Activity 3.4.3 Soils Testing

Introduction

Almost any structure that we build rests on the ground. Before we can design the structure or determine a site grading plan, we must understand the soil conditions. Soil is made up of many different sizes of broken-down rock grains (sand, silt, and clay). How much water a soil will hold, how easily water passes through the soil, and what happens to the soil as it dries is dependent on the combination of these materials in your particular soil. The region's climate and weather conditions and their affect on the soil must be considered.

Before the design of a major project such as a highway, building, bridge, or dam can begin; the ground underneath the proposed construction site must be tested to determine composition and other factors affecting its load-bearing capacity. On large projects, core samples are taken. Engineers use a drill to remove samples of earth at prescribed intervals. Sometimes core samples are taken from a depth of one hundred feet or more. The samples are then brought to the surface for study.

A geotechnical engineer, which is a type of civil engineer, collaborates with a surveyor to map grades, slopes, and any modifications that may have been made to the site. The engineers will determine appropriate locations and depths for taking soil samples. Boring locations will include areas where filling and cutting may occur during construction. In addition, engineers will develop preliminary concepts for drainage structures that may be needed to direct water away.

Not every project needs test borings. However, you must know the basic soil type before you can proceed. In this activity you will test soils to quickly determine the soil properties and, using charts, identify the type of soil. Once you know the type of soil present on a site you will be able to make some preliminary decisions regarding grading and load bearing characteristics.

Equipment

- Sample of soil about the size of a coffee can and collected below the top soil horizon (about 1 to 2 feet)
- 2 mason jars with tops
- 5 gallon pail
- Water
- Mixing bowl
- A 2 ft x 2 ft metal pan
- Rubber mallet
- Sieve collection, ASTM No. 4 and ASTM No. 40. If sieves are not available, use hardware cloth (1/4 in. squares) as a substitute for the No. 4 sieve and fine window screen as a substitute for the No. 40 sieve.
- Bottom sieve pan and cover
- Old newspapers

- Triple-beam balance or digital scale
- Paper towels
- Oven for drying soil samples
- Sample jars of three types of soil: sand, silt, and clay

Procedure

These test methods provide information about the size of the soil particles, the amounts of the various sizes, and the characteristics of the very fine grains. The results of these tests can then be used to estimate the type of soil per the Unified Soil Classification System (USCS). See Table 1 for a summary of the test results and the USCS soil types.

Simple Grain Size Analysis

1. Dry the soil sample in an oven. Use a metal or ceramic mixing bowl or similar container. It is best to dry the soil under low heat (i.e., less than 200ºF) for a few hours. Check soil occasionally and stir.
2. While soil is drying, weigh Mason jars, sieves, and bottom sieve pan. Record the weights in the Table of Sample Soil Weights.
3. Remove soil from oven, place in the metal pan, and pulverize the soil. You may also place in bowl and use fingers. Be sure that all small and large clumps are completely broken apart.
4. Stack sieves with the No. 4 sieve on top, the No. 40 sieve below that, and then finally the bottom pan.
5. Place soil in No. 4 sieve, place cover on top, and shake vigorously.
6. Pull the cover off of the No. 4 sieve and inspect contents to be sure that small dirt clumps do NOT exist on the No. 4 sieve. Manually break up small dirt clumps and sift again.
7. Remove the No 4 sieve from the stack with its soil contents. Weigh the sieve and soil together and record the **No. 4 sieve and retained soil** weight in the Table of Sample Soil Weights.
8. Subtract the weight of the No. 4 sieve from the **No. 4 sieve and retained soil**. The difference is the GRAVEL fraction in the soil sample. Record the Gravel weight.
9. Repeat steps 7 through 9 for the No. 40 sieve. The difference is the coarse and medium-grained SAND fraction in the soil sample.
10. Weigh the bottom pan and its contents. Record and subtract the weight of the empty pan. The difference is the fine SAND, SILT, and CLAY fraction of the soil sample. Record this weight.
11. Pour about half of the contents of the bottom pan into the Mason jar. Weigh and record the **Mason jar and soil** weight.
12. Subtract the weight of the Mason jar from the **Mason jar and soil weight** and record the difference as the weight of **Soil in Mason jar.**
13. Add water to the jar so that ¾ of the jar is filled.
14. Shake the Mason jar, allow the fine sand to settle for 5 to 10 seconds, remove the top, and pour off the dirty water into a 5-gallon pail. Be careful not to spill any of the soil that

has settled to the bottom of the jar into the 5 gallon pail.

15. Repeat steps 13 and 14 until the water is clear. Pour off the clear water. The material remaining in the Mason jar is the fine-grained SAND, SILT, and CLAY that has been removed from the soil sample.
16. Place the Mason jar (without top) and contents into the oven and dry.
17. Remove the jar. Note that the glass jar will be hot.
18. Weigh the jar and contents. Record the weight of the **Mason jar and fine SAND** and subtract the weight of the empty jar. The difference is the weight of **Fine SAND in the Mason jar**.
19. Determine the weight of **Fine SAND in the Mason jar.**
20. Determine the fraction of Fine SAND in the Mason jar and record this value.

$$\text{fraction of sand in mason jar} = \frac{\text{weight of fine SAND in mason jar}}{\text{weight of soil in mason jar}}$$

21. Determine the fraction of **SILT and CLAY in Mason jar** in a similar manner and record the value.
22. Using the fraction of fine SAND, determine the soil sample weight of the fine SAND in the pan. Find the product of the fraction of SAND and the soil sample total weight of SAND, SILT, and CLAY (the last entry in the upper right table). Record this value.
23. Determine the soil sample weight of SILT and CLAY in a similar manner. Record this value.
24. Present the results in the table provided.

Table of Soil Sample Weights

Item	Weight, grams
No. 4 sieve	
No. 40 sieve	
Bottom Pan	
Mason Jar	

Item	Weight, grams	Soil Sample wgt, grams
No. 4 sieve and retained soil		
GRAVEL		
No. 40 sieve and retained soil		
Med. and coarse SAND		
Bottom pan and soil		
Fine SAND, SILT, and CLAY		

Item	Weight, grams	Fraction in Mason jar	Soil Sample wgt, grams
Mason jar **and** soil			
Soil in Mason jar			
Mason jar **and** fine SAND			
Fine SAND **in** Mason jar			
SILT and CLAY **in** Mason jar			
Fine SAND in pan			
SILT and CLAY in pan			

Presentation of Results

Item	Soil Sample weight, grams	Percent in soil sample	
GRAVEL			
Med. and coarse SAND			Total SAND, %
Fine SAND			
SILT and CLAY			

USCS Classification Technique for Coarse-Grained Soils

1) A coarse-grained soil, also called a granular soil, has more than half of the soil grains visible to the naked eye. If the percentage of GRAVEL and SAND is greater than 50%, then the soil is a granular soil.

2) If the soil is predominantly coarse-grained, identify the soil sample as being gravel or sand by estimating whether 50% or more, by weight, of the coarse grains (GRAVEL and SAND) are larger or smaller than the No. 4 sieve size.

3) If the soil is a GRAVEL, identify as being clean (i.e., containing little or no fines, <5%) or dirty (i.e., containing an appreciable amount of fines, >12%). Fines are SILT and CLAY. For clean gravels, final classification is made by estimating the gradation: the well-graded gravels belong to the GW groups, and the poorly graded (uniform) gravels belong to the GP group. Dirty gravels are of two types:
   a) Those with non-plastic (silty) fines (GM)
   b) Those with plastic (clayey) fines (GC)
   c) The determination of whether the fines are silty or clayey is made by the three manual tests for fine-graded soils. See the section below titled *USCS Classification Technique for Fine-Grained Soils.*

4) If a soil is classified as a SAND, the same steps and criteria are used as for gravels in order to determine whether the soil is a well-graded clean sand (SW), poorly-graded (uniform) clean sand (SP), sand with silty fines (SM), or sand with clayey fines (SC).

USCS Classification Technique for Fine-Grained Soils

1) Fine-grained soils, also called cohesive soils, contain greater than 50% SILT and CLAY particles. It is classified into one of six groups (ML, CL, OL, MH, CH, OH) by estimating its dry strength (crushing characteristics), dilatancy (reaction to shaking), and toughness (consistency near the plastic limit), and by identifying it as being organic or inorganic.

2) To complete the following, use the half of the original soil sample left in the pan that was set aside.

3) Dry Strength (Crushing Characteristics)
   a) Mold a pat of soil to the consistency of putty, adding water if necessary.
   b) Allow the pat to dry completely by oven, sun, or air drying.
   c) Test its strength by breaking and crumbling between the fingers.
      i) This strength is a measure of the character and quantity of the colloidal fraction contained in the soil. The dry strength increases with increasing plasticity.
      ii) High dry strength is characteristic for clays of the CH group.
      iii) Typical inorganic silt possesses only very slight dry strength.
      iv) Silty fine sands and silts have about the same slight dry strength, but can be distinguished by the feel when powdering the dried specimen. Fine sand feels gritty, whereas typical silt has the smooth feel of flour.

4) Dilatancy (Reaction to Shaking)
   a) Prepare a pat of moist soil with a volume of about 10 cm^3. Add enough water, if necessary, to make the soil soft but not sticky.

b) Place the pat in the open palm of one hand and shake horizontally, striking vigorously against the other hand several times.
   i) A positive reaction consists of the appearance of water on the surface of the pat which changes to a livery consistency and becomes glossy.
   ii) When the sample is squeezed between the fingers, the water and the gloss disappear from the surface, and the pat stiffens and finally cracks or crumbles.
   iii) The speed of the appearance of water during the shaking process and of its disappearance during squeezing assists in identifying the character of the fines in the soil sample.
      (1) Very fine clean sands give the quickest and most distinct reaction, whereas plastic clay has no reaction.
      (2) Inorganic silts, such as a typical rock flour, show a moderately quick reaction.

5) Toughness

   a. A specimen of soil about 10 cm^3 in size is molded to the consistency of putty. If too dry, water must be added. If sticky, the specimen should be spread out in a thin layer and allowed to lose some moisture by evaporation.
   b. Roll the specimen out by hand on a smooth surface or between the palms into a thread about 3 mm in diameter. Repeatedly fold and refold he thread.
   c. During this manipulation, the moisture content is gradually reduced and the specimen stiffens, finally loses its plasticity, and crumbles when the plastic limit is reached.
   d. After the thread crumbles, the pieces should be lumped together and a slight kneading action continued until the lump crumbles.
   e. The tougher the thread near the plastic limit and the stiffer the lump when it finally crumbles, the more potent is the colloidal clay fraction in the soil.
   f. Weakness of the thread at the plastic limit and quick loss of coherence of the lump below the plastic limit indicate either inorganic clay of low plasticity or materials such as kaolin-type clays and organic clays.

NOTE: Another simple field test that can be used to estimate whether the cohesive soil is higher in silt or clay content is the “smear test.” Use a small clump or form a small pat. The sample should be moist but not wet. Draw your thumb across the sample. If the soil smears smoothly, then it is likely to be high in clay content. If the soil smear appears grainy, then the soil has significant silt or fine sand content.

Table 1

COARSE-GRAINED SOILS (GRANULAR) More than 50% GRAVEL and SAND	Gravelly Soils More than 50% GRAVEL	Clean Gravels will not leave a stain on a wet palm.	**GW**. Well-graded GRAVEL. Various sizes of gravel in sample.	
			GP. Poorly graded GRAVEL. One size of gravel in sample. Uniform.	
		Dirty Gravels will leave a stain on a wet palm.	**GM**. Silty GRAVEL. Non-plastic fines. See ML below to identify.	
			GC. Clayey GRAVEL. Plastic fines. See CL below to identify.	
	Sandy soils More than 50% coarse, medium, and fine grained SAND	Clean Sands will not leave a stain on a wet palm.	**SW**. Well-graded SAND. Various sizes of sand in sample.	
			SP. Poorly graded SAND. One size of sand in sample. Uniform.	
		Dirty Sands will leave a stain on a wet palm.	**SM**. Silty SAND. Non-plastic fines. See ML below to identify.	
			SC. Clayey SAND. Plastic fines. See CL below to identify.	
FINE-GRAINED SOILS (COHESIVE) More than 50% of the soil is SILT and CLAY	Dry Crushing Strength	Dilatancy	Toughness	
	None to slight	Rapid	Low	ML
	Medium to high	None to very slow	Medium to high	CL
	Slight to medium	Slow to none	Medium	MH
	High to very high	none	High	CH
Highly Organic Soils	Readily identifiable by color, odor, spongy feel, and frequently by fibrous texture			OL, OH, and Pt