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Mechanical properties in short-fibers mixture stabilized volcanic cohesive soil

M. Kudo
Department of Civil Engineering, Oita National College of Technology, Oita, Japan

H. Ochiai & K. Omine
Department of Civil Engineering, Kyushu University, Fukuoka, Japan

ABSTRACT: Short fiber-reinforced soil, which is made up of the mixture of low quality soil materials with short fibers of polyester and polypropylene, can improve the mechanical properties and erosive resistance of materials. The stabilized soil has been known to increase strength properties, but not to reach satisfactory expectation. Therefore, the above soil is considered to mix with the stabilized soil. In the present study, short fibers are mixed with the stabilized soil of volcanic-cohesive soil in order to examine the influence on the strength-deformation properties.

1 INTRODUCTION

The short fiber-reinforced soil is the material mixed with short fibers such as polyester and polypropylene with the lengths from dozens of to hundreds of millimeters, and with thickness of about 1~100D. This soil can enhance such the advantageous quality as the mechanical properties and erosion-resistance (Miki,H., Fujii,K. and Obata,T, 1997), especially, it is effective on the soil with low quality materials to be employed.

By mixing short fibers with the stabilized soil of the volcanic-cohesive soil, the effect of the kinds of the stabilizer, added amount of the stabilizer, the length of the short fibers, the mixed amount of short fibers etc. upon the strength-deformation properties was examined in the present study.

2 SAMPLE SOIL AND EXPERIMENTAL METHOD

The specimen used in this test is "Kuroboku" soil, which is the volcanic cohesive soil in Kyushu District, and collected near Taketa City in the southwestern part of Oita Prefecture. Table-1 shows the physical properties of the soil. The specimen was collected in the disturbed state, and the natural water content was 110%. The short fibers used were made of polyester with thickness 6de(diameter 25μm) and the length 15mm and 30mm. The amount of fiber-mixture was set as 0.25%, 0.5% and 1.0% per dry weight of the soil. The stabilizers employed were the cement stabilizer (cement) and the lime stabilizer (lime), and the added amount was 2%, 5%, 15.6% (equivalent to 100kg/m^3), and 31.2% (equivalent to 200kg/m^3) per dry weight of the soil. The test specimens were prepared by mixing about 300gram of Kuroboku soil containing natural water content and 2%, 5%, 15.6% and 31.2% of stabilizer, respectively. Each stabilizer mixed with the above fixed quantity of short fibers was disentangled with thumbs and fingers and carefully mixed uniformly. The test specimens were made by the practice of "Making and Curing Statically Compacted Stabilized Soil Specimen (JGS 0812-2000)". The target of the compaction-degree was for the dry density to become more than 90% of the maximum density. The standard dimension of a specimen was 5cm in diameter, and 12cm in height. A mold was made of a cylinder of vinyl chloride divided into three equal parts in the vertical direction and wrapped from outside by another cylinder. And the specimen in the mold was cured for seven days. After that, unconfined compression tests were carried out with the loading rate of 1% /min. of compression strain. In addition, the direct shear test was carried out to check the cohesion and the angle of shear resistance. The specimen for direct shear test was made in the similar way as the practice of "Test Method for One-dimensional Consolidation Properties of Soils (JGS 0411-2000)". The standard dimension of the specimen was 6cm in diameter, and 2cm in height. After

Table1. Physical properties of Kuroboku soil.

density of soil particles (Mg/m^3)	2.367
liquid limit (%)	152.4
plastic limit (%)	93.95
plasticity index	58.45
maximum dry density (Mg/m^3)	0.638

cured for seven days, the direct shear test was carried out with the loading rate of 1% /min. of shear strain.

3 RESULTS AND DISCUSSION

Typical stress-strain curve is shown in Fig-1 and Fig-2. While the usual soil generates the brittle failure abruptly after the peak strength, the soil mixed with short fibers shows the increase of strength, the increase failure strain and keeps the strength in spite of the progress of the strain.

Fig-2 is the stress-strain curve when a large amount of stabilizer is added. In Fig-2, though the strain at peak strength of short fiber mixed soil is smaller than that of the usual one, each stress-strain curve of stabilized soil shows almost the same gradient near the part of the starting point of the curve. From this, it can be considered that the influence of the increase in the modulus of deformation due to the stabilization is bigger than that of the increase in the strain due to the fiber mixture.

The stabilized soil mixed with short fibers shows the effect of the stabilization at the level of small strain, and, as the strain becomes larger, the effect by short fiber mixture appears. Fig-3 and Fig-4 show the relationship of the peak strength between the mixed and not mixed. The vertical axis in Fig-3 shows the value q_u / q_{us0}. Here q_u is the peak strength of the stabilized soil mixed with short fibers, and q_{us0} is the peak strength of the stabilized soil in which only stabilizer mixed. The horizontal axis is index value (= nxL / D n: amount of addition, L: length of short fiber, D: thickness). (Miki,H., Fujii,K. and Obata,T, 1997) Index value is the one which judges the effect on reinforcement quantitatively by the difference in the length and thickness, and amount of mixture. The vertical axis in Fig-4 shows the value q_u / q_{u0}. Here q_u is the peak strength of the stabilized soil mixed with short fibers, and q_{u0} is the peak strength of usual soil. Fig-3 shows that the increase-rate of strength rises uniformly in proportion to the index value, irrespective of the existence of stabilizer, the kinds, and the added amount.

Fig.4 shows that the peak strength of specimen with lime 15.6%(equivalent to 100kg/m^3) added expresses the same peak strength of the specimen

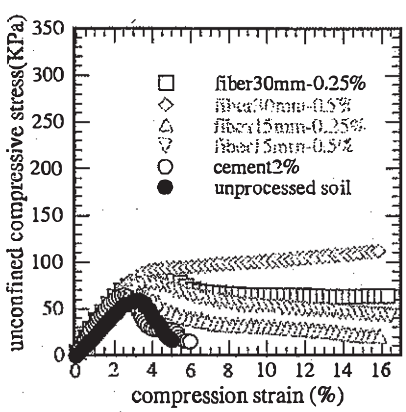

Figure 1. Stress-strain curve (quantity of cement addition 2%).

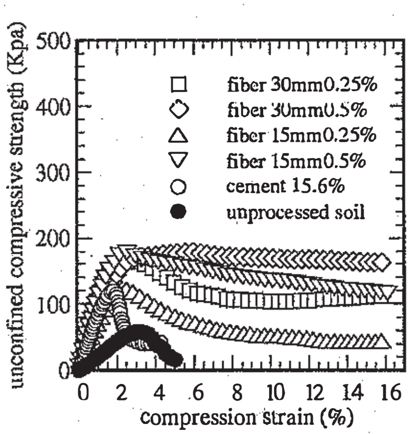

Figure 2. Stress-strain curve (quantity of cement addition 15.6%).

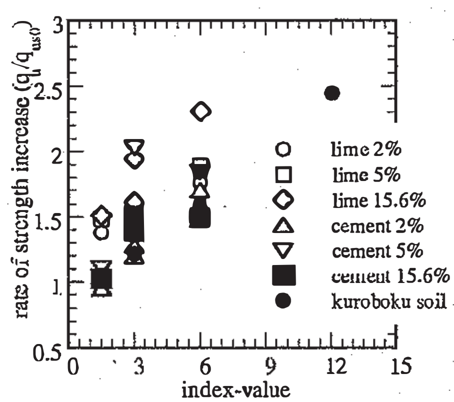

Figure 3. Rate of strength increase (q_u/q_{us0}).

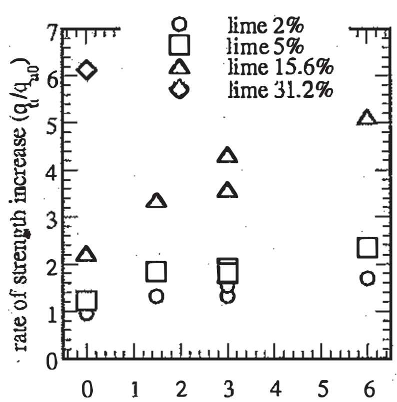

Figure 4. Rate of strength increase (q_u/q_{u0}).

mixed with 5% lime and the short fibers with index value 6. The specimen added 31.2% of lime(200kg/ m^3) also shows the same phenomenon when the specimen with 15.6% lime is mixed with short fibers with index value 6. The above shows that the specimen with combination of the stabilizer with smaller amount and the short fibers can produce the same strength as the strength of the soil processed only by the usual stabilization.

Among the mechanical properties, it is well known that the mixture of short fibers can improve toughness of the soil. The relationship between the residual rate of the strength and index value is shown in Fig.5., and from this figure the increase of toughness can be confirmed. The vertical axis in Fig.5 is the value, when the unconfined compression strength $q_{u15\%}$ in the compression strain 15% of each fiber mixture soil was divided by the peak strength q_u. From Fig.5, according to the growth of the index value, the residual rate of strength approaches 1 and the residual strength can be expected even if big strain occurs. But, when the index value is 6, the residual rate of strength becomes 1, so that the effect cannot be expected even if the index value is enlarged any farther.

Relationship between the change of the rate of modulus deformation and the index value is shown in Fig-6. Vertical axis of the Fig-6 is the value (E_{50} / E_{50S0}); the modulus deformation E_{50} of fiber mixture stabilized soil was divided by the modulus deformation $E_{50S0}$of stabilized soil. Modulus deformation show a tendency of increasing when index value grows big, but, as the modulus deformation can be thought to be greatly influenced by stabilization, a new value (E_{50} / $E_{50\text{-}0}$) which is obtained from the division of the modulus deformation E_{50} of fiber mixture stabilized soil by the modulus deformation $E_{50\text{-}0}$ of usual soil is expressed on the vertical axis in Fig.7. From this figure, the increase of modulus of deformation is thought to be due to the stabilization. Hence, the influence to the modulus of deformation by short fiber mixture is small at the level of a large amount of stabilizer addition, while the increase, though very little, can be seen by the influence of the short fiber mixture at the level of small amount of stabilizer addition.

Relationship between the cohesion and the index value is shown in Fig-8. Although the cohesion is considered to be greatly influenced by stabilization, Fig. 8 shows that the cohesion also tends to increase

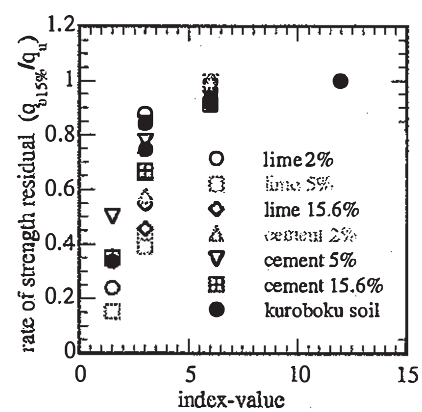

Figure 5. Rate of strength residual (q_u/q_u).

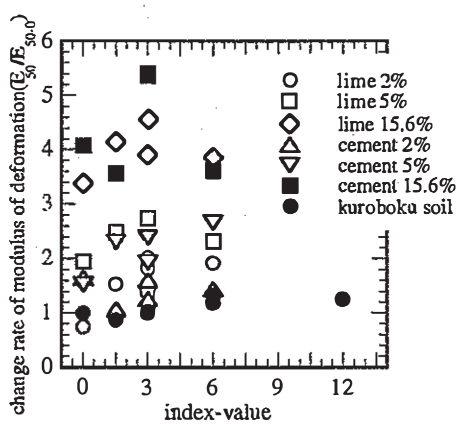

Figure 7. Rate of modulus of deformation change ($E_{50}/E_{50\text{-}0}$).

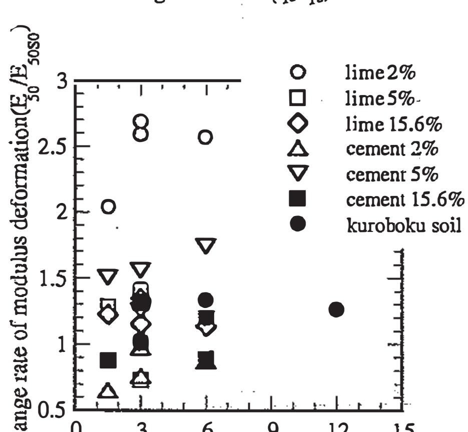

Figure 6. Rate of modulus of deformation change (E_{50}/E_{50S0}).

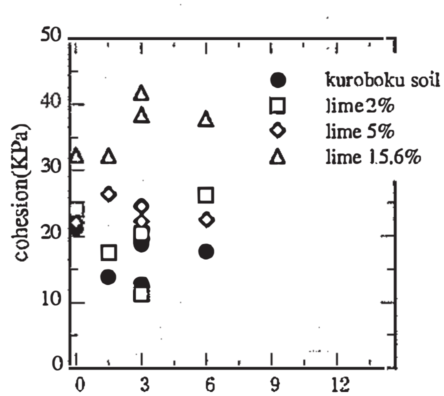

Figure 8. Change of cohesion.

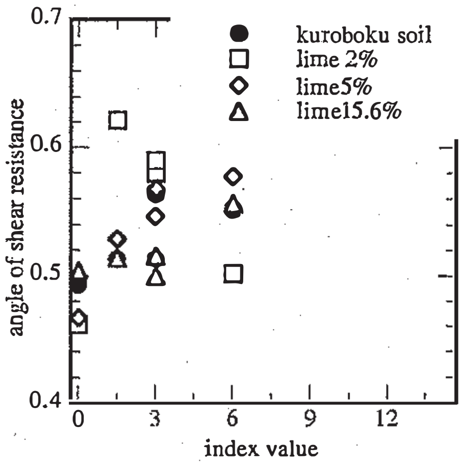

Figure 9. Change of angle of shear resistance.

according to the increase of the index value. The relationship between the angle of shear resistance and the index value is shown in Fig-9, which shows that the angle of shear resistance tends to increase according to the increase of the index value, regardless of the addition of stabilizer. By Fig. 8 and 9, the improvement of strength properties of the soil is confirmed by the mixture of the short fibers.

4 CONCLUSION

The results obtained can be summarized as follows.

1 The strength is increased by mixing fibers, regardless of the existence of the stabilizer, and the added sort and amount.

2 The strength of the stabilizer mixed with short fiber efficiently is about the same as the strength of the stabilizer without any short fibers added with a large quantity of stabilizer.

3 The short fiber-reinforced soil of stabilized soil has shown the effect of stabilization at small strain level, and, as the strain becomes larger, the effect of fiber-mixing appears more and more and the toughness is improved.

4 The deformation-coefficient of the short fiber-reinforced soil is greatly influenced by the increase of the coefficient by stabilization and the influence of increase of the deformation coefficient by fiber mixing is not so large.

REFERENCE

Miki,H., Fujii,K. and Obata,T, 1997. Joint Research on Development of High Grade Soil - Design and Construction Manual of Fiber Mixed Soil Method - (in Japanese) Cooperative Research of PWRI, 1997.