RCC Structure – Footing

Case Example:
Analyze a 3000mm x 3000mm square footing with 650 mm over all depth for a 450mm x 450 mm column subjected to 1200 kN dead load and 500 kN imposed load. Consider soil bearing pressure 200 kN/m^2, Concrete grade M20 and Fe415 steel 25 mm diameter 10 bars in each direction with 50 mm clear cover.

Analysis:
Data:
Characteristic strength of concrete f_{ck} = 20 N/mm^2 = 20e3 kN/m^2
Yield strength of steel = 415 N/mm^2 = 415e3 kN/m^2
Steel area As = $0.25\pi*25^2*10$ = 4909 mm^2
Footing dimension = 3000mmx3000mmx650mm
Footing area: 3m x 3m = 9 m^2
Percent steel pt = As*100/(650*3000) = 0.252%

A. Footing Factored Load:
- (i) DL = 1200 kN
- (ii) Imposed load = 500 kN
- (iii) Factored load P = (DL + LL)*load factor = 2550 kN

B. Effective depth (d):
Footing thickness – clear cover – bar dia1–bar dia2/2 = 650-50-25-25/2 =562.5 mm

C. One-way shear
- (i) Design shear of concrete τ_c = 0.36 N/mm^2 (Refer table 19 IS 456 for τ_c for given percent steel 0.252%)
- (ii) Critical section for one-way shear is at distance 'd' from the face of the column
- (iii) Shear force V acting at this section is given by = (P/2L)*(L-a-2d) = (2550e3/2*3000)(3000-450-2*562.5) =615e3
- (iv) For equilibrium V = τ*L*d
- (v) τ = 615e3/(3000*562.5) = 0.36 kN/mm^2 that is same as τ_c

D. Two-way (punching) shear
- (i) Critical section for two-way shear is at a distance d/2 from the face of the column all around as shown in figure 13 A and 13B IS : 456. Accordingly shear area Ap = 4(a+d)d = 4(0.450+0.5625)*0.5625 = 2.278 m^2
- (ii) Shear force V = Ap*τ_p kN
- (iii) For equilibrium V = $(P/L^2)(L^2-(a+d)^2)$ = $(2550/3^2)*(3^2 – (0.45+0.562)^2)$=2259.8 kN
- (iv) We get τ_p = V /Ap= 2259.8/2.278 = 0.99e3 kN/m^2= 0.99 N/mm^2
- (v) Design punching shear given as $0.25\sqrt{f_{ck}}$. = 1.12 N/mm^2 that is > τ_p calculated

E. Moment and Capacity:

(i) Moment at the face of the column $Mu = (P/L^2)(L (L-a)^2/8) = (2550/3^2)(3(3-0.45)^2/8) = 690.89$ kNm

(ii) Moment capacity $M_{max} = 0.138\ f_{ck}.b.d^2 = 0.138*20e3*3*0.562^2 = 2615$ kNm

(iii) Moment capacity is greater than moment applied at the face of the column.

F. Check Development Length (Clause 26.2.1 IS 456)

(i) $Ld = (\phi*\sigma_s)/(4*\tau_{bd})$

(ii) Design Bond strength τ_{bd} for M20 is given as 1.2 x 1.6 N/mm^2 (added 60% for Tor-rods)

(iii) $\therefore$ Ld = (25*415)/(4*1.92) = 1351 mm

G. Footing Analysis Summary

(i) Footing pressure: 1700 kN/9 m^2 = 188.9 kN/m^2< soil bearing pressure.

(ii) Footing depth is sufficient to resist both One-way and Two-way shear as per critical section mentioned in the code.

(iii) Thickness is sufficient to resist bending moment without compression steel in the footing.

(iv) Percent steel (0.252%) exceeds minimum prescribed as per Clause 26.5.2.1

H. Material Estimates

(i) Concrete volume: $3^2*0.650 = 5.85$ m^3

(ii) Cement quantity: M20 Volume of cement 1:5.5 = 5.85*1440/5.5 = 1532 kg

(iii) Steel quantity: ϕ-25 mm x 60m length $\approx$ 233 kg

Add necessary allowances for wastage, shrinkage etc. to the above estimates.