Screw plate and cone penetrometer as a field testing system

Plat à pas de vis et pénétromètre de cône utilisés au chantier

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SYNOPSIS The screw plate test has been found to be useful for establishing drained and undrained strength and compressibility parameters for soils. This paper outlines results of correlations between the screw plate test and the cone penetrometer in a variety of soil types in South Australia. The results have indicated that, in general, the level of reliability associated with ratios such as E/q_c is low for both drained and undrained conditions. It is suggested that the cone may be used to great advantage in parallel with the screw plate to establish on-site correlations. Once established from relatively few screw plate tests these correlations may be extended throughout the site using a wider program of cone penetration tests.

INTRODUCTION

The screw plate test has been shown to be an appropriate insitu test for the direct determination of soil strength and settlement parameters (Janbu & Senneset, 1973; Kay and Avalle, 1982; Kay and Parry, 1982). The test consists of the measurement of the load versus settlement and settlement versus time behaviour of a plate screwed into the natural soil with a minimum of disturbance at any desired depth in conjunction with a prebored hole. The test has the advantages that the original stress field is little altered, the test orientation is appropriate for most design problems and the strength and settlement parameters for both drained and undrained conditions can be obtained.

The authors have used the device in routine site investigations for many commercial projects since 1977. Typical rates of testing of 3 undrained and 2 drained tests per day have been obtained with a two-man team.

A recently constructed test unit (Kay et al, 1984) has provided for a cone penetrometer test at a distance of 800 mm from the screw plate test borehole. This allows a direct comparison between cone resistance, q_c, and the results obtained from the screw plate test. Because the screw plate test gives what is believed to be a reliable measure of strength and settlement parameters, it can be used to check the often controversial correlations required to interpret cone penetration test results.

This paper investigates correlations between cone penetrometer and screw plate results from tests on a range of soil profiles in South Australia.

TEST DETAILS

Results are reported from 12 sites in the Adelaide and South Australian country area. Data from 5 sand sites are reported in Table I. Data from 3 sites where highly plastic over-consolidated clays occurred are reported in Table II and 4 cases of silty and sandy clays are reported in Table III.

TABLE I

Sands

Site	Depth	Cone Penetrometer		Screw Plate	$\frac{E}{q_c}$
	(m)	q_c (MPa)	F_r (%)	E (MPa)	
North Haven	2.5	7.0	0.9	37	5.3
Glenelg North	2.5	1.5	0.8	34	23
	5.0	1.0	1.7	13	13
Port Lincoln	3.3	9.1		42	4.6
	6.4	5.5		33	6.0
	6.4*	6.0		33	5.5
Port Adelaide (SACBH)	2.1	1.6	0.4	18	11.3
	3.0	9.2	1.6	27	2.9
Port Adelaide (AWF)	2.5	1.8	0.7	35	20
	5.0	0.5	1.0	52	104

* Indicates test in different borehole

DISCUSSION OF RESULTS

Sand Soils

The results from Table I have been plotted as shown in Fig. 1. They suggest that higher values of E/q_c are appropriate at low q_c values, and lower values of E/q_c at higher q_c.

TABLE II

Plastic Clays

	Depth (m)	Cone Penetrometer		Screw Plate			E_u/q_c	E'/q_c	$(q_c - \sigma_o)/c_u$
		q_c (MPa)	F_r (%)	E_u (MPa)	E' (MPa)	c_u (MPa)			
Aquatic Centre	2.0	1.15	10	28		81	24		14
	4.1	1.5	6.0	40	31	103	27	21	14
	2.0*	1.6	8.1	36		117	23		13
Tarlee	1.0	1.8	7.0	52		100	29		18
	3.5	3.5	8.6	116	102	250	33	29	14
Port Augusta	8.2	2.6		53	38	198	20	15	12

* Indicates test in different borehole

TABLE III

Silty and Sandy Clays

	Depth (m)	Cone Penetrometer		Screw Plate			E_u/q_c	E'/q_c	$(q_c - \sigma_o)/c_u$
		q_c (MPa)	F_r (%)	E_u (MPa)	E' (MPa)	c_u (MPa)			
Adelaide Station Bore 5	4.4	4.3	3.3	52	47		12	11	
	5.8	0.9	3.6	76			84		
	9.7	1.5	3.4	42	16		28	11	
Adelaide Station Bore 7	4.5	1.4	1.9	89		67	64		20
	5.0	1.3	1.2	72		57	55		21
	5.4	0.9	1.5	89		69	99		12
	6.0	1.6	1.5	86		58	54		26
Regency Park	2.6	0.8		26	11		33	14	16
	3.6	1.0		43	18		43	18	13
St. Peters Bridges	4.3	1.5	3.7	23		55	15		26
	4.5	6.0	4.5	84	38	232	14	6.3	26

However, considerable scatter exists and it is obvious that there is no unique E/q_c value.

The reason for higher values of E/q_c at lower values of q_c may be explained on the basis that the sands tested are, in their natural state, cemented to some extent. The cone resistance, q_c, is more closely associated with sand density because it is primarily a measure of ultimate shear failure, and is influenced by cementation effects only to a minor extent. On the other hand, at low stress levels the sand modulus measured in the working stress range may be influenced much more by cementation effects. Therefore, at low densities, cementation controls the modulus result and may produce a much higher value than would be expected on the basis of soil density. This could explain both the higher magnitude and the greater variability of E/q_c at low q_c values.

The vital question for design is whether the cementing action can be relied upon to restrict settlement on a long term basis. This question is particularly important in zones of high seismic activity. There is also the possibility that the cementing materials are soluble and that a future collapse of the soil structure may occur due to ground water effects.

Highly Plastic Overconsolidated Clays

Undrained tests from various depths at the three sites indicated E_u/q_c values from 20 to

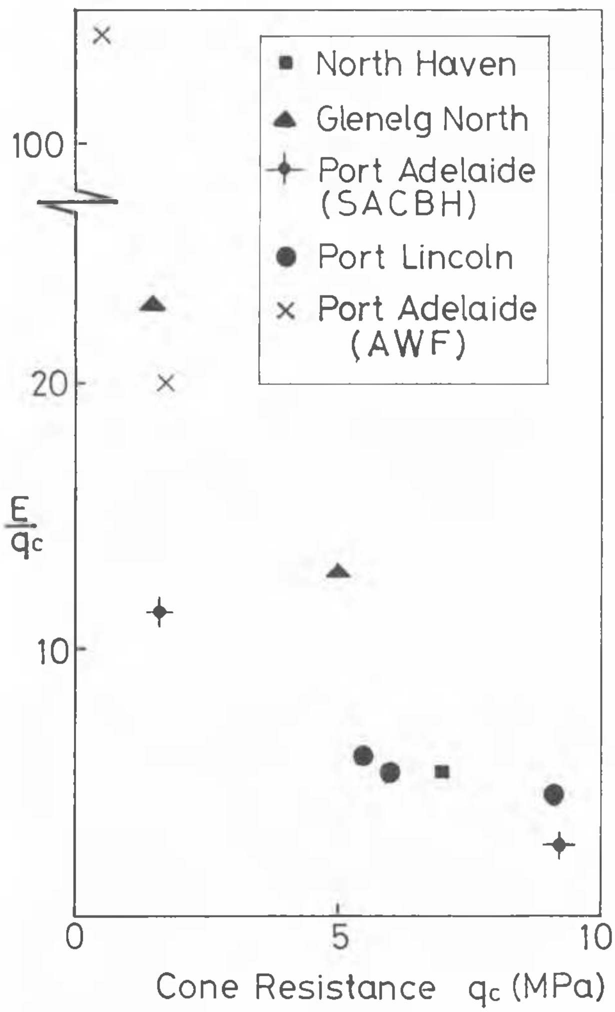

Figure 1: Observed Relation between E/q_c and q_c for Sand Soils.

33 while drained tests indicated E'/q_c values from 15 to 29. From these limited results the cone penetrometer appears to be an unreliable predictor of both the drained and undrained modulus.

On the other hand, the ratio $(q_c - \sigma_o)/c_u$ appears to be consistently within the range 12 to 14 for these South Australian soils except for a near surface test at Tarlee. It may be noted that, although the ratio itself was different, similar repeatability was observed for Gault clay by Kay and Parry (1982).

Silty and Sandy Soils

All of the soils in this group exhibited at least one of three significant anomalies: (i) the E/q_c ratio was inordinately high, (ii) the friction ratio from the cone penetration test was considerably lower than would be expected for silty and sandy clays, and (iii) the ratio of drained modulus to undrained modulus was lower than would be expected. It is notable that all tests in this group were carried out above the water table.

In the Adelaide area problems have been experienced with collapsing soils; in some cases the soils were sands and in others they were aggregated clays. It is likely that all three of the soils tested in this group were collapsing soils of the latter type. Obviously the cone penetrometer is of little use for prediction of a settlement design parameter for these cases. On the other hand, particularly where friction ratio values less than about 2 percent are obtained for soils that are known to be clay soils, the result serves as a warning for the need for further investigation of the potential for collapsing soil problems.

CONCLUSION

A detailed investigation of the relationship between cone resistance and soil parameters from the screw plate test has found considerable scatter and suggests that, at best, such correlations are uncertain. The variation in the E/q_c ratio is very pronounced for low values of q_c for all soils tested. This is the case for both the drained and undrained values of modulus. The ratio $(q_c - \sigma_o)/c_u$ was found to be relatively consistent for the highly plastic over consolidated clays.

The poor correlations for E/q_c indicate that unless highly conservative designs are to be used, q_c values alone, are unreliable for detailed design. On the other hand, if on site correlations can be established, the use of E/q_c in this limited context can be extremely valuable. The screw plate test, by providing a relatively rapid means by which the drained and undrained soils properties can be determined, enables a convenient determination of the on-site correlation required to interpret the cone penetrometer test meaningfully. By conducting screw plate tests in parallel with cone penetrometer soundings, experimental correlations can be obtained for each given situation and results can be applied to cone penetration tests throughout the site at a reasonable level of confidence.

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