Screw Plate Insertion Disturbance in Clay

P.T. BROWN
B.Sc., B.E., Ph.D., M.I.E.Aust
Research Associate, University of Sydney
M.F. ABDEL-LATIF
B.Sc., M.Eng.Sc.
Post Graduate Student, University of Sydney

SUMMARY Laboratory tests in clay using an embedded flat plate and screw plate, and a screw plate inserted under the control of a threaded rod having the same pitch as the screw plate are described. The values of Young's modulus and coefficient of consolidation obtained from these tests are compared in order to estimate the effects of insertion disturbance on the results.

1. INTRODUCTION

The flat plate loading test has long been a popular method for in-situ determination of soil compressibility, but this form of test has two disadvantages. Firstly there are difficulties in obtaining perfect contact between the plate and the soil. Secondly, when it is necessary to determine soil properties at a depth greater than the diameter of the plate, the test must be carried out at the bottom of a borehole, and the soil immediately beneath the plate will have undergone complete vertical stress relief due to the excavation of the borehole. This stress relief can only be approximately reversed by pre-loading the plate since the unloading is uniform, but the loading due to the rigid plate is small at the centre and very large at the edges.

The screw plate test provides a means of carrying out a similar compressibility test, while avoiding these two disadvantages of the flat plate. This test is carried out with a helical plate inserted into the soil by rotation. If the progress of the screw plate is controlled by means of a threaded rod whose pitch is the same as the pitch of the screw plate, the contact between the soil and the plate will be excellent, although there may be some pressure increase beneath the plate during insertion. However if the screw plate is permitted to enter the clay at a smaller rate of entry per revolution than its pitch, good contact between the plate and soil appears unlikely, and the resulting values of modulus at small loads will be too low.

If the screw plate is inserted to a depth of one hole diameter below the bottom of the borehole, the soil beneath the screw plate will have undergone virtually no stress relief, although the cylinder of soil above the screw plate will have been sliced during the insertion process. However with plastic clays there appears to a considerable rejoining at these cuts.

The purpose of the series of tests described in this paper was to obtain an indication of the effect of the screw plate insertion disturbance on values obtained for undrained modulus, drained modulus and coefficient of consolidation in kaolin with over-consolidation ratios of 5 and 10, by comparison with values obtained from tests using an embedded flat plate.

2. DESCRIPTION OF TESTS

A series of laboratory tests were carried out in kaolin consolidated from a slurry in a container 300 mm diameter, similar to that described by Poulos et al (1976) and shown in Fig.1. The resulting clay bed was 86 mm deep and tests were carried out with 30 mm diameter plates on 6 mm diameter shafts at a depth of 43 mm. Although the kaolin was relatively permeable, the reduction in permeability caused by the increase in effective stress at the top and bottom boundaries, from which drainage occurred, caused a slowing of consolidation such that about a month was required to obtain full consolidation at the centre of the container. Consolidation was monitored by plotting the amount of water expelled from the clay against log time.

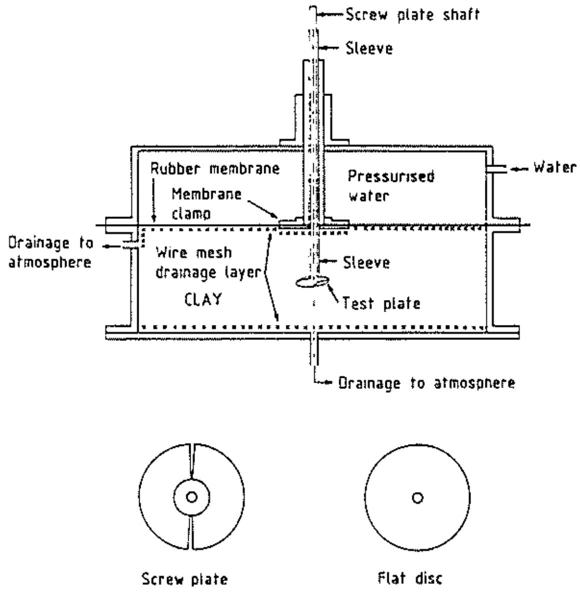

Figure 1. The laboratory test equipment

Tests were carried out with a flat disc and a screw plate, both of which were embedded in the slurry prior to consolidation, and with a screw plate which was inserted by rotation from the clay surface after consolidation was complete. The entry rate of the inserted screw plate was controlled by a threaded rod whose pitch was the same as that of the screw plate, in order to ensure good contact between the soil and the plate. These types of test were chosen so that the effect of screw plate shape could be assessed by comparison of the values of modulus from the buried disc and buried screw plate tests. Also the effect of insertion disturbance could be assessed by comparison of the values of modulus from the buried and inserted screw plate tests.

The first series of tests was carried out in kaolin with an over-consolidation ratio of 5, obtained by consolidation at 250 kPa, followed by unloading to 50 kPa, and the second series of tests was carried out with an over-consolidation ratio of 10, by consolidating at 400 kPa and unloading to 40 kPa.

Each test consisted of application of an increment of dead loading which was maintained until consolidation appeared to be almost complete. In the case of the inserted screw plate, there was a time delay of at least 20 minutes between completing insertion and application of the first load increment, so that all excess pore pressures generated by the insertion process should have dissipated before the start of the modulus test.

Values of displacement of the plates were measured by means of a displacement transducer and recorded in a computer at intervals of about 0.2 seconds initially. increasing to intervals of about 100 seconds at the end of a test lasting 20 minutes. In many cases, a second load increment was applied, which gave similar results to those from the first load increment. The load increments used were 1 to 2 Kg in order to ensure that the soil behaviour was as close to elastic as possible, however the resulting immediate settlements were typically only about 0.003 mm, which may have led to some inaccuracies in displacement measurement.

The first stage of interpretation of the results consisted of trial and error selection of three parameters, namely immediate settlement reading, total final settlement reading and time factor ($F=c_v/a^2$) for conversion of measured time (t) to the dimensionless time factor ($T=c_vt/a^2$). The values of these parameters were then used to convert the readings into values of degree of settlement (U) and dimensionless time factor (T), which were plotted on a computer screen for comparison with the corresponding theoretical values given by Small and Booker (1987) for a rigid disc embedded in a deep soil layer.

The second stage of the interpretation was conversion of the values of immediate and total final settlement to values of Young's modulus for a very deep soil layer, using an assumed value of drained Poisson's ratio of 0.3. In the case of the disc, the equation used is that given by Selvadurai (1979), and included in Selvadurai and Nicholas (1979), for a fully bonded embedded disc of finite stiffness subject to a uniform load over a zone at the centre of the plate. In the case of the screw plates, values of modulus were obtained from curves produced by finite element analysis of bending of the screw plate (Brown, 1991). Finally the values of modulus were corrected for proximity of the boundaries using results from finite element analysis of a stiff embedded plate.

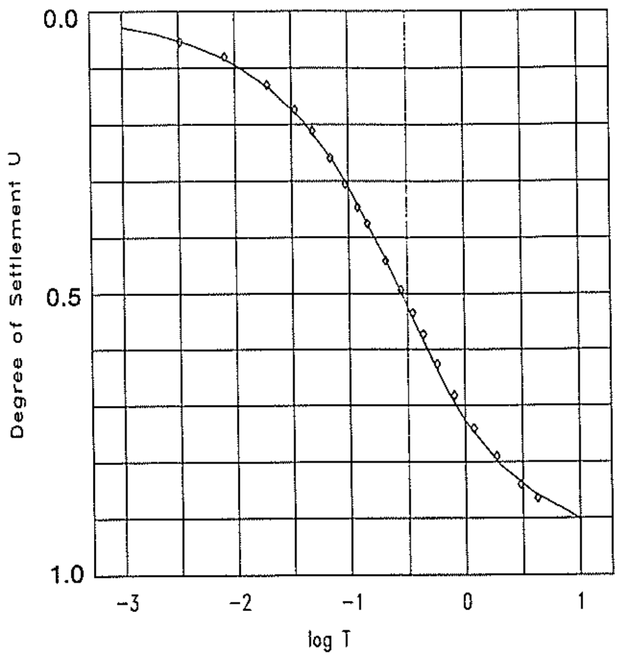

Figure 2. Settlement-time curve for well-consolidated clay

Values of c_v were obtained from the values of $F=c_v/a^2$ where a is the radius of the plate.

A typical successful screw plate test curve is shown in Fig. 2, with the theoretical curve to which it was fitted. When the clay at the centre of the container was not fully consolidated, the subsequent test showed settlement behaviour similar to that for a normally consolidated clay as shown in Fig 3.

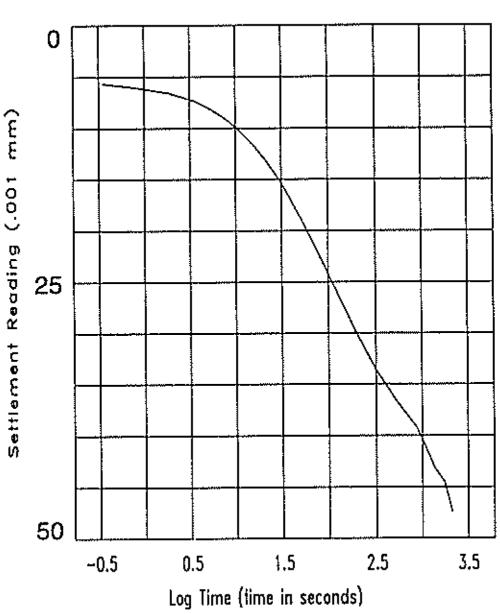

Figure 3. Settlement-time curve for incomplete consolidation

3. TEST RESULTS

The values of modulus and coefficient of consolidation obtained from the tests are shown in Table I. No allowance was made for the proximity of the top, bottom and side boundaries in the calculation of coefficient of consolidation, since in this case it is likely to have an insignificant effect, due to the fact that the dissipation of excess pore pressure is from the zone of positive pressure beneath the plate to the zone of negative pressure above the plate, and little of this dissipation occurs far from the plate.

It will be seen that there is considerable scatter in the results, but nevertheless it seems possible to draw some useful conclusions. While the values of undrained and drained modulus for the disc at OCR=5 are larger than those for the screw plate, the difference is probably not statistically significant due to the small number of values available, and hence it appears that the insertion disturbance of the screw plate is of no more than limited importance. For OCR=5, the values of c_v are somewhat larger for the disc than for the screw plate, whereas one would expect that if the two slots at the cutting edges of the screw plate had any effect it would be to increase the apparent c_v, so we can assume that the slots have no significant effect on the rate of consolidation.

When OCR=10, comparison of the values of undrained modulus from the two forms of screw plate test suggest that there may be a significant effect due to insertion disturbance. However the values of drained modulus and c_v are so much larger in the case of the inserted screw plate that it appears probable that there is a significant difference caused by insertion disturbance.

Since the change in modulus is an increase, it is unlikely to have been caused by the slicing of the clay above the screw plate.

Field testing experience shows that the penetration of the cutting edges of the screw plate causes a pressure increase immediately below the screw plate, and this is likely to be greater for the stiffer clay having OCR=10 than the more compressible clay with OCR=5. If we suppose that for OCR=10 the pressure beneath the screw plate reached 600 kPa compared with the previous consolidation pressure of 400 kPa, when this pressure was released prior to commencement of the modulus test, the OCR would have increased to 15, which could be the cause of the apparent changes in E' and c_v.

TABLE I

TEST RESULTS

Test type	Test Number	Over-Consolidation Ratio	Undrained Young's Modulus MPa	Drained Young's Modulus MPa	Coefficient of Consolidation mm^2/min
Flat disc buried	1	5	90	19	121
	2		90	38	176
	3		59	9	74
	4		56	24	200
Screw plate buried	5	5	51	8.0	68
	6		22	8.1	108
	7		42	9.0	81
	8		39	7.5	119
Screw plate inserted	9	5	59	12.1	68
	10		33	10.8	94
	11		33	9.1	162
	12		55	11.0	95
	13		49	8.8	61
Flat disc buried	14	10	89	15.2	81
	15		49	13.4	53
Screw plate buried	16	10	38	10.2	108
	17		31	4.7	63
Screw plate inserted	18	10	59	33	405
	19		72	46	1188
	20		54	46	256
Oedometer	21	5	-	-	109
	22	10	-	-	87

Values of c_v obtained from oedometer tests on 25 mm thick specimens of the same kaolin as used for the tests described above, are 109 mm^2/min for OCR=5, and 87 mm_2/min for OCR=10. The specimens were compressed to this length during pre-consolidation and were not cut to this length, thus avoiding smearing of the ends. These results provide some confirmation of the conclusion that the values of c_v for OCR=5 have not been significantly affected by the insertion, but that for OCR=10 the effect of insertion is significant.

4. CONCLUSIONS

Tests giving values of Young's modulus and coefficient of consolidation for clay, using embedded flat plates and screw plates, and inserted screw plates have been described and compared.

Despite scatter in the results, it appears that screw plate insertion has little effect on the results when OCR=5, but that the effects are significant when OCR=10.

It seems likely that the increase in OCR from 5 to 10 has caused the pressure increase beneath the screw plate during insertion to become very much higher and so cause a further increase in over-consolidation ratio, thus increasing values of modulus and c_v.

This effect could probably be avoided by allowing the screw plate to enter the soil free of control by the threaded rod until near the desired test depth, and engaging the threaded rod only for the final revolution so as to ensure good contact with the soil.

5. REFERENCES

Brown, P.T. (1991). The Bending of a Screw Plate, submitted to ASTM Geotechnical Testing Journal.

Poulos, H.G., de Ambrosis, L.P. and Davis, E.H. (1976). Method of Calculating Long-Term Creep Settlements. Journal of Geotechnical Engineering Division, A.S.C.E., Vol. 102, No. GT7, pp. 787-804.

Selvadurai, A.P.S. (1979). An Energy Estimate of the Flexural Behaviour of a circular Foundation Embedded in an Isotropic Elastic Medium, International Journal for Numerical and Analytical Methods in Geomechanics, Vol.3, pp. 285-300.

Selvadurai, A.P.S. and Nicholas, T.J. (1979). A Theoretical Assessment of the Screw Plate Test. Proceedings of the Third International Conference on Numerical Methods in Geomechanics, Aachen, pp.1245-1252.

Small, J.C. and Booker, J.R. (1987). The Time-Deflection Behaviour of a Rigid Under-Reamed Anchor in a Deep Clay Layer, International Journal for Numerical and Analytical Methods in Geomechanics, Vol. 11, pp. 269-281.