3D1 ~~2020~~ 2021

a) $\gamma_d = 16 \text{ kN m}^{-3} = \frac{G_s \gamma_w}{1+e}$ $G_s = \frac{100}{38} = \underline{2.63}$

$e = \underline{0.64}$

$\omega = \frac{19}{16} - 1 = \underline{18.75\%}$

b)

ω	6	8	10	12	14	16
γ_{bulk}	19.2	20	20.8	21.4	21.4	21.2
γ_d	18.1	18.52	18.9	19.1	18.8	18.3

Optimum $\omega = \sim \underline{\underline{12\%}}$ Plot graph to determine peak γ_d

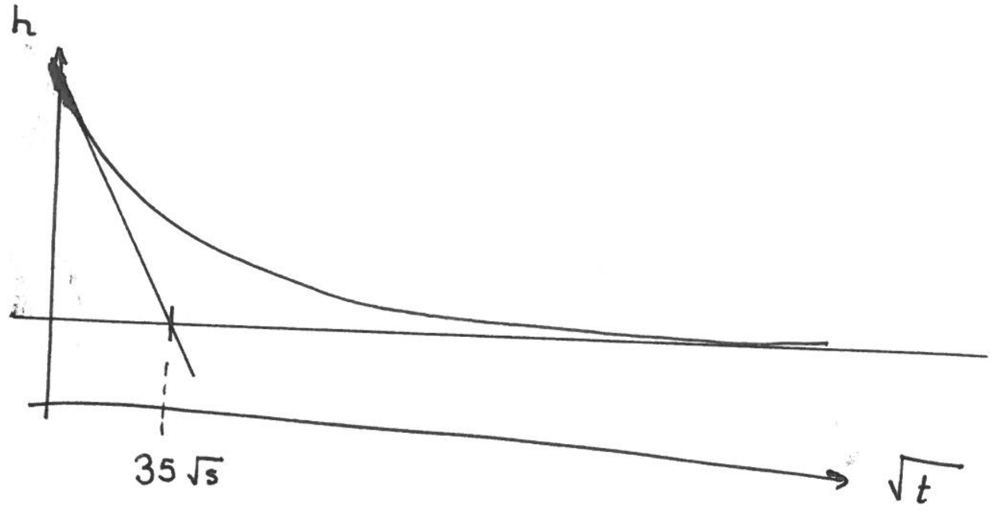
c) wet of optimum :-

high saturation + low air voids → little pore suction.
weak but homogenous material will low permeability.
Suitable for construction if strong enough to allow plant to work without getting bogged down.

dry of optimum

low saturation high air voids → water trapped in particle contacts will high suction giving high strength.
Brittle + susceptible to wetting collapse despite high strength.
Not suitable for embankment construction.

2. Plot $\sqrt{t}$ vs h



$$E = \frac{\Delta\sigma}{\varepsilon} = \frac{20\ kPa}{0.19/20} = \underline{2.1\ MPa}$$

$T_v = 3/4$ when $\sqrt{t} = 35\ \sqrt{s}$

$$C_v \times \frac{35^2}{10_{mm}^2} = \frac{3}{4}$$

$$C_v = \frac{3}{4} \times \frac{0.01^2}{35^2} = 6.1 \times 10^{-8}\ m^2/s$$

$$= 1.93\ m^2/year$$

$$k = \frac{C_v \times \gamma_w}{E} = \frac{6.1\times10^{-8} \times 10{,}000}{2.1\times10^6} = \underline{\underline{2.9\times10^{-10}\ m/s}}$$

b) Assume vertical consolidation (or $\perp$ aquifer)

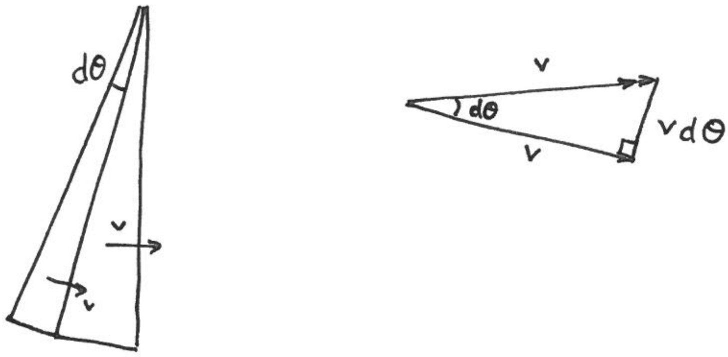
	LHS	RHS		
ρ_{max}	0.057m	0.038m		
month	$T_v = 0.0045$	0.010		
	~~Rf=20~~ $\rho = 4.4mm$	$\rho = 4.4mm$	$\rho = 4.4mm$	$\theta \sim 0$
year	15.3 mm	15.4 mm	$\rho = 15.4mm$	$\theta \sim 0$
	57 mm	38 mm	$\rho_{avg} = 47.5mm$	$\theta = 1.9\times10^{-3}$ (0.1°)

3

a) LB $\rightarrow$ Stress field in eqbm with applied forces which doesn't exceed material strength.
Material must be plastic

UB $\rightarrow$ Compatible mechanism.
Energy dissipated in mechanism UB to capacity.

b) Infinitessimal wedge



$$\text{Energy} = s_u v r d\theta + s_u r v d\theta = 2 s_u r v d\theta$$

$$\int \text{Energy} = \underline{2 s_u r v \theta}$$

c) $V = (s_c d_c N_c s_u + \gamma h) A$

$s_c = 1.2$

$d_c = 1 + \frac{1}{3}\tan^{-1}\left(\frac{2}{3}\right) = 1.196$ $\quad N_c = 5.14 \quad h = 2 \quad \gamma = 16$

i) $V = \underline{3607 \text{ kN}}$

ii) $V = 1.2$ kN $\quad$ Use Meyerhoff. $\quad F = \frac{1}{3}$

assume s_c, d_c unchanged $\rightarrow$ $b_{eq} = 1$

$s_c = 1 + 0.2 \times \frac{1}{3} = 1.06$

$d_c = 1.37$ $\quad e = 1\text{m}$

$V = 1215$ kN $\quad \underline{\text{OK}}$ $\quad \rightarrow$ load @ $\frac{1200 \times 1}{200} = \underline{6\text{m}}$

Curvature only in phase II

$$R_v = 1 - {}^{2}/_{3} \exp\left({}^{1}/_{4} - 3T_v\right) \qquad T_v = \frac{C_v t}{d^2}$$

$$\rho = \frac{\Delta\sigma\, d}{E} R_v$$

d varies linearly across building

maximise $\dfrac{\partial^2 \rho}{\partial d^2}$

Chain rule

$$\frac{\partial \rho}{\partial d} = \frac{\partial \rho}{\partial T_v}\frac{\partial T_v}{\partial d} \qquad \frac{\partial T_v}{\partial d} = \frac{-2 C_v t}{d^3} = \frac{-2T_v}{d}$$

$$\frac{\partial R_v}{\partial T_v} = + \, {}^{2}/_{\cancel{3}} \exp\left({}^{1}/_{4} - 3T_v\right) \qquad \frac{\partial R_v}{\partial d} = \frac{-2C_v t \times 2 \exp\left({}^{1}/_{4} - 3T_v\right)}{d^3}$$

$$\frac{\partial \rho}{\partial d} = \frac{\Delta\sigma}{E}\cancel{d} \times -\frac{4 C_v t}{d^{\cancel{3}2}} \exp\left({}^{1}/_{4} - 3T_v\right) + \frac{\Delta\sigma}{E}\left(1 - {}^{2}/_{3}\exp\left({}^{1}/_{4} - 3T_v\right)\right)$$

$$= \frac{\Delta\sigma}{E}\left(1 - \left(4T_v + {}^{2}/_{3}\right)\exp\left({}^{1}/_{4} - 3T_v\right)\right)$$

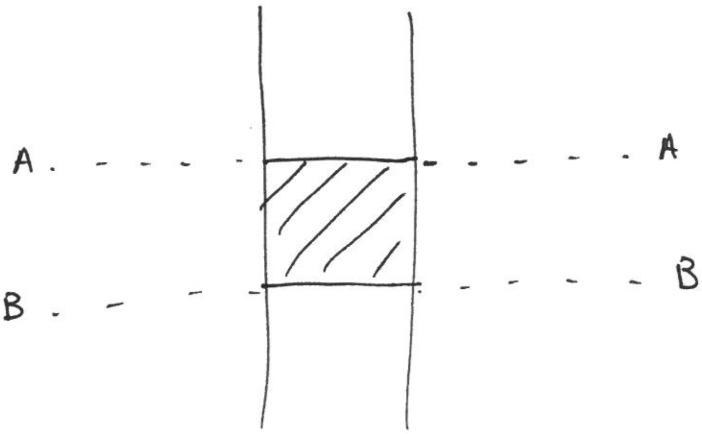
$$\frac{\partial^2 \rho}{\partial d^2} = \frac{\partial}{\partial T_v}\left(\frac{\partial \rho}{\partial d}\right) \times \frac{\partial T_v}{\partial d}$$

$$= \frac{\Delta\sigma}{E}\left(+3\left(4T_v + {}^{2}/_{3}\right)\exp\left({}^{1}/_{4} - 3T_v\right) \cancel{+} - 4\exp\left({}^{1}/_{4} - 3T_v\right)\right) \times -\frac{2T_v}{d}$$

$$\text{Curvature} = -2\frac{\Delta\sigma}{E}\frac{T_v}{d}\left(12T_v - 2\right)\exp\left({}^{1}/_{4} - 3T_v\right)$$

4. If foundation is flexible, stresses below foundation are constant, however centre will settle more than edge
If foundation is stiff, all foundation will displace by same amount, so pressure @ edge must be greater than that at centre.

b) A square foundation could be considered as a section of a strip. Consider UB calculation. Stresses on planes A-A & B-B will dissipate energy, increasing capacity.

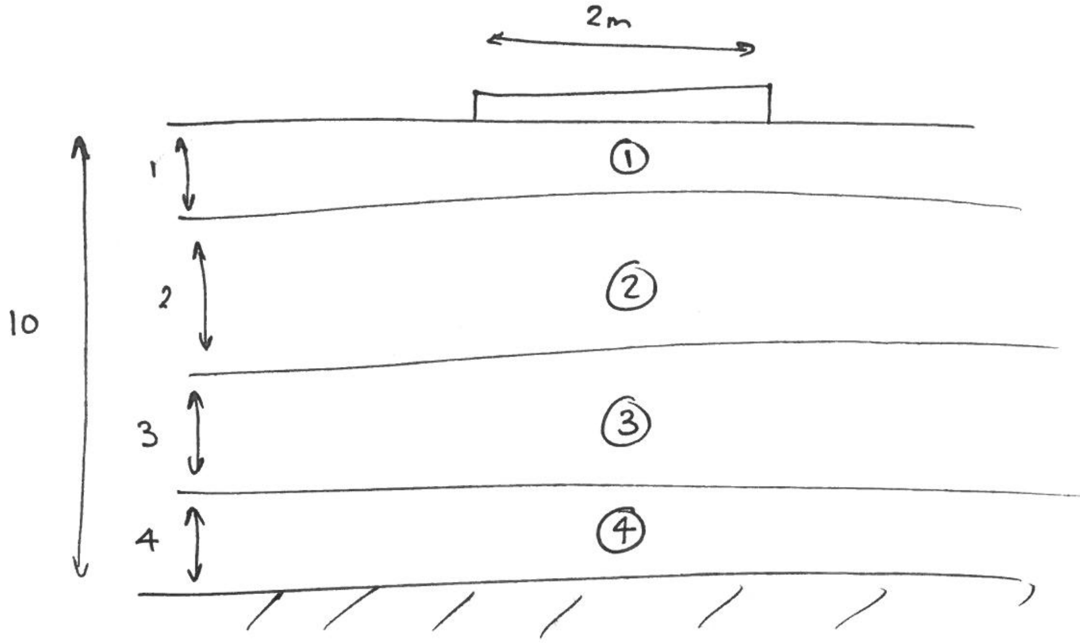


However 3D square mechanism will be shallower than strip. If strength increases with depth, shallow mechanism will utilise lower soil strength leading to lower Sc.

c) $$\omega_c = \frac{(1-\nu)}{G} q_a \qquad \omega_e = \frac{2}{\pi}\omega_c$$

$$= \frac{0.5}{15\times10^3} \times 63.7$$

$$= 2.12 \text{ mm} \qquad \omega_e = 1.35\text{mm}$$



layers increase with depth

$K = 0.05$

	1	2	3	4
σ_0	8	32	72	128
$\Delta\sigma$	57	19	6	5
$K \ln\left(\frac{\sigma_1}{\sigma_0}\right)$ Δv	0.105	0.023	0.004	0.002
$\varepsilon = \frac{\Delta v}{v}$	0.038	0.0085	0.0015	0.0007
$\rho = \varepsilon h$	38 mm	17 mm	4 mm	3 mm

$\rho_T = \underline{\underline{62\,mm}}$

25% $\quad d = 1\,m \qquad C_v = 1\,m^2/yr$

$R_v = 0.25 \qquad T_v = 0.05 \qquad t = 0.05\ yr = 18\ days$

$R_v = 0.95 \qquad T_v = 1 \qquad t = 1\ year$

however at depth $d > 1$ so probably takes longer for

<u>95%</u>.