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The Influence Research of Sampling Disturbance on the Strength of Inland Lacustrine Soft Soil

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Abstract. The soil sampling disturbance was inevitable in geotechnical engineering geological survey; it would change the engineering nature of the soil, and also affect the site geological record and indoor geotechnical test accuracy. This paper studied the relationship between the disturbance degree and the soil strength based on the reference of the new disturbance degree for the phenomenon of sampling disturbance and gave the expression for the disturbance degree and the soil strength. The strength of the disturbed soil sample could be reduced to the in situ strength according to the expression; it would have a certain practical significance.

1. Introduction

The soil sampling disturbance is inevitable in geotechnical engineering geological survey; it will change the engineering nature of the soil, and will also affect the site geological record and indoor geotechnical test accuracy. The in-situ test equipment is more difficult to grasp the boundary conditions, especially large in-situ test depth for reducing the sampling disturbance of soil the field-in-situ testing technology; the indoor test has economic advantages because the accuracy of in-situ testing is difficult to meet the requirements at large in-situ test depth, which is not only flexibly and easily controlled; the drilling sampling and indoor testing are still the commonly used methods [1]. At present, many test personnel do not have a clear understanding of the various aspects of sampling disturbance, and a detailed analysis of the relationship between disturbance and soil yield stress strength. Therefore, it is of practical significance to study the relationship between soil disturbance and soil strength on the basis of the disturbance degree definition of Z. Hong and K. Onitsuka.

2. Disturbance degrees

The constitutive property of the soil was affected, and the physical and mechanical indexes would change after the soil disturbed. This phenomenon was often referred to as the disturbance degree, which is showed by the symbol D [2]. How to establish a function (referred to as a perturbation function) that could correctly reflect the relationship between the change of physical and mechanical parameters and the degree of disturbance was the key to study on the soil motion theory. Many scholars put forward the corresponding disturbance function according to the indoor tests or on-site monitoring results. These results mainly included as follows:

Schmertmann (1955) proposed a method for quantitatively evaluating the degree of sampling disturbance, calculating the sampling disturbance index D by the following equation:

$$D=\frac{e_0-e}{e_0-e_1}=\frac{\Delta e}{\Delta e_0} \qquad (2—1)$$

Where：
e— The pore ratio corresponding to the pre-consolidation pressure Pc for the actual compression curve;
e_0— The initial porosity ratio for soil samples;
e_l— The pore ratio of corresponding to the pre-consolidation pressure Pc for the completely reshape the compression curve.

The smaller the disturbance index D was, the smaller the disturbance for the soil sample was; the disturbance degree of the soil sample was evaluated according to the disturbance index D.

Ladd and Lambe [3] argued that the undrained shear modulus of saturated soil samples was most sensitive to the effect of disturbance, and thus the estimator of disturbance index D could be established:

$$D=\frac{[Eu]-E_{50}}{[Eu]-[E_{50}]} \qquad (2—2)$$

Where：
E_{50} and $[E_{50}]$ are respectively the undrained shear modulus when the strains of "undisturbed" soil samples and remolded soil samples are 50%, which can be measured by tests;
$[E_u]$ is the undrained modulus of the "ideal" soil samples, which can be calculated.

Meng-xi zhang[4] put forward the construction disturbance function based on (p - q - e)that is similar to the destruction of the soil surface in the space:

$$D=\frac{\sqrt{(\Delta p^2+\Delta q^2+\Delta e^2)}}{\sqrt{(p_f^2+q_f^2+e_f^2)}} \qquad (2—3)$$

Where:
P_f, q_f and e_f are respectively the mean stress, partial stress and pore ratio under the damage; and △q, △p, △q must be dimensionless. Otherwise the dimension is problematic, and the atmospheric pressure or the early consolidation pressure can be used to be dimensionless.

The above methods to determine the disturbance of soil could only reflect the disturbance of soil voids caused by sampling disturbance, but there were no detailed studies on soil disturbance and its strength and yield stress.

The consolidation compression curve was described by the log-log coordinate between the specific volume (v = 1+ e) and the consolidation pressure p, and the ln(1+e)-lgp soil compression curve took on a double linear characteristics in the double logarithmic coordinates, the intersection of the two straight lines was the consolidation yield pressure p_y' according to Butterfield's study—Hong and Onitsuka[6]; the traditional volume compression method was amended by applying the Butterfield system, the definition of the disturbance degree is as follows:

$$D=\frac{C_{CLB}}{C_{CLR}}\times 100\% \qquad (2—4)$$

Where：C_{CLB}，C_{CLR} are respectively the slope of the compression curve of the ln(1+e)-lgp in the logarithmic coordinates for the perturbed and remolded soil samples before the yield , seen in Fig. 2.1.

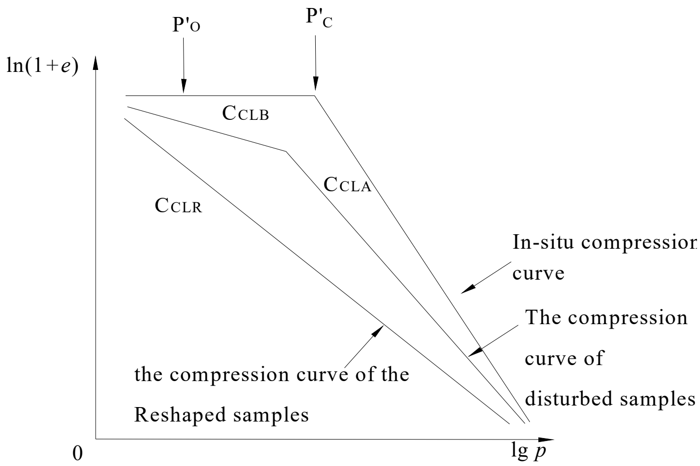

Fig.2.1 Definition of disturbance degree with revised volumetric compression method

Where：

C_{CLA}—The slope of the compression curve after the yield of the perturbed soil sample;

p_0'—The effective stress over the soil;

p_y'—The yield stress for soil samples;

In Fig. 2.1, the in-situ compression curve was the compressive curve of the ideal undisturbed soil sample. The compressive curve of the reshaped soil sample was the indoor compression curve of the remolded soil. The compressive curve of the disturbed soil sample was between the compression curve and the in-situ compression curve for the reconstructed soil.

The soil sample was completely disturbed when the D was equal to 100%, and the compression curve was the remodeling curve, shown in Fig.2.1; it indicated that the soil sample was not disturbed when the D was equal to 0%, and the compression curve was the in-situ compression curve; Hong and Onitsuka [6] found that the C_{CLR} was the liquid limit function of the function of its function through analyzing a large number of experimental; the function is:

$$C_{CLR}=-0.39+0.332\lg wL \qquad (2—5)$$

3. The relationship between disturbance degree and soil strength parameter

Sampling and construction would inevitably cause soil disturbance; the intensity of the soil would change with the change of disturbance after disturbance.

M. nagaraj and SGChung[7] studied the effects of perturbations on soil strength and yield stress, and found that the yield stress ($\lg p_y'$) of soil samples with different disturbances in ln (1+e)-lgp double logarithmic coordinates , $\ln(1+e_y)$ was on the same line where p_y' was the yield stress of the soil; e_y was the porosity of the soil when it was yielded, as shown in Fig.3.1.

The intersection coordinate of the line extension line and the remodeling curve was ($\lg (p_{yr}')$, $\ln (1 + e_r)$). P_{yr}' could be approximated as the equivalent yield stress of the residual strength of remolded soil.

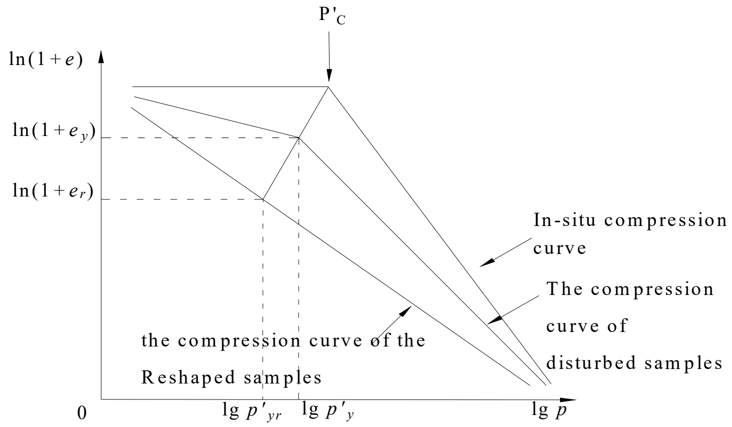

Fig.3.1 Yield stress with different SDs of soft soils

The relationship between the shear strength (kPa) and the liquid limit index for the reconstructed clay sample of soft soil could be obtained by using the linear regression method and the least squares method according to the survey data of the inland river and lake soft soil area:

$$C_U = 39.86e\text{-}1.69I_L \quad (0.3<I_L<1.4) \qquad (3\text{—}1)$$

The results of the analysis were shown in Fig.3.2.

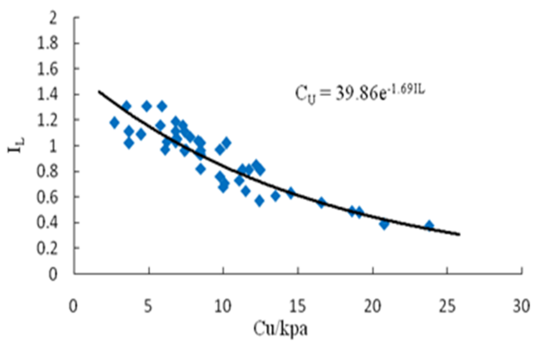

Fig.3.2 Relationship between Cu and IL

The soft soil pre-yield stress p_y' and cross-plate shear strength C_u had a certain relationship from S. Leoueil analysis [8] in the nineties of the last century; the ratio C_u / p_y' was a function of plastic index I_P:

$$f(I_p) = \frac{C_u}{p_y'} = 0.71 + 0.0045 I_p \qquad (3\text{—}2)$$

Then the equivalent of yield stress p_{yr}' of the residual strength of the remolded soil was expressed as:

$$p_{yr}' = \frac{C_u}{0.71 + 0.0045 I_p} = \frac{39.86e^{-1.69 I_L}}{0.71 + 0.0045 I_p} \qquad (3\text{—}3)$$

The void ratio er of the remodel soil:

$$\frac{\ln(1+e_0) - \ln(1+e_r)}{\lg p_{yr}'} = C_{CLR} \qquad (3\text{—}4)$$

Assuming:

The coordinates of the corresponding yield stress of the soil is ($\lg p_c'$, $\ln 1+e_0$);

The coordinates of the corresponding stress of the soil at different disturbances is ($\lg p_y'$, $\ln 1+e_y$);

The complete disturbance of the corresponding yield stress of the soil is ($\lg p_{yr}'$, $\ln 1+e_r$).

The conclusions on a straight line and the above formula were obtained according to the previous generation of the stress point at different disturbances in the ln(1+e)-lgp double logarithmic coordinates:

$$\lg p_c{}' = \frac{\dfrac{\ln(1+e_0)-\ln(1+e_r)}{\lg p_c{}'-\lg p_{yr}{}'}+DC_{CLR}}{\dfrac{\ln(1+e_0)-\ln(1+e_r)}{\lg p_c{}'-\lg p_{yr}{}'}}\bullet \lg p_y{}' = \frac{M+DC_{CLR}}{M}\bullet \lg p_y{}' \qquad M=\frac{\ln(1+e_0)-\ln(1+e_r)}{\lg p_c{}'-\lg p_{yr}{}'} \quad (3—5)$$

Where:
The M was equal to the slope for any two different disturbance degree of yield stress point of attachment of soil slope;
The yield stress of soil at different disturbance degree in log-log coordinate was in a straight line for the same site soil samples. That was:

$$M=\frac{\ln(1+e_0)-\ln(1+e_r)}{\lg p_c{}'-\lg p_{yr}{}'}=\frac{\ln(1+e_0)-\ln(1+e_{y1})}{\lg p_c{}'-\lg p_{y1}{}'}=\frac{\ln(1+e_{y2})-\ln(1+e_{y1})}{\lg p_{y2}{}'-\lg p_{y1}{}'} \quad (3—6)$$

The initial yield stress p_c' of the original soil could be obtained by measuring the initial yield stress p_y' of the soil by the indoor test in the above equation (3-5). P_c' was taken into the formula (3-6). Because the M had been calculated at this time, the void ratio of e_0 of the undisturbed soil and the void ratio of e_r of the remolded soil were obtained.

According to the results of S. Leroueil et al. [8], $f(I_P)=C_u/p_y{}'=0.71+0.0045I_p$, that was:

$$Cu = f(I_P)p_y' = (0.71+0.0045I_p)\ p_y' \quad (3—7)$$

The soil strength C_u of the soil was obtained by taking the formula (3-5) into the formula (3-7); that was the yield stress of the soil was reverted into the soil strength C_u of the soil, and the soil strength C_u' could also be obtained with different disturbance degrees D.

4. Conclusions

The yield stress points of soil samples with different disturbances in ln(1+e)-lgp double logarithmic coordinates were in the same, and the relationship between the disturbance and the strength of the soil was analyzed according to the definition of volumetric compression method of Hong and Onitsuka and the results of M. Nagaraj and S.G.Chung. The expression both the disturbance degree and the strength for the soil were $\lg p_c{}' = (M+DC_{CLR})\bullet \lg p_y{}'/M$. The intensity of the disturbed soil sample could be reduced the in-situ strength according to this expression.

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