On the Filtering Equation to Predict Undrained Shear Strength of Ariake Clay by Electronic Cone Penetration Testing

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Introduction: Evaluation of undrained shear strength (s_u) of clay by using laboratory tests usually faces serious problems due to limited data available and often large scatter caused by sample disturbance. The use of the electronic cone penetration testing (ECPT) is fast expanding in many countries for determining accurate stratigraphic profiles and providing a quantitative measure of soil properties.

In this paper, an appropriate value of electronic cone factor N_{kt}=11 was used to predict s_u of Ariake clay. Filtering equation was proposed to remove the disturbed s_u of Ariake clay and filtered s_u were compared to find fairly good agreement with the s_u values predicted by the electronic cone penetration testing data. The margin of error was about ±20%.

Materials and methods: The ECPT with controlled rate of penetration were carried out at four sites of Ariake clay (Saga sites A, B, C, and D) whose depths ranged between 20 to 25 m. to measure the total cone tip resistance q_t, effective pore water pressure u_d and friction sleeve f_s. The profiles of the effective pore water pressure of all sites are almost similar. In all clay sites there are a general increase in q_t and u_d along with depth. There are sudden decreases in u_d in all sites of Ariake clay especially in sites A, B and C, that suggests the presence of some thin sandy layers

Results and discussion: Undrained shear strength (s_u) is derived by dividing the net cone resistance by a cone factor (N_{kt}) using the bearing capacity equation from undrained deep penetration as following:

$$s_u = \frac{q_t - \sigma_{v0}}{N_{kt}} \quad \text{--------------------------------------(1)}$$

where q_t is the total cone tip resistance and σ_{v0} is the overburden pressure. N_{kt} value in this study proposed as 11, which is considered more applicable to predict safely the values of s_u for Ariake clay (Rashwan et al, submitted to JSIDRE) so

$$s_u = \frac{q_t - \sigma_{v0}}{11} \quad \text{-------------------------------------(2)}$$

To validate the applicability of N_{kt} value of 11, typical profiles of the predicted s_u profiles obtained from the ECPT results using N_{kt} value of 11 and unconfined compression test data as a reference.

Filtering of Undisturbance of Clay: The deformation modulus (E_{50}) is the slope of the initial part of the unconfined compression-shear strain curve. Basically the deformation modulus can be used to check the disturbance in soil. So, it used with effective pore water pressure to check the disturbance or to make a filtration of undisturbance clay.

The effective pore water pressure is proportional to porosity (n_0) as following:

$$u_d = f(n_0) \quad \text{---------------------------------------(3)}$$

Also the deformation modulus is proportional to strength and strength is proportional to n_0, as following:

$$E_{50} = \frac{\frac{q_u}{2}}{\varepsilon_{50}} = f(n_0) \quad \text{-----------------------------(4)}$$

where: q_u is the unconfined compression strength and ε_{50} is the vertical shear strain defines at q_u/2 (kPa)

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From equations (3) and (4), the deformation modulus is a function of effective pore water pressure, so the relationship between E_{50} and u_d becomes:

$$E_{50} = \alpha u_d \quad \text{---(5)}$$

where α is the proportional constant assumed as 15 in this study where represents less disturbance exist.

Figs 1-A~D represent the relationship between u_d and E_{50}. The assumed solid line which has a simple equation represents the least disturbance soil and expressed by the following equation:

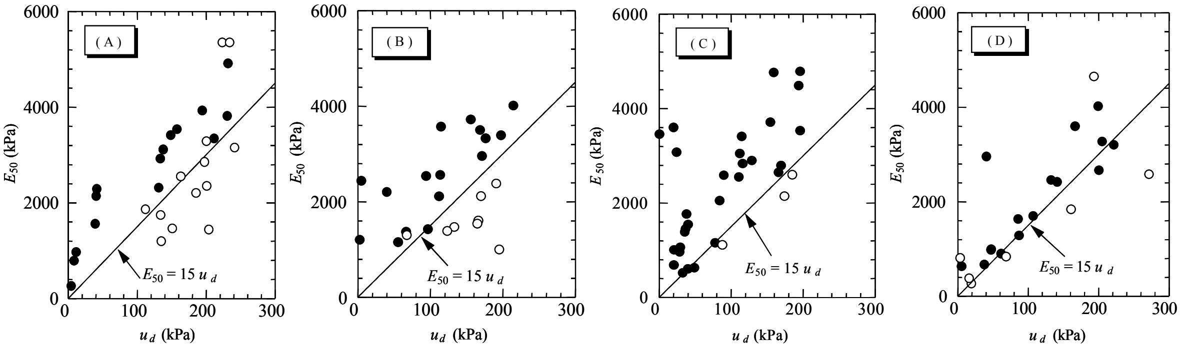

Fig. 1-A~D The relationship between pore water pressure and deformation modulus of Ariake clay

$$E_{50} = 15 u_d \quad \text{---------------------------------------(6)}$$

The points, which located over this proposed line represent undisturbed soil while the points, which located under this line suppose to be disturbed soil.

By removing the disagreement points and redrew the figures again, as shown in **Figs. 2-A~D** where, the filtered s_u compared with predicted s_u obtained from ECPT data and the error was about ±20% calculated depending on the total number of points before removing the disturbed s_u and the number of points remained after removing the disturbed s_u.

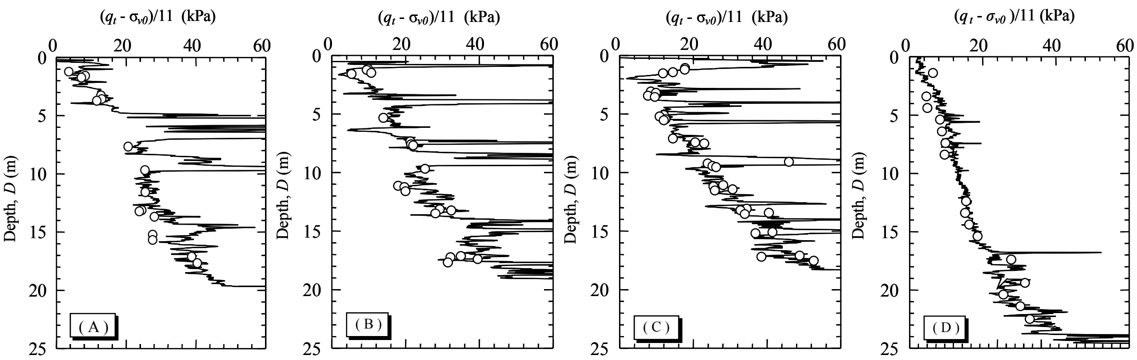

Fig. 2-A~D Modified comparison between predicted and measured s_u from ECPT results and Unconfiend compression test

Conclusion: An appropriate value of electronic cone factor (N_{kt}) proposed as 11 to predict undrained shear strength of clay by using ECPT. Filtering equation was assumed and used to check the disturbance in clay to predict s_u by ECPT data. Filtered s_u were compared to find fairly good agreement with the s_u predicted by the electronic cone penetration testing data with margin of error about ±20%.

References:

1. Rashwan M. A., Koumoto T., Park J.H. and Hino T. (2005): Predicting of wet density and undrained shear strength of clays by electronic cone penetration testing, *Trans. of JSIDRE* (under publication).