Bolton, M. D. & Powrie, W. (1988). *Géotechnique* **38**, No. 2, 324–325

DISCUSSION

The collapse of diaphragm walls

M. D. BOLTON and W. POWRIE (1987). *Géotechnique* **37**, No. 3, 335–353

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In fig. 17 of the Paper, the Authors show a photograph of the failed wall in Test DWC 07 together with the note: 'the presence of numerous small ruptures at angles of approximately $90-\phi'$ to the main slip surfaces is interesting'. What is also interesting is the fact that these 'numerous small ruptures' clearly emanate from the positions of the markers which are set into the clay for the purpose of recording the deformations of the model. The clay, as one might expect, given its high overconsolidation ratio, behaves in a rather brittle manner and it is likely that stress concentrations induced by the markers would facilitate the formation of rupture surfaces. If this is so, then one might also suggest that the pore pressure transducers and their associated cables will also concentrate stresses and initiate ruptures. Presumably the cables run parallel to the model wall in order to avoid reinforcing the soil; such an arrangement, however, amplifies their rupture-formation role.

What is the relevance of this to the likely mechanisms during the failure of a prototype structure in heavily overconsolidated clay with inhomogeneities such as pipes and voids? Such a clay structure, it may be surmised, will exhibit rupture along surfaces precipitated by these 'stress concentrators'.

Author's reply

The Writer raises a matter of considerable importance to research and practice. Brittle materials such as heavily overconsolidated clays are sensitive to flaws and stress raisers which can act as the seat of shear or tensile ruptures. Buried instruments and their supply lines inevitably create stress concentrations in the surrounding soil, and are often found to coincide with ruptures in post-failure investigations. Equally, of course, model testers aim to position their instrumentation as closely as possible to the future site of possible slip surfaces. The possible influence of measurement techniques on that which is to be measured—recognized in particle physics as Heisenberg's uncertainty principle—are of equal concern in every other branch of science. Such influences must be minimized and, ideally and ultimately, quantified.

The Writer points out that complementary shear bands were found to propagate through the photographic markers in Test DWC07. While concurring, the Authors suppose that these particular shear bands are not of great extent, and seem to be secondary features. Certainly, a change of geometry of the active wedge is inevitable when the primary slip surface has been activated and the wall has moved forward. It is at this very late stage, we feel, that the complementary shear bands were formed.

The Writer enquires about the possibly more serious effect of instrumentation on the primary slip surface. It is certainly necessary to minimize such effects, and this can only be achieved by running supply leads into the interior of a plain strain model along the axis of zero strain. Contrary to the suggestion of the Writer, any other arrangement would certainly lead to more severe localization effects, as well as to soil reinforcement. With regard to the quantification of any remaining localization effects, we are still some way from a convincing analysis. This is, in large part, due to the continuing inability to represent shear bands and tension cracks in soil in terms of constitutive relations. Only a small number of research workers are presently able to offer any geometrical, progressive description of shear band formation; most geotechnical analyses are still of an assumed continuum. It is, however, becoming clear that particle size, joints, stiff inclusions and voids are all likely to modify the post-peak behaviour of soils.

For this reason, the Authors stressed in the Paper that an attempted mobilization of peak strengths in excess of the critical state ($\phi_{crit} = 22°$ in the kaolin) would leave the wall vulnerable to progressive failure, which could be more severe in the field than in a relatively ideal centrifuge test. It has been repeatedly pointed out by others, that fully softened critical state parameters were those which were most relevant to first time slides in London clay slopes. It seems prudent to assume that the same should be applied to the collapse of other forms of construction, unless or until we are able to quantify the effects of stress-raisers, and show that the brittle, dilatant component of peak strength is reliable in some circumstances. This design approach is likely to lead to the suppression of soil shear bands. Separate serviceability calculations could then consistently deal with an undamaged continuum.

Finally, it must not be forgotten that two of the models were reported to have failed by hydraulic crack propagation. In our view, the possible implications of permeable layers or channels for the swift destabilization of excavations in clay are frequently unrecognized. Localized seepage may be at least as damaging as localized soil strain.