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Recent Developments in Screw Plate Testing in Adelaide

J.N. KAY and G.W. NICHOLS
University of Adelaide, South Australia
and
P.W. MITCHELL and D.L. AVALLE
Pak-Poy & Kneebone Pty. Ltd., South Australia

SUMMARY Extensive use has been made of the screw plate test in the Adelaide area in recent years for measurement of strength and settlement parameters. Most of the testing has been in stiff clays but similarly useful results have been obtained in soft clays and sands. The screw plate test has been found to be particularly valuable when used in conjunction with the electrical cone penetrometer. The combination of the two has the potential for producing extensive high quality design information at low cost. Two case studies are reported to demonstrate the recent developments.

1 INTRODUCTION

The screw plate load test, used mainly in granular soils in Europe (Janbu and Senneset, 1977) and to some extent in the United States (Schmertmann 1970), was appplied to stiff clay by two of the authors in Adelaide in 1978 (Kay and Mitchell, 1980). Three dimensional consolidation theory was used to interpret drained tests (Kay and Avalle, 1982) and further favourable comparisons were made with triaxial tests and self-boring pressuremeter tests for the Gault clay near Cambridge, England (Kay and Parry, 1982). Since 1982, a considerable amount of commercial testing has been done in the Adelaide area using the screw plate particularly in conjunction with the electrical cone penetration test and the combination has proved to be highly successful. This paper describes the development and application of a trailer mounted unit that conveniently combines the two tests.

In addition, two case studies are discussed, one in which predictions made from screw plate tests are compared with measured settlements and a second in which the use of the cone penetrometer supplemented by screw plate tests leads to considerable cost savings in the final design.

2 DEVELOPMENTS IN TEST EQUIPMENT AND PROCEDURES

2.1 Combined Cone Penetrometer and Screw Plate Test Unit

A test unit that combines facilities for electrical cone penetration testing, screw plate testing, and boring and sampling has been constructed and used extensively by the University of Adelaide since January 1982. The end view of the trailer mounted system is shown in Figure 1. The rear end of the 1.7 t capacity trailer supports a main frame that, for testing, is anchored to the ground at four corners. An upper frame that supports a hydraulic cylinder can readily be moved laterally on the main frame; it can be set at the centre of anchor support for maximum reaction for cone penetration tests then moved to a point 0.8 m away for boring, screw plate tests and sampling as required.

The combination of an electrical cone penetration test with a screw plate test in close proximity has proven to be highly successful in a number of ways. The cone resistance q_c has been shown to have a high correlation with undrained shear strength, c_u for Gault clay in England (see Figure 2 after Kay and Parry, 1982) and the same is proving to be the case in Adelaide. In the relationship where

$$q_c = N_c c_u + \sigma_{vo} \quad (1)$$

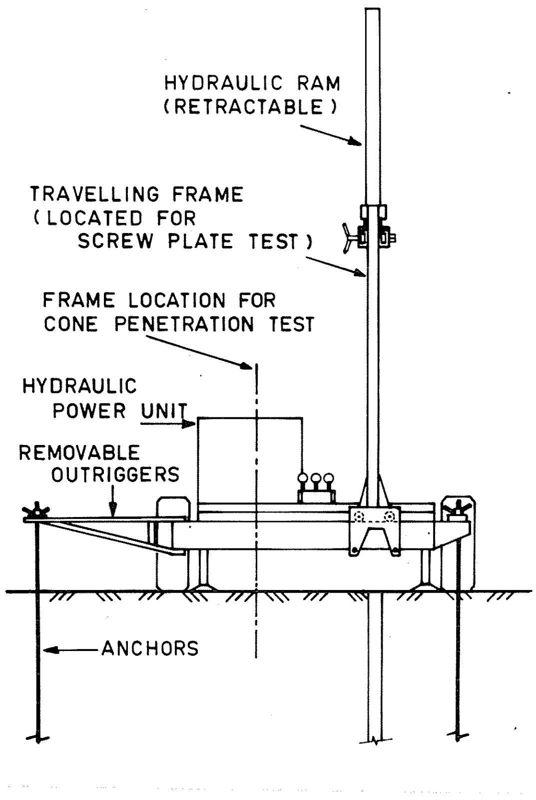

Figure 1 Trailer mounted test unit.

σ_{vo} is the overburden stress, the coefficient N_c was found to be 20 for the Gault clay and 11 to

13 for clays in the Adelaide area. In addition, the friction ratio from the cone has proved to be a good indicator of soil type according to the procedure recommended by Searle (1979). An initial cone test provides ideal guidance for depth and type of screw plate test and also, where appropriate, the required magnitude of load increment for the drained component of the test.

Of particular significance is the fact that the screw plate may be used to calibrate the cone penetrometer on a site-by-site basis. Proposals have been made for correlations between soil stiffness and cone tip resistance but it is likely that for most soils such correlations are only valuable in specific strata at given localities (Ladd et al., 1977). Relatively few screw plate tests are needed on a site to determine, for example, E'/q_c ratios (where E' is the drained Young's modulus) for general interpretation of the cone results. Such a procedure is illustrated in Figure 7 under the "Case Studies" section of this paper.

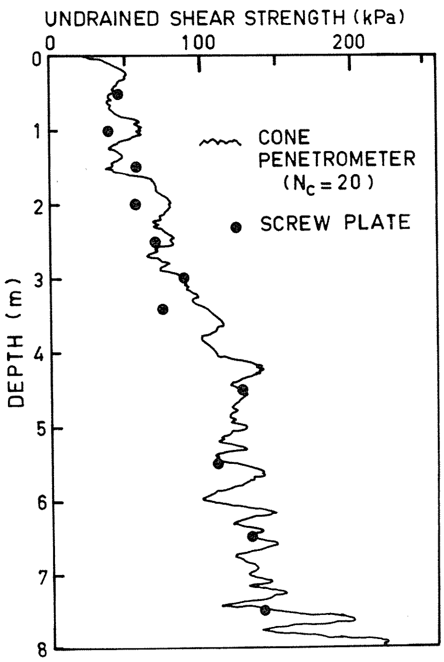

Figure 2 Comparison of cone resistance with undrained strength from screw plate test.

2.2 Tests in Sand Soils

It has become evident that earlier proposals for general relationships between E' and q_c for sands of the form $E'/q_c = 2$ (Schmertmann 1970) should be restricted to normally consolidated sands. Tests by Chapman and Donald (1983) have indicated constrained modulus, M_s, values in a sand tank to be 3 to 15 times the cone tip resistance. Screw plate tests by the authors in Adelaide have shown $E'/q_c = 12$ at Glenelg and $E'/q_c = 5$ at North Haven both in coastal sands. A typical load versus deflection graph for 2.5 m depth at the North Haven site is shown in Figure 3.

For tests in sandy soils where caving of the borehole is likely, a drilling mud circulation system has been incorporated in the test unit. A small axial flow pump circulates a water-bentonite slurry through a water swivel in a rotary drilling arrangement. The slurry carries the displaced soil from the bottom of the borehole to the surface for discharge into a settlement tank. In the tank the coarse grained soils settle out and the overflow is recirculated. When the desired test depth is reached the screw plate is lowered through the bentonite slurry to the bottom of the borehole and screwed ahead about 100 mm for the start of the test as for clay soils.

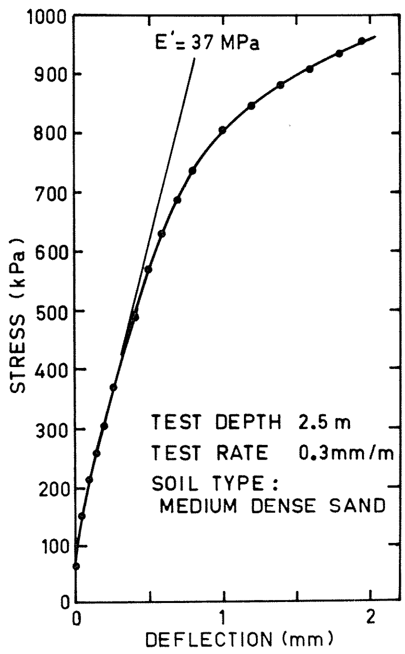

Figure 3 Screw plate test in sand at North Haven

For the determination of Young's modulus, E', for sand a controlled rate of deflection of D/300 mm/min is used where D is the plate diameter in millimeters. E' is computed from

$$E' = 0.42D\Delta\sigma/\Delta\rho \qquad (2)$$

where $\Delta\sigma/\Delta\rho$ is the slope of the stress-deflection graph. This is similar to the relationship used for determination of the drained modulus for clay soils (Kay and Parry, 1982).

The test combination appears to be valuable for a wide range of conditions but it is particularly valuable for cases where some doubt exists in the decision between raft or piled foundations in sand soils. When test procedures are crude there is a natural preference for the more conservative piled foundation in spite of considerably higher costs. Results from the cone penetrometer and screw plate test combination may well provide data that confirm the suitability of a raft design for circumstances where, using conventional methods a more costly piled foundation is indicated.

A point of caution should be noted that is relevant whenever a new method is used that permits some improvement in design procedures. Elements of risk may exist that, although not previously considered in an explicit manner, may be implicitly covered by a larger safety margin. This is applicable to structures founded on sand where a potential for liquefaction due to earthquake loading exists. In conjunction with use of an improved method for static analysis it may be important to separately consider the potential for liquefaction.

3 CASE STUDIES

Two projects have been completed where screw plate tests were used for determination of drained soil modulus. In the first, a 12 storey bank building in the City of Adelaide, a comparison is made between settlement prediction and results of a carefully conducted measurement program. The second involves the exploration and settlement prediction for a grain silo at Tarlee S.A. where the results have a dramatic effect on type and cost of foundations.

3.1 Savings Bank Project

A cross section of the Savings Bank building is shown in Figure 4. The building was constructed

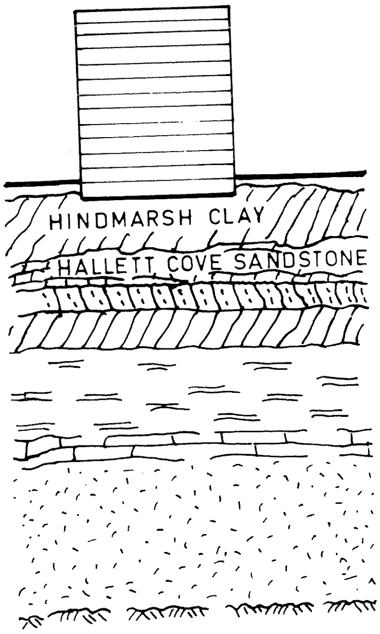

Figure 4 Geologic profile at Savings Bank site

on a 39.5 m x 33.5 m x 0.9 m thick raft foundation. The generalized soil conditions were 10 m of stiff clay overlying a predominantly rock stratum known locally as the Hallet Cove Sandstone. Three screw plate tests in the clay indicated drained Young's modulus (E') values of 45 MPa, 69 MPa and 45 MPa at depths of 1 m, 3 m and 6.1 m, respectively, below the raft-soil interface (Figure 5). Compression of the clay stratum due to the building load was predicted to be 20 mm based on an average E' value of 55 MPa.

A borehole extensometer was installed near the centre of the raft and measurements of compression in the clay stratum have been taken since the start of construction. Results are indicated in Figure 6. The total compression over 9 m of clay thickness is 15 mm and since this implies about 17 mm over the 10 metre thickness, the agreement with predictions is excellent. A more detailed description of this study appears in a paper by the first author and Cavagnaro (Kay and Cavagnaro, 1983).

3.2 Grain Silo Foundation Design

The foundation design project for a grain storage silo at Tarlee S.A. by Pak Poy and Kneebone Pty. Ltd. for South Australian Bulk Handling Ltd.

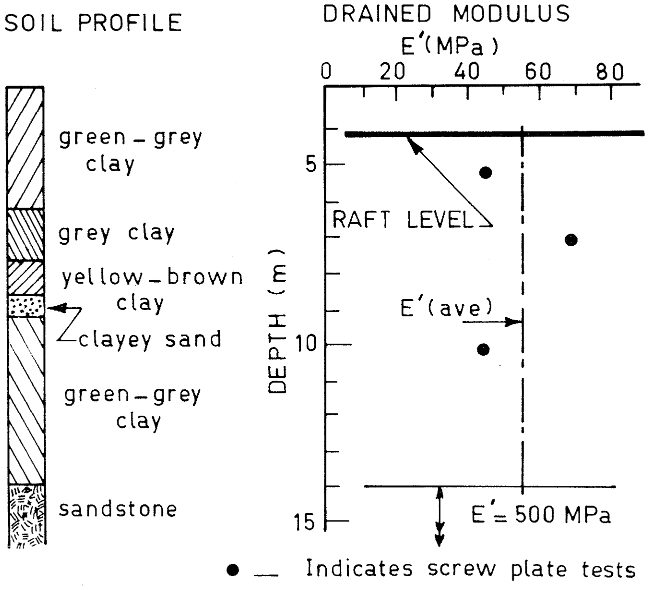

Figure 5 Soil profile and screw plate moduli at Savings Bank site

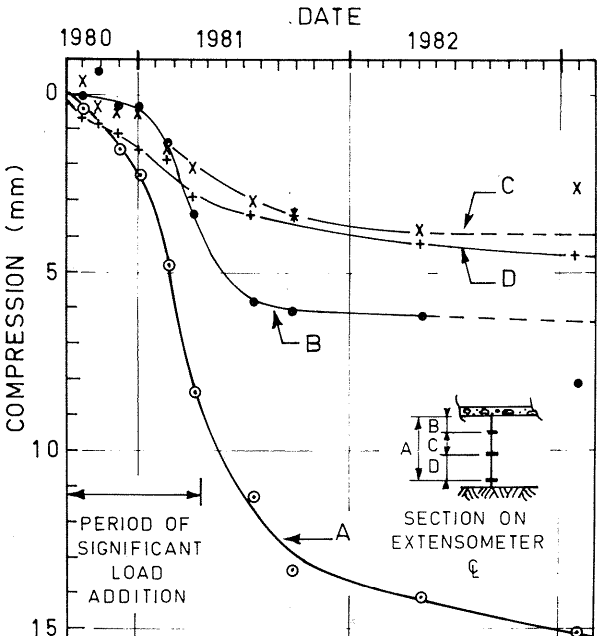

Figure 6 Measured compressions at Savings Bank site.

demonstrates the value of the combination of the electrical cone penetrometer and the screw plate test. Figure 7 shows a summary of cone tip resistance, q_c, three drained Young's modulus, E', values, the computed E'/q_c ratios and the implied design E' values for three distinct strata to a depth of 9.5 m. Unfortunately, the cone test did not extend to a sufficient depth to satisfy requirements for settlement computations. Standard penetration tests, pocket penetrometer results and visual interpretation from an adjacent borehole were used as an indication of E' at greater depths. Estimates were made of E' = 30 MPa from 9.5 m to 16.5 m depth and E' = 150 MPa from 16.5 m to 38 m.

Using a method proposed by the first author (Kay and Cavagnaro, 1983) for layered systems the central settlement was predicted as 52 mm and the differential settlement as 24 mm. A realistic expectation of differential settlement based on these results would be 15 to 30 mm, a range acceptable for this application. An earlier analysis based on standard penetration test N values ranging from 8 to 20 resulted in a recommendation for pile foundations. The cost difference in favour of the raft foundation is estimated to be $200,000.

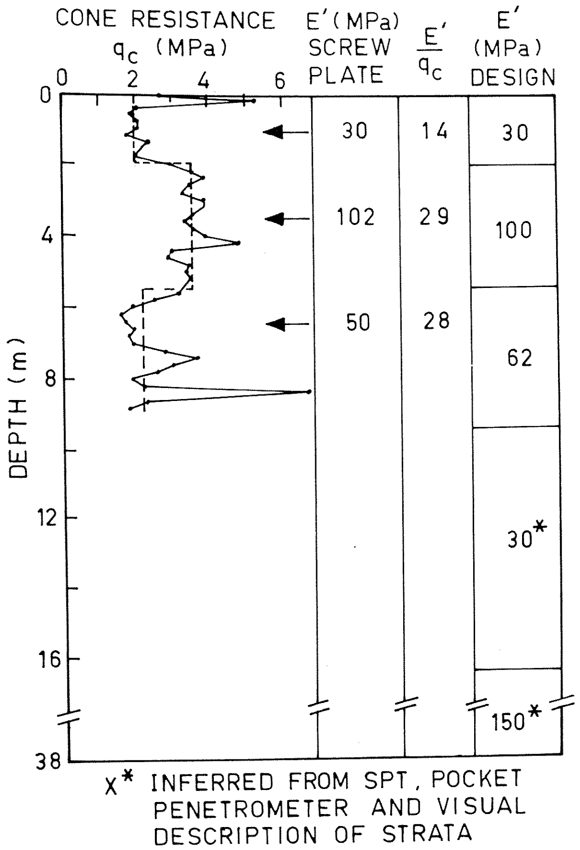

Figure 7 Cone resistance, screw plate moduli and inferred modulus profile for Tarlee site

It is anticipated that a field measurement program will be conducted to evaluate the predictions.

4 CONCLUSION

The screw plate load test has become firmly established as a valuable field test procedure in the Adelaide area and, particularly in conjunction with the electrical cone penetrometer, it appears to offer an economical means for obtaining extensive high quality data on strength and stiffness properties for a wide range of soil types.

Results from a case study of a raft on a stiff clay layer, where measured and predicted settlements are compared, support earlier evidence of the value of the measured properties. A second case study demonstrates the potential that now exists for considerable cost savings when the more recently developed field testing techniques are used.

5 REFERENCES

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