THESIS COMPENDIUM

- Full name of graduate student: Pham Van Hung
- School years: 2003 – 2006
-Title: ***Research on the stability and deformation of soft soil under flooded embankments in Mekong Delta.***
- Major: ***Geotechnical Engineering***
- Major code: ***2.15.03***
- Scientific guidance group: 1. Professor, Doctor of Science Le Ba Luong
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Content of thesis

A- Thesis Objective:

- To estimate the stability and deformation of soft soil under flooded embankments in Mekong Delta fully and more closely to the soft water saturated soil reality in the study area while the practice calculating creep settlement has not been issued yet by the Ministry Of Transport, the research content of this thesis focuses on solving issues such as research on creep shear of soft soil under flooded embankments in Mekong Delta due to shear stress, research on the scientific basis and practice of creep factor of safety (creep stability) due to shear stress, research on creep rate and the change of creep rate of sheared soft soil under embankments affected by the hydrodynamic pressure.
- This thesis also studies and solves the secondary settlement due to the vertical total stress and shear stress on soft soil under flooded embankments, studies the change of viscosity according to the soil structure in the creep shear due to shear stress, and studies signs represented by specific mechanical, physical indicators to identify soil layers in Mekong Delta which could have strong creep due to vertical total stress and shear stress.
- The new research content above is the basic research content solved and presented in this thesis.

B- The achieved research results:

1) Study theory and manufacture experimental equipment measuring moving soil viscosity according to the vane shear method with a slow shear speed.

Viscosity η is calculated from following formula:

$$\eta = \left(\frac{2M}{9.\pi.h^3.\Delta\omega} \ln|r| + \frac{M}{3.\pi.h^2.r.\Delta\omega} - \frac{M}{4.\pi.h.r^2.\Delta\omega} - \frac{2M}{9.\pi.h^3.\Delta\omega} \ln\left|\frac{2}{3}r + h\right| \right)\Bigg|_{r0}^{r1}$$

2) Based on the manufactured equipment and experiments conducted on many water-saturated soft clay soil samples in Mekong Delta, PhD student has found the law stating that the soil viscosity, after reaching its maximum value, decreases when creep displacement happens and when the the creep displacement turns into the sliding state which has the minimum viscosity. This experimental result is consistent with experimental results by means of the modified N.N. Maslov's plane shear testing method. Particularly:

- When being sheared, the initial viscosity $\eta^{ctr}_{đ}$ of the soft clay reaches its maximum value and decreases to a stable value η^{ctr}_{tr}, under a pressure of P = 0 kG/cm^2 the coefficient of viscosity decreases 13.9 times, under a pressure of P = 0,6 kG/cm^2 the coefficient of viscosity decreases 30,4 times, and under a pressure of P = 1,2 kG/cm^2 the coefficient of viscosity decreases 64,3 times.

3) Initial structural viscosity depends significantly the impact pressure level. From P=0 kG/cm^2 to P=1,2 kG/cm^2, this initial structural viscosity increases about 5 times and reaches its maximum value when the rotation angle is from 1^0 to 3^0. Final structural viscosity η^{ctr}_{c} and shear structural viscosity η^{ctr}_{tr} show an unclear dependence on the impact pressure level, they primarily depend on the soil type, soil consistence B and most importantly the pore gas content, however they always follow the law stating that the soil viscosity after increasing to reach its maximum value will decrease to its minimum value when the the creep displacement turns into the sliding state ($\eta^{ctr}_{đ}>\eta^{ctr}_{c}>\eta^{ctr}_{tr}$).

4) Based on N.M. Gerxevanov (1948) and Lomtadze's research results, Ph.D. Student has proved that the equation of the vertical creep strain for vertical total stress is consistent with Raymond & Wahls (1976)'s equation to calculate secondary settlement for vertical total stress, but yet more general and in special cases, Ph.D. Student's equation becomes the Raymond & Wahls's equation.

- The Ph.D. Student's general pure creep settlement equation in relationship with various levels of compression pressure and preconsolidation pressure is:

$$S_s = \frac{C_t.H_1}{(1+e_1).\ln\frac{\sigma_{2C}}{\sigma_{1C}}}.(\log t_2 - \log t_1)$$

Where, e_1 - the void ratio at time t_1, the end of primary consolidation, corresponding to some previous compression pressure.

H_1 - the depth of soil layer after the end of primary consolidation corresponding to some previous compression pressure.

t_1 - The time at the end of primary consolidation corresponds to the soil sample having the void ratio e_1 of the previous primary consolidation.

t_2 - time after the ending time t_1 of primary consolidation.

e_2 - the void ratio corresponding to the time t_2 of the creep period.

C_t - the secondary compression index is calculated from the following formula:

$$C_t = \frac{e_1 - e_2}{\log t_2 - \log t_1}.\ln\frac{\sigma_{2C}}{\sigma_{1C}}$$

C_α - the coefficient of secondary compression is calculated from the following formula:

$$C_\alpha = \frac{C_t}{(1+e_1).\ln\frac{\sigma_{2C}}{\sigma_{1C}}}$$

σ_{1C} - level of compression pressure causing the primary consolidation strain and creep is usually taken from the pre-consolidated pressure. $\sigma_{1C} = \sigma_p$

σ_{2C} - the desired compression pressure causing creep strain due to the impact of construction loads. The compression pressure σ_{2C} under structure foundation is chosen according to the average value of each layer in agreement with the effective normal stress diagram in active zone. Large creep strain will take place in the zone of higher compressive stress than pre-consolidated compressive stress. $\sigma_{2C} \equiv \sigma_Z$

$\ln\frac{\sigma_{2C}}{\sigma_{1C}}$ - Dimensionless creep parameter

5) Based on N.N. Maslov's creep threshold $\tau_{lim} = \sigma tg\,\varphi + c_c$ and stability condition of creep shear: $\int_L \tau.dl \le \int_L \tau_0 dl = \sigma tg\,\varphi + c_c$

Ph.D. Student has researched and proposed formulas evaluating the creep stability condition and creep assurance factors:

- The general formula for calcualting the assurance stable factor F of creep shear:

$$F = \frac{\sum \left(W.tg\varphi_{cu}^{tb} + l.c_{cu}^{tb}.\cos\alpha\right).\frac{1}{m_\alpha}}{\sum W.\sin\alpha};$$

where: $m_\alpha = \cos\alpha + \frac{1}{F}\sin\alpha.tg\varphi_{cu}^{tb}$

- F is also the coefficient of soil's mobilized shearing resistance strength:

$$F = \frac{\tau_0}{\tau_{0m}} \qquad \tau_0 = \sigma.tg\varphi + c$$

τ_{0m}: Enough-mobilized shearing resistance strength which is equilibrium with the shear stress at the section under consideration.

$$\tau_{0m} = \frac{\tau_0}{F} = \frac{\sigma.tg\varphi + c}{F}$$

$$tg\varphi_m = \frac{tg\varphi}{F} \qquad c_m = \frac{c}{F} \qquad \tau_{0m} = \sigma.tg\varphi_m + c_m$$

c_m: mobilized adhesive force; φ_m: mobilized friction angle

- In the case which the live load p is under consideration, the formula is:

$$F = \frac{\sum \left[(W + p).tg\varphi_{cu}^{tb} + l.c_{cu}^{tb}.\cos\alpha\right].\frac{1}{m_\alpha}}{\sum (W + p).\sin\alpha}$$

- In the case of any shear plane with considered interaction force:

  From $E_p = E_t + E$:

$$T_0 = \frac{1}{F}\left(\frac{W.tg\varphi_{cu}^{tb} + l.c_{cu}^{tb}.\cos\alpha}{\cos\alpha + \frac{1}{F}.\sin\alpha.tg\varphi_{cu}^{tb}}\right)$$

$$\Delta E = \left(\sin\alpha - \frac{1}{F}.\cos\alpha.tg\varphi_{cu}^{tb}\right).N - \frac{1}{F}.l.c_{cu}^{tb}.\cos\alpha$$

- In the simple case of circular shear plane with center O and radius R

  From the shear & shear resistance moment equilibrium equation:

$$F = \frac{\sum \left(W.tg\varphi_{cu}^{tb} + l.c_{cu}^{tb}.\cos\alpha\right).\frac{1}{m_\alpha}}{\sum W.\sin\alpha} \qquad m_\alpha = \cos\alpha + \frac{1}{F}.\sin\alpha.tg\varphi_{cu}^{tb}$$

On the basis of above theoretical research and tests in place and in laboratory, Ph.D. Student has proposed to calculate assurance stable factor of creep shear in the following cases:

$$B < 0.55; \varphi_w \approx 10^0; C_w \approx 0.2kG/cm^2; C_c \geq 0{,}08kG/cm^2 thì F_s = 1.7 \div 1.8$$

$$B > 0.55; \varphi_w < 10^0; C_w < 0.2kG/cm^2; C_c \leq 0{,}08kG/cm^2 thì F_s = 1.8 \div 2.5$$

6) On the basis of above theoretical research and tests in place evaluating creep shear and creep stability due to shear stress of soft soil under flooded embankments in Mekong Delta, graduate student has evaluated vertical settlement because creep shear and shear stress causes untill creep shear stops (the stable creep case) at a displacement angle about $2^0 \div 3^0$ which accounts for 16,6 ÷ 22% the total settlement. The creep shear rate, shear rate (when the creep stability is lost) are calculated by the following formulas:

$$V_{tb} = \frac{\gamma}{\eta}\frac{H^2}{2}(\sin\alpha - \cos\alpha tg\varphi) - \frac{c_c}{\eta}H$$

$$V_{tr} = \frac{\gamma}{\eta}\frac{H^2}{2}(\sin\alpha - \cos\alpha tg\varphi)$$

The creep rate has its value about V_{tb}=0.0869 cm/day when not concerning the hydrodynamic pressure, V_{tb}=0.161 cm/day when affected by the hydrodynamic pressure.

7) Besides the parameters, pre-consolidated pressure or the coefficient of pre-consolidated pressure OCR, the void ratio, Ngoài các thông số áp lực tiền cố kết hay hệ số tiền cố kết OCR, hệ số rỗng, soil consistence B, graduate student has proposed a formula calculating the pore gas content. Tests in place and in laboratory evaluate have given the results that when the ratio v_a/v > 4,5% (v_a : the volume of pore gas, v: the volume of soil), the soft soil in in Mekong Delta is easy to lose creep stability and has a large creep settlement value due to shear stress and vertical total stress.

Ho Chi Minh City, March 20, 2012

Scientific Advisor 1	Scientific Advisor 2	PhD. Student
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