V-218 RELATIONSHIP BETWEEN E_{50} AND E_P OF LIME-TREATED ARIAKE CLAY BY FINITE ELEMENT METHOD

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1. INTRODUCTION

Unconfined compression test is a common test to determine the unconfined compressive strength of stabilized base and subbase materials. Meanwhile, deformation modulus of the stabilized materials is often evaluated by secant modulus of elasticity E_{50} in geotechnical engineering. However, modulus of elasticity from plate loading test, E_P, is adopted in pavement structure analysis preferably. In the study, a finite element method (FEM) is proposed to examine the relationship between the secant modulus of elasticity from unconfined compressive tests E_{50} and the modulus of elasticity from plate-loading test E_P. Hyperbolic model, a non-linear elastic model, is assumed, and parameters needed for the hyperbolic model were calibrated for the lime-treated Ariake clay with fly ash (LAF) from unconfined compressive test data[1].

2. ANALYSIS MODELS

Material model[2]

Hyperbolic model of the strain-stress relationship is as follow:

$$(\sigma_1 - \sigma_3) = \varepsilon / (a + b\varepsilon) \quad (1)$$

in which σ_1 and σ_3 = the major and minor principal stresses; ε = the axial strain; and a and b = constants whose values may be determined experimentally. If equation (1) is transformed as the following linear relationship between $\varepsilon/(\sigma_1 - \sigma_3)$ and ε, equation (2), then a is reciprocal of the initial tangent modulus, E_I, and b is the reciprocal of the asympotatic value of stress difference which the stress-strain curve approaches at infinite strain $(\sigma_1 - \sigma_3)_{ult}$

$$\varepsilon/(\sigma_1 - \sigma_3) = a + b\varepsilon \quad (2)$$

In unconfined compressive test σ_3=0. The tangent modulus, E_t at any point on the stress-strain curve are conveniently expressed as

$$E_t = (1 - R_f\ \sigma_1 / q_u)^2\ E_I \quad (3)$$

where $R_f = (\sigma_1 - \sigma_3)_f / (\sigma_1 - \sigma_3)_{ult}$, and $(\sigma_1 - \sigma_3)_f$ is the failure strength, q_u in the unconfined compression test. All the parameters in equation (3) can be obtained from the unconfined compression test.

FE Models

FE models of plate-loading test and uniaxial test used in the study are axisymmetric. For plate-loading test, the width of the model is 1.5 m. The depth is 1.95 m. For uniaxial test, the model is 2.5 cm in width 10 cm in depth. A linear strain quadrilateral element is used for the two cases. Totally, 64 elements are adopted for plate-loading test. However, only two equal size elements are used for the uniaxial test. Boundary conditions are applied in such ways that no vertical displacement at the bottom and no horizontal displacement at the right side and the axisymmetric axle for plate-loading test. No vertical displacement for uniaxial test in addition to the axisymmetric as well is assumed.

Calibration of hyperbolic model

Using the required mathematical formulas, parameters necessary for the simple hyperbolic model of the LAF are calibrated by means of the unconfined compression test data. Fig.1 is an example of the calculated stress-strain curve by the FE model with calibrated parameters together with experimentally determined stress-strain curve for two cases. One is for the case with 10 % lime content after 7 days curing. The other is that with 30% lime content after 28 days curing. The stress-strain relation from tests in both cases can be fitted well by a hyperbolic model, especially when the lime content is lower and within the scope of stress level interested in pavement.

Keywords: FEM, pavement material, hyperbolic model, unconfined compression test, plate-loading test
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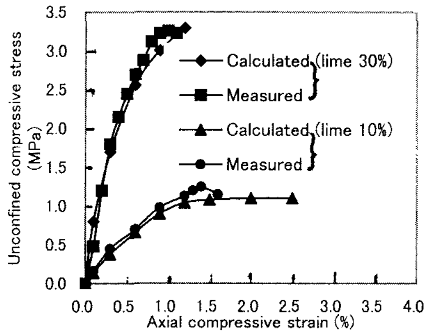

Fig.1 Measured and calculated curves of the stress -strain of the LAF

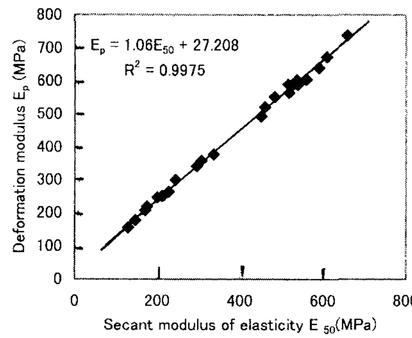

Fig.2 Relationship between E_{50} and E_p of the LAF

3. RESULTS AND DISCUSSIONS

Deformation modulus from the unconfined compression test is defined by the ratio of the half of the maximum unconfined compressive strength σ_m to the corresponding vertical axial compressive strain ε.

$$E_{50} = \sigma_m / 2\varepsilon \quad (4)$$

With regards to the plate-loading test, deformation modulus of tested materials is calculated using the following equation based on elastic theory.

$$E_p = \pi\, p\, a\, (1-\mu^2)/2\delta \quad (5)$$

where p is the average pressure exerted on the plate, a, the radius of the plate (0.15 m in the study), δ, the displacement corresponding to the pressure and μ, Poisson's ratio of the material (0.3 in the study). The ratio of p/δ is not a constant at different pressure of the calculated p-δ curve due to the non-linearity of materials. Consequently, the value of E_p varies with the pressure or the displacement concerned. Just like the tangent modulus of the material, the value is dependent on the stress state. In the study, it is calculated when the displacement reaches 1.25 mm, a limit as subbase in pavement structure.

Figure 2 shows the relationship between the secant modulus of elasticity from unconfined compression test FE model and the modulus of elasticity from plate loading test FE model using the calibrated parameters. It is indicated that they are related well by a linear line as seen in the figure. The regression representing the relationship between the secant modulus from the unconfined compression test E_{50} (MPa) and the deformation modulus from plate-loading test E_p (MPa) for the LAF mixture is proposed as follows:

$$E_p = 1.06\, E_{50} + 27.2 \quad (6)$$

4.CONCLUSIONS

Finite element method can be employed to investigate the numerical relationship between the secant modulus of elasticity E_{50} and the deformation modulus E_p of the lime-treated soft clay. E_p necessary for the determination of layer equivalent factor can be evaluated from the secant modulus of elasticity from the unconfined compressive tests, E_{50} on the basis of the relationship between two modulus of elasticity.

Regression between the two moduli of elasticity is proposed for the LAF. The numerical regression of the E_{50} and E_p indicates that E_p is larger than E_{50} in magnitude and increase linearly with the E_{50}. The ratio of E_p / E_{50} decrease with the increase of E_{50}.

5.REFERENCES

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