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STANDARD OPERATING PROCEDURE

Procedure for Determining Soil Particle Size Using the Hydrometer Method

KEY WORDS
Sand, silt, clay, texture, classification, sodium hexametaphosphate

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Environmental Monitoring Branch organization and personnel, such as management, senior scientist, quality assurance officer, project leader, etc., are defined and discussed in SOP ADMN002.

1.0 INTRODUCTION

Particle size analysis is the determination of percent sand, silt and clay components in a soil. The Bouyoucos Hydrometer method adapted from Gee and Bauder (1986) is used to determine the soil texture of the fine earth fraction (<2000 μm) of the soil sample. This method follows USDA soil classifications for particle sizes.

1.1 Purpose

To provide standardized instruction for the use of the hydrometer method for soil composition classification.

1.2 Definitions and Abbreviations

1.2.1 Clay- soil particles < 2 μm

1.2.2 Silt- soil particles <50 μm-2 μm

1.2.3 Sand- soil particles <2000 μm-50 μm

1.2.4 ASTM- American Society for Testing and Materials

1.2.5 USDA- United States Department of Agriculture

1.2.6 HMP- Sodium Hexametaphosphate

1.2.7 PSA- particle size analysis

2.0 MATERIALS

2.1 Standard hydrometer, ASTM no. 152 H, with Bouyoucos scale in g/L

2.2 Electric stirrer (malted-milk-type)

2.3 Plunger or rubber stoppers for 1000-mL sedimentation cylinders

2.4 Sedimentation cylinders with 1000-mL mark

2.5 600-mL beakers or quart mason jars

2.6 Pentanol

2.7 Sodium-hexametaphosphate (HMP) solution (50 g/L)

2.8 Sieve 2-mm screen

2.9 Electric oven and weighing jars or .5 pint mason jars

2.10 Balance

2.11 Stop watch/ timer

2.12 100-mL and 2-L volumetric flasks

2.13 Mortar and pestle

2.14 Safety goggles

2.15 Latex gloves

2.16 Dust mask

2.17 Distilled water

2.18 Submersible Thermometer

2.19 Data sheet (Figure 1.)

3.0 PROCEDURES

3.1 Soil sample collection

3.1.1 Collect surface soil samples according to SOP# FSSO002.00. Collect a minimum of 500g of soil. Soil can be processed immediately or allowed to air dry in bags or jars.

3.2 Sample Preparation

3.2.1 Weigh approximately 150 g soil from sample and place into an oven-safe jar. Oven dry at 105 C° for 24 h following SOP# MET 001.00.

3.2.2 Grind oven-dry soil with mortar and pestle to break up chunks and loosen clods. Use 2mm mesh sieve to remove gravel and record weight of <2 mm and > 2mm fractions on data sheet.

3.2.3 Ten to100 g of the <2mm soil will be used for the test as discussed in Section 3.5.1. Preserve excess for duplicate sampling or in case sample is spilled.

3.3 HMP Solution Preparation

3.3.1 Measure 100 g sodium hexametaphosphate on a balance. In a volumetric flask, combine sodium hexametaphosphate and distilled water for a total volume of 2000 mL. Stir until dissolved.

3.4 Soil Dispersion

3.4.1 Weigh oven dry soil and put it into a 600-mL beaker. Add 250 mL distilled water and 100 ml HMP. Soak over night.

3.4.1.1 Soil texture will determine amount of soil needed for test soil sample size. Ten to 20 g may be enough for fine clays but 60 to 100 g may be needed for coarse sands.

3.4.2 Transfer soil/ HMP mixture to dispersing cup and mix for 5 min with an electric mixer. Pour mixture into sedimentation cylinder and add distilled water to reach 1 L.

3.5 Calibration with a Blank

3.5.1 In a sedimentation cylinder, add 100 mL HMP to 900 mL room temperature distilled water to make 1L total volume solution. Mix with plunger and record temperature.

3.5.2 Gently, lower the hydrometer into the cylinder. Read and record where the upper edge of the meniscus surrounds the stem of the hydrometer. Periodically throughout the test, read and record this measurement (R_L) for solution viscosity and soil concentration analysis corrections.

3.6 Hydrometer Measurements

3.6.1 Allow samples to reach ambient temperature and record temperature. Insert plunger into cylinder and mix thoroughly. Use upward strokes to remove sediment from bottom and finish with five or six smooth strokes.

3.6.1.1 Storing DI water and hexametaphosphate in room where measurements will be taken will speed this process.

3.6.1.2 An alternative to plunging is to stopper the cylinder and shake it end over end for 1 min.

3.6.1.3 Add one drop pentanol if surface of suspension is foamy.

3.6.2 When mixing is complete, gently place hydrometer into the suspension. Take a reading at 30 s. Repeat this step 2 to 3 more times. At the end of the third trial, leave the hydrometer in the

cylinder and take a reading at 60 s. Remove, rinse and dry hydrometer. Reinsert hydrometer 10 s before each reading. Take additional readings at 90 min and again at 1440 min. Record these as R. Also record R_L from the calibration blank and the temperature at each time.

4.0 CALCULATIONS

Derivations and sources for these equations can be found in Gee and Bauder (1986).

4.1 Preliminary Calculations

The calculated value for B can be used for all time intervals if temperature of samples was kept relatively constant throughout. B provides corrections for the density and viscosity variations of the HMP solution.

4.1.1 $B = 30\eta / [g(\rho_s - \rho_l)]$

Where
η = fluid HMP solution viscosity (Eq. 4.1.3) in poise, g $cm^{-1}s^{-1}$
g = gravitational constant, cm/s^2
Constant 980 cm/s^2
ρ_s = soil particle density, g/cm^3
Assume standard 2.65 g/cm^3
ρ_l = HMP solution density (Eq. 4.1.2), g/cm^3

4.1.2 $\rho l = \rho°(1 + 0.630\ C_S)$

Where
ρl = HMP solution density at temperature t, g/cm^3
$\rho°$ = water density at temperature t, g/cm^3
At temp 20° C = 0.998 g/cm^3
At temp 25° C = 0.997 g/cm^3
C_S = concentration of HMP, g/cm^3
0.05 g/cm^3

4.1.3 $\eta = \eta°(1+ 4.25\ C_S)$

Where
η = HMP solution viscosity at temperature *t* in poise, g $cm^{-1}s^{-1}$
$\eta°$ = water viscosity at temperature *t* in poise, g $cm^{-1}s^{-1}$
At temp 20° C = 0.01 g $cm^{-1}s^{-1}$
At temp 25° C = 0.0089 g $cm^{-1}s^{-1}$
C_S = concentration of HMP, g/ cm^3
as prepared in 3.3.1 = 0.05 g/cm^3

4.2 Particle Diameter (X) Calculation for Each Time Interval

These calculations are used to determine particle diameter in solution at each time (t) interval. Note: this equation does not use SI units.

4.2.1 $X = \theta(t)^{-1/2}$

Where
X = mean particle diameter in suspension, μm at time *t*
θ = sedimentation parameter (Eq. 4.2.2), μm $min^{1/2}$
t = time in minutes

4.2.2 $\theta = 1000(Bh')^{1/2}$

Where
θ = sedimentation parameter, μm $min^{1/2}$
h′ = effective hydrometer depth, cm
B = see section 4.1 correction for HMP solution

4.2.3 *h′* = -0.164 R +16.3

Where
h′ = effective hydrometer depth, cm
R = uncorrected hydrometer reading, g/L

4.3 Summation Percentage (P) for each Time Interval

4.3.1 $P = C/C_o \times 100$

Where
P = summation of percentage for given time interval

C = concentration of soil in suspension (Eq. 4.3.2), g/ L
C_o = oven-dry weight of soil sample used for test as determined in sec 3.4.1.1

4.3.2 $C = R - R_L$

Where
C = concentration of soil in suspension, g/ L
R = uncorrected hydrometer reading, g/ L
R_L = hydrometer reading of blank solution, g/ L

4.4 Clay Fraction Determination

4.4.1 Use hydrometer readings, both R and R_L, at 1.5 h and 24 h.

4.4.2 Use equations 4.2 and4.3 to determine effective particle diameter (X) and summation percentage (P) for 1.5 h and 24h readings.

4.4.3 Calculate percent clays ($P_2\mu m$) with equation:

$$P_2\mu m = m \ln (2 / X_{24}) + P_{24}$$

Where
X_{24} = mean particle diameter in suspension at 24 h (Eq. 4.2.1)
P_{24} = summation of percentage at 24h (Eq. 4.3.1)
$m = (P_{1.5} - P_{24}) / \ln (X_{1.5} / X_{24})$= slope of the summation percentage curve between *X* at 1.5 h and *X* at 24 h
$X_{1.5}$ = mean particle diameter in suspension at 1.5 h (Eq.4.2.1)
$P_{1.5}$ = summation percentage at 1.5 h (Eq.4.3.1)

4.5 Sand Fraction Determination.

4.5.1 Use hydrometer reading, both R and R_L, at 30 s (use average of the readings) and 60 s.

4.5.2 Use equation 4.2 and 4.3 to calculate summation percentages for 30 s and 1 m.

4.5.3 Calculate $P_{50}\mu m$ with equation:

$$P_{50}\mu m = m \ln (50 / X_{60}) + P_{60}$$

Where
X_{60} = mean particle diameter in suspension at 60 s (Eq. 4.2.1)
P_{60} = summation of percentage at 60 s (Eq. 4.3.1)
$m = (P_{30} - P_{60}) / \ln (X_{30} / X_{60})$= slope of the summation percentage curve between X at 30 s and X at 60 s (1 min)
X_{30} = mean particle diameter in suspension at 30 s (Eq. 4.2.1)
P_{30} = summation percentage at 30 s (Eq. 4.3.1)

4.5.4 Subtract computed P_{50} μm value from 100 to obtain sand percentage

4.6 Silt Fraction Determination

4.6.1 Use the equation:

% silt = 100 – (% sand + % clay)

5.0 SAFETY

Sodium hexametaphosphate is a non-hazardous material but may be irritating to skin and eyes. Dust may be irritating to lungs if inhaled. Care should be taken to avoid inhalation. Handle powered HMP in a well-ventilated area or fume hood. Chemical-safety goggles should be worn while pouring HMP solution and during blending to avoid contact with eyes. In case of contact, flush eyes with cold water for 15 minutes. Latex gloves should be worn to avoid contact with skin. Hands and contaminated skin should be washed thoroughly with soap and water after handling. Sweep, vacuum, scoop or remove spilled sodium hexametaphosphate. Flush residual area with water. In case of spills on clothes, wash thoroughly before wearing again. See the MSDS for more information on contamination and spills.

Sodium hexametaphosphate is not considered a hazardous material when disposed. Dried HMP may be discarded in the landfill and HMP solution may be disposed in sink. See the MSDS for more information on disposal.

Pentanol is considered to be slightly toxic. Avoid direct contact. It can be harmful if swallowed or inhaled or absorbed through the skin. Pentanol should be handled only in a hood while wearing impervious gloves and goggles. Contact lenses should not be worn in a laboratory. If spilled, evacuate area, and ventilate. Absorb on vermiculite or similar material. Sweep, scoop and hold for proper disposal. Then wash contaminated surfaces to remove residues. See the MSDS for latest information on proper use and cleanup of 1-pentanol.

When handling soil samples, care should be taken to avoid inhalation of dust particles. A dust mask should be worn while grinding and sieving soil. Typical laboratory safety practices should be followed when working with soil.

6.0 REFERENCES

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