Telemetric Measurement of Pore Pressure in Soil Samples

Mesure télémétrique de la pression interstitielle dans des échantillons de sol

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SUMMARY

A new method of telemetric measurement of pore pressure in soil samples has been developed. The piezometer consists of a pressure transducer and a transistorized subminiature short-wave transmitter which may be switched on and off by a radio signal. To actuate the transducer, a volume change of about 1 cu. mm. is necessary. The piezometers have a diameter of about 25 mm and a height of 25 mm, a further reduction of the size being possible under certain conditions.

SOMMAIRE

Un nouveau procédé a été développé pour mesurer à distance la pression de l'eau interstitielle dans des échantillons de sol. La cellule piézométrique consiste en une partie traduisant la pression et en un émetteur onde courte, sous volume réduit. Cet émetteur à transistors est télécommandé par un signal de radio. Le changement de volume nécessaire au fonctionnement de la cellule est environ d'un millimètre cube. L'instrument complet a 25 mm de haut et 25 mm de diamètre; dans certaines conditions, il semble possible de le rapetisser d'avantage.

TO DETERMINE THE STRENGTH characteristics of soil samples, the triaxial test is found to be very convenient. The evaluation of the test is based on the measurement of the following parameters during the test: cell pressure σ_3 and deviator stress $\sigma_1 - \sigma_3$, volume change and diameter change of the sample, pore pressure. It is common to all measuring procedures that only a very small volume change may be allowed in order to avoid any flow of the pore fluid which might affect the pore pressure.

There are two principles for measuring pore pressures: (1) By means of a null indicator, the pore pressure is compensated by an external pressure, thus causing no volume change. The external pressure is then measured. (2) The pore pressure causes the deformation of a pressure transducer, thus involving a small volume change. The deformation of the transducer is measured either mechanically or electrically.

If larger soil samples are tested in the triaxial apparatus, installations have to be provided to measure pore pressures within the sample in addition to the ceramic stones at top and bottom. This is necessary when during the testing period the pore pressure cannot equalize within the sample due to its low permeability. Especially in the failure plane, the pore pressure will differ from that in the adjacent soil. Since the maximum shear resistance is calculated from the parameters in the failure plane, the knowledge of pore pressures in the failure plane is essential. The location of the failure plane cannot be predicted, therefore a reasonable number of piezometers should be installed. The connecting elements of the piezometers interfere with the stress-strain state of the sample and tightening problems are raised.

In order to avoid the above-mentioned disadvantages, a special measuring procedure has been developed. In this case, the pore pressure is transmitted by means of a wireless short-wave signal. The piezometer consists of a pressure transducer and a transistorized subminiature transmitter. The pore pressure causes the deflection of a membrane in the transducer which results in a proportional frequency change of the transmitter. The deflection of the membrane is about 1 to 2 by 10^{-2} mm at maximum pressure, the volume change being in the range of 1 cu. mm.

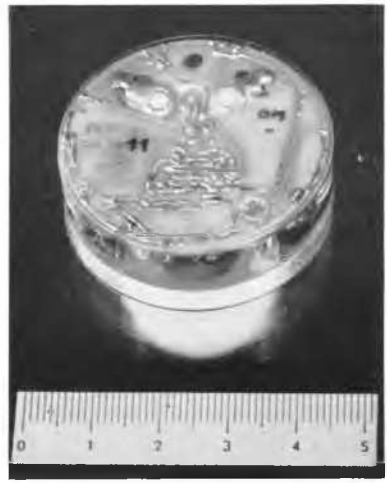

FIG. 1. Piezometer.

Ceramic filter, pressure transducer, and subminiature-transmitter are mounted together. Taking advantage of microminiature electronic components, it was possible to reduce the size of the piezometer to about 25 mm in diameter and 25 mm in height. The subminiature transmitter contains a printed circuit and is cast into a block of epoxy resin in order to gain high mechanical stability. By means of mechanical provisions, the piezometer may withstand high soil pressures without disturbing the measurement of pore pressures. Fig. 1 shows a piezometer, 40 mm in diameter and 25 mm in height; Fig. 2 shows the receiver.

FIG. 2. Receiver.

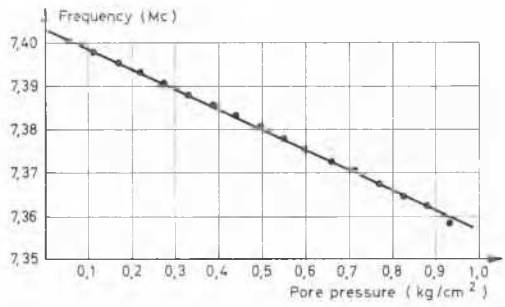

FIG. 3. Calibration curve of piezometer.

Each piezometer transmits an individual short-wave frequency. The frequency distribution on the short-wave band depends on the frequency change resulting from the measured pressure change. For identification, the subminiature transmitter emits a low-frequency signal which in addition indicates the condition of the rechargeable batteries.

By means of a radio signal, the transmitter may be switched on and off permitting discharge of the batteries only during measuring periods. Previous tests showed that the standby time is about 3 to 6 months. During this period, an actual transmitting time of 10 to 40 hours is available depending on the type of batteries used. This operating period may be assumed to be sufficient when the short time of actual measurements is considered. When the test is finished, the batteries may be recharged and the piezometer will be ready for new tests. A short-wave receiver of high sensitivity receives the signal of the piezometers, which is then transferred electronically, indicated on a high-speed digital counter, and printed by a printer. Since the average deviation from linearity and the effect of hysteresis is found to be smaller than ± 2 per cent, a calibration factor can be given to calculate pore pressure from the received signal frequency.

Performing the triaxial test, it is sufficient to place an antenna between the outer cell and the soil sample which couples all the piezometers installed to the receiver. To switch the subminiature transmitters of the piezometers on and off, either the same antenna or a separate one must be energized by a high-frequency power generator. This signal actuates an electronic switch inside the subminiature transmitters and enables the transmission of pore-pressure signals. Piezometers of the kind just mentioned operate without additional precautions in soil samples of 30 cm to 100 cm in diameter being tested in large triaxial cells. In smaller triaxial cells, the distances between the piezometers and the antenna are much smaller. Therefore, research is being done to reduce the size of the piezometers even more, resulting in dimensions of 15–20 mm in diameter and 10–15 mm in height; such reductions are considerable since the transmitted energy can be very small in this case. Research work of this kind depends on restrictions resulting from the microminiature components available.

Piezometers of different sensitivity fulfil the demands of different kinds of triaxial tests. Since the piezometers are very small, a great number may be installed in the sample. Due to the absence of connecting elements the piezometers are able to follow the local displacements without disturbing the stress-strain state in the sample. During the test of rock-clay skeleton samples some of the piezometers may fail due to local overload. Since the number of installed piezometers is great, a calculation of pore-pressure distribution can yet be done from the results of the remaining ones.

All the principles of the special behaviour of ceramic-filter materials must be considered when using this type of pore-pressure transducer. These principles have been investigated mainly by Dr. Bishop in connection with the use of different types of ceramics to measure water-pressure and air-pressure separately. During recent studies, gauges to measure soil pressure had been developed operating on the same principal. They have been used with good results in quite a number of tests. It may be predicted that the new measuring procedure may simplify the measurement of pore pressures and will, under certain conditions, enable tests which previously have not been possible due to the application of conventional methods.