Period #26: Compaction of Soils (II)

A. Review

1) Compaction is the process by which loose soils are applied to a construction site and densified. The objective of compaction is to remove air voids from the soil.

2) The degree of compaction of a soil is expressed in terms of its dry density ρ_d or dry unit weight γ_d. (These measure grain packing.)

3) Moisture density tests are typically performed on soils before they are applied to construction sites.

   - Moisture density tests involve compacting a soil at a number of different water contents w with a specific amount of compactive energy.
   - Results are plotted as dry unit weight versus water content.

4) The maximum degree of compaction that can be possibly be achieved for a given soil at a given water content w is the so−called zero−air voids dry unit weight $(\gamma_d)_{zav}$:

$$(\gamma_d)_{zav} = G_s\gamma_w/(1+wG_s)$$

In practice, this density can never be achieved.

B. Percent Compaction or Relative Compaction

- In the field the questions that have to be answered are:

  a) to what dry density must the soil be compacted? and

  b) how can this be achieved efficiently?

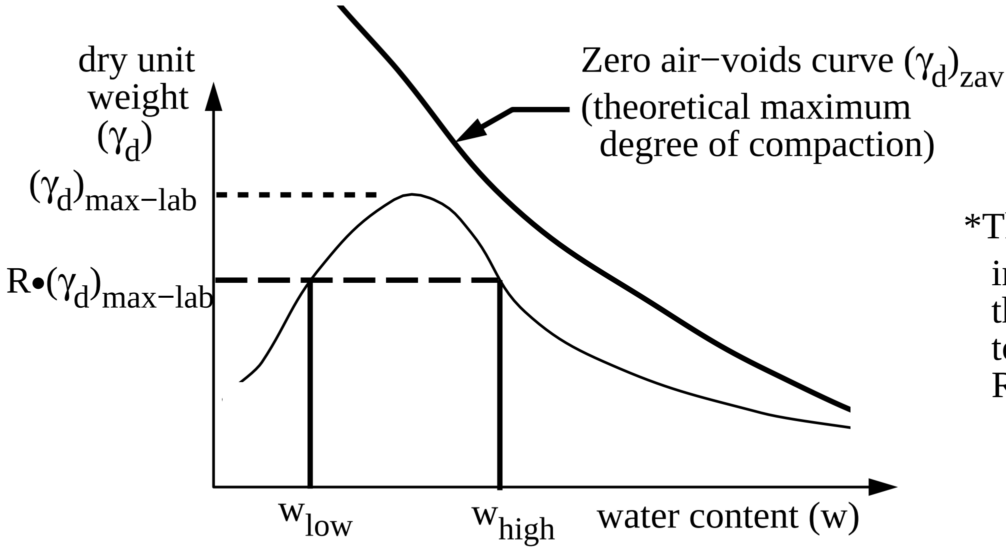
- For many construction applications involving roadway subgrades and trench backfills, etc., there are typically codes provided by federal, state, and local agencies specifying the minimum **percent compaction** or **relative compaction** that must be achieved.

- The guidelines typically specify that the field compaction must meet or exceed a certain level as follows:

$$(\gamma_d)_{field} \geq R \bullet (\gamma_d)_{max-lab}$$

where:
- R is a relative compaction, and
- $(\gamma_d)_{max-lab}$ is the maximum dry density achieved for a given level of compactive effort (Standard Proctor, for example).

- For many roads owned by local municipalities, codes exist stating that soils in roadway subgrades must be compacted so that the minimum dry density achieved exceeds 95% of the Standard Proctor Maximum dry density.



*The range $w_{low} - w_{high}$ indicates the range at which the soil should be compacted to achieve relative compaction R, at a given energy level.

- The degree compaction achieved in the field (R_{field}) is typically stated with reference to the maximum dry unit weight associated with a specific level of compactive effort (SP, MP, etc).

$$R_{field} = (\gamma_d)_{field} \; / \; (\gamma_d)_{max-lab}$$

Note: $(\gamma_d)_{max-lab}$ is associated with a reference level of compactive effort E_{ref}.

- The relative compaction achieved in the field can easily exceed 1 (or 100%) if compactive energy applied to the soil is exceeds E_{ref}.

- Relative compaction R should not be confused with relative density D_r because they are **not** the same:

$$D_r = \left[\frac{e_{max} - e}{e_{max} - e_{min}}\right] = \left[\frac{\gamma_d - (\gamma_d)_{min}}{(\gamma_d)_{max} - (\gamma_d)_{min}}\right] * \left[\frac{(\gamma_d)_{max}}{\gamma_d}\right]$$

$$R = \left[\gamma_d \;/\; (\gamma_d)_{max}\right]$$

- Example 26.1

- Example 26.2:

C. Design and Selection of Fill Materials

When selecting soils to be imported to a construction site the following procedure is typical:

1) Survey the local soil sources that could possibly be used.

2) Obtain soil samples from each source, and perform the necessary tests to classify the soil via either AASHTO or the UCS systems.

- The classification itself will often tell whether or not a given soil is suitable for an intended application. (Recall, for example, the AASHTO classification system.)
- Soils with large shrinkage ratios (SR) should be avoided, and also soils with high plasticity indices (PI) since they indicate a tendency to shrink/expand.
- **Organic matter which can decay should generally be avoided as fill material unless special precautions are taken.**

3) Once a soil is found to be suitable, for an intended application, perform the necessary moisture−density study.

4) If local codes/guidelines are not provided, a study would be needed to determine the minimum relative field compaction of the soil.

- Factors would be:
  - ♠ required shear strength of the soil; and
  - ♠ maximum allowable settlements under design loads.

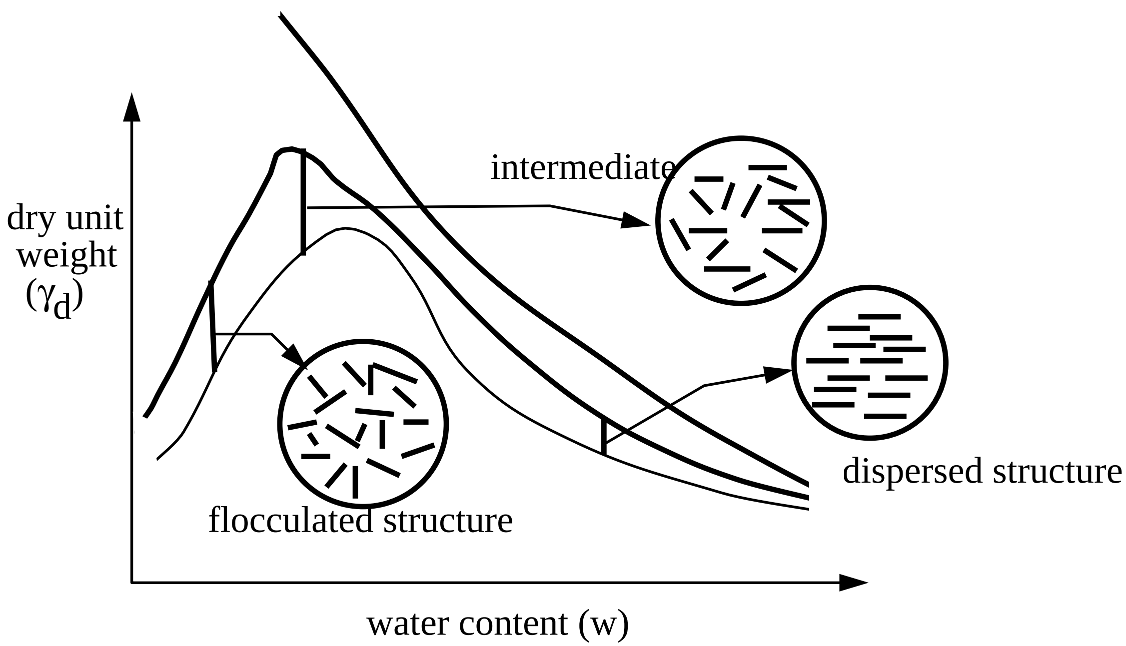
D. Strength of Compacted, Cohesive Soils

- When soils are compacted at high water contents, **dispersed** structure is formed, with the flaky, plate−like soil grains aligningthemselves.

  ♠This can result in the compacted soils having reduced shear strengths.

- It is typically more desireable to have compacted cohesive soils achieve **flocculated** structures, since the soil's shear strength will be somewhat higher.

  ♠This is typically achieved by compacting a soil on the dry side of the optimum water content..



• Increasing the water content at which soil is compacted:

a) increases the likelihood of obtaining dispersed soil structure with reduced shear strengths.
b) increases the pore pressure in the soil, decreasing the short term shear strength.

E. Compaction of Soils in the Field

1. Getting the Job Done

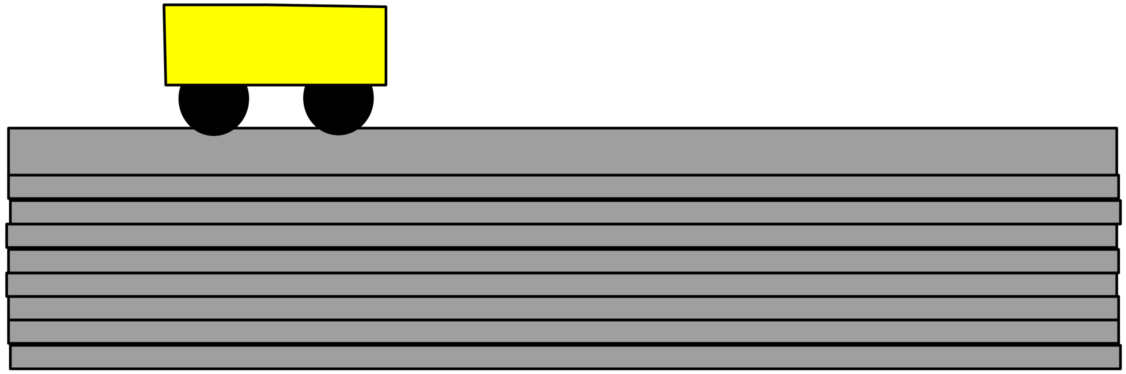
• In the field, fill soils are typically imported to a site and applied to the existing grade level in layers which are called **lifts**.

• When a lift of soil is first placed, it will be very loose. Special compaction equipment is then used to compact this lift of soil:

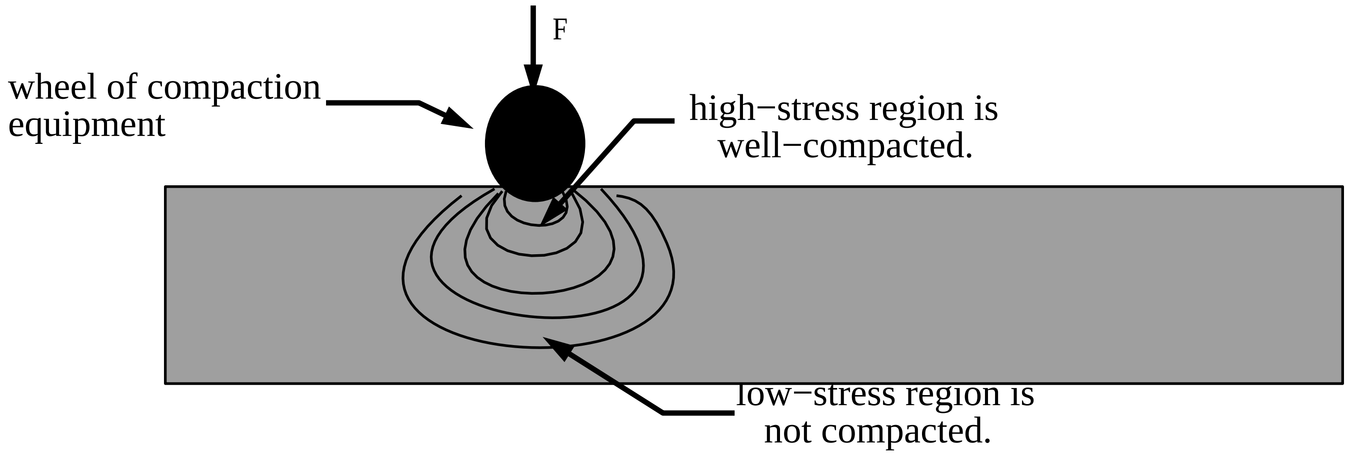
Equipment Type	Soil Type
smooth−wheeled rollers:	sands & gravels
pneumatic rubber−tired rollers:	silts & clays
sheepsfoot rollers:	silts & clays
vibratory rollers:	sands & gravels
vibratory tampers:	sands & gravels

• To increase the compactive energy applied to the soil in the field:

a) increase the mass/weight of the compaction equipment;
b) decrease the thickness of lift thicknesses; and
c) increase the number of machinery passes.



- If lift thicknesses are too large, then the following will occur:
  - ♠ Soil at the top of the lift will be well−compacted;
  - ♠ Soil at the bottom of the lift will not be compacted;
  - ♠ This is sometimes called the Oreo−Cookie effect.



- For most compaction equipment, lift thicknesses should typically be on the order of six inches (6") or 15cm.

- Water contents must be closely monitored during field compaction.

  - If the soil gets too wet, it will be impossible to compact.
  - If the soil is too dry, it will be difficult to compact.
  - Since it is easier to add than remove water, it is best to maintain water contents on the dry side of optimal during field compaction.

2. Quality Assurance/Monitoring

- Engineers (or technicians) working either for the earth work contractor or the owner of the facility are usually onsite to monitor the compaction process.

  - The fill is sampled at random, and dry unit weights of the compacted soil are measured to make sure that they are exceed the minimum acceptable values.
  - Sampling rates:
    - ♠ For large fills: about 1 sampling per (1000−2000 m^2) per lift.
    - ♠ For small fills (< $1000m^2$): 2 or 3 samples per lift
    - ♠ Thus for a fill with lateral dimensions of 100m by 100m, one would expect to take 5 − 10 sample measurements per lift.

- For each field sample:
  - The dry unit weight of the soil is measured;
  - The water content of the soil is measured.
  - This is done almost instantaneously using **nuclear density probes.**
- To assure that the entire fill is compacted above the minimal density requirements:
  - The average density measured should be well above the minimum required.
  - Statistical methods can be used for this purpose.
- Engineers/technicians monitoring the compaction process should look for systematic errors:
  - Are specific regions of the fill being sytematically undercompacted for some reason?

F. The importance of field compaction

- It is often easy to think that cutting corners on compaction can be done with no obvious ill effects.
- This is not true!
- Many of the annoyances we observe in our paved infrastructure can be attributed at least in part to improper soil compaction:
  - Pot holes, cracked/broken pavements and broken pipelines are some very common examples.