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Pile Skin Friction in Clays

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ABSTRACT

A simple method is presented for calculating static shaft resistance of a pile driven into clay. The method is based on correlations derived for marine clays between index properties and strengths. Applications of the method to half a dozen full-scale pile load tests of high quality, and including a wide range of plasticity properties, overconsolidation ratios and strengths, are described. Except for short piles in very stiff to hard clays, the predictions agree very well with the measurements. The correlation presented allows an assessment of residual skin friction and indicates the importance of the liquidity index of the clay in static capacity calculations.

INTRODUCTION

Driven pipe piles are commonly used in the North Sea to support offshore platforms. Compared to piles used on land, offshore piles are very long and compressible and are designed to carry substantially higher loads. In the North Sea, pile tip penetrations as deep as 102 m below the seafloor have been achieved for 2.48-m OD piles (*Offshore Engineer*, 1993).

This paper presents a simple method to evaluate skin friction of piles driven into clays, on the basis of effective stress analysis. The method utilises the liquidity index of the clay as the basic soil parameter for predicting residual skin friction in clays.

Observations in several full-scale pile load tests and model piles (e.g. Cox et al., 1979; Gibbs et al., 1992; Clarke et al., 1992) show that after the peak capacity is mobilised, the sustained pile head load reduces with increasing pile head displacements. Typically, the residual (post-peak) capacity has been shown to be 10% to 20% lower than the peak capacity. This effect has been attributed to pile length (compressibility) and softening in the pile skin resistance as the pile displacements become large.

CORRELATIONS

Based on results of conventional unconsolidated-undrained (UU) triaxial compression tests, a correlation has been developed between the ratio of the residual strength to the original effective horizontal ground stress, and the liquidity index of the clay. This correlation is presented in Fig. 1 (Mirza, 1995). The liquidity index (LI) is defined as:

$$LI = (w - PL) / PI \qquad (1)$$

where w is the natural water content, PL is the plastic limit and PL is the plasticity index, defined as the numerical difference between the liquid limit (LL) and the plastic limit (PL). Determination of these limits is assumed to follow British Standard 1377 (1975).

The data in Fig. 1 represent results from 257 UU triaxial com-

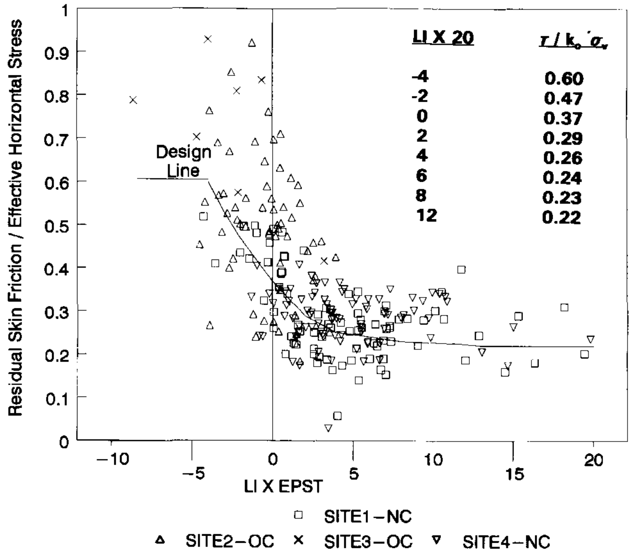

Fig. 1 Ratio of residual friction to effective horizontal stress versus liquidity index times EPST

pression tests on North Sea clays which span a wide range of stress history, strength and plasticity.

To use the correlation in Fig. 1, values of the effective horizontal stress, $'\sigma_h$, and the LI are required. The other variable, EPST (Epsilon total), represents the actual final vertical strains undergone by the test samples during shearing. In the majority of tests EPST was around 20%. Therefore in entering Fig. 1, a value of 20% should be assumed for EPST. The original effective horizontal stress, $'\sigma_h$, is calculated from the product of the original effective overburden pressure, $'\sigma_v$, and the coefficient of earth pressure at rest, K_o. By combining correlations proposed by Skempton (1957), Mayne (1980) and Meyerhof (1976), the value of K_o may be estimated using the equation:

$$K_o = \{0.34 + 0.41\ PI/LL\} \cdot \{S_u / [\,'\sigma_v\,(0.11 + 0.0037\ PI)]\}^{0.59} \qquad (2)$$

where Su is the measured triaxial undrained shear strength.

In developing Fig. 1, the value of K_o has been limited by K_p, Rankine's coefficient of passive earth pressure assuming zero cohesion, and the empirical coefficient for normally consolidated clay by Jaky (1994) as:

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