Self-Adjusted Pneumatic Loading Oedometer for 1D Consolidation

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ABSTRACT

This research aimed to develop an automatic Oedometer which was soil testing equipment. The traditional equipment requires an operator to manually place loads and read values of a vertical displacement. The traditional Oedometer was improved in two parts namely self-adjusted loading and automatically record vertical displacement value. The applied load of the developed equipment was generated from pressure that was supplied by a pneumatic system. The pressure of an air-compressor was controlled by the electro-pneumatic regulator and changed to load via air-cylinder equipment. The load cell transducer was used to measure the applied load value of the developed equipment. The vertical displacement of soil sample was measured by linear variable displacement transformer (LVDT) transducer. This developed equipment was controlled by a particular software application that was written in Visual Basic computer program language. The controlling program was used to adjust the value of applied load and to record the vertical displacement value of soil sample. The recording value was saved in a text file which was convenient to import into MS Excel for further analysis. To verify the accuracy of the developed equipment, the researchers conduct 1D consolidation test for both the developed and the traditionalOedometer. The verification procedure began from loaded soil sample by the traditionalOedometer until the applied stress more than pre-consolidation pressure then the soil sample was unloaded. Next, the same soil specimen was reloaded by the automatic Oedometer until the end of the testing stage. Finally, the obtained results were used to draw the consolidation graph for comparing the settlement values between the traditional and the modified equipment. The findings showed that the vertical displacement that was obtained from the developed apparatus was in excellent agreement with those obtained from the original one. However, this developed equipment was not a completed automatic-equipment because it still needed an operator to fill water of the soil sample.

Keyword: *1D Oedometer; Consolidation; Automatic*

1. INTRODUCTION

Three types of settlement arecalculated to predict the approximate settlement in soil when the soil is subjected to a stress increase, including 1) immediate settlement, 2) primary settlement, and 3) secondary settlement. The most important settlement is the primary settlement which is usually called “consolidation settlement”.

Consolidation settlement is the result of a volume change due to the expulsion of water from the void spaces of the soil mass.This type of settlement can cause large settlement value at a final stage of settlement. The consolidation settlement value can be estimated by using one-dimensional consolidation theory that is proposed by Terzaghi.

An Oedometer or Consolidometer is used for measuring the compression of a soil sample when the sample is subjected to a constant stress. The traditional Oedometer, which was developed by Terzaghi, is used for one-dimensional consolidation test. This equipment uses mechanical weights to generate applied stresses for loading soil sample (as shown in Fig. 1).The test procedure is time consuming process due to the duration of each loading stage may need to be 24 hours or more to ensure that the soil sample is achieved approximately 100 percent complete primary consolidation before the next loading stage is applied. However, primary consolidation can be achieved less than three hours for loading stage that generates applied stress less than the pre-consolidation pressure. Normally, the applied stress for the next loading stage is doubled of current applied stress. The relationship between stress and strain is expressed by a graph of void ratio and effective stress at the end of primary consolidation of each loading stage.

One of disadvantages for the existing Oedometer is that it requires a laboratory operator to change a dead-weight which is used to generate the applied stress. A proving ring is used for measuring the load that is applied to the soil sample. The other disadvantage of this equipment is that it requires another operator to take reading of vertical displacement values at relatively short time intervals for each loading stage. Dial gauge is used for measuring the vertical displacement of the soil sample due to the applied load.

In this paper, a prototype of an automatic Oedometer was proposed to minimize the testing time and the effort involved.Mechanical measuring tools were replaced by electronic equipment, and a computer program was developed to control the testing process.The developed computer program provides the automated loading and data acquisition systems. The results of consolidation test between the developed and the traditional equipment were studied to evaluate the efficiency of the developed equipment.

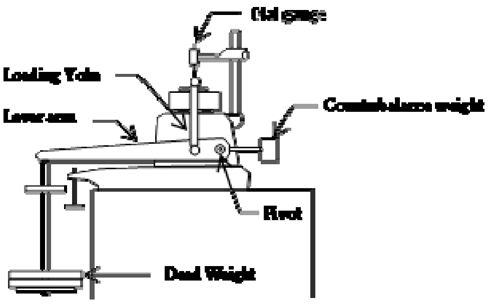

Fig. 1 one-dimensional Oedometer developed by Terzaghi

2. SYSTEM OVERVIEW

The major components of the developed automatic Oedometer arethe computer program and electrical equipment. The computer program is used to control the required tasks (controlling applied stress and recording displacement) within automatic system while the electrical equipment is used to change physical quantities to electrical signal which can be read and controlled by the computer program.

2.1. Concept

Fig. 2 illustrates the concept of an application of computer program and electrical equipment to develop a prototype of the automatic Oedometer. There are two separated tasks that the proposed system must performnamely controlling task and recordingtask.

For the controllingtask, the applied stress will be generated from the air pressure that is transformed to applied stress by using the air cylinder.The air pressure will be controlled by the developed computer program. The computer program will calculate the current applied load from the reading signal of the loading sensor and adjust the applied load by sending some signal to the air pressure regulator. The computer program will continually adjust the applied pressure until the different value between the current and the required applied stress isin the acceptable level.

For the recording task, this partwill begin after the controlling task is achieved. The computer program will calculate the vertical displacement from the reading signal ofthe displacement sensor. The vertical displacement values will be recorded automatically into a text file which is easily to use for further analysis. These displacement values will be recorded continually depending on the setting time interval.

2.2. Hardware

The structures of the proposed automatic Oedometer for one-dimensional consolidation test consist of eight major components (Fig. 3) as follows:

- Air compressor: the air compressor is used to generate and to store air pressure.
- Electro-pneumatic regulator: this electrical equipment is used to control the air pressure that is supplied to the air-cylinder.
- Air-cylinder: the air pressure will be transformed to the applied load by this equipment.
- Load cell transducer: this equipment is used to change load quantity to the electrical signal.
- LVDT transducer: this equipment is used to change displacement quantity to the electrical signal.
- Consolidometercell: the soil sample is contained within this component.
- Loading Frame: this component is used for generating reaction load to the soil sample.
- Interface unit: the interface unit is used to supply the power (for transducers) and to connect transducers to a computer.

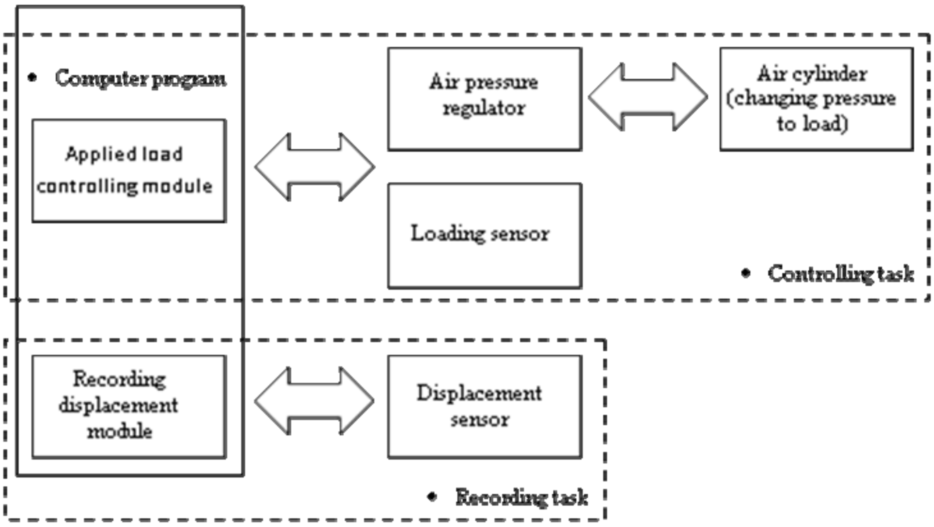

Fig. 2 Concept ofs elf-adjusted pneumatic loading one-dimension Oedometer

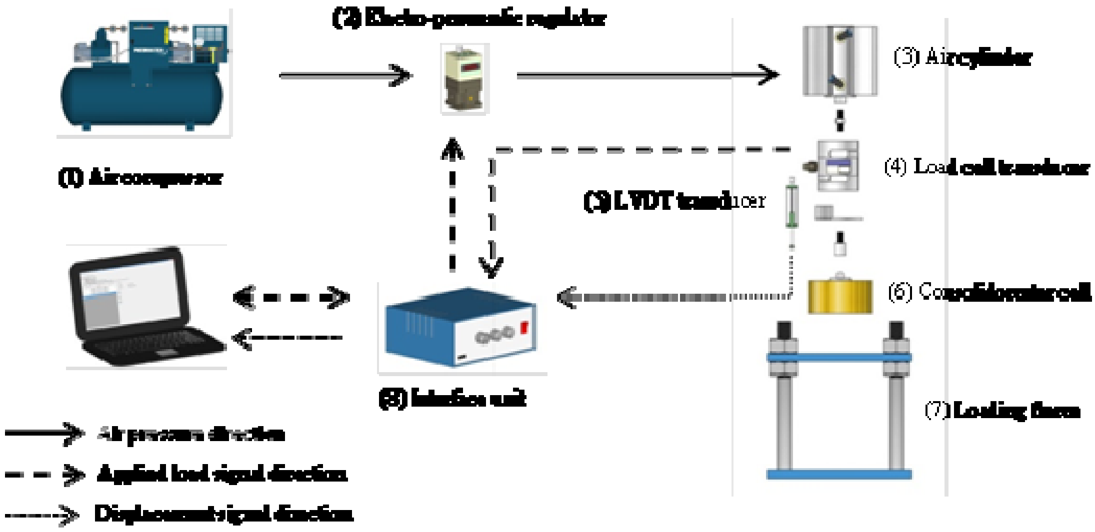

Fig.3 Structures of self-adjusted pneumatic loading one-dimensional.

2.3. Software

A particular computer program was developed to control the applied load and to record vertical displacement values of the soil sample. This developed computer program controls these two processes individually. The controlling applied load process will begin first for adjusting the applied load value to the first loading stage. Then, the recording process will start and continually recorddisplacement values until it reaches the last reading time or the end of primary consolidation (depends on which one is occurred first). Next, the controlling process will start again for changing the applied load value to the next loading stage. After that, the recording process will be launched again for recording the vertical displacement of the current loading stage. These two processes will be repeated until the applied load value reaches the last loading stage.

The flow chart ofcontrolling applied load process can be shown as Fig. 4 (a). The computer program begins from reading the required applied load values. Next, it will send some signal to the electro-pneumatic regulator to adjust the air pressure. After that, it will read the electrical signal from the load cell transducer and transform the reading signal to an engineering value (the current applied load). Then this current applied load value will be compared with the required applied load value. The computer program will use the comparison result as the information for adjusting the sending signal.Then the adjusted signal will be sent to the electro-pneumatic regulator to increaseor decrease the air pressure. These processes will be repeated until the current applied load value reaches the acceptable level.

Fig. 4 (b) shows the flow chart of recording vertical displacement process. This process will begin after the controlling applied load value process is terminated. The computer program will get the reading time from the input data. Next, the computer program will check a current time value until it equal to the reading time. Then the computer program will read a signal from the LVDT transducer and record that value into a text file. Next, the computer program will adjust the reading time to a next reading time. These processes will be repeated until the current timeequals to the last reading time value.

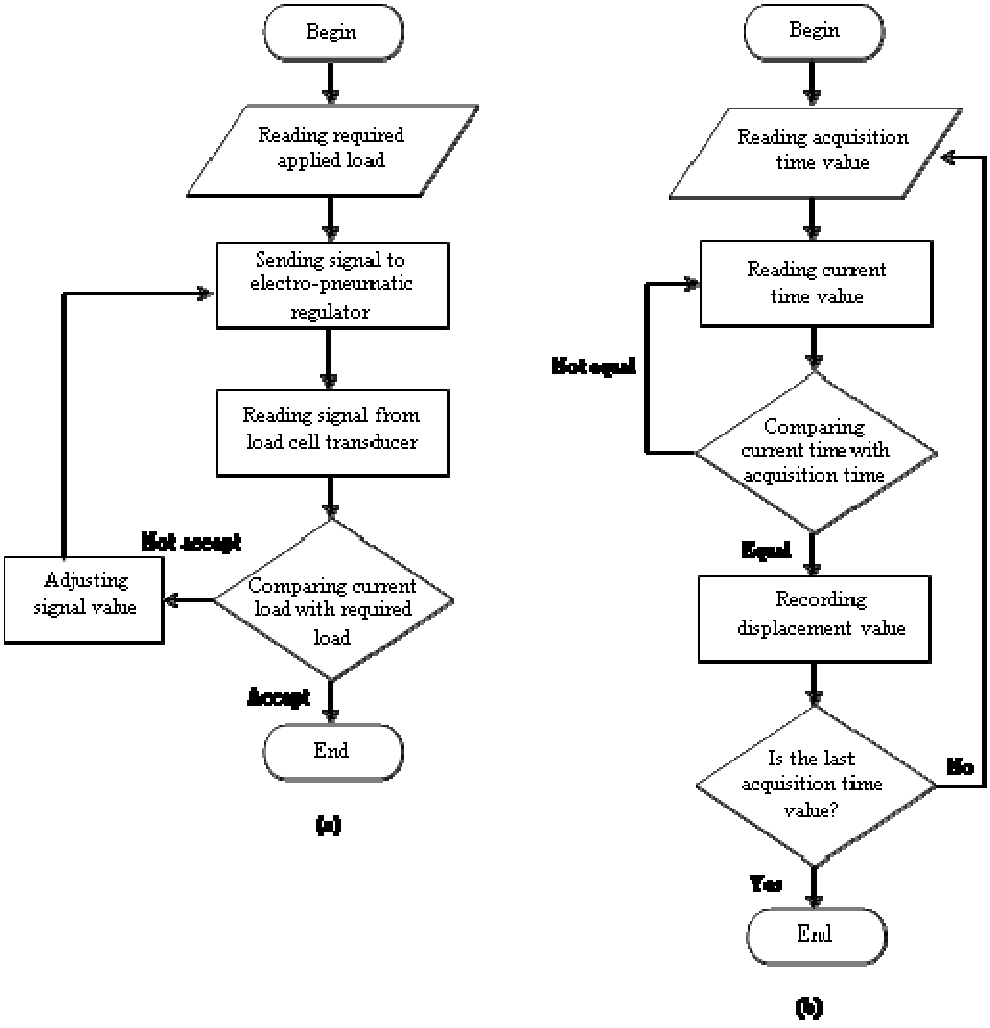

Fig. 4 Flow charts (a) controlling applied load; (b) recording vertical displacement.

3. VALIDATION

To verify the consistency, the authors conducted three consolidation tests by using both the developed and the traditional Oedometer. The depth of soil sample, which is silty clay, varies from 2.00 m. to 11.00 m. The consolidation test was performed according to the test procedure of ASTM D2435-96. First, the soil sample was tested by using the traditional Oedometer. The applied stress will be increased until it is more than pre-consolidation pressure, then the soil sample was unloaded. After that the testing equipment will be changed to be the developedOedometer by moving only consolidation cell from the traditional Oedometer to the developedOedometer. Next, the soil sample will be reloaded again by the developed equipment until it reaches the last required applied stress.

3.1. Equipment configuration

The first step of using automatic Oedometer is to set the equipment. The graphic user interface (GUI) for this step is shown in Fig. 5. There are two major parts that must be set before running the consolidation test, including transducer configuration and data acquisition configuration. The first part is for setting the calibration factor, which is used to calculate engineering values, for both transducers (load cell and LVDT). The second part is for setting the data logger options such as communication port, sample acquisition rate, reading channels, sampling method, etc.

3.2. Initial Information

As shown in Fig. 6, this step is to input the initial information that is required by the computer program. There are four part of this step namely 1) identifying recorded file name, 2) setting initial voltage of transducer, 3) inputting project information, and 4) inputting soil sample information.

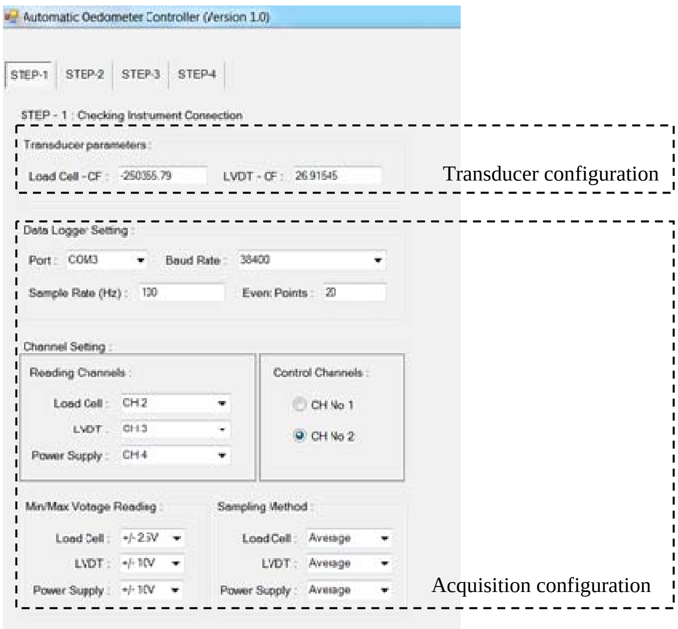

Fig. 5 *GUI of equipment configuration.*

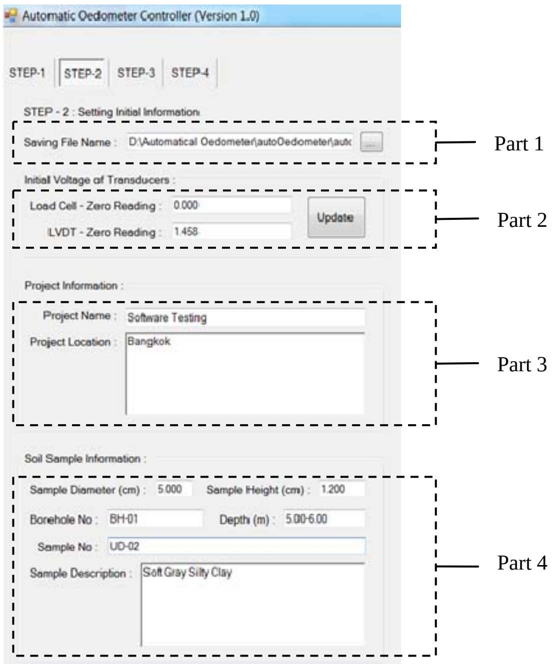

Fig. 6 *GUI of initial information*.

Some information is needed while some information can be omitted. The saving file name is needed to identify the name and location of the recorded file. The initial voltage of both transducers must be input due to these values must be usedfor calculating the engineering values of both transducers. The diameter and height value of soil sample are needed for computing the applied stress and strain respectively.The other information which is additional information can be omitted such as project name, project location,borehole number, soil sample number, and other soil information can also be input in this step. This information will be saved in the top part of the recorded file before vertical displacement values.

3.3. Setting applied stress and recording time

The third step of using this equipment is to set the details of consolidation testing. Fig. 7 shows the GUI of this step which requires the details of each loading stage, including applied stress, recording time, and delay time before starting the next loading stage. Due to the flexibility design for defining the recording time, the reading time can be set as the absolute or interval time by using keyword identification.The "[con]" keyword was used for absolute recording time whereas the "[dif]" keyword was used for interval recording time. The unit of time can be set as second ("[s]"), minute ("[m]"), and hour ("[h]") depends on the user.

The user can set the acceptable level of the different value between the current and the required applied stress in this GUI. The tolerance value of settlement is used to check the approximate 100 percent of primary consolidation has been achieved.

3.4 Running consolidation test

Fig. 8 illustrates the GUI while testing soil consolidation. The GUI will show the recorded data in tabular format at the left hand side of the GUI while on the right hand side of the GUI, the computer program will plot the relationship between vertical displacement values and elapse time.

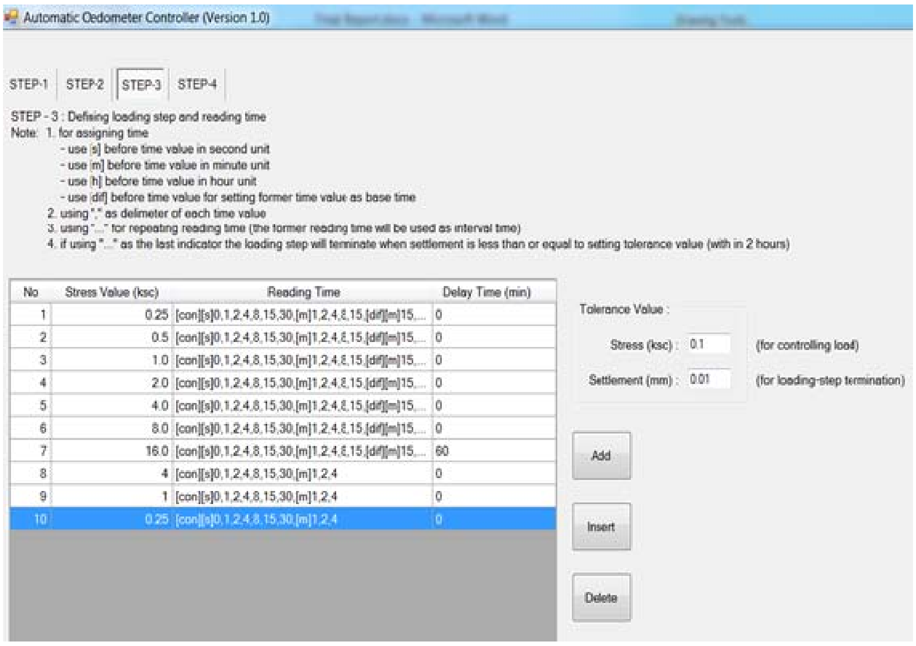

Fig. 7 *GUI of setting applied stress and reading time.*

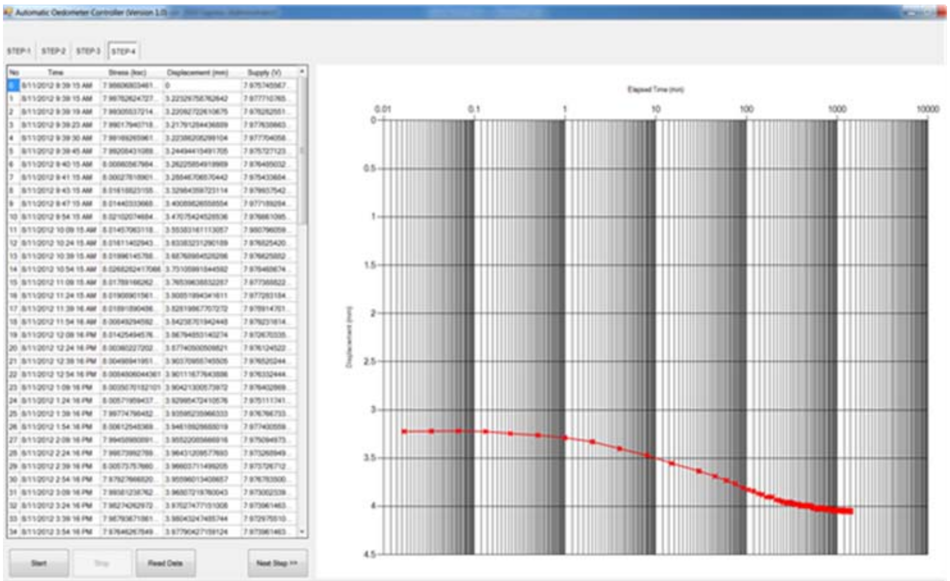

Fig. 8 *GUI of running consolidation test.*

4. EVALUATION AND FINDINGS

Three consolidation tests were performed to validate the developed equipment. For the traditional equipment, the duration of testing is five days due to it needs to perform the test for 24 hours for each loading stage to make sure that the soil sample achieves the end of primary consolidation. For the developed equipment, the duration of testing was shorter than the traditional equipment due to when the developed equipment detects the point that the soil sample has been achieved the end of primary consolidation (for loading stage that required less than 24 hours to achieve the end of consolidation), it will terminate the current loading stage and perform the next loading stage immediately.

The consolidation curves from both the traditional and the developedOedometer were plotted together as shown in Fig. 9. The dash line shows the relationship between stress and strain that was obtained from the traditional Oedometer while the solid line shows the stress-strain curve that was obtained from the developed Oedometer. As illustrated by the straight line, both consolidation curves were excellent consistency with each other.

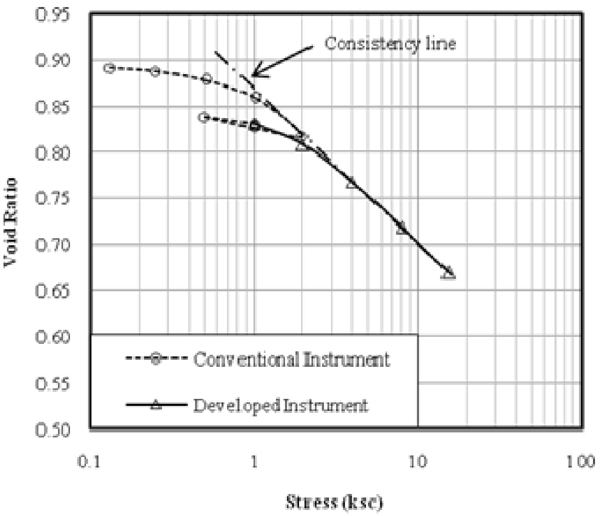

Fig. 9 Consolidation curve of tranditional and automatic Oedometer

5. CONCLUSIONS

The main contribution of this research is the development of a self-adjusted pneumatic loading one-dimensional Oedometer. The automatic system was developed based on two parts (hardware and software). The electro-pneumatic regulator was used to control the air pressure that was supplied by the air compressor. The two transducer types were used to transform physical quantities to electrical signal. The load cell transducer was used to transform the applied load to the electrical signal while the LVDT transducer was used to change the displacement value to the electrical signal. The computer program, which consisted of two main modules, was used to control the developed equipment. The first module was named as controlling applied load module which was used to control the electro-pneumatic regulator. This module will send electrical signal to electro-pneumatic regulator to adjust the air pressure. In case of the current applied stress is less than the required stress, the controlling module will send increasing signal to the electro-pneumatic regulator to increase the air pressure. On the other hand, it will send decreasing signal to the electro-pneumatic regulator to decrease the air pressure when the current stress is greater than the required stress. This controlling module was usedto maintain the current stress to be the required stress until the end of loading stage. The second module was used to record the vertical displacement values of soil sample. This module will compare the current time with the recording time, if both value is equal the recording module will record the current data, including the current time, the current stress, and the current displacement to the specific text file. The recording module will continually record all displacement in the same file until it reaches the last recording time.

The verification of the self-adjusted pneumatic loadingOedometer was performed by comparing the consolidation curve that was obtained from the developed equipment with the consolidation curve that was obtained from the traditional Oedometer. The findings show that the two consolidation curves were in the excellent agreement that means the developed equipment can be used instead of the traditional equipment. Although the developed equipment does not require the operators for both changing the applied load and reading the vertical displacement values but it still needs the operator to fill in the water of the soil sample.

6. ACKNOWLEDGEMENTS

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REFERENCES

[1] Tribhop Khonchom. “Factor Effecting Consolidation and Permeability of Soft Bangkok Clay.”Master of Engineering Thesis, Kasetsart University,2003.

[2] ASTM D 2435 1996. Standard test method for one-dimensional consolidation properties of soils.

[3] Mohammed Y. Fattah, Mohammed A. L. Al-Nneami, and Falah H. Rahil. “Comparative experiments between conventional and quick one-dimensional consolidation tests.”Proceedings of the 4th Jordanian civil engineering conference, 2006.

[4] Braja M. Das. Fundamentals of geotechnical engineering. CA: Brooks/Cole, 2000.

[5] J. Blewett, W.J. McCarter, T.M. Chrisp, and G. Starrs. “An automated and improved laboratory consolidation system.” Canadian geotechnical journal, vol 39, pp. 738-743, Jan. 2002.

Wuttinan Pratoom, photograph and biography not available at the time of publication.

Siriporn Tangwiboonpanich, photograph and biography not available at the time of publication.