CIV-474 Compaction SEISMIC GROUP UET LHR

Q.1 Derive from first principles, an expression for the percentage of air voids in a soil in terms of the dry density γ_d, the density of water γ_w, the specific gravity of the soil particles G_s and the moisture content W.

A standard BS compaction test on a soil yielded the following readings:

Bulk density (Mg/m3)	Moisture Content (%)
1.965	6.24
2.050	8.16
2.076	9.12
2.114	11.04
2.117	12.0
2.067	14.88
1.991	17.76

OMC

Plot the curve of the dry density against moisture content together with the zero and 5 per cent air void lines given that the specific gravity of the soil particles is 2.65. Determine the maximum dry density and optimum moisture content appropriate to these test results.

$G_s = 2.65$

$\gamma_{d\,max} = ?$

OMC = ?

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Q.2. Briefly describe the BS Compaction (Proctor) test and with with the aid of a sketch explain how the results can be used to obtain values for the maximum dry density and the optimum moisture content of a soil.

A sample of clay, having a mineral grain specific gravity of 2.72, when compaction had a bulk density of 1.827 Mg/m^3 and a moisture content of 20 per cent. A further sample of the soil compacted in the same manner was found to have the same bulk density but with a moisture content of 24 per cent. Determine the percentage decrease in dry density and air void content of the soil.

Q.3 (a) List the main factors which influence the compaction of soils.

(b) A BS Compaction (Proctor) test carried out on a soil having a mineral grain specific gravity of 2.70 gave the following data:

Bulk density (Mg/m3)	Moisture Content (%)
2.128	6.40
2.219	8.00
2.271	9.80
2.259	11.80
2.214	13.60
2.165	15.80

Using these results plot the dry density against moisture content curve, together with the zero air void line. Determine the void ratio, degree of saturation and bulk density of the soil at the optimum moisture content.

Q.4 A sample of soil taken from a newly formed embankment had a mass of 28.644 kg, a volume of 0.015 m^3 and a moisture content of 11.5 per cent. The specific gravity of the soil particles is 2.68. Calculate the dry density, the void ratio the degree of saturation and the air void content of the sample.

Q.5 A sample of a soil to be used in an embankment structure was subjected to a laboratory compaction test which indicated a maximum dry density of 1.802 Mg/m^3 and an optimum moisture content of 15.7 per cent. The average values of bulk density and moisture content obtained from tests on samples following compaction on site were 1.991 Mg/m^3 and 16.2 per cent respectively.

Determine the percentage compaction achieved and give reasons for the fact that the field compaction is different from that obtained in the laboratory.

Q.6 The natural moisture content of a borrow material is 8 percent. Assuming 3000 g of moist soil for a standard compaction test, how much water is to be added to bring the sample to 11, 13, 15, 17, and 20 percent water contents?.

Q.7 A soil has a bulk density of 1.91 Mg/m^3 and a water content of 9.5%. The value of G_s 2.70. Calculate the void ratio and degree of saturation of the soil. What would be the values of density and water content if the soil were fully saturated at the same void ratio?

Q.8 A soil specimen is 38 mm in diameter and 76 mm long and in its natural condition weighs 168.0 g. When dried completely in an oven the specimen weighs 130.5 g. The value of G_s is 2.73. What is the degree of saturation of the specimen?.

Q.9 Soil has been compacted in an embankment at a bulk density of 2.15 Mg/m^3 and a water content of 12%. The value of G_s is 2.65. Calculate the dry density, void ratio, degree of saturation and air content. Would it be possible to compact the above soil at a water content of 13.5% to a dry density of 2.00 Mg/m^3?.

Q.10 The following results were obtained from a standard compaction test on a soil:

Mass(g)	2010	2092	2114	2100	2055
Water Content(%)	12.8	14.5	15.6	16.8	19.2

The value of G_s is 2.67. Plot the dry density/water content curve and give the optimum water content and maximum dry density. Plot also the curves of zero, 5% and 10% air content and give the value of air content at maximum dry density. The volume of the mould is 100 cm^3.

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Q=1

Derivation:

% of air voids

$$n_a = \frac{V_a}{V_v} \times 100$$

As

$$\because \gamma_w = \frac{W_w}{V_w} \qquad \because w = \frac{W_w}{W_s}$$

$$V_w = \frac{W_w}{\gamma_w} \qquad W_w = wW_s$$

$$V_w = \frac{wW_s}{\gamma_w}$$

$$V = V_a + V_w + V_s$$

$$1 = V_a + V_w + V_s$$

$$V_a = 1 - V_w - V_s$$

$$= 1 - \frac{wW_s}{\gamma_w} - \frac{W_s}{\gamma_w G_s}$$

$$V_a = 1 - \frac{W_s}{\gamma_w}\left(w - \frac{1}{G_s}\right) \quad \text{—— (1)}$$

Hence, also

$$n_a = \frac{V_a}{V_v} = \frac{V_a}{1 - V_s} = \frac{V_a}{\left(1 - \frac{W_s}{G_s\gamma_w}\right)}$$

$$V_a = n_a\left(1 - \frac{W_s}{G_s\gamma_w}\right) \quad \text{—— (2)}$$

equating (1) and (2)

$$1 - \frac{W_s}{\gamma_w}\left(w - \frac{1}{G_s}\right) = n_a\left(1 - \frac{W_s}{G_s\gamma_w}\right)$$

$$1 - \frac{W_s w}{\gamma_w} - \frac{W_s}{G_s\gamma_w} = n_a - \frac{n_a W_s}{G_s\gamma_w}$$

$$1 - n_a = \frac{W_s w}{\gamma_w} + \frac{W_s}{G_s\gamma_w} - \frac{n_a W_s}{G_s\gamma_w}$$

$$1 - n_a = \frac{W_s w G_s}{\gamma_w G_s} + \frac{W_s}{G_s\gamma_w} - \frac{n_a W_s}{G_s\gamma_w}$$

$$1 - n_a = \frac{W_s}{G_s\gamma_w}\left(wG_s + 1 - n_a\right)$$

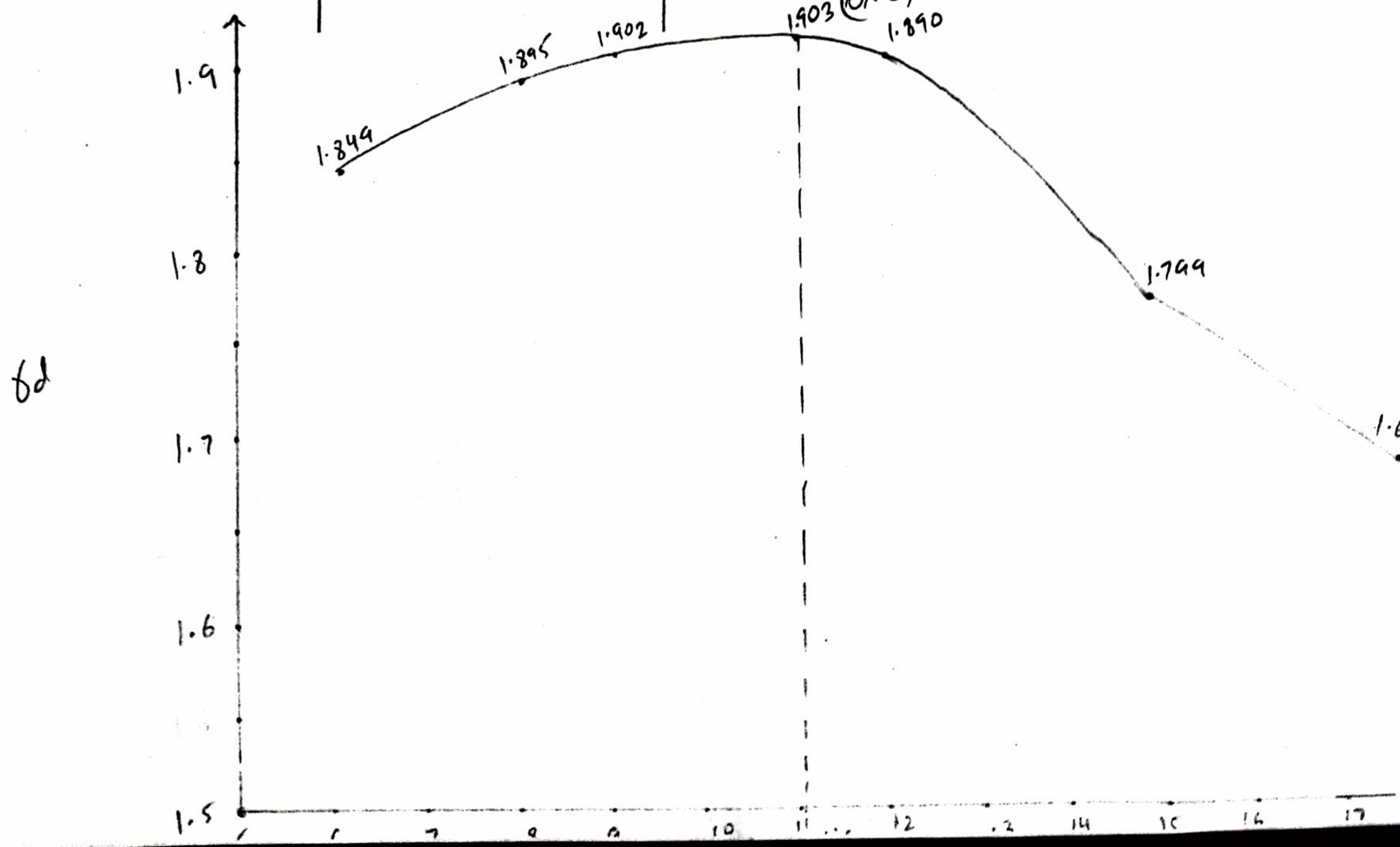
$$W_s = \frac{(1-n_a)(G_s \gamma_w)}{(1-n_a+wG_s)}$$

As $\gamma_d = \frac{W_s}{V}$ and $V = 1$ therefore $\gamma_d = W_s$

$$\gamma_d = \frac{(1-n_a)(G_s \gamma_w)}{(1-n_a+wG_s)}$$

: BS compaction test :

Bulk density (γ_b) Mg/m3	Moisture content % (w)	$\gamma_d = \frac{\gamma_b}{1+w}$
1.965	6.24	1.849
2.05	8.16	1.895
2.076	9.12	1.902
2.114	11.04	1.903
2.117	12	1.890
2.067	14.88	1.799
1.991	17.76	1.690



Q=2

Data:

$G_s = 2.72$

$\gamma_b = 1.827\ Mg/m^3$ $\gamma_b = 1.827\ Mg/m^3$

$w_1 = 20\%$ $w_2 = 24\%$

a) % decrease in γ_d = ?

% decrease in n_a = ?

Sol:

a) $\gamma_d = \frac{\gamma_b}{1+w_1}$ $\gamma_d = \frac{\gamma_b}{1+w_2}$

$\gamma_d = 1.5225\ Mg/m^3$

$\gamma_d = 1.4734\ Mg/m^3$

% decrease in $\gamma_d = \frac{1.5225 - 1.4734}{1.5225} \times 100$

$= 3.225\%$

b) $\gamma_d = \frac{(1-n_a)\, G_s \gamma_w}{(1 - n_a + w_1 G_s)}$ $\gamma_d = \frac{(1-n_a)\, G_s \gamma_w}{(1 - n_a + w_2 G_s)}$

$1.5225 = \frac{(1-n_a)\, 2.72 (1)}{1 - n_a + (0.2)(2.72)}$ $1.4734 = \frac{(1-n_a)(2.72)(1)}{1 - n_a + (0.24)(2.72}$

$n_a = 0.308$ $n_a = 0.228$

% decrease in $n_a = \frac{0.308 - 0.228}{0.308} \times 100$

$= 26\%$

Q=3 a

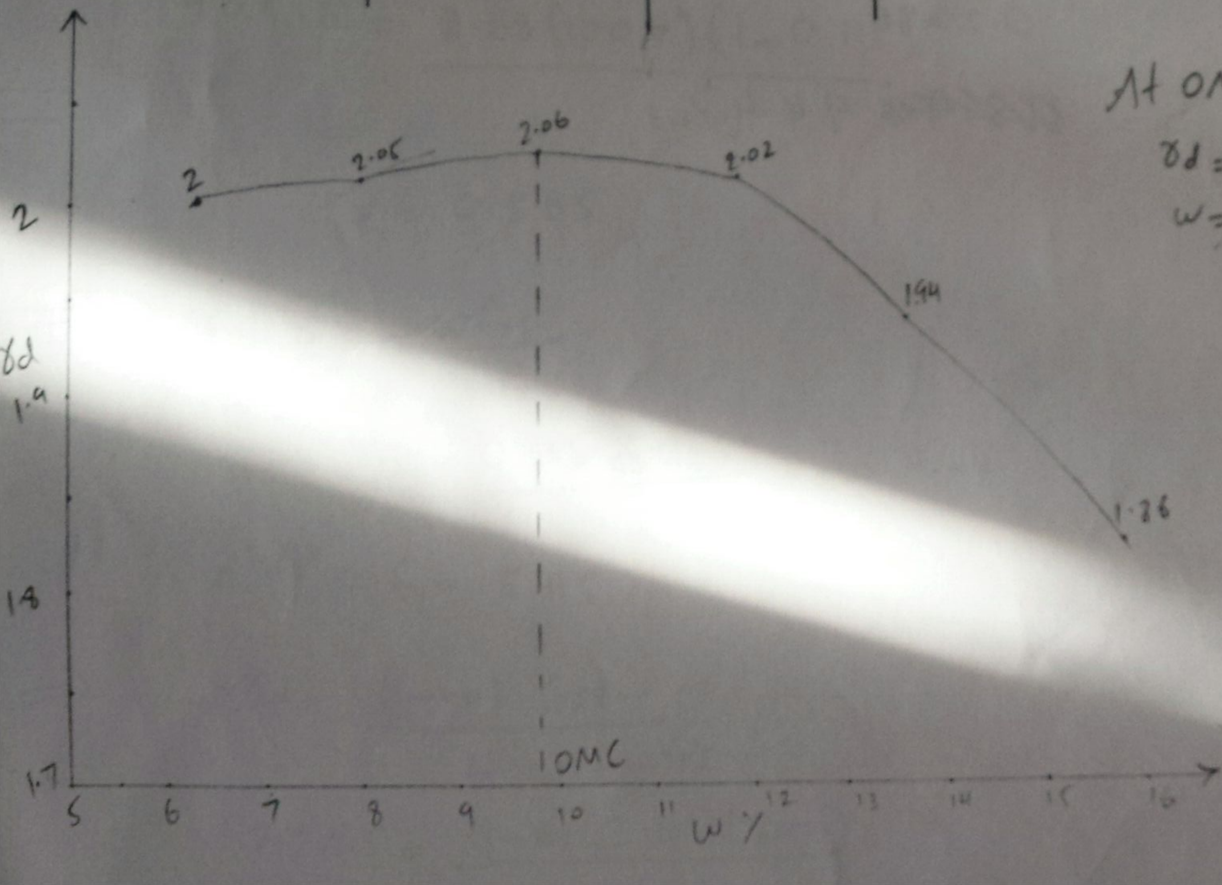
Factors affecting the compaction of soil:

1) Effect of Soil type
2) Effect of compaction effort
3) Addition of admixtures
4) Water content.

Q=3 (b)

$G_s = 2.70$

Bulk density γ_b (Mg/m3)	Moisture content (w%)	γ_d
2.128	6.4	2
2.219	8	2.05
2.271	9.8	2.06
2.259	11.8	2.02
2.214	13.6	1.94
2.165	15.8	1.86



At OMC

$\gamma_d = 2.1$

$w = 10\%$

⇒ Bulk density:

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

$$2.1\,(1+0.1) = \gamma_b$$

$$\boxed{\gamma_b = 2.31\ Mg/m^3}$$

⇒ Void ratio

$$\frac{\gamma_b}{\gamma_w} = \frac{G_s(1+w)}{1+e}$$

$$\frac{2.31}{1} = \frac{(2.70)(1+0.1)}{1+e}$$

$$e = 0.2886$$

⇒ degree of saturation:

$$e = \frac{wG_s}{S}$$

$$S = \frac{(0.1)(2.70)}{0.2886} \times 100$$

$$S = 94.4\%$$

Q=4

Data:

$m = 28.644\,kg$

$V = 0.015\,m^3$

$w = 11.5\%$

$G_s = 2.68$

$\gamma_d = ?$

$e = ?$

$S = ?$

$n_a = ?$

Sol:

$$\gamma_b = \frac{W}{V}$$

$$= \frac{28.644}{0.015}$$

$$\gamma_b = 1909.6\,kg/m^3$$

$$\Rightarrow \gamma_d = \frac{\gamma_b}{1+w}$$

$$= \frac{1909.6}{1+0.115}$$

$$\gamma_d = 1712.65\,kg/m^3$$

$$\Rightarrow \gamma_b = \frac{G_s \gamma_w (1+w)}{1+e}$$

$$1909.6 = \frac{2.68(1000)(1+0.115)}{1+e}$$

$$e = 0.565$$

$$\Rightarrow S = \frac{w G_s}{e}$$

$$= \frac{0.115 \times 2.68}{0.565} \times 100$$

$$S = 54.5\%$$

$$\Rightarrow \gamma_d = \frac{(1-n_a) G_s \gamma_w}{1-n_a+wG_s}$$

$$1712.65 = \frac{(1-n_a)(2.68)(1000)}{1-n_a+(0.115)(2.68)} \times 100$$

$$\Rightarrow n_a = 45.43\%$$

Q=5

Data:

$\gamma_{dmax} = \gamma_d = 1.802\ Mg/m^3$ }
$w = OMC = 15.7\%$ } ⇒ lab

$\gamma_b = 1.991\ Mg/m^3$ }
$w' = 16.2\%$ } compacted fill

% compaction achieved = ?

Sol:

For field

$$\gamma_d = \frac{\gamma_b}{1+w} = \frac{1.991}{1+0.162}$$

$\gamma_d = 1.7134\ Mg/m^3$

$$C_R = \frac{\gamma_d\ field}{\gamma_{d\,max}\ lab} \times 100$$

$$= \frac{1.7134}{1.802} \times 100$$

$C_R = 95\%$

Q-6"

Data:

$w = 8\%$

$W = 3000 g$

How much water is to be added to bring sample to 11, 13, 15, 17, 20 % water contents?

Sol:

$W = W_w + W_s$

$W_w = W - W_s$

$= 3000 - 2777.78 g$

$W_w = 222.22 g$

This is already existing water in the total weight.

$W_s = \frac{W}{1+w}$

$= \frac{3000}{1+0.08}$

$W_s = 2777.78 g$

When $w = 11\%$

$w = \frac{W_w}{W_s}$

$W_w = 0.11 \times 2777.78$

$W_w = 305.555 g$

Extra water reqd. to bring $w = 11\%$

$= 305.555 - 222.22$

$= 83.33 g$

When $w = 13\%$

$W_w = 0.13 \times 2777.78$

$W_w = 361.11$

Extra water

$= 361.11 - 222.22$

$= 138.89 g$.

When $w = 15\%$

$W_w = 0.15 \times 2777.78$

$W_w = 416.67 g$

Extra water

$= 416.67 - 222.22$

$= 194.447 g$

When $w = 17\%$

$W_w = 0.17 \times 2777.78$

$W_w = 472.222g$

Extra water

$= 472.222 - 222.22$

$= 250g$

When $w = 20\%$

$W_w = 0.2 \times 2777.78$

$W_w = 555.56g$

Extra water

$= 555.56 - 222.22$

$= 333.33g$

Q = 7

Data:

$\gamma_b = 1.91 \, Mg/m^3$

$w = 9.5\%$

$G_s = 2.70$

$e = ?$

$S = ?$

$\gamma_b = ?$

$w = ?$

if soil is fully saturated at same 'e' i.e $S = 100\%$

Sol:

$$\gamma_b = \frac{G_s \gamma_w (1+w)}{1+e}$$

$$1.91 = \frac{(2.7)(1)(1+0.095)}{1+e}$$

$$\boxed{e = 0.548}$$

$$S = \frac{w G_s}{e}$$

$$= \frac{(0.095)(2.7)}{0.548}$$

$$\boxed{S = 46.8\%}$$

$$e = \frac{w G_s}{S}$$

$$w = \frac{eS}{G_s}$$

$$= \frac{(0.548)(100)}{2.7}$$

$$\boxed{w = 20.29\%}$$

$$\gamma_b = \frac{G_s \gamma_w (1+w)}{1+e}$$

$$= \frac{(2.7)(1)(1+0.2029)}{1+0.548}$$

$$\boxed{\gamma_b = 2.098 \, Mg/m^3}$$

Q=8

Data:

$d = 38mm = 3.8\ cm$
$l = 76\ mm = 7.6\ cm$ $\Rightarrow V = \frac{\pi d^2}{4} \times l = \frac{\pi (3.8)^2}{4}(7.6) = 86.192\ cm^3$

$W = 168g$
$W_s = 130.5g$ $\Rightarrow W_w = 37.5g$

$G_s = 2.73$

$S = ?$

Sol:

$S = \frac{V_w}{V_v} \times 100$

$= \frac{37.5}{38.392} \times 100$

$S = 97.68\%$

$\because \gamma_w = \frac{W_w}{V_w}$

$V_w = \frac{W_w}{\gamma_w}$

$V_w = 37.5\ cc$

$V = V_v + V_s$

$V_v = V - V_s$

$= 86.192 - 47.8\ cc$

$V_v = 38.392\ cc$

$V_s = \frac{W_s}{\gamma_w G_s}$

$= \frac{130}{2.7}$

$V_s = 47.$

Q=9

Data:

$\gamma_b = 2.15\ Mg/m^3$
$w = 12\%$
$G_s = 2.65$

$\gamma_d = ?$
$e = ?$
$S = ?$
$n_a = ?$

Is it possible to compact at $w = 13.5\%$, $\gamma_d = 2\ Mg/m^3$

Sol:

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

$= \frac{2.15}{1+0.12}$

$\gamma_d = 1.919\ Mg/m^3$

$\gamma_b = \frac{G_s \gamma_w (1+w)}{1+e}$

$2.15 = \frac{(2.65)(1+0.12)}{1+e}$

$e = 0.38$

$\Rightarrow \quad S = \dfrac{wG_s}{e}$

$= \dfrac{(0.12)(2.65)}{0.38}$

$\boxed{S = 83.68\%}$

$\Rightarrow \quad \gamma_d = \dfrac{(1-n_a)G_s\gamma_w}{(1-n_a+wG_s)}$ ✓

$\frac{V_a}{V}$

$n_a = 0.165$

$\boxed{n_a = 16.5\%}$

Would it be possible to compact the above soil at a $w = 13.5\%$ and $\gamma_d = 2.00 \text{ Mg/m}^3$?

$S = \dfrac{wG_s}{e}$

$= \dfrac{(0.135)(2.65)}{0.325} \times 100$

$S = 110.07\%$

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

$2 = \dfrac{(2.65)}{1+e}$

$e = 0.325$

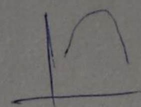
Since $S = 110.07\%$ which is greater than fully saturation i.e $> 100\%$. Hence it is not possible to compact.

$Q = 15''$

Mass (g) W	Water content (w)	$W_s = \frac{W}{1+w}$	$\gamma_d = \frac{W_s}{V}$
2010	12.8	1781.914	17.819
2092	14.5	1827.074	18.271
2114	15.6	1828.719	18.287
2100	16.8	1797.945	17.979
2055	19.2	1723.993	17.240

$G_s = 2.67$

plot γ_d / w curve



plot 0, 5%, 10% air content

$V = 100\ cm^3$

For 0, 5%, 10% Air void lines: $w = S\left[\frac{\gamma_w}{\gamma_d} - \frac{1}{G_s}\right]$

γ_d g/cc	w% S = 100%	S = 95%	S = 90%
17	21.37	20.3	19.23
18	18.1	17.19	16.29
19	15.18	14.42	13.66

$\gamma_{d\,max} = 18.36$ g/cc

$w = 15.1$

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

$S = \frac{w G_s}{e}$

$e = 0.454$

$S = 88.8\%$

$n_a = 11.2\%$ at max.