Sample undergraduate tutorial sheet

Module: Geotechnical Engineering

Tutorial – Consolidation – Solutions

1. A saturated sample of a normally consolidated clay gave the following results when tested in a consolidation apparatus (each loading increment was applied for 24 hours).

Consolidation pressure (kPa)	Thickness of sample (mm)
0	17.32
53.65	16.84
107.3	16.48
214.6	16.18
429.2	15.85
0	16.51

After the sample had been allowed to expand for 24 hours it was found to have a water content of 30.2 %. The particle specific gravity of the soil was 2.65.

(i) Plot the void ratio to effective pressure.

(ii) A 6.1 m layer of the soil is subjected to an existing effective over burden pressure at its centre of 107.3 kPa, and a foundation load will increase the pressure at the centre of the layer by 80.5 kPa.

Determine the probable total consolidation settlement of the layer.

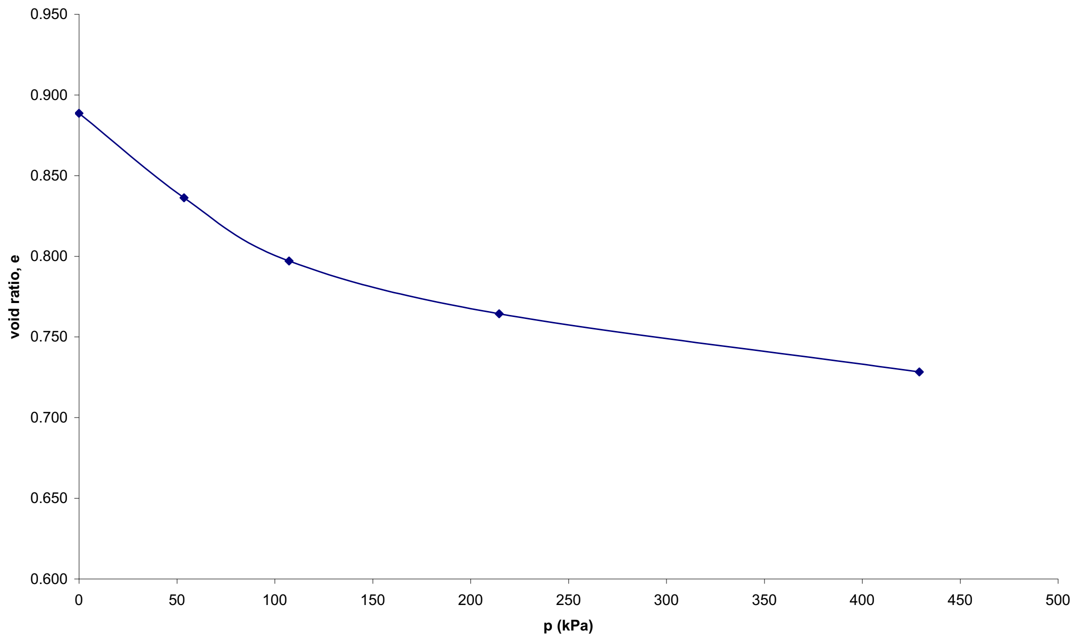
(88 mm)

$e = wG_s = 0.302 \times 2.65 = 0.800$

$de = (1 + e) / 16.51 = 0.1090$

Pressure	H (mm)	dH (mm)	de	e
0	17.32	0.81	0.088	0.889
53.65	16.84	0.33	0.036	0.836
107.3	16.48	-0.03	-0.003	0.797
214.6	16.18	-0.33	-0.36	0.764
429.2	15.85	-0.66	-0.072	0.728
0	16.51	0	0.000	0.800

e – p plot:



Settlement by m_v:

e at 107.3 kPa = 0.797
e at 187.8 kPa = 0.771

$$m_v = \frac{\left(\frac{0.797-0.771}{80.5}\right)}{1+0797} = 0.000180 \text{ m}^2/\text{kN}$$

Settlement, $\rho_c = m_v \times H \times dp = 0.000180 \times 6.1 \times 80.5 \times 1000 = 88$ mm

2. A soil sample of thickness 19.1 mm in an oedometer test experienced 30 % primary consolidation after 10 minutes. How long would it take the sample to reach 80 % consolidation?

(80 min)

$$T = \frac{c_v t}{H^2} \Rightarrow c_v = \frac{0.071 \times 9.55^2}{10} = 0.6475 \text{ mm}^2/\text{min}$$

From Fig 5.4: $T_{80} = 0.567$

$$t_{80} = \frac{T_{80}\, H^2}{c_v} = \frac{0.567 \times 9.55^2}{0.6475} = 80 \text{ mins}$$

3. A 5 m thick clay layer has an average c_v value of 5.0 x 10^{-2} mm^2/min. If the layer is subjected to a uniform initial excess pore pressure distribution, determine the time it will take to reach 90 % consolidation (i) if drained on both surfaces and (ii) if drained on its upper surface only.

((i) 200 years, (ii) 800 years)

(i) $T_{90} = 0.848$: H = 2.5 m

$$t_{90} = \frac{0.848 \times 2500^2}{0.05} = 106 \times 10^6 \text{ mins} \approx 200 \text{ years}$$

(ii) H = 5 m

$$t_{90} = \frac{0.848 \times 5000^2}{0.05} = 424 \times 10^6 \text{ mins} \approx 800 \text{ years}$$

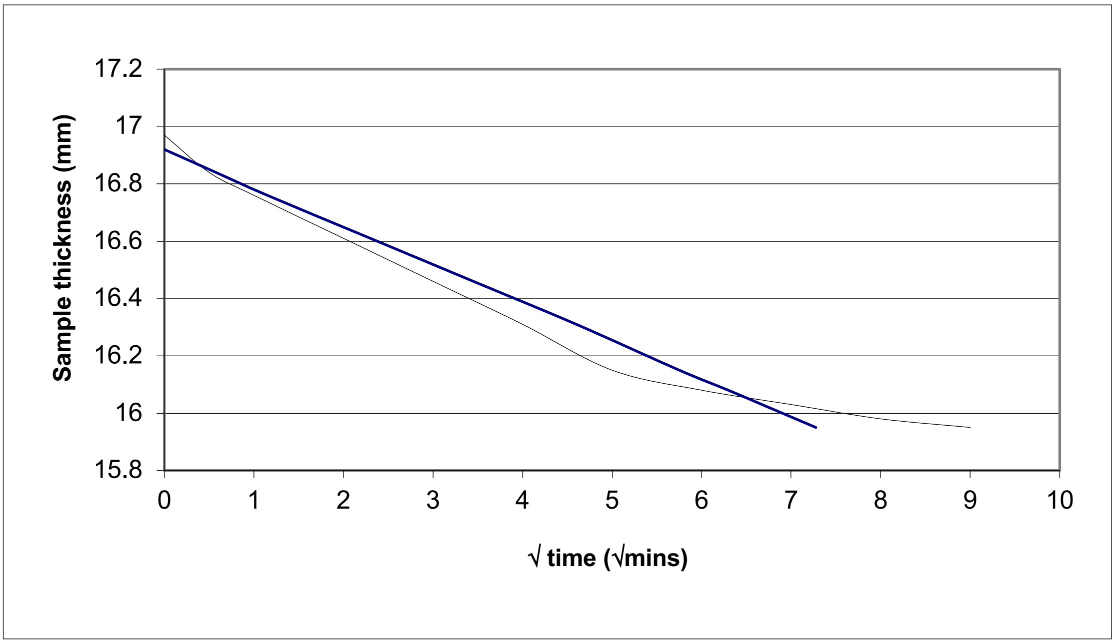
4. In a consolidation test the following readings were obtained for a pressure increment:

Sample thickness (mm)	Time (min)
16.97	0
16.84	$\frac{1}{4}$
16.76	1
16.61	4
16.46	9
16.31	16
16.15	25
16.08	36
16.03	49
15.98	64
15.95	81

(i) Determine the coefficient of consolidation of the sample.
(ii) From the point for U = 90 % on the test curve, establish the point for U = 50 % and hence obtain the test value for t_{50}. Check your value from the formula

$$t_{50} = \frac{T_{50} H^2}{c_v}$$

(c_v = 1.28 mm^2/min, t_{50} = 10.4 min)



Corrected zero value = 16.9 mm
$\sqrt{t_{90}}$ value (read from plot) = 6.7 mins

t_{90} = 44.9 mins

Mean thickness of sample = (16.9 + 15.95) / 2 = 16.45

H = 16.45 / 2 = 8.22 mm

$$c_v = \frac{0.848 \times 8.22^2}{44.9} = 1.28 \text{ mm}^2\text{/min}$$

$$t_{50} = \frac{T_{50}\, H^2}{c_v} = \frac{0.197 \times 8.22^2}{1.28} = 10.4 \text{ mins}$$

5. A sample in a consolidation test had a mean thickness of 18.1 mm during a pressure increment of 150 to 290 kPa. The sample achieved 50 % consolidation in 12.5 min. If the initial and final void ratios for the increment were 1.03 and 0.97 respectively, determine values for the coefficient of volume compressibility and of consolidation of the sample.

(m_v = 0.2113 × 10^{-3} mm²/kN; c_v = 1.29 mm²/min)

$$a = \frac{de}{dp} = \frac{1.03-0.97}{290-150} = \frac{0.06}{140} = 0.000429 \text{ m}^2\text{/kN}$$

$$m_v = \frac{a}{1+e_1} = \frac{0.000429}{2.03} = 0.0002113 \text{ m}^2\text{/kN}$$

$$= 0.2113 \times 10^3 \text{ mm}^2\text{/kN}$$

$$c_v = \frac{T_{50} H^2}{t_{50}}$$

From Fig 5.4: T_{50} = 0.197

$c_v = \frac{0.197 \times 9.05^2}{12.5}$ = 1.29 mm^2/min