

Adaptation of Geotechnical Experiments for Remote Testing

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INTRODUCTION

In many institutions across the country and worldwide, soil mechanics laboratory is a mainstay of undergraduate Civil, Environmental, and Construction Engineering curricula. Given the inherent variability of soils, laboratory experience gives students an appreciation of the judgment required in geotechnical analysis and design as well as the uncertain nature of the measured properties. Observing soil behavior under compression and shear helps students understand challenging concepts, such as the fact that these properties are time and load dependent. This part of the report describes the adaptation of two undergraduate soils laboratory experiments, namely Triaxial and Consolidation, to be able to remotely run and control them either independently or in a classroom setting. The remote adaptation allows for internet-enabled observation and control. Two approaches are applied and compared. One approach that is applied to the Triaxial experiment is to use software that comes with off the shelf automated equipment and provide internet access through computer hosting programs such as “Netmeeting®” or “PCANYWHERE®”. The second approach that is applied to the consolidation experiment is to automate a traditional device and develop control software using LabView.

TRIAXIAL EXPERIMENT

One of the tests conducted in soil mechanics laboratories is Consolidated Undrained Triaxial Compression Test for Cohesive Soils (ASTM D4767-95). This test is used for estimating the strength and stress-strain relationship of a cylindrical soil specimen subjected to confining stress and sheared in compression without drainage at a constant rate of axial deformation (strain controlled). The specimen size varies but typically is 50 mm in diameter and 150 mm in height. In general, three specimens are tested at different effective stress levels to define a failure envelope. In order to automate this test, the axial stress is applied using low torque motor control with a screw actuator that transfers the load to the sample using a piston. An electronic load cell is used to measure the axial load. The axial deformation is monitored using an LVDT and the pore pressure within the sample is monitored using pore pressure transducers. The chamber pressure is controlled and

monitored using digital pneumatic pressure regulators that are capable of applying and controlling pressures within +/- 2 kPa.

Implementation Using Equipment-specific Control Software:

For triaxial equipment that has its own control software, such as the geotechnical engineering experiment considered in this study, the simplest way to remotely operate it is to use equipment-specific software in conjunction with control software such as Microsoft Netmeeting. Net-meeting permits password protected access of a particular computer to the users and allows them to run the experiment software remotely. A version of Microsoft Netmeeting is used to remotely run the experiment and control the equipment computer. The test chamber for the triaxial experiment is shown in Fig. 1 (a) while the computer-controlled loading frame is shown in Fig. 1(b).



Figure 1. Set for Triaxial Experiment: a) Testing Chamber and b) Loading Frame

Software Setup for Triaxial Experiment

The software needed to remotely control the experiment and collect the data include three programs as follows:

Microsoft Netmeeting™: Most Windows™ operating systems come with a version of Microsoft Netmeeting™. This program enables users to remotely access other computers. Setting up Netmeeting is easy as one only double clicks on the Netmeeting icon to open the

program. Next, one enters in the IP address of the computer being contacted. Finally, the “telephone” button on the right side of the window is activated to access the caller. The computer receiving the call must be set to receive “phone” calls.

Digiflow-GP: This program runs the pump that controls and monitors the water pressure. This pressure was preset to 10, 20, or 40 psi as specified for the experiment. Once the correct pressure level is set, the pump is activated. The pressure can be monitored in a “pressure” window. Before testing has begun, the pump may need to be adjusted to allow it to reach the desired pressure.

Sigma 1-CU: Essentially, this program controls the test and collects the data. Other than the constant pressure controlled by the pump along with the Digiflow-GP software, this program runs the entire test and records all pressure and deformation data. This software controls the motor equipment which applies the load to the soil sample until failure. The strain rate and reading schedules can be modified to a desired resolution so that the user can maximize data collection at important points, as well as ensure that testing is conducted for the desired period of time. The displacement for a sample is calculated as a function of its measured height and with time.

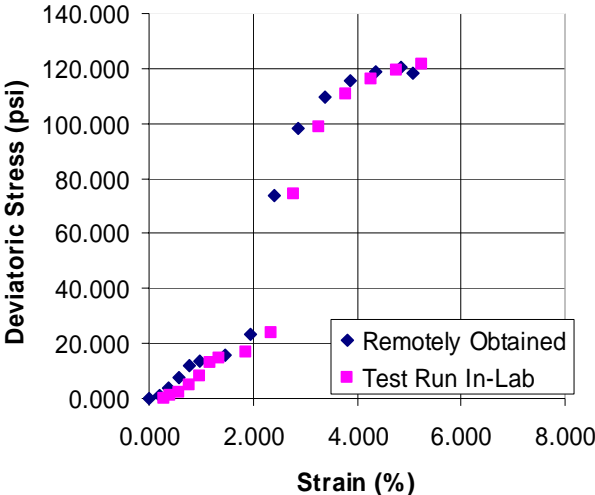


Figure 2. Results Obtained from Test Run Remotely Versus Test Run in Lab

CONSOLIDATION TESTING

Pressure-controlled consolidation testing device as seen in Figure 1 was adapted to be available for remote control experiment. The device is used for determining the magnitude and rate of consolidation of a soil specimen restrained laterally and drained axially while subjected to incremental loadings.



Figure 1. Air-controlled consolidation testing device

In this case, the device was outfitted with a load cell to monitor the applied load, a pressure regulator to specify pressure to be applied to the specimen, and in a feedback loop arrangement, adjust the applied load, and electronic LVDT to monitor deformation with time. Figure 2 shows the scheme of system setup for control of applied pressure to the consolidation cell. This scheme is developed with the framework of LabView software. This system proceeds by asking the user to input the pressure magnitude into the computer. After inputting pressure, an electronic signal is sent to the pressure regulator to apply the air pressure consistent with the sets and controls of the experiment. Throughout the test, displacement data are acquired with time according for a given pressure increment. Acquired data are saved and plotted using Excel[®] data sheet format.

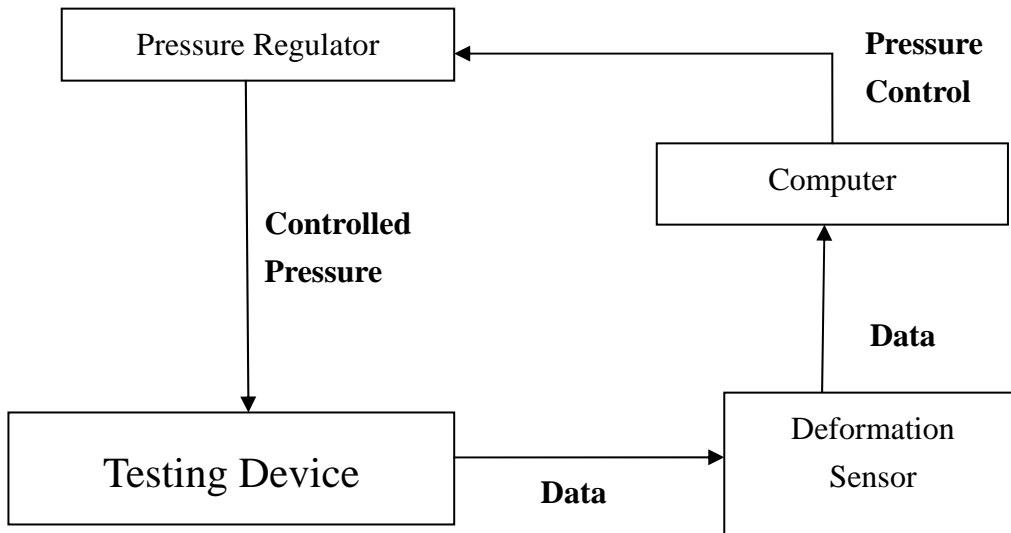


Figure 2. Scheme of Control System for the Consolidation Experiment

Figure 3 shows the Labview program screen developed as a part of automating the consolidation experiment. During test, the graph of displacement versus time is displayed on the screen, using real time scale. Raw data are saved as an excel file. From DAQ DAC0 pressure channel, user can control magnitude of pressure to be applied. The monitoring of the actual loading being applied to the test specimen is collected using a load cell, converted to stress and displayed within the DAQ ACH0 as current applied pressure, in terms of average value as well standard deviation. Finally, DAQ ACH4 channel acquire the data from displacement sensor during test and display displacement as function of time. When the test is completed, all data are saved as excel file to a folder named by the user. The test is run remotely by accessing the computer through Netmeeting.

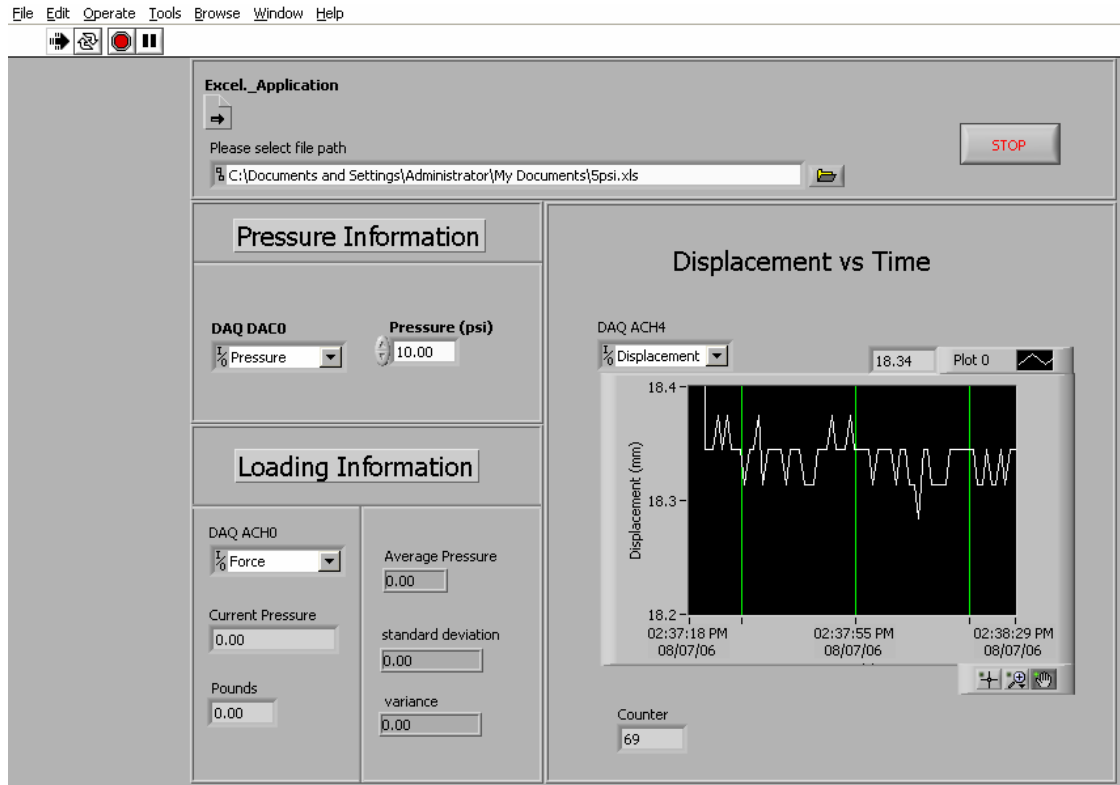


Figure 3. Labview Screen

Remotely-Controlled Experiment Versus Manual Operation

Several consolidation tests were run to judge the quality of the data using the developed system. In addition to a test run remotely, one test was run using consolidation device similar to the one that was automated (where air pressure is used to apply the stress on the specimen) and a second test was run using traditional Oedometer device where weights are used to apply the stress to the specimen. Two types of samples were used in the consolidation testing; a residual soil typically used in the undergraduate soil mechanics class. This soil is classified as silt with low plasticity (ML). In addition, a sample consisting of the same soil but with 20% kaolinite added is used. This soil is classified as clay with low plasticity (CL). Physical properties of each sample are presented in Table 1. Samples were preconsolidated under 1 tsf loading for more than 24 hours. Results of each test were presented traditional void ratio versus pressure on log scale, or as “e-log p plot.” Figures 4 and 5 show the e versus log p of residual soil and 20% kaolinite-residual soil mix, respectively. While the magnitude of void ratio under applied stress obtained from the

two “air pressure” devices was similar, the magnitude of Coefficient of compressibility (Cc) and re-compressibility (Cr) generally agree. Table 2 presented the results of Cc and Cr of each test. Data in Table 2 show that while the results maybe device-specific (i.e they are different depending on whether pneumatic or traditional loading was used) the automated data are similar to that manually obtained from the pneumatic consolidometers.

Table 1. Soil Properties of samples

	20% kaolinite mixed soil	Residual Soil
Gs	2.65	2.65
LL	44	37
PL	19	31
PI	25	6
Classification	CL	ML

Table 2. Summary of Cc, Cr

	Soil Type	Cc	Cr
Oedometer	Residual soil	0.29	0.042
	20% mix	0.33	0.050
Manual	Residual soil	0.28	0.031
	20% mix	0.31	0.051
Remote	Residual soil	0.36	0.053
	20% mix	0.37	0.056

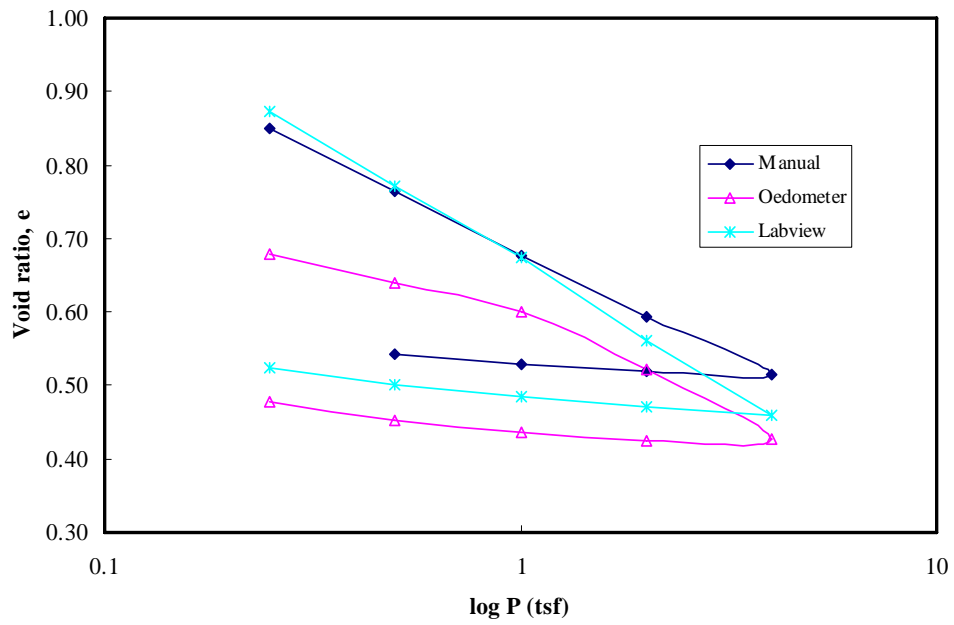


Figure 4. e versus log P curves of CE342 Soil

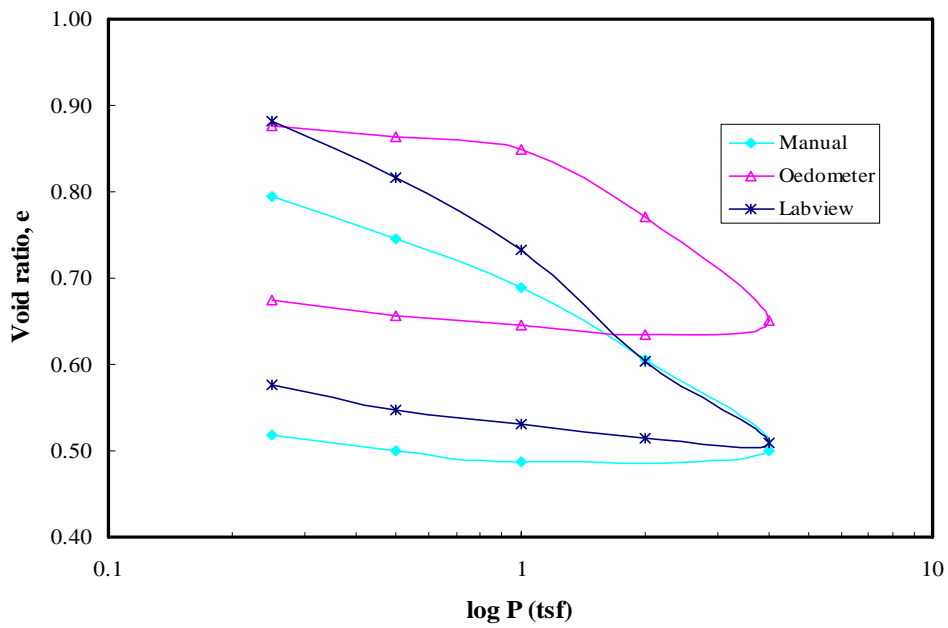


Figure 5. e versus log P curves of 20% kaolinite mixed CE342 Soil

Challenges with Remote Triaxial Experiment

As a part of this research, an undergraduate student was given the task of running the experiment remotely and then in the lab in order to provide comments on challenges he faced. Fig. 2 shows stress-strain data obtained from the same test run remotely and then in the laboratory. Both tests which were conducted by one undergraduate student considered same soil (sand) and the same confining pressure. Both tests were run by an undergraduate student. The results are virtually identical within the limits of experimental errors and the inherent variability in sample properties due to variation induced during preparation.

The student summarized the remote experience with the following statement “The testing in general was of good quality and full of frustrating moments.” A summary of challenges faced are:

- i.** Test Set up: it was a challenge learning how to set up the test sample properly. Once the O-rings and membrane were attached to the base of the tri-axial device, sand was added at a specifically desired density. Attaching the cylinder wall and the top of the chamber had to be done very delicately. The sample set up time was approximately 20 minutes. These challenges are however inherent in this type of testing whether or not it is performed remotely.
- ii.** During Consolidation Phase: applying confining pressure to the sample went flawlessly, except in a few instances where the sample leaked under relatively high pressure. Using 40 psi, the sample sprang a small leak at the bottom of the cylinder and caused the test to be a loss. In this instance the sample had to be taken completely apart, equipment cleaned, and reconfigured.
- iii.** During the Shearing Phase: testing went almost flawlessly. These tests were run under 10, 20, and 40 psi confining stress. The only issue that arose when dialing the computer in the laboratory using Microsoft Netmeeting™ is getting error message stating: “The other party did not accept your call.” This issue was resolved by simply clicking on “call” and then selecting “automatically accept calls” for the host computer.

Challenges with Remote Consolidation Experiment

Benefits and limitations of adapting existing consolidation equipment and developing own control software are as follow:

- i. Developing of own system in terms of hardware and software allows for adaptation of existing equipment and control of multiple devices with single software program. In this study, the cost of adapting one consolidation device was less than \$3000.
- ii. The system is flexible enough to extend to various geotechnical experiments such as direct shear testing for example.
- iii. The development of specific programming allows for implementation of safety features that prevent potentially damaging testing parameters as well as the tailoring of the program to teaching needs. For example, in our undergraduate programs, students run the test for 24 hours. The instruction language within the LabView software can be adapted to terminate the test within the 24-hr period. It can also be programmed to start/terminate loading at certain time of the day while maintaining the continuity of data with time (which can be advantageous for multiple labs on the same day)
- iv. The advantage of data collection and reduction during the test eliminate the human error in misreading dial gages or applying the wrong pressure magnitudes.

In terms of limitations, it was clear that extensive overhaul of the existing equipment was needed. The control sensors need to be procured and expertise is needed in operation of electronics data acquisition systems. In addition, extensive programming was needed in initial phase in order to obtain desired results and the software development became fairly “specific” to the test being conducted.

SUMMARY

Two geotechnical experiments were adapted to be run remotely. These are Triaxial and Consolidation testing. The mode of remote control was different for each to investigate the best approach to implement such adaptation. For the Triaxial experiment, an off-the-shelf computer program is used to run the computer-controlled experiments. The computer

run the experiment is then accessed using Microsoft Net Meeting software. For the Consolidation experiment, LabView software was used as the development platform. A pneumatic-type odometer was adapted for computer control by adding a load cell, digital pressure regulator, and LVDTs. The experiment-control software was then developed to apply and control pressure and collect deformation with time.

Demonstrated difference in two possible approaches for adaptation of geotechnical experiments for remote control includes level of difficulty in development and advantages of each approach. The first approach of using NetMeeting with off-the-shelf control software necessitate that the Triaxial device is fitted with the necessary electronic sensors for computer control. In addition, the use of off-the-shelf control software is limiting given the inability to access the source code and make changes to suit a given situation. The second approach of using LabView provides a greater flexibility of controlling the experiment, collecting data and managing access of users. The use of LabView however necessitates more effort initially during the adaptation stage including the ability to outfit the existing equipment with electronic sensors.

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