README

This documentation consists of the laboratory procedures for each of the geotechnical engineering experiments designed to be done anywhere with common household materials. These experiments are strictly for educational purposes and should not be used to attain actual soil data for any type of infrastructure, construction, or land alteration.

The experiments were designed for students learning in a virtual format to be able to understand geotechnical concepts through physical activities much like those that students participate in when in-person. This project was made possible by the sponsorship of Georgia Tech’s Blended Online Learning Discipline Fellowship.

~A. Lynnae Stypulkowski

**LAB SESSION 1:**

**Particle Size Distribution**

**Particle Size Distribution**

This experiment is conducted to quantify the relative distribution of soil type for different combinations of soil. Soil has vastly different compositions of grain sizes and grain sizes play a big role in the properties and characteristics of soil. This experiment utilizes sedimentation to distinguish the difference in grain sizes; larger particles will settle first and therefore the different soil types will settle in stratified layers, with the largest particles on the bottom.

**Procedure:**

1. Watch the demonstrational video
2. Check to make sure that you have all the materials necessary for the test:
   1. Three different soil combinations
   2. Three clear and similarly sized containers
   3. Water
   4. Ruler
   5. Labels
   6. Pen
   7. Funnel (optional)
3. Label each container with what the soil combinations have been labeled with
4. Pour each soil into its respective container
5. Pour water into the container so that the water level is about 1.5-2x higher than the soil layer
6. Close the container tightly, and shake the container for 15-30 seconds, ensuring that all the soil has suspended in the water for at least some amount of time
7. Place the container in an undisturbed location for at least 24 hours
8. Using the ruler, measure the total height of soil in the container, from three different locations around the container, make note of these measurements and denote them as
9. Observe the soil in each container closely, look for any changes in color, any layering occurring, or any inconsistencies and make note of them
10. If there are observable stratified layers, measure the depth of each of them besides the top one at the same locations you made your first measurements (step 8)
11. Be sure to label them so that they are easily differentiated
    1. I had 3 layers, so I labeled them , for bottom, middle, and top respectively
12. To analyze the top layer, subtract the height of the middle and bottom layer from the total height of the soil from each measurement location
13. Average each measurement

    2. … and do the same for and
14. To understand the distribution (), you need to get the % of each soil type, therefore take the average height of each stratified layer and divide it by the average height of the entire layer of soil and multiply by 100%

**Discussion Questions**

If the soil samples were pre-determined by weighing the amount of each soil type, then how could observing their heights in containers conflict with the original pre-determined distribution?

If observing combinations of sand, silt, and clay, what order would these soil types settle in? i.e. which soil type would be the bottom, middle, and top layer?

This experiment obviously estimates the distribution of each soil type heavily, can you think of possible causes that would make the results to this experiment unreliable?

**LAB SESSION 2:**

**Soil Indices**

**Soil Index Tests**

Soil index tests are some of the most basic, but important tests to determine soil index properties of fine-grained soils. The goal is to find Atterberg’s Limits, which are used to classify soils via the USCS. The Atterberg’s Limits that you will be estimating for this experiment are the liquid limit () and the plastic limit (). Each Atterberg Limit is a water content value that defines the transition of a soil boundary. \*note: the terms moisture content and water content are used interchangeably.

If you are performing the experiment on the same soil used in the demonstrational video it can be assumed that:

(specific gravity) (in-situ water content)

It can also typically by assumed that:

(water density)

**Procedure:**

1. Watch the demonstrational video
2. Check to make sure that you have all the materials necessary for the test:
   1. ~40 – 50 g of fine grain soil
   2. 3 measuring cups that give small values (smallest value needs to be at most 10 mL)
   3. Water
   4. Stirrer (spoon, butter spread knife, small spatula, etc.)
   5. Funnel (optional)
3. Fill the cup to a known volume with the dry soil, I chose 40 mL. You can use a funnel to make this easier if you have one handy
4. Tamp the soil to make it a flat layer and to minimize voids as much as possible
5. Make note of the volume of dry soil ()
6. Using a second measuring cup add 5-10 mL of water, but be precise with the amount of water you add and make note of this ()
7. Homogenize the water so that everything is evenly distributed, take your time with this as it is an essential step
8. Use a third measuring cup and line it up on top of the cup with soil and water so that the two mouths of the cup line up perfectly
9. While holding the two cups together flip them over
10. Observe as the soil pours into the empty cup OR if you’ve reached the plastic limit observe how it sticks to the inside of the original cup
11. If the plastic limit was not achieved, repeat steps 6 – 10, keeping track of how much water was added (, being increment of water you have added)
12. Once most of the soil sticks to the inside of the cup after flipping, the plastic limit has been reached, make note of which water increment this occurred at ()
13. The next step is to achieve the liquid limit of the soil, which is done by continuing to add water in increments until the soil flows like a fluid into the empty cup; continue steps 6-10 until you’ve reached the liquid limit
14. Note what increment of water the liquid limit was achieved ()
15. Add up the volume of water taken to achieve the plastic limit and the liquid limit
    1. Note that because you are adding the volumes of water that it took to reach the plastic limit and then the ones that occurred after that to reach the liquid limit
16. Convert each volume measurement to mass (), because water content is typically given by masses of soil constituents
17. Now you can calculate the water content at the plastic limit and liquid limit respectively
18. With this information the plasticity and liquidity index ( and respectively) can be measured using the following equations
    1. , leave values in their percent form
    2. , you can evaluate this equation in decimal or percent form

**Discussion Questions**

Using the plasticity chart below, classify this soil. If it is known, does this match the actual soil type?

This experiment obviously estimates the soil indices heavily, can you think of possible causes that would make the results to this experiment unreliable?

Through literature review, explain why soil indices tests are only done on fine grain soils.

Chart, line chart

Description automatically generated

(Budhu, 2015)

**References**

Budhu, M. (2015). *Soil mechanics fundamentals.* John Wily & Sons, Ltd.

**LAB SESSION 3:**

**Hydraulic Conductivity**

**Falling Head Permeability Test**

Hydraulic conductivity is the coefficient that relates the hydraulic gradient to laminar flow velocity in granular material. The two main laboratory tests that aide in determining hydraulic conductivity are the constant head permeameter test and the falling head permeameter test. In this lab session, the falling head permeameter test will be conducted on 3 different types of sand: coarse grain sand (type ASTM 20-30), medium grain sand (type AFS 50/70), and fine grain sand (type Ottawa F110).

**Procedures**

1. Watch the demonstrational video.
2. Check to make sure that you have all of the materials necessary for the test:
   1. Clear plastic tube ~ 1 foot in length – we will call this the cylinder
   2. Filter paper
   3. Wire mesh
   4. Hose clamp
   5. 3 varying types of sand or silt/sand combination
   6. Plastic solo cup
   7. Timer
3. In the video the cylinder has already been prepared, if yours is not secure the filter paper and wire mesh to the outside of the plastic tube using the hose clamp
4. Mark the cylinder 4 inches from the bottom (end with filter paper and mesh), 9 inches from the bottom, and 11 inches from the bottom
5. Fill the cylinder slowly with one of the types of soil
6. Tamp the bottom of the cylinder on a hard surface, hard enough to see some rearranging of particles, but gently enough to not cause damage to the equipment
7. Add more sand until there is approximately 4 inches of sand in the cylinder (i.e. height of the sand in the tube should be 4 inches)
8. Place the cylinder in the solo cup (filter end down), and then place the entire apparatus into a sink or area that is okay to get wet
9. Begin filling the solo cup (outside of the cylinder) with water until the water level is right at or above the soil level in the cylinder
10. Water will begin soaking through the soil pores, and the water level in the solo cup will begin to decrease because it is equilibrating in the sand. Continue adding water to the solo cup outside of the cylinder to keep the water level in the solo cup even with or higher than the soil level until you see water rise above the top of the soil
11. Using the small clear cup, gently fill the cylinder to the top with water and prepare your timer
12. Watch as the water level in the cylinder decreases and begin your timer when the water level is even with the most top line (11 inches from the bottom)
13. Stop your timer when the water level in the cylinder is even with the middle line labeled (9 inches from the bottom)
14. Record this time ()
15. Remove the cylinder from the solo cup and empty the water from the solo cup.
16. If you want to re-use this soil for a future experiment try not to lose any of it, let most of the water drain from the cylinder and then empty the coarse sand into a pan or plate, spreading it so that the particles are in a thin layer
17. Leave the sand in a pan/plate to dry. If possible, place the sand in an oven safe dish and heat it into the oven at 230 °F for a few hours. DO NOT place the sand near a fan or AC unit that could blow the sand around and off the tray
18. Repeat this process for the other soil types. Make sure that each type of soil is in its own pan/tray and labeled. We don’t want to mix the sands or forget which sand is which

**Calculations**

For this situation, , because the cylinder has a constant diameter. The length of flow path is the height of the soil sample, therefore . The distance from to is 2 inches, and . The parameter that is to be measured during each experiment is the time ().

**Discussion Questions**

1. Typically, the falling head permeameter test is used on fine-grain soils, while the constant head permeameter test is typically used on coarse-grain soils. How and why do you think this could alter your results? Find a journal publication to back your theory and cite this source.
2. Viscosity of water is dependent on the temperature. All values in this lab were assumed to be at 20 °C. However, the actual temperature could have been higher or lower. How would the viscosity and water temperature affect the measured hydraulic conductivity?

**LAB SESSION 4:**

**Consolidation**

**1-D Consolidation Test**

Consolidation tests are done to measure the magnitude and rate of consolidation of soil when it is restrained laterally and drained axially while subjected to increasing loads. This test is designed to simulate the one-dimensional consolidation and drainage conditions. In the field, e.g., the placement of a fill material. The magnitude of consolidation for coarse-grained soils is much less compared to fine-grained soils. However, the rate of consolidation of fine-grained soils is much slower because of their lower coefficient of permeability.

In this experiment, the soil sample is confined in a rigid syringe and loaded at the top of the sample using a syringe plunger. The soil can deform vertically in the syringe, but not horizontally. Once a load is applied on the soil sample, the water in the pore space will be “squeezed out”, and water will drain through the bottom of the syringe. The soil particles will then settle into the pore space that the water had occupied.

The initial void ratio of the soil is calculated from the mass of the soil, the specific gravity, and the total volume readings. As the test progresses, we calculate the void ratio at any load using total volume readings. A graph will be plotted of the void ratio on a linear scale vs. the load on the plunger using a logarithmic scale.

**Procedure**

1. Watch the demonstrational video
2. Check to make sure that you have all the materials necessary for the test
   1. Fine grain soil
   2. Modified syringe\*
   3. Plastic solo cup
   4. Spoon
   5. Stir stick
   6. Small cup
   7. Wood base\*
   8. Filter paper
   9. 2 Hook screws\*
   10. 10-lb test braided fishing line
   11. 2 Nails
3. If this experiment is being conducted as part of the at-home lab kits then you can skip to step 9
4. \*Drill very small holes in the syringe just above the 20 mL and 25 mL marks to allow excess water escape. Cover the 20 mL holes with water-proof tape such as duct tape or electrical tape
5. \*Cut 2 Slits into the plunger of the syringe to allow the fishing line to be fed over the plunger
6. \*Drill the wood block with a hole at one end that is just slightly bigger than the diameter of the syringe. The syringe should be equipped with a wide lip that prevents it from falling through the hole, make sure the hole is not bigger than this lip
7. \*Drill two small holes on the side of the wood block in-line with the hole for the syringe. These small holes should have a diameter slightly smaller than the hook screws
8. \*Tie the fishing line to each hook screws approximately 1 foot from each other using a clinched knot on each screw
9. Cut the filter paper to be approximately 1 cm2
10. Remove the plunger from the syringe and place a piece of filter paper in the bottom of the syringe so that it is flat on the bottom of the syringe (using a stir stick may help)
11. Pour water into the small cup, and then place your finger at the bottom of the syringe while holding the stir stick in place so that the filter paper doesn’t move
12. Slowly pour water from the small cup into your syringe until the water level is at the 25 mL mark. If the filter paper moves around a little at first that is okay, it will eventually sink to the bottom, and using the stir stick can ensure that it goes back to a flat position covering the hole in the bottom of the syringe
13. Using the plastic spoon, add a little bit of soil to the syringe. Be sure that the stir stick is still holding the filter paper in place, you want to avoid letting any soil get below the filter paper
14. Continue to add a little bit of soil to the syringe, checking the filter paper to ensure it is still in place often and that no soil has gotten underneath it
15. Once you have about 10 mL of water, it should be safe to remove the stir stick, because the soil is applying enough force to the filter paper that it won’t move
16. Agitate the soil-water mixture (give it a stir) using the stir stick to ensure that the soil is not settling in distinct layers. Continue agitating the soil-water mixture for every 3-5 mL of soil added
17. Continue adding soil and agitating the mixture until the soil level is at or slightly above the 20 mL mark (hiding by the black tape). This should be around 30 g of soil, which is the approximate value we will use when calculating the void ratio ()
18. Place the wooden block on the edge of a surface so that the end with the small hole is hanging off of a surface (i.e. you should be able to see the ground if you look down through the small hole)
19. Place the solo cup on the floor directly below this hole to catch excess water
20. Place the syringe through the hole and allow water to flow freely out of the bottom of the syringe into the solo cup
21. Remove the black tape from the syringe, you will see water escaping from the holes that were below the tape, this is fine
22. Ensure any water escaping from the bottom of the syringe is clear. THIS IS VERY IMPORTANT! It means that the filter paper is properly in place and that the setup of the test was a success
23. Read the soil level in the syringe. If this soil level is < 20 mL, add more soil to the syringe until it is as close to 20 mL as possible
24. Replace the plunger into the syringe. It is easiest to do this by pushing down on the back end of the wood block that lies on the surface so that the block does not flip. Replacing the plunger takes some force…
25. Push the plunger down until it is flush with the soil level and covering the holes at both 25 and 20 mL
26. Line up the plunger so that the slits are in line with the small drill holes on the sides of the wood block. Also line up the syringe so that it is easy for you to take volume readings
27. Take the hook screws that are tied with fishing line and screw one of them into the side of the wood plank into one of the pre-drilled holes. Screw it just enough so that it is secure and will not fall out but leave most of the threads out of the wood. While screwing, make sure that fishing line is being wrapped around the screw so that the fishing line is tightening as the screw tightens
28. Take the fishing line and slide it into the slits of the plunger
29. Take the second screw and measure the length of line necessary to make the fishing line taught between the two screws and slits in the plunger
30. Wrap the fishing line around the first screw until this desired length is achieved. Stay as close to the hook part of the screw as you can
31. Once you have reached the desired length, screw the second screw in just enough so that it is secure and will not fall out. Be sure that the fishing line is also wrapping around the screw in the opposite direction so that it is getting shorter
32. Double check that the fishing line is taught
33. Place the nails into each hook screw so that you can have levers to ease the force needed to turn the screws
34. To start, screw each screw ¼ of a turn to make it tighter. If there is no water escaping from the bottom of the syringe continue screwing the screws tighter by ¼ turn each
35. Once you see the first bit of water escape from the syringe, wait for the water to stop dripping from the bottom of the syringe and record the volume that the tip of the plunger is currently at. This will be your reading at “0” turns in the table below.
36. Turn the screws ¼ of a turn each again, making the screws tighter and wait until the water has stopped dripping from the bottom of the syringe, then take your volume reading of where the tip of the plunger is at. This will be your second reading of “¼ turns”
37. Continue turning each screw ¼ of a turn, waiting for the water to stop dripping, and recording the volume in the syringe until you have made a total of 2.5 turns (2 2/4)
38. Once you get to 2.5 turns, continue turning each screw ¼ of a turn and let the pressure dissipate when you see water escaping from the bottom of the syringe. Not as much water will dissipate now that there is less water in the overall system. Therefore, if you do not see any water escaping, you do not have to wait.
39. Keep track of the number of turns it took until failure in the line occurs, this typically occurs ~3-5 turns
40. Read the final volume reading in the syringe and mark the last box in the table with the final amount of turns and this volume reading

|  |  |
| --- | --- |
| # of turns  (each screw) | Volume Reading  (mL) |
| 0.01 |  |
| 1/4 |  |
| 2/4 |  |
| 3/4 |  |
| 1 |  |
| 1 – 1/4 |  |
| 1 – 2/4 |  |
| 1 – 3/4 |  |
| 2 |  |
| 2 – 1/4 |  |
| 2 – 2/4 |  |
| For Failure | |
|  |  |

**Calculations**

(Assume Gs = 2.65)

( is the volume reading in the syringe)

Stress are calculated based on the pound test that the fishing line can hold and where your line failed. Stress will be in the units of psi.

**Discussion Questions**

Create a graph that graphs void ratio (y-axis) vs stress (psi) in log scale. As shown in the table above at “0 turns” we will assume slight stress of 0.01 turns was added to the soil, because 0 cannot be plotted logarithmically. What is the compression () and recompression indices ()?

Assuming the soil is normally consolidated, what would the primary consolidation settlement () be? Measure the initial heigh using a ruler from where the first volume reading measurement was on the syringe (). The syringe measurements are approximately 5.875 in (15 cm) from the bottom of where 30 mL is read.

**LAB SESSION 5:**

**Shear Strength**

**Direct Shear Test**

Strength tests are done to measure the magnitude that different soil types can handle under varying conditions. The direct shear test in particular measures the shear stress within the soil skeleton, by applying a defined compression load normal to the soil, and an increasing tension load in the shear direction until the box moves causing shear failure.

The materials used for this lab will be used for a home-made direct shear test to measure the strength of different soil types. It is important to not only test different types of soil, but also to measure the soil with varying normal stresses applied. The strength of each soil type will be used in combination with the known normal stress to calculate the friction angle.

**Procedure**

1. Watch the demonstrational video
2. Check to make sure that you have all the materials necessary for the test
   1. 2 different sand types
   2. Plastic ring
   3. Spring scale
   4. Printer paper
   5. Sandpaper
   6. Weights
   7. Rubber band or thin rope
   8. Cardboard
3. If the weight of the weights is unknown measure them using the spring scale
4. Place the weights in a plastic shopping bag and hang them from the spring scale and measure the reading on the spring scale, record these values
5. Lay the sandpaper so that one edge lays on top of the printer paper a few inches
6. Wrap the rubber band or string around the ring and hook the hook screw through the rubber band / string
7. Sprinkle a thin layer of one of the sands onto the sandpaper. Ensure this layer is larger around than the ring
8. Place the ring on top of the thin sand layer
9. Fill the ring about halfway full of the same sand that was sprinkled on the sandpaper
10. Cut the cardboard to fit inside the ring
11. Lay the cardboard on top of the sand inside the ring. Use the cardboard to flatten the sand to make it a level layer
12. Place the first weight on top of the cardboard
13. Hold the hook screw over the printer paper and hold both down still with one hand
14. With the other hand slide the sandpaper away from the spring scale and read the measurement of the spring scale when the ring begins to slide across the sandpaper. Make note of the force it took to slide the ring
15. Repeat steps 7-11 with the same sand
16. Add the second, heavier normal force, to the sand this time and then repeat steps 13 and 14
17. Repeat steps 7-16 again, but use the other type of sand this time
18. Calculate the normal and shear stress of each trial
    1. , The normal force () and the cross-sectional, circular, area of the ring () are used to calculate the normal stress ()
    2. , The force applied to move the ring () and the profile area of the ring () are used to calculate the shear stress ()
19. Then create a graph like that in the video to create a line for each type of soil and calculate the friction angle

**Discussion Questions**

Which type of soil is stronger (higher friction angle)? What about the soil properties helps with the strength of the soil?

Do your results line up with that of the typical friction angle you would see for this type of soil? Use literature to justify your response.