The unit weight of soil in the field can be measured using a sand cone test or a nuclear density gauge. Measurement using a nuclear device is quicker, and is therefore the preferred method in most cases. Sand cone tests are still performed, however, (if the nuclear gauge is suspected to be out of calibration, for example) and engineers should understand how they work.

In the sand cone test, a metal plate is placed on the soil to be measured. The metal plate has a circular hole in its middle, and the technician removes soil from the region immediately below the hole. This soil is usually placed in a sealed container for future weighing and moisture content determination.

The technician weighs the sand cone, places it cone-side down over the hole in the plate, and opens a valve allowing the sand to flow from the bottle into the hole and cone. When the sand has stopped flowing, the technician shuts the valve and weighs the sand cone again. He or she then calculates the weight of sand in the hole and then the volume of the hole as follows.

\[ W_{\text{sand in hole}} = W_{\text{sand cone initially}} - W_{\text{sand cone final}} - W_{\text{sand in cone + plate}} \]

\[ V_{\text{hole}} = \frac{W_{\text{sand in hole}}}{\gamma_{\text{sand}}} \]

The weight of the sand in the cone + plate are measured in the lab ahead of time; and the unit weight of the sand is provided by the vendor (and can be measured in the lab also). The sand cone test is summarized in Figure 1 below.

![Sand Cone Test Diagram](image-url)

**Figure 1.** Sand Cone
Example. Calculate the % compaction of a soil using the data below.

Given: \( \gamma_{\text{sand}} = 98 \text{pcf} \)
\( W_{\text{sand in cone + plate}} = 0.76 \text{ lb} \)
\( \gamma_{d, \text{max}} = 118 \text{ pcf} \) (from a modified Proctor test)

Measured in the field: \( W_{\text{soil}} = 1.35 \text{ lb} \)
\( W_{\text{cone initially}} = 3.26 \text{ lb} \)
\( W_{\text{cone final}} = 1.42 \text{ lb} \)
\( \omega_{\text{soil}} = 16\% \)

Calculations:
\( W_{\text{sand in hole}} = W_{\text{sand cone initially}} - W_{\text{sand cone final}} - W_{\text{sand in cone + plate}} \)
\( W_{\text{sand in hole}} = 3.26 \text{ lb} - 1.42 \text{ lb} - 0.76 \text{ lb} = 1.08 \text{ lb} \)

\[ V_{\text{hole}} = \frac{W_{\text{sand in hole}}}{\gamma_{\text{sand}}} = \frac{1.08 \text{ lb}}{98 \text{ pcf}} = 0.0110 \text{ cf} \]

\[ \gamma_{\text{soil}} = \frac{W_{\text{soil}}}{V_{\text{hole}}} = \frac{1.35 \text{ lb}}{0.0110 \text{ cf}} = 123 \text{ pcf} \]

\[ \gamma_{d} = \frac{\gamma}{1 + \omega} = \frac{123 \text{ pcf}}{1 + 0.16} = 106 \text{ pcf} \]

\[ R = \% \text{ compaction} = \frac{\gamma_{d}}{\gamma_{d, \text{max}}}, \quad R = 90\% \]