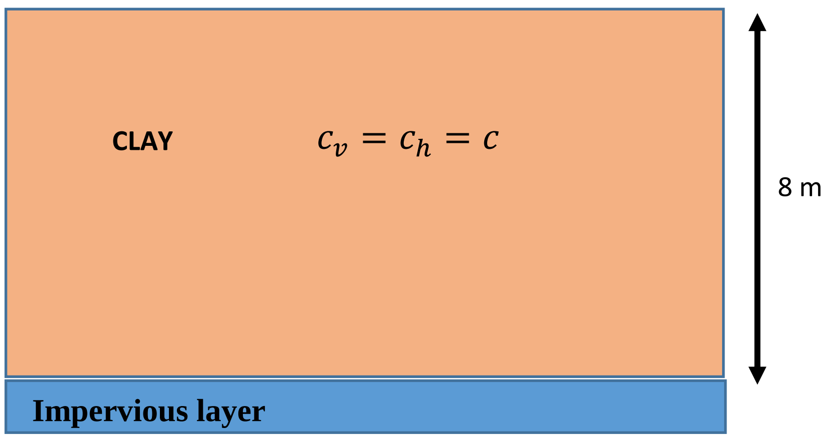
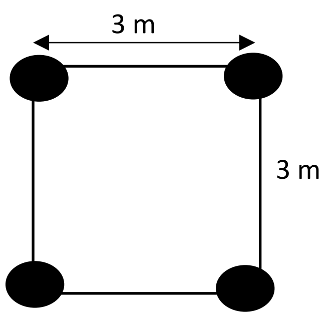
CE464 GROUND IMPROVEMENT FALL 2016 **HOMEWORK 3 ANSWER KEY**

1) (4 points) A half-closed clay layer is 8 m thick and it can be assumed that horizontal and vertical coefficient of consolidation are equal, $c_v = c_h$. Vertical sand drains 300 mm in diameter, spaced at 3 m in a square pattern, are to be used to increase the rate of consolidation of the clay under the increased vertical stress due to the construction of an embankment. Without sand drains, the degree of consolidation at the time the embankment is due to come into use has been calculated as 25%. What degree of consolidation would be reached with the sand drains at the same time?





Vertical Sand Drains:

$$Diameter = d_w = 0.3\ m$$

$$Spacing = S = 3.0\ \text{m}$$

Square Pattern

$$d_e = 1.13 * S \ for\ square\ pattern$$

$$d_e = 1.13 * 3 = 3.39\ m \quad \& \quad d_w = 0.3\ m$$

$$n = \frac{d_e}{d_w} = \frac{3.39}{0.3} = \mathbf{11.3}$$

$$F(n) = \frac{n^2}{n^2 - 1} * \left[\ln(n) - \frac{3}{4} + \frac{1}{n^2} + \frac{1}{n^4}\right]$$

(OR)

$$F(n) = \ln(n) - 0.75$$

$$F(n) = \frac{11.3^2}{11.3^2 - 1} * \left[\ln(n11.3) - \frac{3}{4} + \frac{1}{11.3^2} + \frac{1}{11.3^4}\right] = 1.696 \ \ (Other\ formulation, 1.675)$$

- Without Sand Drains:

$$U = 25\% \rightarrow T_v = \frac{\pi}{4} * U^2 = \frac{\pi}{4} * 0.25^2 = 0.049$$

$$T_v = \frac{(c_v * t)}{d^2} \rightarrow t = (T_v * d^2)/c_v$$

Where $c_v = c_h(OR\ c_r) = c$

$$t = \frac{0.049 * 8^2}{c} = \frac{3.136}{c}$$

Time is constant for both cases, with and without vertical sand drains.

- With Sand Drains:

$$(1 - U) = (1 - U_v) * (1 - U_r)$$

$$U_v = 0.25\ as\ stated\ in\ question\ (only\ vertical\ drainage, no\ sand\ drains)$$

$$U_{radial} = U_{horizontal} = 1 - e^{\frac{-8*T_h}{F(n)}}$$

$$T_h = T_r = \frac{c_h * t}{d_e^2}$$

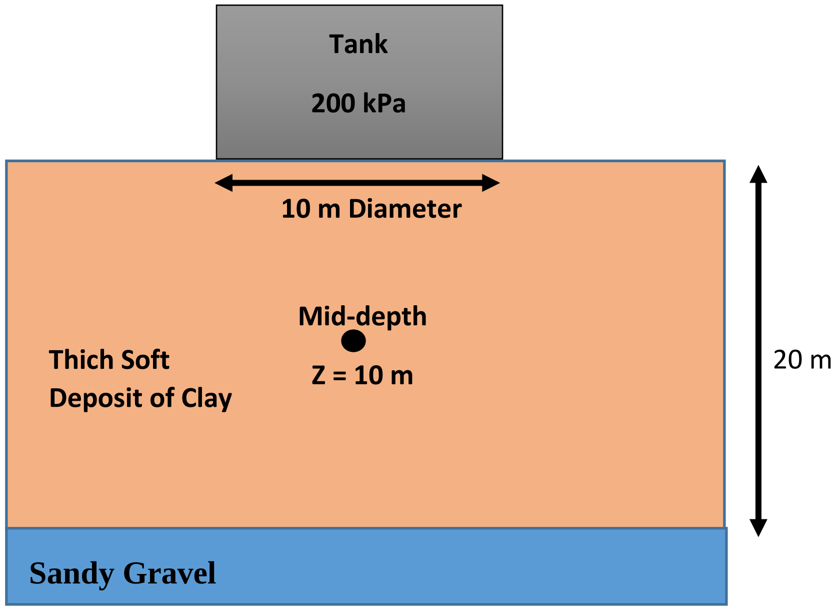
$$T_h = \frac{c * \left(\frac{3.136}{c}\right)}{3.39^2} \rightarrow T_h = 0.273$$

$$U_{radial} = 1 - e^{\frac{-8*0.273}{1.696}} = \mathbf{0.724}$$

$$(1 - U) = (1 - 0.250) * (1 - 0.724)$$

$$U = 0.793 = \mathbf{79.3}\%$$

2) (6 points) A foundation for a tank is to be constructed on a 20 m thick soft deposit of clay. Below the soft clay is a sandy gravel. The calculated primary consolidation settlement cannot be tolerated and it was decided that the soil should be preconsolidated by a wide embankment that produces the same final settlement as the tank. The data available are: cv = 6 m2/yr, ch = 10 m2/yr, mv = 0.2 m2/MN. The foundation of the tank is circular, its diameter is 10 m, it will be placed at the ground surface and it will apply 200 kPa pressure. Do not subdivide the clay and use 2V:1H stress distribution. The width of prefabricated vertical drain to be used is 110 mm and its thickness is 7 mm. Determine the spacing of a square grid of the PVD drains to achieve 18 cm settlement in 4 months.



Clay:

$$c_v = 6\frac{m^2}{yr}$$

$$c_h = 10\frac{m^2}{yr}$$

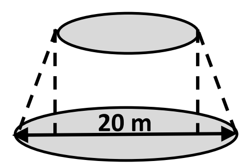
$$m_v = 0.2\frac{m^2}{MN}$$

You have a widely placed embankment which produce same settlement as tank. First find amount of settlement due to the load of tank (which is same in the case of wide embankment).

$$S_{tank} = \sum H * m_v * \Delta\sigma'$$

To find stress increase due to the load of tank at the mid-depth of clay, use 2V-1H approach:

$$\Delta\sigma' = \frac{200 * \pi * \frac{10^2}{4}}{\pi * \frac{(10 + 2 * 5)^2}{4}} = 50\ kPa$$



$$S_{tank} = H * m_v * \Delta\sigma' = 20\ m * 0.0002\frac{\mathrm{m}^2}{\mathrm{kN}} * 50\ \mathrm{kPa} = 0.2\ \mathrm{m}$$

Now, you know how much settlement will occur under tank (same as under the wide embankment). Then spacing of square grid of PVD drains is asked in the question. This drain system should achieve 18 cm settlement in 4 months.

This is the general formulation when there are both vertical and horizontal drainage.

$$(1 - U) = (1 - U_v) * (1 - U_r)$$

$$U = \frac{18}{20} = 0.90 = 90\%\ (with\ both\ vertical\ and\ horizontal\ drainage)$$

$$T_v = \frac{(c_v * t)}{d^2} = \frac{6 * \frac{4}{12}}{10^2} = 0.02$$

$$T_v = \frac{\pi}{4} * U^2 \; for \; U_v < 60\%$$

$$0.02 = \frac{\pi}{4} * U^2 \rightarrow U_v = \mathbf{16}\%$$

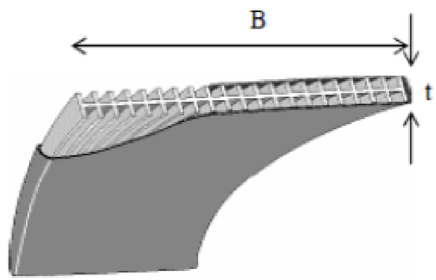
$$(1 - 0.9) = (1 - 0.16) * (1 - U_r) \rightarrow U_r = 0.88 = \mathbf{88}\%$$

$$B = 110 \; mm$$

$$t = 7 \; mm$$

$$d_w = \frac{2 * (B + t)}{\pi} = \frac{2 * (110 + 7)}{\pi}$$

$$d_w = 74.5 \; mm$$



$$U_h = U_r = 1 - e^{\frac{-8 * T_h}{F(n)}} \quad and \quad T_h = T_r = \frac{c_h * t}{d_e^2}$$

$$d_e = 1.13 * S \; (square \; pattern)$$

$$U_r = 0.88 = 88\%$$

You know degree of radial consolidation U_h and T_h , now, only unknown parameter is spacing (S). Let's write U_h again:

$$0.88 = 1 - e^{\frac{-8 * \frac{c_h * t}{d_e^2}}{\ln\left(\frac{d_e}{d_w}\right) - 0.75}}$$

$$0.88 = 1 - e^{\frac{-8 * \frac{10 * \frac{4}{12}}{(1.13 * S)^2}}{\ln\left(\frac{1.13 * S}{0.0745}\right) - 0.75}}$$

$$\boldsymbol{S = 1.94 \; m \, , \quad use \; 1.9 \; m}$$