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LAB WRITE-UP

INVESTIGATING THE ENGINEERING PROPERTIES OF FINE-GRAINED SOILS WITH VARYING PORE FLUID

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L A B O R A T O R Y   A S S I G N M E N T

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My lab partner Claire and I worked alongside UCLA's Civil and Environmental Engineering Department over the course of the 8-week High School Summer Research Program. Our daily lab supervisor provided us with a thorough explanation of their entire project and what we would contribute to their research. Our lab setting was fairly convenient since it was next doors to the office where we had the opportunity to see the other graduate students working. At the beginning of the program, we typically conducted preliminary experiments in the lab to verify previously recorded data. As the program progressed, we became more involved in helping our DLS with his current projects by conducting a greater variety of experiments.

P R E P A R A T I O N   W O R K   F O R   P R O J E C T

A - JOURNAL ARTICLES

Tiwari, et al. "Consolidation and swelling behavior of major clay minerals and their mixtures," *Applied Clay Science* Vol. 54 (2011)

Investigators test the consolidation and swelling behaviors of soil specimen containing various clay minerals. Through experimentation, they were able to establish a wide range of correlation equations as well as triangular correlation charts to relate the consolidation and swelling behavior of soils with their liquid limit and mineral composition. This article is pertinent to our research since it involves testing the soil specimen for various engineering properties, which is similar to what our experimentation involves.

CRITIQUE: I believe that the article was able to clearly explain their methods and procedure, and did a good job of conveying their results and conclusions. However, I did not understand why quartz was one of the primary minerals used in their experimentation since quartz is not considered a clay mineral and proved to have minimal effect on the consolidation and swelling indices of the soil specimen.

Stewart, et al. "Liquefaction-Induced Lateral Spreading in Near-Fault Regions during the 1999 Chi-Chi, Taiwan Earthquake*." Journal of Geotechnical and Geoenvironmental Engineering* Vol. 132 (2006)

Researchers investigate the impact that the Chi-Chi earthquake of 1999 had on the landscape. They noted severe examples of liquefaction in the inland areas of Wu-Feng, Nan-Tou, and Yuanlin. The performance of these areas is compared with that of other locations where ground improvement was performed before the earthquake. With the data gathered from the incident, researchers were able to update various databases containing information potentially linked to liquefaction triggering.

CRITIQUE: While the journal article gave a great amount of insight concerning the events that occurred in Chi-Chi, it seemed that the majority of the article focused more on explaining the consequences of the earthquake rather than actually analyzing the data collected. Instead of providing extensive data analysis, the researchers merely stated that their findings in Chi-Chi were added to a database and would be useful for future research, which does not give much insight as to how their findings will benefit the field.

B - LAB SAFETY PROTOCOLS AND PROCEDURES

Before starting the actual research project, we were given a textbook that provided background knowledge about geotechnical engineering that was necessary to understand before starting the experiments. After reading through the chapters, our DLS would sit us down and review the key concepts with us.

By week two, we were introduced to several experiments, called Atterberg Limits tests, which involves determining the water content at points where the soil exhibits certain properties. Our DLS taught us how to conduct the tests one day, and we then conducted the tests on soil with known properties several times. Afterwards, our DLS compared our results with his to verify that we knew how to conduct the experiment correctly.

Later into the program, we learned about consolidation and shear wave velocity tests, which involved a modified version of an oedometer that incorporated the use of an oscilloscope. We learned how to conduct these tests by observing our DLS prepare the soil samples and operate the machinery.

RESEARCH PROJECT

A - SCIENTIFIC RESEARCH QUESTION

How can the frequency of cyclic softening in sites with fine-grained soils be reduced?

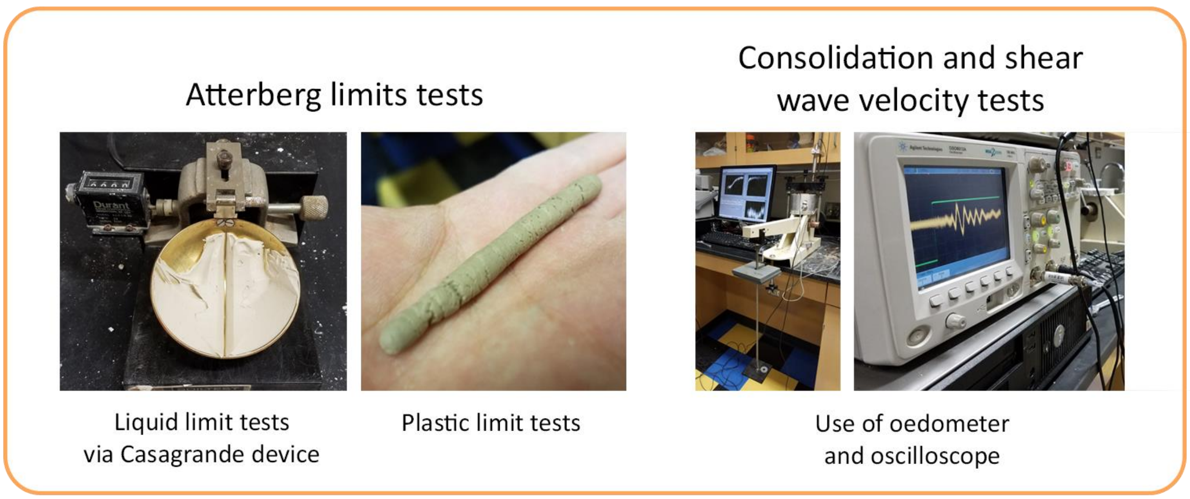
B - CONTEXTUAL BACKGROUND AND REAL WORLD APPLICATION

Liquefaction occurs when a cyclic stress, such as an earthquake, causes coarse-grained soil, like sand and gravel, to lose its strength and behave like a liquid. A similar phenomenon called cyclic softening occurs in fine-grained soils, such as silts and clays; other factors, like water salinity, can influence the soil's behavior under stress. Research on how salinity affects fine-grained soils has been conducted in the past; however, due to a lack of knowledge regarding specific details about their behavior, the data could not be adapted to practice. Plasticity index, a characteristic of soils, has widely been considered the driving factor in determining a soil's engineering properties. Our research aims to find the similarities and differences between soils with similar plasticity index. By investigating the engineering properties of fine-grained soils with varying water salinity, engineers will better understand how fine-grained soils act while undergoing seismic activity and how salinity may affect their behavior. Geotechnical engineers may apply this information to areas with fine-grained soils in order to build more stable foundations, thereby reducing damage to the landscape in the future.

C - MATERIALS AND METHODS

Fine-grained soil mixtures were prepared by mixing silt with varying amounts of bentonite clay (clay contents of 5%, 10%, and 15%). Afterwards, either fresh or salt water was added to the soil mixtures, creating two samples for each mixture. Atterberg Limits tests were then conducted on the soil samples in order to find the liquid limit, plastic limit, and plasticity index. The liquid limit is the water content at which soil begins to behave like a liquid; the plastic limit is the water content at the boundary between a soil's plastic and semi-solid states. The plasticity index is the liquid limit minus the plastic limit, and is often used to classify soils.

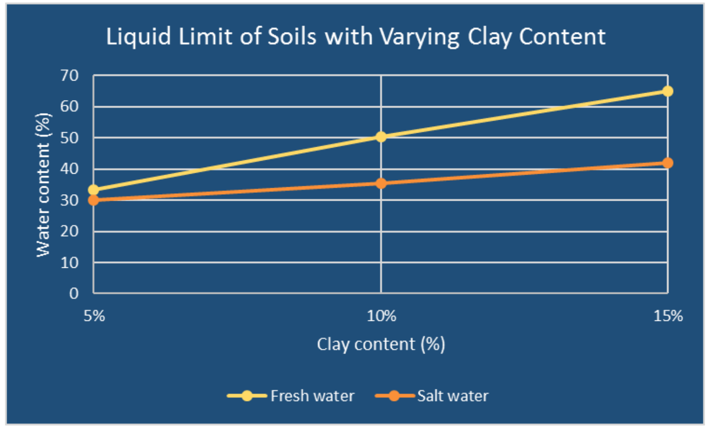
The stiffness and consolidation properties of the soil specimens under different loads were also observed by using a modified version of an oedometer, which is a mechanism that allows for the observation of a soil's consolidation behavior. This modified version of an oedometer includes an oscilloscope, which is used to determine a soil's shear wave velocity, a characteristic that determines the stiffness of a soil.



D - DATA

The liquid limits of soil samples with varying clay content were found with the use of a Casagrande device. After graphing the data, it can be observed that an increase in clay content of the soil resulted in an increase in the liquid limit. Another important observation is how altering the clay content had a greater impact on samples with fresh water than on samples with salt water.

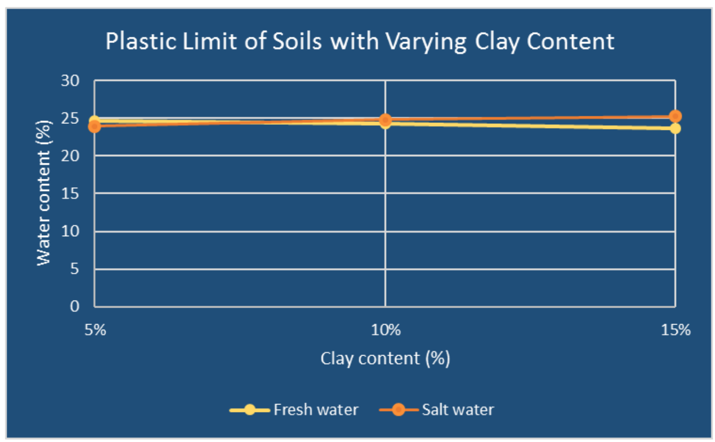
Liquid limit		
Clay content	Fresh	Salt
5%	33.303	29.912
10%	50.388	35.259
15%	65.118	42.021



A graph showing liquid limit vs. clay content for fresh and salt water samples.

The plastic limits of soil samples with varying clay content were then found by conducting plastic limit tests, which involves rolling out the soil samples on a glass plate to a certain diameter. Since the soil samples had similar plastic limit values regardless of the amount of clay, the data showed that the plastic limits for the tested samples did not follow a clear trend. Therefore, altering the clay content had very minimal effect on the plastic limit of the soil samples.

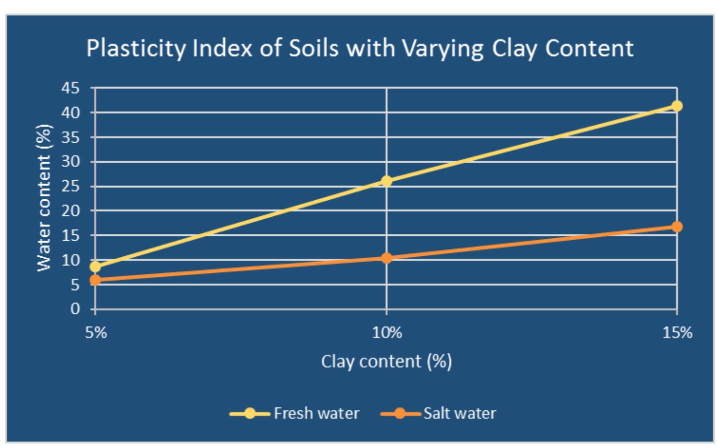
Plastic limit		
Clay content	Fresh	Salt
5%	24.614	23.951
10%	24.294	24.823
15%	23.703	25.247



A graph showing plastic limit vs. clay content for fresh and salt water samples.

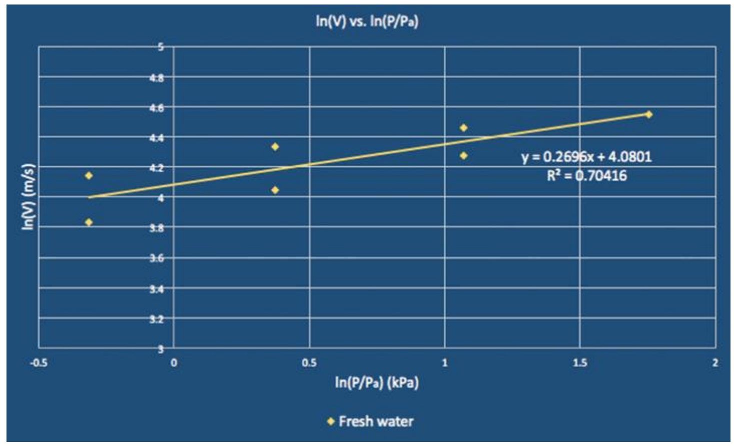
From these two graphs, we were able to calculate the plasticity index for each soil sample. The plasticity index followed a similar trend previously shown by the liquid limit: as the clay content of the soils increased, their plasticity indices increased as well. Similarly, clay content had a more significant impact on the samples fresh water than on the samples with salt water.

Plasticity Index		
Clay content	Fresh	Salt
5%	8.689	5.961
10%	26.094	10.436
15%	41.415	16.774



A graph showing plasticity index vs. clay content for fresh and salt water samples.

After the Atterberg limits tests, consolidation behavior was observed and shear wave velocity experiments were conducted on a sample of 5% bentonite clay with fresh water. Increasing weights were added to the soil sample and the shear wave velocity was calculated at each loading stage. As consolidation pressure increased, shear wave velocity increased. Weights were then taken off and the shear wave velocity was calculated at each unloading stage. As consolidation pressure decreased, shear wave velocity decreased. At the same pressure, the velocity values were higher during the unloading stages than during the loading stages.



A graph showing the natural log of shear wave velocity vs. the natural log of consolidation pressure for a sample of 5% bentonite clay with fresh water.

E - ANALYSIS AND CONCLUSIONS

Increasing the clay content within all soil samples resulted in an increase in the liquid limit and the plasticity index. Altering the clay content also had a more significant impact on fresh water samples. However, altering the clay content seemed to have minimal effect on the plastic limit of the samples within the clay content range that we tested.

Increasing consolidation pressure causes an increase in shear wave velocity, while decreasing consolidation pressure causes a decrease in shear wave velocity. Also, at the same consolidation pressures, the soil had higher shear wave velocities at the unloading stages than on the loading stages.

From the consolidation and shear wave velocity experiments, a relationship was found between the consolidation pressure and shear wave velocity of the soil sample and is represented in this equation.

$$V = 59.145\left(\frac{P}{P_a}\right)^{0.269}$$

Where:
V = shear wave velocity (m/s)
P = consolidation pressure (kPa)
P_a = atmospheric pressure (kPa)

At this time, no clear conclusions can be made about the characteristics of soils with similar plasticity index. More experiments would need to be conducted in order to reach a definitive conclusion.

CURRENT AND FUTURE WORK

Our research project was left off while we were conducting a consolidation and shear wave velocity test on a soil sample with salt water. Our project made significant progress since we conducted a variety of experiments while changing the clay content and pore fluid salinity of our soil samples. With our experimentation, our research team gained insight on how clay content and pore fluid salinity affected the characteristics of soil.

Future work would include more Atterberg limits tests at greater ranges of clay content, consolidation and shear wave velocity experiments on other soil samples, and simple shear tests to observe the stress-strain behavior of soils. By finding the relationships between the characteristics of fine-grained soils and their behavior under seismic activity, geotechnical engineers may be able to apply this information in the establishment of better foundations and prevention of damage to the landscape in the future.