

A geochemical investigation of the sensitivity of a normally consolidated clay from Drammen, Norway

MOUM, J., LÖKEN, K. and TORRANCE, J. K. (1971). *Géotechnique* 21, No. 4, 329–340.
Discussion (1972) 22, No. 3, 542–544.

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Balasubramonian and Morgenstern have made interesting observations concerning the investigations on the Drammen clay. The Authors are grateful and compliment them for detecting the discrepancy between the salinity measurements and the cation concentrations in boring I. A careful check of the original laboratory data has revealed that their assumption that the reported Mg concentration in boring I is ten times the actual value is correct. As a result of this error the results must be interpreted in a slightly different manner than originally with the emphasis on magnesium concentration being decreased. This error has a slight influence on the values given for absorbed Mg in Table 1 of the Paper in that the values should be increased with 0.45 as a maximum down to 0.04 as a minimum. The corrected values for boring I are presented in Fig. 1 with the results for boring II. In this new plotting an error in the scale for the K/Na ratio (Fig. 4) and an error in the scale for cations in the pore-water (Fig. 5) have been corrected.

The addition experiments with K and Mg in Fig. 7 show the remarkable effect of these ions on the remoulded shear strength and hence the sensitivity of the leached Drammen clay. The error in Mg concentration invalidates the original argument that Mg is chiefly responsible for the decrease in sensitivity in the lower part of boring I. The decrease in sensitivity must be attributed to all those ions which increase in the lower portion of the profile and which are known to have considerable effect on remoulded shear strength even in low concentration, namely, Mg, Ca and K. The proportion of the increase in shear strength attributable to each of these ions cannot be determined from the present experiments.

For the results from Tinghuset it would appear that the sensitivity in both borings seems to

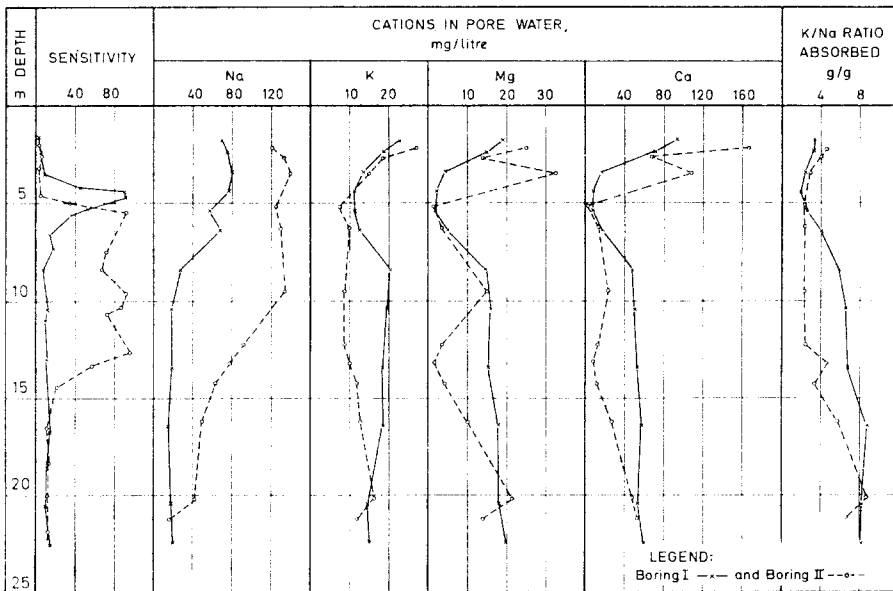


Fig. 1. Sensitivity, porewater chemistry and K/Na ratio (absorbed): corrected values

be a function of some appropriate summation of all the cations present in the pore water. Especially, it should be noted that the influence from Mg, Ca and K is predominant, whereas the influence from Na at the actual concentrations is not noticeable.

The probable events at Tinghuset remain the same except that at an earlier time in boring I the Mg concentration must have been less than 2.0 mg/litre at all points below 5 m, and has subsequently increased. The same is the case for K and Ca where the limits are approximately 11 and 7.5 mg/litre respectively. This minimum suggests that some gentle weathering process has been proceeding from below and has been attacking the minerals; probably releasing Mg from chlorite, Ca from calcium carbonate, and K from the hydrous micas present. This weathering process also appears to be occurring in boring II but is less advanced. It is suggested that the term desensitized clay is appropriate to use with this clay material which has previously had a lower salinity and hence a higher sensitivity than it now possesses. The Na concentrations in both borings clearly show that the leaching has occurred from below and that the degree of leaching is less in boring II than in boring I. This is in accordance with a similar difference in degree of weathering, as shown by the concentration of K, Mg and Ca.

Balasubramonian and Morgenstern doubt as to how the salt additions were made. The salts were added to the natural soil (without monoionizing) giving a slight increase in water content.

The results obtained by Balasubramonian and Morgenstern using the Gapon equation are interesting. As they state, this approach could only be made where the total salinity, soil type and soil strength are constant with depth. Under these conditions they assume the validity of the Gapon equation. At Tinghuset the factors are sufficiently close to constant that the approach is worth trying.

However, a major problem arises as to the validity of the Gapon equation as related to shear strength. As shown by Rosenqvist (1955), the various monovalent cations have a different influence on the mechanical properties of clay pastes depending on their polarizability. The results of the addition experiments done in connexion with the Tinghuset investigation further show a similarly different influence for Mg and Ca. Thus, the mechanical properties of a clay paste depend not only on the valence. Further, the Gapon equation gives the relationship for adsorption of one kind of monovalent and one kind of divalent cation as related to their concentrations in the pore water. As shown by Löken (1970) on similar types of clay, the various monovalent and divalent cations have different replacing abilities. Therefore, the Authors doubt that the validity of the summation of all the monovalent cations to make up for M_0 and all the divalent cations to make up for D_0 .

A third problem with the Gapon equation used in this way is that the sensitivity is definitely dependent on salinity. If the salinity is high the sensitivity will be low and if the salinity is extremely low the sensitivity will be high regardless of the value of the Gapon relationship. The interesting results obtained in the present case using the Gapon equation would, in the Authors' opinion with the present state of knowledge, appear to be fortuitous. Summarizing, the remoulded shear strength of mineral pastes is a function of all the cation concentrations summed appropriately and of the water content and mineralogy of the soil system.

The Authors agree that further research is necessary before a complete relationship can be set up between the mechanical properties of a clay paste and the concentrations of different cations in the pore water.

REFERENCES

- Löken, T. (1970). Recent research at the Norwegian Geotechnical Institute concerning the influence of chemical additions on quick clay. *Geol. För. Stock. Förh.* **92**, Part 2, 133–147.
- Rosenqvist, I. Th. (1955). Investigations in the clay-water system. Publication 9, p. 112. Oslo: Norwegian Geotechnical Institute.

Postgraduate courses

University of Birmingham

Twelve-month courses in foundation engineering, mineral chemistry and applied geophysics leading to the M.Sc. will begin on 1 October, 1973. Details are obtainable from the Assistant Registrar (Science and Engineering), University of Birmingham, P.O. Box 363, Edgbaston, Birmingham, B15 2TT.

University of Durham

A one-year M.Sc. course in engineering geology will begin on 1 October, 1973. Details may be obtained from the Reader in Engineering Geology, University of Durham, South Road, Durham.

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Index for *Géotechnique*

The index for volume XXII (1972) will be distributed with the March 1973 issue.

Colliery spoil tips—after Aberfan. G. McKechnie Thomson and S. Rodin. Institution of Civil Engineers, 1972, paperback, demy 8vo, 64 pp, £1.

The discussion on this subject which was held at the Institution on 31 October, 1972, will be published in *Proceedings*, Part 2. Written contributions should be sent to the Managing Editor by 31 January, 1973

Corrigendum

September 1972 Géotechnique

On p. 545, the price of the Proceedings of the 5th European Regional Conference should be 2500 pesetas, which is approximately US \$39.