Comparison between Dilatometer and Other In-Situ and Laboratory Tests in Malaysian Alluvial Clay

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SYNOPSIS

A site investigation was conducted in a typical Malaysian alluvial clay deposit using the self boring pressuremeter (SBP) in conjunction with dilatometer (DMT) tests. Other tests conducted at the site also included piezocones and boreholes with piston sampling. This paper presents and compares DMT results against the parameters obtained from the SBP tests. The DMT prediction of geotechnical parameters at this site will also be compared to previous studies carried out on other soft ground areas in Malaysia. The predictions by DMT appear to be encouraging and consistent with the findings by others.

INTRODUCTION

Work on the usefulness of the DMT in predicting soil parameters in the Malaysian alluvial clay deposit have previously been reported by Wong & Dobie (1990) and Wong & Ibrahim (1991). This work is now extended to investigate the DMT predictions of parameters normally obtained by the SBP test. The study also provided an opportunity to update the database on the DMT predictions of some geotechnical parameters.

The DMT predictions in this paper will be based on Marchetti's (1980) correlations which were derived from site investigations undertaken over 40 sites in a variety of lightly over-consolidated soils. The soil parameters that will be investigated include limit pressure (P_L), coefficient of earth pressure at rest (K_0), horizontal stress (σ_{ho}), undrained shear strength (s_u), shear modulus (G) and overconsolidation ratio (OCR).

Findings from SBP and DMT tests will also be compared to results reported by Clarke & Wroth (1988), Powell (1990) and Lutenegger (1990).

LOCATION OF SITE AND DESCRIPTION OF SOIL PROFILE

The site is located at Sungai Besar in the coastal plain of Selangor, on the west coast of Peninsula Malaysia. The subsurface profile with the typical soil properties are as shown in Fig. 1.

A 1m thick fill has been placed over the existing ground which is underlained by very soft to soft silty clay layer to depths of about 28m. Visual inspection of recovered piston samples which were split open revealed seashell fragments and organic specks to be distributed throughout the depth. The clays are normally to lightly overconsolidated with overconsolidation ratio ranging between 1 and 2.

Moisture contents in the clay normally exceeds 100%, with the liquid limits generally exceeding the moisture content value for depths below 14m. The particle size distribution of the marine clay content consists of 60% clay, 35% silt and 5% sand. Organic content ranges between 5% to 20%.

EQUIPMENT AND TEST PROCEDURES

The dilatometer developed by Marchetti (1980) consist of a stainless steel blade with a thin circular expandable steel membrane on one side. Details of the test procedures have already been described by Dobie & Wong (1990). In general, the test procedures conforms to those outlined in the draft ASTM standard for DMT testing.

The SBP or more commonly known as Camkometer is of the type manufactured by the Cambridge Insitu Testing Ltd (UK). The tests were generally conducted according to the procedures outlined by Windle & Wroth (1977). Each test, which consists of 3 load-reload cycles, were carried out at about 1m intervals.

INTERPRETATION OF DMT AND SBP TESTS

Interpretation of parameters from DMT results will be computed from correlations derived by Marchetti (1980).

Values of horizontal stress σ_h were computed from the derived K_0 equation with a known water table while values of G were assessed from DMT values of M, the constrained modulus with a suitable choice of Poisson's ratio.

In the case of the SBP tests, the limit pressure was derived by visual inspection while the s_u was back analysed using the Gibson & Anderson (1961) technique. The shear modulus G was determined from slope of the load-reload loops measured in the SBP test.

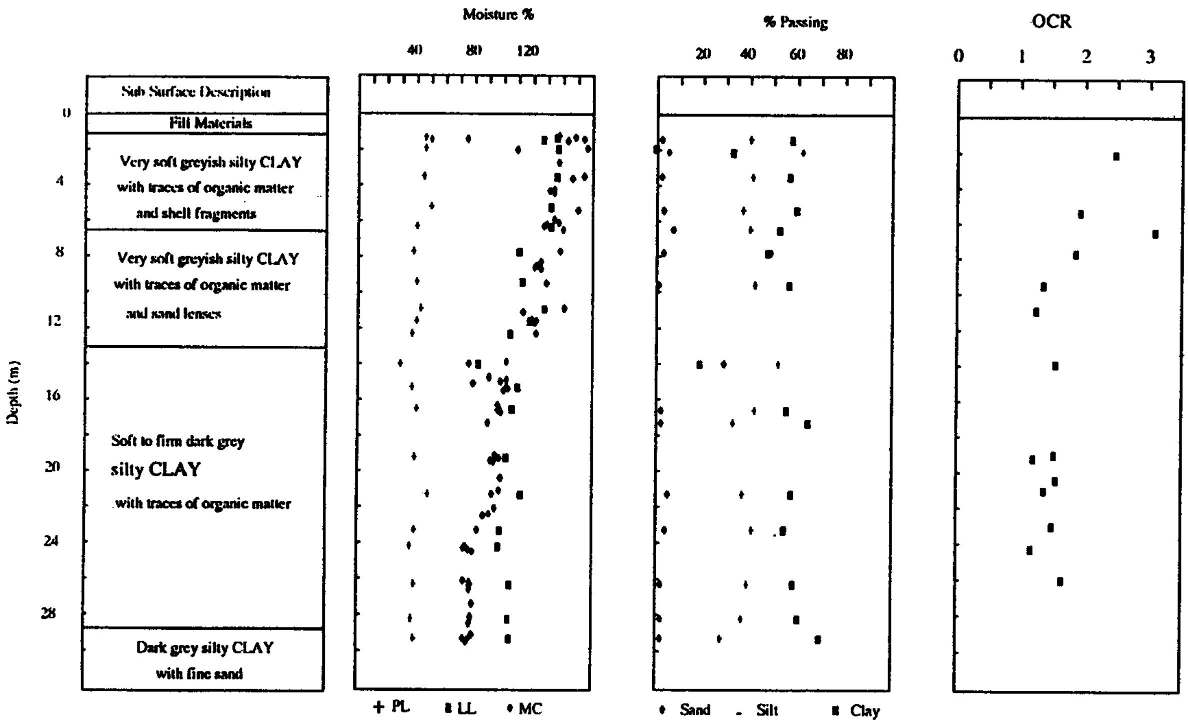

Fig. 1 - Soil properties of Sungai Besar, Selangor

COMPARISON BETWEEN P_1 AND P_L

Fig. 2 shows the graphical plots of P_1 of the DMT and limit pressure, P_L of the SBP tests. The limit pressure is defined as the pressure that could be attained at infinite expansion. It can be seen from Fig. 2 that P_1 is generally greater than P_L. This is to be expected as the P_1 pressure is obtained when the soil has already experienced close to an infinite expansion simply due to the insertion of the dilatometer blade. In turn, P_L of the SBP was obtained in soil tested at lower strain levels. Powell (1990) confirmed this observation when he reported that the P_1 value were seen to fall close to P_L values obtained using push-in-pressuremeter or full-displacement cone pressuremeter tests, both of which are penetration type devices.

The straight line graph in Fig. 2 also suggest a linear relationship between P_1 and P_L but Clarke et. al. (1988) has reported that the relationship tends to be more site specific. More tests are currently being conducted at other sites to confirm this finding. As shown in Table 1, the P_1/P_L ratio obtained from tests performed on Malaysian clays have been found to be within the ranges reported by others on soft clays.

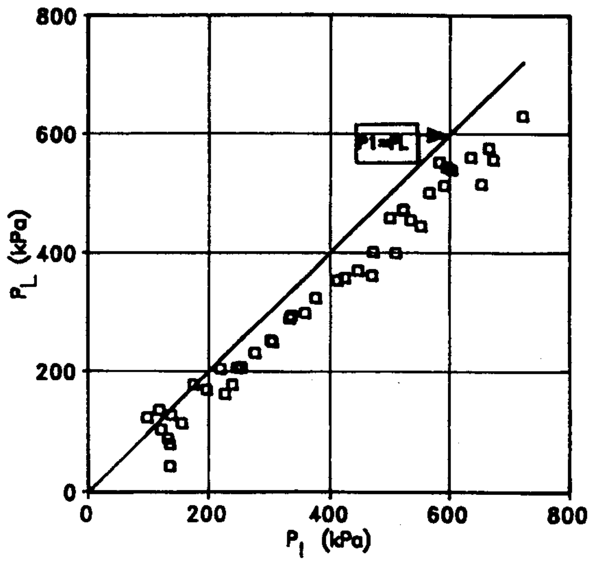

Fig. 2 - Comparisons between P_1 and limit pressure P_L

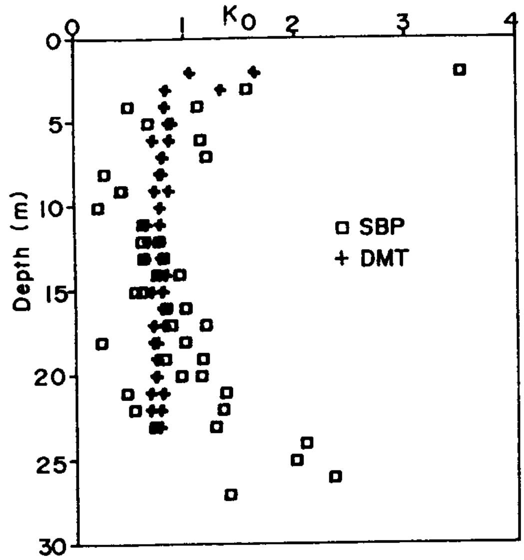

Fig. 3 - Comparison of K_0

COEFFICIENT OF EARTH PRESSURE AT REST, K_0

The K_0 profile with depth for both the SBP and DMT tests are presented as in Fig. 3. Generally the DMT appears to predict reasonably the K_0 values for the top 20m. At depths greater than 20m, the DMT K_0 values were underpredicted by as much as 40%. The values are replotted on the graphs of K_0 against horizontal stress index, K_D (Fig. 4) with the correlation lines by Marchetti (1980) and Lacasse & Lunne (1988) included. K_0 data obtained from consolidation tests carried out on undisturbed samples from other Malaysian alluvial clay sites using the Brooker & Ireland (1965) relationship are also included in the plot. The Marchetti correlation tends to underpredict K_0 values which were derived from SBP tests about 40% for Malaysian clays. K_0 values from laboratory tests compared fairly well with the established correlations.

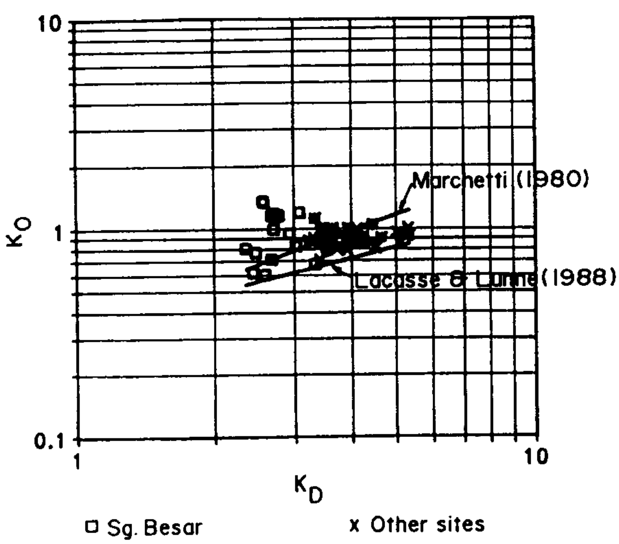

Fig. 4 - Graph of K_0 vs K_D

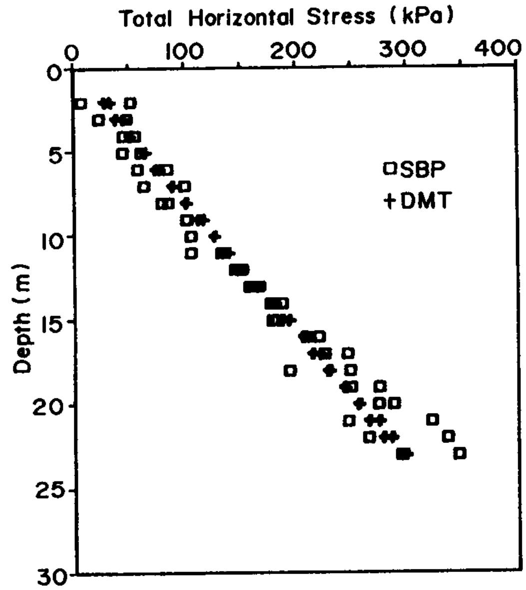

Fig. 5 - Comparison of σ_{ho}

INSITU HORIZONTAL STRESS (σ_{ho})

Although the horizontal stress is rarely an issue in soft clays for practising engineers, it leads to the derivation of K_0 which may be of a more useful parameter. An estimate of the insitu horizontal stress, σ_{ho} was obtained from SBP test using the Marsland & Randolph method as in Fig. 5. The derived σ_{ho} from DMT test is also plotted in the graph. It is evident that the DMT results correspond satisfactorily with the SBP derived σ_{ho}. The finding appears to fall within the ranges reported by others as summarised in Table 1 below.

UNDRAINED SHEAR STRENGTH s_u

The s_u parameter from DMT and SBP tests are compared against values obtained from adjacent

TABLE 1: SUMMARY OF COMPARISON BETWEEN SBP AND DMT TESTS

PARAMETER	MALAYSIAN ALLUVIAL CLAYS	CLARKE & WROTH (1988) (soft clays only)	POWELL (1990)	LUTENEGGER (1990)
P_1/P_L	1.0 to 1.4	1.34 to 1.47	1.0 to 1.4	1.1 to 1.8
$\frac{\sigma_{hoDMT}}{\sigma_{hoSBP}}$	1.0 to 1.2	1.08 to 1.58	0.8	-
$\frac{s_{uDMT}}{s_{uSBP}}$	0.8 to 1.0	0.85 to 1.20	0.8 to 1.0	-
$\frac{G_{DMT}}{G_{SBP}}$	0.1 to 0.3	0.3 to 0.62	-	-

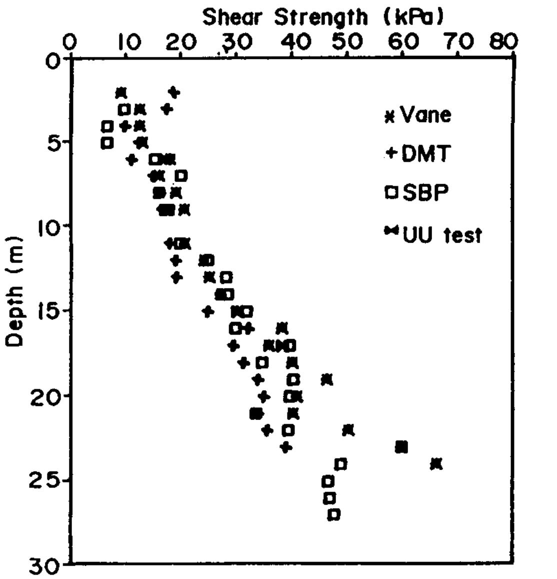

Fig. 6 - Comparison of s_u vs depth for the various insitu tests

penetration vane tests and unconsolidated drained triaxial test as shown typically in Fig. 6. Although the comparison between the tests appear to be satisfactory, both the DMT and SBP tests tend to underpredicted s_u by as much as 20%. The s_{uDMT}/s_{uSBP} ratio ranges from 0.8 to 1.0 and are well within the ranges reported by others listed in Table 1 below. The results from the Sungai Besar are replotted in a normalised form as shown in Fig. 7 and compared to results from alluvial clay sites in other coastal areas of Malaysia as follow:

Site A - Johore
Site B - Perak
Site C - Penang
Site D - Selangor

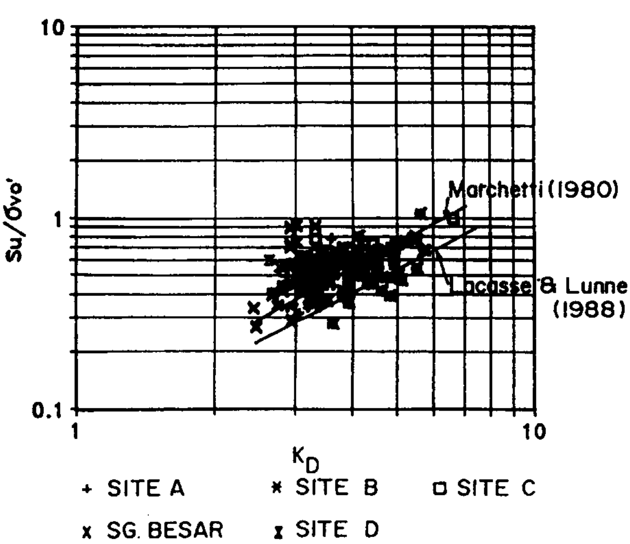

Fig. 7 - Graph of K_D vs s_u/σ_{vo}'

The plot suggests that correlations by Marchetti (1980) appear to be satisfactory while that by Lacasse et al (1988) underpredicts s_u.

SHEAR MODULUS

The shear modulus G computed from the SBP tests is based on the third load-reload cycle (about 5% strain). These values are compared against laboratory derived values from unconsolidated undrained triaxial tests assuming a Poisson's ratio of 0.3 as shown in Fig. 8. The values from the UU tests included initial tangent and secant modulus taken at about 50% of the maximum stress level. The SBP derived shear modulus appears to overpredict laboratory values by as much as 50%. The shear modulus computed from the dilatometer constrained modulus K_D underpredicted the G values by a magnitude of about four. Similar results were also reported by Clarke & Wroth (1988) as shown in Table 1. These results however, contradict the findings by Chang (1991) which reported good correlations between the dilatometer modulus E_D and the secant modulus E_{50} from the triaxial UU test on Singapore marine clay. As such, more tests will need to be conducted to confirm this finding.

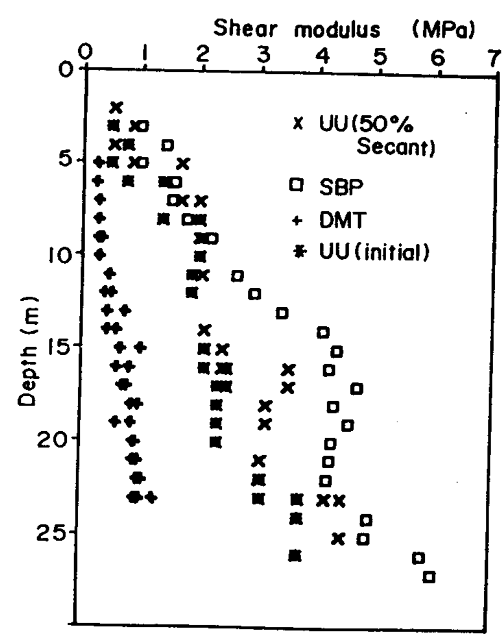

Fig. 8 - Comparison of G from SBP, DMT and UU tests

OVERCONSOLIDATION RATIO

As evident in Fig. 9, the DMT tests have revealed its ability to predict OCR satisfactorily as the database for Malaysian clays generally fall within the correlations derived by Lacasse et. al. (1988). Marchetti's correlation clearly overestimated the OCR values.

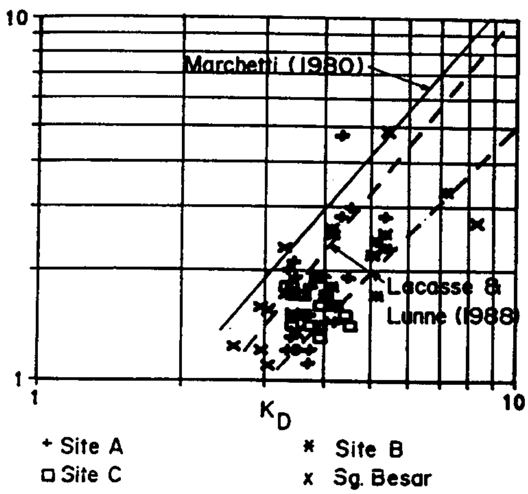

Fig. 9 - Graph of K_D vs OCR

SUMMARY AND CONCLUSIONS

Investigations have revealed that for soft clays, SBP derived parameters such as the limit pressure K_0 and σ_{ho} can be predicted reasonably by DMT tests. However, the predicted shear modulus G from DMT tests grossly underestimates SBP values and further work will need to confirm this finding. Studies have also shown that the DMT can predict reasonably other geotechnical parameters such as s_u and OCR with reasonable accuracy when compared to other reference tests. With such a database developed for Malaysian alluvial clays, the DMT can now be confidently employed in typical soft ground investigation with beneficial cost savings owing to its simplicity in operation and speed. The DMT have also been employed in quality control works prior to and after ground improvement work, especially in embankments constructed over soft ground. However, in view of the limited space, typical results will not be presented in this paper.

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