Proc. Instn Civ. Engrs, Part 2, 1974, 57, Dec., 821–823

TN 89 DISCUSSION

The use of multi-stage triaxial tests to find the undrained strength parameters of stony boulder clay

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Work performed on the Cheshire boulder clays has suggested that their sensitivity is of the order of one—a figure frequently assumed to apply to most boulder clays. The variation in strength of the three 38 mm dia. specimens may therefore be due to factors other than damage to the specimen caused by stones hitting the cutting edge. These include the ratio of stone size and quantity to sample cross-sectional area and lateral variations in stone size and quantity within the U4 tube.

22. The cross-sectional area of a 100 mm dia. specimen is seven times greater than that of a 38 mm dia. specimen and the volume of a 100 mm dia. × 200 mm long specimen is nineteen times greater than that of a 38 mm dia. × 76 mm long specimen. The consequence of this is that a stone having a significant effect on the result of a 38 mm dia. triaxial test will possibly have only 5–10% of that effect on the result of a 100 mm dia. test. It would be difficult to generalize because it is not only the ratio of stone size to specimen which is important, but also the potential interaction of that stone with other stones and the clay matrix. The Author has stressed the importance of cutting and splitting a specimen of stony boulder clay after testing to ensure that it does not contain any particles that are large compared with the size of the specimen. What criteria did he adopt in this respect and what adjustment of the results (other than complete rejection) does he advocate when excessively large particles are found?

23. The effect of soil fabric is also relevant in the case of the Cheshire boulder clays which have a labyrinthine fabric. The presence of this fabric in small specimens may well give rise to a very low peak strength and specimens lacking a portion of the fabric may well yield a higher peak strength. It is thus possible to obtain three specimens from one U4 tube, each containing differing proportions of the fabric, which will yield three Mohr circles which are virtually useless. This potential danger would be reduced using 100 mm dia. specimens.

24. When the possible reasons for variations in the strength of three 38 mm dia. triaxial specimens, tested at different pressures, are considered in relation to 100 mm dia. specimens it is apparent that these comments remain applicable to a reduced degree. This would explain why the Author found that triaxial tests on three 100 mm dia. samples gave more rational Mohr circles but still did not allow a unique Mohr–Coulomb failure envelope to be drawn. The conclusion to be drawn is that, although 100 mm dia. multi-stage testing may well yield a unique Mohr–Coulomb envelope,

Paper published: *Proc. Instn Civ. Engrs*, Part 2, 1974, 57, June, 367–372.

the parameters C_u and ϕ_u obtained are unique only for the particular sample tested and must not be construed as being any more representative of the soil mass than the sample itself.

25. Not withstanding the overall difficulties of applying the shear strength parameters obtained, we have found that 100 mm dia. multi-stage testing has many advantages over the testing of three 38 mm dia. specimens. In addition specimens are less susceptible to drying out during handling (by a factor of 7–19), six times the volume of soil is tested for perhaps little extra cost, damage to the specimens due to cutting is less than when a second cutting stage is necessary and there is less likelihood of an operator taking intact clay sections in between fissures with a 200 mm long specimen than with a 76 mm long specimen. The consequences of this last action are that a test on an intact 38 mm dia. specimen would yield a higher shear strength value than a test performed on a 100 mm dia. specimen containing a fissure. We have also found that it is frequently impossible to prepare even two acceptable 38 mm dia. specimens from a U4 tube.

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Messrs Booth, Forde and Edge have suggested that, because the sensitivity of boulder clays is generally accepted to be of the order of unity, the variations of strength found from 38 mm dia. specimens were more likely to be due to excessive stone content than to sample disturbance. Sensitivity is usually regarded as a measure of the loss of strength due to the breakdown of the microstructure of the soil and is defined as the ratio of the undisturbed shear strength to the remoulded shear strength. The disturbance to the 38 mm dia. specimens during sampling and preparation was not so much a remoulding of the soil giving rise to a rearrangement of the particles in the matrix, but a larger scale disturbance which gave rise to cracks, holes and gouges in the sample, i.e. there were distinct visible signs of disturbance. The 100 mm dia. specimens were found to have fewer visible signs of this type of disturbance than the 38 mm dia. specimens. Also the effect of this type of disturbance is likely to be less, the larger the specimen size. For example, a surface indentation say 10 mm deep will have much more effect on the measured strength of a 38 mm dia. specimen than that of a 100 mm dia. specimen. Thus while the variability of measured strengths of 38 mm dia. specimens was most probably due to sample disturbance, the smaller variation in strength found with larger samples may have been due to the stone content.

27. After the 100 mm dia. specimens were tested they were cut and split to see if any stones in them appeared to be large compared with the specimen size. This was not a quantitative examination as this would have been quite complicated and have involved measurement, not only of the stone size but also its position within the specimen and its orientation with respect to the principal stresses. If in my judgement a stone appeared likely to have given the specimen a measured strength which was probably unrepresentative then the results were rejected. No attempt was made to adjust the results in these cases. It should be stressed that only occasionally was it felt necessary to reject specimens because of oversize stones.

28. The contributors have rightly pointed out that the shear strength parameters measured in a single multi-stage test are unique for that specimen only. I did not intend to give the impression that only one test was required to get unique shear strength parameters for the soil mass. Sufficient multi-stage tests have to be carried out on single specimens to give a representative number of values of undrained shear strength parameters.

29. The contributors have reiterated some of the advantages of testing 100 mm dia. specimens and have pointed out the difficulty of obtaining 38 mm dia. specimens of boulder clay from a U4 tube. Sample recovery of boulder clay in U4 tubes is poor.[6] It is therefore essential to obtain the maximum reliable information from the minimum quantity of sampled material. This may be achieved by multi-stage testing

of single specimens, 100 mm high and 100 mm in diameter, using lubricated end platens which give more uniform stress conditions within the specimen than the conventional fixed end tests.[7]

References

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7. Anderson W. F. Factors influencing the measured properties of Glasgow region till. *Ground Engng*, 1974, **7**, Mar., No. 2, 20–27.