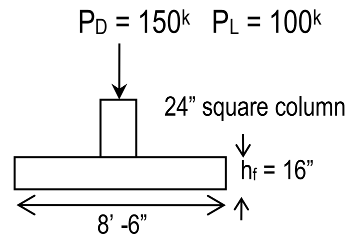
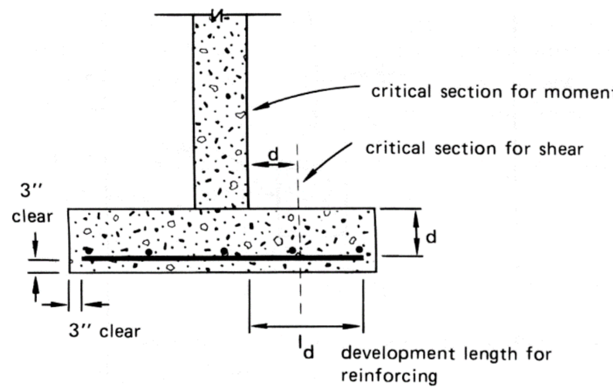
Examples:
Foundations

<u>Example 1</u>



For the 16 in. thick 8.5 ft. square reinforced concrete footing carrying 150 kips dead load and 100 kips live load on a 24 in. square column, determine if the footing thickness is adequate for 4000 psi . A 3 in. cover is required with concrete in contact with soil. Also determine the moment for reinforced concrete design.

SOLUTION:



1. Find design soil pressure: $q_u = \frac{P_u}{A}$

$P_u = 1.2D + 1.6L = 1.2\ (150\text{ k}) + 1.6\ (100\text{ k}) = 340\text{ k}$

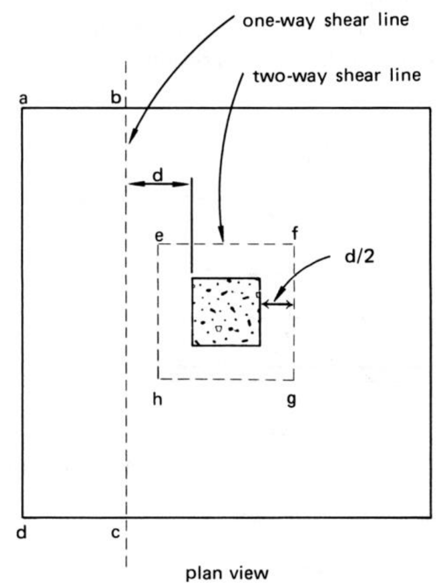
$q_u = \frac{340k}{(8.5\,ft)^2}$ = 4.71 k/ft^2

2. Evaluate one-way shear at d away from column face (Is $V_u < \phi V_c$?)

d = h_f – c.c. – distance bar intersection

presuming #8 bars:

d = 16 in. – 3 in. (soil exposure) – 1 in. x (1 layer of #8's) = 12 in.



V_u = total shear = q_u (edge area)

V_u on a 1 ft strip = q_u (edge distance) (1 ft)

V_u = 4.71 k/ft^2 [(8.5 ft – 2 ft)/2 – (12 in.)(1 ft/12 in.)] (1 ft) = 10.6 k

ϕV_c = one-way shear resistance = $\phi 2\lambda\sqrt{f'_c}$ bd

for a one foot strip, b = 12 in.

$\phi V_c = 0.75(2)(1)\sqrt{4000}$ psi)(12 in.)(12 in.) = 13.7 k > 10.6 k OK

3. Evaluate two-way shear at d/2 away from column face (Is $V_u < \phi V_c$?)

b_o = perimeter = 4 (24 in. + 12 in.) = 4 (36 in.) = 144 in

V_u = total shear on area outside perimeter = P_u – q_u (punch area)

V_u = 340 k – (4.71 k/ft^2)(36 in.)^2(1 ft/12 in.)^2 = 297.6 kips

ϕV_c = two-way shear resistance = $\phi 4\,\lambda\sqrt{f'_c}\,b_od$ = 0.75(4)(1)$\sqrt{4000}$ psi)(144 in.)(12 in.) = 327.9 k > 297.6 k OK

4. Design for bending at column face

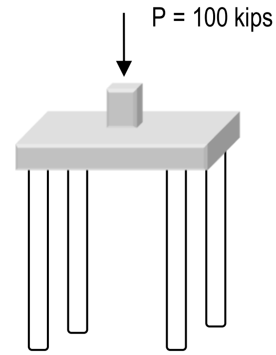
$M_u = w_uL^2/2$ for a cantilever. L = (8.5 ft – 2 ft)/2 = 3.25 ft, and w_u for a 1 ft strip = q_u (1 ft)

M_u = 4.71 ksi(1 ft)(3.25 ft)²/2 = 24.9 k-ft (per ft of width)

To complete the reinforcement design, use b =12 in. and trial d = 12 in., choose ρ, determine A_s, find if $\phi M_n > M_u$.....

Example 2

Determine the depth required for the group of 4 friction piles having 12 in. diameters if the column load is 100 kips and the frictional resistance is 400 lbs/ft².



SOLUTION:
The downward load is resisted by a friction force. Friction is determined by multiplying the friction resistance (a stress) by the area: $F = fA_{SKIN}$

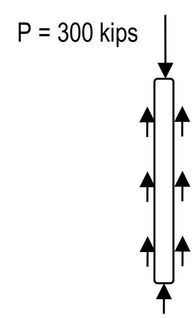
The area of n cylinders is: $A_{SKIN} = n(2\pi\frac{d}{2}L)$

Our solution is to set P ≤ F and solve for length:

$$100k \le 400\, {}^{lb}\!/\!{}_{ft^2}\,(4^{piles})(2\pi)(\frac{12in}{2})L\cdot(\frac{1ft}{12in})\cdot(\frac{1k}{1000lb})$$
$$L \ge 19.9\, {}^{ft}\!/\!{}_{pile}$$

Example 3

Determine the depth required for the friction and bearing pile having a 36 in. diameter if the column load is 300 kips, the frictional resistance is 600 lbs/ft² and the end bearing pressure allowed is 8000 psf.



SOLUTION:
The downward load is resisted by a friction force and a bearing force, which can be determined from multiplying the bearing pressure by the area in contact: $F = fA_{SKIN} + qA_{TIP}$

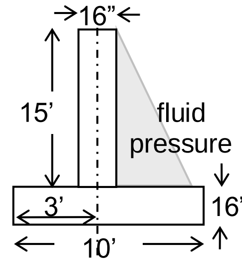
The area of n cylinders is: $A_{TIP} = \pi\frac{d^2}{4}$

Our solution is to set P ≤ F and solve for length:

$$300k \le 600\, {}^{lb}\!/\!{}_{ft^2}\, 2\pi(\frac{36in}{2})L\cdot(\frac{1ft}{12in})\cdot(\frac{1k}{1000lb}) + 8000\, {}^{lb}\!/\!{}_{ft^2}\,\pi\frac{(36in)^2}{4}\cdot(\frac{1ft}{12in})^2\cdot(\frac{1k}{1000lb})$$
$$L \ge 43.1ft$$

Example 4

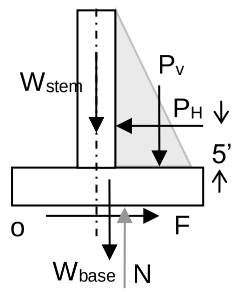
Determine the factor of safety for overturning and sliding on the 15 ft retaining wall, 16 in. wide stem, 10 ft base, 16 in. heigh base, when the equivalent fluid pressure is 30 lb/ft^3, the weight of the stem of the footing is 4 kips, the weight of the pad is 5 kips, the passive pressure is ignored for this design, and the friction coefficient for sliding is 0.58. The center of the stem is located 3' from the toe.

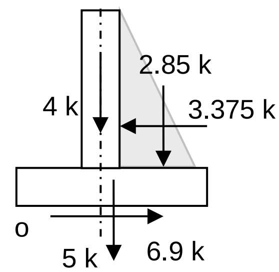


SOLUTION:

This is a statics problem, there is no design of materials involved. Overturning is determined by moments from acting forces and the moment from the resisting force. Sliding is determined by the acting horizontal forces and the resisting sliding force which is determined by mulitplying a friction coefficient based on the materials in contact, μ, by a normal force, N: $F = \mu N$

Find all unknown forces and draw the free body diagram with the weights at the centers of gravity of the stem and base:





The horizontal fluid (equivalent) pressure is a triangularly distributed load with the maximum distributed load equal to the density of water multiplied by the height: $w_h = \gamma H$.

$$w_h = (30\,{}^{lb}\!/\!_{ft^3})(15\,ft)(1\,ft\,strip) = 450 \text{ lb/ft}$$

The horizontal force, P_H = wL/2 acts at a distance of 1/3 the height from the "fat end" of the triangle is

$$P_H = (450\,{}^{lb}\!/\!_{ft})\frac{15\,ft}{2}\cdot\left(\frac{1k}{1000lb}\right) = 3.375 \text{ k}$$

The vertical force from the maximum distributed pressure, P_V = wL over the right side of the base (in the middle of 6.33 ft) is:

$$P_V = (450\,{}^{lb}\!/\!_{ft})\left[10\,ft - 3\,ft - \frac{16in}{2}\cdot\left(\frac{1\,ft}{12in}\right)\right]\cdot\left(\frac{1k}{1000lb}\right) = 2.85 \text{ k}$$

The total downward loads must be resisted by the normal force acting "up":

N = 4 k + 2.85 k + 5 k = 11.85 k

F = (0.58)(11.85 k) = 6.9 k

Overturning requirement:

$$SF = \frac{M_{resist}}{M_{overturning}} \geq 1.5 - 2$$

The total resisting moment will be from those moments counterclockwise about 0:

$M_{resisting}$ = 4 k(3 ft) + 5 k(5 ft) + 2.85 k (10 ft – 6.33 ft/2)
= 56.5 k-ft

The overturning moment is only from the horizontal fluid force (clockwise):

$M_{overturning}$ = 3.375 k(5 ft + 16 in.(1 ft/12 in.)) = 21.4 k-ft

$$SF = \frac{56.5^{k-ft}}{21.4^{k-ft}} = 2.64 \geq 1.5 \quad \text{OK}$$

Sliding requirement:

$$SF = \frac{F_{horizontal-resist}}{F_{sliding}} \geq 1.25 - 2$$

The total resisting force will be from those opposite the hydraulic force (to the right):

$F_{resisting}$ = 6.9 k

The sliding force is only from the horizontal fluid force (to the left):

$F_{sliding}$ = 3.375 k

$$SF = \frac{6.9k}{3.375k} = 2.04 \geq 1.25 \quad \text{OK}$$