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STUDIES OF SENSITIVITY AND ELECTRO-KINETIC POTENTIAL IN
LEDA CLAY

BY
E. PENNER

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Studies of Sensitivity and Electro-kinetic Potential in Leda Clay

In a previous communication¹, an anomalous difference was pointed out between two supposedly similar geological deposits from widely separated regions of the world. Whereas a relationship between sensitivity (the ratio of undisturbed shear strength to remoulded shear strength) and pore-water salt concentration has been reported for some Norwegian marine soils, this was not true for Leda clay from the Ottawa-Hull area in the St. Lawrence Lowland region of eastern Canada.

This has now been substantially confirmed at several new locations in the Ottawa-Hull area. Except for one location, the pore-water salt content is low and the sensitivity is not uniquely dependent on the amount of salt present. Fig. 1 shows that at specific conductivities of less than $4 \times 10^{-3} \text{ ohm}^{-1} \text{ cm}^{-1}$ the sensitivity varied from 11 to 1,000+; as expected, at high specific conductivities the sensitivity remained relatively low.

What has been particularly puzzling, and for which no reason has been advanced, is the wide variation in

Fig. 1. Salt concentration of the pore water in terms of specific conductivity, as a function of sensitivity

Fig. 2. Electrokinetic potentials of undisturbed Leda clay as a function of sensitivity

sensitivity that is observed in this area for soils of low pore-water salt concentrations, which sometimes appear almost identical in other respects such as strength, water content, grain-size distribution, and clay mineral content.

Measurements of the electro-kinetic potential in undisturbed samples of this soil have shown that potential increases directly with increasing sensitivity. The electro-osmotic technique was selected because it has an important advantage for this type of investigation as it can be adapted to measure the electro-kinetic potential of undisturbed soil in its natural pore-water electrolyte environment. Because of the difficulties that are involved in electro-osmotic measurements and the uncertainties in using the appropriate values for dielectric constant and viscosity in calculating the potential, the numerical values recorded in this communication have a formal significance only, although they may be more confidently used for comparative purposes.

The results shown in Fig. 2 are for the same soils as in Fig. 1. Although there is scattering, the trend is thought to be sufficiently definite to be significant. The greatest deviations are for those soils that have a low surface area as compared with the average, although the clay-size content is essentially the same. One must assume from this that there are also purely physical factors which influence sensitivity.

The trend of the measured relationship between sensitivity and electro-kinetic potential—a first step in our investigations—simplifies the understanding of the

wide variations in sensitivity, and such variations in potential need no longer be postulated to explain the phenomena. It follows that the higher the electro-kinetic potential, hence also the interparticle repulsion, the greater will be the loss in strength expressed in terms of sensitivity. The basic causes for the large variations in electro-kinetic potential at low pore-water salt content are not known in most instances, but in at least one case a change in the $\text{Na}^+/\text{Ca}^{++}$ ratio in the pore water has been thought to be responsible.

In other investigations, measurements of the electro-kinetic potential at various stages of leaching (field pore-water salt concentration 10–15 gm/l.) gave an increase in potential as leaching proceeded. This supports Rosenqvist's theory of leaching to explain the formation of Norwegian quick clays. There is some doubt, however, based on recent geological evidence², about the marine origin of Leda clay; it is now thought that a large proportion of the Leda clay deposits in the Ottawa–Hull area consists of re-worked marine sediments that have been re-suspended and subsequently sedimented in an almost fresh-water environment as the salinity of the Champlain Sea was decreasing. In one location near Ottawa a salty marine clay remnant appears to be flanked by such deposits. A similarity which is characteristic of all the deposits is the flocculated structure, but it is known that rather small concentrations of electrolyte during sedimentation are required to bring this about. If, in fact, these are essentially fresh-water deposits, the existing theory for sensitivity based on the salt-leaching is not satisfactory. Some progress is being made in exploring sensitivity on a new basis.

The main intent of the present communication is to show the trend in the measured relationship between electro-kinetic potential and sensitivity. Details of the apparatus and technique and more complete results are to be published shortly.

EDWARD PENNER

Soil Mechanics Section,
Division of Building Research,
National Research Council,
Ottawa.

¹ Penner, E., *Nature*, 197, 347 (1963).

² Gadd, N. R., Paper 62–16, *Geol. Surv. Canada* (1962).