PRACTICAL COURSE – III CLASSIFICATION & COMPACTION

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REMINDER

GROUP INDEX

- $GI = (F_{200}-35)[0.2 + 0.005\ (LL-40)]+0.01(F_{200}-15)(PI-10)$

FOR GROUP A-2-6 and A-2-7

- $GI = 0.01(F_{200}-15)(PI-10)$

F200 = percentage passing through the No.200 sieve

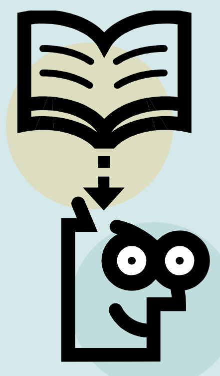
REMINDER

SOME EXPLANATIONS OF GROUP INDEX GI

1. If equation gives a negative value then **GI=0**;
2. Round up the value calculated by equation to an integer;

(for example; GI= 9.8 then GI≌ 9)

3. The GIs for soil groups **A-1-a, A-1-b, A-2-4, A-2-5** and **A-3** are always zero (0).



QUESTION 1

- Classify these soils according to AASHTO criteria.

SIEVE	SIZE	PERCENT PASSING				
		A	B	C	D	E
No.4	4.76	94	98	100	100	100
No.10	2	63	86	100	100	100
No.20	0.85	21	64	98	100	100
No.40	0.425	10	54	93	99	94
No.60	0.25	7	42	88	95	82
No.100	0.15	5	37	83	90	66
No.200	0.075	3	6	77	86	45
0.01 mm	0.01	-	-	65	42	26
0.002 mm	0.002	-	-	60	47	21
Liquid Limit	-	-	-	63	55	36
Plasticity index	-	NP	NP	25	28	22

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		A	B	C	D	E
No.4	4.76	94	98	100	100	100
No.10	2	63	86	100	100	100
No.20	0.85	21	64	98	100	100
No.40	0.425	10	54	93	99	94
No.60	0.25	7	42	88	95	82
No.100	0.15	5	37	83	90	66
No.200	0.075	3	6	63	86	45
0.01 mm	0.01	-	-	65	42	26
0.002 mm	0.002	-	-	60	47	21
Liquid Limit	-	-	-	63	55	36
Plasticity index	-	NP	NP	25	28	22

Table 1. AASHTO Soil Classification System

SML Fort Worth	Soil Mechanics							AASHTO Classification System			
	Granular Materials (35% or less passing No. 200)							Silt-Clay Materials (More than 35% passing No. 200)			
	Group A-1		Group	Group A-2				Group	Group	Group	Group A-7
	A-1-a	A-1-b	A-3	A-2-4	A-2-5	A-2-6**	A-2-7**	A-4	A-5	A-6	(A-7-5, A-7-6)
<u>Sieve Analysis</u> Percent Passing No. 10 . . . . No. 40 . . . . No. 200	50 max 30 max 15 max	- 50 max 25 max	- 51 min 10 max	- - 35 max	- - 35 max	- - 35 max	- - 35 max	- - 36 min	- - 36 min	- - 36 min	- - 36 min
Characteristics of fraction passing No. 40: Liquid limit . . . . . Plasticity index . . .	- 6 max		- N.P.	40 max 10 max	41 min 10 max	40 max 11 min	41 min 11 min	40 max 10 max	41 min 10 max	40 max 11 min	41 min *11 min
Usual types of significant constituent materials	Stone Fragments gravel and sand		Fine sand	Silty or clayey gravel and sand				Silty Soils		Clayey soils	
General rating as subgrade.	Excellent to good					Fair to poor					

Group Index (GI) = (F-35) [0.2 + 0.005 (LL - 40)] + 0.01 (F-15) (PI-10)
Where: F = percentage passing a No. 200 sieve,
LL = Liquid Limit, and
PI = Plasticity Index

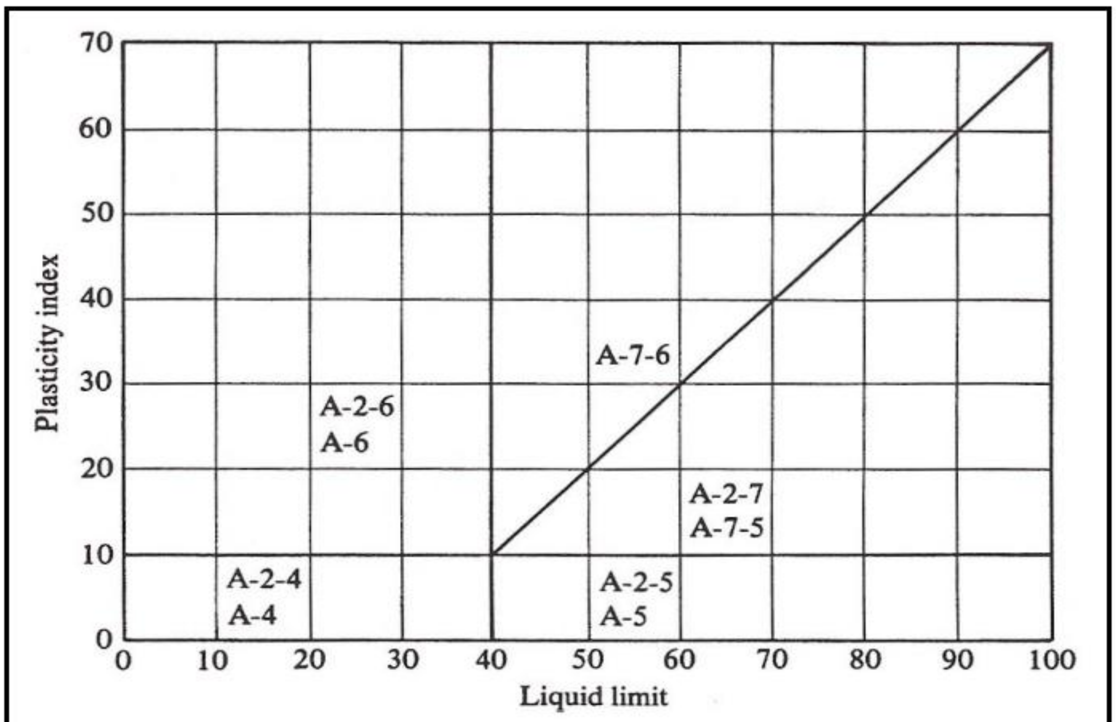
Group index should be shown in parentheses after group symbol, as: A-2-6(3), A-4(5), A-6(12), A-7-5(17), etc.
When the combined Group Indices are negative, the Group Index should be reported as zero.

* Plasticity index of A-7-5 subgroup is equal to or less than (LL-30). Plasticity index of A-7-6 subgroup is greater than (LL - 30).

** When working with A-2-6 and A-2-7 subgroups the Partial Group Index (PGI) is determined from the PI portion only.

	SOIL				
	A	**B**	**C**	**D**	**E**
Soil Class	A-1-b	A-3	A-7-5	A-7-6	A-6
Group Index	0	0	16	23	5
Liquid Limit	-	-	63	55	36
Plasticity Index	NP	NP	25	28	22

Table 2. Range of LL and PI for Soils in Groups A-2 through A-7



C	**D**	**E**
A-7-5	A-7-6	A-6
16	23	5
63	55	36
25	28	22

RELATIVE DENSITY

REMINDER

- The relative density (D_r) is used to characterize the density of natural granular soil.

$$D_r = \frac{e_{max} - e}{e_{max} - e_{min}} \times 100\%$$

$$= \frac{\gamma_{dmax}}{\gamma_d} \times \frac{\gamma_d - \gamma_{dmin}}{\gamma_{dmax} - \gamma_{dmin}} \times 100\%$$

Relative Density (%)	Descriptive Term
0-15	Very loose
15-35	Loose
35-65	Medium
60-85	Dense
85-100	Very dense

QUESTION 2

In laboratory, the weight, volume and specific gravity of an undisturbed fine sand is weighed as 3.63 kg., 0.00198 m^3 and 2.70, respectively. Afterwards, tests are employed to find the extreme void ratios of this soil, as a result, the maximum and minimum void ratio of this soil is determined as 0.35 and 0.95. Simply determine the relative density and the dry unit weight of the soil.

Determination of the void ratio of undisturbed soil:

$$V_s = \frac{M_s}{G_s \rho_w} = \frac{3.63\ kg}{2.70 \times 10^3\ kg/m^3} = 0.00134\ m^3$$

$$V_V = V_T - V_S = 0.00198\ m^3 - 0.00134\ m^3 = 0.00064\ m^3$$

$$e_0 = \frac{V_V}{V_s} = \frac{0.00064\ m^3}{0.00134\ m^3} = 0.475$$

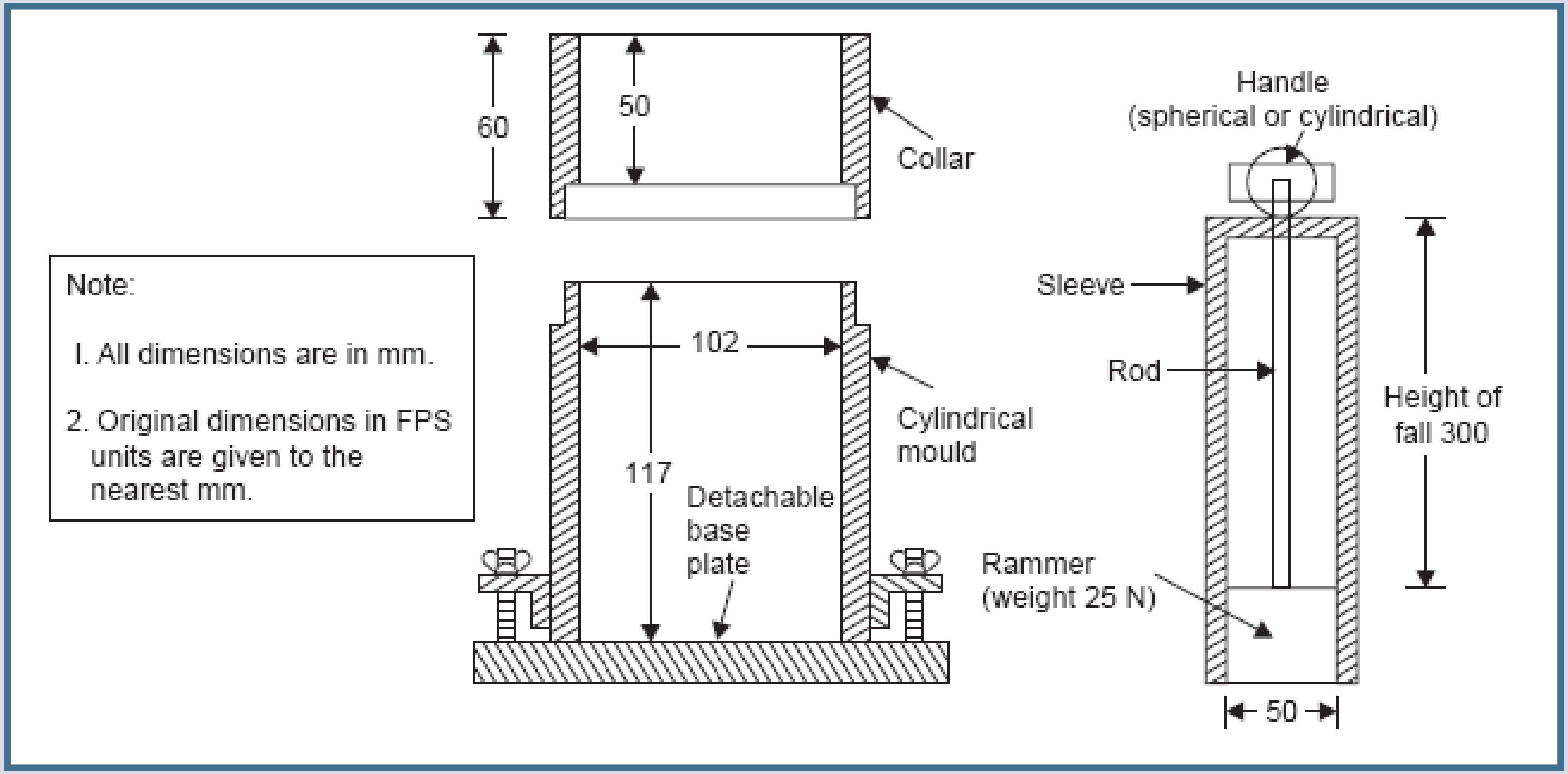
$$D_r = \frac{e_{max} - e_0}{e_{max} - e_{min}} = \frac{0.95 - 0.475}{0.95 - 0.35} \times 100\ \% = 79\ \%$$

$$\gamma_d = \frac{M_s}{V_T} = \frac{3.63\ kg}{0.00198\ m^3} = 1.83\ t/m^3$$

STANDARD PROCTOR TEST

REMINDER

In Standard Proctor Test, soil is compacted by giving 25 blows to three levels using a metal rammer of 2.5 kg., falling from 30 cm. height. Performance of the test in 3 or 4 water contents lead to a knowledge of various water contents and dry unit weights.



REMINDER

Ege University
Engineering Faculty
Civil Engineering Department
Soil Mechanics Laboratory

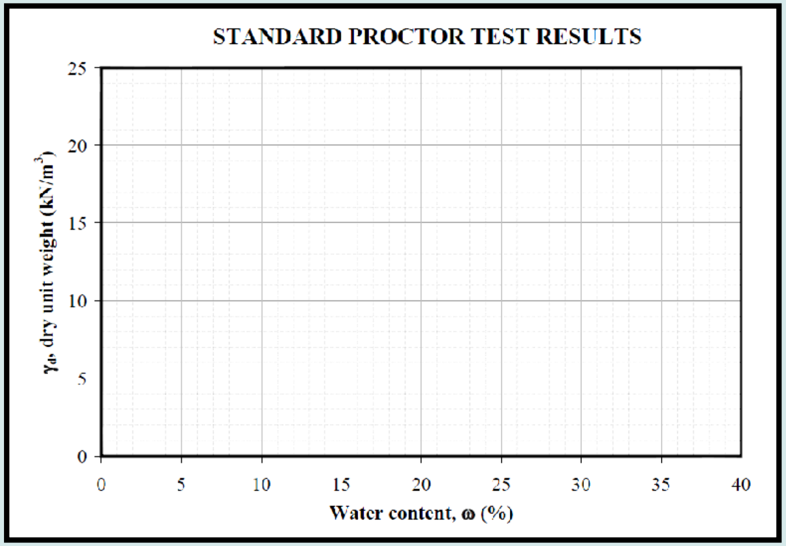
Job Name :
Boring No:
Sample No :
Depth :
Date :
Tested By :

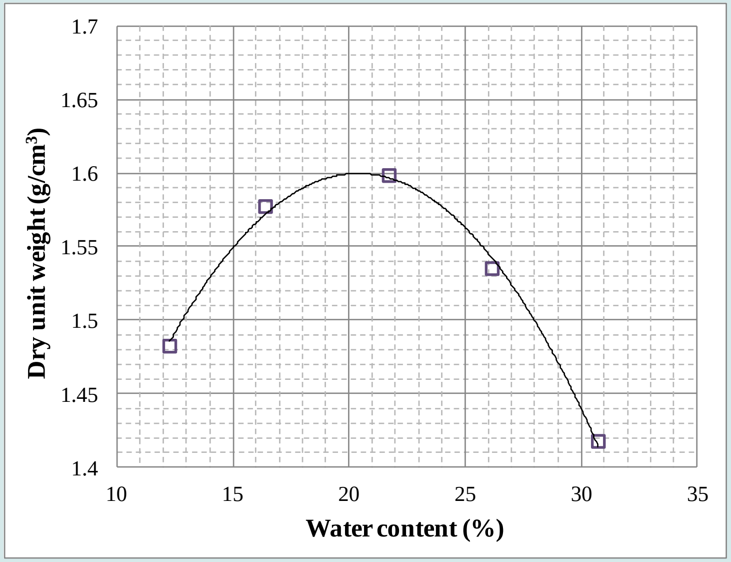
	STANDARD PROCTOR TEST				
Determination of dry unit weight					
Test Number	1	2	3	4	5
Weight of wet soil+compaction mould(g)					
Weight of compaction mould (g)					
Weight of wet soil (g)					
Natural unit weight of soil(gr/cm^3)					
Dry unit weight of soil (gr/cm^3)					
Void ratio					
Determination of water content					
	SPECIMEN FROM THE LOWER PART				
Test no	1	2	3	4	5
Weight of wet soil+container(g)					
Weight of dry soil+container(g)					
Weight of water (g)					
Weight of container(g)					
Weight of dry soil(g)					
Water content, ω(%)					
	SPECIMEN FROM THE MIDDLE PART				
Test no	1	2	3	4	5
Weight of wet soil+container(g) Weight of dry soil+container(g) Weight of water (g)					
Weight of container(g)					
Weight of dry soil(g)					
Water content, ω(%)					
	SPECIMEN FROM THE UPPER PART				
Test no	1	2	3	4	5
Weight of wet soil+container(g)					
Weight of dry soil+container(g)					
Weight of water (g)					
Weight of container(g)					
Weight of dry soil(g)					
Water content, ω(%)					

AVERAGE WATER CONTENT VALUES

1	2	3	4	5

Determination of zero air voids (saturation) curve					
Calculation	1	2	3	4	5
Saturation level, S (%)	100	100	100	100	100
Water content, ω(%)					
Dry unit weight (g/cm^3)					





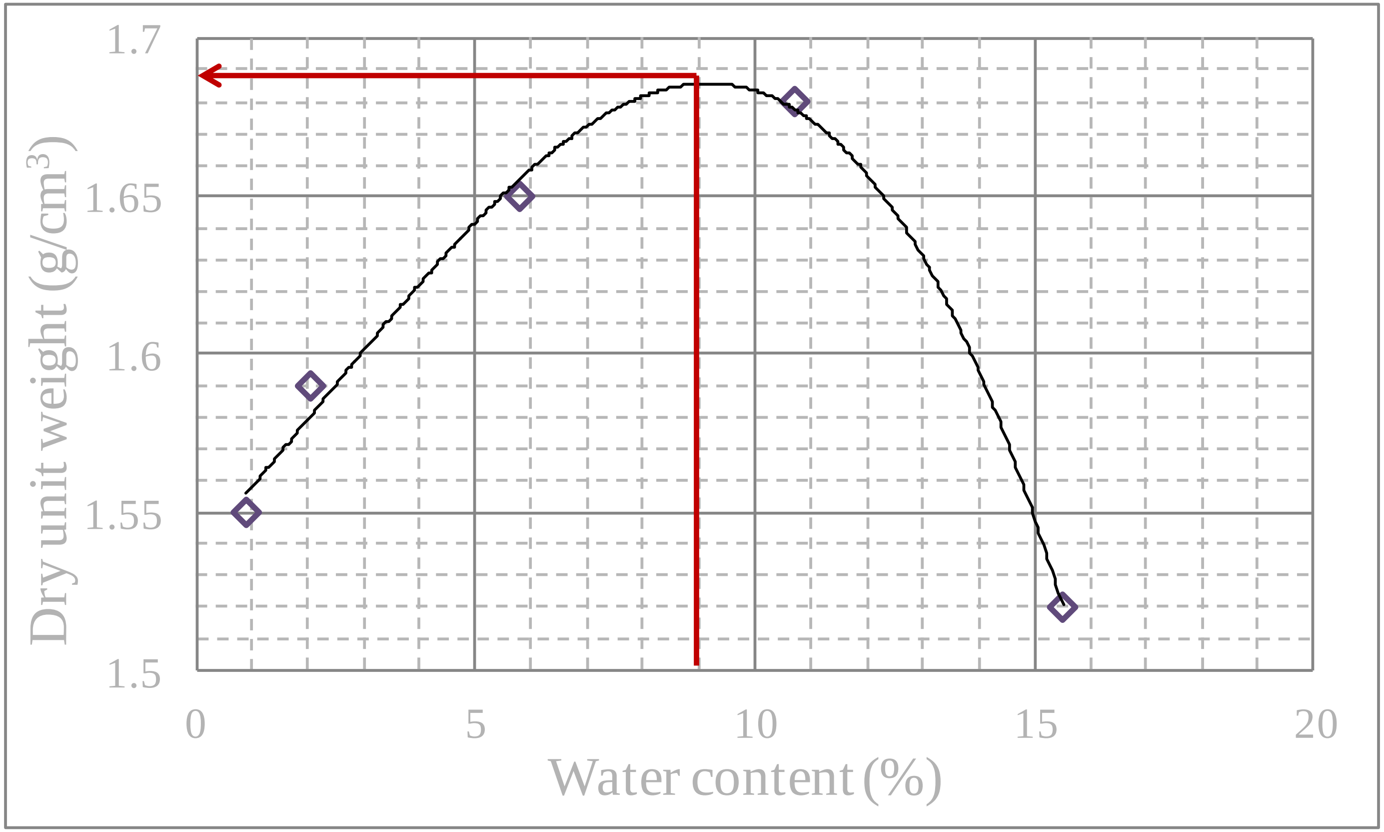
QUESTION 3

- Standard Proctor test results on a medium sand is given below. Determine the optimum moisture content and maximum dry unit weight of soil. Specific gravity of soil is 2.68.

Test Number	**1**	**2**	**3**	**4**	**5**
Weight of wet soil + compaction mold (g)	5052.5	5094.9	5206.4	5316.8	5216.1
Weight of compaction mold (g)	3560	3560	3560	3560	3560
Weight of wet soil (g)	1492.5	1534.9	1646.4	1756.8	1656.1
Water Content	0.17	2.05	5.79	10.71	15.50

Test Number	**1**	**2**	**3**	**4**	**5**
Weight of wet soil + compaction mold (g)	5052.5	5094.9	5206.4	5316.8	5216.1
Weight of compaction mold (g)	3560	3560	3560	3560	3560
Weight of wet soil (g)	1472.5	1534.9	1646.4	1756.8	1656.1
Natural unit weight of soil (g/cm^3)	1.56	1.63	1.74	1.86	1.75
Water Content (%)	0.9	2.05	5.79	10.71	15.50
Dry unit weight of soil (g/cm^3)	1.55	1.59	1.65	1.68	1.52

$$\gamma_d = \frac{\gamma_n}{1 + w}$$



Maksimum dry unit weight (g/cm^3)	1.69
Optimum water content (%)	9

QUESTION 4

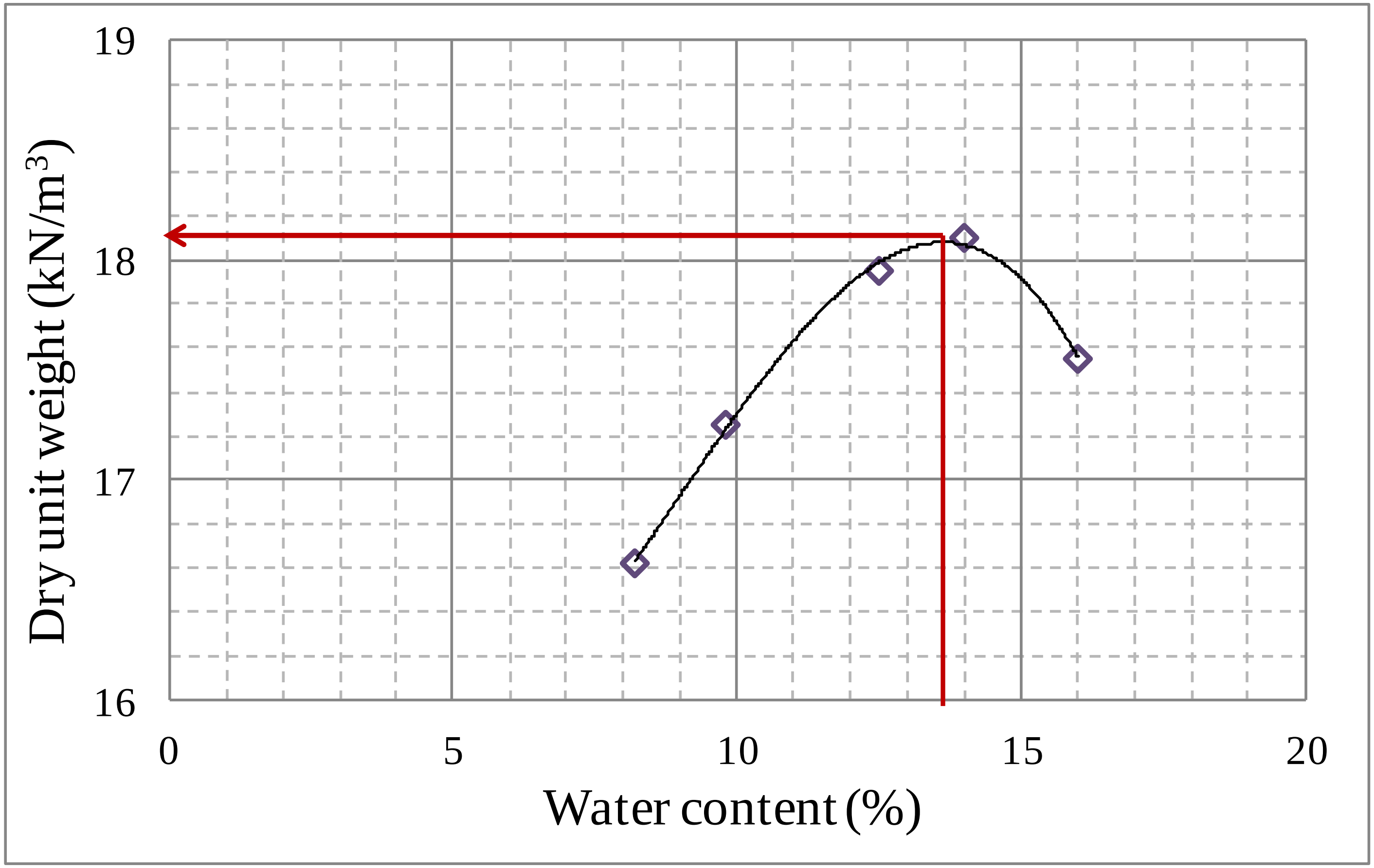
- A landfill will be constructed using a sandy silt. The natural void ratio and specific gravity of the material in the borrow area are determined as 0.95 and 2.70 respectively. The results of Standard Proctor test conducted on this soil is given below.

a) Draw the compaction curve and determine the maximum dry unit weight & optimum moisture content values.
b) Calculate the saturation level of the compacted soil in optimum moisture content.

c) The Proctor tests on the soil obtained from the borrow area revealed that water content and wet unit weight of the compacted soil are determined as 12 % and 19.60 kN/m^3, respectively. Regarding to this knowledge, simply determine if the 95 % relative compaction level condition is satisfied or not.

d) Determine the possible volume of landfill that can be constructed, by use of the excavated 30000 m^3 soil from the borrow area.

γd (kN/m^3)	16.62	17.25	17.95	18.10	17.55
W (%)	8.20	9.80	12.50	14.00	16.00



Maksimum dry unit weight (kN/m^3)	18.10
Optimum water content (%)	13.7

b) Saturation level of the compacted soil;

$$e = \frac{2.70 \times 9.81}{18.10} - 1 = 0.463, S = \frac{G_s w}{e} = \frac{0.137 \times 2.7}{0.463} = 0.8 \quad or \quad \%80$$

c) e= 12% , γ_n=19.6 kN/m^3

$$\gamma_d = \frac{\gamma_n}{1+\omega} = \frac{19.6}{1+0.12} = 17.5\, kN/m^3$$

$$\text{Relative compaction} = \frac{\gamma_{d,field}}{\gamma_{d,\max(lab)}} = \frac{17.5}{18.12} = \%96.7 > \%95.0\; OK!$$

d) $$\gamma_n = \frac{G\gamma_w(1+\omega)}{(1+e)} \Rightarrow e = \frac{2.7\times 9.81(1+0.12)}{19.6} - 1 = 0.514$$

$$\frac{V_T}{V_S} = \frac{Total\ volume}{Volume\ of\ \ grains} = \frac{1+e_{fill}}{1}$$

$$V_T = V_S\left(1+e_{fill}\right)$$

$$\frac{30000}{1+0.95} = \frac{V_{fill}}{1+0.514} \Rightarrow V_{fill} = 23293\ m^3$$

ZERO AIR VOIDS CURVE & SATURATION CURVES

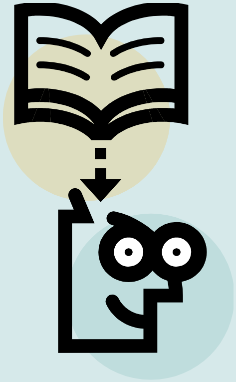
REMINDER

- Dry unit weight at a specific saturation level may be calculated by :

$$\gamma_d = \frac{\gamma_s}{1+e} = \frac{\gamma_s}{1+\frac{Gw}{S}}$$

- If the saturation level, S is assumed to be 1,

$$\gamma_{zav} = \frac{\gamma_w}{\frac{1}{G}+w}$$



QUESTION 5

- Standard Proctor Tests on a sandy clay revealed the following outcomes. Determine the optimum moisture content of this soil and draw the saturation curves for 90, 95 saturation levels and zero air voids curve (S=1). Unit weight of grains is 2.70 g/cm^3.

Test No	**Natural (wet) unit weight (g/cm^3)**	**Water content (%)**
1	1.87	5
2	2.04	8
3	2.13	10
4	2.20	13
5	2.16	16
6	2.09	19

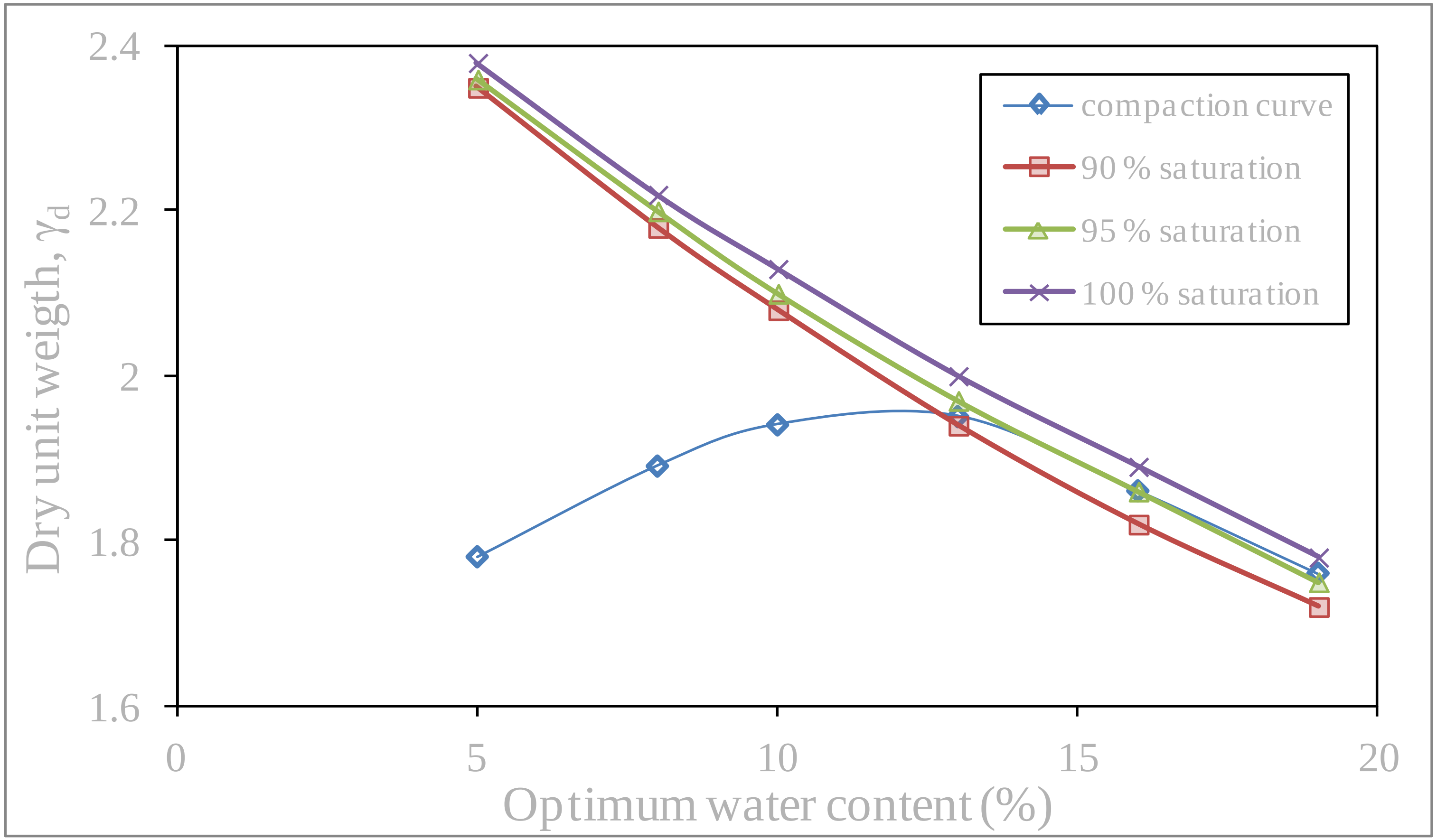
The equation for saturation curves is below:

$$\gamma_d = \frac{\gamma_s}{1+e} = \frac{\gamma_s}{1+\frac{Gw}{S}}$$

Substituting the unknowns, (for S= 90 %)

$$\gamma_d = \frac{\gamma_s}{1+e} = \frac{\gamma_s}{1+\frac{G\omega}{S}} = \frac{2.70}{1+\frac{2.70\times\omega}{0.90}} = \frac{2.70}{1+3\times\omega}$$

Test no	Wet unit weight (g/cm^3)	Water content (%)	Dry unit weight (g/cm^3)	Dry unit weight @ 90% saturation level (g/cm^3)	Dry unit weight @ 95% saturation level (g/cm^3)	Dry unit weight @ 100% saturation level (g/cm^3)
1	1.87	5	1.78	2.35	2.36	2.38
2	2.04	8	1.89	2.18	2.20	2.22
3	2.13	10	1.94	2.08	2.10	2.13
4	2.2	13	1.95	1.94	1.97	2.00
5	2.16	16	1.86	1.82	1.86	1.89
6	2.09	19	1.76	1.72	1.75	1.78



2.4
2.2
2
1.8
1.6
Dry unit weigth, γd
0
5
10
15
20
Optimum water content (%)
compaction curve
90 % saturation
95 % saturation
100 % saturation

QUESTION 6

- An embankment for a highway 30 m wide and 1.5 m thick is to constructed from a sandy soil, trucked in from a borrow pit. The water content of the sandy soil in the borrow pit is 15 % and its void ratio is 0.69. Specifications require the embankment to be compacted to a dry unit weight of 18 kN/m^3. Determine, for 1 km length of embankment, the following;

a) The dry unit weight of sandy soil from the borrow pit required to construct the embankment assuming that G_s= 2.70;
b) The number of 10 m^3 truckloads of sandy soil required to construct the embankment;
c) The weight of water per truck load of sandy soil;
d) The degree of saturation of the in-situ sandy soil.

a) The borrow pit's dry unit weight;

$$\gamma_d = \frac{G_s \gamma_w}{1+e} = \frac{2.7(9.8)}{1+0.69} = 15.7\ kN/m^3$$

b) The volume of the finished embankment;

$$V = 30\ m\ (1.5m)(1\ km\ long) = 45 \times 10^3 m^3$$

Volume of borrow pit required ;

HINT

weight of soil from borrow pit = weight of soil to construct the embankment

$$Volume\ of\ borrow\ pit\ soil\ required = \frac{\gamma_{d(req)}}{\gamma_{d(borrow\ pit)}}(V)$$

$$Volume\ of\ borrow\ pit\ soil\ required = \frac{18}{15.7}(45 \times 10^3)m^3$$

$$Number\ of\ truck\ trips = \left(\frac{18}{15.7}\right)\left(\frac{45 \times 10^3\ m^3}{10\ m^3}\right) = 5160$$

c) Weight of dry soil in 1 truck-load;

$$W_d = 10\ m^3\left(15.7\frac{kN}{m^3}\right) = 157\ kN$$

$$Weight\ of\ water = wW_d = (0.15)\ (157kN) = 23.6\ kN$$

d) Degree of saturation;

$$S = \frac{G_s w}{e} = \frac{2.7(0.15)}{0.69} = 0.59 = 59\%$$