(d) COMPRESSIBILITY AND CONSOLIDATION

D1. A normally consolidated clay has the following void ratio *e* versus effective stress σ' relationship obtained in an oedometer test.

(a) Plot the *e* - σ' curve.

(b) Plot the *e* - log σ' relationship and calculate the compression index.

Effective Stress σ' (kN/m^2)	:	50	100	150	200	300
Void ratio, *e*	:	0.97	0.91	0.85	0.81	0.75

D2. A 6-m deep layer of sand overlies a 4m thick clay layer. The clay layer is underlain by sandy gravel. The water table is at the ground surface and the saturated unit weight for both the sand and the clay is 19 kN/m^3. A 3-m thick layer of fill (unit weight 20 kN/m^3) is to be placed rapidly on the surface over an extensive area. Assume that the data given in Problem 1 corresponds to that of a representative sample from the clay, whose coefficient of consolidation is 2.4 m^2/year.

(a) Calculate the total and effective vertical stresses and the pore water pressure at the centre of the clay layer before the fill is placed, immediately after the fill is placed, and after the clay has consolidated under the vertical stress increment due to the fill.

(b) Without subdividing the clay layer, calculate the final consolidation settlement due to the placement of the fill using

(i)

$$\frac{\Delta H}{H_0} = \frac{\Delta e}{1+e_0};$$

(ii) coefficient of volume compressibility;

(iii) compression index.

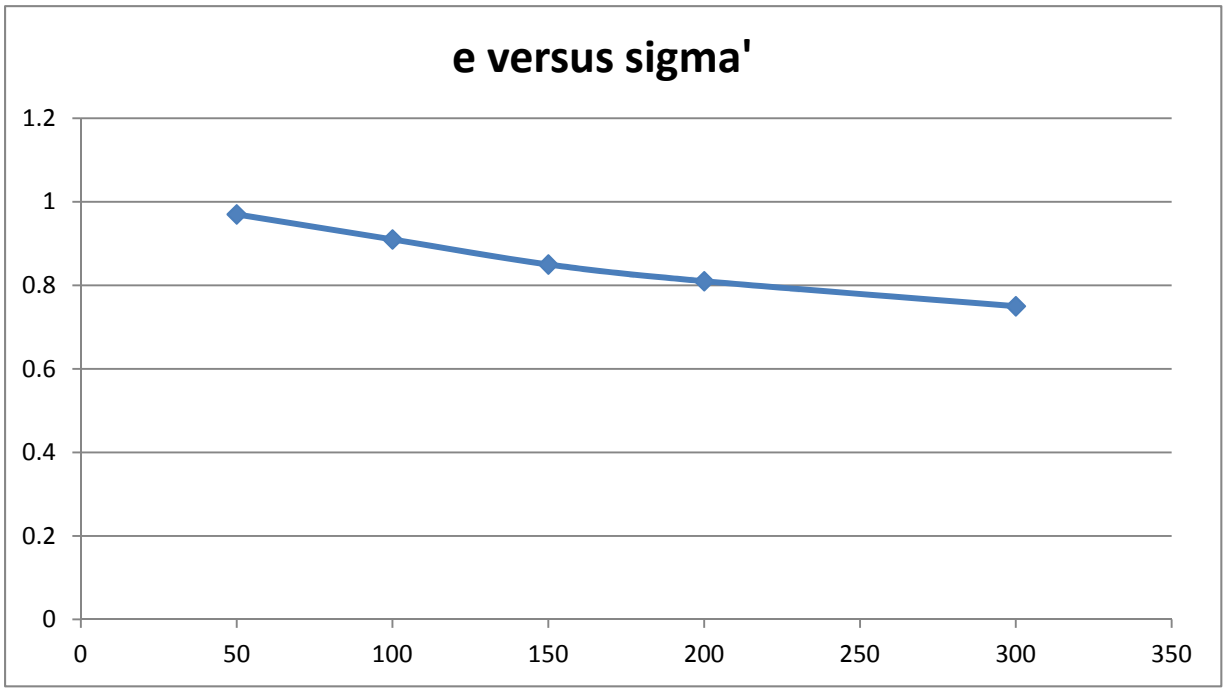
(c) What is the degree of consolidation U_z at the centre of the clay layer when the pore water pressure at that depth is equal to 125 kN/m^2? What is the effective stress at that depth at that time?

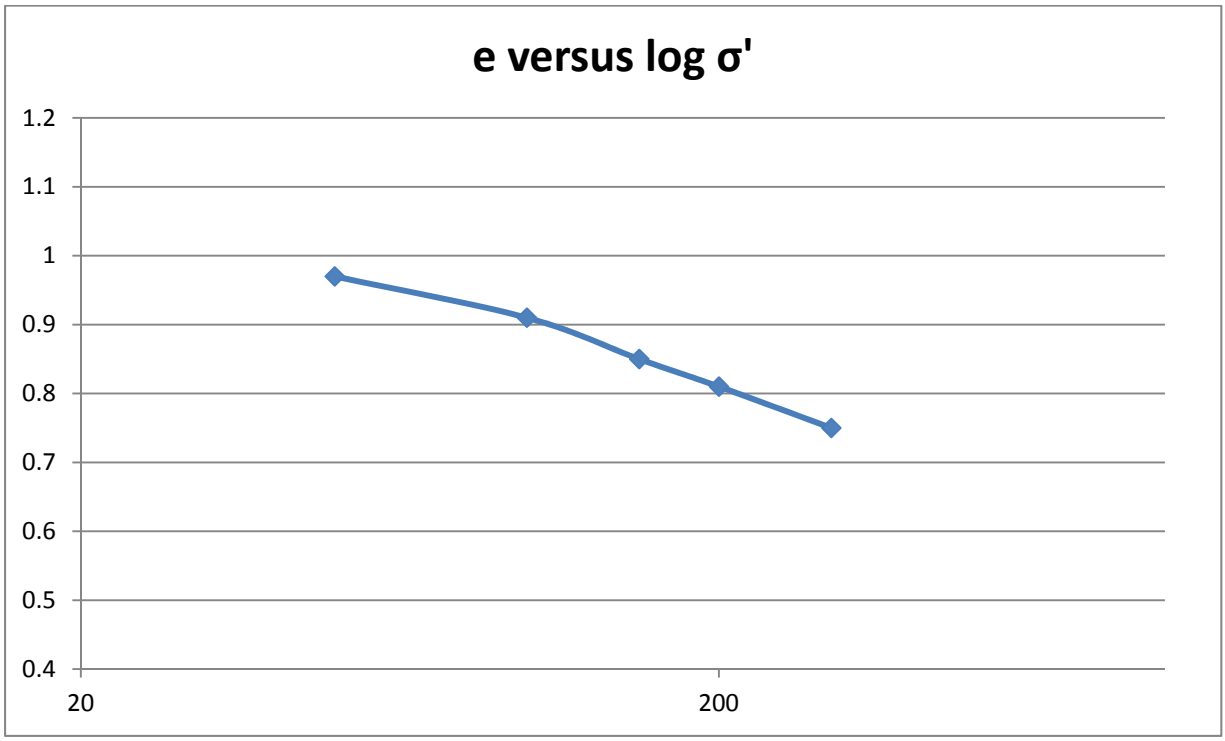
(d) How long will it take to reach 50 % *average* degree of consolidation U?

(e) What is the settlement at the end of 20 months?

(f) What time is required for 40 mm settlement?

D1)





$$C_c = \left|\frac{\Delta e}{\Delta log\sigma}\right| = \frac{0.91 - 0.75}{log\frac{300}{100}} = 0.33$$

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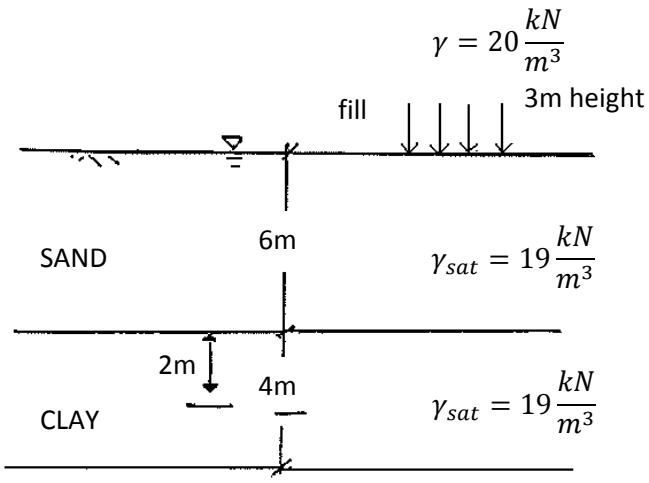
D2)



a) Before fill is placed

$\sigma = 8 * 19 = 152\frac{kN}{m^2}$

$u_0 = 8 * 10 = 80\frac{kN}{m^2}$

$\sigma' = \sigma - u = 72\frac{kN}{m^2}$

Immediately after fill is placed

$\sigma = 8 * 19 + 3 * 20 = 212\frac{kN}{m^2}$

$u = u_0 + u_{ie} = 80 + 60 = 140\frac{kN}{m^2}$

$\sigma' = \sigma - u = 72\frac{kN}{m^2}$

After clay has consolidated (long term)

$\sigma = 212\frac{kN}{m^2}$

$u = u_0 = 80\frac{kN}{m^2}$

$\sigma' = 132\frac{kN}{m^2}$

b) i)

$$\frac{\Delta H}{H_0} = \frac{\Delta e}{1 + e_0}$$

$$\sigma_0' = 72\frac{kN}{m^2} \rightarrow e_0 = 0.944$$

(from e-log σ graph)

$$\sigma_1' = 132\frac{kN}{m^2} \rightarrow e_1 = 0.868$$

$$S_c = -\Delta H = -4000 * -\frac{0.076}{1 + 0.944} = 156.4\,mm$$

ii) m_v for this pressure range involved is:

$$m_v = -\frac{1}{1+e_0} * \frac{\Delta e}{\Delta \sigma'} = -\frac{1}{1+0.944} * \frac{-0.076}{132-72} = 6.52 * \frac{10^{-4} m^2}{kN}$$

$$S_c = m_v * H * \Delta \sigma' = (6.52 * 10^{-4}) * 4 * 60 = 0.1565m = 156.5\ mm$$

iii) $S_c = H_0 * \frac{C_c}{1+e_0} * \log\left(\frac{\sigma_1'}{\sigma_0'}\right) = 4000 * \frac{0.33}{1+0.944} * \log\left(\frac{132}{72}\right) = 178.7\ mm$

Result is somewhat different; because pressure range involved is not completely on the straight line portion; the slope of which is C_c.

c) $$u = u_0 + u_e = 125 \frac{kN}{m^2}$$

$$u_0 = 80 \frac{kN}{m^2}$$

Excess pore water pressure

$$u_e = 125 - 80 = 45 \frac{kN}{m^2}$$

$$u_z = \frac{u_{ie} - u_e}{u_{ie}} = \frac{60-45}{60} = 0.25 = 25\%$$

$$(u_{ie} = initial\ excess\ pore\ water\ pressure)$$

$$\sigma' = \sigma - u = 212 - 125 = 87 \frac{kN}{m^2}$$

d) $$u = 50\% \rightarrow T_v = 0.196 \qquad d = 2m\ (double\ drainage)$$

$$C_v = \frac{2.4 m^2}{year}$$

$$T_v = \frac{C_v * t}{d^2} \rightarrow t = \frac{T_v * d^2}{C_v} = \frac{0.196 * 2^2}{2.4} = 0.327\ year \cong\ 4\ months$$

e) $$T_v = \frac{C_v * t}{d^2} = \frac{2.4 * \left(\frac{20}{12}\right)}{2^2} = 1.0 \rightarrow u = 94\%$$

$$S = 0.94 * S_c = 0.94 * 156 = 146.6\ mm$$

f)

$$u = \frac{40\ mm}{156\ mm} = 25.6\% \rightarrow T_v \cong 0.06$$

$$t = \frac{T_v * d^2}{C_v} = \frac{0.06 * 2^2}{2.4} = 0.1\ year = 1.2\ month$$