RSSB-JE 2020

Rajasthan Staff Selection Board

Combined Junior Engineer Direct Recruitment Examination

Civil Engineering

Soil Mechanics and Foundation Engineering

Well Illustrated **Theory** *with*
Solved Examples and **Practice Questions**

MADE EASY Publications

Soil Mechanics and Foundation Engineering

Contents

CHAPTER 4

Soil Compaction

4.1 Introduction

Construction of many structures requires “stabilisation” of the soil mass i.e. an artificial improvement of its engineering properties. There are various methods of soil stabilisation, the most common being the mechanical stabilisation and the simplest technique of mechanical stabilisation is compaction.

Compaction is a process by which the soil particles are artificially rearranged and packed together into a closer state of contact by mechanical means in order to reduce the volume of air voids of the soil and thus increase its dry density.

A soil mass can be compacted by either a dynamic process or a static one. In the dynamic method the soil mass is compacted by repeated applications of a dead load, while in static method, compaction is done by a steady increase of static load.

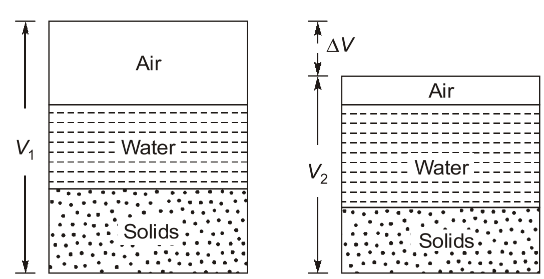
Do you know? The dynamic method gives better result in coarse grained soils and static method is suitable for less permeable fine grained soils.

4.2 Principles of Compaction

Usually when soil is excavated from one place, transported and dumped in another place it is loosened up to a great extent. In an uncompacted fill, the void ratio is relatively high and the corresponding density is low. Consequently, the shearing strength of uncompacted soil is low while its permeability is high. A structure on such a fill may crack extensively due to non uniformity of settlement. Therefore, it is necessary to artificially compact the fill.

Soil compaction is the process where soil particles are forced to pack more closely by reducing air voids. This can be achieved by applying some mechanical energy (static or dynamic) on soil fill.

The degree of compaction of a soil is measured in terms of dry unit weight i.e. the amount of soil solids that can be packed in a unit volume of the soil.



(a) Before compaction (b) After compaction

Remember: Compaction is somewhat different from consolidation. In consolidation volume reduction takes place due to expulsion of pore water from saturated voids.

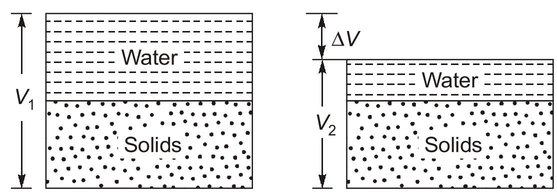
4.3 Difference between Compaction and Consolidation

4.3.1 Compaction

- Almost an instantaneous phenomenon.
- Soil is always unsaturated.
- Densification is due to a reduction in the volume of air voids at a given water content.
- Specified compaction techniques are used in this process.

4.3.2 Consolidation

- It is a time dependent phenomenon.
- Soil is completely saturated.
- Volume reduction is due to expulsion of pore water from voids.
- Consolidation occurs on account of a load placed on the soil.



(a) Before consolidation (b) After consolidation

4.4 Advantages of Compaction

Proper compaction of a soil mass lead to

- Increase in shear strength of soil.
- Improved stability and bearing capacity of soil.
- Reduction in compressibility and permeability of soil.
- Increase in the load carrying capacity of soil subgrade.
- Prevention of determental-settlements and undesirable volume changes through swelling and shrinkage.

4.5 Settlement During Compaction

Let e_0 be the initial void ratio before compaction has been started. After compaction, the void ratio of soil be e_f.
We know,

Void ratio, $$e = \frac{V_v}{V_s} = \frac{H_v}{H_s} \quad (\because V \propto H)$$

$\therefore$ $$e_0 = \frac{H_{V_1}}{H_s}$$

$\Rightarrow$ $$H_{V_1} = e_0 H_s$$

Similarly, $$H_{V_2} = e_f H_s$$

$\therefore$ change in the thickness of soil layer

$$\Delta H = H_{V_1} - H_{V_2} = (e_0 - e_f)H_s$$

$\therefore$ $$\frac{\Delta H}{H} = \frac{(e_0 - e_f)H_s}{H_s + e_0 H_s} = \frac{e_0 - e_f}{1 + e_0}$$

$$\Delta H = \left(\frac{e_0 - e_f}{1 + e_0}\right)H$$

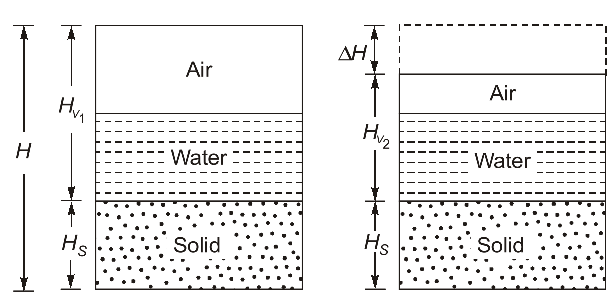


Fig. Settling compaction

4.6 Proctor Test

(A) Standard Proctor Test

- Standard volume mould (944 cc or 1/30 cubic feet).
- Filled up with soil in three layers.
- Each layer is compacted by 25 blows of standard hammer (weight 2.495 kg or 5.5 lbs) falling through 304.8 mm (12 inch).
- Dry weight is calculated by knowing the wet weight of compacted soil and its water content.

Dry unit weight,

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

where, γ = bulk unit weight

$$= \frac{\text{weight of compacted soil}}{\text{volume of the mould}}$$

w = water content

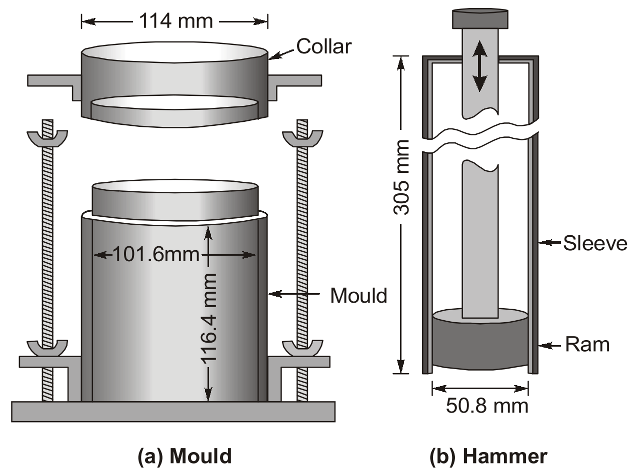


Fig. Standard Proctor

- Test is repeated at different water contents.
- Compaction curve is plotted between moisture content and dry unit weight.
- The peak of compaction curve corresponding to the maximum dry unit weight is referred as $\gamma_{d(max)}$.
- The moisture content corresponding to $\gamma_{d(max)}$ is known as optimum moisture content (OMC) at a given compactive effort.

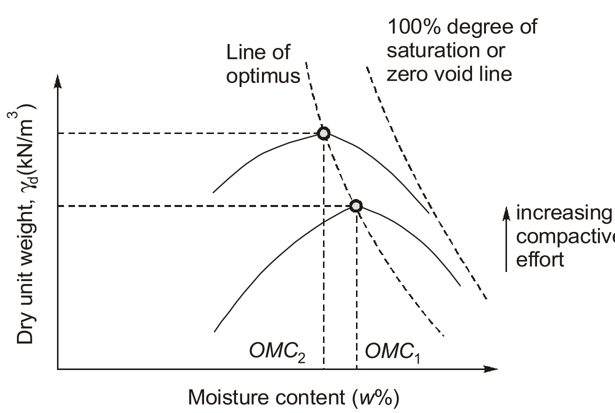


Fig. Compaction Curve

NOTE

- Typical values of maximum dry unit weights range from 16 to 20 kN/m^3 with the widest range being 13 to 24 kN/m^3.
- Typical optimum moisture content values ranges from 10 to 20% with a maximum range of 5 to 30%.
- Maximum dry unit weight so obtained is only for a given amount of compaction effort and method of compaction. It is also not necessary that the maximum dry unit weight can be obtained in the field.

  The specifications for compaction of fills in the field are usually based on maximum dry unit weight but sometimes on both the maximum dry unit weight and the OMC.

$$\text{Relative compaction} = \frac{\gamma_{d(\text{field})}}{\gamma_{d(\text{max})}} \times 100$$

Example - 4.2 The compactive energy (kJ/cum) used for modified proctor test is approximately equal to

(a) 1856 (b) 1250
(c) 595 (d) 2695

Solution: (d)

Compactive energy per unit volme in modified proctor test

$$E = \frac{5 \times 25 \times 4.54 \times 0.4572 \times 9.81}{944 \times 10^{-6}}$$

$$= 2696.30 \text{ kJ/m}^3$$

Student's Assignment

Q.1 The basic action involved in sheep foot rolling is
(a) Kneading (b) Pressing
(c) Tamping (d) Vibration
[UPRVUNL : AE]

Q.2 At what value of saturation does the zero air voids curve in a compaction test represent the dry density?
(a) 0% (b) 80%
(c) 100% (d) 50%

Q.3 Which one of the following is the correct statements?
Vibratory rollers are suitable for compacting
(a) organic soil
(b) clays
(c) sands and gravels
(d) clayey silts

Q.4 Why are sheep foot rollers more effective in compacting clayey soils?
(a) There is differential expulsion of water under the roller
(b) Contact pressure is high
(c) Roller speed is high
(d) Drum width is large

Q.5 The height of hammer drop in standard proctor test and modified proctor test, respectively is
(a) 30 cm and 15 cm (b) 15 cm and 30 cm
(c) 30 cm and 45 cm (d) 45 cm and 30 cm
[DMRC]

Q.6 Compaction of soil is aimed at
(a) Decreasing dry density
(b) Increasing porosity
(c) Decreasing void ratio
(d) Decreasing shear strength

Q.7 Compaction of soil is measured in terms of
(a) Dry density (b) Specific gravity
(c) Compressibility (d) Permeability

Q.8 For conducting a standard proctor compaction test, the weight of hammer (P in kg), the fall of hammer (Q in mm), the number of blows per layer (R) and the number of layers (S) required are respectively.

	P	Q	R	S
(a)	5.89	550	50	3
(b)	4.89	450	25	3
(c)	3.60	310	35	4
(d)	2.60	310	25	3

[RPSC : JE]

Q.9 If specific gravity of soil solids of a soil having optimum moisture content 16.5% and maximum dry density 1.57 g/cc is 2.65, void ratio at optimum moisture content is
(a) 0.588 (b) 0.688
(c) 0.788 (d) 0.888

Q.10 The maximum dry density upto which any soil can be compacted depends upon
(a) amount of compaction energy alone
(b) moisture content alone
(c) both compaction energy and moisture content
(d) none of these

Q.11 At optimum moisture content of soil mass, the soil saturation will be around
(a) 100% (b) 90 – 95%
(c) 0% (d) none of these

Q.12 The insitu void ratio of a granular soil deposit is 0.50. The maximum and minimum void ratios of the soil were determined to be 0.75 and 0.35. G_s = 2.67 the relative density and relative compaction of the soil are respectively

(γ_w = 9.8 kN/m^3)
(a) 62.5%, 89.9% (b) 89.9%, 62.5%
(c) 62.5%, 96.6% (d) 89.9%, 96.6%

Q.13 The zero-air voids curve is non-linear owing to
(a) the standard proctor test data of dry density and corresponding water content plotting as a non-linear curve
(b) the dry density at 100% saturation being a non-linear function of the void-ratio
(c) the water content altering during compaction
(d) the soil being compacted with an odd number of blows

Q.14 Following statement are made on compacted soil, where DS stands for soil compaction on Dry Side of OMC and WS stands for soil compacted on Wet Side of OMC. Identify incorrect statement
(a) Soil structure is flocculated on DS and dispersed on WS.
(b) Construction of pore water pressure is low on DS and High on WS.
(c) Soil on drying, shrinkage is high on DS and Low on WS.
(d) On addition to water, swelling is high on DS and low on WS.

Q.15 OMC-SP and MDD-SP denote the optimum moisture content and maximum dry density obtained from standard Proctor compaction test, respectively. OMC-MP and MDD-MP denote the optimum moisture content and maximum dry density obtained from the modified Proctor compaction test, respectively. Which one of the following is correct?
(a) OMC-SP < OMC-MP and MDD-SP < MDD-MP
(b) OMC-SP > OMC-MP and MDD-SP < MDD-MP
(c) OMC-SP < OMC-MP and MDD - SP >MDD-MP
(d) OMC-SP > OMC-MP and MDD-SP > MDD-MP

ANSWER KEY — STUDENT'S ASSIGNMENT

1. (a)	**2.** (c)	**3.** (c)	**4.** (b)	**5.** (c)
6. (c)	**7.** (a)	**8.** (d)	**9.** (b)	**10.** (c)
11. (b)	**12.** (a)	**13.** (b)	**14.** (c)	**15.** (b)

HINTS & SOLUTIONS — STUDENT'S ASSIGNMENT

1. (a)

Sheeps foot rollers are suitable for compacting fine grained soil such as clays. It consist of four wheels and on each wheel kneading boots/feet are fixed.

4. (b)

Under sheep foot rollers the contact pressure is very high and this results in kneading action which is responsible for effective compaction of clayey soils.

5. (c)

Standard proctor test

Height of fall = 304.8 mm $\simeq$ 30 cm

Modified proctor test

Height of fall = 457.2 mm ≃ 45 cm

6. (c)

Compaction of soil is the process of increasing the unit weight of soil by forcing the soil solids into a dense state and reducing the air voids.

7. (a)

Compaction is measured quantitatively in terms of dry unit weight (γ_d) of soil.

8. (d)

Standard proctor test:

- Weight of hammer ≃ 2.6 kg
- Height of fall = 31 cm ≃ 310 mm
- Compacted in 3 layers with 25 blows in each layer

9. (b)

Given, $\gamma_d = 1.57$; $w = 0.165$; $G = 2.65$

Using, $$\gamma_d = \frac{G \cdot \gamma_w}{1+e}$$

$$1.57 = \frac{2.65 \times 1}{1+e}$$

$$1 + e = 1.688$$

$$\therefore \quad e = 0.688$$

12. (a)

Relative density

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

$$= \frac{0.75 - 0.50}{0.75 - 0.35} \times 100 = 62.5\%$$

$$\gamma_{d(max)} = \frac{G_s \gamma_w}{1 + e_{min}}$$

$$= \frac{2.67 \times 9.8}{1 + 0.35} = 19.38 \text{ kN/m}^3$$

$$\gamma_{d(min)} = \frac{G_s \gamma_w}{1 + e_{max}}$$

$$= \frac{2.67 \times 9.8}{1 + 0.75} = 14.95 \text{ kN/m}^3$$

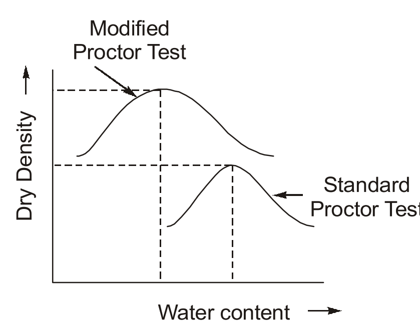
$$\gamma_{d(insitu)} = \frac{G_s \gamma_w}{1 + e_{insitu}}$$

$$= \frac{2.67 \times 9.8}{1 + 0.50} = 17.44 \text{ kN/m}^3$$

∴ Relative compaction,

$$\frac{\gamma_{d(insitu)}}{\gamma_{d(max)}} = \frac{17.44}{19.38} \times 100 = 89.9\%$$

15. (b)



OMC – SP > OMC – MP

MDD – SP < MDD – MP

■■■■