EARTH SC/ ENVIR SC 2B03
Environmental Soil Science
J.E. Smith, 2012

LAB #2
PARTICLE SIZE ANALYSIS

Due week of Nov 12/2012 at the beginning of your lab

INTRODUCTION

In any given soil, grain size can range from extremely small clay particles to large stones and gravel. The grain size distribution of a soil can be determined by calculating the percentages of sand, silt and clay present in the sample. This particle size analysis can be used to assign a textural class to the soil, which controls the general physical properties of the soil. There are several methods of particle size analysis, two of which will be performed in this lab: mechanical sieving and sedimentation by the hydrometer method.

Mechanical Sieving involves measuring the mass of soil caught in each sieve against the original total weight of the sample; in order to calculate the percent of the soil that passed through each sieve. A plot of percent passing vs. grain size diameter can be obtained, representing the grain size distribution of the soil sample. This method of particle size analysis can be used for a large range of particle sizes (0.02 mm to 2.00 mm in diameter). However, the probability of a particle passing through a sieve depends on the nature of the particle, the number of particles of that size, and the properties of the sieve. As a result, this method often requires pretreatment of the sample in order to achieve good results. Pretreatment can involve the removal of moisture, carbonates, soluble salts and organic matter by heating and chemical reactions. In addition, further preparation could involve physically removing all visible organic material, including grass clumps, roots, branches etc, and breaking up hard soil chunks with a rubber mallet. However, due to time restrictions, it is not possible to perform these treatments in the lab, thus it can be assumed that these substances have already been removed.

Sedimentation analysis is based on the principle that soil particles are denser than water, so they typically sink, settling at a velocity proportional to their size. Meaning the bigger the soil particles, the faster they fall through the solution. Therefore, sedimentation analysis relies on the relationship between settling velocity and particle diameter as described by Stokes Law:

$$v = \frac{d^2 g(r_s - r_1)}{18h}$$

v =	terminal velocity	r_s =	particle density
d =	particle diameter	r_1 =	water density
g =	gravitational force	h =	water viscosity

By applying Stokes Law to particle analysis it is assumed that 1) the terminal velocity of settling particles is attained instantaneously; 2) settling and resistance are entirely due to the viscosity of the fluid; 3) the particles are smooth and spherical; and 4) there are no interaction between individual particles in the solution. These assumptions are met for soil particles that are less than 80 μm in diameter.

In addition, no pre-treatment of the soil samples is necessary in the sedimentation process; however there can be some associated error with this assumption depending on the composition of the soil samples. For example, the presence of soluble salts or gypsum may cause the flocculation or clumping of clay particles which will affect the particle settling velocity. In this case, a significant amount of the dispersion agent, such as Calgon® can be used to prevent such an occurrence.

Sedimentation analysis can be conducted following the ***Hydrometer Method***; which involves placing a soil sample in a cylinder of water and measuring the density of water that is displaced by the soil particles as they settle out of suspension with a hydrometer. As soil particles settle out of suspension past the depth of the hydrometer, the density of the solution drops. Large particles settle out first, thus the decreasing hydrometer readings correspond to a decrease in particle size over time.

There are two types of hydrometers used in this lab: ASTM 152H and ASTM 151H, discernable from the labelled paper inside the bulb of the hydrometer. The ASTM 152H measures the concentration of soil in suspension in g/L and the ASTM 151H measures the specific gravity of the solution (dimensionless).

Reading the hydrometers can be tricky. The ASTM 152H ranges from 0 g/L to 60 g/L and increases by increments of 1 g/L. Whereas, the ASTM 151H hydrometer is a little more difficult to read, because it increases by increments of 0.0010 as seen in Figure 1.

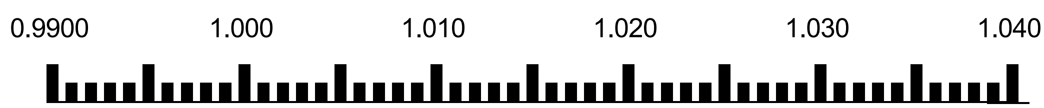

Figure 1: ASTM 151H hydrometer scale.

All measurements must be recorded in g/L, thus a graph converting specific gravity to g/L is provided in Figure 2. Once the hydrometer reading is in units of g/L, then this value can be used in a series of equations to determine its particle size equivalent.

Hydrometers, ASTM 152H and ASTM 151H are calibrated at 20°C. Correction of hydrometer readings for other temperatures, solution viscosity and density effects are made by taking a hydrometer reading in a blank (no soil) solution (R_L). This reading should be taken immediately before adding your soil sample. Thus, the correction of soil concentration in suspension at any given time is $C_t = R_t - R_L$ where R_t is the observed hydrometer reading in g/L.

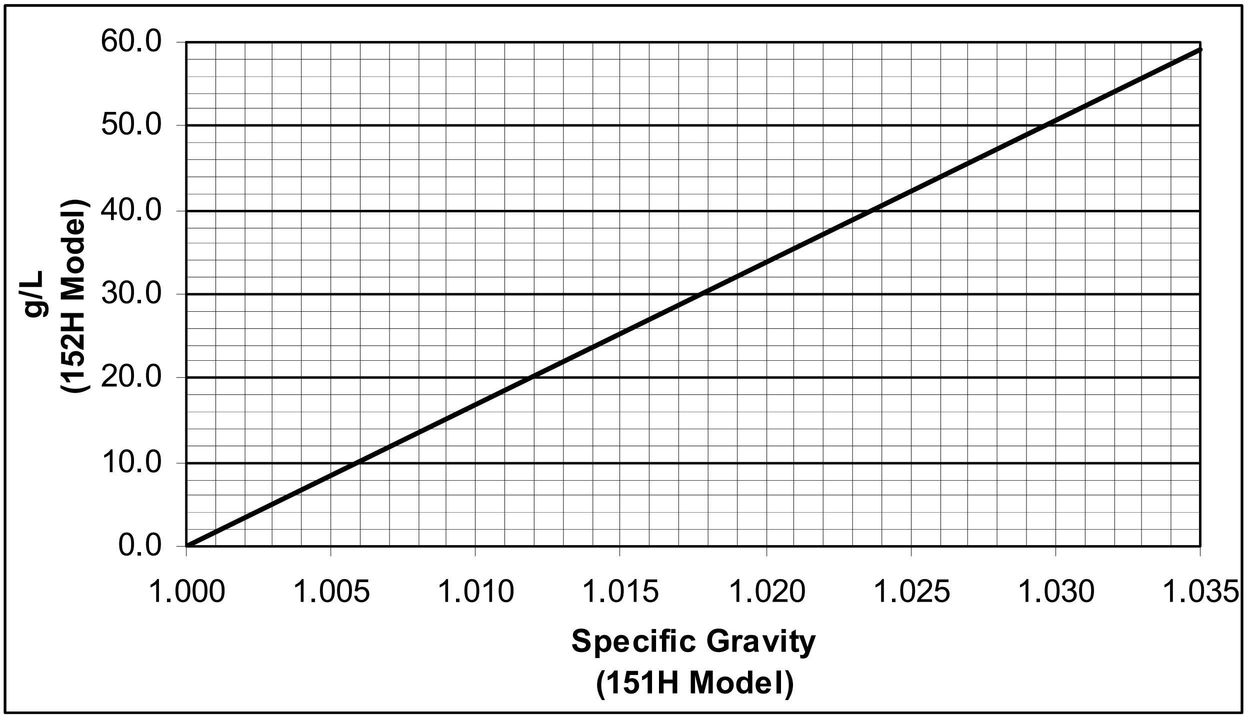

Figure 2: Hydrometer Conversion Chart

PURPOSE

To determine the unknown grain size distributions of two soil samples using two different techniques.

OBJECTIVES

- To become familiar with the methods commonly employed to determine the composition of a soil sample.
- To determine the limitations of each procedure.
- To determine the textural class of the soil samples based on their particle distribution.

PROCEDURE

Part 1: Mechanical Sieving

Due to time constraints and the destructive nature of this grain size distribution test, you will only sieve a sample of the provided soil [redacted], which has been oven dried at 105°C for approximately 24 hours.

Equipment

6 sieves, sieve pan, cover	weighing dishes/ paper towel	soil
shaker	rubber mallet & brush	scale

Method

1. Weigh a large crucible weighing dish (W_1) (***Table 1***).

2. Place approximately 75 g of pre-treated soil in the weighing dish and record total weight (W_2) (***Table 1***).

3. Retrieve a bottom pan, a lid and the appropriate sieves. Each sieve is labelled with the pore size in mm. Choose 6 sieves between the pore sizes (*i*) 0.07 mm to 2.00 mm. Brush all sieves to remove any stray particles from previous experiments. Also, check to make sure none of the sieves are damaged.

4. Assemble the sieves in a size-ordered stack, with the coarsest (largest) sieve at the top and the finest at the bottom. Place the sieve pan on the bottom and a sieve cover on the top of the stack. Record the pore sizes in ***Table 1***.

5. Remove the cover and pour the pre-weighed sample into the top sieve. Replace the sieve cover, place the stack on the sieve shaker, secure it and pre-test for stability. Turn the shaker on for 10 minutes. *If you are unsure, ask the T.A. for assistance.*

6. Record mass of emptied weigh dish (W_3) in ***Table 1***.

7. Turn off the shaker and carefully remove the sieve stack.

8. Weigh a series of weighing dishes (W_{di}) (***Table 1***). Be sure to label each dish with the intended pore size (*i*) that will be emptied on it. *Can use any type of dish.*

9. Remove the top sieve and pour its contents into the pre-weighed weighing dish and weigh the sample + dish (W_{dsi}) (***Table 1***). Be sure to brush out all the soil from the sieve into the weighing dish.
10. Remove the next sieve from the stack and pour its contents into another weighing dish and weigh the sample + dish. Repeat this step until you have measured the weight of the soil caught in each sieve tray and the bottom pan.

Record all values in ***Table 1.***

11. Brush the sieves clean and return the sieves to the proper storage area.

<u>Part 2:</u> Hydrometer Method for Sedimentation Analysis

Due to time constraints and the texture of the provided soils, you will only conduct sedimentation analysis on [redacted] **soil.**

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Equipment

hydrometer	1.5-2.0g of dispersing agent (Calgon®)
1L graduated cylinder	stopwatch, second hand watch, or clock
distilled water	stirring device
soil	plastic weighing boats

Method

1. Record weight of empty plastic weighing dish (W_d) in ***Table 3***.

2. Accurately weigh out approximately 80 g of dry loam soil, using a plastic weighing boat. Record weight of dish and sample (W_{ds}) in ***Table 3***.

3. Place the soil sample into a beaker, gently break up any harden chunks of soil with a rubber mallet. Then add some water to the beaker and mix into a slurry. This will ensure that you measure the sedimentological properties of the sample only.

4. Fill a 1L graduated cylinder to the 1L line with distilled water.

5. Weigh out approximately 1.5 - 2.0 g of dispersing agent in a plastic weighing boat.

6. Add the dispersing agent to the graduate cylinder and mix vigorously with provided stirring device.

7. Check the scale of the hydrometer to determine the type of model: the 152H model is in g/L and the 151H model uses the dimensionless scale of specific gravity. Reminder: if you're using the 151H hydrometer, you must convert your values to g/L using the conversion graph provided in the ***Introduction*** (Figure 2).
8. Carefully place the hydrometer slowly into the water in the graduate cylinder (do not bang it against the side of the cylinder or drop it in the water). Release it as close to its natural floating point as possible. If necessary, use your finger to

stop any oscillations of the hydrometer. **Use extra caution when using the hydrometers as they are fragile and very expensive.*

9. Take a blank (no soil) hydrometer reading (R_L). Record this value in ***Table 3***.

10. Remove approximately 200 mL of water from cylinder.

11. Add the soil slurry to the graduated cylinder, rinse beaker with distilled water to ensure that all of sample is added to the graduated cylinder.

12. Top cylinder back up to the 1 L line. **Note, the exact volume of solution in cylinder must be known (V_T) and recorded in **Table 3**.*

13. Using the provided stirring device, drag the stirring disk up and down several times to disperse the soil evenly throughout the water column.

14. As soon as you finish mixing, start the stopwatch.

15. Take hydrometer readings at <u>30-second</u> intervals <u>for two minutes</u> (R_t). Then take readings at <u>3, 5, 10, 30, 60, 90</u> and <u>120 minutes</u>. Record these values in ***Table 3***. **Note, this is the minimum number of data points required.*

16. Once you are finished, carefully remove from the hydrometer. Clean and return all equipment to the proper storage areas. Use appropriate waste bins for Calgon® solution/ soil slurry.

FINAL LAB REPORT

<u>Part 1:</u> Sieving Analysis

1. Calculate the initial weight of the soil sample using the values recorded in ***Table 1.***

   Initial mass of sample = (mass of weighing dish + soil) – (mass of empty dish)

   $$W_S = W_2 - W_1$$

2. Calculate the weight of soil caught in each sieve tray using values recorded in ***Table 1*** as follows:

   Weight of soil in sieve *i* = (weight of dish + soil from sieve *i*) – (weight of empty dish)

   $$W_{si} = W_{dsi} - W_{di}$$

3. Find the total weight that passed through the sieve stack (W_t) by totalling the values in the W_{si} column in ***Table 1***. This value should be close to the initial sample weight (W_s) (before sieving) otherwise some of your soil sample was

lost.

4. Calculate the percentage of soil caught by each sieve tray, including the bottom pan using the following equation:

   % caught = (W_{si} / W_t) x 100
   W_s = weight of soil in sieve *i* (g)
   W_t = total weight that passed through sieve stack (g)

5. Calculate the % cumulative passing value for the top sieve:

   % cum. passing in top sieve = 100 – (% caught in top sieve)

6. Calculate the % cumulative passing value for each remaining sieve as follows:

   % cum. passing = (% cum. passing from above sieve) – (% caught from current sieve)

7. Plot the percent cumulative passing vs. grain size diameter (sieve pore size) on the semi-log, grain size distribution graph paper provided.

8. Repeat the above steps for the provided dataset for the loam soil (***Table 2***). Include on your grain size distribution results for the loam soil on the same graph paper as the sand.

***** Sample Calculation of Grain Size Distribution Chart from Mechanical Sieving*****

Sieve Pore Size *(i)* (mm)	**Mass of Empty Weighing Dish, W_{di} (g)**	**Mass of Weighing Dish + Soil Caught in Sieve *i*, W_{dsi} (g)**	**Mass of Soil Caught in Sieve *i*, W_{si} (g) (W_{dsi}-W_{di})**	**% Caught**	**Cumulative % passing**
0.7	1.5	23.5	22	23.0	77.0
0.5	2.0	58.0	56	58.3	18.7
0.2	1.0	14.0	13	13.5	5.2
Bottom Pan	1.5	6.5	5	5.2	0.0
			W_t (g) = 96		

Example Calculations:

W_t = 22 + 56 + 13 + 5 = 96 g

% caught (0.7mm) = ($W_{S0.7}$/ W_t) x 100 = (22g/ 96g) x 100 = 22.9%
% cumulative passing (0.7mm) = 100 - 23.0 = 77.1%
% cumulative passing (0.5mm) = 77 - 58.3 = 18.7%

<u>Part 2:</u> *Hydrometer Analysis*

1. Calculate the actual weight of the soil sample using the values recorded in ***Table 3****.*

Actual mass of sample = (mass of weighing dish + soil) – (mass of empty dish)

$$W_T = W_{dT} - W_d$$

2. Calculate total concentration of soil in suspension at time *0* (C_T) using total mass of sample (W_T) and known volume of solution in graduated cylinder (V_T).

3. Correct the hydrometer readings (concentration of soil in suspension at time *t*) in ***Table 3*** for each time interval as follows:

Corrected Reading = (Actual Hydrometer Reading) – (Blank Hydrometer Reading)

$$C_t = R_t - R_L$$

4. Calculate the summation percentage (P) for each hydrometer reading as follows:

$P = C_t/C_T * 100$
C_T = total concentration of soil sample in solution (g/L)
C_t = corrected hydrometer concentration (g/L)

5. Calculate the effective hydrometer depth (h) for hydrometer reading (R_t) – related to specific design and shape of hydrometer.

h = the effective hydrometer depth (cm) for a standard 152H hydrometer
$= (-0.164\ cm \cdot L \cdot g^{-1}) \cdot R_t + 16.3cm$
R_t = the hydrometer reading at time *t* (g/L)

6. Find the Sedimentation Parameter (q) in units of $cm \cdot sec^{½}$ for each time interval using the following formula:

$q = (Bh)^{1/2}$

B = constant describing particle movement in a solution
= 9.9×10^{-5} cm·sec
h = the effective hydrometer depth (cm)

7. Convert q to units of µm·min^{½} since X and t are reported in µm and minutes.

$$\text{cm}\cdot\text{sec}^{1/2} \times (10\ \text{mm}/\ 1\ \text{cm}) \times (1000\ \mu\text{m}/\ 1\ \text{mm}) \times (1\ \text{min}^{1/2} / \sqrt{60}\ \text{sec}^{1/2})$$

8. Calculate the particle diameter (X) in units of µm using the following equation:

$$X = qt^{-1/2}$$

q = the sedimentation parameter (µm·min$^{1/2}$)
t = the time of the hydrometer reading (min)

9. Using the hydrometer data, a fine particle distribution curve can be obtained by plotting the summation percentage (P) vs. the particle diameter (X). This graph should be plotted on the same semi-log paper as the sieving data. The curve from the sieving method and the hydrometer method can be joined to produce a complete grain size distribution for the loam soil. **Note, grain diameter (scale on x-axis) on provided semi-log graph paper is in mm; thus all calculated X values will need to be converted from µm to mm.*

Sample Calculation of Grain Size Distribution Chart from Sedimentation Analysis

Time, t (min)	*Concentration of soil in suspension at time t (hydrometer reading) R_t (g/L)*	*Corrected Concentration C_t (g/L) ($R-R_L$)*	*Summation Percentage, P (%)*	*Effective Hydrometer Depth, h (cm)*	*Sedimentation Parameter, q (µm·min^{½})*	*Particle Diameter, X (µm)*
0.5	11	9	21.8	14.5	48.9	69.2
1	10	8	19.4	14.7	49.2	49.2
1.5	9	7	17.0	14.8	49.5	40.4
2	8	6	12.5	15.0	49.7	35.2
	R_L = 2 g/L	C_T =41.2 g/L				

Example Calculations:

C_T = total mass of soil in 1 L of water = 41.23 g/L

P (0.5min) = $(C_t / C_T) \times 100$ = (9g/ 41.2g) x 100 = 21.8%
h (0.5min) = -0.164 R_t + 16.3 = -0.164 (11) + 16.3 = 14.5 cm
q (0.5min) = $(Bh)^{1/2}$ = $((9.9\times10^{-5})\cdot 14.5)^{1/2}$ = 0.0379 $cm\cdot sec^{½}$
= $(0.0379 cm\cdot sec^{½})(10mm/1cm)(1000\mu m/1mm)(1min^{½}/\sqrt{60}sec^{½})$
= 48.9 $\mu m\cdot min^{½}$
X (0.5min) = $qt^{-½}$ = $(48.9)(0.5)^{-½}$ = 69.2 µm or 0.0692 mm

QUESTIONS

1. Describe some of the disadvantages and advantages of each particle size method. List some possible sources of error associated with each method.

2. Explain how both mechanical sieving and the hydrometer method could be modified slightly and adapted to provide insight on soil structure instead of only soil texture.

3. In a few words, what is the difference between the particle size distribution curve obtained by the hydrometer method compare to the curve obtained by the sieving method for the loam soil? How are the two particle distribution methods related to the type of the soil?

4. Compare the grain size distribution curves for the sand and loam soil. Is there a lot of difference in the data? Is one of the soils more or less coarse than the other? Is one soil more or less well graded than the other?

5. Use the particle distribution curves to determine the percent of sand, silt and clay in the soil. Classify the soil (e.g. silty-loam, sandy-clay, etc.) by referring to the textural triangle in Figure 4.6 - *The major soil textural classes are defined by the percentages of sand, silt and clay according to the heavy boundary lines shown of the textural triangle,* of your 2B03 text book.

6. Based on your assigned textural classification of the each soil type, what are some basic properties and/or behaviours you could expect to observed in these soils.

DATA

Table 1: Sieving Data for the ~~Sand~~

Group Members:		
Sample Weight before Sieving		
Parameter	***Description***	***Recorded Value***
W_1(g)	Mass of empty weighing dish	
W_2(g)	Mass of dish + soil sample	
W_3(g)	Mass of emptied dish	
Sieving Data		
Sieve Pore Size (i) (mm)	***Mass of Empty Weigh Dishes W_{di}, (g)***	***Mass of Dish + Mass of Caught Sample in Sieve W_{dsi} , (g)***
bottom pan		

Table 2: Sieving Data for the Loam Soil

Sample Weight before Sieving		
Parameter	***Description***	***Recorded Value***
W_1(g)	Mass of weighing dish (g)	158.55
W_2(g)	Mass of dish + soil sample (g)	254.04
W_3(g)	Mass of emptied dish (g)	158.56
Sieving Data		
Sieve Pore Size (i) (mm)	***Mass of Empty Weigh Dishes W_{di} (g)***	***Mass of Dish + Mass of Caught Sample in Sieve W_{dsi} (g)***
2.00	1.30	3.218
1.40	1.31	3.953
1.00	1.32	5.395
0.500	1.30	15.025
0.125	1.30	49.418
0.065	1.33	7.994
bottom pan	1.33	19.397

Table 3: Hydrometer Method Data for the ~~Loam Soil~~

Data before Test	
Parameter	***Recorded Value***
Mass of empty weighing dish (W_d) (g)	
Mass of dish + soil sample (W_{dT}) (g)	
Blank Hydrometer Reading (R_L) (g/L)	
Total Volume of Solution (V_T) (L)	

Hydrometer Test Data	
Time, *t* (min)	**Concentration of Soil in Suspension (Hydrometer Reading) R_t (g/L)**
0.5	
1	
1.5	
2	
3	
5	
10	
30	
60	
90	
120	