Florida Method of Test for Minimum Resistivity of Soil and Water

Designation: FM 5-551

1. SCOPE

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 & Rasor Model SR-2).

2.2. Soil Box: Designed such that the cross-sectional area (cm2) 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 greater and a resolution of 0.1 g or better.

2.4. Other: Test leads, thermometer, flat spatula, mixing spoon, large non-corrosive bowl (glass, porcelain enamel coated, or stainless steel) for mixing, 100-mL graduated cylinder, squeeze bottle for cleaning, and disposable nitrile gloves.

3. REAGENTS

3.1. Conductivity standard, sodium chloride, 250 µS/cm (for example, Fisher Scientific catalog #22366032) (**Note 1**).

3.2. Distilled (or higher purity) water with a minimum resistivity of 200,000 ohm-cm (**Note 2**).

Note 1: The conductivity standard is not a requirement of this method but can be used as a best practice to verify proper functionality of the test equipment.

Note 2: Distilled (or higher purity) water stored in containers that are not airtight will absorb ions from acidic and basic gases in the atmosphere resulting in lower resistivity of the water over time.

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 collecting samples. Excessive moisture should be avoided by sampling from areas that have been allowed to gravity drain. If the soil sample has excess free moisture, place 2.2 lb (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. If sampling from ground level, remove the top 12 in. (30 cm) to eliminate vegetation and debris before sampling. The soil sample may be taken from underneath standing water, but free-standing water should not be included with the sample. Soil samples should be placed in plastic (watertight) bags. The bag should be squeezed down snugly around the sample and sealed 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 occur in areas conducive to collecting a representative sample. Care should be observed to avoid sampling from stagnant or pooled water unless a structure will be placed in such an area.

The water sample container shall be clean, at least 1 qt (1 L) in size and be either glass or plastic with an airtight lid. Rinse the container several times with the water to be collected. When possible, submerge the sample container below the surface of the water to avoid 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.

4.3. Transporting Samples: Maintain test samples in a cool dark area after sampling and during transport to the test facility.

4.4. Storing Samples: Store water and soil samples at or below 39°F (4°C). Care should be taken to prevent freezing of the samples. 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:

If as-received results are desired, do not dry the sample (**Note 3**).

5.2.1 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 four hours or until a constant mass is achieved. Sieve through a No. 10 mesh (2 mm) sieve. Split the sample per **AASHTO R 76** to obtain 1,300 g ± 5%.

5.2.2. 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 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 R 76** to obtain 1,300 g ± 5%.

Note 3: An “as-received” sample is one that is tested without drying and most closely represents the in-situ conditions at the time of sampling.

5.2.3. 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 distilled water, cover, and let stand for 24 hours at room temperature. Collect the leachate using clean equipment to avoid contamination.

6. PROCEDURE

6.1. All tests shall be performed at a standard temperature of 73° ± 3°F (23° ± 1.7°C)

6.2. Equipment Set-up: Rinse the soil box, mixing bowl, and utensils with distilled 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**).

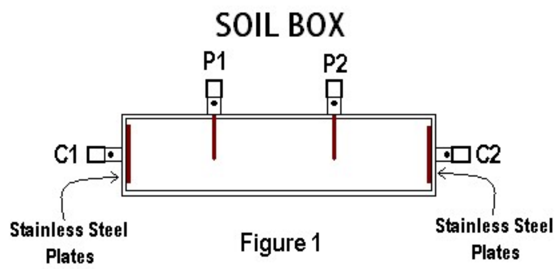

Figure 1

6.3. Resistivity of Water:

6.3.1. Completely fill soil box with water 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.

6.3.2. Record the resistivity in ohm-cm and temperature in °C of the sample (for example, 3,000 ohm-cm @ 25°C).

6.4. Resistivity of "As-Received" Soil:

6.4.1. If an "as-received" soil resistivity is requested, bring the soil sample and distilled 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, 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.

6.4.2. Record the "As-received" soil resistivity in ohm-cm and temperature in °C.

6.5. Minimum Resistivity of "As-Received" or of Dried, Sieved Soil:

6.5.1. Bring the soil sample and distilled water to room temperature. Place 1,000 g of soil sample into a large bowl.

6.5.2. Add 100 mL of distilled water to the soil sample and mix thoroughly (**Note 4**).

Note 4: For soils that are difficult to mix, wear disposable gloves and mix soil with gloved hands.

6.5.3. 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 5**).

Note 5: 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.

6.5.4. Repeat steps in **Section 6.5.2** and **Section 6.5.3**. The measured resistivity should decrease. When the resistivity of the soil sample begins to increase the minimum value has been identified.

6.5.5. Record the lowest resistivity obtained as the minimum resistivity in ohm-cm, the total volume of water used in mL, and measure and record the temperature of the sample in the soil box in °C.

6.6. Resistivity of a Small Soil Sample:

If soil resistivity is requested for a sample that is less than 1,000 g (**Note 6**), follow the steps outlined in 6.5 using increments of distilled water equal to 10% of the soil sample. For example, a 900 g sample would be diluted using 90 mL of distilled water.

Note 6: A sample size of less than 1,000 g is not appropriate for Retaining Wall Select Backfill.

6.7. Resistivity of Coarse Aggregate:

Follow steps outlined in **Section 6.3**.

7. RECOMMENDATIONS

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 and fill the soil box to the top. Connect the soil box to the resistivity meter as described in the manufacturer's instruction manual and verify the resistivity of the conductivity standard. Record the conductivity standard resistivity in ohm-cm and the measurement temperature in °C. If the measured resistivity is more than ±5% of the value in **Table 1** for the measurement temperature, troubleshoot, correct the problem, and 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. REPORT

8.1. The following information should be reported.

8.1.1. Resistivity of the sample in Ohm-cm.

8.1.2. Temperature of the sample when tested in °C.

9. PRECISION AND BIAS

9.1. Precision: For two test materials, multi-laboratory standard deviations of a single test result 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”.

9.2. Bias: Single-operator, single-laboratory bias for this method was evaluated using a Nilsson Model 400 analog meter, 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.

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