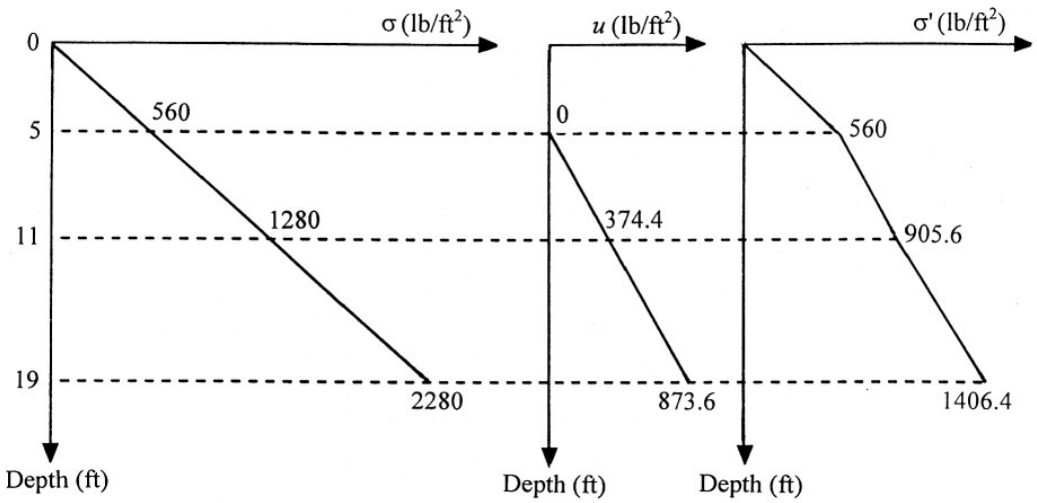
# Chapter 9

9.1

| | lb/ft$^2$ | | |
|---|---|---|---|
| Point | $\sigma$ | $u$ | $\sigma'$ |
| *A* | **0** | **0** | **0** |
| *B* | (5)(112) = **560** | **0** | **560** |
| *C* | 560 + (6)(120) = **1280** | (62.4)(6) = **374.4** | **905.6** |
| *D* | 1280 + (8)(125) = **2280** | 374.4 + (62.4)(8) = **873.6** | **1406.4** |

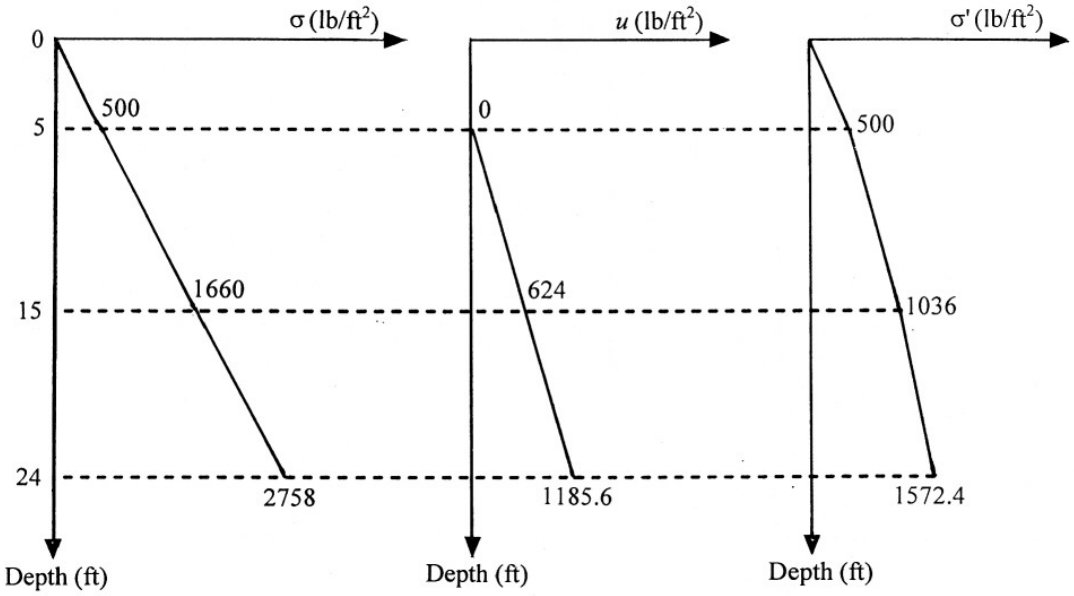
The plot is given below.




9.2

| | lb/ft$^2$ | | |
|---|---|---|---|
| Point | $\sigma$ | $u$ | $\sigma'$ |
| *A* | **0** | **0** | **0** |
| *B* | (5)(100) = **500** | **0** | **500** |
| *C* | 500 + (10)(116) = **1660** | (62.4)(10) = **624** | **1036** |
| *D* | 1660 + (9)(122) = **2758** | 624 + (62.4)(9) = **1185.6** | **1572.4** |

The plot is shown on the following page.

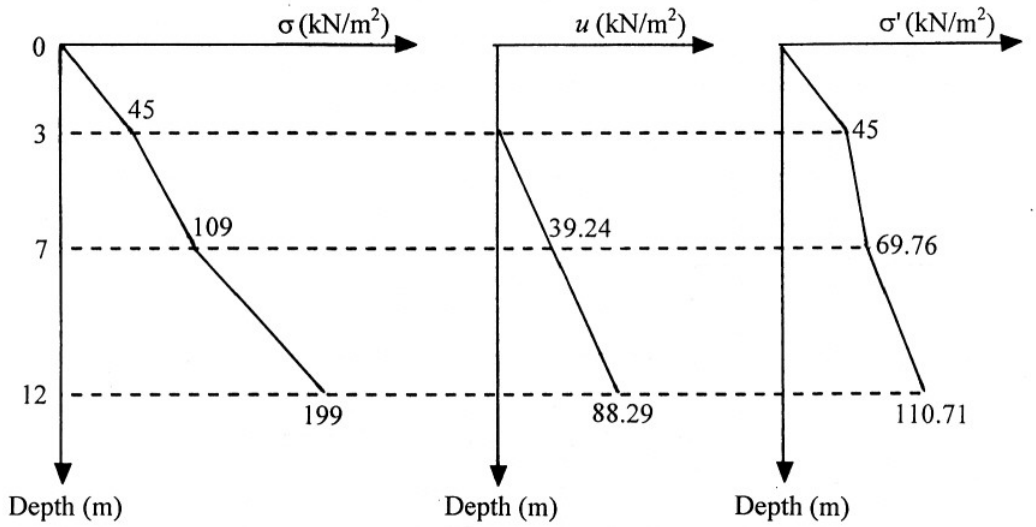



Problem 9.2

9.3

| | kN/m$^2$ | | |
|---|---|---|---|
| Point | σ | *u* | σ′ |
| *A* | **0** | **0** | **0** |
| *B* | (3)(15) = **45** | **0** | **45** |
| *C* | 45 + (4)(16) = **109** | (9.81)(4) = **39.24** | **69.76** |
| *D* | 109 + (5)(18) = **199** | 39.24 + (9.81)(5) = **88.29** | **110.71** |

The plot is shown below.



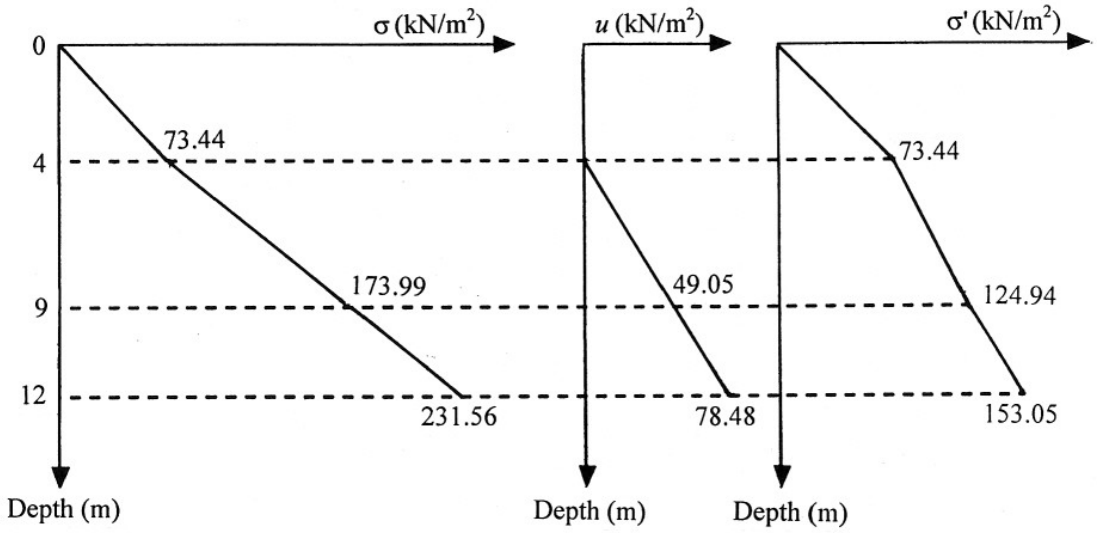
9.4 $$\gamma_{d\,(\text{sand})} = \frac{G_s\gamma_w}{1+e} = \frac{(2.62)(9.81)}{1+0.4} = 18.36\ \text{kN/m}^3$$

$$\gamma_{\text{sat(sand)}} = \frac{\gamma_w(G_s+e)}{1+e} = \frac{(9.81)(2.68+0.6)}{1+0.6} = 20.11\ \text{kN/m}^3$$

$$\gamma_{\text{sat(clay)}} = \frac{\gamma_w(G_s+e)}{1+e} = \frac{(9.81)(2.73+0.81)}{1+0.81} = 19.19\ \text{kN/m}^3$$

| | kN/m$^2$ | | |
|---|---|---|---|
| Point | $\sigma$ | $u$ | $\sigma'$ |
| *A* | **0** | **0** | **0** |
| *B* | (4)(18.36) = **73.44** | **0** | **73.44** |
| *C* | 73.44 + (5)(20.11) = **173.99** | (9.81)(5) = **49.05** | **129.94** |
| *D* | 173.99 + (3)(19.19) = **231.56** | 49.05 + (9.81)(3) = **78.48** | **153.05** |

The plot is shown below.



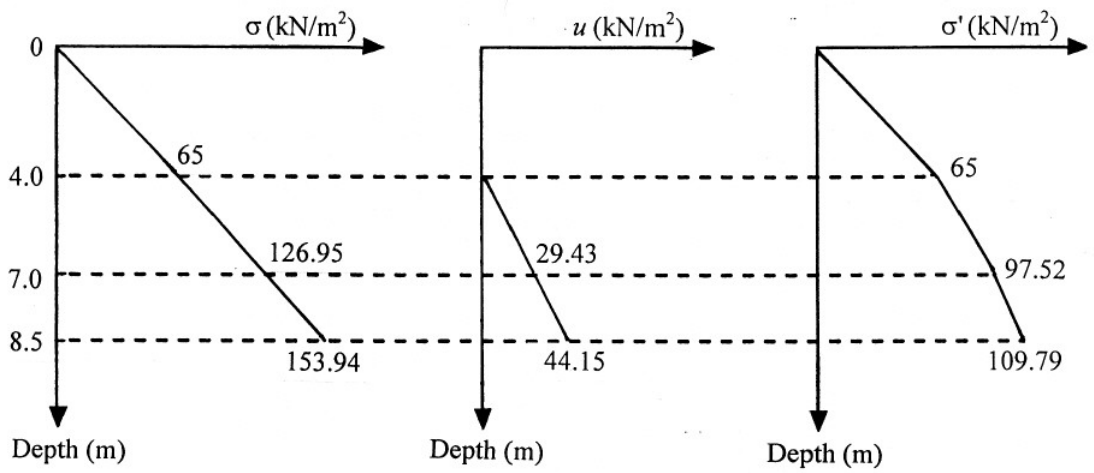

9.5 $$\gamma_{d\,(\text{sand})} = \frac{G_s\gamma_w}{1+e} = \frac{(2.65)(9.81)}{1+0.6} = 16.25\ \text{kN/m}^3$$

$$\gamma_{\text{sat(sand)}} = \frac{\gamma_w(G_s+e)}{1+e} = \frac{(9.81)(2.68+0.52)}{1+0.52} = 20.65\ \text{kN/m}^3$$

$$\gamma_{\text{sat(clay)}} = \frac{\gamma_w(G_s+e)}{1+e} = \frac{(9.81)\left(\frac{1.1}{0.4}+1.1\right)}{1+1.1} = 17.99\ \text{kN/m}^3$$

| | kN/m$^2$ | | |
|---|---|---|---|
| Point | σ | *u* | σ′ |
| *A* | **0** | **0** | **0** |
| *B* | (4)(16.25) = **65** | **0** | **65** |
| *C* | 65 + (3)(20.65) = **126.95** | (9.81)(3) = **29.43** | **97.52** |
| *D* | 126.95 + (1.5)(17.99) = **153.94** | 29.43 + (9.81)(1.5) = **44.158** | **109.79** |

The plot is shown below.




9.6 a. $\gamma_{d\,(\text{sand})} = \dfrac{G_s\gamma_w}{1+e} = \dfrac{(2.66)(9.81)}{1+0.52} = 17.17 \text{ kN/m}^3$

$$\gamma_{\text{sat(clay)}} = \frac{(G_s+e)\gamma_w}{1+e} = \frac{(2.75+1.0)(9.81)}{1+1.0} = 18.39 \text{ kN/m}^3$$

| | kN/m$^2$ | | |
|---|---|---|---|
| Depth (m) | σ | *u* | σ′ |
| 0 | **0** | **0** | **0** |
| 5 | (17.17)(5) = **85.85** | **0** | **85.85** |
| 9 | 85.85 + (18.39)(4) = **159.41** | (9.81)(4) = **39.24** | **120.17** |

b. $\gamma_{\text{sat(sand)}} = \dfrac{(G_s+e)\gamma_w}{1+e} = \dfrac{(2.66+0.52)(9.81)}{1+0.52} = 20.52 \text{ kN/m}^3$

$\sigma = (5)(20.52) + (4)(18.39) = 176.16 \text{ kN/m}^2$

$u = (9)(9.81) = 88.29 \text{ kN/m}^2$

$\sigma' = 176.16 - 88.29 = 87.87 \text{ kN/m}^2$

CHANGE IN $\sigma'$: $120.17 - 87.87 =$ **$32.3 \text{ kN/m}^2$**

c. Let the height of rise be $h$. So, at any time, at the bottom of the clay layer,

$\sigma = (5 - h)(17.17) + (h)(20.52) + (4)(18.39) = 159.41 + 3.35h$

$u = (4 + h)(9.81) = 39.24 + 9.81h$

$\sigma' = (159.41 + 3.35h) - (39.24 + 9.81h) = 120.17 - 6.46h$

CHANGE IN $\sigma'$: $15 = (120.17) - (120.17 - 6.46h)$; $h =$ **2.32 m**

9.7 $$\gamma_{\text{sat(clay)}} = \frac{(1+w)G_s\gamma_w}{1+wG_s} = \frac{(1+0.35)(2.72)(62.4)}{1+(0.35)(2.72)} = 117.4 \text{ lb/ft}^3$$

Let the depth of the excavation be $H$. So, $(20 - H)(117.4) - (12)(62.4) = 0 = \sigma'$.

$H \approx$ **13.62 ft**

9.8 $$\gamma_{\text{sat(clay)}} = \frac{(1900)(9.81)}{1000} = 18.64 \text{ kN/m}^3$$

$\sigma_A = (7 - 5)(18.4) + h\gamma_w$

$u_A = 3\gamma_w$

$\sigma'_A = (2)(18.64) + h(9.81) - (3)(9.81) = 0$

$h =$ **0.8 m**

9.9 $$i = \frac{h}{H_2} = \frac{1.5}{2.5} = 0.6$$

$$q = kiA = \left(\frac{0.12}{100} \times 60 \text{ m/min}\right)(0.6)(0.45) = \textbf{0.019 m}^3\textbf{/min}$$

9.10 a. $$i = \frac{h}{H_2} = \frac{1.2}{2} = 0.6$$

$$q = kiA = (0.1)(0.6)(0.5 \times 100^2 \text{ cm}^2) = \textbf{300 cm}^3\textbf{/sec}$$

b. $i_{cr} = \dfrac{\gamma'}{\gamma} = \dfrac{G_s - 1}{1+e} = \dfrac{2.68-1}{1+0.55} = 1.08$

Since $i < i_{cr}$, **no boiling**.

c. $i = i_{cr} = \dfrac{h}{H_2}; \quad 1.08 = \dfrac{h}{2}$

$h$ = **2.16 m**

9.11 From Eq. (9.17), $FS = \dfrac{D\gamma'}{C_o \gamma_w (H_1 - H_2)}$

$D$ = 6 m; $\gamma'$ = 19 – 9.81 = 9.19 kN/m$^3$; $H_1 - H_2$ = 5.6 – 2.2 = 3.4 m;

$D/T$ = 6/10 = 0.6. From Table 9.1, $C_o$ = 0.339.

$$FS = \frac{(6)(9.19)}{(0.339)(9.81)(3.4)} = \mathbf{4.88}$$

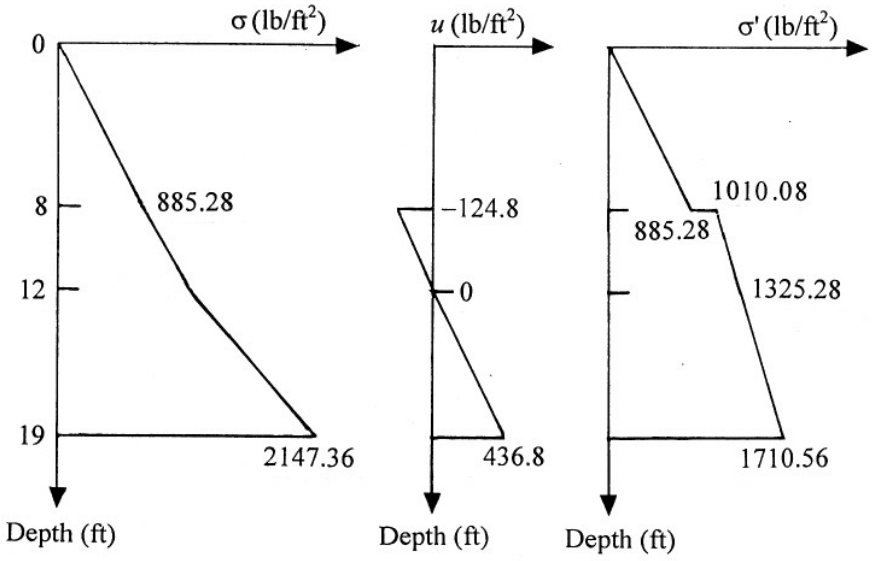
9.12 $\gamma_{d\,(\text{sand})} = \dfrac{G_s \gamma_w}{1+e} = \dfrac{(2.66)(62.4)}{1+0.5} = 110.66 \text{ lb/ft}^3$

$$\gamma_{\text{sat(sand)}} = \frac{\gamma_w (G_s + Se)}{1+e} = \frac{(62.4)[2.71 + (0.5)(0.75)]}{1+0.75} = 110 \text{ lb/ft}^3$$

$$\gamma_{\text{sat(clay)}} = \frac{\gamma_w (G_s + e)}{1+e} = \frac{(62.4)(2.72 + 0.95)}{1+0.95} = 117.44 \text{ lb/ft}^3$$

| | lb/ft$^2$ | | |
|---|---|---|---|
| Depth (ft) | $\sigma$ | $u$ | $\sigma'$ |
| 0 | **0** | **0** | **0** |
| 8 | (110.66)(8) = **885.28** | **0** | **885.28** |
| | | (–0.5)(62.4)(4) = **–124.8** | **1010.08** |
| 8 + 4 = 12 | 885.28 + (110)(4) = **1325.28** | **0** | **1325.28** |
| 12 + 7 = 19 | 1325.28 + (117.44)(7) = **2147.36** | (7)(62.4) = **436.8** | **1710.56** |

The plot is given below.




9.13 $$\gamma_{d\,(\text{sand})} = \frac{(2.66)(9.81)}{1+0.5} = 17.4\ \text{kN/m}^3$$

$$\gamma_{\text{sat(sand)}} = \frac{(9.81)[2.71+(0.65)(0.75)]}{1+0.75} = 17.92\ \text{kN/m}^3$$

$$\gamma_{\text{sat(clay)}} = \frac{(9.81)(2.72+0.95)}{1+0.95} = 18.46\ \text{kN/m}^3$$

| | kN/m² | | |
|---|---|---|---|
| Depth (m) | σ | $u$ | σ′ |
| 0 | **0** | **0** | **0** |
| 5 | (17.4)(5) = **87** | **0** | **87** |
| | | (–0.65)(9.81)(3) = **–19.13** | **106.13** |
| 5 + 3 = 8 | 87 + (17.92)(3) = **140.76** | **0** | **140.76** |
| 8 + 3.5 = 11.5 | 140.76 + (18.46)(3.5) = **205.37** | (3.5)(9.81) = **34.34** | **171.03** |

The plot is given.