DEPARTMENT OF TRANSPORTATION
DIVISION OF ENGINEERING SERVICES
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METHOD OF TEST FOR MECHANICAL ANALYSIS OF SOILS

CAUTION: Prior to handling test materials, performing equipment setups, and/or conducting this method, testers are required to read **"SAFETY AND HEALTH"** in Section I of this method. It is the responsibility of the user of this method to consult and use departmental safety and health practices and determine the applicability of regulatory limitations before any testing is performed.

A. SCOPE

This method describes a procedure for the quantitative determination of the distribution of particle sizes in soils. It is a modification of AASHTO Designation: T 88.

B. APPARATUS

1. Beakers: A supply of beakers is required. Each beaker shall have a 250 mL capacity.

2. Sieves: Standard sieves shall conform to the requirements described in AASHTO Designation: M 92. The various sizes include: No. 4, No. 8, No. 16, No. 30, No. 50, No. 100 and No. 200.

3. A riffle splitter shall have chutes with a width of 3/8 inch.

4. Balance: The balance shall have a sensitivity of 0.1 g.

5. Stirring apparatus: A mechanically operated stirring apparatus is required. It shall consist of an electric motor suitably mounted to turn a vertical shaft approximately 10,000 RPM without load, a replaceable stirring paddle (metal, plastic or hard rubber) and a dispersion cup that conforms to the requirements described in AASHTO Designation: T 88.

6. Hydrometer: The hydrometer shall be graduated to read in g/L of suspension at a temperature of 68°F and shall conform to the requirements for a "152 H Hydrometer" described in AASHTO Designation: T 88.

7. Thermometer: A floating glass thermometer shall be accurate to within 1.0°F.

8. Sedimentation cylinder: A transparent cylinder approximately 18 inches in height and 2.5 inches in diameter shall be marked for a volume of 1000 mL.

9. Water bath or constant temperature room: A water bath or constant temperature room is required for maintaining the soil suspension at a constant temperature during the hydrometer analysis. A satisfactory water bath is an insulated tank that maintains the soil suspension at a convenient constant temperature as near 68°F as facilities will permit. In cases where the work is performed in a room at an automatically controlled temperature, the water bath is not necessary and subsequent reference to a constant temperature bath shall be interpreted as meaning either water bath or constant temperature room.

10. Timer: A watch or clock shall be capable of recording 24-h periods. It

must be accurate to within 1 s in a 60-s period.

11. Graduated cylinder: A graduated cylinder, or similar measuring device, is required for accurately measuring quantities up to 125 mL.

C. MATERIALS

1. Dispersion agent.

   a. Sodium hexametaphosphate solution:

      (1) Dissolve 40.0 g of sodium hexametaphosphate granules [$(NaPO_3)_6$ or $NaPO_3$] in 1 L of distilled or good quality tap water at a temperature not exceeding 100°F.

      (2) To ensure the granules are completely dissolved, mix the solution until no solid material is visible and then allow the mixture to stand at least 4 h before using.

      NOTE: solutions of this salt, if acidic, slowly revert or hydrolyze back to the orthophosphate form with a resultant decrease in dispersing action. Solutions should be prepared frequently (at least once a month) or adjusted to pH of 8 or 9 by means of sodium carbonate. Bottles containing solutions should have the date of preparation marked on them.

   b. Sodium tripolyphosphate solution (alternate):

      (1) Sodium tripolyphosphate may be substituted if sodium hexametaphosphate is not available.

      (2) Dissolve 18.8 g of sodium tripolyphosphate ($Na_5P_3O_{10}$) in 1 L of water. Follow the instructions for dissolving the sodium hexametaphosphate.

2. Water: The water used in this test shall be distilled or good quality tap water.

D. PREPARATION OF SAMPLE

1. Prepare the "as received" soil sample in accordance with California Test 201.

2. Split or quarter the mechanical analysis test sample from the passing No. 4 sieve fraction. The mass of the test sample should vary between 65 g for silt and clay samples to 115 g for very sandy samples.

3. At the same time the mechanical analysis test sample is taken, split or quarter a portion determined to be at least 100 g from the passing No. 4 sieve material and determine the moisture content according to California Test 226.

4. Place the mechanical analysis test sample in a 250-mL beaker.

5. Measure out 125 mL of the dispersion agent and pour the fluid into the beaker with the test sample.

6. Stir the sample until it is thoroughly wet. Then allow the sample to soak a minimum of 15 h.

7. At the end of the soaking period, transfer the material into the mechanical dispersion apparatus cup.

   NOTE: Exercise care to minimize the amount of water when rinsing the material out of the beaker into the dispersion cup. The cup should not be filled to more than two-thirds nor less than one-half full.

8. Stir the contents of the dispersion cup with the mechanical stirring apparatus for 1 min.

E. TEST PROCEDURE

1. Immediately after dispersion, transfer the water-soil slurry to the sedimentation cylinder. Then add sufficient water, having a temperature within 5°F of the constant temperature bath, to bring the level to the 1000 mL mark.

2. Using the palm of the hand over the open end of the sedimentation cylinder (or a rubber stopper in the open end), mix the contents of the sedimentation cylinder by alternately turning it upside down and right side up approximately 60 times/min (count the turn upside down and back to right side up as 2 turns). Any material remaining in the bottom of the sedimentation cylinder during the first few turns should be loosened by vigorously shaking the sedimentation cylinder while it is in the inverted position.

3. At the end of the 1 min mixing process, record the time, and immediately set the sedimentation cylinder into the constant temperature water bath.

4. Take hydrometer readings at the end of 1 h and 24 h. Readings at other times may be made, if desired.

    a. When taking a hydrometer reading, carefully and slowly lower the hydrometer into the cylinder about 20 to 25 s before the reading is to be taken to ensure that it comes to rest before the appointed reading time. Take the reading at the top of the meniscus formed by the suspension around the stem of the hydrometer. As soon as the reading is taken, carefully remove the hydrometer and rinse it clean with water.

    b. After each hydrometer reading, determine the temperature of the suspension by inserting a thermometer into the cylinder.

    c. Observe the contents of the cylinder after each hydrometer reading to detect flocculations. A sample has flocculated when the suspended particles collect together in small lumps or gels and settles toward the bottom. This results in a clear line of demarcation between the flocculated particles and the liquid above it, which may be cloudy to clear. The dispersion agent prescribed in this test procedure is effective in preventing flocculation in most soil samples. However, in those exceptional cases when this dispersion agent is not effective, flocculation will occur and hydrometer readings are not valid. In these cases where the determination of particle size distribution by the hydrometer method is not possible, the particle size distribution by sieve analysis shall be reported along with a notation that the material flocculated during the test.

5. After taking the final reading, pour the contents of the cylinder onto a No. 200 sieve. Rinse the material retained on the sieve with tap water until the water is clear. Transfer the material retained on the sieve to a suitable container, dry it to constant mass in an oven at a temperature of 230°F ± 9°F and perform a sieve analysis in accordance with Section G in California Test 202.

F. CORRECTIONS

1. Before the percentage of soil remaining in suspension can be calculated as described in Section G, the hydrometer reading must be corrected for the following:

    a. Specific gravity of the suspending medium: Formulas for percentages of soil remaining in suspension, as given in Section G of this test method, are based on the use of distilled or good quality tap water as

the suspending medium. A dispersion agent is used in this water, however, and the specific gravity of the resulting liquid is appreciably greater than that of water.

b. Temperature of the suspending medium: The soil hydrometer is calibrated to read at 68°F, and variations from this standard temperature result in inaccurate hydrometer readings. The amount of error increases as the variation from the standard temperature increases.

c. Apparent hydrometer reading: Hydrometers are graduated by the manufacturer to be read at the bottom of the meniscus formed by the liquid on the stem. Since it is not possible to secure readings of soil suspensions at the bottom of the meniscus, readings must be taken at the top and a correction applied.

2. A composite correction for the above items (specific gravity of the suspending medium, temperature of the suspending medium, and apparent hydrometer reading) may be determined experimentally as follows:

a. Prepare 1000 mL of the liquid used in this test by diluting 125 mL of the dispersion agent to the required 1000 mL with distilled or good quality tap water.

b. Pour this liquid in a sedimentation cylinder and place the cylinder in the constant temperature bath set to one of the bracketing temperatures to be used.

c. When the temperature of the liquid in the sedimentation cylinder becomes constant, insert the hydrometer. After the prescribed 20 to 25-s interval, allowed for the hydrometer to come to rest. Read the hydrometer at the top of the meniscus formed on the stem. The hydrometer reading is the composite correction for this temperature.

d. Change the constant temperature bath to the second bracketing temperature and repeat the above procedure to obtain the composite correction for this temperature.

e. Plot these corrections on arithmetic coordinate paper as hydrometer reading versus temperature. Draw a straight line between the two plotted points to establish the composite corrections for intermediate temperatures.

f. Since the composite correction for hydrometer readings will be greater than zero in the acceptable range of expected test temperatures, subtract the applicable composite correction from the test hydrometer readings to obtain the corrected hydrometer reading.

G. CALCULATIONS

1. Calculate the oven dry mass of the sample in the hydrometer test using the following formula:

Oven Dry Mass = Wet mass/[(% Moisture/100) +1]

2. Calculate the percent of soil in suspension by use of the following formula:

$$P = 100\ R/W$$

Where:

P = Soil remaining in suspension, in %
R = Corrected hydrometer reading, g/L
W = Oven dry mass of the sample used in the hydrometer test, to the nearest 0.1 g

3. The average maximum diameter of soil particles in suspension, corresponding to the most commonly used hydrometer

reading time intervals, are listed in Table 1. This table is based on average values calculated by Stokes' Law and shall be used to obtain the maximum particle size in suspension corresponding to the hydrometer reading times.

TABLE 1
AVERAGE MAXIMUM GRAIN DIAMETER IN SUSPENSION

Sedimentation Time	Average Maximum Grain Diameters in Suspension (microns)
20 s	74
40 s	53
1 min	39
2 min	28
5 min	18
15 min	10
30 min	7
1 hr	5
2 hr	305
4 hr	2.5
6 hr	2
7 hr	1.7
24 hr	1

4. Combine the grading of the retained No. 4 sieve material with the grading of the hydrometer test sample to obtain the "as received" grading in accordance with "Calculations" in California Test 202.

H. REPORTING OF RESULTS

Report the total percentages passing each sieve size and the percentage of material in suspension at the designated sedimentation times to the nearest 1%.

I. SAFETY AND HEALTH

Soils and waters may contain bacteria and/or organisms that can be harmful to one's health. Be sure to clearly identify those soils and waters that may contain contaminates.

It is recommended that the tester review each MSDS for the various materials used in this method (such as sodium hexametaphosphate, tripolyphosphate, etc.). Dust masks and protective gloves are advised when handling materials.

Wear protective eyewear when operating the mechanical dispersion apparatus and while mixing the contents of the sedimentation cylinder.

Prior to handling, testing or disposing of any waste material, testers are required to read Part A, (Section 5.0), Part B, (Section 5.0, 6.0, 10), and Part C, (Section 1.0) of Caltrans Laboratory Safety Manual.

REFERENCES:
AASHTO Designations: T 88 and M 92
California Tests 201, 202 and 226

End of Text
(California Test 203 contains 5 pages)