



# Florida Method of Test For Minimum Resistivity of Soil and Water

Designation: FM 5-551

## 1. SCOPE

- 1.1. This method covers the laboratory determination of resistivity of soil and water using a soil resistance meter and soil box. This method can also be used for the determination of the resistivity of coarse aggregate.

## 2. APPARATUS

- 2.1. Resistivity Meter: Any four-pin terminal, null-balancing ohmmeter or multimeter capable of four-wire resistance measurements from one to one million ohms, either analog or digital (as examples, MC Miller Model 400A, Nilsson Model 400, and Tinker & Razor Model SR-2).
- 2.2. Soil Box: Designed such that the cross-sectional area (cm<sup>2</sup>) of the sample, with the box filled level, divided by the distance (cm) between the pins is equal to 1 cm (for example, MC Miller catalog #37008).
- 2.3. Analytical Balance: An analytical balance with a capacity of 2,000 g or more and a resolution of 0.01 g or better.
- 2.4. Other: Test leads, thermometer, flat spatula, mixing spoon, large non-corrosive (glass, enamel coated, or stainless steel) bowl for mixing, 100-mL graduated cylinder, squeeze bottle for cleaning, and disposable nitrile gloves.

## 3. REAGENTS

- 3.1. Conductivity standard, sodium chloride, 250  $\mu$ S/cm (for example, Fisher Scientific catalog #22366032).
- 3.2. Distilled or deionized water (hereafter referred to as dilution water) with a resistivity of 200,000 ohm-cm or greater (Note 1).

**Note 1:** Deionized or distilled water stored in containers that are not airtight will over time absorb ions from acidic and basic gases in the atmosphere. Absorbed ions will lower the water's resistivity.

## 4. SAMPLES



- 4.1. **Soil Sampling:** Every effort should be made to obtain a soil sample that is representative of the bulk material. Use clean tools for gathering samples. Excessive moisture should be avoided by sampling from an area that has been allowed to gravity drain for a short time. If the soil sample has excess free moisture, place approximately 2.2 pounds (1 kg) of the soil on top of a suitable sieve and cover with plastic. Allow the sample to drain for a minimum of one hour. This step may be performed in the lab prior to testing.

If the soil sample is obtained from a heap that has been sitting for a long time, take the sample from a depth below the weathered surface where the moisture content appears to have stabilized. Avoid taking the sample from near a weathered soil surface. If sampling from ground level, remove top 12" (30 cm) to eliminate vegetation and debris before sampling. The soil sample may be taken from underneath standing water, but excess water should not be included with the sample. Soil samples should be placed in plastic or plastic-lined bags. Squeeze the bag down snugly around the sample and seal tightly to minimize contact with air.

- 4.2. **Water Sampling:** Water samples should be obtained from the main channel of rivers and streams. Sampling from other bodies of water such as lakes or ponds should be obtained from areas conducive to the capture of representative samples. Care should be observed not to sample from stagnant or pooled water unless a structure will be placed in such an area. Sample the water just below the surface to alleviate introduction of floating debris such as leaves, sticks, foam or trash. Fill the sample container to the top to eliminate introducing air into the sample and tightly seal the lid. The sample container shall be clean, at least 1 quart (1 liter) in size, and be either glass or plastic with an airtight lid. When possible, submerge the sample container below the surface of the water to completely fill and secure lid underwater.
- 4.3. **Transporting the Samples:** Maintain test samples in a cool dark area after sampling and during transport to the test facility.
- 4.4. **Storing Samples:** Store water samples at or below 39°F (4°C). Care should be taken to prevent freezing of the samples. Analysis of a soil sample "as received" is preferred. If, however, soil samples cannot be analyzed within ~ 1 day of receipt, dry soil samples per Section 5.2 and store dried soil at room temperature prior to analysis. Analyze samples within seven (7) days of collection.

## 5. SAMPLE PREPARATION

- 5.1. **Preparation of Water:**

Allow test sample to reach room temperature.

## 5.2. Preparation of Soil:

**Loose Granular Soils:** Spread the sample in a thin layer on a clean tray and dry under ambient conditions until a constant mass is achieved, or dry in an oven at no higher than 140°F (60°C) for approximately four hours or until a constant mass is achieved. Sieve through a No. 10 mesh (2 mm) sieve. Split the sample per AASHTO R76 to obtain 1,300 g ± 5%.

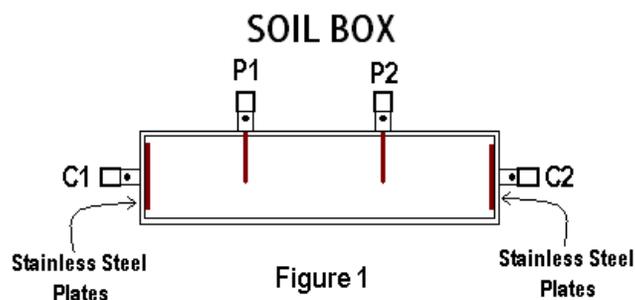
**Muck and Soils with Clay:** Spread the sample in a thin layer on a clean tray and dry under ambient conditions until a constant mass is achieved, or dry in an oven at no higher than 140°F (60°C) for approximately four hours or until a constant mass is achieved. Using a rawhide mallet or other suitable device pulverize the sample and sieve through a No. 10 mesh (2 mm) sieve. Split the sample per AASHTO R76 to obtain 1,300 g ± 5%.

## 5.3. Preparation of Coarse Aggregate:

Split the sample per AASHTO R 76 to obtain 1,300 g ± 5% and place aggregate in a suitable container. Add 1,200 mL of dilution water, cover and let stand for 24 hours at room temperature. Collect the leachate using clean equipment to avoid contamination.

## 6. TEST PROCEDURE

6.1 **Equipment Set-up:** Rinse the soil box, mixing bowl, and utensils with dilution water before starting and after completion of each test. Follow the manufacturer's instructions for properly connecting the test leads between the meter and the soil box. A standard soil box will have plates for application of current at both ends and a pair of electrode pins for reading potential evenly spaced between the plates (Figure 1).



6.1. Resistivity of Water:



- 6.1.1. Completely fill soil box with sample and connect it to the resistivity meter as described in the manufacturer's instruction manual and determine the resistivity and temperature of the sample in the soil box.
  - 6.1.2. Record the resistivity in ohm-cm and temperature in °C of the sample (for example, 3,000 ohm-cm @ 25°C).
- 6.2. Resistivity of "As-Received" Soil:
  - 6.2.1. If an "as-received" soil resistivity is requested, bring the soil sample and dilution water to room temperature. Place 1,000 g of "as-received" soil sample into a large bowl. Remove any debris (such as grass, roots, sticks or rocks, etc.). Fill the soil box to the top with the soil sample, taking care to fill any voids, and strike off any excess soil on the top of soil box. Connect the soil box to the resistivity meter as directed in the manufacturer's instruction manual and determine the resistivity and temperature of the sample in the soil box.
  - 6.2.2. Record the "as received" resistivity in ohm-cm and temperature in °C of the sample. Proceed to Section 6.3 to determine minimum resistivity.
- 6.3. Minimum Resistivity of "As-Received" or of Dried, Sieved Soil:
  - 6.3.1. Bring the soil sample and dilution water to room temperature. Place 1,000 g of soil sample into a large bowl.
  - 6.3.2. Add 100 mL of dilution water to the soil sample and mix thoroughly (Note 3).
  - 6.3.3. Fill the soil box to the top with the soil sample, taking care to fill any voids, and strike off any excess soil on the top of soil box. Connect the soil box to the resistivity meter as described in the manufacturer's instruction manual and determine the soil resistivity. Record the total volume of water used in mL and the resistivity in ohm-cm. Place soil sample back into mixing bowl (Note 4).
  - 6.3.4. Repeat steps 6.3.B and 6.3.C. The measured resistivity should decrease. When the resistivity of the soil sample begins to increase, record the total volume of water used in mL and the higher resistivity, and measure and record the temperature in °C of the sample in the soil box.
  - 6.3.5. Record the lowest resistivity obtained as the minimum resistivity in ohm-cm and the temperature in °C of the sample.



6.4. Resistivity of a Small Soil Sample:

6.4.1. If soil resistivity is requested for a sample that is less than 1,000 g, follow the steps in 6.3, and complete step 6.3.B. using increments of 10% dilution water instead of 100 mL (Note 4).

6.5. Resistivity of Coarse Aggregate:

6.5.1. Follow step 6.1

**Note 2:** “As received” sample is one that is left undisturbed in the container it was placed in the field until tested.

**Note 3:** In some soils, even a trace amount of salt will affect the resistivity reading. Avoid transferring salt from hands to sample. For soils that are difficult to mix, wear disposable gloves and mix soil with gloved hands.

**Note 4:** In many cases the minimum resistivity will occur after soil slurry is formed. As water is added, mix the soil slurry thoroughly and pour the water from the slurry into the box until the box is filled. If the water alone cannot fill the soil box, add enough of the remaining soil to completely fill the box.

**Note 5:** A sample size of less than 1,000 g is not appropriate for select backfill (FDOT material 092L).

7. BEST PRACTICES

7.1. Determine Resistivity of Conductivity Standard: Test the conductivity standard at least once per quarter and after the resistivity meter has undergone repair or replacement. Bring the conductivity standard to room temperature. Fill the soil box to the top with conductivity standard. Connect the soil box to the resistivity meter as described in the manufacturer’s instruction manual and verify that the conductivity standard resistivity is 4,000 ohm-cm @ 25°C. Refer to Table 1 for the conductivity of the standard for testing at temperatures between 20°C and 30°C. Record the conductivity standard resistivity in ohm-cm and the measurement temperature in °C. If the resistivity at measurement temperature is outside ±5%, troubleshoot and correct the problem, then re-test. Rinse the soil box well with dilution water after testing the conductivity standard.

**Table 1 Temperature-Dependence of a 250 µS/cm NaCl Conductivity Standard**

Temperature, °C	Resistivity, ohm-cm
20	4,440
21	4,350
22	4,250
23	4,170
24	4,080



25	4,000
26	3,920
27	3,850
28	3,780
29	3,710
30	3,650

## 8. PRECISION AND BIAS

- 8.1. Bias: Single-operator, single laboratory bias for this method was evaluated using a Nilsson Model 400 analog meter and a McMiller 280-mL soil box and repeated measures of two aqueous standards with resistivities at 25°C of 2,000 ohm-cm and 4,000 ohm-cm. After correcting for measurement temperatures in the range of 21°C to 23°C, average biases were -30 ohm-cm (-1.3%) for the 2,000 ohm-cm standard and 30 ohm-cm (0.7%) for the 4,000 ohm-cm standard. With no correction for temperature, average biases were 100 ohm-cm (5%) for the 2,000 ohm-cm standard and 300 ohm-cm (7%) for the 4,000 ohm-cm standard.
- 8.2. Reproducibility: For two test materials, multi-laboratory standard deviations of a single test results were dependent on soil minimum resistivity (Table 2). For materials with similar minimum resistivity, the results of two properly-conducted tests in different laboratories on the same material are not expected to differ by more than the ohm-cm shown in the column labeled “Acceptable Range of Two Results.”

**Table 2 Multi-Laboratory Precision for FM 5-551 Minimum Resistivity**

Material	Average, ohm-cm	Standard Deviation, ohm-cm	Acceptable Range of Two Results
Sand (A-3)	12,200	1,090	3,090
Sand (A-3)	2,310	430	1,230