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Applicability of the Marchetti Dilatometer Test to Soft Ground in Japan

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SYNOPSIS To evaluate the existing correlations between Marchetti dilatometer test (DMT) results and conventional soil parameters for alluvial soft ground in Japan, field tests of the DMT were performed. As a reference test to compare with the DMT results, self-boring pressuremeter tests, a series of the laboratory soil tests were conducted. It was found that soil type, constrained modulus, coefficient of lateral earth pressure at rest and undrained shear strength estimated from the DMT well agree with that by the reference tests. Consequently, the typical existing correlations could be reconfirmed for alluvial soft ground in Japan.

INTRODUCTION

The Marchetti Dilatometer Test (DMT), widely used in North America and Europe, has grown to one of more popular sounding same as cone penetration test (CPT). The popularity of the DMT lies on the following reasons (Lutenegger, 1988).

1) simple operation without special electric technique,
2) reproducible results,
3) cost effectiveness,
4) wide variation of penetration equipment and rods.

The dilatometer consists of a hard steel blade which has a thin steel membrane on one side of the blade. The membrane is expanded by compressed gas after the blade is inserted into ground. The pressures when the membrane lift off the plane of the blade, when a central expansion of the membrane leaches 1mm and when the membrane touches the plane after unloading are measured as p_0, p_1, p_2, respectively. Marchetti (1980) proposed the following indices corrected by membrane stiffness using these pressures.

Material Index : $I_D = (p_1 - p_0) / (p_0 - u_0)$ (1)

Horizontal Stress Index : $K_D = (p_0 - u_0) / \sigma_v'$ (2)

Dilatometer Modulus : $E_D = 34.7(p_1 - p_0)$ (3)

where u_0 is in situ pore water pressure and σ_v' is effective overburden pressure. The test mechanism is described by Marchetti (1980) and the test procedures are shown in Marchetti and Crapps (1981) and Schmertmann (1986) in detail.

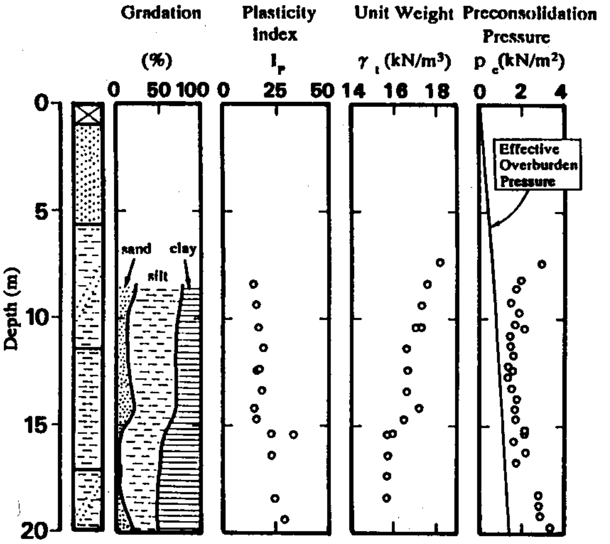

Fig. 1 Soil Profile and Properties at Komatsugawa site

The results of the DMT are used to estimate unit weight, coefficient of lateral earth pressure at rest, overconsolidation ratio, constrained modulus , undrained shear strength for clays (Marchetti, 1980, 1985; Lacasse and Lunne, 1988), friction angle of sands (Schmertmann, 1982; Marchetti, 1985) and coefficient of consolidation (Robertson et al., 1988). The interpretation of the test is generally based on empirical correlations. These correlations, therefore, depend on local soil properties. However, there is no report on the evaluation of the existing correlations for the ground in Japan.

The purpose of this paper is to evaluate whether it is possible to estimate the soil parameters by using the DMT results for the soft ground in Japan. To check the validity of the DMT result, the authors performed a large testing program consisting of dilatometer tests, triaxial tests, self-boring pressuremeter tests, cone penetration tests and hydraulic fracture tests.

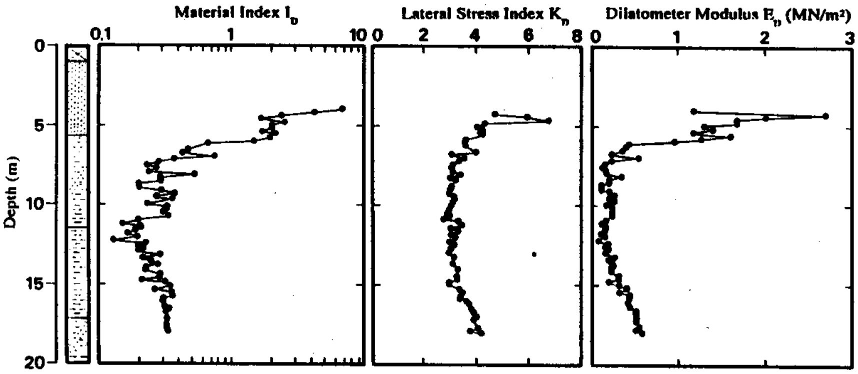

Fig. 2 The variation of the DMT Indices with Depth

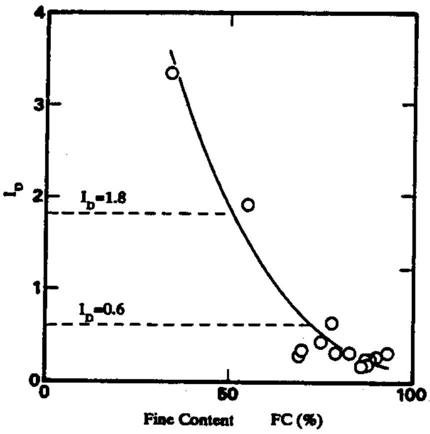

Fig. 3 Relationship between Fine Content FC and Material Index I_D

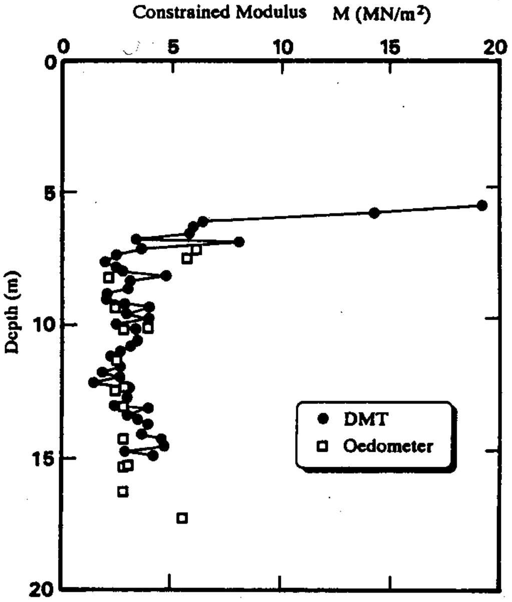

Fig. 4 The variation of Constrained Modulus M with Depth

DESCRIPTION OF TEST SITE

The site was selected in an area named Komatsugawa in the northern coast of Tokyo Bay. The ground was covered with loose delta sand of 6 m underlain with soft alluvial cohesive soil to the depth of 21 m. The ground water table was 1 m to 2 m deep from ground surface with seasonal variation. The soil profile and the typical results of the laboratory tests are shown in Fig. 1. The cohesive soil at this site contained 5 to 20 percent of sands and seemed to be lightly overconsolidated as shown in Fig. 1.

INTERPRETATION OF TEST RESULTS

soil type

The variations of the DMT indices with depth at Komatsugawa site are shown in Fig. 2. The soil classification method of the DMT proposed by Marchetti (1980) using material index I_D is as follows,

$1.8 < I_D$	sand
$0.6 < I_D < 1.8$	silt
$I_D < 0.6$	clay

The I_D values of Komatsugawa site shown in Fig. 2 are very small for clays and very high for sands. Since the range of I_D values is wide, it will be easy to determine a soil type from this value.

Fig. 3 shows the relationship between I_D and fine contents FC obtained from the laboratory test. Although the data has a considerable scatter, a distinct trend in decreasing I_D with increasing FC seems generally reasonable. It can be seen that the soil classification using I_D is reasonable for alluvial soil deposit at Komatsugawa site. Particularly, I_D of 1.8 seems to corresponds to FC of 50 % which is the boundary between fine-grained soil and coarse-grained soil.

constrained modulus

Marchetti (1980) proposed the following equation to estimate the constrained modulus M_{DMT} by using E_D.

$$M_{DMT} = R_M \cdot E_D \tag{4}$$

for $I_D \leq 0.6$ $\quad R_M = 0.14 + 2.36\log(K_D)$

for $0.6 < I_D < 3.0$ $\quad R_M = R_{MO} + (2.5 - R_{MO})\log(K_D)$

here $\quad R_{MO} = 0.14 + 0.15(I_D - 0.6)$

for $I_D \geq 3.0$ $\quad R_M = 0.50 + 2\log(K_D)$

for $K_D > 10$ $\quad R_M = 0.32 + 2.18\log(K_D)$

Always $\quad R_M \geq 0.85$

The variations of M_{DMT} calculated from Eq.(4) and the constrained modulus by the laboratory oedometer test M_{OED} with depth are presented in Fig. 4. The M_{OED} values are defines as the reciprocal of the coefficient of volume compressibility m_v near preconsolidation pressure. It can be seen from Fig. 4 that the M_{DMT} well agree with the M_{OED} and hence constrained modulus or coefficient of volume compressibility can be predicted from the DMT for alluvial cohesive soils.

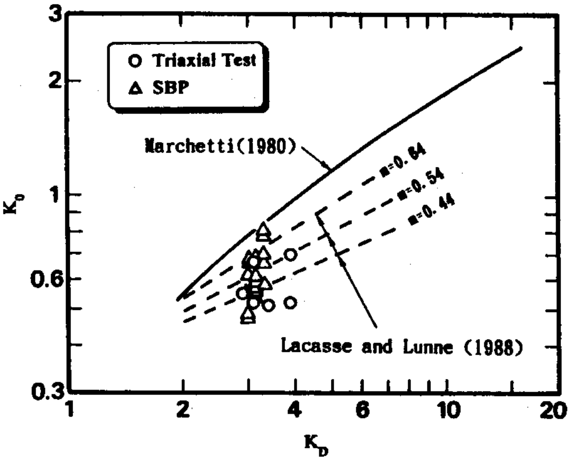

Fig. 5 Relationship between Lateral Stress Index K_D and the Reference value of K_0

coefficient of lateral earth pressure at rest K_0

Fig. 5 shows the correlation between horizontal stress index K_D and reference values of K_0 obtained from the laboratory K_0-consolidation tests and from the self-boring pressuremeter tests for cohesive soil at Komatsugawa site. The lines shown in Fig. 5 denote the following equations proposed by Marchetti (1980) and Lacasse and Lunne (1988), respectively.

$$K_0 = (K_D / 1.5)^{0.47} - 0.6 \quad (5)$$

$$K_0 = 0.34 K_D^{m} \quad (K_D < 4) \quad (6)$$

where $m = 0.44$ for highly plastic clays and $m = 0.64$ for low plasticity clays (Lacasse and Lunne, 1988). Concerning the present data, it can be seen that the K_0 values calculated from Eq.(5) proposed by Marchetti (1980) may be overestimated and the K_0 values from Eq.(6) by Lacasse and Lunne(1988) is more reasonable for the present data.

The K_0 values obtained from various methods are plotted against depth in Fig. 6. The K_0 values by the DMT were calculated from Eq.(6) for the present data of the DMT with $m = 0.54$ as average value. The reference values of K_0 have obtained from K_0-consolidation tests, self- boring pressuremeter tests, hydraulic fracture tests by BAT (O-kochi et al., 1984) and predicted value from plasticity index I_P. The method using I_P was proposed by Massarsh (1979) as follows.

$$K_0 = 0.44 + 0.42 I_P / 100 \quad (7)$$

It can be seen from Fig. 6 that the K_0 values obtained from the DMT by using Eq.(6) are reasonable as far as comparing to the K_0 values obtained from self-boring pressuremeter tests and K_0- consolidation tests that are generally considered to be reliable to estimate K_0 value. On the other hand, it may be seen that the K_0 values obtained from hydraulic fracture tests are overestimated and the K_0 values from I_P are underestimated.

undrained shear strength

Undrained shear strength S_u can be predicted from following equation proposed by Marchetti (1980).

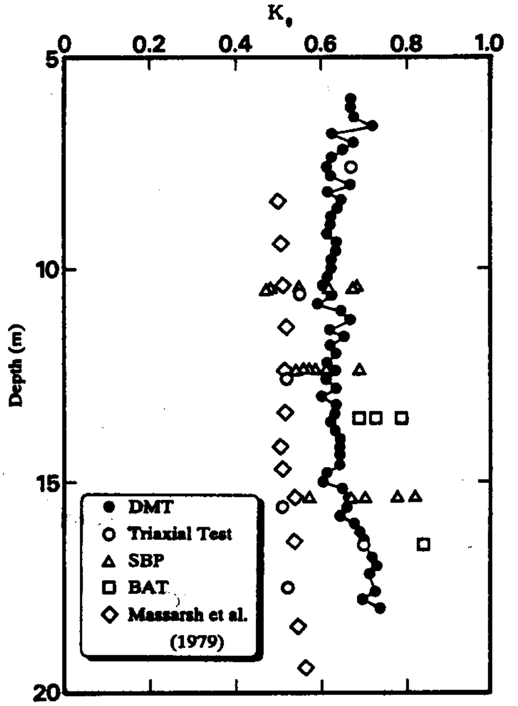

Fig. 6 Relationship between K_0 Values Obtained from Various Methods and Depth

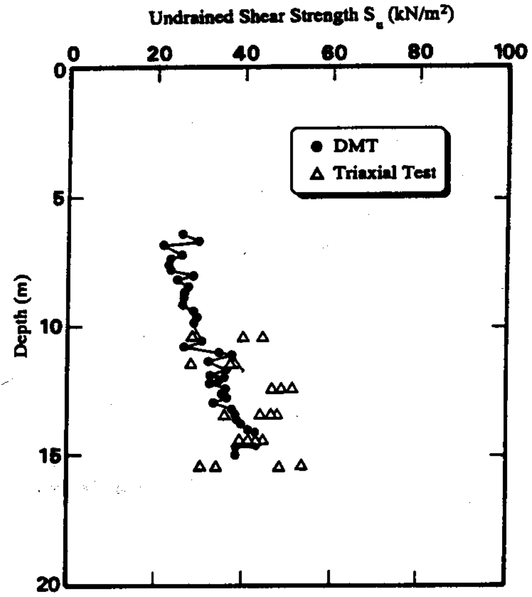

Fig. 7 Relationship between Undrained Shear Strength Su and Depth

$$S_u = 0.22\sigma_v'(0.5K_D)^{1.25} \quad (8)$$

This equation can be applied for $I_D \leq 0.6$. Fig. 7 shows the relationship between the undrained shear strength obtained from Eq.(8) and the S_u values from unconsolidated undrained triaxial compression tests. It

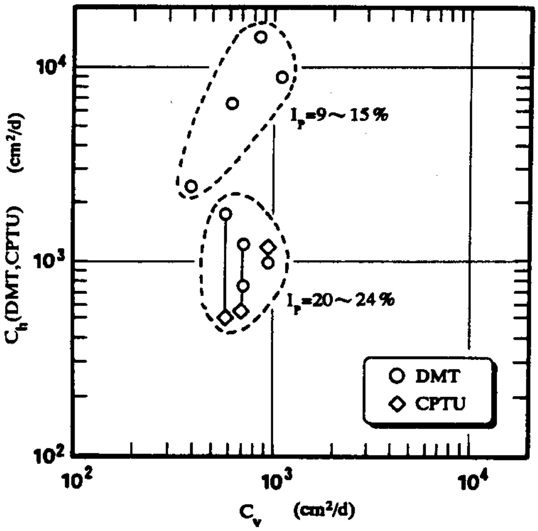

Fig. 8 Correlation between Coefficient of Consolidation obtained from the DMT, the CPTU and that from Oedometer Test

can be said from Fig.7 that Eq.(8) proposed by Marchetti (1980) can be used to estimate S_u in alluvial cohesive soils.

coefficient of consolidation

Robertson et al. (1988) demonstrated that the DMT closing pressure, p_2, is similar to pore water pressure in the ground near the blade during penetration of the blade and that the dissipation process of p_2 corresponds to that of pore water pressure. On this basis, Robertson et al. (1988) proposed the method to determine the horizontal coefficients of consolidation C_h(DMT) by using the p_2 dissipation curves of the DMT. Fig. 8 shows the relationship between the C_h(DMT) values estimated by this method and the vertical coefficients of consolidation C_v(OED) obtained from the laboratory oedometer test using the samples at the same depth as the DMT. The horizontal coefficients of consolidation obtained from the piezocone dissipation test, C_h(CPTU), on the basis of the method proposed by Torstensson (1977) , are also shown in Fig. 8. The symbols of C_h(CPTU) in the figure are connected by the line with the C_h(DMT) of the same depth. Although it will be difficult to contrast C_v with C_h, C_h seems to approximate to C_v in case that C_v is relatively high same as the present data (Yoshikuni, 1979). It may be seen from Fig. 8 that the values of C_h(DMT) and C_h(CPTU) seem to be similar and that the values of C_h(DMT) in accordance with the C_v obtained from oedometer for the highly plastic clay, though the C_h(DMT) seem to be overestimated for low plastic clay.

CONCLUSIONS

From a limited amount of results on alluvial soil at Komatsugawa site obtained by the present study, the following conclusions were obtained:

(1) Soil classification by the Material Index I_D is suitable for alluvial deposit.

(2) Undrained shear strength and constrained modulus estimated by the method proposed by Marchetti (1980) show good agreement with the results of triaxial compression test and oedometer test , respectively.

(3) Coefficient of lateral earth pressure at rest obtained from the method proposed by Lacasse and Lunne (1988) is in accordance with that by self-boring pressuremeter test and laboratory K_0-consolidation test.

(4) The coefficient of consolidation obtained from the DMT dissipation test proposed by Robertson et al. (1988) is similar to that of laboratory oedometer test for highly plastic clay, though it is not for low plastic clay.

The conclusions reduced from this investigation may be shown for the case of Komatsugawa site. However, this investigation will provide a possibility of the DMT test result.

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