1.0 SCOPE

This method describes the procedure for using the balloon method density equipment in the determination of in-place field densities of fine grained soils, sand-base cement stabilized mixtures, asphalt or aggregate contaminated subgrades and granular base courses.

2.0 EQUIPMENT

Volumeasure or Volutester and accessory equipment

- Sieves: 20,000 Fm and 5,000 Fm
- mixing spoon
- tablespoon
- garden trowel
- square-nosed shovel
- plastic jars and lids
- paint brush
- pick
- drying pans
- wash basin
- chisel
- hammer

Data Sheet: Field Density Test, MAT 6-23.

3.0 PROCEDURE

3.1 Equipment Preparation

1. Assemble the Volumeasure or Volutester as directed in the applicable manufacturers equipment manual.

2. Calibrate the pressure gauge as directed in the Supplement section of this test method (ATT-8S).

   NOTE: The calibration is required at the start of the job, whenever the calibration is in doubt or after the balloon is changed.

3. Obtain the Final Pressure Reading from the last pressure gauge calibration and record it in line "H".

4. Label and tare a density jar including the lid. Record the jar number and the tare weight in line "P" of the data sheet as shown in Figure 1.

5. The data sheet has 5 vertical columns for recording 5 tests per sheet. When more than one test will be performed in the field, label and tare the required number of plastic density jars and record the weights and numbers of the containers in line "P", one per vertical column.
3.2 Volume of Hole

If a fine grained soil sample or a sand-base CSBC sample has less than 7% of the total sample weight retained on the 5 000 Fm sieve, the volume of the test hole must be at least 1150 cm\(^3\). When testing contaminated subgrade and base courses, use Table 1 to determine the volume of the density hole, according to the topsize of the aggregate being tested.

### Table 1: Minimum Test Hole Volumes (Based on Maximum Particle Size)

<table>
<thead>
<tr>
<th>Maximum Particle Size (Fm)</th>
<th>Minimum Test Hole Volume (cm(^3))</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 000</td>
<td>1 150</td>
</tr>
<tr>
<td>10 000</td>
<td>1 350</td>
</tr>
<tr>
<td>12 500</td>
<td>1 450</td>
</tr>
<tr>
<td>16 000</td>
<td>1 600</td>
</tr>
<tr>
<td>20 000</td>
<td>1 750</td>
</tr>
<tr>
<td>25 000</td>
<td>1 950</td>
</tr>
<tr>
<td>40 000</td>
<td>3 050</td>
</tr>
</tbody>
</table>

1. Select the test location and record the station, location and depth below grade (or base course lift) and date in the appropriate lines of the heading portion of the data sheet, in the column corresponding to the number of the density jar to be used for the test.

2. Use the square nosed shovel and the garden trowel to remove soil until a representative moisture content is reached from an area larger than the density plate. Typically a 50 mm depth should be removed.

3. Level the surface with the square-nosed shovel.

4. Place the density plate on the surface, press down and slide the plate.

5. Remove the plate and trim the high spots with the garden trowel.

6. Repeat steps 4 and 5 until the plate sits level and flat on the prepared site. This is very important at the point where the soil meets the edges of the hole in the density plate.

7. Insert the Volumeasure or Volutester in the recess of the density plate and secure it in place by tightening the two clamping devices. Mark the density plate and base plate so that the two can be realigned in the same position when taking the final reading.

8. Open the air release valve and insert the pump in the pressure position.

9. Hold the instrument snugly on the surface with one hand, and pump with the other until a pressure dial reading of 3.0 p.s.i. is reached.

10. Close the air release valve. When the water level is stationary, lower your eye parallel to the surface of the water. Read the bottom of the meniscus and record the Initial Scale Reading at 3.0 Pressure in line "0".
## Field Density Tests

### Site Location and Visual Description

<table>
<thead>
<tr>
<th>Station</th>
<th>Location</th>
<th>Depth Below Grade (Range) m</th>
<th>Date Tested</th>
<th>Hand Method Soils Classification</th>
<th>Estimated Moisture Content %</th>
<th>Estimated Percent Compaction %</th>
</tr>
</thead>
<tbody>
<tr>
<td>10+816</td>
<td>1.5 m RT.</td>
<td>0.270-0.460</td>
<td>95.08.06</td>
<td>C1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Volume of Hole (Sand Method)

| A | Weight of Sand + Container Before Test g |
| B | Weight of Sand + Container After Test g |
| C | Weight of Sand in Funnel and Hole of Density Pan g |
| D | Weight of Sand Used A - B - C g |
| E | Unit Weight of Calibrated Sand g / cm³ |
| F | Volume of Hole D / E cm³ |

### Volume of Hole (Ballon Method)

| G | Initial Scale Reading at 3.0 Pressure cm³ |
| H | Final Pressure Reading (from Gauge Calibration) |
| I | Final Scale Reading cm³ |
| J | Final Actual Reading (Cylinder Calibration Chart) cm³ |
| K | Initial Actual Reading (Cylinder Calibration Chart) cm³ |
| L | Volume of Hole J - K cm³ |

### Wet Density

| M | Weight of Wet Soil + Rocks + Container g |
| N | Weight of Rocks from Hole g |
| O | Weight of Wet Soil + Container M - N g |
| P | Weight of Container (No. ___) g |
| Q | Weight of Wet Soil O - P g |
| R | Volume of Rocks from Hole N / 2.6 cm³ |
| S | Corrected Volume F - R or L - R cm³ |
| T | Wet Density 1000 Q / S or 1000 Q / F kg / m³ |

### Moisture Content and Dry Density

| U | Weight of Wet Soil + Pan g |
| V | Weight of Dry Soil + Pan g |
| W | Weight of Pan (No. ___) g |
| X | Weight of Water U - V g |
| Y | Weight of Dry Soil V - W g |
| Z | Moisture Content 100 X / Y % |
| AA | Dry Density 100 T / (100 + Z) kg / m³ |

### Field Density to Maximum Dry Density Correlation

| BB | Moisture-Density Relation Curve Number |
| CC | Optimum Moisture Content % |
| DD | Maximum Dry Density kg / m³ |
| EE | Percent Compaction 100 AA / DD % |

### Remarks

- Site 1: Dark Brown Sandy Clay; Material from B.P. #5
- Site 2
- Site 3
- Site 4
- Site 5

### Compaction and Construction Equipment

- 2-1.5 m Sheepfoot, 2-Blades, 1-Cat & Scraper

**Figure 1**
NOTE: Always read the water level the same way each time, that is, the bottom of the meniscus.

11. Remove the pump and insert it in the vacuum position.

12. Open the air release valve; pump the balloon up into the graduated cylinder and close the air release valve.

13. Loosen the clamping devices and turn them out of the way.

14. Remove the Volumeasure or Volutester from the density plate. Leave the density plate in place.

15. Use the excavating utensils to dig the density hole as follows:

   a) Use the trowel or chisel and hammer to shape a circle approximately 6 mm inside the density plate opening. Hold the trowel or chisel vertically. Where rocks are firmly seated, they may have to be pried loose.

   b) Use the trowel or chisel and mixing spoon to loosen the soil, working outward and upward from the middle of the circle to the edge shaped in (a).

   c) Use the mixing spoon to transfer the loosened soil and rocks into the empty labelled jar, taking care not to lose any material. Position the jar over the density plate when transferring soil, so that spilled material will fall on the plate and can be retrieved.

   d) Place the lid on the density jar between transfers to prevent moisture loss through evaporation.

   e) Use the paint brush to brush material on the density plate into the hole and brush the sides of the hole to remove loosened material to the bottom.

   f) Repeat steps (b) to (e) until the walls of the excavation are relatively smooth and the volume of the hole meets the minimum required size shown in Table 1.

   NOTE: Never pry the digging tools against the edge of the hole. This will cause the sides of the hole to distort, giving an erroneous volume.

16. Place the Volumeasure or Volutester in the recess on the density plate and secure it in place by tightening the two clamp devices. The mark on the density plate should match with the line on the base plate.

17. Insert the pump in the pressure position and open the air release valve.

18. Allow the balloon to fall into the hole until the water level is stationary.

20. Pump until the pressure dial reading reaches the value recorded as Final Pressure Reading (line "H").

21. Close the air release valve and when the water level remains stationary, lower your eye parallel to the surface of the water. Read the bottom of the meniscus and record as Final Scale Reading (line "I").

22. Reverse the pump, open the valve and pump the balloon up into the graduated cylinder.

23. Loosen the clamping devices and remove the apparatus from the hole.

24. Replace all the testing equipment in the equipment box.

25. Use the Final Scale Reading (line "I") and the Cylinder Calibration Chart to obtain the Final Actual Reading (line "J"). Ensure the cylinder number on the chart matches the number on the cylinder.

26. Use the Initial Scale Reading (line "G") and the Cylinder’s Calibration Chart to obtain the Initial Actual Reading (line "K").

27. Calculate the volume of the hole in cm$^3$ (line "L") as follows:

\[ Volume \text{ of Hole (cm}^3) = \frac{Final \text{ Actual Reading \& Initial Actual Reading}}{3} \]

Where the cylinder is graduated in cubic feet (1/10 000 ft$^3$ increments) determine the volume in cubic centimetres using the formula:

\[ Volume \text{ (cm}^3) = Volume (ft^3) \times 28317 \text{ cm}^3/ft^3 \]

3.3 **Soils Classification**

1. Use the garden trowel to excavate a strip of soil from along the side from the top to the bottom of the density hole.

2. Identify the soil as directed in ATT-29, SOILS IDENTIFICATION, Hand Method.

3. In the Remarks section of the form on the numbered line corresponding to the vertical test column number being used, record:

   a) The results of the hand method test.

   b) A description of the soil in common terms, e.g., dark brown sandy clay with some small white pebbles.

   c) A description of the origin of the soil, e.g., common excavation at station 21+090.
d) Evidence of stratification of any kind, e.g., moisture content, soil type, or density.

e) Problems with the density test, e.g., rocks, broken balloons, etc.

4. In the Visual Description portion of the form, on the numbered line corresponding to the test column number being used, enter:

a) Based on the hand test results, record the unified soil type in the Hand Method Soils Identification line.

b) Make an estimation of the moisture content of the in place soil expressed as a relationship between the actual moisture content and the estimated optimum moisture content based on the plastic limit test, e.g., 1% wet, 2% dry, etc. Enter the results on the Estimated Moisture Content line.

c) Based on the ease with which the hole was excavated and knowing the relative moisture content of the soil, estimate the percent compaction of the in-place soil. Record the value on the Estimated % Compaction line.

Make this estimation by mentally comparing the ease with which the hole was dug to the ease with which each run of the Moisture-Density Relation test could be cleaned from the mould. Attempt to mentally match the in-place moisture content with the corresponding Moisture-Density Relation test run number.

3.4 Wet Density

Determine the density of the test site using one of the following methods:

a) Proceed with Section 3.4.1 if testing -5 000 Fm materials containing less than 7% oversize. These materials include fine grained soils from grading and subgrade preparation projects and sand-base cement stabilized mixtures.

b) Proceed with Section 3.4.2 if testing -5 000 Fm materials containing more than 7% retained on the 5 000 Fm sieve, such as asphalt or aggregate contaminated subgrade.

c) Proceed with Section 3.4.2 if testing +5 000 Fm materials, such as granular base course mixtures.

3.4.1 Minus 5 000 Fm Material

The following procedure is performed on soils containing less than 7% retained on the 5 000 Fm sieve.
1. Weigh the density jar, contents and lid. Record as Wt. of Wet Soil + Rocks + Container (line "M").

2. Calculate the total weight of the wet sample as follows:

\[ \text{Wt. of Wet Soil & Rocks} + \text{Wt. of Wet Soil, Rocks & Container} + \text{Wt. of Container} \]

3. Dump the contents of the jar into a wash basin.

4. If the sample contains any rock, separate the rocks larger than 5 000 Fm in diameter as follows:
   a) visually, if the sample is composed mostly of clay or silt and is too wet to be sieved, or
   b) by sieving the entire sample through the 5 000 Fm sieve, if the sample is sandy.

5. Weigh the material retained on the 5 000 Fm sieve in a tared container.

6. Calculate the percent retained on the 5 000 Fm sieve using the formula:

\[ \% \text{Retained 5000 Fm Sieve} = \left( \frac{\text{Wt. Retained on 5000 Fm Sieve}}{\text{Wt. of Wet Soil & Rocks}} \right) \times 100\% \]

7. If the result is less than 7%, proceed with step 8 below. If the sample has more than 7% oversize, add the +5 000 Fm rocks to the sample and proceed with Section 3.4.2, step 3.

8. Soak the +5 000 Fm rocks in water and wash the rocks until they are clean. If the rocks are slightly dirty, just brush the rocks until clean.

9. Dry the washed rocks to a constant weight. Record the Dry Weight of Rocks from Hole in line "N". Discard the +5 000 Fm rocks.

10. Calculate the volume of the rocks in cm³ encountered in the density sample (line "R"), knowing the average density of rock (2.6 g/cm³) as follows:

\[ \text{Vol. of } \%5000 \text{ Fm Rocks (cm³)} = \frac{\text{Weight of } \%5000 \text{ Fm Rocks}}{2.6} \]

11. If the density soil did not contain rocks larger than 5 000 Fm:
   a) Transfer the Volume of Hole (line "L") to the Corrected Volume line (line "S").
   b) Transfer the Wt. of Wet Soil + Rocks + Container (line "M") to Wt. of Wet Soil + Container line (line "0").
   c) Proceed to step 14.
12. Calculate the Volume of the -5 000 Fm Soil in cm³ (line "S") as follows:

\[
\text{Volume of -5 000 Fm Soil (cm}^3) = \text{Volume of Hole} \times \text{Volume of } +5 000 \text{ Fm Rocks}
\]

13. Determine the Weight of Wet Soil and Tare (line "0") using the formula:

\[
\text{Wt. of Wet Soil \& Tare} = \text{Wt. of Wet Soil, Tare \& Rocks} \times \text{Wt. of } +5 000 \text{ Fm Rocks}
\]

14. Calculate the Weight of -5 000 Fm Wet Soil (line "Q") as follows:

\[
\text{Wt. of Wet Soil (g)} = \text{Wt. of Wet Soil \& Tare} \times \text{Wt. of Tare}
\]

15. Calculate the Wet Density in kg/m³ (line "T") of the -5 000 Fm material using the formula:

\[
\text{Wet Density (kg/m}^3) = \frac{\text{Wt. of Wet Soil}}{\text{Volume of Soil}} \times 1000
\]

### 3.4.2 Contaminated Subgrade or Granular Base Course

1. Weigh the density jar, contents and lid. Record as Wt. of Wet Soil + Rocks + Container (line "M").

2. Calculate the weight of wet sample as follows:

\[
\text{Wt. of Wet Soil \& Rocks (g)} = \text{Wt. of Wet Soil, Rocks \& Container} \times \text{Wt. of Container}
\]

3. Sieve the entire sample through a 20 000 Fm sieve into a tared large mixing pan.

4. Weigh the material passing the 20 000 Fm sieve.

5. Calculate the percent passing the 20 000 Fm sieve using the formula:

\[
\% \text{ Passing 20 000 Fm Sieve} = \frac{\text{Wt. Passing 20 000 Fm Sieve}}{\text{Wt. of Wet Soil \& Rocks}} \times 100\%
\]

6. If the percent passing the 20 000 Fm sieve is at least 70%, proceed with step 7, below. If the result is lower than 70%, discontinue the field density procedure.

7. Soak the +20 000 Fm rocks in water and wash the rocks until they are clean. If the rocks are slightly dirty, just brush the rocks until clean.

8. Dry the washed rocks to a constant weight. Weigh and record as Wt. of Rocks from Hole (line "N"). Discard the +20 000 Fm rocks.
9. Calculate the volume in cm³ of the +20 000 Fm rocks encountered in the density sample (line "R"), knowing the average density of rock (2.6 g/cm³) as follows:

\[
\text{Vol. of } +20 \ 000 \ Fm \ Rocks \ (cm^3) \times \frac{\text{Weight of } +20 \ 000 \ Fm \ Rocks}{2.6}
\]

10. If the density soil did not contain rocks larger than 20 000 Fm:
   a) Transfer the Volume of Hole (line "L") to the Corrected Volume line (line "S").
   b) Transfer the Wt. of Wet Soil + Rocks + Container (line "M") to Wt. of Wet Soil + Container line (line "O").
   c) Proceed to step 13.

11. Calculate the volume in cm³ of the -20 000 Fm soil (line "S") as follows:

\[
\text{Volume of } & -20 \ 000 \ Fm \ Soil \ (cm^3) \div \text{Volume of Hole } \& \text{Volume of } +20 \ 000 \ Fm \ Rocks
\]

12. Determine the Weight of Wet Soil and Tare (line "0") using the formula:

\[
\text{Wt. of Wet Soil } \& \text{ Tare } \div \text{Wt. of Wet Soil, Tare } \& \text{Rocks } \& \text{Wt. of } +20 \ 000 \ Fm \ Rocks
\]

13. Calculate the Weight of Wet -20 000 Fm Soil (line "O") as follows:

\[
\text{Wt. of Wet Soil (g)} \div \text{Wt. of Wet Soil } \& \text{ Tare } \& \text{Wt. of Tare}
\]

14. Calculate the Wet Density in kg/m³ (line "T") of the -20 000 Fm material using the formula:

\[
\text{Wet Density (kg/m}^3) \div \text{Wt. of Wet Soil} \times 1000
\]

### 3.5 Moisture Content

1. Label and tare a container. Record the pan number and tare weight as Wt. of Pan (line "W").

2. A soon as the +5000 or +20 000 Fm rocks have been separated from the soil, select from the wash basin a representative moisture content sample as follows:

   a) If testing -5 000 Fm materials, obtain at least 250 g of fine grained soil, or take a 1000 g minimum sample of sand-base cement stabilized base course mixture.

   b) If testing +5 000 Fm material, take at least 500 g of contaminated subgrade, or obtain a 1000 g minimum sample of granular base course mixture.
3. Weigh the container and the wet soil and record as Wt. of Wet Soil + Pan (line "U").

4. Oven dry the fine grained soil or contaminated subgrade sample as directed in ATT-15, MOISTURE CONTENT, Oven Method as follows:
   a) Use the conventional oven set at 110EC ± 5EC to dry the sample to a constant weight (ATT-15, Part I, Soil and Aggregate), or
   b) Use the microwave oven to dry the sample for calibrated length of time for the particular soil type (ATT-15, Part IV, Microwave Method). Do not use the microwave to dry a sample contaminated with asphalt.

   Use the stove burners to dry the cement stabilized mixture or granular base course aggregate to a constant weight at a temperature not exceeding 150EC, as directed in ATT-14, MOISTURE CONTENT, Open Pan Method.

5. Weigh the hot dry sample and record as Wt. of Dry Sample + Pan (line "V").

6. Calculate the Weight of Water removed (line "X") as follows:
   \[
   \text{Wt. of Water (g)} = \frac{\text{Wt. of Wet Soil & Tare & Wt. of Dry Soil & Tare}}{\text{Wt. of Dry Sample + Pan}}
   \]

7. Determine the Weight of Dry Soil (line "Y") as follows:
   \[
   \text{Wt. of Dry Soil (g)} = \frac{\text{Wt. of Dry Soil & Tare}}{\text{Wt. of Tare}}
   \]

8. Calculate the Moisture Content in % (line "Z") of the soil using the formula:
   \[
   \text{Moisture Content (%) } = \frac{\text{Wt. of Water}}{\text{Wt. of Dry Soil}} \times 100\%
   \]

3.6 Dry Density

1. Calculate the Dry Density in kg/m³ (line "AA") of the soil using the formula:
   \[
   \text{Dry Density (kg/m³)} = \frac{\text{Wet Density}}{100 \% \text{Moisture Content in %}} \times 100\%
   \]
3.7 Percent Compaction

Compare the road dry density obtained on -5000 Fm materials with less than 7% oversize to the maximum dry density obtained using ATT-23 or ATT-20 (fine-grained soils), or ATT-22, Section 3.1 (sand-base cement stabilized base mixes). In these procedures the material is compacted in a 102 mm diameter mold and given 25 blows per lift.

Compare the road dry density obtained on +5000 Fm materials with less than 30% retained on the 10000 Fm sieve to the maximum dry density obtained using ATT-19 (asphalt or aggregate contaminated subgrade) and ATT-22, Section 3.2 (granular-base cement stabilized mixtures). In these procedures the material is compacted in a 152 mm diameter mold and given 56 blows per lift.

For all tests, the standard tamper (2.5 kg and 305 mm drop) is used and the material is compacted in 3 lifts.

1. Obtain from the corresponding Moisture-Density Relation test the Curve No., the Optimum Moisture Content and Maximum Dry Density and record the values in lines "BB", "CC" and "DD" respectively.

2. Determine the Percent Compaction (line "EE") using the formula:

\[
\text{Percent Compaction} \ (%) = \left( \frac{\text{Road Dry Density}}{\text{Maximum Dry Density}} \right) \times 100\%
\]

4.0 HINTS AND PRECAUTIONS

1. Do not allow unprocessed density test samples to sit in the sealed density jars for extended periods of time. With some soil types, a large amount of moisture from the sample will condense on the inside of the pail leading to erroneous moisture contents.

2. Ensure that all in-place densities correlate with actual conditions on the road. Never report to the contractor unrealistic or erroneous test results. In any case the section must be retested.

3. Do not press down too tightly on the volumeasure or volutester during either the initial or final readings, as this may disturb the soil. Hold the unit down just enough to prevent the unit from rising.

4. When taking the final cylinder reading on the density hole, pump the balloon to the calibrated pressure. If this pressure is exceeded when testing cement stabilized base courses and soft wet materials, the balloon will push the material and enlarge the hole.

5. Ensure the cylinder number matches the number on the calibration chart.