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ONE DIMENSIONAL CONSOLIDATION PROPERTIES OF SOLID USING INCREMENTAL LOADING TEST: EXPERIMENTAL SETUP BASED ON A LABView APPROACH

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ABSTRACT

This work describes an experimental setup that was developed in order to automate the One-dimensional consolidation properties of soil test. This experimental setup assures repeatability in the data acquisition test, avoiding human errors. The described setup is based on LabVIEW, LVDT sensors, a 16 Bit Data Acquisition Board, a Load device and a Consolidometer. The experimental setup was developed according to the standard ASTM D2435 / D2435M - 11.

Keywords: monitoring, experimental setup, LabVIEW, consolidation properties test.

INTRODUCTION

Consolidation is the process of time-dependent settlement of saturated clayey soil when subjected to an increased loading. In this test a soil specimen is restrained laterally and loaded axially with total stress increments. Each stress increment is maintained until excess pore water pressures are completely dissipated. During the consolidation process, measurements are made of change in the specimen height and these data are used to determine the relationship between the effective stress and void ratio or strain, and the rate at which consolidation can occur by evaluating the coefficient of consolidation

In this work, is described an experimental setup, for the Geotechnical Laboratory of the Polytechnic Institute of Bragança, that was developed in order to automate the one-dimensional consolidation properties of soil test. This experimental assures repeatability in the data acquisition test, avoiding human errors. The experimental setup was developed according to the standard ASTM D2435 / D2435M - 11 [1]. The system, developed for acquisition and data register for soil consolidation tests, is based on an LVDT (Linear Variable Differential Transformer) sensor, a data acquisition board and a PC software LabVIEW™ application.

CONSOLIDATION SETTLEMENT - CONCEPT

Consolidation settlement occurs in clays where the value of permeability prevents the initial excess pore water pressures from draining away immediately. The design loading used to calculate consolidation settlement must be consistent with this effect.

The term consolidation is used to describe the pressing of soil particles into a tighter packing in response to an increase in effective stress as shown Fig. 1. The volume of solids remains constant (i.e., the compression of individual particles is negligible), only the volume of the voids changes. The resulting settlements is known as consolidation settlement, δ_c. This is the most important source of settlement in soils, and its analysis is one of the cornerstones of geotechnical engineering [2].

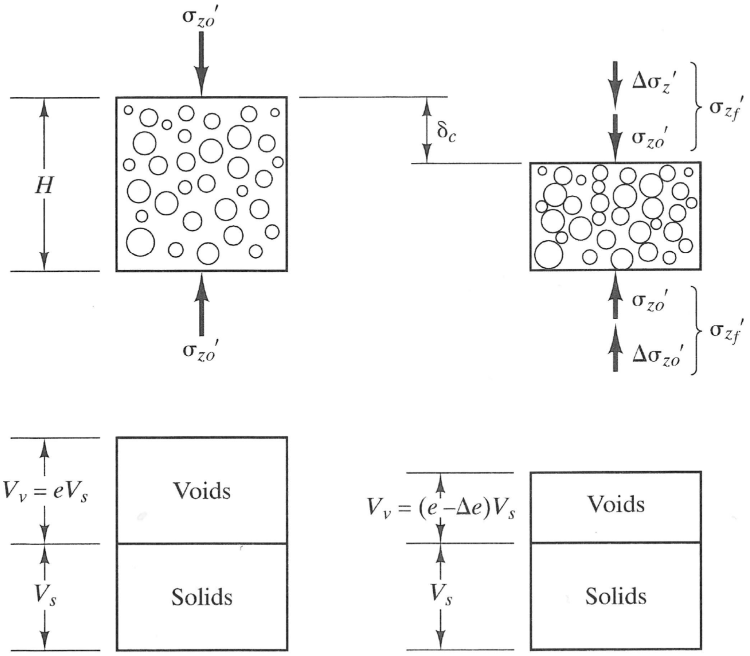


Fig. 1 - Consolidation of solid particles under the influence of an increasing vertical effective stress [2]

Consolidation analysis usually focus on saturated soils (S=100%), which means the voids are completely filled with water. Both the water and the solids are virtually incompressible, so consolidation can occur only as some of the water is squeezed out of the voids.

CONSOLIDATION TEST

To predict consolidation settlement in a soil, it is necessary to know its stress-strain properties (i.e, the relationship between σ_z' and ε_z). This normally involves bringing a soil sample to the laboratory, subjecting it to a series of loads, and measuring the corresponding settlements.

The apparatus generally used in the laboratory to determine the primary compression characteristics of soil is known as the consolidation test apparatus (or oedometer) and is illustrated in Fig.2a.

The soil sample is encased in a steel cutting ring. Porous discs, saturated with air-free water, are placed on top of and below the sample which is them inserted in the oedometer. A vertical load is then applied and the resulting compression measured by means of a dial gauge at interval time, readings being taken until the sample has achieved full consolidation (usually for a period of 24 hours). Further load increments are then applied and the procedure repeated, until the full stress range expected in situ has been covered by the test (Fig.2b).

The vertical pressure depends mainly on the expected site pressure, including overburden pressure. A load increment ratio of unity is used in conventional testing. Load increment ratio (LIR) of unity means that the load is doubled each time. As referred to each pressure increments are maintained for a period of 24 hours. The specimen consolidates with free drainage occurring from top and bottom faces. Dial gauge readings are noted at 6, 15, 30 secs, 1, 2, 4, 8, 15, 30 min, 1 hr, 2, 4, 8 and 24 hrs.

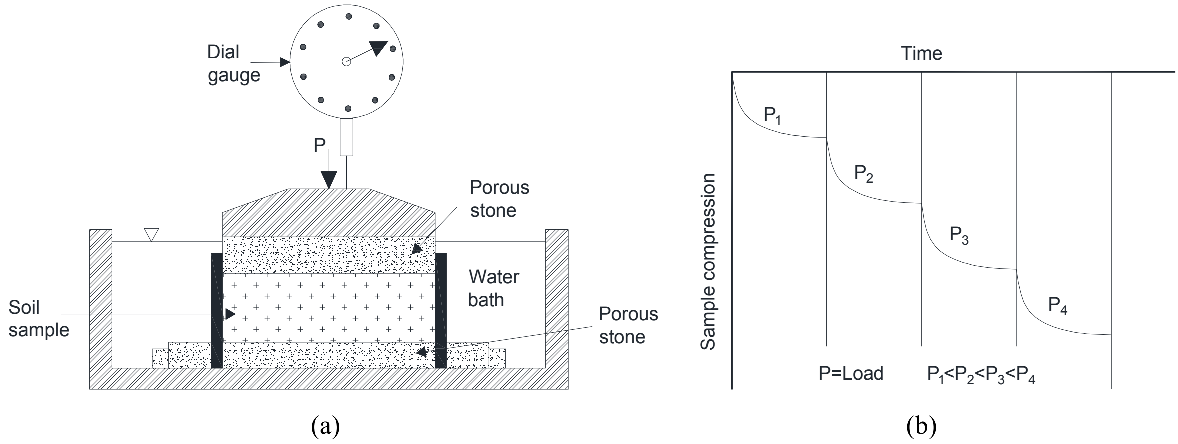


Fig. 2 - Tensile test results: (a) consolidation apparatus; (b) typical test results [3]

When consolidation under the final pressure is complete, the specimen is unloaded and allowed to swell. In this way an expansion to time curve can also be obtained. After the loading has been completely removed the final thickness of the sample can be obtained, from which it is possible to calculate the void ratio of soil for each stage of consolidation under the load increments. The graph of void ratio to consolidation pressure can then be draw, such a curve generally being referred to as an e-p curve (Fig.3a)

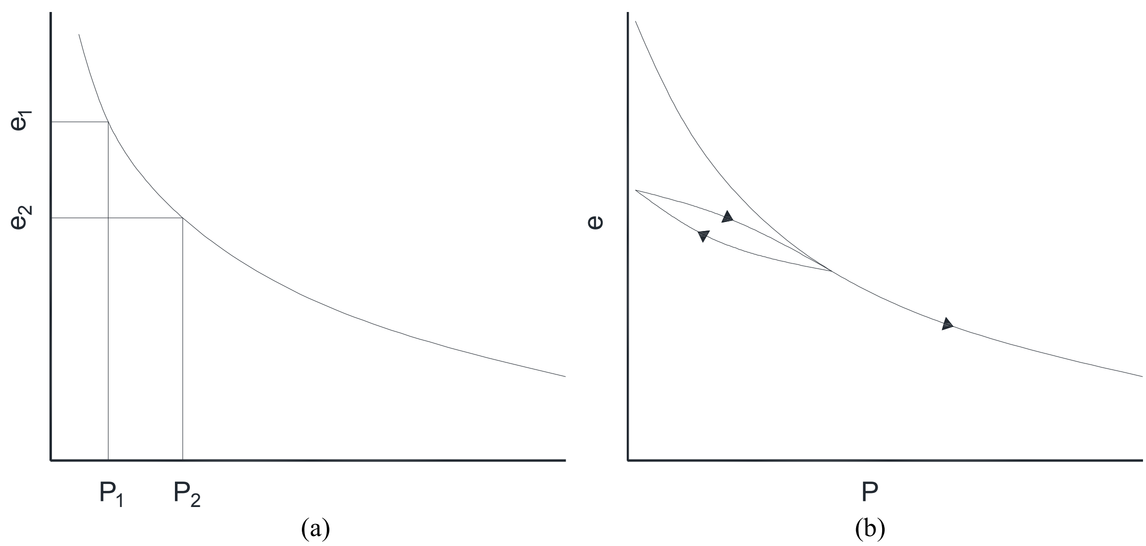


Fig. 3 - Void ratio to effective pressure curve: a) typical e-p curve; b) effect of expansion [3]

The results can also be presented in a semi log graph paper with applied pressure on log scale at abscissa and corresponding void ratio as ordinate on linear scale. The void ratio corresponding to each applied LIR is defined as the pressure can be calculated from the dial gauge reading and dry weight of specimen is taken at the end of the test.

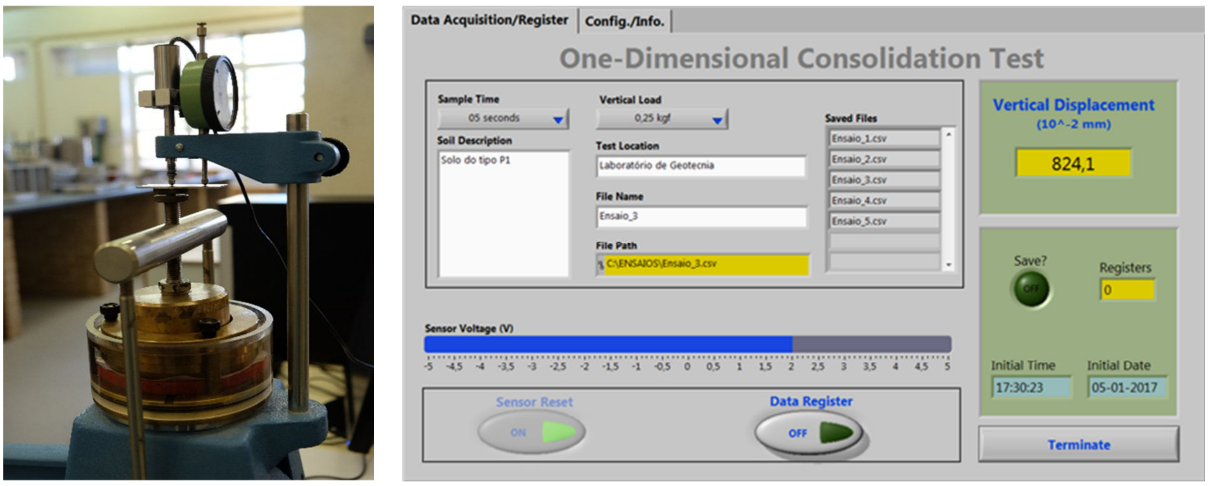
DATA ACQUISITION SYSTEM

The system, developed for acquisition and data register for soil consolidation tests, is based on an LVDT (Linear Variable Differential Transformer) sensor, a data acquisition board and a PC software LabVIEW™ application. The proposed system is intended to replace the analog existing setup, in which all the data was registered manually, as shown in Figure 4. This experimental setup assures repeatability in the data acquisition test, avoiding human errors.

The applied LVDT is appropriate to be used in the existing mechanical system in order to execute the necessary tests. The used sensor has built in the necessary signal conditioning in order to obtain an output that is directly proportional to the linear displacement. The used sensor is DC powered and has an input range from ± 5mm. Its characteristic was obtained experimentally being powered with a source voltage of ± 5V. In this conditions the sensor sensitivity is 600mV/mm, having an output voltage of ± 3,5V and an input current of 12 mA.

The used data acquisition board was the NI PCI-6202, which is a generic multifunctional board. Due to its characteristics it was considered adequate for this application, mainly due to its high resolution. The data acquisition board features are PCI Bus, 8 differential Analog inputs, 16 single ended Analog inputs, 16 bit Analog to Digital converter, sampling rate of 250kS/s, 24 digital I/O.

Fig.4 shows the main window of the developed LabVIEW software interface. This environment provides a friendly user interface for the final user.



(a) (b)

Fig. 4 – (a) Analog and Digital Experimental Setups; (b) Main Window of the developed application

The user has the possibility to select the sample time, being the available sample times 5, 10, 15, 20 and 30 seconds. In the developed tests, the most commonly used sample time, was of 5 seconds. The data is registered in a CSV file (comma separated values file), being very common in data acquisition systems.

Each register adds a line to the stored file, being its limit restriction imposed by the Excel Software. Before the data register the user must introduce some necessary information, such as soil description, file name and the test location and the applied load. The applied load corresponds to weight of the load that can have valued from 0,25 kg to 256 kg. Each time that the load has to be changed, the data acquisition is stopped, this parameter has to be changed in the software interface, being also possible, at this moment, to change the sample time.

In the main software window, there is some information available, namely a table with vertical scroll that shows the stored files, a horizontal slide that shows the LVDT output voltage and it is also shown the linear displacement in 10^-2 mm scale. In the user interface it are also available Boolean controls that allows the user to start and stop registering data and also to set a new zero for the sensor.

RESULTS OF A REAL TEST

This section presents the results of a real test. The results obtained in the software are presented in Fig. 5, where the layout file is presented (in a CSV file). Briefly, this file presents the time vs the vertical displacement reading. With these results, it is possible to make the graph presented in Fig. 6 (representation of the vertical displacement of a sample with the square root of time. This type of graph is used to determine the rate of soil consolidation, being very important to determine the time needed to process the consolidation.

Description of soil type P1								
Start date: 03-02-2017								
Seconds	Minutes	Hours	Time	Hour	Data	SQRT(minutes)	Displacement (10^-2 mm)	Applied load (kgf)
0	0	0	00:00:00	10:55:51	03/02/2017	0	31,7	2
5	0,08	0,001389	00:00:05	10:55:55	03/02/2017	0,29	32,6	2
10	0,17	0,002778	00:00:10	10:56:00	03/02/2017	0,41	32,8	2
15	0,25	0,004167	00:00:15	10:56:05	03/02/2017	0,5	32,9	2
20	0,33	0,005556	00:00:20	10:56:10	03/02/2017	0,58	33,1	2
25	0,42	0,006944	00:00:25	10:56:15	03/02/2017	0,65	33,6	2
30	0,5	0,008333	00:00:30	10:56:20	03/02/2017	0,71	33,6	2
35	0,58	0,009722	00:00:35	10:56:25	03/02/2017	0,76	34,1	2
40	0,67	0,011111	00:00:40	10:56:30	03/02/2017	0,82	34,3	2
45	0,75	0,0125	00:00:45	10:56:35	03/02/2017	0,87	34,5	2
50	0,83	0,013889	00:00:50	10:56:40	03/02/2017	0,91	34,6	2
55	0,92	0,015278	00:00:55	10:56:45	03/02/2017	0,96	34,9	2
60	1	0,016667	00:01:00	10:56:50	03/02/2017	1	35	2
65	1,08	0,018056	00:01:05	10:56:55	03/02/2017	1,04	35,4	2
70	1,17	0,019444	00:01:10	10:57:00	03/02/2017	1,08	35,4	2
75	1,25	0,020833	00:01:15	10:57:05	03/02/2017	1,12	36	2
80	1,33	0,022222	00:01:20	10:57:10	03/02/2017	1,15	36,1	2
85	1,42	0,023611	00:01:25	10:57:15	03/02/2017	1,19	36,2	2

Fig. 5 - Example of csv file layout of the data acquisition program, time vs vertical displacement reading.

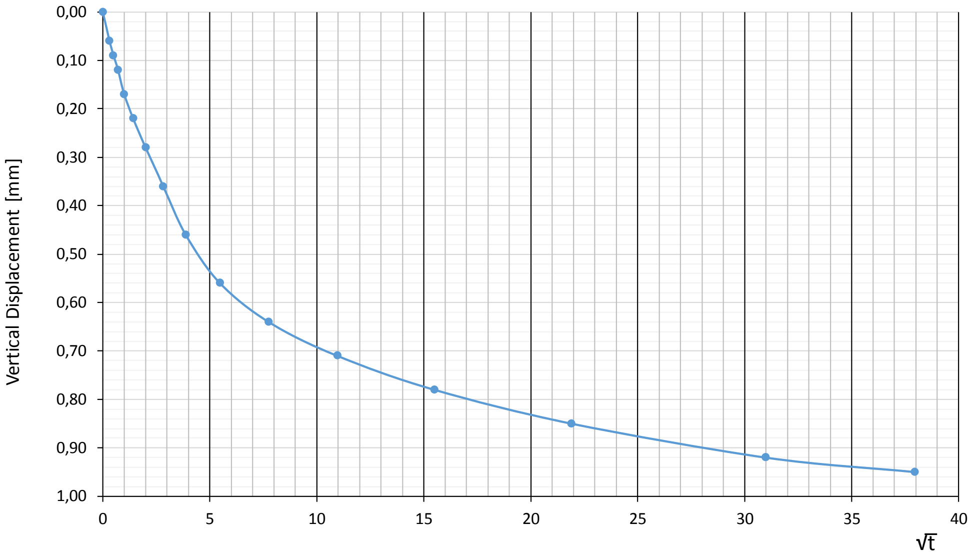


Fig. 6 - Vertical displacement of a sample with the square root of the time (in minutes).

CONCLUSIONS AND FUTURE WORK

This paper describes an experimental setup that was developed in order to automate the One-dimensional consolidation properties of soil test. This experimental setup has the goal to assure repeatability in the data acquisition test, avoiding human errors. The described setup is based on LabVIEW, LVDT sensors, a 16 Bit Data Acquisition Board, a Load device and a Consolidometer. The experimental setup was developed according to the standard ASTM D2435 / D2435M - 11. As future work, the authors intend to expand the experiment working with three consolidation cells simultaneously, sharing the same data acquisition board. This approach has as goal speeding up the consolidation tests, allowing a better rentabilization of the data acquisition board, which is an expensive resource.

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