Design of Mat/Raft Foundation
Mat or raft foundation is a large concrete slab supporting several columns in two or more rows.

It is used where the supporting soil has low bearing capacity.

The bearing capacity increased by combining all individual footings in to one mat –since bearing capacity is proportional to width and depth of foundations.

In addition to increasing the bearing capacity, mat foundations tend to bridge over irregularities of the soil and the average settlement does not approach the extreme values of isolated footings.

Thus mat foundations are often used for supporting structures that are sensitive to differential settlement.
• Design of uniform mat
• Design Assumptions
  – mat is infinitely rigid
  – planner soil pressure distribution under mat

• Design Procedure
I. Determine the line of action of the resultant of all the loads acting on the mat
II. Determine the contact pressure distribution as under
  – If the resultant passes through the center of gravity of the mat, the contact pressure is given by

\[ \sigma = \frac{Q}{A} \]
If the resultant has an eccentricity of $e_x$ and $e_y$ in the $x$ and $y$ direction

$$\sigma_{\text{max/ min}} = \frac{Q}{A} \pm \frac{Qe_x}{I_{yy}} x \pm \frac{Qe_y}{I_{xx}} y$$

The maximum contact pressure should be less than the allowable soil pressure

- Divide the slab mat into strips in $x$ and $y$ directions. Each strip is assumed to act as independent beam subjected to the contact pressure and the columns loads.
- Determine the modified column loads
- Draw the shear force and bending moment diagrams for each strip.
- Select depth of mat for shear requirement
- Select steel reinforcement for moment requirement
• **Example**
• A mat foundation is to be designed by the conventional method (rigid method) for the loadings shown in Fig. below.

  • All columns are 40X40cm
  • Ultimate soil bearing pressure, \( q_{ult} = 100 \text{kPa} \)
  • \( f_{yk} = 300 \text{MPa} \Rightarrow f_{yd} = 300/1.15 = 260.87 \text{ Mpa} \)
  • C25 \( \Rightarrow f_{ck} = 20 \text{MPa} \Rightarrow f_{ctk} = 1.5 \text{ MPa} \),
• Location of c.g. of loads

\[ \sum P = (600 + 750 + 600) \times 2 + (1800 + 1800 + 1320) \times 2 = 13740 \text{kN} \]

\[ 13740 \bar{X} = (750 + 1800 + 1800 + 750) \times 5 + (600 + 1320 + 1320 + 600) \times 10 \]

\[ \bar{X} = 4.65 \text{m} \]

\[ e_x = 5 - 4.65 = 0.35 \]

\[ X' = 5 + 0.35 = 5.35 \text{m} \]

\[ B_{\text{min}} = 2 \times (5.35 + 0.20 + 0.15) = 11.40 \text{m} \]

\[ 13740 \bar{Y} = (600 + 750 + 600) \times 18 + (1800 + 1800 + 1320) \times 12 + (1800 + 1800 + 1320) \times 6 \]

\[ \bar{Y} = 9 \text{m} \]

\[ e_y = 6 + 6/2 - 9 = 0 \]

\[ L_{\text{min}} = 2 \times (9 + 0.20 + 0.15) = 18.70 \text{m} \]

• Dimension of Mat 11.40 X 18.70m
• Actual contact pressure
\[ \sigma = \frac{\sum P}{(BL)} = \frac{13740}{(11.40 \times 18.70)} = 64.45 \text{kPa} < \sigma_{\text{ult}} = 100 \text{kPa} \]

• Thickness of the mat
• Punching shear
• Punching shear under 1800kN load
Take \( d = 0.70 \text{m} \) and \( \rho = \rho_{\text{min}} = 0.50 / f_{yk} = 0.50 / 300 = 0.0017 \)
\[ k_1 = (1 + 50 \rho) = (1 + 50 \times 0.0017) = 1.085 \]
\[ k_2 = 1.6 - d = 1.6 - 0.70 = 0.90 \text{, Take } K_2 = 1 \]
\[ P_r = (0.85 + 0.4 + 1.105)2 + (0.4 + 3 \times 0.70) = 7.21 \text{m} \]

• Net shear force developed
• \( V_d = 1800 - \sigma \times (2.355 \times 2.50), \sigma = 64.45 \text{kP} \)
• \( V_d = 1800 - 64.45 \times (2.355 \times 2.50) = 1420.55 \text{kN} \)
Punching shear resistance

\[ V_{up} = 0.25 f_{ctd} k_1 k_2 ud \ (MN) \]

\[ V_{up} = 0.25 \times 1000 \times 1.085 \times 1.00 \times 7.21 \times 0.70 \]

=1369.00kN < \( V_d \) ... NOT OK! Increase the depth

Take \( d = 0.75 \) m and \( \rho = \rho_{min} = 0.50 / f_{yk} = 0.50 / 300 = 0.0017 \)

\[ k_1 = (1 + 50\rho) = (1 + 50 \times 0.0017) = 1.085 \]

\[ k_2 = 1.6 - d = 1.6 - 0.75 = 0.85 \]

\[ P_r = (0.85 + 0.4 + 1.125)^2 + (0.4 + 3(0.75)) \]

=7.40m

Net shear force developed

\[ V_d = 1800 - \sigma^* (2.375 \times 2.65) \]

\( \sigma = 64.45 \) kP

\[ V_d = 1800 - 64.45 \times (2.375 \times 2.65) = 1394.37 \text{kN} \]
• Punching shear resistance

\[ V_{up} = 0.25f_{ctd} k_1 k_2 ud \ (MN) \]

\[ V_{up} = 0.25 \times 1000 \times 1.085 \times 1.00 \times 7.40 \times 0.75 \]
\[ = 1505.44kN > V_d \text{ .. OK!} \]

• Check punching shear under 1320kN

\[ P_r = (1.125 + 0.15 + 0.4)^2 + (0.4 + 3(0.75)) = 6.00m \]

• Net shear force developed

\[ V_d = 1320 - 64.45 \times (1.675 \times 2.65) = 1033.92kN \]

• Punching shear resistance

\[ V_{up} = 0.25f_{ctd} k_1 k_2 ud \ (MN) \]

\[ V_{up} = 0.25 \times 1000 \times 1.085 \times 1.00 \times 6.00 \times 0.75 \]
\[ = 1220.63kN > V_d \text{ .. OK!} \]
• Check punching shear under 600kN
  \[ P_r = (1.125+0.15+0.4) + (1.125+0.15+0.4) \]
  \[ = 3.35m \]

• Net shear force developed
  \[ V_d = 600 - 64.45 \times (1.675 \times 1.675) = 419.18\text{kN} \]

• Punching shear resistance
  \[ V_{up} = 0.25f_{ctd} k_1 k_2 u_d \quad (\text{MN}) \]
  \[ V_{up} = 0.25 \times 1000 \times 1.085 \times 1.00 \times 3.35 \times 0.75 \]
  \[ = 681.52\text{kN} > V_d \quad \text{OK!} \]
Soil reaction analysis:
Divide the slab mat into strips in x and y directions.

- Strip A
- Strip B
- Strip C
- Strip 1
- Strip 2
- Strip 3
- Strip 4
• Strip A, \((64.45)*3.55 = 228.80\text{kN/m}\)
• Strip B, \((64.45)*5.00 = 322.25\text{kN/m}\)
• Strip C, \((64.45)*2.85 = 183.68\text{kN/m}\)
• Strip 1 & Strip 4, \((64.45)*3.35 = 215.91\text{kN/m}\)
• Strip 2 & Strip 3 \((64.45)*6.00 = 386.70\text{kN/m}\)

• Shear force and Bending moment diagrams for each strip

• Strip A
\[ \sum_{i=1}^{4} P_i = 600 + 1800 + 1800 + 600 = 4800 \text{ kN} \]

- \( \Sigma R = 228.80 \times 18.70 = 4278.56 \text{ kN} \)
- \( \Sigma V = \Sigma P - \Sigma R = 4800 - 4278.56 = 521.44 \neq 0 \)

- Hence take average of \( \Sigma P \) and \( \Sigma R \)

- I.e., \((4800 + 4278.56)/2 = 4539.28 \text{ kN}\)

- \( \sigma_{avg} = (4539.28)/18.70 = 242.74 \text{ kN/m}\)
- \( P_{1avg} = P_{4avg} = (4539.28/4800) \times 600 = 567.41 \text{ kN} \)
- \( P_{2avg} = P_{3avg} = (4539.28/4800) \times 1800 = 1702.23 \text{ kN} \)
• Strip 1 & Strip 4, \((64.45)\times 3.35 = 215.91\text{kN/m}\)

\[\sum P_i = 600 + 750 + 600 = 1950 \text{ kN}\]

\[\Sigma R = 215.91 \times 11.40 = 2461.37 \text{kN}\]

\[\Sigma V = \Sigma P - \Sigma R = 1950 - 2461.37 = -511.37 \neq 0\]

Hence take average of \(\Sigma P\) and \(\Sigma R\)

I.e., \(1950 + 2461.37 \)/2 = 2205.69kN

\[\sigma_{\text{avg}} = (2205.69) / 11.40 = 193.48 \text{kN/m}\]

\[P_{1\text{avg}} = P_{3\text{avg}} = (2205.69/1950) \times 600 = 678.67 \text{kN}\]

\[P_{2\text{avg}} = (2205.69/1950) \times 750 = 848.34 \text{kN}\]