Assignment 1 - Solutions

(Due: 24 September, 2019 by 17:00)

Q1. The results from gradation (sieve and hydrometer) analysis and Atterberg limits determination on **six soils, A through F**, are summarized in the tables below.

For each soli:

a). Plot the grain-size distribution (GSD) curve. Use the provided excel file and show **all** soils' GSDs **on the same plot**.

b). Determine the effective size (*D_{10}*), *D_{30}* and *D_{60}* and calculate the uniformity coefficient and the coefficient of curvature.

c). Determine the percentages of **gravel, sand, fines, silt and clay** as per USCS.

d). Classify the soil by the USCS and provide both **the group symbol and the group name**.

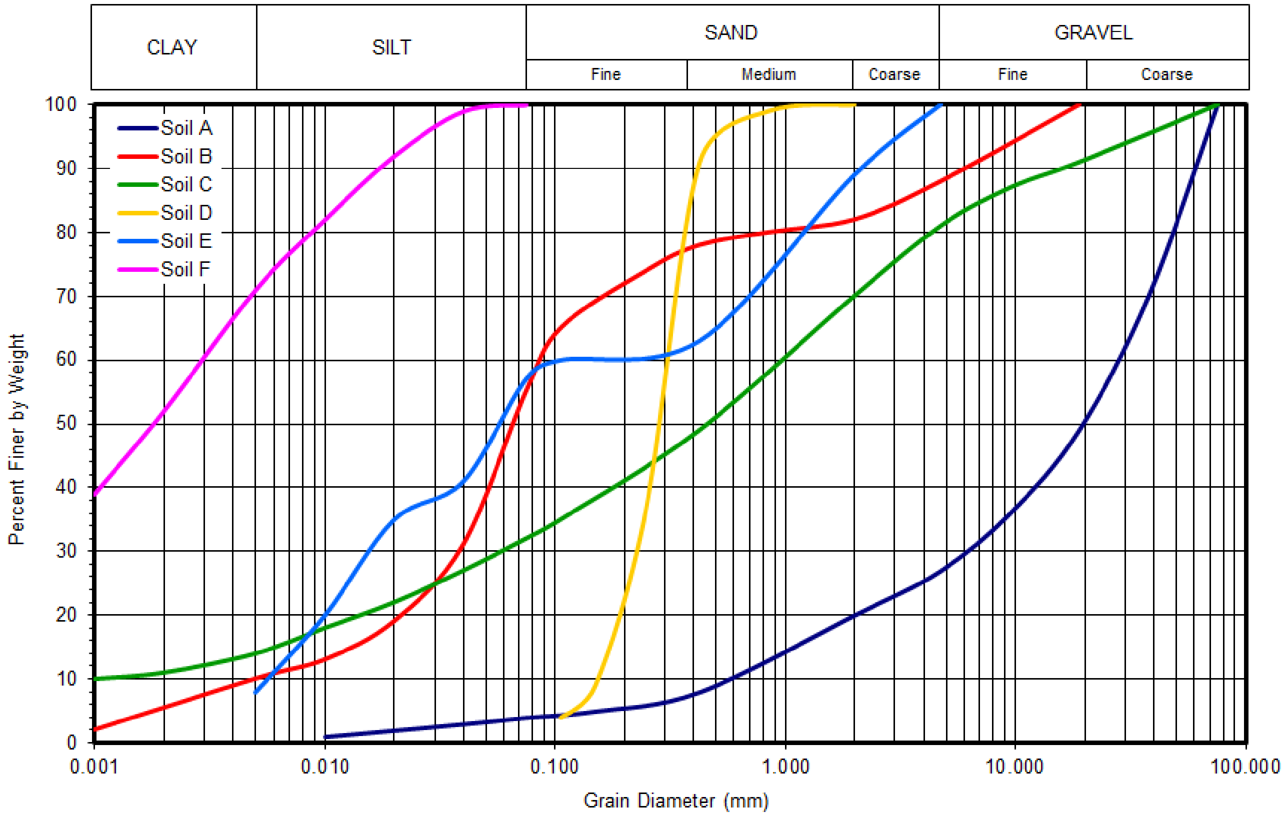
Sieve #	Percent passing by weight					
	Soil A	Soil B	Soil C	Soil D	Soil E	Soil F
3 in.	100	-	100	-	-	-
1 ½	70	-	-	-	-	-
¾	49	100	91	-	-	-
⅜	36	-	87	-	-	-
No. 4	27	88	81	-	100	-
No. 10.	20	82	70	100	89	-
No. 20	-	80	-	99	-	-
No. 40	8	78	49	91	63	-
No. 60	-	74	-	37	-	-
No. 100	5	-	-	9	-	-
No. 140	-	65	35	4	60	-
No. 200	4	55	32	-	57	100
40 μm	3	31	27	-	41	99
20 μm	2	19	22	-	35	92
10 μm	1	13	18	-	20	82
5 μm	-	10	14	-	8	71
2 μm	-	-	11	-	-	52
1 μm	-	2	10	-	-	39

Note: Missing data is indicated by a dash in the column.

Property	Soil A	Soil B	Soil C	Soil D	Soil E	Soil F
w_n (%)	27	14	14	11	8	72
LL	13	35	35	--	28	60
PL	8	29	18	NP	NP	28

Solution:

a) The GSD curves for the six soils A through F are summarized in the figure:



b) Determination of the effective size (D_{10}), D_{30} and D_{60} and the uniformity coefficient and the coefficient of curvature:

Soil #	Effective Size, D_{10}	D_{30}	D_{60}	C_u	C_c
	(mm)	(mm)	(mm)	(-)	(-)
A	0.600	6.000	28.000	46.667	2.143
B	0.005	0.039	0.087	17.400	3.497
C	0.001	0.060	0.980	980.000	3.673
D	0.160	0.210	0.300	1.875	0.919
E	0.006	0.014	0.106	18.276	0.319
F	-	-	0.003	-	-

$$C_U = \frac{D_{60}}{D_{10}}$$

$$C_c = \frac{D_{30}^2}{D_{10} D_{60}}$$

c) Determination of the percentages of gravel, sand, fines, silt and clay as per USCS:

Soil	Gravel (%)	Sand (%)	Fines (silt + clay)	Silt (%)	Clay (%)
A	73	23	4	4	0
B	12	33	55	45	10
C	19	49	32	18	14
D	0	100	0	0	0
E	0	43	57	49	8
F	0	0	100	29	71

d) Classification of the soils by the USCS:

Property	Soil A	Soil B	Soil C	Soil D	Soil E	Soil F
w_n (%)	27	14	14	11	8	72
LL	13	35	35	--	28	60
PL	8	29	18	NP	NP	28
PI	5	6	17	0	0	32

Soil A: GW Well-graded gravel with sand

Soil B: ML Sandy silt

Soil C: SC Clayey sand with gravel

Soil D: SP Poorly graded sand

Soil E: ML Sandy silt

Soil F: CH Fat clay

Q2. The following data were obtained from a **liquid-limit test** on a silty clay:

No of blows	Water content, %
35	41.1
29	41.8
21	43.5
15	44.9

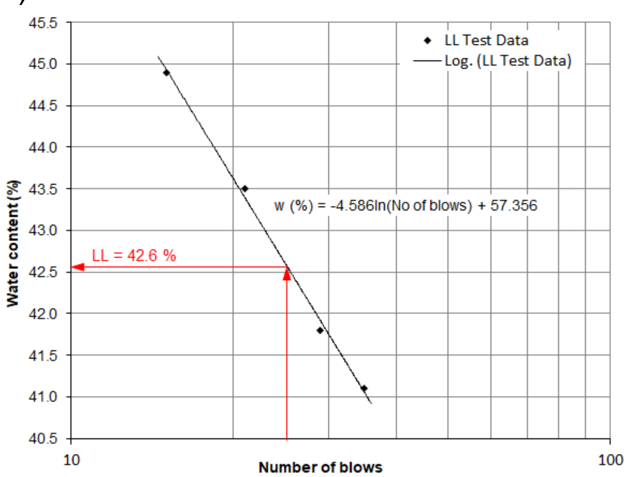
Two plastic-limit determinations had water contents of 23.1% and 23.6%. Determine the **LL, PI, the flow index, and the toughness index**.

Hint: the flow index is the slope of the water content versus log of number of blows in the liquid-limit test, and the toughness index is the PI divided by the flow index.

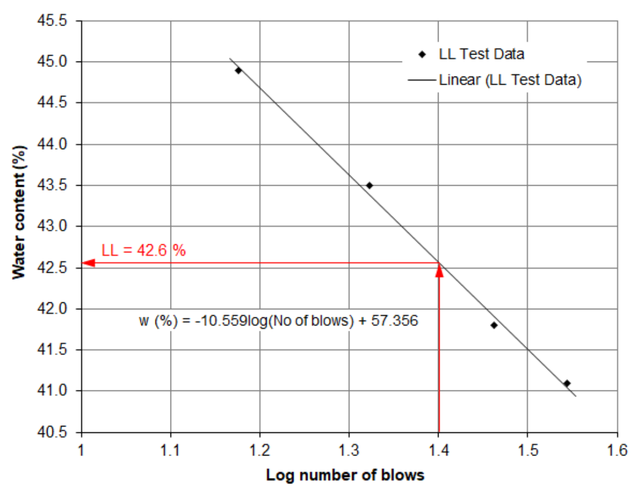
Solution:

The figure below shows two ways of plotting the data and obtaining the flow line and the LL: a) test data is plotted on a logarithmic horizontal scale and arithmetic vertical scale (Note that Excel fits a **ln** instead of **log** trend line); b) test data is plotted on arithmetic horizontal and vertical scales but Log of number of blows instead of Number of blows is plotted on the horizontal scale.

a)



b)



Both plots show LL = 42.6%.

The flow index is easily obtained from b) and the regression line equation as I_F = 10.6.

As there are two test results for the PL, take the average value as:

PL = (23.1+23.6)/2 = 23.4%

PI = LL – PL = 42.6 – 23.4 = 19.2

Toughness index = PI/ I_F = 19.2/10.6 = 1.81

Q3. A cylinder contains 510 cm^3 of **loose dry sand** which weighs 740 g. Under a static load of 200 kPa the volume of the sand is reduced **by 1%**, and then by vibration it is further reduced **by 10% of the original volume**. Assume the solid density of the sand grains is 2.65 Mg/m^3. Calculate the **void ratio, porosity, dry density, and total (bulk) density** corresponding to each of the following cases:

a). Loose sand;

b). Sand under static load;

c). Vibrated and loaded sand.

Solution:

$$V_s = \frac{M_s}{\rho_s} = \frac{740}{2.65} = 279.25 \text{ cm}^3$$

Note: $\rho_s = 2.65 \text{ Mg/m}^3 = 2.65 \text{ g/cm}^3$

Dry sand => $V_w = M_w = 0$

a) Loose sand

$V_t = 510 \text{ cm}^3$

$V_v = V_t - V_s = 510 - 279.25 = 230.75 \text{ cm}^3$

$$e = \frac{V_v}{V_s} = \frac{230.75}{279.25} = \underline{0.826}$$

$$n = \frac{V_v}{V_t} \times 100\% = \frac{230.75}{510} \times 100\% = \underline{45.2\%}$$

$$\rho_{dry} = \frac{M_s}{V_t} = \frac{740}{510} = 1.45 \text{ g/cm}^3 = \underline{1.45 \text{ Mg/m}^3}$$

$\rho_{dry} = \rho_{total} = \underline{1.45 \text{ Mg/m}^3}$

b) Sand under static load

$$V_t = \frac{510}{1.01} = 504.95 \text{ cm}^3$$

$V_v = V_t - V_s = 504.95 - 279.25 = 225.70 \text{ cm}^3$

$$e = \frac{V_v}{V_s} = \frac{225.70}{279.25} = \underline{0.808}$$

$$n = \frac{V_v}{V_t} \times 100\% = \frac{225.70}{504.95} \times 100\% = \underline{44.7\%}$$

$\rho_{dry} = \frac{M_s}{V_t} = \frac{740}{504.95} = 1.47\ g/cm^3 = \underline{1.47\ Mg/m^3}$

$\rho_{dry} = \rho_t = \underline{1.47\ Mg/m^3}$

c) Vibrated and loaded sand

$V_t = \frac{510}{1.10} = 463.64\ cm^3$

$V_v = V_t - V_s = 463.64 - 279.25 = 184.39\ cm^3$

$e = \frac{V_v}{V_s} = \frac{184.39}{279.25} = \underline{0.660}$

$n = \frac{V_v}{V_t} \times 100\% = \frac{184.39}{463.64} \times 100\% = \underline{39.8\%}$

$\rho_{dry} = \frac{M_s}{V_t} = \frac{740}{463.64} = 1.60\ g/cm^3 = \underline{1.60\ Mg/m^3}$

$\rho_t = \rho_{dry} = \underline{1.60\ Mg/m^3}$

Q4. Three compaction tests at varying compaction energy levels have been performed and the results are summarized in the table below. Assume the solid density of the soil grains is 2.68 Mg/m^3 and:

a). Plot the **compaction curves** (dry unit weight vs. water content) for the three tests;

b). Determine the **maximum dry unit weight and optimum water content** for **each test;**

c). Calculate the degree of saturation at the optimum point for the **Modified Proctor** test;

d). Plot the **100% saturation** (zero air voids curve). Also plot the **70%, 80%, and 90% saturation** curves.

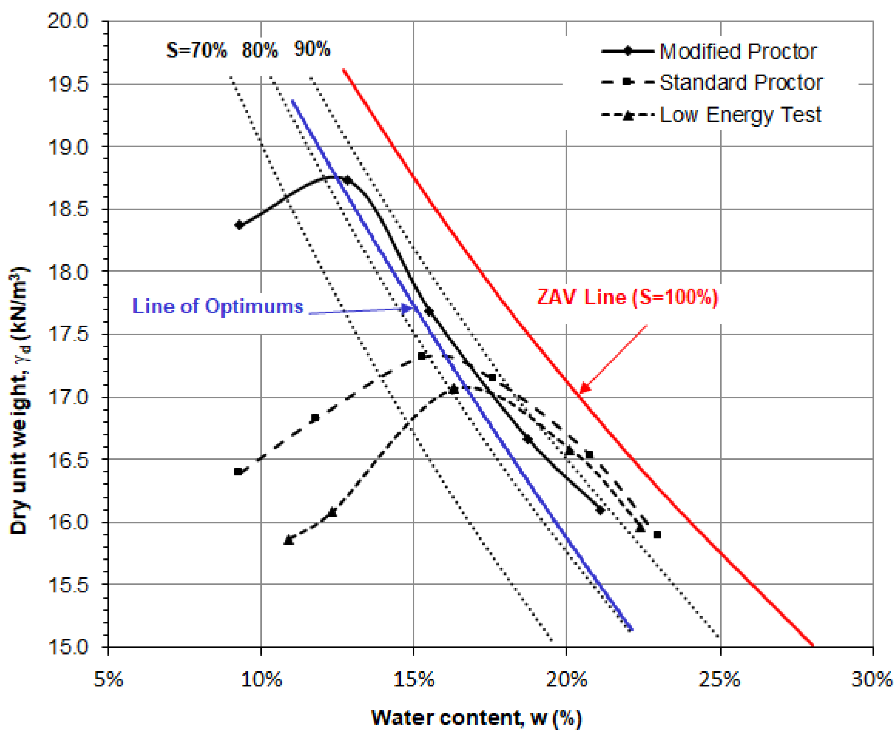
e). Plot the **line of optimums**.

All required curves should be presented on the same plot!

Test A (Modified Proctor)		Test B (Standard Proctor)		Test C (Low Energy Test)	
ρ_d (Mg/m^3)	w (%)	ρ_d (Mg/m^3)	w (%)	ρ_d (Mg/m^3)	w (%)
1.873	9.3%	1.671	9.3%	1.617	10.9%
1.910	12.8%	1.715	11.8%	1.639	12.3%
1.803	15.5%	1.765	15.3%	1.740	16.3%
1.699	18.7%	1.747	17.6%	1.690	20.1%
1.641	21.1%	1.685	20.8%	1.627	22.4%
		1.619	23.0%		

Solution:

a) See Plot below:



b)

	Test A (Modified Proctor)	Test B (Standard Proctor)	Test C (Low Energy Test)
w (%)	12.5%	15.1%	17.1%
γ_d (kN/m^3)	18.75	17.34	17.10

c)

$$\gamma_d = \frac{G_s \gamma_w}{1 + \left(\frac{wG_s}{S} \right)}$$

$$18.75 = \frac{(2.68 * 9.81)}{1 + \left(\frac{0.125 * 2.68}{S} \right)} \rightarrow S = 0.832 = 83.2\%$$

d)

Use $\gamma_d = \frac{G_s \gamma_w}{1 + \left(\frac{wG_s}{S} \right)}$ to plot the 70%, 80% and 90% saturation.

Use $\gamma_d = \frac{G_s \gamma_w}{1 + wG_s}$ to plot the zero air voids curve.

e) Line of optimums connects the optimum points of all compaction curves.