ON THE TEST OF THE MODULUS OF RUPTURE OF SOIL SAMPLE

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SYNOPSIS

This paper presents the relation between the modulus of rupture and the unconfined compressive strength. To obtain this relation, the undisturbed and disturbed soil samples have been used. The test for modulus of rupture is very simple and the necessary amount of sample is not so much, and the reliance of this test is the same as the unconfined compression test.

INTRODUCTION

When the load was applied on a cylindrical sample in the direction of a diameter of a cylindrical sample as shown in Fig. 1, the crack of failure appeared generally along the diameter in the direction of loading. This crack was caused by the tension perpendicular to the direction of loading and was closely connected with the following value of σ_t .

$$\sigma_t = \frac{2P}{\pi dl} \dots\dots\dots (1)$$

- where σ_t : Modulus of rupture (kg per sq cm)
 P : Value of load at which the test piece breaks (kg)
 d : Diameter of the test piece (cm)
 l : Length of the test piece (cm)

This method has been already used for determining the strength of the concrete, and the value of σ_t is nearly equal to the pure tensile strength. As soil is less elastic than concrete, the value of σ_t is not considered to show the pure tensile strength, but it can be said that this value should have some relations to the strength of soils.

The test of the modulus of rupture is the simplest among the soil tests, namely the time required for test is short and the necessary amount of soil sample is not so much. This research has been carried out to obtain the relation between the values of σ_t and the values of the unconfined compression strength. The samples used were undisturbed and disturbed soils.

THE TEST FOR THE UNDISTURBED SAMPLES

The experiment was carried out at the rice-field of the right bank of the Rokkaku-river in Tachibana, Takeo City, Saga Prefecture. The samples were soft clayey soil

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Fig. 1. Explanatory Figure of the Test

of the Ariake seaside, and were taken out by thin walled tube. The test of the modulus of rupture and the unconfined compression test were performed at the site immediately after the samples were taken out. The physical properties of the samples are as follows :

Grading	2.0~0.05 mm	3.7~16.0%
	0.05~0.005 mm	49.5~63.0%
	0.005 mm~	24.0~41.5%
Specific gravity		2.58~2.70
Liquid limit (moist sample)		69~113
Plasticity index (moist sample)		36~ 69

The testing machine was a strain-controlled unconfined compression apparatus, and the velocity of compression was 2.0 mm per min in every case. For the test of modulus of rupture, the diameter of the test piece was 7.4~7.5 cm and the length was about 1/2 and 1/3 of diameter. In this case 1/1.8~1/2.2 were regarded as 1/2 group, and 1/2.8~1/3.2 were regarded as 1/3 group. For the unconfined compression test, the diameter of the test piece was 5.0~5.1 cm and the length was 10.4~12.0 cm.

The cracks in the test piece occurred mostly along the diameter in the direction of loading as expected, therefore, the equation (1) could be used, But for the soil as disturbed soft clay which does not show brittle failure, and as the vertical crack appears at the large deformation, the application of the equation (1) is not proper.

The results of the above-mentioned test are showed in Fig. 2, and the relations between the modulus of rupture σ_t (kg per sq cm) and the unconfined compressive strength σ_c (kg per sq cm) are as follows :

For the test pieces of $\frac{\text{length}}{\text{diameter}}$
 $= 1/1.8 \sim 1/2.2$
 $\sigma_t = 0.145\sigma_c \dots\dots\dots (2)$

For the test pieces of $\frac{\text{length}}{\text{diameter}}$
 $= 1/2.8 \sim 1/3.2$
 $\sigma_t = 0.152\sigma_c \dots\dots\dots (3)$

It is already known that the relation between $\log \sigma_c$ and the natural void ratio is linear as in Fig. 3. Similarly, the relation between $\log \sigma_t$ and the natural void ratio is linear as in Fig. 4.

THE TEST FOR THE UNDISTURBED SAMPLES

The sample was red sandy loam which was obtained at Shingu-cho, Kasuyagun, Fukuoka Prefecture, and the properties of this sample were as follows :

Fig. 2. Relation Between the Modulus of Rupture and the Unconfined Compressive Strength

Fig. 3. Relation Between the Unconfined Compressive Strength and the Natural Void Ratio

- $\frac{\text{Length}}{\text{Diameter}} = \frac{1}{1.8} \sim \frac{1}{2.2}$ (Diameter 7.4~7.5cm)
- × $\frac{\text{Length}}{\text{Diameter}} = \frac{1}{2.8} \sim \frac{1}{3.2}$ (Diameter 7.4~7.5cm)

Fig. 4. Relation Between the Modulus of Rupture and the Natural Void Ratio

Grading	2.0~0.05 mm	66%
	0.05~0.005 mm	24%
	0.005 mm~	10%
Specific gravity		2.68
Liquid limit		51
Plasticity index		13

A strain-controlled unconfined compression apparatus was used for the unconfined samples, and the velocity of compression was 1.0 mm per min in every case. For the test pieces of the test of modulus of rupture, the diameter were 3.35 cm and 5.0 cm and for both diameters the ratios of length to diameter 1 and 2 were adopted. For the unconfined compression test, two kinds of test pieces were used, namely diameter 3.35 cm, length 6.70 cm and diameter 5.0 cm, length 10.0 cm. The former corresponded to the test of modulus of rupture for diameter 3.35 cm and the latter corresponded to the similar test for diameter 5.0 cm. Moisture contents of the samples were 10~30% with intervals of about 2%. Compaction was carried out by tamper.

The cracks at the test of modulus of rupture appeared vertically similar to the case of undisturbed samples.

For the samples of the same dry density and moisture content (allowable errors were ± 0.02 g per cu cm for dry density, and $\pm 0.5\%$ for moisture content), we obtained relations shown in Fig. 5 and Fig. 6. The relations between the modulus of rupture σ_r and the unconfined compressive strength σ_c are as follows:

Case of diameter 3.35 cm.

For the test piece of $\frac{\text{length}}{\text{diameter}} = 1.0$

$$\sigma_t = 0.140\sigma_c \dots\dots\dots (4)$$

For the test piece of $\frac{\text{length}}{\text{diameter}} = 2.0$

$$\sigma_t = 0.154\sigma_c \dots\dots\dots (5)$$

Case of diameter 5.0 cm.

For the test piece of $\frac{\text{length}}{\text{diameter}} = 1.0$

$$\sigma_t = 0.134\sigma_c \dots\dots\dots (6)$$

For the test piece of $\frac{\text{length}}{\text{diameter}} = 2.0$

$$\sigma_t = 0.138\sigma_c \dots\dots\dots (7)$$

Fig. 5. Relation Between the Modulus of Rupture and the Unconfined Compressive Strength (diameter 3.35 cm)

Fig. 6. Relation Between the Modulus of Rupture and the Unconfined Compressive Strength (diameter 5.0 cm)

CONSIDERATION

We can make the following equations between σ_t and σ_c from the equations (2) to (7).

$$\sigma_t = 0.14 \sim 0.15\sigma_c \dots\dots\dots (8)$$

or

$$\sigma_c = 7\sigma_t \dots\dots\dots (9)$$

For the test of modulus of rupture cracks appear earlier than for the unconfined compression test. The time required for the former is usually 1/2 to 1/3 in comparison with the latter. If the test piece is brittle, the failure takes place from cracks in both tests, but the judgement of appearance of crack is easier at the test of modulus of rupture. The reliance of the tests is thought as almost same from the result and in Figs. 3 and 4.

One more merit of the test of modulus of rupture is that the necessary amount of sample is not so much. It is convenient that the length of the test piece is about one half or one third of diameter for the test.

For the problems on the soft foundation, the results of unconfined compression test are generally used for calculation. Then, the test of modulus of rupture can be used for practical purposes applying equation (9).

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