2.4 Compaction Test

● Definition

- Compaction is the densification of soils by the application of mechanical energy.

2.4.1 Advantages which occur through compaction

1) An increase on shear strength
2) A decrease in compressibility
3) A decrease in permeability
4) Undesirable volume change, for example, frost action, swelling, and shrinkage may be controlled.

2.4.2 Testing method

- Standard Compaction Test (Proctor Test)

  * Compacting soil samples ((-)No.4 sieve) into a 944 cm^3 mold in three layers with 25 blows per layer, using a 24.5 N compaction rammer dropping 0.305 m (Compacting Energy = 593.7 kJ/m^3)

    Repeat it for samples with different water contents.

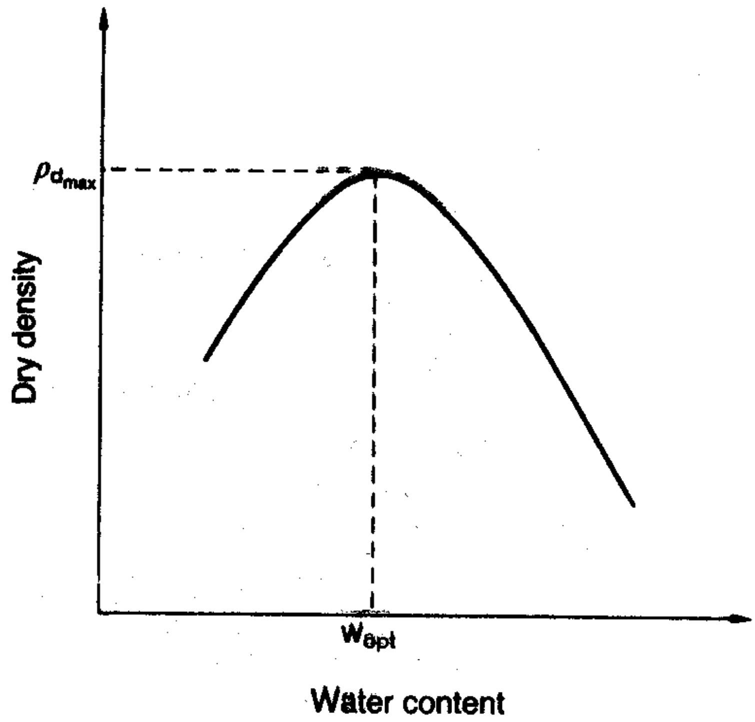

Fig. 1.11 Dry density–water content relationship.

* On the dry side of the optimum, the compact process becomes more efficient at any given compaction effort as the water content increases because of the increase of the lubrication effect. Contrarily, on the wet side, the blows of rammer simply increase the excess pore pressure and accordingly decrease the shear strength, and the rammer energy shears the soil rather than increasing the unit weight further.
* Compaction curve (Relation between dry unit weight and water content) is obtained. ⇒ Can determine maximum dry unit weight and optimum water content.

* Comments on test results

1) Reproducible? (Possibility of inconsistent test conditions.)

   - Fresh samples or the reusing samples, temperature, whether layers are of about equal thickness, excess quantity of soil in mold, distribution of blows on any layer, and how well the water is distributed within sample, curing time for dry soils after mixing soils with water, and et al.

   - $\gamma_{d(\max)}$ can vary by as much as 0.8 to 1.2 kN/m^3 (0.08 ~ 0.12 g/cm^3) without some attentions.

2) 5 well placed points (2% spacing of water contents and 2-3 on wet side and 2-3 on dry side) are appropriate.

2.4.3 Compaction in the field

- Rolling with sheep foot, or smoothed wheel or wobble-wheel rollers with pressure and/or vibration)
- Relative compaction, RC (can be more or less than 100 and should be specified with referencing test such as standard compaction test and modified compaction test).

$$RC = \gamma_{df}/\gamma_{dL} \times 100\ (\%)$$

2.4.4 Soil structure and behavior associated with the compacting process and water content

- Wet side of OMC
  1. Dispersed structure (parallel particle orientations)
  2. Has somewhat lower shear strength and can undergo larger settlements without cracking and has a lower permeability.
  3. Useful condition for the clay core of earth dam.
- Dry side of OMC
  1. Flocculated structure (random particle orientation)
  2. Has higher shear strength at lower strains (brittle behavior) and higher permeability.
  3. Desirable condition for road works and the soil shell around clay core in earth dam

2.4.5 The modified compaction test

1) Increase of the use of heavy military (or civil) aircraft (or vehicle) after World War II. ⇒ Require a higher subgrade density than that provided by the standard compaction unit weight. ⇒ Introducing a modified test with higher input energy (rather than use of the relative compaction higher than 100%).

2) Details of the test are as follows ;

   Mold : 944 cm^3

   Rammer : 44.5 N

   Soil layers : 5 layers and 25 blows per layer

   Rammer fall : 0.46 m

   Compaction energy: 2710.5 kJ/m^3

   - Higher compaction energy (about 5 times than that in standard compaction) results in a 5 to 10 percent increase in unit weight and decrease in OMC.

2.4.6 The Harvard Miniature Compaction Test

- To duplicate more closely field compaction.
- Consisting of a mold with 15/16 inch diameter and 2.816 inch length (a volume of 1/454 ft^3 (62.4 cm^3)).
- Compacting soils by tamping. (3 layers at 25 tamps per layer)

  A tamper employing a spring loaded plunger (89 N and 178 N).
- No direct correlation between the proctor test and Harvard miniature test. (OMC at Harvard miniature test is less than that at standard compaction test.)

- Advantages :

  1. Small amounts of soil are required.

  2. Obtain specimens for unconfined or triaxial test.

2.5 Relative Density Determination

- To determine the state of density of a cohesionless soil with respect to its maximum and minimum densities.
- Relative density

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

$$\text{or} \quad D_r = \left(\frac{\rho_f - \rho_{\min}}{\rho_{\max} - \rho_{\min}} \right) \left(\frac{\rho_{\max}}{\rho_f} \right)$$

- Problem: how to properly define the soil in its densest and loosest states.
- Recommendation method
  1. For the densest state: Fill standard compaction mold in several layers, and for each layer, confining in some manner and vibrating (or tapping the mold on the sides). Try 3-4 times. The largest density value is taken as the job control value.
  2. For the loosest state:
     - Pour soils into the compaction mold with a container which has a spout with at least length of 150 mm and diameter of 12 mm (for (-) No.4)
     - Use graduated cylinder (wet pluviation) :
     - Carefully pour the soil into the mold with collar.
- Test precision

Density	Between labs	Same technician
minimum	0.27 to 0.40 kN/m^3	0.07 to 0.14 kN/m^3
maximum	0.38 to 0.71 kN/m^3	0.13 to 0.22 kN/m^3