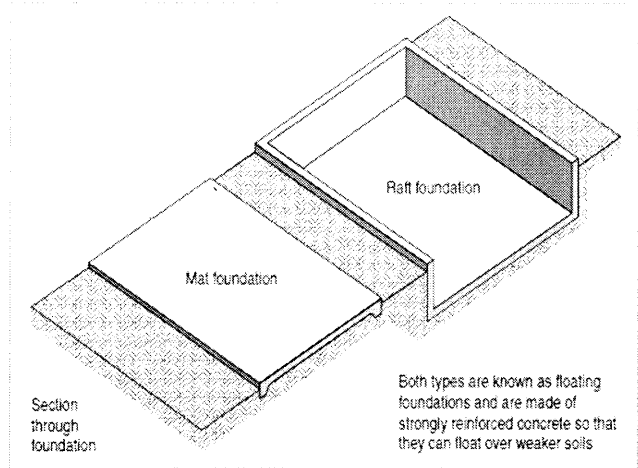## 7.0   Mat / Raft Foundations
7.1   Introduction

A 'raft' or a 'mat' foundation is a combined footing which covers the entire area beneath of a structure and supports all the walls and columns.

This type of foundation is most appropriate and suitable when the allowable soil pressure is low, or the loading heavy, and spread footings would cover more than one half the plan area. Also, when the soil contains lenses of compressible strata which are likely to cause considerable differential settlement, a raft foundation is well-suited, since it would tend to bridge over the erratic spots, by virtue of its rigidity.

On occasions, the principle of floating foundation may be applied best in the case of raft foundations, in order to minimise settlments.

A mat foundation comes to be more economical than the individual footings when the total base area required for individual footings exceeds about one half of the area covered by the structure.

7.2   Common Types of Raft Foundations

Common types of raft foundations in use are illustrated in Fig.
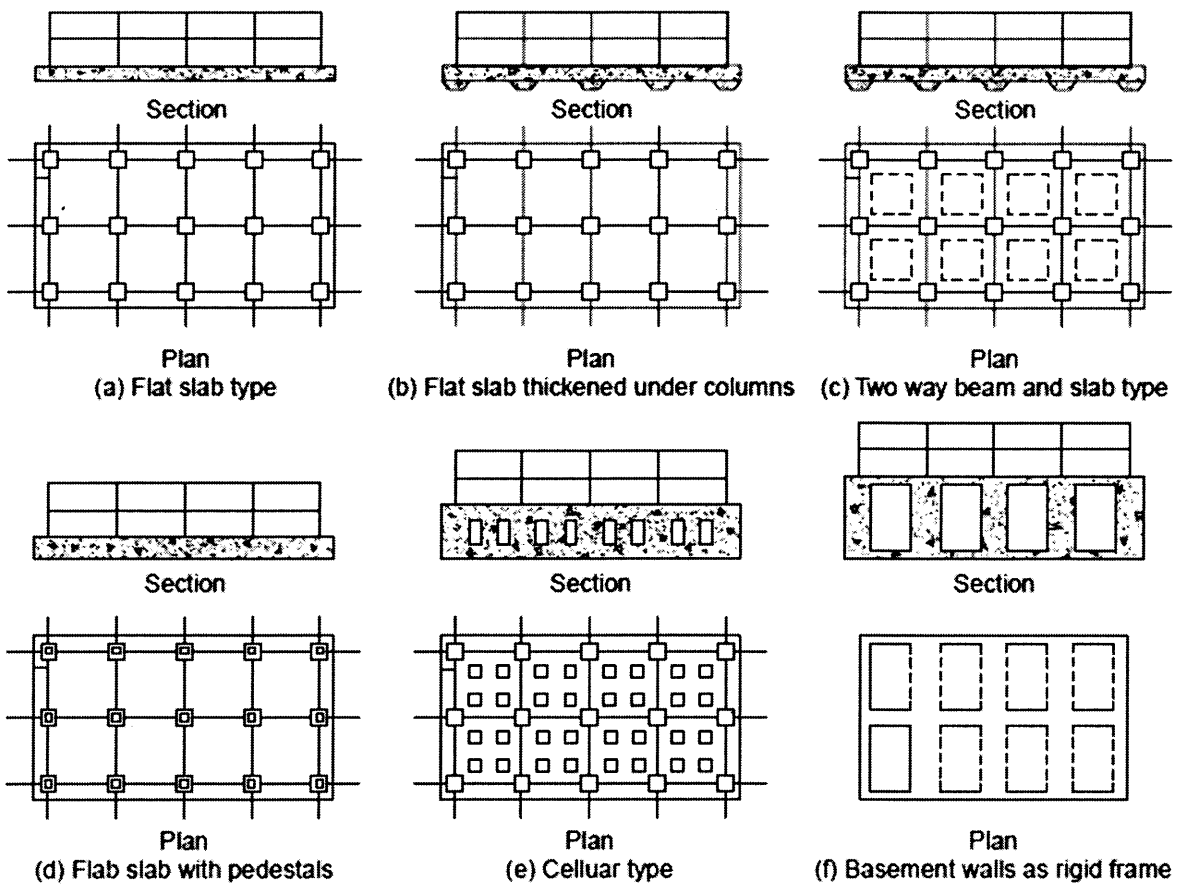
Common types of raft foundations (Teng, 1976)

7.3 Bearing capacity and settlement of Mat foundation
Bearing Capacity of Rafts on Sands

❖ Since the bearing capacity of sand increases with the size of the foundation and since rafts are usually of large dimensions, a bearing capacity failure of raft on sand is practically ruled out.

❖ As a raft bridges over loose pockets and eliminates their influence, the differential settlements are much smaller than those of a footing under the same pressure. Hence, higher allowable soil pressures may be used for design of rafts on sands.

❖ Terzaghi and Peck (1948), as also Peck, Hanson and Thornborn (1974), recommend an increase of 100% over the value allowed for spread footings. The design charts developed for the bearing capacity from N-values for footings on sands may be used for this purpose. The effect of the location of water table is treated as in the case of footings.

❖ Allowable bearing capacity for **surface-loaded** footings with settlement limited to approximately 25 mm

$$q_a = \frac{N_{55}}{0.08}\left(\frac{B+0.3}{B}\right)^2\left(1+0.33\frac{D}{B}\right)$$

for: $0 \le D \le B$ and $B > 1.2$ m

The safe bearing capacity can be determined as per Teng's (1962)

❖ From shear failure criteria

$qns = 0.22N^2B\,W_y + 0.67(100+N^2)DfWq$

❖ The safe settlement pressure for a settlement of 25mm is given by,

$qnp = 17.5\,(N-3)\,W_y\ \ kN/m^2$

The equation is further modified as Teng's equations for safe settlement pressure are found conservative and Bowel's gave equations for a safe settlement of 25mm.

$q_{np} = 12.2N((B+0.3)/B)^2\,R_d W\gamma$ Where, $Rd = 1+0.33\,(Df/B)$

7.4 Compensated foundation
Bearing Capacity of Rafts on Clays

The net ultimate bearing capacity is divided by the factor of safety to obtain the net allowable soil pressure for a footing. The same principle is applicable to rafts on clay. Accordingly, the factor of safety, η, in terms of net soil pressure, is given by

$$\eta = \frac{cN_c}{(q-\gamma D_f)}$$

where, c = unit cohesion,
N_c = bearing capacity factor for cohesion,
q = gross soil pressure or contact pressure,
γ = unit weight of soil,
and D_f = depth of raft below ground surface.

In other words,
❖ Factor of safety against bearing capacity failure can be represented as,

$$qnu = Cu * N_c$$

$$q_{nu} = c_u * 5 \left(1 + 0.2\frac{D_f}{B}\right)\left(1 + \frac{0.2B}{L}\right)$$

$$q_{ns} = q_{nu}/F$$

Or,

$$F = q_{nu}/q_{ns}$$

$$F = Cu * 5(1 + 0.2\ Df/B)\ (1 + 0.2B/L)/(\frac{Q}{A} - \gamma\ Df)$$

IS 6403 recommends a minimum factor of safety 2.5, usually F is taken as 3.

❖ It is obvious that the factor of safety is very large for rafts established at such depths that γD_f is nearly equal to q and it is obvious that the factor of safety is very large for rafts established at such depths that γD_f is nearly equal to q.

i.e,

$q = Q/A = \gamma\ D_f$, implies F= ∞
And $D_f = (Q/A\ \gamma)$

❖ The foundation satisfying above requirements is known to be 'fully compensated foundation' (Peck, Hanson and Thornburn, 1974), or floating foundation.

7.5 Analysis of mat foundation

Step 1: Calculate the column load

$$Q = Q_1 + Q_2 + Q_3 + \ldots\ldots\ldots\ldots\ldots + Q_n$$

Step 2: determine the pressure on the soil (q) below the mat at a point A,B,C,D....... by using the equation.

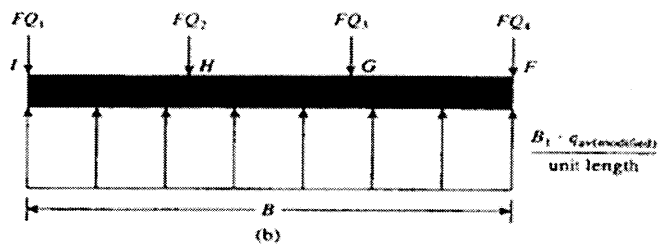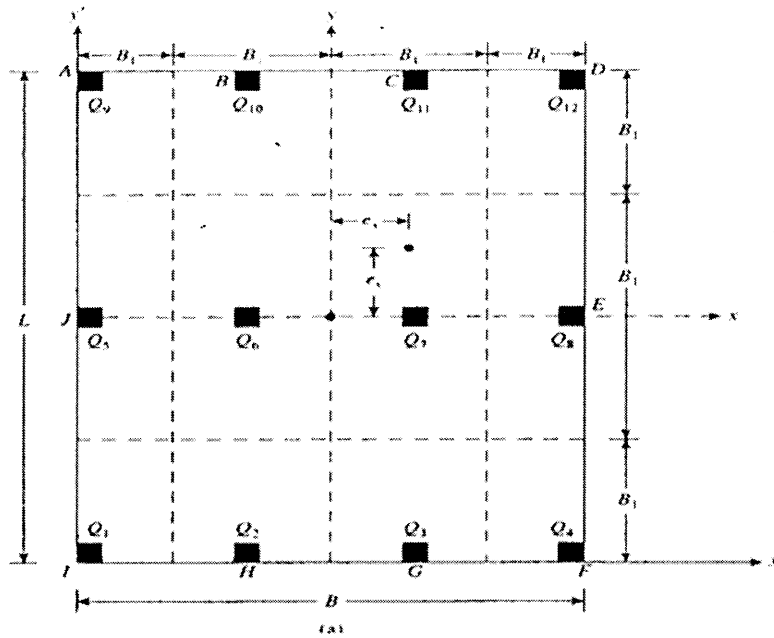$$q = \frac{Q}{A} \pm \frac{M_y x}{I_y} \pm \frac{M_x y}{I_x}$$

Where: A = B*L = Area of mat

$I_x = (1/12)\ BL^3$ = Moment of inertia about the x axis

$I_y = (1/12)\ LB^3$ = Moment of inertia about the y axis

Mx = moment of the column loads about the x axis = $Q*e_y$

My = moment of the column loads about the y axis = $Q*e_x$

(a)

(b)

$$X' = \frac{Q_1 x'_1 + Q_2 x'_2 + Q_3 x'_3 + \cdots}{Q}$$

and

$$e_x = X' - B/2$$

Similarly,

$$Y' = \frac{Q_1 y'_1 + Q_2 y'_2 + Q_3 y'_3 + \cdots}{Q}$$

and

$$e_y = Y' - L/2$$

Step 3: Compare the values of the soil pressure determined in step 2 with net allowable soil pressure to check if $q \leq q_{na}$.

Step 4: Divide the mat into several strips in x and y directions. let the width of any strip be B_1.

Step 5: Draw the shear (V) and moment (M) diagram for each individual strip (in x and y direction). For example , take the bottom strip in the x direction of, its average soil pressure can be given as

$$q_{av} = \frac{q_I + q_F}{2}$$

Where q_I and q_F = soil pressure at point I and F as determined from step2.

The total soil reaction is equal to $q_{av} B_1 B$. Now obtain the total column load on the strip as $Q_1 + Q_2 + Q_3 + Q_4$. The sum of the shear between the adjacent strips has not been taken into account. For this reason, the soil reaction and column load need to be adjusted, or

$$\text{Average load} = \frac{q_{av} B_1 B + (Q_1 + Q_2 + Q_3 + Q_4)}{2}$$

Now, modified average soil reaction,

$$q_{av(modified)} = \frac{q_{av}(Average\ Load)}{q_{av} B_1 B}$$

Step 5: Draw the shear (V) and moment (M) diagram for each individual strip (in x and y direction). For example , take the bottom strip in the x direction of, its average soil pressure can be given as

Also, the column load modification factor is

$$F = \text{Average Load} / (Q_1 + Q_2 + Q_3 + Q_4)$$

So, the modification column loads are FQ_1, FQ_2, FQ_3 and FQ_4. This modified loading on the strip under consideration is shown in figure.

Step 6: Now, shear force and bending moment diagram for this strip can be drawn. This procedure can be repeated for all strips in x and y directions.

Step 7: Design the individual strips for the bending moment and shear force found in step 6. The raft is designed as an inverted floor supported at columns.