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## CE 363 – SOIL MECHANICS

**Lab. Session 4 – Grain Size Distribution by Sedimentation (Hydrometer)**

## Purpose of the test

Determine the grain size distribution (GSD) of the fine fraction (smaller than 75m) of a soil sample.

In order to obtain the entire GSD of a soil, sieve analysis (lab session 3) must be done on the same sample. In this lab session, you are given the fine particles that are separated from the rest of the soil by a fine sieve. These fines constitute a known fraction of the total soil sample. In other words, the soil sample for this test is a fraction of the original soil. This means in an actual test, you have to merge data from these two tests to obtain the entire GSD.

**Note:** ASTM D422 suggests putting the fraction of soil that is finer than #10 into this test. However, this means particles as large as 2mm will go into the sedimentation test. Many engineers use #40 or #200 sieves instead. The standard allows changing the separation sieve, but requires this separation sieve size to be indicated in the data sheet and properly taken into account in the calculation stage.

# Equipment

* High-speed stirrer
* Scale
* Hydrometer
* Thermometer
* Ruler
* Two 1L-volume cylinders
* Distilled water
* Squirt bottle
* Temperature bath (or another water container deep enough to take the hydrometer)
* Dispersing agent: sodium hexametaphosphate (NaPO3)6
* Large evaporating dish

# General Rules

* Do not oven-dry hydrometer specimen before the test.
* If the soil contains salt or other soluble material, the experiment results will be affected.
* Always take hydrometer readings on top of the meniscus (see 4.1.).
* When taking a hydrometer reading, insert and withdraw the device into the suspension slowly and carefully. Proper insertion procedure is: (i) slowly submerge the hydrometer until you barely feel an upwards resultant force (uplift) on the device, (ii) release the device so that it moves slightly up and comes to equilibrium. A few practice readings before starting the test is recommended.
* When transferring soil, slurry or suspension from one container to another, leave no solid behind – wash everything into the new container. This must be done using minimal amount of water, as the water accumulates and may reach impractical volumes before the start of the test. Use of a squirt bottle helps this aim.

## Specimen Preparation

Weight 50 gr soil (dry weight)

5 g sodium hexametaphospahate is added to the soil.

In order to obtain a slurry, one tea-glass of distilled water is poured.

In this lab session, (NaPO3)6 should be dissolved.

In an actual test, letting the slurry temper overnight in a closed container, but skip this part in this lab session due to time limitations.

Use a stirrer to mix the mixture for 5-10 minutes.

# Calibration

* 1. *Meniscus reading:* Meniscus is the water climbing up the hydrometer stem due to interfacial properties.
* Insert the hydrometer into clear water.
* Take a reading at the top of the meniscus
* Take another at the level of the flat water surface. This is the true measurement.
* The difference between the readings is the meniscus correction, and should be added to all readings taken from the top of meniscus.
  1. *Height of fall:* The height of fall is from the water surface to centroid of the hydrometer bulb. This distance varies linearly with density.
* Find centroid of the bulb. Measuring the bulb by a ruler and marking the center with a pen is acceptable.
* Measure the distance from the centroid to a low density reading and a high density reading, to construct a linear equation between them.
  1. *Water elongation:* When hydrometer is inserted, it displaces and stretches the suspension, increasing the height of fall. So the real height of fall is less than what you calculate in 4.2.
* Determine average volume of submerged portion of the hydrometer. You can do this by weighing the hydrometer and dividing its mass by the density measurement. You can take a constant number (such as the average of your density measurements, or the mean of the measurement range of the hydrometer), as the volume of the stem is negligible; or you can tie this calculation to each density measurement during the test.
* Determine cross section area of the cylinder by dividing volume of 1000 cm3 by height of the 1 lt mark from the base of the cylinder.
* Elongation is equal to Vhyd / 2Acyl
  1. *Density changes due to temperature and solute concentration:* Have a separate column of water with 5 g sodium hexametaphosphate in the same environment as the test cylinder. This is the reference fluid. Multiple tests in the same environment can share a single reference fluid.
* Take a reference density measurement (of this fluid) using the hydrometer before the test.

Read at the top of the meniscus.

* Measure the temperature of the reference fluid.
* The difference between density of pure water at this temperature and that of the reference fluid is the effect of the sodium hexametaphosphate.
* For any hydrometer reading, density of fluid can be calculated as density of pure water at the measurement temperature plus the effect of (NaPO3)6, as will be done in part 7.1.

# Test Procedure

Prepare the control jar by adding sodium metaphosphate (NaPO3) solution and sufficient distilled water to produce 1000 ml.(This solution can be made by mixing 55 g of dry chemical with enough water to make 1000 ml).

All slurry should be transferred into the 1-liter test cylinder.

 Distilled water should be poured the cylinder up to 1 L mark.

 Mix slurry and water by inverting the suspension.

Wait 1 hour for the temperature equilibration, but in this lab session skip this part.

 For the advantages of the students, they should practice how to submerge the hydrometer into the suspension.

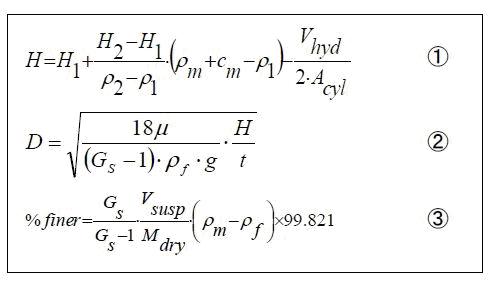
Measure the temperature of the suspension (Skip this part in this lab session, and take the temperature 22o C.

 Start the clock, and take data 30 sec. (if possible), 60 sec., 120 sec., but it is taken in this lab session when the hydrometer level is changed.

 Clean the hydrometer in each step for the accuracy of the test (in our test, it is done twice)

Waiting for a long time permits the students to see changing the level of the hydrometer.

## Calculations



**Figure 1:** Formulas for calculations

**According to 1st formula;**

H=20+ (9-20)\*(1.025+0.001-1)/ (1.05-1)-75/ (2\*28.274) = 12.9537 cm **(for the first line)**

**According to 2nd formula;**

D=sqrt(18\*0.961\*12.954/(2.64-1)\*1.003\*981\*30)= 0.068 cm **(for the first line)**

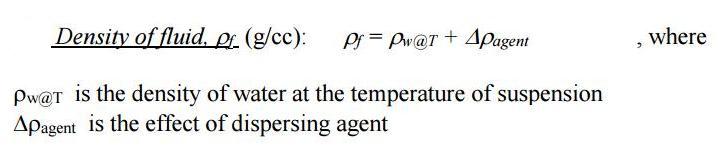
**According to 3rd formula;**

%finer = 2.64\*1000\*(1.025+0,001-1.003)\*99.821/ ((2.64-1)\*39) = 94.778 **(for the first line)**

• In the third formula, we measured percentage of fine for our 39 g dry soil, but now we estimate it for 50 g soil. (At the beginning of the experiment, totally I had 50 g soil.)

% adjusted finer = 94.778\*(39/50) = 73.9268 % **(for the first line)**

•While in other case, if the temperature of suspension changed when the experiment was continued, we will use the this formula:



F**igure 2:** Formula for the density of fluid (ρf)

**According to this formula;**

At T=22°C, ρf = 1.003 g/cm^3

ρw@T = 1.025 g/cm^3 **(for the first line)**

**Δ**ρagent = ρf - ρw@T = 1.025-1.003 = 0.022 g/cm^3 (the effect of the sodium hexametaphosphate)

Calculations that are shown above were done only first row of the table given below.

**Table 1:** Data Sheet for the Hydrometer Test

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| DATA TO BE RECORDED |  |  |  | DATA TO BE CALCULATED |  |  |  |
| Time (s) | Temp.(°C) | Density of Fluid (ρf) | Density of Suspension (ρm) (g/cm^3) | Height of Fall (H) (cm) | Equivalent Diameter (D) (cm) | Percentage Finer Than D (%) | Adjusted Percentage Finer Than D (%) |
| 30 | 22 | 1,003 | 1.025 | 12.9537 | 0.068 | 94.778 | 73.9268 |
| 60 | 22 | 1,003 | 1.0248 | 12.9977 | 0.0481 | 93.954 | 73.2841 |
| 120 | 22 | 1,003 | 1.0243 | 13.1077 | 0.0342 | 91.894 | 71.6773 |
| 240 | 22 | 1,003 | 1.0239 | 13.1957 | 0.0243 | 90.246 | 70.3919 |
| 480 | 22 | 1,003 | 1.0236 | 13.2617 | 0.0172 | 89.01 | 69.4278 |
| 900 | 22 | 1,003 | 1.0233 | 13.3277 | 0.0126 | 87.773 | 68.4629 |
| 1800 | 22 | 1,003 | 1.023 | 13.3937 | 0.0089 | 86.537 | 67.4989 |
| 3600 | 22 | 1,003 | 1.0226 | 13.4817 | 0.0063 | 84.889 | 66.2134 |
| 7200 | 22 | 1,003 | 1.0223 | 13.5477 | 0.0045 | 83.652 | 65.2486 |
| 14400 | 22 | 1,003 | 1.022 | 13.6137 | 0.0032 | 82.416 | 64.2845 |
| 28800 | 22 | 1,003 | 1.0218 | 13.6577 | 0.0023 | 81.592 | 63.6418 |
| 86400 | 22 | 1,003 | 1.0211 | 13.8117 | 0.0013 | 78.708 | 61.3922 |

# 8. Discussion of Results

In this informative experiment, how to determine particle size distribution by Hydrometer experiment was learned with the guidance of Berkan Söylemez. In the light of data obtained from hydrometer, particle size of the materials those are smaller than 0.074 mm were determined. However, because of the time constraints, some of the experiment steps were skipped, and it, of course, affected the accuracy of the experiment. For example, in the real hydrometer experiment, there is a pool which enables the tester to keep the temperature of the hydrometer and environment constant. Moreover, the temperature of the hydrometer should have been measured in each step, but it was not taken into account because of the time limitation, as stated before. Another important point is that surface of the hydrometer should have been cleaned so that the materials accumulated around the hydrometer could not influence the results, yet it was only done once. This experiment was made to measure the particle size distribution of the materials those are below the sieve of number of 200 (0.074 mm). Owing to the reasons mentioned above, the results may not be accurate, but the purpose of this experiment was comprehended. Graph of adjusted percentage finer than D is given below:

**Graph. 1:** Adjusted percentage finer than % - Equivalent diameter (mm)