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SWELLING OF HIGHLY PLASTIC CLAYS UNDER CENTRIFUGE LOADING

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A.1 Soil Preparation

In order to prepare the soil for centrifuge testing, the processed soil was passed through Sieve #10 into a mixing bowl, until approximately 300 grams of sieved soil was obtained. The appropriate amount of distilled water was added using a spray bottle to achieve the target water content. Usually, 3.5% additional water mass was added to the soil to account for water loss during the mixing process. A light coat of water was sprayed on the surface of the soil and mixed into the soil using a spatula. This was repeated until the water within the spray bottle was depleted. The soil and water were also hand mixed in addition to mixing with the spatula. The soil and water mixture was placed in a Ziploc bag for at least one day. This allowed the water to evenly distribute throughout the soil particles. The acceptable range of water contents for centrifuge testing was approximately +/- 0.5% of the target water content.

A.2 Permeameter Cup Preparation

The top cup, cup base, and the porous disks were cleaned and air dried before each centrifuge test. These components are shown in Figure 1.

Figure 1: Components of Plastic Permeameter Cup: Top Cup, Cup Base, and Porous Disks

The top and base were shaken vigorously to remove any water in the small crevices, and the porous disks were shaken on a paper towel in order to remove water trapped within the 1/32" holes. The following list describes the permeameter cup preparation after it has been cleaned and dried:

- Overlay the porous disk with the filter paper, and use scissors to cut the filter paper to the diameter of the disk. Two filter papers are required for each permeameter cup.
- Record the mass of the top cup and cup base and screw the base to the top cup.
- Insert a porous disk to rest on the bottom ledge of the top cup.
- Place a thin layer of vacuum grease 1.5 cm high on the inside rim of the bottom of the top cup. This is the area where the compacted and expanding soil will be in contact with the cup.
- Insert the cut filter paper on top of the porous disk and press down to ensure the filter paper, porous disk, and cup ledge are in good contact with one another.

- Record the mass of the constructed cup.
- Record the height of the cup to the nearest 1/1000” using the mounted caliper. The caliper arm is placed inside the opening of the top cup until the tip of the arm contacts the small metallic plate that is on top of the filter paper. Adjust the position of the cup to where the height measurement can be taken in the center of the filter paper. To determine the target height of the compacted soil specimen within the permeameter cup, 1 cm is added to this height (1 cm corresponds to the target sample height after compaction).
- Using the mounted caliper, record the height of the top porous disk lying on top of the filter paper.

A.3 Soil Sample Compaction

The test specimens were compacted to a height of 1 cm. In order to obtain a 1 cm high specimen compacted to the desired dry unit weight, the mass of soil required to achieve the testing conditions was predetermined. Knowing the target dry unit weight, the target water content, and specimen height and diameter, we then back-calculated the mass of soil needed to achieve the desired conditions.

The specimen height was monitored throughout the compaction process using a small metal plate with a thickness of 0.039” as shown in Figure 2. The marks on the metal plate designate the point at which the caliper arm is placed to measure the specimen height. The specimen height is monitored on five points across the surface of the specimen: the middle, top, right, bottom, and left as shown in Figure 2. The air vent along the top cup serves as the reference point for taking the different height measurements across the specimen’s surface.

(a) ***(b)***

Figure 2: (a) Location of Sample Height Measurements throughout Testing Procedure (b) Metal Plate Used in Determining Sample Height

The subsequent stages in the test procedure are as follows:

- Place the constructed permeameter cup on the scale and zero it. Pour the predetermined mass of cured soil out of the Ziploc bag into the cup using a funnel. During the pouring process, it is beneficial to pause and vibrate the cup by shaking and/or tapping to evenly

distribute the soil particles. To account for soil mass loss during compaction, we recommend adding 0.1 grams of soil to the predetermined mass. Once all of the soil has been poured into the cup, check to see if the soil has been distributed evenly. Sometimes, manual adjustment of the soil particles may be needed to prevent significant unequal densities within the soil.

- Close the Ziploc bag to keep the cured soil from losing moisture. The water content of this soil will be taken later in the test procedure.
- Begin compacting using your thumb in order to densify the soil enough to withstand the bearing load produced by the small diameter compactor (Figure 3).

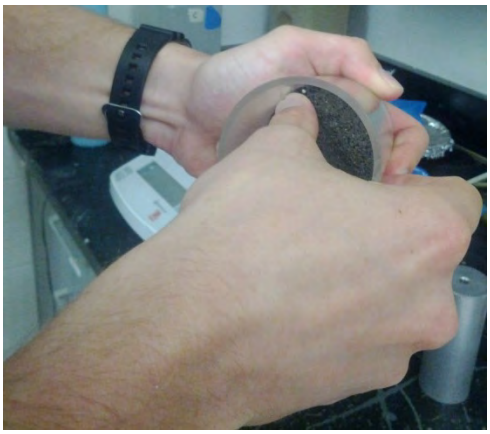

Figure 3: Densification of Soil Using Thumb

- Begin to compact the soil using the small diameter kneading compactor (Figure 4), while trying to maintain a constant height across the top surface of the specimen. Continue to monitor the change in specimen height using the vertical caliper and the metal plate.
    - Note: the small diameter kneading compactor creates an uneven surface on the top of the compacted specimen. In order to create a flatter surface for the top filter paper and porous disk to sit on, we used the larger diameter compactor in conjunction with a rubber mallet, as described in the next bullet point.

Figure 4: Compaction of Soil Specimen Using Small Diameter Kneading Compactor

- When the specimen height reaches approximately 0.03” from the target height, begin compacting the soil with the large diameter compactor. Slide the compaction rod along the inner wall of the permeameter cup until it is sitting on the soil specimen; hold the compactor in place with your thumb. The bottom of the compactor should be flush with the soil, and the side of the compactor should be flush with the inner wall of the cup. Using the side of the rubber mallet, gently tap the top of the compactor four times (Figure 5). Rotate the cup 45 degrees, and continue the tapping procedure until the full 360 degree rotation is completed. Check the specimen height at the locations previously mentioned after each 360 degree rotation.
    - Note: soil will rise along the inner diameter of the top cup due to compaction. Remove the soil by using a dental hook along the rim of the top of the specimen. This soil should be placed back in the cup and re-compacted using the small kneading compactor prior to continuing with the large diameter compactor.

Figure 5: Compaction of Soil Specimen Using Rubber Mallet and Large Diameter Compaction Rod

- Alternate between the compaction techniques (using the small and large compactors) until the target height is reached. During this point in the compaction process, the small compactor is most useful in densifying a small area of the specimen in order to achieve the 1 cm specimen height in that location.
- Record the final specimen heights using the metal plate at the middle, top, right, bottom, and left of the sample (Figure 6).
    - Note: it is critical that the soil specimen is compacted as close to 1 cm as possible in the center, since this is where the in-flight data acquisition system will be recording the swell data. An acceptable range for the middle sample height was deemed +0.001” and -0.002” from the target height. Regarding the top, right,

bottom, and left sample heights, an acceptable range was +0.002” and -0.005” from the target height.

Figure 6: Measurement of Compacted Specimen Using Metal Plate and Mounted Caliper

- Record the mass of the permeameter cup and the compacted soil.

A.4 Permeameter Cup Assembly

The procedure for assembling the permeameter cup after the sample has been compacted within the tolerable range involved the following:

- Place the filter paper and the top porous disk on the soil and seat it with your thumb by applying pressure in the center of the porous disk.
- Record the height of the sample at the center of the cup using the mounted caliper
- Record the mass of the permeameter cup.
- Record the mass of the overburden washers and place them upon the top porous disk.
- Place approximately 25.65 grams of stacked washers on the top porous disk. Make sure the center of the washers aligns with the center of the porous disk (Figure 7). The 26.65 grams simulate half the weight of the 2 cm of water head to be added during the swelling process.

Figure 7: Assembled Permeameter Cup with Overburden Washers and Washers Simulating 51.3 Grams of Overburden from the Ponded Water

- Insert the assembled permeameter cup into the metal swing-out bucket. The metal buckets should already be hanging from the arms of the rotor within the centrifuge.
- Insert the linear position sensor (LPS) into the center holes of the washers until it reaches the center of the top porous disk. Ensure there is good contact between the LPS and the top porous disk, as well as good contact between the top cap and the permeameter cup.
- Place a piece of electrical tap along the metal bucket and top cap in order to stabilize the LPS during centrifugation.
- Adjust the centrifuge RPMs to the desired testing conditions.
- The final assembly is displayed in Figure 8.

Figure 8: Assembled Testing Setup within the Centrifuge

A.5 Seating Load and Compression Cycles

The seating load and compression cycles of the specimen determine the seating height of the sample and the height of the specimen after compaction. Two cycles are completed to ensure these heights have been accurately measured by the data acquisition system. The steps to complete the compression/decompression cycles are:

- Press the START button on the control board of the centrifuge.
- Monitor the accelerometer readings to determine when the g-Level reaches a value corresponding to 2–3 g's. After reaching the target g-Level, wait approximately 5 minutes or however long it takes for the height measurements to reach a constant level.
- Adjust the RPM dial reading accordingly to obtain the target g-Level for the test. After reaching the target g-Level, wait at least 15 minutes for the height of the samples to reach a constant level.
- Press STOP on the centrifuge and wait until the accelerometer reading signifies the centrifuge is no longer spinning.

A.6 Final Permeameter Cup Preparation

- Remove the permeameter cup from the metal bucket and take out the metal washers from inside the cup.
- Insert the washers, providing the overburden mass for the permeameter cup.
- Zero the mass of the cup on the scale and add 51.3 grams of distilled water to the cup (51.3 grams of water is the mass that approximately corresponds to 2 cm of ponded water head) (Figure 9).

Figure 9: Final Permeameter Cup Assembly with 2 cm of Ponded Water Head and Overburden Washer

- Insert the cup into the centrifuge as described in Section A.4.
- Wait for one output reading and then press START. Monitor the accelerometer reading to ensure the centrifuge reaches the target g-Level and adjust the RPMs if needed.
- Take the water content of the mixed soil in the Ziploc bag according to ASTM D 2216. This water content is the compaction water content for the test specimen.

A.7 Test Duration

The protocol used in this study involves running the centrifuge test for 2 days. The 2-day test duration was chosen for the following reasons:

1. Primary swelling of the sample is completed within 1 day of starting the centrifuge test.
2. Secondary swell is observed and its rate can be determined when the swell data is plotted on a semi-log scale.
3. Little information is gained regarding the swell potential and behavior of soils when the test continues for longer than 2 days.

A.8 Test Termination

After the 2-day centrifuge testing period, the test is terminated with the following procedure:

- Push STOP on the centrifuge and flip the switch activating the max brake. Wait for the centrifuge to stop spinning.
- Once the centrifuge has stopped spinning, and one more output reading has taken place, press the stop button on the Labview program control screen.
- Push STOP again to deactivate the magnetic locking mechanism for the centrifuge door. Open it and remove the permeameter cups from the metal buckets.
- Record the weight of the permeameter cup.
- Record the weight of the base of the permeameter cup and pour out the outflow water.
- Remove the overburden washer and pour out the ponded water. We recommend applying pressure with the thumb to the center of the top porous disk during the pouring process. This helps ensure that most of the water trapped between the interfaces of the porous disk, filter paper, and the specimen is removed, and not incorporated into the hand-measurement of the swell potential.
- Attach the cup base to the top cup and record the heights of the specimens in the previously described locations (Figure 2).
- Remove the soil specimen by unscrewing the cup base and sliding the specimen from the bottom to the top of the cup.
- Gently dry the outer surface of the test specimen and take a water content measurement according to ASTM D 2216.
    - Note: the soil sample will have small pockets of water on its top surface due to the ponded water added for the centrifuge swell testing. These water pockets are not absorbed by the soil, and should not be considered in final water content measurement after swelling has taken place. Therefore, the water is removed by gently patting the outer specimen surface with a paper towel.