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Publisher's version / Version de l'éditeur:

Canadian Geotechnical Journal, 8, 2, pp. 341-345, 1971-05

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**ELECTRONIC MEASUREMENT OF CHANGES IN THE VOLUME OF
PORE WATER DURING TESTING OF SOIL SAMPLES**

BY

R. J. MITCHELL AND K. N. BURN

Reprinted from
CANADIAN GEOTECHNICAL JOURNAL
VOL. 8, NO. 2, MAY 1971
p. 341

RESEARCH PAPER NO. 471
OF THE
DIVISION OF BUILDING RESEARCH

OTTAWA
May 1971

Price 10 cents

NRCC 11821

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Electronic Measurement of Changes in the Volume of Pore Water During Testing of Soil Samples

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Received December 21, 1970

Two systems are described for electronic recording of changes in the volume of pore water for triaxial testing of soils: one using a miniature force transducer to measure by direct weighing; the other based upon a float system connected to the core of a differential transformer. Both systems provide measurement of volume change at least as accurately as may be obtained by visual reading of burettes graduated to 0.1 cm^3 , i.e. to $\pm 0.05 \text{ cm}^3$.

L'article décrit deux méthodes pour enregistrer électroniquement les changements volumiques de l'eau interstitielle pour les essais triaxiaux des sols: la première utilise un transducteur à faible tension pour mesurer par la pesée directe; l'autre est basée sur un système de flottaison raccordé au noyau d'un transformateur différentiel. Les deux méthodes fournissent les mesures du changement volumique aussi exactement qu'on peut les obtenir à l'aide de burettes graduées à 0.1 cm^3 , c'est-à-dire $\pm 0.05 \text{ cm}^3$.

To complete automatic recording of all pertinent parameters during triaxial testing, two instruments were developed for electronic measurement of water-content changes in soil samples. These instruments were designed for use in systems where air pressure is used to "back pressure" the pore fluid.

The first instrument operates on the direct-weighing principle and appeared, initially, to be the more accurate method of measuring volume change. Problems became apparent, however, during calibration, and a second instrument operating on a float-displacement principle was developed. Both instruments are described in this note.

Direct-weighing Instrument

Details of the design and a photograph of the first instrument are presented (Figs. 1 and 2). The weighing container is physically independent of all leads and accuracy is limited only by the performance of the weighing transducer. A layer of silicon oil is floated on the surface of the pore fluid to reduce the long-term effect of evaporation.

The weighing transducer used with this instrument operates on a system of flexible metal proving discs attached to floating strain gauge wires. Applied air pressures equalize throughout

FIG. 1. Direct-weighing instrument (design), full scale.

the instrument and interior of the transducer. Measurement accuracy was found to be $\pm 0.5 \text{ cm}^3$ (as predicted by the transducer characteristics) under no back pressure. The application

TABLE 1. Performance of instruments

Instrument	Capacity cm ³	Power supply	Output	Transducer accuracy	Calibration			Remarks
					Constant	Stability	Accuracy	
Direct-weighing	30	7 V, d.c.	60 mV, d.c.	± 0.15 % full scale	1.95 mV/cm ³	Average 0.01 cm ³ /day under pressure	± 0.05 cm ³	Reduced accuracy under pressure due to drift correction
Float-displacement	20	7 V, d.c.	± 6 V, d.c.	± 0.5 % full scale	0.609 V/cm ³	Negligible drift	± 0.02 cm ³	Operation independent of ambient pressure

FIG. 2. Direct-weighing instrument.

FIG. 3. Float-displacement instrument.

of pressure caused a small change in the transducer reading and resulted in a nearly linear drift of the transducer readings under constant load. Complete enclosure of the transducer in the pressure chamber failed to eliminate drift. Sealing the transducer from the pressure by means of a latex membrane eliminated the drift, but it seriously reduced the sensitivity of the transducer.

A major modification using flexible pressure and pore water leads was tried; the leads were sealed into the weighing container and the complete system was weighed. Although this eliminated transducer drift, it was found that pressure changes affected the flexibility of the leads and the readings changed if an external agency caused minor fluctuations in the alignment of the system.

Calibration information for this instrument is presented in Table 1. The prototype is used for volume measurement in tests that do not require a back pressure.

Float-displacement Instrument

A photograph and details of the design of the second instrument are shown in Figs. 3 and 4. The measuring system is composed of a d.c.d.t. (direct current differential transformer) transducer with a core supported on a glass float. Glass floats were blown from 3-mm o.d. by 1-mm i.d. pyrex tubing; each float weighs approximately 1 g and displaces a volume of about 8 cm³. The core and stainless extension rod have a total weight of about 4 g, leaving a buoyant force of approximately 3 g. The float is submerged in silicon oil (5 centistoke viscosity), which gives a stable air-fluid meniscus while reducing the long-term effects of evaporation and diffusion. The 1-mm diameter extension rod is supported in the glass sleeve extension of the float by a stainless nut. Applied air pressures immediately equalize throughout the interior of the instrument due to clearances between the core and the bore of the transducer and between the threaded rod and the glass sleeve of the float. The instrument is carefully mounted in a vertical axis in order that the core and extension rod ride with minimum friction inside the windings. Measurement accuracy was found to be ± 0.02 cm³ if the pore fluid moved continuously in one direction; it was reduced to ± 0.05 cm³ if the direction changed

FIG. 4. Float-displacement instrument (design), full scale.

the result of core friction in the transducer rather than a meniscus effect. The instrument is designed for a maximum working pressure (back pressure) of 5 kg/cm². The transducer readings are independent of the applied back pressure.

Two of these instruments have been in operation for 6 months and have performed satisfactorily. Performance information is given in Table 1.

Concluding Remarks

In addition to fulfilling their main purpose of recording changes in volume of pore water, both instruments offer the following advantages:

(1) Measurement accuracy equal to or better than normal burette readings

(2) Linear calibration relationships

(3) Use of power supplies and mode of readout similar to those used to record the other parameters of force, pressure, and displacement of the triaxial test

(4) Small change in back pressure (level of fluid in gauge) for a large range of volume change

The superior performance of the float-displacement instrument has resulted in its adoption in preference to the direct weighing instrument. The latter instrument would warrant fur-

ther consideration, however, if a more suitable weighing transducer became available.

Acknowledgments

The authors wish to express their sincere thanks to D. MacMillan and K. Timmins for their assistance in testing and for valued comment during the development of these instruments.

This paper is a contribution from the Division of Building Research, National Research Council of Canada, and is published with the approval of the Director of the Division.