Part IIA Paper 3D1 2003 Answers

1. a) points ($w$, $e$) are (0.06, 0.472), (0.10, 0.400), (0.14, 0.420), (0.18, 0.523)
to find saturation lines in this range, use $w = S_r\, e / G_s$ for $e = 0.4$ and 0.5
optimum compaction at $e = 0.39$, $\rho_d = 1906$ kg m$^{-3}$
$\rho_d$ is preferred to $e$ because it does not require a measurement of $G_s$
field compaction is calibrated against Proctor test, e.g. by energy per unit volume
b) optimum water content 11%
wet of optimum water is trapped in voids and prevents compaction
dry of optimum air is trapped, with macro-pores held open by fines in suction
c) true that soil suction on dry increases effective stress, stiffness and strength
not true that soil overall will swell – the fines in suction swell and soften so that macro-pores will collapse on wetting, giving overall settlement
engineer should demand $w > 11\%$ and $e < 0.45$, say to keep $S_r > 0.75$

2. a) $E_o \approx 476$ kPa, $C_v \approx 5.7 \times 10^{-8}$ m$^2$ s$^{-1}$, $k \approx 1.2 \times 10^{-9}$ ms$^{-1}$
b) $\Delta\sigma'_v \approx 35$ kPa in the field instead of 50 kPa
correct $E_o$ by assuming a $\lambda$-line, $E_o \approx 390$ kPa
$k \approx 1.2 \times 10^{-9}$ ms$^{-1}$ as before, $C_v \approx 4.8 \times 10^{-8}$ m$^2$ s$^{-1}$
c) $\rho_{ult} \approx 0.54$ m, $\rho_{1\,year} \approx 0.46$ m taking $d = 1.5$ m
45700 tonnes
corrected $\Delta\sigma'_v \approx 40$ kPa
field trial fill to confirm, especially rate of drainage

3. a) compression on λ-lines, on yield surfaces, involves grain crushing and rearrangement
unload-reload on κ-lines involves grain contact elasticity, with some rearrangement
b) for A go to 206 kPa, for B go to 500 kPa and then swell to 50 kPa
$c_u = 47$ kPa, A→C $\delta u = +95$ kPa, B→C $\delta u = -61$ kPa
c) normally consolidated soil A will settle too much if it drains, but it gets stronger
overconsolidated soil B will soften too much if it drains, and swell slightly

4. a) grain crushing, critical friction
b) $\sigma'_{crit} = 3954$ kPa, $\tau_{crit} = 2471$ kPa for constant volume shearing, e.g. pile driving
c) 40.6°, 10.8°; 49.3°, 21.6°
d) at $\sigma' = 395$ kPa, $\tau_{max} = 339$ kPa; at $\sigma' = 39.5$ kPa, $\tau_{max} = 46$ kPa
straight line will not fit critical state and implies strength at zero effective stress
power law works perfectly for $\beta = 0.86$