Particle size Analysis for Soil Texture - Hydrometer method

Particle size analysis determines the particle size distribution of individual particles (sand, silt, and clay) in a soil sample. The USDA classification separates soil into different-sized mineral particles: sand (0.05 to 2 mm), silt (0.002 to 0.05 mm), and clay (<0.002 mm). The variations in the distribution of these particles determine the soil texture. The particle size analysis procedure involves pretreatment followed by chemical and physical dispersion and subsequent separation of particles according to their sizes by sieving or sedimentation. Pretreatment enhances the separation or dispersion of aggregates in soils with high organic matter, carbonate coatings and iron oxides that bind soil particles together. This is followed by chemical dispersion using dispersing agents like sodium hexametaphosphate, which can create repulsive forces between particles to separate them. Chemical dispersion is followed by physical dispersion using shakers, electric mixers, or ultrasonic probes that accomplish separation by shaking, rubbing, rolling, or vibrating. The dispersed particles are then separated according to their sizes, either by sieving or sedimentation.

The hydrometer method applies Stoke's law, which considers sedimentation of particles to be dependent on the particle diameter and settling velocity (Gee and Bauder, 1986). A Bouyoucos hydrometer is used to determine the density (g L^{-1}) of the soil particles settling at different times due to differences in their particle size and settling rates. This method allows for multiple measurements on the same soil suspension, facilitating particle size determination with minimum effort.

Sources

Bouyoucos, G.J. 1962. Hydrometer method improved for making particle size analyses of soils. Agron. J. 54:464-465.

Gee, G.W. and J.W. Bauder. 1986. Particle-size Analysis. p 383-411 In A. Klute (ed.) Methods of Soil Analysis Part 1. Soil Science Society of America Book Series 5, Madison, Wisconsin, USA.

Dane, J. H., & Topp, C. G. (Eds.).2020. Methods of soil analysis, Part 4: Physical methods (Vol. 20). John Wiley & Sons.

American Society for Testing and Materials. 2008. Standard test method for particle-size analysis of soils D422-63 (2007). 2008 Annual Book of ASTM Standards 04.08:117-127. American Society for Testing Materials, Philadelphia.

OSU Soil Fertility Lab.2020. - Procedure for Soil Particle Size (Texture): 2-Hour Hydrometer Method

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Materials

Equipment and Apparatus:

Hydrometer, ASTM Standard No. 152/151 H, with Bouyoucos scale in g L^{-1} @ 68 ^{0}F
Thermometer, Fahrenheit (Thermpro)
Electric Soil Mixer/Stirrer with >10,000 rpm motor (Humboldt) with metal dispersion cup
Analytical Weighing scale with ± 0.01 g resolution
Timer
Sedimentation cylinder, 1 L capacity
Measuring cylinder, 100 ml capacity/ 100 ml bottle top dispenser
Beakers, 600 ml capacity

Reagents:

5% Sodium Hexametaphosphate Dispersing Solution
1 L Volumetric flask
Sodium Hexametaphosphate $(NaPO_3)_6$
Distilled water
Magnetic stir bar
Amyl alcohol

Reagent Preparation

Soil sample

1. Soil should be oven-dried, ground, and passed through a 2 mm sieve (10 mesh size).
2. Place a weigh boat on the analytical scale, tare it, and weigh 50 g for fine-textured soil (silt, clay loam) and 100 g for coarse-textured soils (sand, sandy loam, loamy sand)
3. Make sure to include a soil check (Lab reference sample with known particle size distribution) for quality control and blank (without soil) with each analysis batch.

Pretreatment - (Conduct pretreatment after step 1 and continue with step 2 after pretreatment)

Organic soils with OM> 3.5% or carbonates >2 % - pretreatment must be done to prevent underestimation of clay content or overestimation of silt content.

1. Removal of carbonates: Add 50 mL distilled water to the beaker followed by 1M HCl in small quantities sufficient to make the pH between 3.0 and 4.0. Stir the solution and let sit for 10 minutes till no effervescence.
2. Removal of organic matter: Add 10 mL of hydrogen peroxide (H_2O_2) to the beaker. Wait for frothing to subside. Then heat to 90 ^{0}C and add further 10 ml portions of hydrogen peroxide until frothing vanishes. Rinse down walls of beaker and continue heating for about an hour to ensure excess hydrogen peroxide is consumed.

Single or both removal procedures can be applied based on the soil sample. After the final removal procedure is employed, continue with step 2 in the abovementioned procedural outline.

5% Sodium Hexametaphosphate Dispersing Solution

1. Add 50 g Sodium Hexametaphosphate $(NaPO_3)_6$ to a 1 L volumetric flask
2. Place a magnetic stir bar, add 500 ml DI water, and stir at moderate speed until fully dissolved.
3. After dissolution, make up the volume to 1 L with DI water.
4. Calculate the amount of dispersing solution required based on the number of samples planned for analysis. Each sample requires 100 ml 5% $(NaPO_3)_6$.

Hydrometer calibration

1. Add 100 ml of 5% sodium hexametaphosphate solution to the sedimentation cylinder and make up the volume to 1L with DI water.
2. Mix thoroughly with a plunger/stopper cylinder and do end-over-end shaking.
3. Place the hydrometer slowly into the sedimentation cylinder and wait for it to stop moving.
4. Read the upper edge of the meniscus surrounding the hydrometer stem at the solution's surface. This is the hydrometer reading of the blank (without soil) solution.
5. Take the blank hydrometer reading at 40 seconds (R_{B1}) and 2 hours (R_{B2}).

Assay Method

Analysis

1. Add 50 or 100 g soil (fine/coarse-textured) weighed into a 600 ml beaker.
2. Add 100 mL of 5% $(NaPO_3)_6$ reagent to 600 ml beaker containing weighed soil. Add 100 mL dispersing solution to an empty beaker which will be considered a blank.
3. Add 250 ml of DI water or up to 10 cm of rim.
4. Stir the solution for 10 seconds using a rod and let it sit undisturbed for the next 30 minutes (Rinse the rod into a waste water bucket between each sample).
5. Pour the sample solution into the metal dispersion cup. Make sure to remove all soil particles from the beaker into the dispersion cup by using a wash bottle with DI water.
6. Fill the dispersion cup with DI water up to $3/4^{th}$ of the cup.
7. Stir the soil on the electric mixer/stirrer for 5 minutes (10000 rpm)
8. Transfer the soil suspension to the 1000 ml sedimentation cylinder. Wash all contents in the cup into the sedimentation cylinder using distilled water. Fill up the volume to 1 L in the sedimentation cylinder.
9. Allow time for the suspension to stand for some time to equilibrate thermally.
10. Insert the plunger into the suspension in the cylinder and mix it thoroughly until sediments at the bottom have dislodged and a uniform suspension is formed/stopper the cylinder and do end-over-end shaking.

11. Put three drops of amyl alcohol to soil suspension if froth is formed to dissipate it.
12. Start a timer/stopwatch for 40 seconds, gently insert the hydrometer into the soil suspension at 15 seconds, and let it stabilize.
13. Record the hydrometer level at the solution surface at 40 seconds and measure the temperature of the suspension.
14. Remove the hydrometer, rinse using DI water, and wipe it dry with a kimwipe before reuse.
15. Leave the measuring cylinder undisturbed for 2 hours. After 2 hours, again lower the hydrometer into the solution mixture and, after stabilization, record the hydrometer and temperature reading.

Corrections

- Temperature correction

The hydrometer is calibrated to read at 68^0F. If the room temperature at which the sample hydrometer readings were taken is different from 68 ^{0}F, a correction factor of 0.36 g L^{-1} needs to be added to the hydrometer reading for each 1^0F above 68^0F and subtracted for each 1^0F below 68^0F. This should be done for all soil samples, blanks, and checks at both time intervals.

- *Solution viscosity and density correction:*

The temperature-corrected hydrometer reading from the soil suspension (R) should be subtracted from the temperature-corrected hydrometer reading taken from the blank solution (without soil) at 40 seconds (R_{B1}) and 2 hours (R_{B2}). This is done to correct the effects that the density of the dispersion solution might have caused on the density of the solution mixture.

Calculations

1. The first reading at 40 seconds provides the amount of clay and silt (in g) suspended in 1 L of solution. This value subtracted from 100 gives the solution's sand content (settled at the end of 40 seconds). *R- R_{B1}= Corrected hydrometer reading at 40 secs*
% Sand = 100 – (R- R_{B1}/Weight of dry soil) x 100

2. The second reading at 2 hours provides the amount of clay (in g) suspended in 1 L of solution. *R- R_{B2}=Corrected hydrometer reading at 2 hours*

% Clay = (R- R_{B2}/Weight of dry soil) x 100

3. Silt content is determined with the following equation:
% Silt = 100 – (% Sand + % Clay)

Clean-up and Disposal

1. After recording the hydrometer values, dispose of the water in the solution mixture to a sink and the concentrated soil at the bottom to the waste bucket.
2. Rinse the hydrometer and used apparatus thoroughly with DI water and allow it to air-dry.

After estimating the sand, silt and clay percent in the sample, the textural class can be determined using the Soil textural triangle or Soil texture calculator provided by USDA-NRCS.