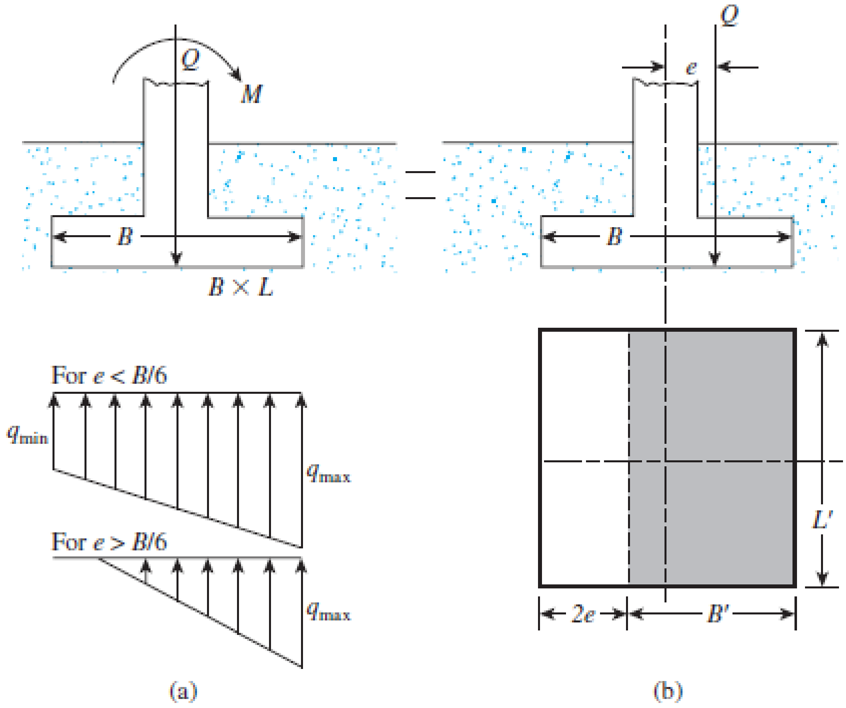
- **Eccentrically Loaded Foundations**

In several instances, as with the base of a retaining wall, foundations are subjected to moments in addition to the vertical load, as shown in Figure below. In such cases, the distribution of pressure by the foundation on the soil is not uniform. The nominal distribution of pressure is

$$q_{max} = \frac{Q}{BL} + \frac{6M}{B^2L}$$

and

$$q_{min} = \frac{Q}{BL} - \frac{6M}{B^2L}$$



where

Q = total vertical load
M = moment on the foundation

Figure 3.13b shows a force system equivalent to that shown in Figure 3.13a. The distance

$$e = \frac{M}{Q} \tag{3.35}$$

is the eccentricity. Substituting Eq. (3.35) into Eqs. (3.33) and (3.34) gives

$$\boxed{q_{max} = \frac{Q}{BL}\left(1 + \frac{6e}{B}\right)} \tag{3.36}$$

and

$$\boxed{q_{min} = \frac{Q}{BL}\left(1 - \frac{6e}{B}\right)} \tag{3.37}$$

Note that, in these equations, when the eccentricity e becomes $B/6$, q_{min} is zero. For $e > B/6$, q_{min} will be negative, which means that tension will develop. Because soil cannot take any tension, there will then be a separation between the foundation and the soil underlying it. The nature of the pressure distribution on the soil will be as shown in Figure 3.13a. The value of q_{max} is then

$$q_{max} = \frac{4Q}{3L(B - 2e)} \tag{3.38}$$

The exact distribution of pressure is difficult to estimate.

Figure 3.14 shows the nature of failure surface in soil for a surface strip foundation subjected to an eccentric load. The factor of safety for such type of loading against bearing capacity failure can be evaluated as

Ultimate Bearing Capacity under Eccentric Loading—One-Way Eccentricity

1. Effective Area Method (Meyerhoff, 1953)
2. Prakash and Saran Theory
3. Reduction Factor Method (For Granular Soil)

Effective Area Method (Meyerhoff, 1953)

In 1953, Meyerhof proposed a theory that is generally referred to as the *effective area method*.

The following is a step-by-step procedure for determining the ultimate load that the soil can support and the factor of safety against bearing capacity failure:

Step 1. Determine the effective dimensions of the foundation (Figure 3.13b):

$$B' = \text{effective width} = B - 2e$$
$$L' = \text{effective length} = L$$

Note that if the eccentricity were in the direction of the length of the foundation, the value of L' would be equal to $L - 2e$. The value of B' would equal B. The smaller of the two dimensions (i.e., L' and B') is the effective width of the foundation.

Step 2. Use Eq. (3.19) for the ultimate bearing capacity:

$$q'_u = c'N_c F_{cs} F_{cd} F_{ci} + qN_q F_{qs} F_{qd} F_{qi} + \tfrac{1}{2}\gamma B' N_\gamma F_{\gamma s} F_{\gamma d} F_{\gamma i} \tag{3.40}$$

To evaluate F_{cs}, F_{qs}, and $F_{\gamma s}$, use the relationships given in Table 3.4 with *effective length* and *effective width* dimensions instead of L and B, respectively. To determine F_{cd}, F_{qd}, and $F_{\gamma d}$, use the relationships given in Table 3.4. However, do not replace B with B'.

Step 3. The total ultimate load that the foundation can sustain is

$$Q_{\text{ult}} = q'_u \overbrace{(B')(L')}^{A'} \tag{3.41}$$

where A' = effective area.

Ultimate Bearing Capacity under Eccentric Loading — Two-Way Eccentricity

Consider a situation in which a foundation is subjected to a vertical ultimate load Q_{ult} and a moment M, as shown in Figures 3.19a and b. For this case, the components of the moment M about the x- and y-axes can be determined as M_x and M_y, respectively. (See Figure 3.19.) This condition is equivalent to a load Q_{ult} placed eccentrically on the foundation with $x = e_B$ and $y = e_L$ (Figure 3.19d). Note that

$$e_B = \frac{M_y}{Q_{\text{ult}}} \tag{3.52}$$

and

$$e_L = \frac{M_x}{Q_{\text{ult}}} \tag{3.53}$$

If Q_{ult} is needed, it can be obtained from Eq. (3.41); that is,

$$Q_{\text{ult}} = q'_u A'$$

where, from Eq. (3.40),

$$q'_u = c'N_c F_{cs} F_{cd} F_{ci} + qN_q F_{qs} F_{qd} F_{qi} + \tfrac{1}{2}\gamma B' N_\gamma F_{\gamma s} F_{\gamma d} F_{\gamma i}$$

and

$$A' = \text{effective area} = B'L'$$