

DISCUSSION

Stress-state–permeability relations for overconsolidated clays

T. S. NAGARAJ, N. S. PANDIAN and P. S. R. NARASIMHA RAJU (1994). *Géotechnique* **44**, No. 2, pp. 349–352

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The Authors present data from consolidation and falling head tests on reconstituted residual soils consolidated from a slurry in a standard oedometer to support their conclusions that there is generalized stress state relationship for uncemented fine grained soils and that there is a unique relationship between e/e_L and $\log k$.

Burland (1990) shows that there is an intrinsic compression line in which the void index—a function of the void ratio—is a simple cubic function of the effective vertical stress. He compares the parameters forming the void index with e_L to show that, although correlations with e_L are valid, the deviation from a best-fit line increases as e_L increases or decreases. Fig. 3 shows data taken from Burland (1990) replotted in terms of e/e_L to show that, for normally

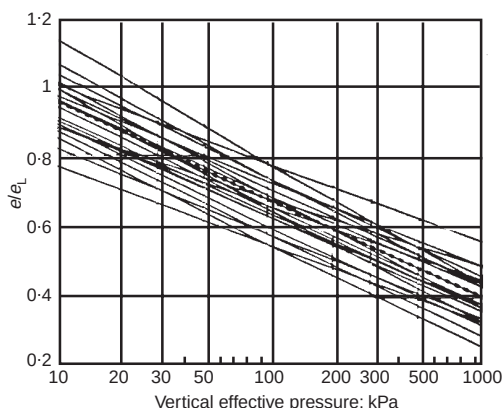


Fig. 3. Data from reconstituted clays normally consolidated taken from Burland (1990) and plotted in terms of e/e_L (the dotted line is taken from Fig. 2(b))

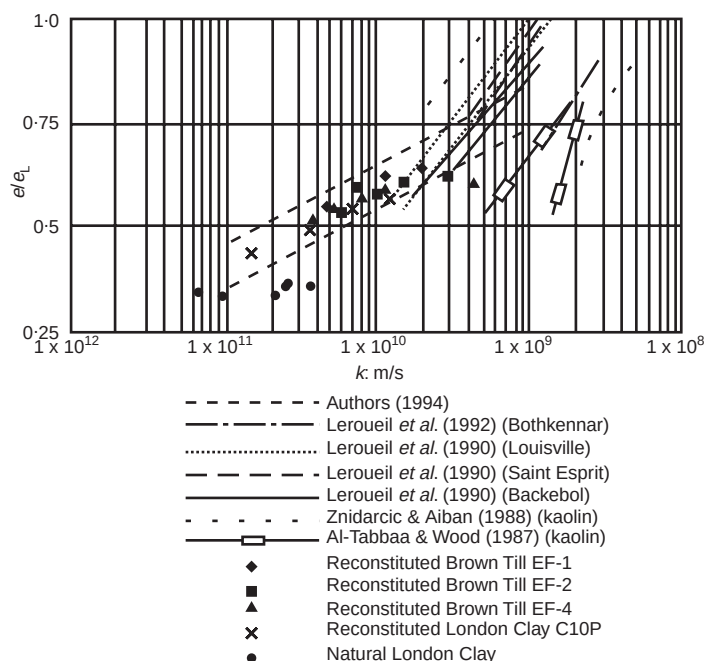


Fig. 4. Data from a number of tests on natural reconstituted clays

consolidated reconstituted soils, there is no unique correlation but that the curves for the soils are, for practical purposes, parallel and lie within a broad band. In that case it may be better to use the void index to normalize data rather than e_L as used by the Authors.

The data from the permeability tests fall within a band which is shown in Fig. 4. Additional data from a variety of permeability tests on natural and reconstituted clays are also plotted in Fig. 4.

The test results identified by the symbols have been carried out using a flow pump to create a low hydraulic gradient in specimens of reconstituted clay within a flexible wall permeameter. The apparatus and test results are described in detail by Araruna, Clarke & Harwood (1995). They show that the data from reconstituted clays lie about the line proposed by the Authors. Data from natural soils do not fall within the band but this could be due to the effects of fabric. Other published data on reconstituted clays and on natural clays do not fall within the bounds of the data given by the Authors, thus casting doubt on their claim of a unique relationship between e/e_L and $\log k$ even for reconstituted clays.

The results presented are taken from falling head tests carried out in an oedometer. No information is given on the heads used nor on the method used to determine void ratio. It is assumed that the void ratio was derived from the final water content or the initial dimension of the specimens. In either case the void ratio shown in Figs 1 and 2 is not measured; it is most likely taken from the compression curves as the void ratio at the end of each stage of loading or unloading.

As the overconsolidation ratio increases (i.e. the effective stress reduces), the effects of seepage-induced swelling become significant. Although the Authors give no details of the heads of water used in their tests, consider a head of 0.5 m at the start of a test on a specimen allowed to swell to a consolidation pressure of 25 kN/m²—the lowest used by the Authors. The effective stress during the test will vary from 20 kN/m² to 25 kN/m², and so further swelling will take place during the permeability test and the void ratio will be greater than that shown in Fig. 2. Moreover, the measured permeability will be greater than the actual permeability as some inflow will be a consequence of swelling. This effect becomes less significant as the consolidation pressure increases. As a consequence the constants given in equation (4) may be incorrect.

The Authors show that results from falling head tests on one dimensionally consolidated soils give a generalized stress state relationship in the form of e/e_L and $\log \sigma_v'$, and that there is a unique

relationship between e/e_L and $\log k$. These do not apply to all soils—in particular natural soils where the effects of fabric may have a significant influence on the results.

Authors' reply

Figure 3 shows the data of 16 soils which are not reported by Burland (1990). However, the information available from Burland has been analysed by considering both the normalizing parameters, i.e. the void ratio at the liquid limit and the void index. Figs 5 and 6 show that the dispersions in both the generalizations are the same and not that one is superior to the other.

Russel & Mickle (1970), Wroth & Wood (1978) and Whyte (1982) have shown that the liquid limit state of all fine-grained soils corresponds to an effective stress (osmotic suction) of about 6 kPa with a shearing resistance of about 1.7–2 kPa. All the soils at a pressure of 6 kPa should therefore have a value of e/e_L of close to unity. Fig. 3 shows that even at 10 kPa some soils equilibrate to values of e/e_L of far greater than unity. This could be possible only in remoulded sensitive soils resulting from thixotropic effects due to the presence of cementing material. In such situations e_L is not the generalizing parameter and the

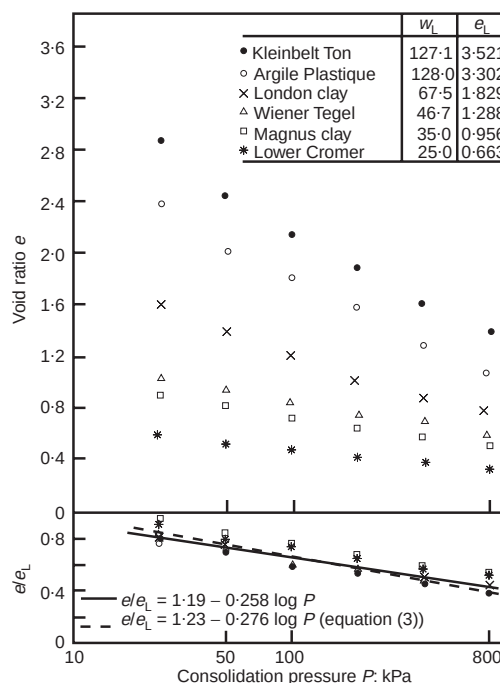


Fig. 5. Data of reconstituted normally consolidated clays taken from Burland (1990) and plotted in terms of e and e/e_L against $\log P$

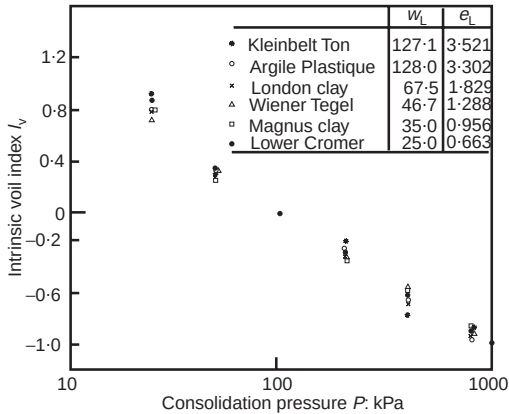


Fig. 6. Data of reconstituted normally consolidated clays taken from Burland (1990) and plotted in terms of intrinsic void index I_v against consolidation pressure P

proposed stress-state equation with corresponding constants is not valid.

As soil varies so greatly it is obvious that a single model cannot be applicable to all soil systems. Before applying a model, it is necessary to identify the nature of the soil system. Messrs Harwood, Clarke and Araruna compare the data of sensitive soils and kaolin with the proposed relationship between e/e_L and $\log k$. According to equation (3), for normally consolidated saturated uncemented soils, there is a compatible value of e/e_L for an overburden pressure. Any deviation from the compatible value indicates a deviation from the normally consolidated saturated uncemented state. In sensitive soils, e/e_L corresponding to overburden pressure is greater than e/e_L calculated using equation (3) for normally consolidated soils.

In such a situation of sensitive soils the proposed equation (equation (3)) is not applicable. For soft sensitive soils Narasimha Raju (1995) proposed another equation for predicting permeability behaviour by considering the natural void ratio e_0 as the normalizing parameter. The Authors proposed the e/e_L - $\log k$ relationship by taking natural soils which contain different minerals as reported in Table 1. Fig. 7 shows the analysis of data of Griffiths & Joshi (1990). The experimental and predicted paths of kaolinite and kaolinitic soils indicate that a small percentage of bentonite is enough to change the behaviour of kaolinite. Hence, the proposed equation is valid for kaolinitic soils also but not for kaolinite for which the behaviour is fully controlled by the fabric at cluster level which encloses the micropores. The proposed relations are considered neither universal, and are not claimed to be so. The main aim of the investigation was to show the ability of stress-state permeability interrelations to assess the changes in permeability for incremental effective stress changes.

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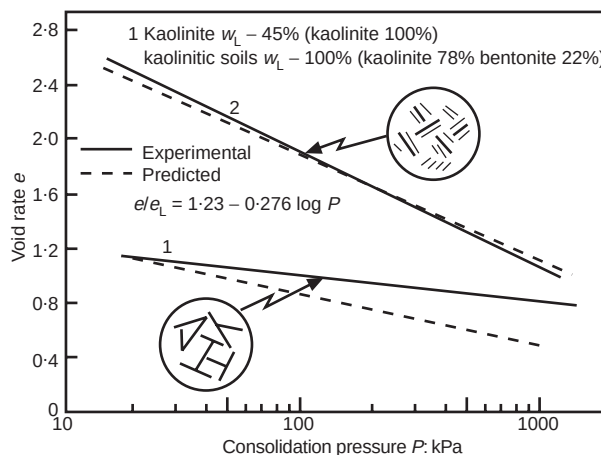


Fig. 7. e against $\log P$ for kaolinite and kaolinitic soils (data from Griffiths & Joshi, 1990)

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