14

Determination of Field Unit Weight of Compaction by Sand Cone Method

14.1 Introduction

In the field during soil compaction it is sometimes necessary to check the compacted dry unit weight of soil and compare it with the specifications drawn up for the construction. One of the simplest methods of determining the field unit weight of compaction is by the sand cone method, which will be described in this chapter.

14.2 Equipment

1. Sand cone apparatus consisting of a one-gallon glass or plastic bottle with a metal cone attached to it
2. Base plate
3. One-gallon can with cap
4. Tools to dig a small hole in the field
5. Balance with minimum readability of 0.01 lb
6. 20-30 Ottawa sand
7. Proctor compaction mold without attached extension
8. Steel straightedge

Figure 14.1 shows the assembly of the equipment necessary for the determination of the field unit weight. Figure 14.2 is a schematic diagram showing the dimensions of the metal cone (see item 1).

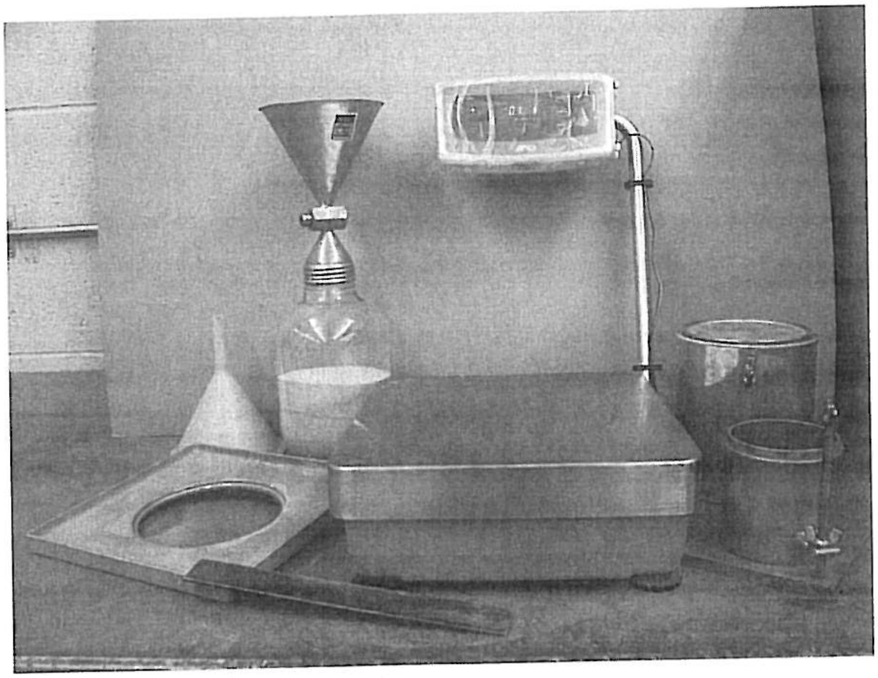

Figure 14.1. Assembly of equipment necessary for determination of field unit weight of compaction.

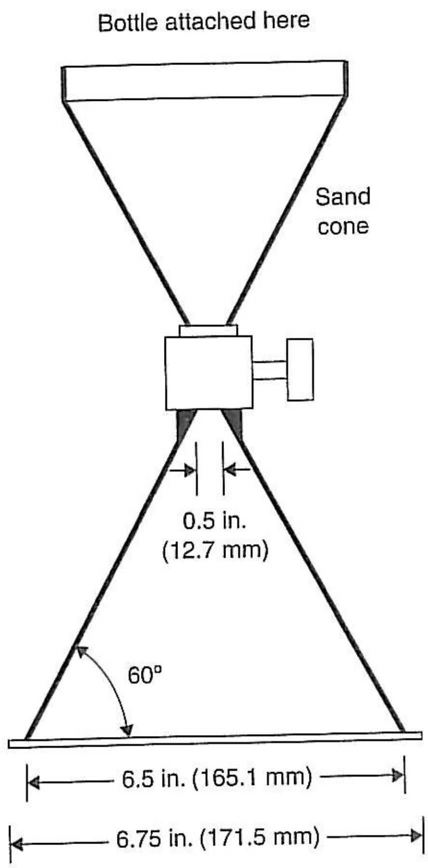

Figure 14.2. Dimensions of metal cone.

14.3 Procedure—Laboratory Work

Determination of Dry Unit Weight of 20-30 Ottawa Sand

1. Determine the weight of the Proctor compaction mold, W_1.
2. Using a spoon, fill the compaction mold with 20-30 Ottawa sand. Avoid any vibration or other means of compaction of the sand poured into the mold. When the mold is full, strike off the top of the mold with the steel straightedge. Determine the weight of the mold and sand, W_2.

Calibration of Cone

3. We need to determine the weight of the Ottawa sand that is required to fill the cone. This can be done by filling the one-gallon bottle with Ottawa sand. Determine the weight of the bottle + cone + sand, W_3. Close the valve of the cone, which is attached to the bottle. Place the base plate on a flat surface. Turn the bottle with the cone attached to it upside down and place the open mouth of the cone in the center hole of the base plate (Fig. 14.3). Open the cone valve. Sand will flow out of the bottle and gradually fill the cone. When the cone is filled with sand, the flow of sand from the bottle will stop.

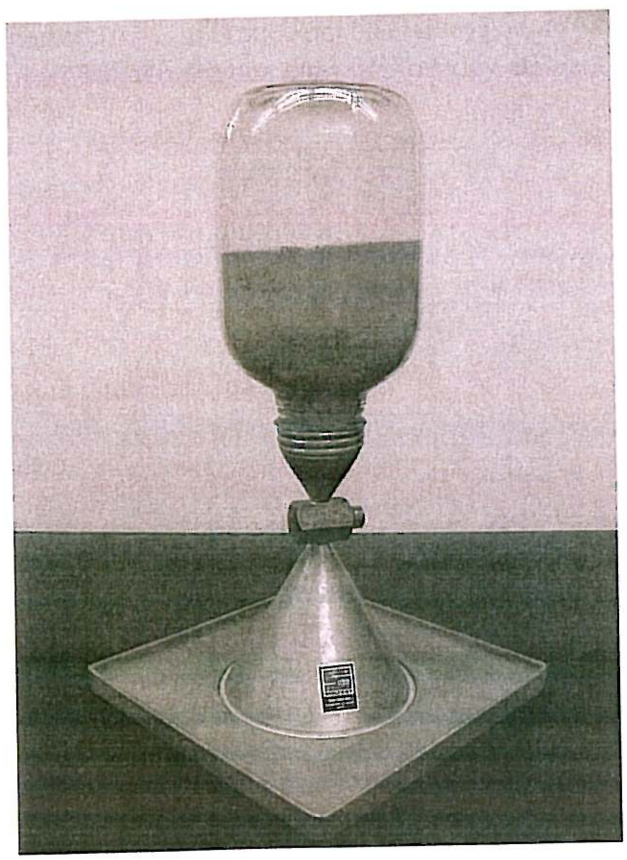

Figure 14.3. Calibration of sand cone.

Close the cone valve. Remove the bottle and cone combination from the base plate and determine its weight, W_4.

Preparation for Field Work

4. Determine the weight of the gallon can without the cap, W_5.
5. Fill the one-gallon bottle (with the sand cone attached to it) with sand. Close the valve of the cone. Determine the weight of the bottle + cone + sand, W_6.

14.4 Procedure—Field Work

6. Now proceed to the field with the bottle and the cone attached to it (filled with Ottawa sand—Step 5), the base plate, the digging tools, and the one-gallon can with its cap.
7. Place the base plate on a level ground in the field. Under the center hole of the base plate, dig a hole in the ground using the digging tools. The volume of the hole should be smaller than the volume of the sand in the bottle minus the volume of the cone.
8. Remove *all* the loose soil from the hole and put it in the gallon can. Close the cap tightly so as not to lose any moisture. Be careful not to move the base plate.
9. Turn the gallon bottle filled with sand, with cone attached to it, upside down and place it on the center of the base plate. Open the valve of the cone. Sand will flow from the bottle to fill the hole in the ground and the cone (Fig. 14.4). When the flow of sand from the bottle stops, close the valve of the cone and remove it.

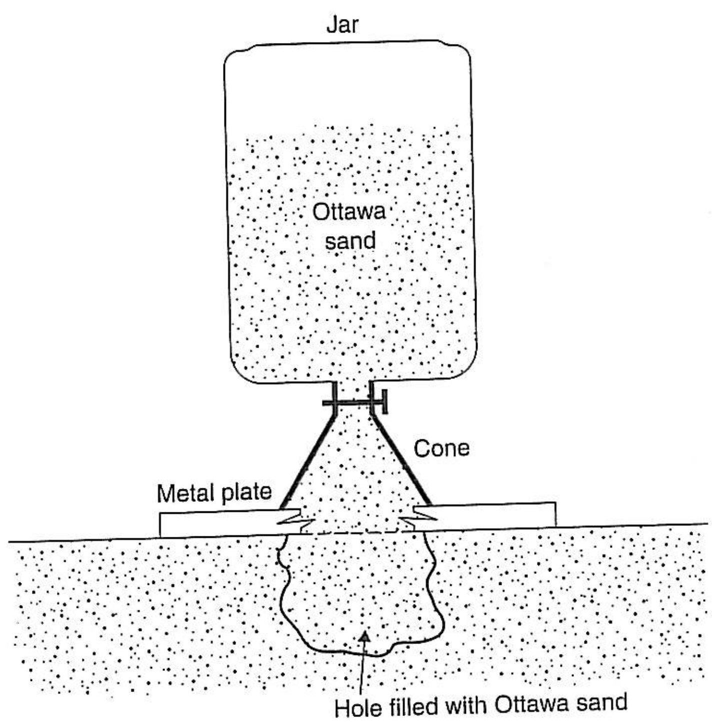

Figure 14.4. Ottawa sand filling hole in ground.

10. Bring all the equipment back to the laboratory. Determine the weight of the gallon can + moist soil from the field (without the cap), W_7. Also determine the weight of the bottle + can + sand after use, W_8.
11. Put the gallon can with the moist soil in the oven to dry to a constant weight. Determine the weight of the can without the cap + oven-dry soil, W_9.

14.5 Calculations

A sample calculation to determine the dry unit weight of field compaction by the sand cone method is given in Table 14.1. With reference to the table, the following calculations are required.

1. Calculate the dry unit weight of sand (line 4),

$$\gamma_{d(\text{sand})} = \frac{W_2 - W_1}{V_1} = \frac{\text{line 2} - \text{line 1}}{\text{line 3}} \tag{14.1}$$

   where V_1 is the volume of the Proctor mold.
2. Calculate the weight of sand to fill the cone (line 7),

$$W_c = W_4 - W_3 = \text{line 6} - \text{line 5} \tag{14.2}$$

3. Calculate the volume of the hole in the field (line 10),

$$V_2 = \frac{W_6 - W_8 - W_c}{\gamma_{d(\text{sand})}} = \frac{\text{line 8} - \text{line 9} - \text{line 7}}{\text{line 4}} \tag{14.3}$$

4. Calculate the moist field unit weight (line 14),

$$\gamma = \frac{W_7 - W_5}{V_2} - \frac{\text{line 12} - \text{line 11}}{\text{line 10}} \tag{14.4}$$

5. Calculate the moisture content in the field (line 15),

$$w\,(\%) = \frac{W_7 - W_9}{W_9 - W_5} \times 100 = \frac{\text{line 12} - \text{line 13}}{\text{line 13} - \text{line 11}} \times 100 \tag{14.5}$$

6. Calculate the dry unit weight in the field (line 16),

$$\gamma_d = \frac{\gamma}{1 + (w\,(\%)/100)} = \frac{\text{line 14}}{1 + (\text{line 15}/100)} \tag{14.6}$$

14.6 General Comments

There are at least two other methods to determine the field unit weight of compaction. They are the *rubber balloon method* (ASTM D-2167) and use of the *nuclear density meter.* The procedure for the rubber balloon method is similar to the sand cone method in that a test hole is made, the moist weight of the soil is removed from the hole, and its moisture

Table 14.1. Field Unit Weight—Sand Cone Method

Location *Madeira Canyon/Provence*

Tested by ________ Date ________

Item	Quantity
Calibration of Unit Weight of Ottawa Sand	
1. Weight of Proctor mold, W_1	10.35 lb
2. Weight of Proctor mold + sand, W_2	13.66 lb
3. Volume of mold, V_1	1/30 ft³
4. Dry unit weight, $\gamma_{d(\text{sand})} = \frac{W_2 - W_1}{V_1}$	99.3 lb/ft³
Calibration Cone	
5. Weight of bottle + cone + sand (before use), W_3	15.17 lb
6. Weight of bottle + cone + sand (after use), W_4	14.09 lb
7. Weight of sand to fill cone, $W_c = W_4 - W_3$	1.08 lb
Results from Field Tests	
8. Weight of bottle + cone + sand (before use), W_6	15.42 lb
9. Weight of bottle + cone + sand (after use), W_8	11.74 lb
10. Volume of hole, $V_2 = \frac{W_6 - W_8 - W_c}{\gamma_{d(\text{sand})}}$	0.0262 ft³
11. Weight of gallon can, W_5	0.82 lb
12. Weight of gallon can + moist soil, W_7	3.92 lb
13. Weight of gallon can + dry soil, W_9	3.65 lb
14. Moist unit weight of soil in field, $\gamma = \frac{W_7 - W_5}{V_2}$	118.32 lb/ft³
15. Moisture content in field, $w\,(\%) = \frac{W_7 - W_9}{W_9 - W_5} \times 100$	9.54%
16. Dry unit weight in field, $\gamma_{d(\text{sand})} = \frac{\gamma}{1+(w\,(\%)/100)}$	108.11 lb/ft³

content is determined. However, the volume of the hole is determined by introducing into it a rubber balloon filled with water from a calibrated vessel, from which the volume can be read directly.

Nuclear density meters are now used in some large projects to determine the compacted dry unit weight of a soil (ASTM D-2922). The density meters operate either in drilled holes or from the ground surface. The instrument measures the weight of the wet soil per unit volume and also the weight of the water present in a volume of soil. The dry unit weight of compacted soil can be determined by subtracting the weight of the water from the moist unit weight of the soil.

Sand Cone Method

Field Unit Weight

Location ______________________________

Tested by ______________________________ Date ________

Item	Quantity
Calibration of Unit Weight of Ottawa Sand	
1. Weight of Proctor mold, W_1	
2. Weight of Proctor mold + sand, W_2	
3. Volume of mold, V_1	
4. Dry unit weight, $\gamma_{d\,(\text{sand})} = \dfrac{W_2 - W_1}{V_1}$	
Calibration Cone	
5. Weight of bottle + cone + sand (before use), W_3	
6. Weight of bottle + cone + sand (after use), W_4	
7. Weight of sand to fill cone, $W_c = W_4 - W_3$	
Results from Field Tests	
8. Weight of bottle + cone + sand (before use), W_6	
9. Weight of bottle + cone + sand (after use), W_8	
10. Volume of hole, $V_2 = \dfrac{W_6 - W_8 - W_c}{\gamma_{d\,(\text{sand})}}$	
11. Weight of gallon can, W_5	
12. Weight of gallon can + moist soil, W_7	
13. Weight of gallon can + dry soil, W_9	
14. Moist unit weight of soil in field, $\gamma = \dfrac{W_7 - W_5}{V_2}$	
15. Moisture content in field, $w\,(\%) = \dfrac{W_7 - W_9}{W_9 - W_5} \times 100$	
16. Dry unit weight in field, $\gamma_{d\,(\text{sand})} = \dfrac{\gamma}{1 + (w\,(\%)/100)}$	