DEVELOPMENT OF AN AUTOUMATIC DATA PROCESSING FOR TRIAXIAL COMPRESSION TEST

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(Manuscript Received on November 01st, 2007, Manuscript Revised March 09th, 2008)

***ABSTRACT**: In triaxial compression test using in soil mechanics, three parameters need to be monitored: pressure, displacement and drainage volume during testing time. The drainage volume during the test flows through a vertical pipe which accompanied with a ruler. Pressure and displacement are indicated by gauges. In manual operation, these parameters are recorded by examiner after certain duration. This paper studies on developing an automatic data processing for automatic recording these parameters. A camera is used to track the drainage level then its volume is determined. Digital pressure sensor and displacement sensor are used to measure pressure and displacement. Two PIC 18F458s are used to receive signals from sensors and connect to PC through RS232. The test results in the required forms are given using software. Experiment has been done to verify the proposed solution.*

1. INTRODUCTION

A typical geotechnical engineering project begins with a site investigation of soil and bedrock on and below an area of interest to determine their engineering properties including how they will interact with, on or in a proposed construction. Examining of soil properties, especially in shear stress, is indispensable to understanding of the area in or on which the construction will take place. There are two main kinds of the test: direct shear test and triaxial test.

Direct shear test is used to find the shear strength parameters of soil quickly. In direct shear test, only the stresses at failure are known, whereas in the triaxial test, the complete state of stress is assumed to be known at all stages during the test. Therefore, triaxial test is the most confident test to determine the property of soil although it is quite complex and time-consuming. There are two types of the test machine: completely automatic machine and semiautomatic machine. The first one gives exactly the results of experiment and convenience for examiner but its cost is very high. The second one has lower cost but it is inconvenience for examiner to get the testing results during test processing because it usually takes two or three days, even a week to perform the test. At the moment, there is the demand of upgrade the second one to the first one by using some simple and low cost data acquisition systems using a personal computer. The data acquisition systems must attain some advantages, such as: automatic record testing result during test; attain the required accuracy; easy manufacture with acceptable costs.

There are some commercial automatic testing machines available in domestic market. However, it cannot be used with the exit testing machine in companies. To be convenient for users, this study proposes an automatic system which acts like a “plug-in” part with easy operating functions.

Three parameters need to be monitor are drainage volume, pressure and displacement of the specimen. A camera sensor, pressure load cell and displacement transducer are used. A controller is designed to drive the camera along the vertical drainage pipe to track the water level then drainage volume. All signals from sensors are recorded and sent to PC by using wide-used microcontroller PIC 18F458s. These parameters are then used to predict how the material will behave in some engineering application. Also by a simple software code, testing result can be given in a desired report form. Experiment has been done to verify the proposed solution.

2.THREE AXIAL TEST REQUIREMENTS & AXIAL TEST EQUIPMENT

2.1.Triaxial test requirements

Triaxial tests usually have two applications: confining stress or deviator stress and are generally classified as one of three conditions of drainage during application of the confining pressure and loading. The three drainage conditions for testing are the (UU), (CU), and (CD) referenced below.

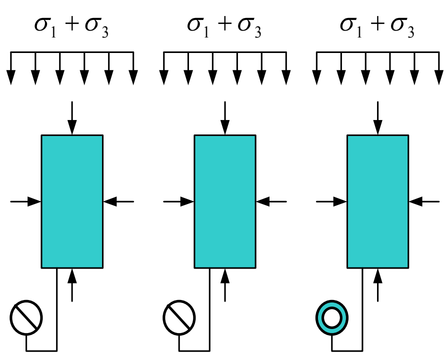

Fig 1. Types of test

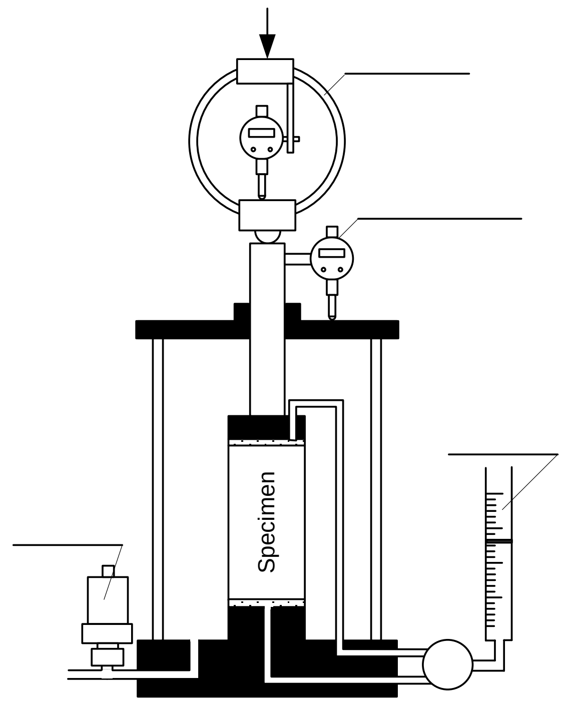

Fig 2. Overall model

Unconsolidated-Undrained (UU): No drainage is allowed during application of the cell pressure or confining stress and no drainage is allowed during application of the deviator stress. This test is generally performed on undisturbed saturated samples of fine grained soils (clay, silt and peat) to measure the in situ undrained shear strength.

Consolidated-Undrained (CU): Drainage is allowed during application of the confining stress so that the specimen is fully consolidated under this stress. No drainage is permitted during application of the deviator stress. This test is performed on undisturbed samples of cohesive soil, on reconstituted specimens of cohesionless soil and, in some instances, on undisturbed samples of cohesionless soils which have developed some apparent cohesion resulting from partial drainage. Generally, the specimen is allowed to consolidate under a confining stress of known magnitude and is then failed under undrained conditions by applying an axial load. The volume change that occurs during consolidation should be measured.

Consolidated-Drained (CD): Drainage is permitted both during application of the confining stress and the deviator stress, such that the specimen is fully consolidated under the confining stress and no excess pore pressures are developed during testing. Consolidated drained tests are performed on all types of soil samples, including undisturbed, compacted and reconstituted samples.

2.2 Axial test equipment

No axial test equipment is made in Vietnam. All companies use the axial test machines imported from foreign countries. One of the most common test machines used in Vietnam now is imported from China because of their low price and functions. Overall model is showed below.

As already stated above, three parameters needed to be determined during axial are pressure, displacement and drainage volume. In this machine, all of these parameters are not recorded automatically. The output signal of pressure is electricity and is displayed on led light. Displacement is defined in mechanical transfer indicator. Drainage volume is monitored with a vertical pipe. The drainage running out from the test machine is directed to this pipe. Rely on mark lines on pipe, the examiner can determine drainage volume.

All parameters are recorded by examiner and calculated on paper or on computer.

2.3 Problem statement

During test performance, the examiner must record the parameters continuously. There are some problems:

(1) The accuracy of results

The accuracy of drainage parameter is not high because the drainage is determined by low accuracy equipment and recorded by examiner's eyes.

Some results calculated based on graph of parameters. Because the number of parameters is few, the graph is not smooth enough. In otherwise, the results are determined visually, so the accuracy of the results is not able to be high.

The time which the examiner records the parameters is different from the real time. Because the parameters change continuously during test processing and the examiner can not look at watch and equipments displaying parameter at the same time.

(2) Inconveniences in recording parameters and calculating results

The triaxial test sometimes lasts a week, so the examiner must waste so much time for recording the parameters.

The examiner also wastes time for entering all parameters and calculating the results on paper or computer without software packet.

3. SYSTEM DESIGN

The design system must be overcome all problem stated above. Three parameters need to be monitor are drainage volume, pressure and displacement of the specimen through camera sensor, pressure load cell and displacement transducer. All signals from sensors are recorded and sent to a personal computer by using wide-used microcontroller PIC 18F458s. These parameters are then used to predict how the material will behave in some engineering application. Also by a simple software code, testing result can be given in a desired report form. The proposed system is given in Fig.3.

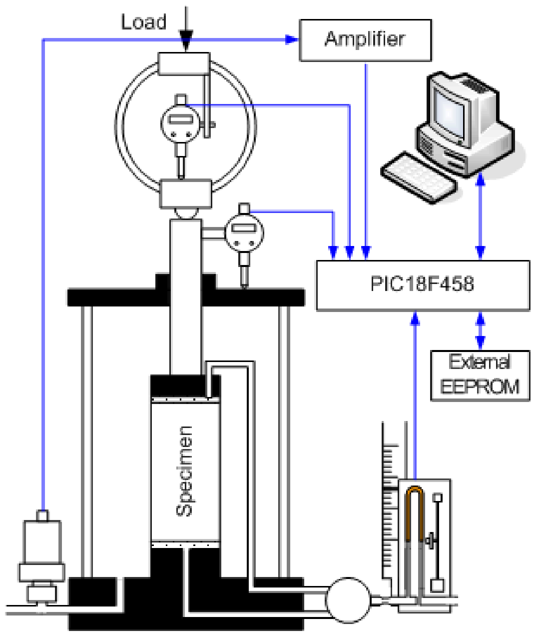

Fig 3. Proposed automatic data acquisition system

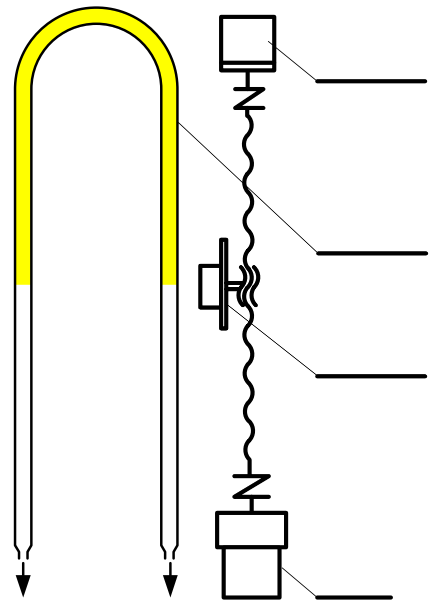

Fig 4. Drainage volume measuring using camera

3.1 Measurement of drainage volume change

The drainage water running out from compression testing machine, enters a vertical pipe. There is the color oil above water for easy tracking water level. Camera is controlled to track water and color oil boundary by nut-screw system. An encoder is assembled in coaxial screw to determine the water volume.

To perform next test, there are two ways: return the boundary to original position by a pump or change the moving direction of the boundary by changing the pipe input to the pipe output.

Test the accuracy of camera

Some suppositions:

Moving direction of the camera and boundary are parallel.

The oil color and the light are stable.

Some features of camera:

The maximum dimensions of camera window are 143x80 pixels.

Set color parameters (R-G-B) freely to track object.

Return the coordinates of object mass to micro controller of PC.

Tracking color speed is 17 frames/second

Communicate with micro controller or PC through RS232.

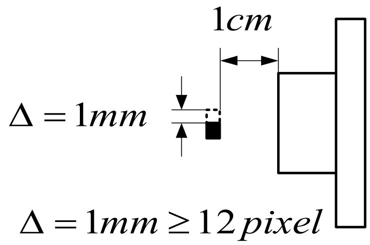

Fig 5. Accuracy of camera test

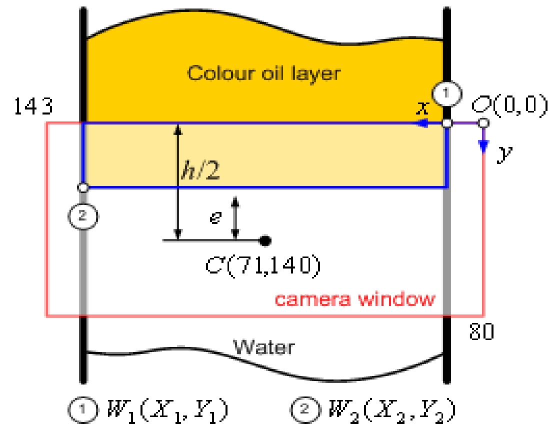

Fig 6. Error calculating diagram

In the test, camera must be connected to the PC. Rely on the software which supported by manufacturer, we can view objects which tracked by camera and define their color values and set tracking color values to camera.

The test was carried out as follows: Put the color point in front of camera, it is about one centimeter far from camera. Move this point 1mm follow to the vertical of camera (Fig.5). The number of changing pixels is 12 pixels. Therefore 1 pixel is equivalent to 0,1mm. With the dimension of pipe using in test machine, 0,1mm is equivalent to 0.01ml. If the controller is quite good and some noises are not too many, the minimum error can be 0,01ml while the minimum error which users require is 0,1ml. So the method using camera to track the color is able to satisfy completely user's requirements.

Error calculate

During the processing, micro controller sends continuously "TC Rmin Rmax Gmin Gmax Bmin Bmax \r" (Track Color) to the camera. Rmin, Rmax, Gmin, Gmax, Bmin, Bmax are the color values of object which are determined by software when the camera is connected to the computer. Camera will return the coordinates of object mass's opposite corners. In Fig.6, they are $W_1(x_1, y_1)$, $W_2(x_2, y_2)$.

The goal of the controller is that the camera window has the same center with the color and water boundary. The camera parallels to the boundary, so the coordinates x_1, x_2 are constant. Therefore, the error calculation relies on y_1, y_2 only. In Fig.6, y_1 is always zero. The error is calculated as follows:

$$e = \frac{h}{2} - y_2$$

where, e : the deviation of the camera window's center and the boundary between color oil and water; h : height of camera window; and y_2 : height of tracking object mass.

Communication Diagram

PIC18F458 communicates with camera to verify the position of the boundary and controls the motor. This motor will drive the camera to follow closely the boundary. At the same time, PIC18F458 also receives signals from encoder to calculate the drainage volume and sends these signals to another PIC18F458 through I2C. This PIC18F458 receives three signals: the drainage volume, pressure and displacement from sensors at the same time. All signals are sent to PC through RS232. With specialized software, experiment results can be calculated quickly and accurately.

Some basic functions of controller:

Control motor to drive camera to track the boundary with the fastest speed.

Get the signal from encoder to calculate the drainage level

Receive and save all signals from sensors to external eeprom.

Send all saved signals to PC.

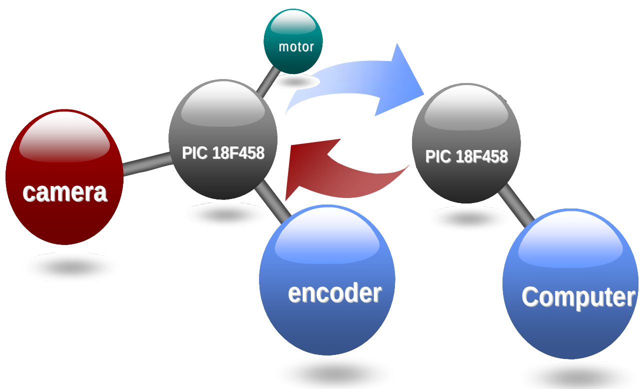

Fig7. Communication diagram

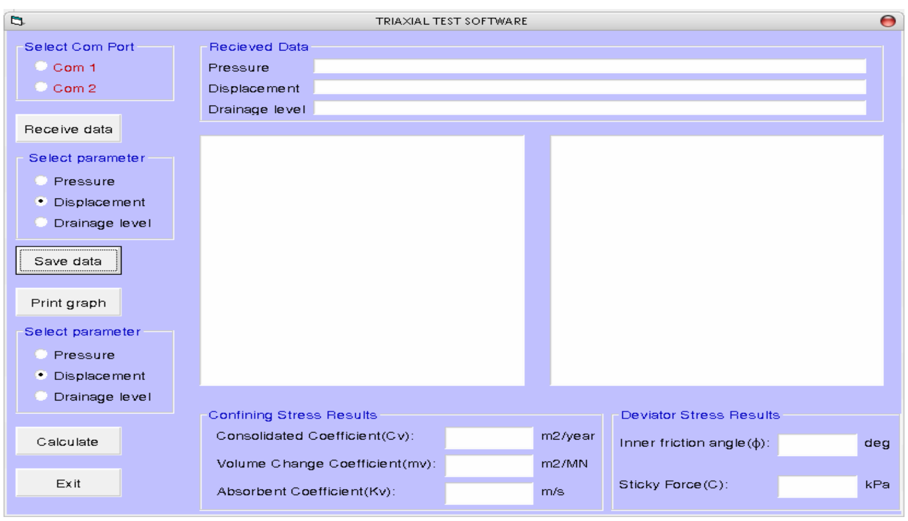

Fig 8. Software interface

3.2 Displacement measurement

The output of indicator is digital signal and can be connected directly to micro processor and is recorded and saved exactly and easily. However, it is very difficult to set zero position for this equipment because of its sensibility. Because the accuracy of the equipment is very high, the measurement value will change when we push zero-set button. This problem can be solved by micro processor.

3.3 Pressure transducer

The output of the pressure transducer is analog signal. Because the output voltage is very small, it must be use magnified by amplification circuit. After being magnified, the analog signal is put into A-D converter of PIC18F458. To decrease the noises, amplifier and filter must be optimized as good as possible.

3.4 Software packet

To be convenient for users and to increase the accuracy of data reading results, the software which receives, saves the parameters and calculates the results must be enclosed with measurement system. Some basic functions of software are follows: receive parameters from the measuring equipment; store the parameters; plot the graph of the parameters; and calculate the results.

4. EXPERIMENT RESULTS

The proposed measure equipment was tested in Survey & Construction Ltd. Co. Some parameters using in this experiment as the following:

Triaxial testing machine
Nanjing Soil Instrument Co.,Ltd , TSZ30-2.0
Pressure load cell
Hengtong Electionics BP9325
Range: 0~2MPa
Nonlinearity: ±0.2%
Zero Output: 0±1mV
Span output: 100±30mV

Displacement Transducer
Mitutoyo, 543-452B
Range: 25,4mm
Resolution: 0,001mm
Camera
CMU Camera
Resolution: 143x80pixel
Capture speed: 17 frames/s

The testing results are given in the Fig.10, 11 and 12. Each of graphs includes two experience results: results recorded by examiner; results recorded by measurement equipment. On the whole, these results are quite suitable. With displacement measurement, the graph of the results recorded by measurement equipment is quite smooth. This is obvious because the output of the displacement transducer is digital signal. However, the graphs of volume and pressure change have some break points. This problem is caused by electrical noises of amplifier and A-D converter in measuring pressure and light noises and mechanical noises of drainage measuring equipment. To solve this problem, more tests of experience results must be done to estimate noises to improve measurement equipment.

Fig 9. Experiment setup

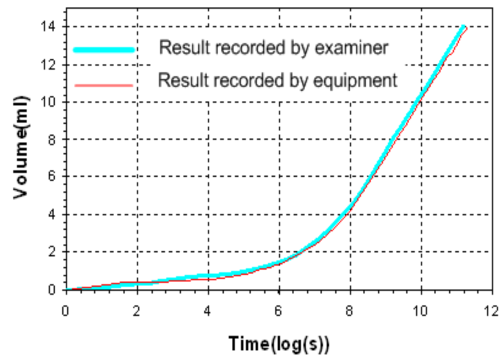

Fig 10. Experiment result of volume measurement

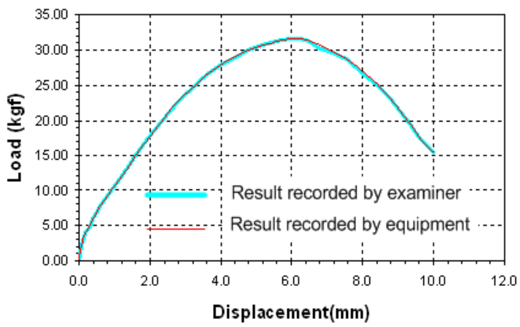

Fig 11. Experiment result of displacement measurement

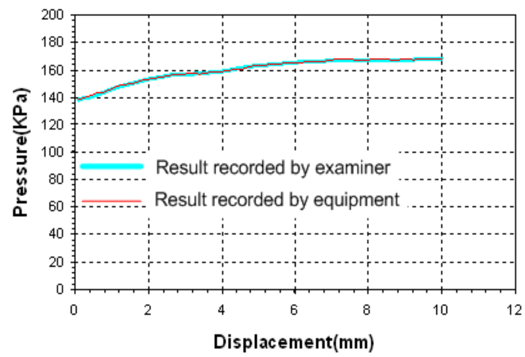

Fig 12. Experiment result of pressure measurement

5. CONCLUSION

This paper introduced mainly the design and control methods of the measurement equipment using for the triaxial compression test. In this paper, micro controller PIC18F458 is used to control camera to track displacement of water level and receives signal from encoder to calculate the drainage level. Software coded on PC can receive signals from micro controller and calculate final experiment results. Using the automatic measuring system, the soil compression test can be automated completely. However, in carrying the test out, sometime the graphs of parameters are not smooth. This problem is caused of the low stability of the camera used in our laboratory. So it is necessary to make more detailed examinations on testing stability of the camera in order to check its reliability.

NGHIÊN CỨU XÂY DỰNG HỆ THỐNG THU NHẬN VÀ XỬ LÝ DỮ LIỆU THÍ NGHIỆM CHO MÁY NÉN BA TRỤC

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TÓM TẮT: *Trong máy nén ba trục sử dụng cho lĩnh vực cơ học đất, ba thông số: áp suất nén mẫu, chuyển vị của mẫu và thể tích nước thoát ra khi thí nghiệm mẫu, cần được ghi lại. Trong quá trình thí nghiệm, nước thoát ra từ mẫu chảy qua một ống thủy tinh thẳng đứng, trên đó có các vạch mức chỉ thị dùng để đọc mức nước từ đó suy ra thể tích nước thoát ra. Áp suất và chuyển vị của mẫu được ghi nhận thông qua các đồng hồ đo áp suất và chuyển vị. Trong các máy nén ba trục vận hành thong thường, các thông số này được các kỹ thuật viên theo dõi và ghi nhận định kỳ bằng cách đọc các đồng hồ đo, mức nước chảy ra trong ống và ghi vào bảng. Bài báo này giới thiệu một hệ thống ghi nhận ba thong số cần đo nêu trên một cách tự động. Một camera được dùng để ghi mức nước, từ đó suy ra thể tích nước chảy ra rừ mẫu. Cảm biến áp suất và chuyển vị được dùng để đo áp suất và chuyển vị mẫu. Vi điều khiển PIC18F458 được dùng để thu nhận dữ liệu đo và nối với máy tính qua cổng RS232. Kết quả đo được xuất ra tập tin (file) hoặc dạng đồ thị theo yêu cầu người sử dụng. Kết quả nghiên cứu đã được ứng dụng tại phòng thí nghiệm cũng như tại công ty TNHH Tư vấn Khảo sát Xây dựng hỗn hợp H.A.I. cho thấy tính khả thi cao của hệ thống đã xây dựng.*

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