Hattab, M. *et al.* (2014). *Géotechnique* **64**, No. 1, 89–90 [http://dx.doi.org/10.1680/geot.13.D.02]

DISCUSSION

Behaviour of a sensitive marine sediment: microstructural investigation

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Contribution by G. Mesri

Preconsolidation pressure σ'_p is the effective vertical stress, imposed under laterally constrained condition, at which significant destructuration takes place in natural soft clay. It is a yield effective vertical stress that signals the onset of compression range dominated by interparticle slip and significant particle rearrangement. Mechanisms of precompression, secondary compression and aging, including chemical bonding or cementation, may contribute to the magnitude of preconsolidation pressure. Therefore, the authors' assertion (Hattab *et al.*, 2013) that 'the presence of these bonds leads to an overestimation of the preconsolidation stress σ'_p' is rather confusing and misleading.

Typical shape of the yield envelope of soft clay deposits (e.g. see figures 20.2–20.7 (Terzaghi *et al.*, 1996)) corresponds to σ'_{pI}/σ'_p values less than 1 and in the range of 0·5–0·8 (see figures 20.8 and 20.9 (Terzaghi *et al.*, 1996)), where σ'_{pI} is preconsolidation pressure (yield stress) displayed in compression under equal all around pressure. A clay sediment structure developed in the field under laterally constrained compression, displays lower resistance to compression under isotropic loading. For the Gulf of Guinea clay, the authors report $\sigma'_p = 63$ kPa, corresponding to a reasonable value of $\sigma'_p/\sigma'_{v0} = 1{\cdot}73$; however, they also report a value of $\sigma'_{pI} = 110$ kPa, which is higher than σ'_p. Either the specimens for the oedometer and isotropic loading tests came from completely different depths in the seabed or the definition of σ'_{pI} from Fig. 5(b) is rather uncertain.

As a part of a comprehensive investigation of composition and compressibility of Mexico City clay, Mesri *et al.* (1975) introduced LIR (liquidity index ratio; the ratio of liquidity index of undisturbed soil to liquidity index of a reconstituted specimen by consolidation from slurry, both defined at preconsolidation pressure, σ'_p) as a means of estimating the source of a natural clay structure, where LIR is the ratio of the liquidity index of undisturbed clay to the liquidity index of the same clay, laboratory sedimented, both defined at the consolidation pressure equal to σ'_p (in the absence of e–σ'_v data on a laboratory sedimented specimen, the end-of-primary e–log σ'_v curve of a specimen remoulded at natural water content is used). For the moderately sensitive Mexico City clay structure, LIR averaged to 1·64, whereas for the Leda clay from Eastern Canada, LIR was in the range of 2·22–2·47. Similar high values of LIR apply to other highly structured clays from Eastern Canada. The structure of Mexico City clay has resulted from sedimentation, primary consolidation (some chemical alteration), secondary compression and thixotropic hardening, whereas the structure of the highly sensitive soft clays of Eastern Canada has developed through sedimentation, primary consolidation, secondary compression, interparticle bonding and pore-water salt reduction through leaching or diffusion. The LIR is 1·90 for the Gulf of Guinea clay, based on Fig. 5(a), possibly suggesting a moderate chemical bonding.

Note that the oedometer test data in Fig. 5(a) suggest a Gulf of Guinea clay specimen with specimen quality designation (SQD, measured in terms of volumetric strain experienced by a specimen when subjected to its in situ effective stress condition) (Terzaghi *et al.*, 1996) near 4% and $\Delta e/e_0$ near 6% that are consistent with the authors' report that it is quite difficult to extract undisturbed specimens from deep sea sediments.

The authors' 'small consolidation stress domain' corresponds to consolidation and shear inside the yield envelope of the natural sediment. The consolidation–shear behaviour of a structured clay deposit inside this domain is expected to be different from that in 'high consolidation stress domain' that results in a destructured clay (e.g. see figures 18.5 and 20.7 in Terzaghi *et al.*, 1996; Mesri & Hayat, 1993).

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Authors' response

The topic of the paper was to examine, from an experimental point of view, the bonding of a clayey sediment by a glue. The aim was to address the following questions.

(*a*) What damage will be induced by the breaking of the glue in the microstructure of the intact clayey sediment?
(*b*) What is the difference between this damage and the mechanisms developed in remoulded and reconstituted sediments?

The phenomenon of preconsolidation per se was not considered in this study, but the question raised by Professor Mesri offers the authors the opportunity to explain in more detail their point of view on the subject.

Preconsolidation pressure as defined in this paper is the maximum in situ vertical stress to which the clay sample has been submitted. But since the natural bonding within the microstructure does create supplementary strength, preconsolidation may well appear to be higher than it actually is. It is this consideration which underlies the authors' purportedly problematic assertion that the presence of bonds leads to an overestimation of the effective preconsolidation stress. Preconsolidation, defined by Professor Mesri, is in fact what the authors call the *apparent* preconsolidation which, in one-dimensional compression tests, corresponds to a marked increase in the slope of the compression curve at the onset of destructuration of the clay structure. The destructuration obtained from isotropic loading, unlike the destructuration generated by one-dimensional compression tests, is – as stated – more progressive and also more likely to occur in the earlier phases of loading. Consequently, the slope of the compressibility curve tends to evolve more slowly. Unlike one-dimensional compression tests, isotropic loading creates particular difficulties for apprehending a truly reasonable value for the apparent preconsolidation (see Figs 5(a) and 5(b)). This explains why the values suggested by the authors are somewhat higher.

NOTATION

e void ratio
e_0 in situ void ratio

σ'_p preconsolidation pressure measured under laterally constrained compression
σ'_{pI} preconsolidation pressure measured in compression under equal all around pressure
σ'_v effective vertical stress
σ'_{v0} effective overburden pressure

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