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Shear behavior of decomposed granite soil reinforced with fibre

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ABSTRACT: Fibre has been used frequently for the improvement of soft soil because of its capability of drainage and filtering as well as simple construction, Especially, the effect of fibre on soil improvement has brought engineer's attentions and experimental studies have been carried out in order to examine its applicability and compatibility(Guide 1985). Even though these studies have proved the applicability, simplicity and economical efficiency of construction, the characteristics of shear behaviour, which plays a role in analysis of stability of reinforced soil have not properly evaluated because of its complexity. Therefore, it is necessary to investigate the characteristics of the behaviour reinforced soil mechanically and physically through the laboratory and in-situ tests. Among them, mechanical study is generally adopted rather than physically approach because the latter has limitation in time and cost. In contrast, laboratory tests have difficulty conducting the same condition as in-situ. Nevertheless, many researchers prefer to laboratory test because failure mechanism of soil can be investigate by comparison of the results from experiments and theory.

In this study, a series of experiments were conducted on decomposed granite soil with/without reinforcement. In addition, Numerical approach using modified Cam-clay model was performed in order to predict the behaviour of decomposed granite soil.

1 INTRODUCTION

Ground improvement using fibre has gained popularity because of not only its advantages in drainage, separation and filtering but also simple construction. Among of advantages of fibre, the effect of improvement has brought primary concern to engineers, and therefore several experimental researches have been carried out to examine the applicability and validation of fibre (Broms, 1977. Guido, et al. 1985). From these researches, the economical efficiency and simplicity has been verified.

Nevertheless, the characteristics of shear behaviour which play an important role in stability analysis of reinforced soils have not clarified because of complexity yet. This brings immediate requirement for reinforced soils to be verified physically or mechanically by means of field tests and laboratory tests. Since the former, however, has difficulties in time and cost, most of experimental researches tend to be limited to the laboratory tests. In fact, the laboratory test has also difficulties that can not reproduce the same conditions as in field, and it is inevitable that there is an error between personal.

And but yet, it is widely used up to date from the point that the failure mechanism of soil can be verified easily through comparative analysis between theoretical and experimental results.

In this study, a series of experiments were conducted on decomposed granite soils with/without fibre reinforcement. In addition, numerical approach using modified cam-clay model was performed in order to predict the behaviour of decomposed granite soils.

2 EXPERIMENT

2.1 *Material*

Since the properties of granite soil such as particle size vary according to treatment and testing method, it is necessary to adjust the same conditions of sample soils as in field before tests. In addition, since the methods of sample preparation have great effect on the behaviour, much caution is required to secure uniformity. In order to secure the uniformity of sample soils the preliminary treatment, in which every 500 g of sample granite soils being passed through the sieve number four is filled in each bag and dropped 30 times by gravity from 2 m height, is performed. After the preliminary treatment, the soils are passed through the sieve number ten. Using this sample soil, all the specimens were prepared with the optimum moisture content.

2.2 *Test*

In order to investigate the effect of fibre reinforcement on granite soil, a series of consolidation-undrained(CU) tests with stress control were carried out. The elastic modulus of fibre used in these tests was 9.8 MPa. Also, the ration of length to diameter of a specimen was set to 2 in order to minimize the frictional resistance.

In case of dynamic compaction, it is very difficult to prepare a specimen because the particle distribution may be changed due to parcel crush, and the specimen can hardly stand by itself. Therefore, all the specimens were prepared by means of Harvard compactor that has dimensions 7.16 cm in height and 3.33 cm in diameter.

Having place a specimen in triaxial testing chamber, Co_2 and back pressure were used to saturate the specimen. By injection of Co_2 into the specimen, entrapped air can be removed much easier. The specimen was assumed to be fully saturated when the coefficient of pore water pressure, B, reaches over 0.95. After saturation, the specimen was consolidated isotropically for 60 minutes. This consolidation time was determined from preliminary tests. In other words, the compress of specimen was completed in 60 minutes. Four different confining pressures which are 70, 100, 130 and 160 kPa were used. The properties of material are shown in Table 1. Table 2 shows the specimen with different conditions of fibre reinforcements.

Table 1. Material property.

γd_{max} (kN/m^3)	OMC (%)	LL, PL (%)	Percent passing #200 (%)	Gs	USCS	G/T Tensile strength (kN/m^2)
16.95	14.27	NP	20.60	2.71	SM	980

2.3 *Results*

Figure 1 shows the relationship between deviator stresses and axial strains according to the reinforcement locations and layers. The figure presents that the strengths appear to increase with an increase of layers. It also indicates that the locations have great effect on reinforcement. From these observations, it may be concluded that the strengths of soil is dependent not only on the location of fibre but also on the number of layers.

Table 2. Specimens with different fibre reinforcement.

	Case 1	Case2	Case3	Case4	Case5
Sample					

Table 2. Continued.

	Case6	Case7	Case8	Case 9
Sample				

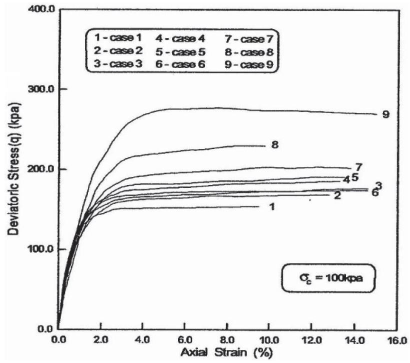


Figure 1. Results of triaxial compression tests with different locations of fibre reinforcement.

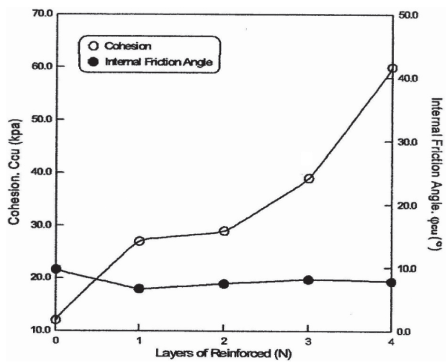


Figure 2. Changes in Cohesion (C_{CU}) and frictional angle (Φ_{CU}) with respect to layers.

The changes in cohesion (C_{CU}) and frictional angle (Φ_{CU}) with respect to the number of reinforcement layers are shown in Fig. 2.

According to this figure, the cohesion seems to increase with an increase of the number of layers while the frictional angles appear to remain constant apparently. This may indicate that fibre has much effect on the cohesion of soil than the frictional angle. Fig. 3 represents the ratios of stresses with respect to the number of layers, the ratio of the space length (d) to specimen height (H), and the ratio of the space length (d) to the diameter of loading cap. From the figures, it may be observed that the stress ratios seem to increase with a decrease of the space ratios. This might be because that the effect of surface friction becomes smaller as the ratios (d/H, d/D) get larger before the surface friction develops large enough. In addition, the stress ratios tend to decrease rapidly when the ratio of the space length to the specimen height (d/H) is less than 0.3 as well as the ratio of the space length to the loading cap diameter (d/D) is less than 0.7.

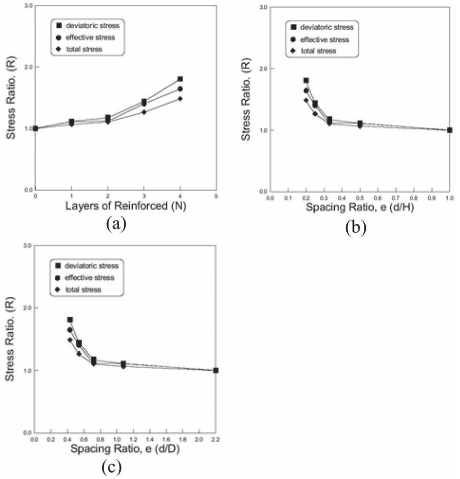
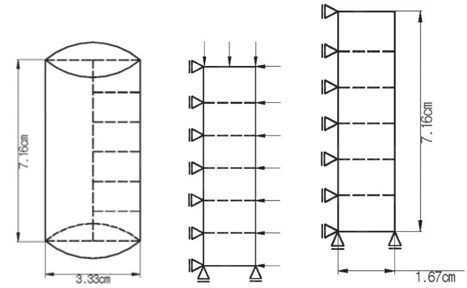


Figure 3. Changes of stress ratios in reinforced layers and spacing ratios.



(a) Model specimen (b) Boundary condition

Figure 4. Model specimen and boundary conditions.

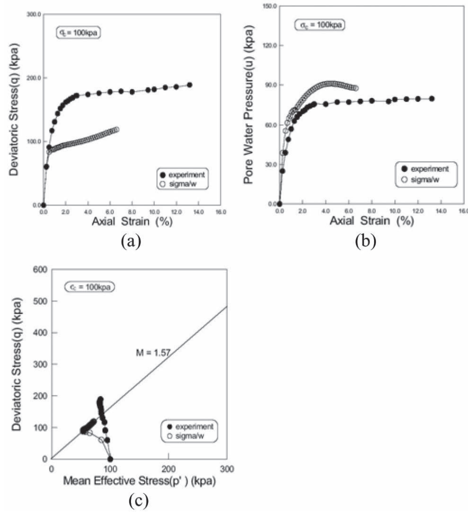


Figure 5. (a) Deviator stress vs. axial strain, (b) pore water pressure vs. axial strain, (c) deviator stress vs. mean effective stress.

3 FEM ANALYSIS

3.1 *Boundary conditions*

FEM analysis had been performed with axisymetry condition. In this analysis, quadrilateral elements with 4 nodes were adopted. The model specimen and boundary conditions for analysis are shown in Fig. 4. During the finite element analyses, fibres were modelled with bar elements. Modified cam-clay model was used as a dominant constitutive law in the FE analysis. The parameters for analysis are shown in Table 3.

Table 3 Parameters.

λ	χ	T	M	υ	OCR	P_c(kPa)
0.0765	0.0108	1.9632	1.57	0.25	1	100

The results of FE analyses were compared with those obtained from experiments in Fig. 5. In case of 4, in which a fibre was installed in the middle of a specimen, the predicted deviator stresses seem not to have a good agreement with those obtained from experiments. Mean while, the pore water pressure from prediction appears to be much close to the measured values.

As shown in Fig. 5(a), the deviator stresses appear to remain constant after reaching the peak value at 3% of axial strain. The deviator stresses obtained from prediction seem to be much larger than the measured values. This might be because that the modified cam-clay model does not take into account the characteristics of weathering, dilatancy and particle crush. In contrast, the measured pore water pressures appear to be larger than those obtained from prediction as shown in Fig. 6(b). Fig 6(c) represents the paths of deviator stresses obtained from both experiments and predictions. As we can see, the stress paths are different from each other. For experiments, the stress path seems to follow that of over consolidated clay. On the other hand, the predicted values appear to decrease from the beginning. In fact special soils such as granite soil and so on may have their unique stress history depending on weathering process. The analyses are, however, dominated by preconsolidation pressure which is one of the initial conditions. Therefore this may give rise to the difference in stress path between experiment and prediction.

Similar trends were also observed in other tests. In conclusion, it may be said that the modified cam-clay model has limitation to simulate such a strain hardening type of soil behaviour.

4 CONCLUSIONS

In this paper, experimental and numerical approaches to investigate the reinforcement effect of fibre on granite soils were carried out.

Based on the investigation, the authors have obtained the following results.

(1) The strength is influenced by the number of reinforced layers and the locations of fibres.
(2) The number of reinforced layers has effects on not the frictional angle but the cohesion. It implies that fibres contribute to the restraint of tension developing.
(3) Comparing with pore water pressure, the deviator stresses obtained from prediction were far different from the measured values. Therefore it is concluded that the modified cam-clay model simulates the behaviour of strain hardening types of soils not so well.

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