Chapter 6

6.1 Eq. (6.4): $\gamma_{\text{zav}} = \dfrac{\gamma_w}{w + \dfrac{1}{G_s}} = \dfrac{62.4}{w + \dfrac{1}{2.75}} = \dfrac{62.4}{w + 0.3636}$.

The table can now be prepared.

w (%)	γ_{zav} (lb/ft^3)
5	**150.9**
8	**140.7**
10	**134.6**
12	**129.0**
15	**121.5**

6.2 $\gamma_{\text{zav}} = \dfrac{9.81}{w + \dfrac{1}{2.65}} = \dfrac{9.81}{w + 0.3773}$

w (%)	γ_{zav} (kN/m^3)
5	**23.15**
8	**21.45**
10	**20.55**
12	**19.73**
15	**18.60**

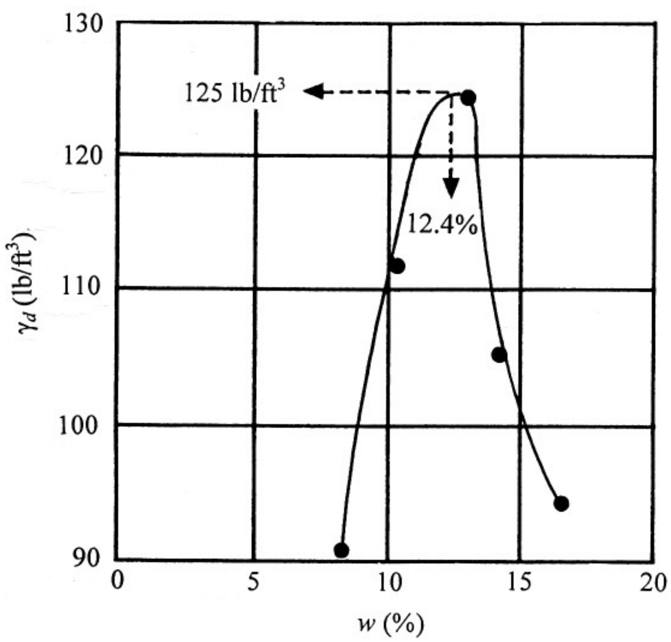
6.3 $\rho_d = \dfrac{G_s \rho_w}{1 + \dfrac{G_s w}{S}}$

			ρ_d @ S (kg/m^3)		
G_s	ρ_w (kg/m^3)	w (%)	80%	90%	100%
2.67	1000	10	**2002**	**2059**	**2107**
		20	**1601**	**1676**	**1741**

6.4

Volume (ft^3)	Weight of soil mass, W (lb)	$\gamma = \dfrac{W}{V}$ (lb/ft^3)	W (%)	$\gamma_d = \dfrac{\gamma}{1+\dfrac{w(\%)}{100}}$ (lb/ft^3)
$\frac{1}{30}$	3.26	97.8	8.4	90.2
$\frac{1}{30}$	4.15	124.5	10.2	113.0
$\frac{1}{30}$	4.67	140.1	12.3	124.8
$\frac{1}{30}$	4.02	120.6	14.3	105.5
$\frac{1}{30}$	3.63	108.9	16.8	93.2

The plot of γ_d versus w is shown. γ_d $\approx$ **125 lb/ft³ @ w = 12.4%**



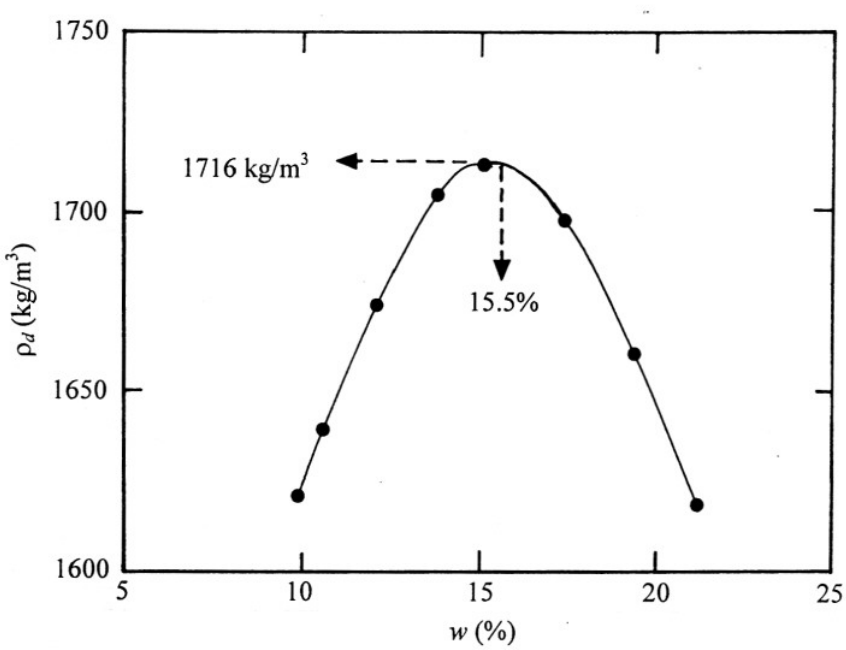
6.5 $\gamma_d = \dfrac{G_s\gamma_w}{1+e}$; $125 = \dfrac{(2.72)(62.4)}{1+e}$; $e \approx \mathbf{0.358}$

$$S = \frac{wG_s}{e} = \frac{(0.124)(2.72)}{0.358} = 0.94 = \mathbf{94\%}$$

6.6

Volume of mold V (cm^3)	Mass of wet soil M (kg)	$\rho = \frac{M}{V}$ (kg/m^3)	w (%)	ρ_d (kg/m^3)
943.3	1.68	1781.0	9.9	1620.6
943.3	1.71	1812.8	10.6	1639.1
943.3	1.77	1876.4	12.1	1673.9
943.3	1,83	1940.0	13.8	1704.7
943.3	1.86	1971.8	15.1	1713.1
943.3	1.88	1993.0	17.4	1697.6
943.3	1.87	1982.4	19.4	1660.3
943.3	1.85	1961.2	21.2	1618.2

The plot of ρ_d versus w is shown.



From the graph, $\rho_{d(\max)}$ = **1716 kg/m^3** and w_{opt} = **15.5%**.

6.7 $$\rho_d = \frac{\rho}{1+w} = \frac{1705}{1+\frac{10.5}{100}} = 1543\ \text{kg/m}^3$$

$$R = \frac{\gamma_d}{\gamma_{d(\max)}} = \frac{1543}{1716} = \mathbf{89.9\%}$$

6.8 $\gamma_{\text{(in situ)}}$ = 105 lb/ft^3; $\gamma_{d\,\text{(in situ)}} = \dfrac{105}{1+\dfrac{18}{100}} = 88.98\ \text{lb/ft}^3$; $\gamma_{d\text{(compacted)}}$ = 103.5 lb/ft^3

$$\text{Volume of soil to be excavated} = (10{,}000)\left(\frac{103.5}{88.98}\right) = \mathbf{11{,}632\ yd^3}$$

Weight of moist soil to be transported = $(11{,}632 \times 27)(105)$ lb

$$\text{Number of truck loads} = \frac{(11{,}632)(105)}{(20)(2000)} = 824.4 \approx \mathbf{825}$$

6.9 Dry unit weight of solids required

$$= 8000\gamma_d\ \text{kN} = (8000)\left(\frac{G_s \times 9.81}{1.7}\right) = 46{,}164.7G_s\ \text{kN}$$

Borrow pit	γ_d at borrow pit (kN/m^3)	Volume to be excavated from borrow pit = [$46{,}164.7G_s/\gamma_{d\text{(borrow pit)}}$]	Cost/m^3 (\$)	Total cost (\$)
A	$\dfrac{G_s \times 9.81}{1+0.82} = 5.39G_s$	8564.9 m^3	8	68,519.20
B	$\dfrac{G_s \times 9.81}{1+1.1} = 4.67G_s$	9885.4 m^3	5	49,427.00
C	$\dfrac{G_s \times 9.81}{1+0.9} = 5.16G_s$	8946.6 m^3	9	80,519.40
D	$\dfrac{G_s \times 9.81}{1+0.78} = 5.51G_s$	8378.3 m^3	12	100,539.60

Borrow Pit B

6.10 From Eq. (6.11): $D_r = \left[\dfrac{\gamma_{d\text{(field)}} - \gamma_{d\text{(min)}}}{\gamma_{d\text{(max)}} - \gamma_{d\text{(min)}}}\right]\left[\dfrac{\gamma_{d\text{(max)}}}{\gamma_{d\text{(field)}}}\right]$

$$0.78 = \left[\frac{\gamma_{d\text{(field)}} - 93}{104-93}\right]\left[\frac{104}{\gamma_{d\text{(field)}}}\right];\quad \gamma_{d\text{(field)}} = 101.35\ \text{lb/ft}^3$$

$$R\,(\%) = \frac{\gamma_{d\,(\text{field})}}{\gamma_{d\,(\max)}}(100) = \left(\frac{101.36}{104}\right)(100) = \mathbf{97.5\%}$$

6.11 $$D_r = \left[\frac{\rho_{d\,(\text{field})} - \rho_{d\,(\min)}}{\rho_{d\,(\max)} - \rho_{d\,(\min)}}\right]\left[\frac{\rho_{d\,(\max)}}{\rho_{d\,(\text{field})}}\right];\quad 0.7 = \left[\frac{\rho_{d\,(\text{field})} - 1510}{1682 - 1510}\right]\left[\frac{1682}{\rho_{d\,(\text{field})}}\right]$$

$\rho_{d(\text{field})}$ = **1626.4 kg/m³**

$$R(\%) = \frac{\rho_{d\,(\text{field})}}{\rho_{d\,(\max)}} \times 100 = \left(\frac{1626.4}{1682}\right)(100) = \mathbf{96.7\%}$$

6.12 a. $$R = 0.9 = \frac{\gamma_{d\,(\text{field})}}{\gamma_{d\,(\max)}} = \frac{\gamma_{d\,(\text{field})}}{108};\quad \gamma_{d\,(\text{field})} = \mathbf{97.2\ lb/ft^3}$$

b. $$D_r = D_r = \left[\frac{\gamma_{d\,(\text{field})} - \gamma_{d\,(\min)}}{\gamma_{d\,(\max)} - \gamma_{d\,(\min)}}\right]\left[\frac{\gamma_{d\,(\max)}}{\gamma_{d\,(\text{field})}}\right] = \left(\frac{97.2 - 93}{108 - 93}\right)\left(\frac{108}{97.2}\right) = 0.311 = \mathbf{31.1\%}$$

c. $\gamma = \gamma_d(1 + w) = (97.2)(1 + 0.12) =$ **108.86 lb/ft³**

6.13 In the field:

Sand used to fill the hole and cone: 5.99 kg – 2.81 kg = 3.18 kg

Sand used to fill the hole: 3.18 kg – 0.117 kg = 3.063 kg

Volume of the hole: $\dfrac{3.063\,\text{kg}}{1667\ \text{kg/m}^3} = 0.001837\ \text{m}^3$

Moist density of compacted soil: $\dfrac{3.331}{0.001837} = 1813.2\ \text{kg/m}^3$

$$\gamma = \frac{(1813.2)(9.81)}{1000} = 17.79\ \text{kN/m}^3$$

$$\gamma_d = \frac{\gamma}{1+\frac{w(\%)}{100}} = \frac{17.79}{1+\frac{11.6}{100}} = \mathbf{15.94\ kN/m^3}$$

6.14 $$S_N = (1.7)\sqrt{\frac{3}{(D_{50})^2}+\frac{1}{(D_{20})^2}+\frac{1}{(D_{10})^2}} = (1.7)\sqrt{\frac{3}{(1.3)^2}+\frac{1}{(0.19)^2}+\frac{1}{(0.11)^2}} = \mathbf{18}$$

Rating: **GOOD**

6.15 $$S_N = (1.7)\sqrt{\frac{3}{(0.61)^2}+\frac{1}{(0.25)^2}+\frac{1}{(0.09)^2}} = \mathbf{20.65}$$

Rating: **FAIR**