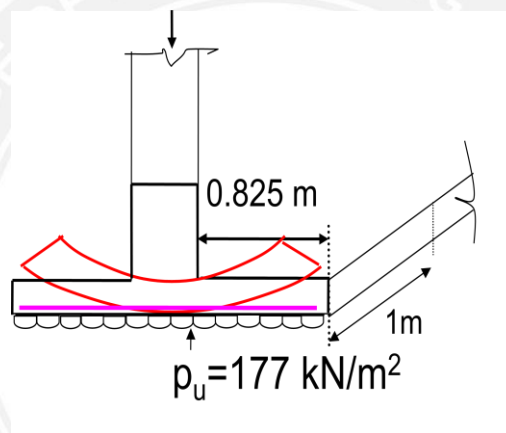Consider one meter width of the slab (b=1m)

Load per m run of slab at ultimate = 177 x 1 = 177 kN/m

Cantilever projection of the slab (For smaller column)

$$=1000 - 350/2 = 825 \text{ mm}$$

Maximum ultimate moment   = 177 x 0.825^2/2 = 60.2 kN-m.

For M25 and Fe 250, Q $_{u\ max}$ = 3.71 N/mm^2

Required effective depth = $\sqrt{(60.2 \times 10^6/(3.71 \times 1000))}$ = 128 mm

Since the slab is in contact with the soil clear cover of 50 mm is assumed.

Using 20 mm diameter bars

Required total depth = 128 + 20/2 + 50 =188 mm say 200 mm

Provided effective depth = d = 200-50-20/2 = 140 mm

Check the depth for one - way

shear considerations- At 'd' from face

Design shear force=V_u=177x(0.825-0.140)=121kN

Nominal shear stress=τ_v=V_u/bd=121000/(1000x140) =0.866MPa

Permissible shear stress

P_t = 100 x 2415 /(1000 x 140) = 1.7 %, τ_{uc} = 0.772 N/mm^2

Value of k for 200 mm thick slab =1.2

Permissible shear stress = 1.2 x 0.772 = 0.926 N/mm^2

$\tau_{uc} > \tau_v$ and hence safe

The depth may be reduced uniformly to 150 mm at the edges.

Check for development length

$L_{dt} = [0.87 \times 250 / (4 \times 1.4)]\Phi = 39\,\Phi$

$= 39 \times 20 = 780$ mm

Available length of bar $= 825 - 25 = 800$mm

> 780 mm and hence safe.

Transverse reinforcement

Required $A_{st} = 0.15bD/100$

$= 0.15 \times 1000 \times 200/100 = 300 \text{mm}^2$

Using $\Phi 8$ mm bars, Spacing $= 1000 \times 50/300$

$= 160$ mm

Provide distribution steel of $\Phi 8$ mm at 160 mm c/c, <300, $<5d$

Design of Longitudinal Beam

Load from the slab will be transferred to the beam.

As the width of the footing is 2 m, the net upward soil pressure per meter length of the beam

$= w_u = 177 \times 2 = 354$ kN/m

Shear Force and Bending Moment

$V_{AC} = 354 \times 0.9 = 318.6$ kN, $V_{AB} = 1050 - 318.6 = 731.4$ kN

$V_{BD} = 354 \times 1.7 = 601.8$kN, $V_{BA} = 1500 - 601.8 = 898.2$ kN

Point of zero shear from left end C

$X_1 = 1050/354 = 2.97$m from C or

$X_2 = 7.2 - 2.97 = 4.23$ m from D

Maximum B.M. occurs at a distance of 4.23 m from D

$M_{uE} = 354 \times 4.23^2 / 2 - 1500 (4.23 - 1.7) = -628$ kN.m

Bending moment under column A $= M_{uA} = 354 \times 0.9^2 /2 = 143.37$ kN.m

Bending moment under column B $= M_{uB} = 354 \times 1.7^2 = 511.5$ kN-m

Let the point of contra flexure be at a distance x from the centre of column A

Then, $M_x = I050x - 354 (x + 0.9)^2 / 2 = 0$

Therefore x = 0.206 m and 3.92 m from column A

i.e. 0.68 m from B.

Depth of beam from B.M.

The width of beam is kept equal to the maximum

width of the column i.e. 400 mm. Determine the
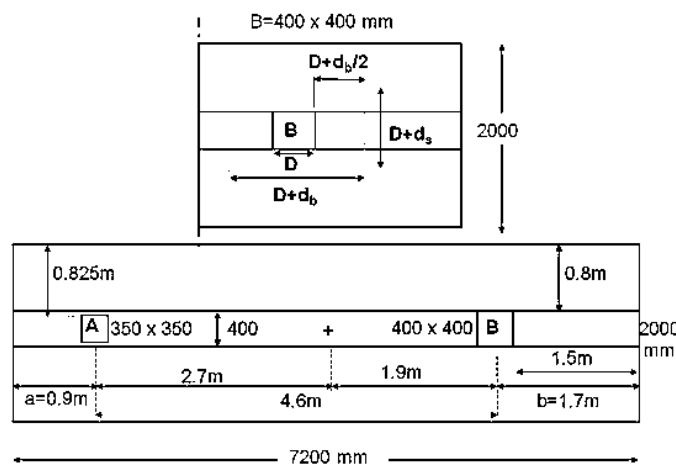
depth of the beam where T- beam action is not available.

The beam acts as a rectangular section in the cantilever portion, where the maximum positive

moment = 511.5 kN/m.

$$d = \sqrt{(511.5 \times 10^6/ (3.73 \times 400))} = 586 \text{ mm}$$

Provide total depth of 750 mm. Assuming two rows of bars with effective cover of 70 mm.

Effective depth provided = d= 750-70 = 680 mm

(Less than 750mm and hence no side face steel is needed

In this case b=D=400 mm, d_b=680 mm, d_s=140 mm

Area resisting two - way shear

$$= 2(b \times d_b + d_s \times d_s) + 2 (D + d_b)ds$$
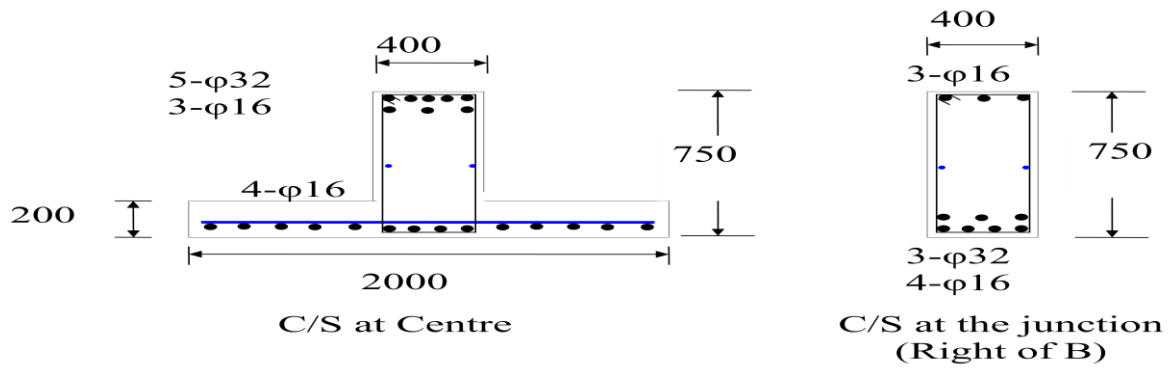
$$= 2 (400 \times 680+ 140 \times 140) + 2(400+680) 140= 885600 \text{ mm}^2$$

Design shear=P_{ud}= column load – W_u x area at critical section

$$= 1500 - 177 \times(b + d_s) \times (D + d_b)$$

$$=1500-177 \times (0.400+0.140) \times (0.400+ 0.680) \quad =1377.65kN$$

$$\tau_v=P_{ud}/b_o d$$

400
5-φ32
3-φ16
750
4-φ16
200
2000
C/S at Centre

400
3-φ16
750
3-φ32
4-φ16
C/S at the junction
(Right of B)

$$= 1377.65 \times 1000/885600 = 1.56 \text{ MPa}$$

Shear stress resisted by concrete $= \tau_{uc} = \tau_{uc} \times K_s$

where, $\tau_{uc} = 0.25 \sqrt{f_{ck}} = 0.25 \sqrt{25} = 1.25 \text{ N/mm}^2$

$K_s = 0.5 + d / D = 0.5 + 400/400 = 1.5 \leq 1$ Hence $K_s = 1$

$\tau_{uc} = 1 \times 1.25 = 1.25 \text{ N/mm}^2 \cdot$

Therefore Unsafe

350x350   400x400

0.9 m   4.6 m   1.7 m

Side face
2- Φ12

3- Φ16   (5-Φ32 + 3- Φ16) (3-Φ32 + 3- Φ16)   3- Φ16

3-Φ32
+
4-Φ16

Φ12@300,   Φ12@140,   Φ12@300,   Φ12@120,   Φ12@300,
2L Stp   4L Stp   2L Stp   4L Stp   2L Stp

Φ20@130   Φ8@160

2 m

7200 mm

Plan of footing slab