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Automated K_0 consolidation in stress path cell

Consolidation automatisée K_0 dans une cellule triaxiale Bishop et Wesley

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ABSTRACT

Due to the fact that several natural soils have been deposited under zero lateral strain, it is worth to carry out triaxial tests without lateral deformations known as K_0 consolidation. In this case the real K_0 value is not known in advance. In order to measure this value, a LabVIEW software is used to control a Bishop and Wesley stress path cell. The software program can operate three digital pressure-volume controllers that measure and control the volume change and pore water pressure, the radial stress and the axial stress or strain. This paper describes a fully automated K_0 consolidation of the test sample at zero radial strain. Using the horizontal Hall effect local strain transducer, radial deformations can be directly measured on the soil specimen. Therefore radial strain can be monitored continuously during the consolidation process. Steering that the volume change of the soil specimen must always be equal to the vertical deformation keeps the average cross-sectional area constant. This method is applicable only to saturated soils. In this research a constant rate of the axial deformation is applied and by means of a feedback signal from the horizontal local strain transducer the radial stress is controlled in order to keep the radial strain zero. From several triaxial test results, it is found that the LabVIEW program enables to control the stress path cell for investigating the real K_0 value in consolidation.

RÉSUMÉ

Les sols naturels se déposant généralement à déformation latérale nulle, il est nécessaire d'exécuter des essais triaxiaux sans déformation latérale, encore dénommés à consolidation K_0. Dans ce cas, la valeur K_0 n'est pas connue a priori. Pour mesurer cette valeur, un logiciel LabVIEW est utilisé pour contrôler une cellule à chemin de contraintes imposé Bisshop et Wesley. Le programme pilote trois contrôleurs pression-volume qui mesurent et contrôlent le changement de volume, la pression interstitielle, la pression radiale et la pression ou déformation axiale. Cet article décrit une méthode complètement automatique de réaliser une consolidation K_0 (à déformation radiale nulle) d'un échantillon. En utilisant des capteurs de déformation locale horizontale à effet Hall, les déformations radiales sont mesurées directement sur l'échantillon. Ainsi, la déformation radiale peut être contrôlée en permanence durant le processus de consolidation. Lorsqu'on s'assure que le changement de volume de l'échantillon correspond à tout moment à sa déformation verticale, la section horizontale moyenne de l'échantillon reste constante. Cette méthode est seulement applicable aux sols saturés. Dans cette étude, une vitesse de déformation axiale constante est appliquée et la contrainte radiale est ajustée à partir du signal en retour du capteur de déformation locale horizontale, dans le but de conserver une déformation radiale nulle. A partir de résultats d'essais triaxiaux, il est montré que le programme LabVIEW est capable de contrôler la procédure d'exécution d'une consolidation K_0.

1 INTRODUCTION

In-situ soils have different stresses in vertical and horizontal directions expressed by the coefficient of earth pressure at rest, K_0. K_0 is the ratio of the effective horizontal stress, σ'_h, to the effective vertical stress, σ'_v, in a soil that exists under the condition of no horizontal deformation as shown in equation 1.

$$K_0 = \frac{\sigma'_h}{\sigma'_v} \tag{1}$$

In the most cases K_0 differs from unity. Since Bishop and Henkel (1962) have introduced the K_0 triaxial test, there are many researches using this technique: Lewin (1971), Abdelhamid and Krizek (1976), Menzies et al. (1977), Vincenzo (1981), Atkinson et al. (1987), Germaine and Ladd (1988), Tatsuoka (1988), Sheahan et al. (1990), Thooft (1992), Zdravković and Jardine (2000). Some researches show triaxial test results with computer controlling: Menzies (1988), Lo Presti et al (1995), Sheahan et al. (1990) and Toll (1999). This paper also focuses on the control and measurement of K_0 consolidation triaxial testing using computer control. It describes the full setup of a triaxial stress path cell Bishop and Wesley type with local strain sensors. LabVIEW software is used to control applied stresses and monitor volume changes and deformations. Using local strain sensors, both vertical and horizontal deformations can be directly measured on a soil sample. The details of applying these local strain sensors are clearly described in Clayton and Khatrush (1986) and Clayton et al. (1989).

2 EXPERIMENTAL SET-UP

2.1 *Triaxial stress path apparatus with local strain sensors*

In the Laboratory of Soil Mechanics, a computer-controlled hydraulic triaxial stress path cell is used for performing the triaxial K_0 consolidation test. A LabVIEW program is modified and applied to control this cell. The system as shown in Figure 1 is based on the classic Bishop and Wesley type stress path triaxial cell (1975) and the GDS digital pressure/volume controllers. Three of these pressure controllers connect the computer to the triaxial stress path cell as follow:

- one for axial stress and axial displacement control.
- one for cell pressure control.
- one for setting back pressure and measuring volume change.

The controllers regulate accurately both pressure and volume change of de-aired water supplied to the triaxial stress path cell for controlling axial load or axial deformation, cell pressure and back pressure.

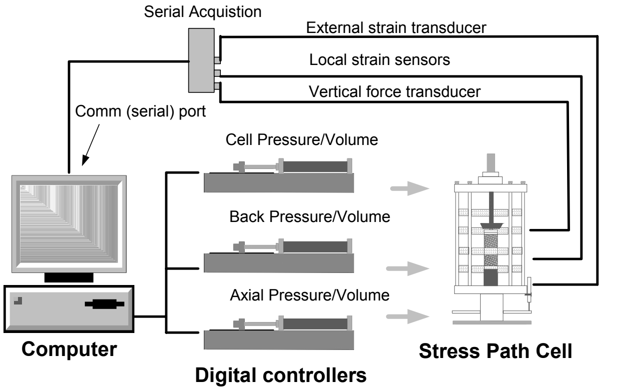

Figure 1. Schematic of the system.

In this research an internal load cell is introduced to the stress path cell. The internal load cell accurately measures the axial stress on the specimen. It has a capacity of 8 kN and its response to cell pressure changes is negligible. A LVDT monitors externally the vertical deformation. Pore pressure is measured by the back-pressure controller. The Hall effect local strain transducers can measure locally the vertical and horizontal deformation on the specimen. The digital controllers, LVDT, the Hall effect local strain transducers and the internal load cell are connected to the computer.

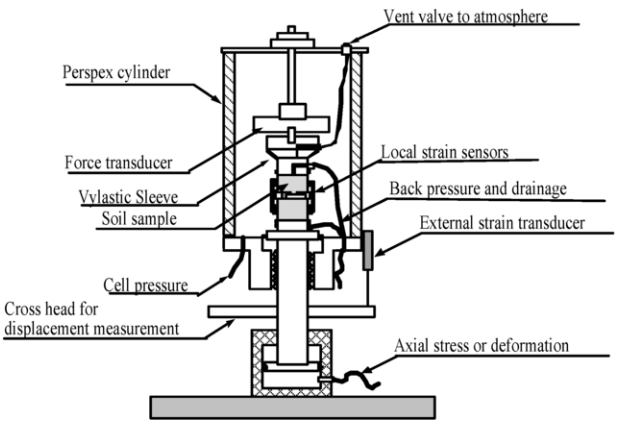

Figure 2. Diagrammatic layout of the stress path cell.

In conventional strain measurements in the triaxial test, deformations of the specimen are measured outside the triaxial cell. This introduces significant errors in the computation of the strains due to the compliant of the apparatus itself and bedding errors. Contacts between the specimen ends and the apparatus are not perfectly smooth and aligned as described in Scholey et al. (1995). Therefore in order to avoid these problems and obtain more accurate strain measurements, the research also uses local strain measurement sensors directly on the specimen as described in Clayton and Khatrush (1987) and Clayton et al. (1989). In triaxial testing, there is friction between the unlubricated ends of the soil specimen and the end platens. So to some extent the end platens are restrained vertically and laterally. This zone will be restrained at both ends to one third of the specimen height while the middle third has less disturbance to the effect from end restraint. It is suggested that radial and axial deformation measurement should locally be performed on the specimen in this zone. Figure 2 shows the set up of both radial and axial Hall effect local deformation transducers on the soil specimen in a triaxial stress path cell. The position of the radial local deformation transducer is at the specimen mid-height and the position of the local vertical deformation transducers are at the middle third of the specimen height. Figure 3 shows the mounting of both axial strain sensors and a radial strain sensor on the sample.

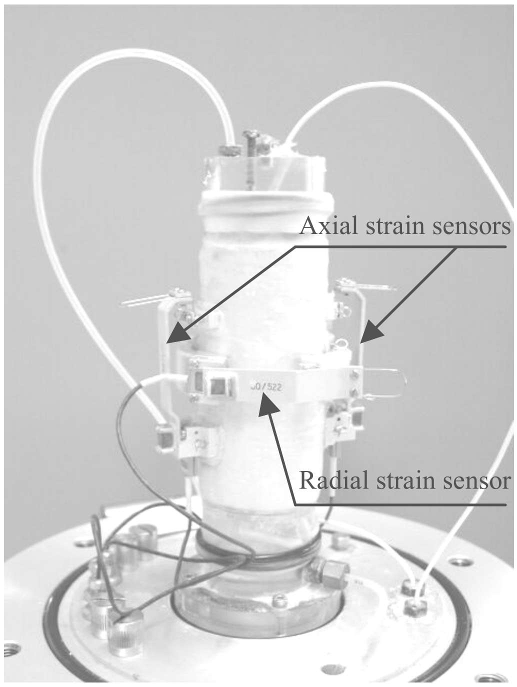

Figure 3. Mounting of Hall effect sensors in the stress path cell.

2.2 *Soil materials*

In the Laboratory of Soil Mechanics, two types of material are used. One is the Belgian Boom clay and another is the Kaolinite clay. A reconstituted Boom clay sample is prepared in the standard Proctor test. Afterwards a homogeneous sample is taken by means of a cylindrical tube 50 mm in diameter and 100 mm in height. The specific gravity of the reconstituted Boom clay sample, G_s, is 2.71, the water content is 34.74 % and the wet unit weight is 17.95 kN/m³. In the same way, a reconstituted Kaolinite clay specimen of 53 mm in diameter and 101 mm in height is prepared with G_s of 2.65, water content of 27.9 % and wet unit weight of 19.63 kN/m³.

3 TESTING PROGRAMME

3.1 *K_0 consolidation*

It is sometimes important to carry out triaxial tests under conditions of zero lateral strain. These tests are known as the K_0 consolidation. The K_0 test consolidates a saturated soil sample at zero horizontal strain keeping the cross-sectional area constant. The horizontal deformation of the sample should be in the range of ±1 μm. The volume change in the porewater duct must always be the same as the value of the axial deformation times the original cross-sectional area. This test begins without an excess pore pressure and no development of the excess pore pressure during the test is allowed. The method for K_0 consolidation triaxial compression tests and extension tests is clearly explained in the Japanese Geotechnical Standard 0525-2000 and 0526-2000. This method can only be used with saturated soils.

3.2 *LabVIEW programming*

The LabVIEW software is used to control the test. Figure 4 shows the flowchart of the K_0 consolidation procedure. Under conditions that the soil sample must be saturated and the cross-sectional area constant, a water volume equals to the volume change of the sample is extracted out at the same rate of axial deformation. The test is performed with axial deformation rate of 0.1 mm/hour. During this increase of axial deformation, the horizontal deformation is measured and kept constant by adjusting the radial stress. In case the horizontal deformation increases, the radial stress is also increased in steps of 2 kPa in order to keep the cross-sectional area of the soil sample constant. In opposite way if the horizontal deformation decreases, the radial stress is decreased in the same rate of 2 kPa. The test will automatically stop when the target effective vertical stress, σ'_v, is reached.

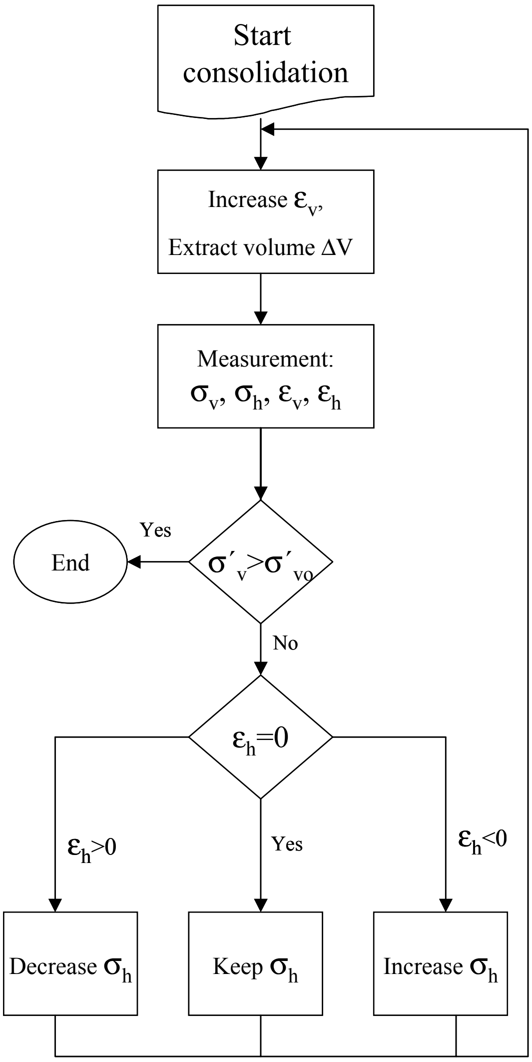

Figure 4. K_0 consolidation flowchart.

4 EXPERIMENTAL RESULTS

Figure 5 presents the K_0 value of the reconstituted Boom clay under K_0 condition and the value of 0.601 is calculated from the slope of the σ'_h versus σ'_v graph. Using Jaky's formula, a drained friction angle of 23.5° is calculated. In the same way, Figure 6 presents the data of the reconstituted Kaolinite clay. The K_0 value of 0.67 and friction angle of 19.3° are found. Both friction angles from the reconstituted Boom clay and the reconstituted Kaolinite clay are laying in the range of typical values of soft clays 20-25°.

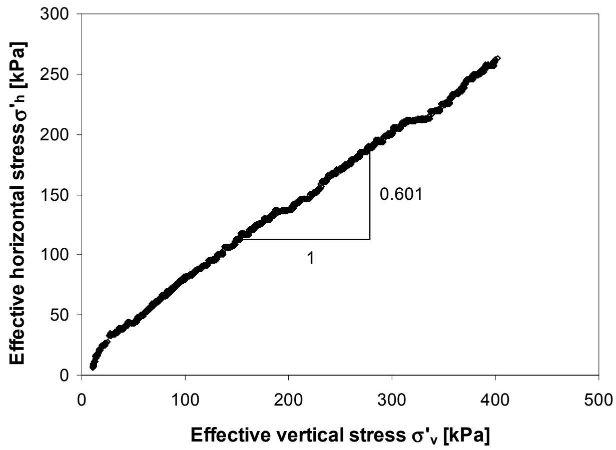

Figure 5. K_0 consolidation of a reconstituted Boom clay.

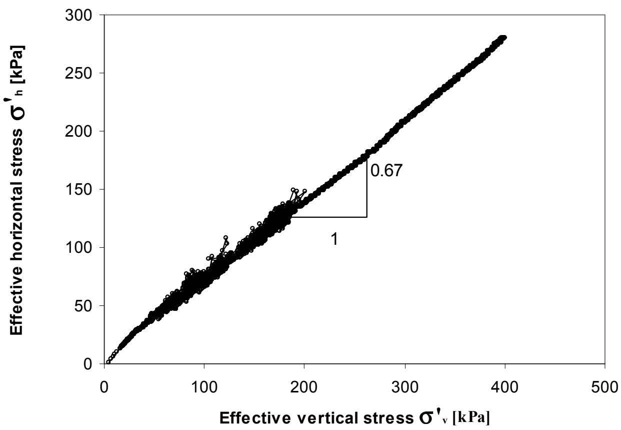

Figure 6. K_0 consolidation of a reconstituted Kaolinite clay.

5 CONCLUSIONS

A LabVIEW software programme is developed to control the stress path cell, offering the possibility to perform the K_0 consolidation triaxial test in a fully automated manner. The K_0 value can be obtained from the slope of the σ'_h versus σ'_v graph during the K_0 test. Using local strain sensors, there is an advantage to monitor deformations directly on the sample.

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