

**Carleton University**  
**CIVE 3208 (EART 4107): Geotechnical Mechanics**

**Assignment #1**

**Tutorial: Oct. 15, HS 1301, 1:00-2:30 PM**

**Due: October 17**

1. The following results were obtained from sieve analyses and Atterberg limits of three soils – A, B and C. Classify each of these soils according to the USCS. (15 marks)

Sieve No	Soil A (mass retained, g.)	Soil B (mass retained, g.)	Soil C (mass retained, g.)
4	0	0	0
10	20.2	48.2	15
20	25.7	19.6	98
40	40.4	60.3	90
100	18.1	37.2	182
200	27.2	22.1	109
Pan	68.2	--	6
LL	23%	Non-plastic	Non-plastic
PL	8%		

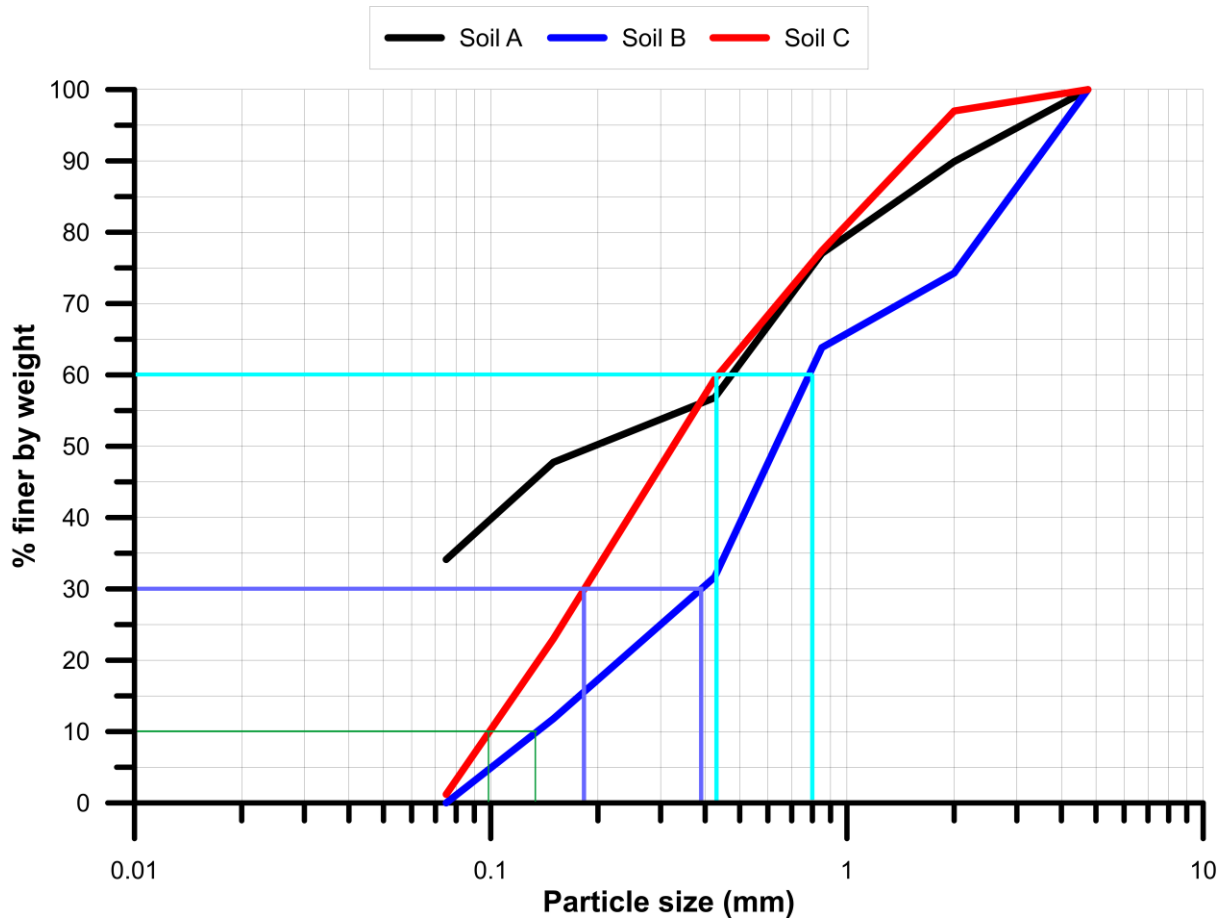
**Solution:**

Total mass A = 199.8 g.

Total mass B = 187.4 g

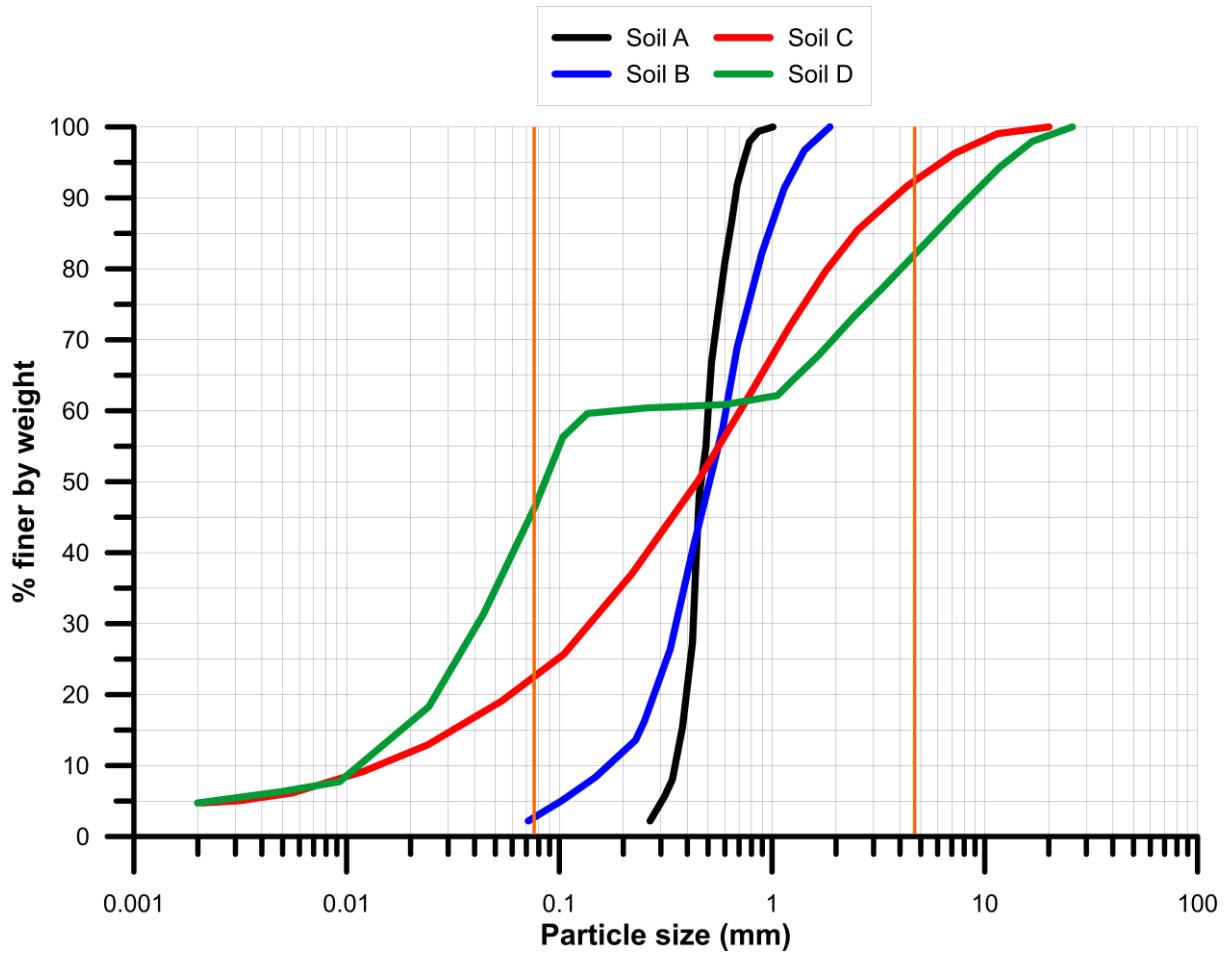
Total mass C = 500 g.

Sieve No	Opening (mm)	Soil A (% finer)	Soil B (% finer)	Soil C (% finer)
4	4.75	100.00	100.00	100.00
10	2.0	89.89	74.28	97.00
20	0.85	77.03	63.82	77.40
40	0.425	56.81	31.64	59.40
100	0.15	47.75	11.79	23.00
200	0.075	34.13	0.00	1.20
D <sub>10</sub>			~0.13 - ~0.14	0.1
D <sub>30</sub>			0.4	~0.18
D <sub>60</sub>			0.8	~0.42
Cu			6.15	4.2
Cc			1.54	0.77
		<b>SC</b>	<b>SW – SP</b> (depending on D <sub>10</sub> )	<b>SP</b>



2. For the given particle-size distribution curves;
  - a. Classify each soil based on Unified Classification System. (10 marks)

**Solution:**



	Soil A	Soil B	Soil C	Soil D
D <sub>10</sub>	~0.35 mm	~0.18 mm	~0.014	~0.011
D <sub>30</sub>	~0.43 mm	~0.35 mm	~0.15	~0.04
D <sub>60</sub>	~0.5 mm	~0.6 mm	0.7	~0.12
Cu	1.43	3.33	50	10.9
Cc	1.06	1.13	2.3	1.21
	<b>SP</b> Poorly-graded sand	<b>SP</b> Poorly-graded sand	<b>SM</b> Silty sand	<b>SM</b> Silty sand with gravel

3. In its natural condition a soil sample has a mass of 2290 g and a volume of  $1.15 \times 10^{-3} \text{ m}^3$ . After being completely dried in an oven the mass of this sample is 2035 g. The value of  $G_s$  for the soil is 2.65. Determine the bulk density, bulk unit weight, water content, void ratio, porosity, and degree of saturation. (10 marks)

**Solution:**

$$M_{bulk} = 2290 \text{ g.}$$

$$V_{bulk} = 1.15 \times 10^{-3} \text{ m}^3$$

$$M_s = 2035 \text{ g.}$$

$$G_s = 2.65$$

$$M_w = 255 \text{ g.} \rightarrow w = \frac{M_w}{M_s} = \frac{255}{2035} = 0.125 = 12.5\%$$

$$\rho_b = \frac{M_{bulk}}{V_{bulk}} = \frac{2.29 \text{ kg}}{1.15 \times 10^{-3} \text{ m}^3} = 1991.3 \text{ kg / m}^3$$

$$\gamma_{bulk} = \rho_b \gamma_w = 19.53 \text{ kN / m}^3$$

$$\gamma_{dry} = \frac{\gamma_{bulk}}{1+w} = \frac{19.53}{1+0.125} = 17.36 \text{ kN / m}^3 = \left( \frac{G_s}{1+e} \right) \gamma_w \rightarrow e = 0.498$$

$$n = \frac{e}{1+e} = 0.33$$

$$S = \frac{wG_s}{e} = \frac{0.125(2.65)}{0.498} = 0.665 = 66.5\%$$

4. Prove the following equations: (10 marks)

$$\gamma_d = \frac{G_s \gamma_w}{1+e}$$

$$S = \frac{wG_s(1-n)}{n}$$

**Solution:**

$$\gamma_{dry} = \frac{G_s}{1+e} \gamma_{water} = \frac{W_s}{V_t}$$

$$G_s = \frac{W_s}{V_s \gamma_w} = \left( \frac{\rho_s}{\rho_w} \right)$$

$$e = \frac{V_{void}}{V_s},$$

$$n = \frac{V_{void}}{V_t},$$

$$w = \frac{W_w}{W_s}, \quad S = \frac{V_w}{V_v}$$

$$V_t = V_s + V_v \rightarrow V_s = V_t - V_v$$

$$(a) \gamma_{dry} = \frac{W_s}{V_t} = \frac{G_s}{1+e} \gamma_{water} = \frac{\frac{W_s}{V_s \gamma_w}}{1 + \frac{V_{void}}{V_s}} \gamma_{water} = \frac{\frac{W_s}{V_s}}{\frac{V_s + V_{void}}{V_s}} = \frac{W_s}{V_t}$$

$$(b) S = \frac{wG_s(1-n)}{n} = \frac{V_w}{V_v} = \frac{\left( \frac{W_w}{W_s} \right) \left( \frac{\rho_s}{\rho_w} \right) \left( 1 - \frac{V_{void}}{V_t} \right)}{\frac{V_{void}}{V_t}} = \frac{\left( \frac{W_w}{W_s} \right) \left( \frac{W_s}{V_s} \frac{V_w}{W_w} \right) \left( \frac{V_t - V_{void}}{V_t} \right)}{\frac{V_{void}}{V_t}} = \frac{V_w (V_s)}{V_{void}} = \frac{V_w}{V_v}$$

5. A soil has been compacted in an embankment at a bulk density of  $2.15 \text{ Mg/m}^3$  and a water content of 12%. The value of  $G_s$  is 2.65.
- Calculate dry density, void ratio and degree of saturation. (10 marks)
  - Would it be possible to compact the above soil at a water content of 13% to a dry density of  $2.0 \text{ Mg/m}^3$ ? (5 marks)

**Solution:**

$$\rho_{bulk} = 2.15 \text{ Mg} / \text{m}^3 = 21.1 \text{ kN} / \text{m}^3$$

$$w = 0.12$$

$$G_s = 2.65$$

$$(a) \rho_{dry} = \frac{\rho_{bulk}}{1+e} = \frac{2.15}{1+0.12} = 1.92 \text{ Mg} / \text{m}^3 \rightarrow \gamma_d = 18.83 \text{ kN} / \text{m}^3$$

$$\gamma_{dry} = \frac{G_s}{1+e} \gamma_{water} \rightarrow \frac{18.83}{9.81} = \frac{2.65}{1+e} \rightarrow e = 0.38$$

$$S = \frac{wG_s}{e} = \frac{0.12(2.65)}{0.38} = 0.84 \rightarrow 84\%$$

$$(b) \text{ if } \gamma_{dry} = 2 \text{ Mg} / \text{m}^3 = 19.62 \text{ kN} / \text{m}^3 = \frac{2.65}{1+e} 9.81 \rightarrow e = 0.325$$

$$S = \frac{wG_s}{e} = \frac{0.13(2.65)}{0.325} = 1.06 \rightarrow NO, S \leq 1$$

6. If a granular soil is compacted to a bulk unit weight of  $20.45 \text{ kN/m}^3$  at a moisture content of 18%, what is the relative density of the compacted soil, given  $e_{max} = 0.85$ ,  $e_{min} = 0.42$ , and  $G_s = 2.65$ ? (5 marks)

What is the relative compaction? (5 marks)

**Solution:**

$$\gamma_{bulk} = 20.45 \text{ kN} / \text{m}^3$$

$$w = 0.18; e_{max} = 0.85; e_{min} = 0.42$$

$$G_s = 2.65$$

$$D_r = ?, e = ?$$

$$\gamma_{bulk} = \frac{G_s(1+w)\gamma_w}{1+e} = \frac{2.65(1+0.18)9.81}{1+e} = 20.45 \rightarrow e = 0.5$$

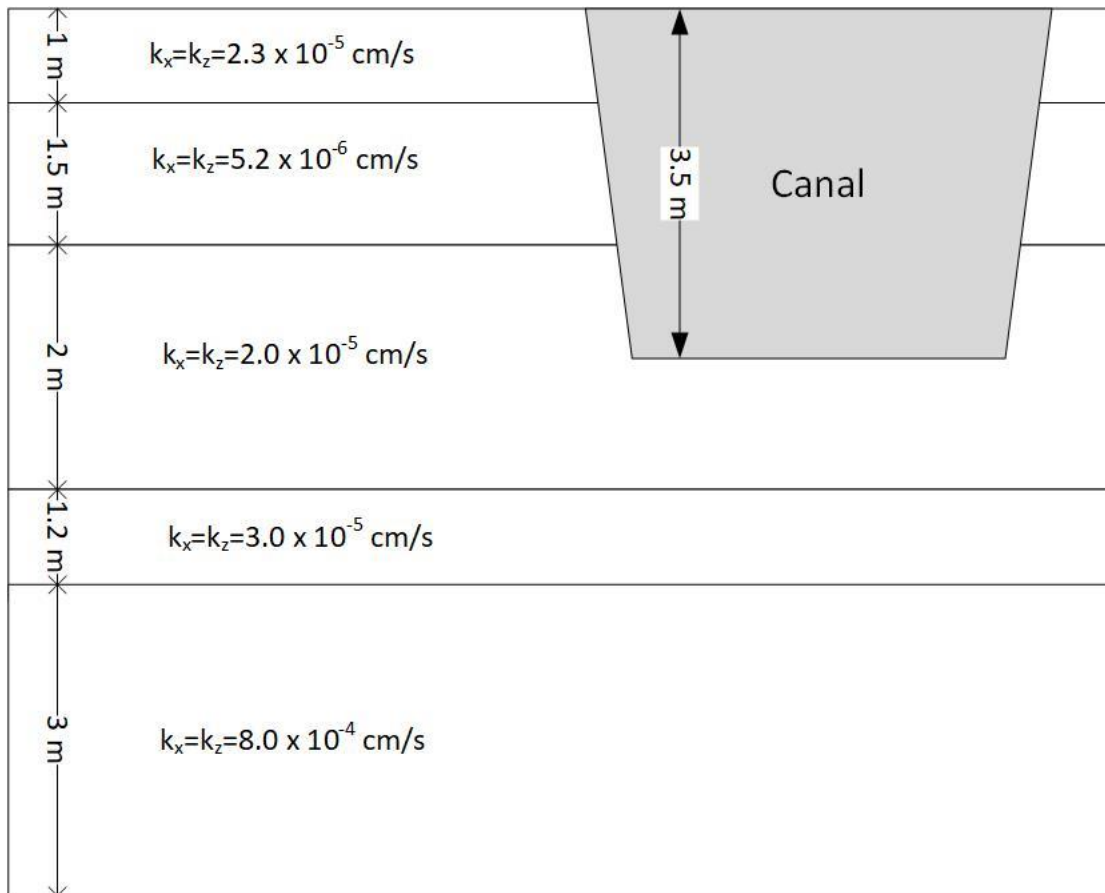
$$D_r = \frac{e_{max} - e}{e_{max} - e_{min}} = \frac{0.85 - 0.5}{0.85 - 0.42} = 0.814$$

$$\gamma_{dry} = \frac{20.45}{1+0.18} = 17.33 \text{ kN} / \text{m}^3$$

$$\gamma_{drymax} = \frac{G_s\gamma_w}{1+e_{min}} = \frac{2.65(9.81)}{1+0.42} = 18.3 \text{ kN} / \text{m}^3$$

$$R_c = \frac{\gamma_{dry}}{\gamma_{drymax}} = \frac{17.33}{18.3} = 94.7\%$$

7. A canal is cut into a soil with a stratigraphy shown in the figure. Calculate the ratio of the equivalent horizontal hydraulic conductivity to the equivalent vertical hydraulic conductivity for **flow through the sides of the canal**. (15 marks)



**Solution:**

$$k_{x-eq} = \frac{1}{H_0} (z_1 k_{x-1} + z_2 k_{x-2} + z_3 k_{x-3})$$

$$k_{z-eq} = \frac{H_0}{\left( \frac{z_1}{k_{z-1}} + \frac{z_2}{k_{z-2}} + \frac{z_3}{k_{z-3}} \right)}$$

$$H_0 = 3.5 \text{ m}; z_1 = 1 \text{ m} \ \& \ z_2 = 1.5 \text{ m} \ \& \ z_3 = 1 \text{ m}$$

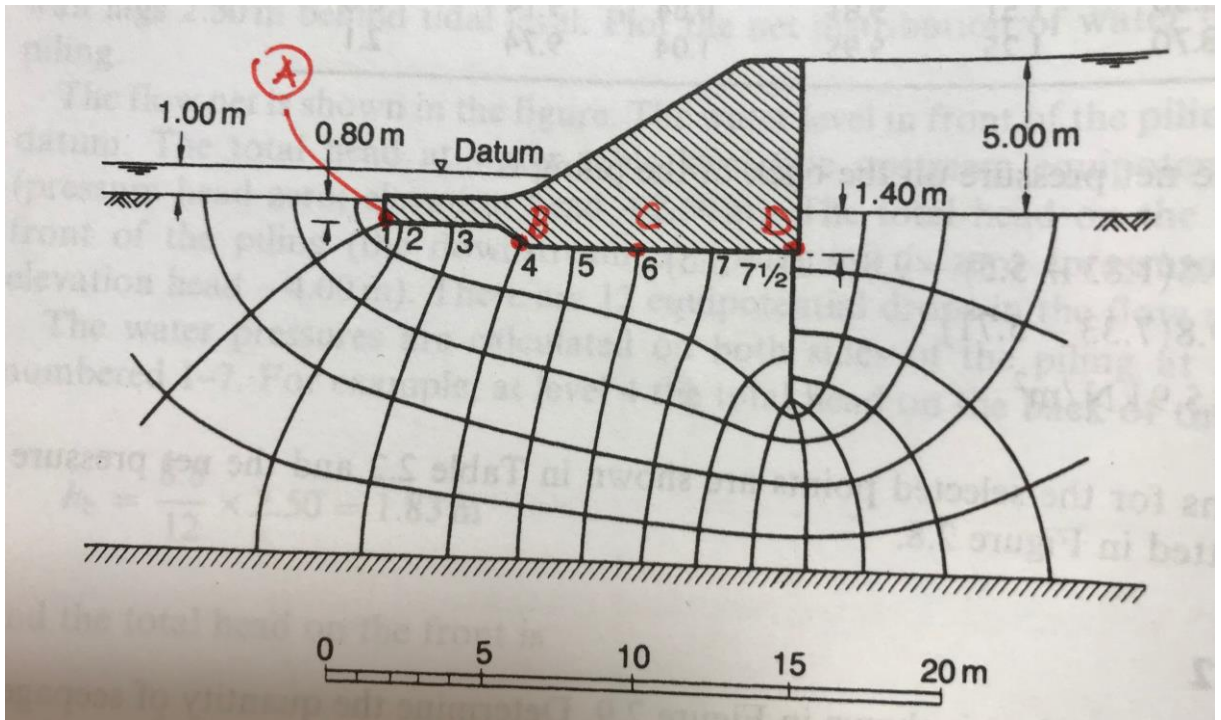
$$k_{x-eq} = \frac{1}{3.5} \left[ (1 \text{ m} \times 2.3 \times 10^{-5} \text{ cm/s}) + (1.5 \text{ m} \times 5.2 \times 10^{-6} \text{ cm/s}) + (1 \text{ m} \times 2.0 \times 10^{-5} \text{ cm/s}) \right]$$

$$k_{x-eq} = 1.45 \times 10^{-5} \text{ cm/s}$$

$$k_{z-eq} = \frac{3.5}{\left( \frac{1 \text{ m}}{2.3 \times 10^{-5} \text{ cm/s}} + \frac{1.5 \text{ m}}{5.2 \times 10^{-6} \text{ cm/s}} + \frac{1 \text{ m}}{2.0 \times 10^{-5} \text{ cm/s}} \right)} = 9.16 \times 10^{-6} \text{ cm/s}$$

$$\frac{k_{x-eq}}{k_{z-eq}} = \frac{1.45 \times 10^{-5} \text{ cm/s}}{9.16 \times 10^{-6} \text{ cm/s}} = 1.58$$

8. Determine the quantity of seepage under the dam and plot the distribution of uplift pressure at points A to D. The coefficient of permeability of the foundation soil is  $2.5 \times 10^{-5} \text{ m/s}$ . (15 marks)



Solution:

$\Delta H =$  total head loss = 4 m.

$\Delta h =$  head loss at each equipotential line

$\Delta h = \Delta H / N_d$

$N_d =$  equipotential lines = 15

$N_f =$  # of flow channels = 5

$\Delta h = \Delta H / N_d = 4 \text{ m} / 15 = 0.277$

$$(a) \quad q = k \Delta H \frac{N_f}{N_d} = (2.5 \times 10^{-5} \text{ m/s})(4 \text{ m}) \left( \frac{5}{15} \right) = 3.33 \times 10^{-5} \text{ m}^3 / \text{s}$$

$$h_t = \Delta H - (N_d \Delta h)$$

(b)

Point	$h_z$ Elevation head	$N_d$	$h_t$ total head	$h_p = h_t - h_z$	$U_p = h_p \gamma_w$ (kPa)
A	-1.8 m	14	$4 - 14 \times 0.27 = 0.27$	$0.27 - (-1.8) = 2.07$	$2.07 \times 9.81 = 20.3$
B	-2.4 m	11	$4 - 11 \times 0.267 = 1.1$	3.5	34.3
C	-2.4 m	9	$4 - 9 \times 0.267 = 1.6$	4	39.24
D	-2.4 m	7.5	$4 - 7.5 \times 0.267 = 2.67$	4.397	43.13