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Use of decomposed granite soils as backfill for reinforced earth structures

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ABSTRACT : Decomposed granite soils are widely distributed almost all over the nation. According to current practice, however, most of them are too fine to use as backfill for reinforced earth structures. In order to explore the possibility of using fine decomposed soils, a series of direct shear tests is performed. The tests shows that the interface friction angles between the soil containing different fines and rough surface reinforcements are not much different. The cohesion component between soils and rough surface reinforcements, which has been disregarded in current practice, exhibit in the interface to some extent. When those factors are involved in the design, the test results suggest a possibility of using much fine soils as the backfill.

1 INTRODUCTION

Granite and granitic gneiss are dominant rock types in the Korean peninsula, which have been almost completely weathered in shallow depth up to 2 to 5 meters from the ground surface. The decomposed granite soils are distributed over approximately two thirds of the land, and thus they are easily available at low cost as construction materials, when the gradation is satisfied with specification for earth structures. On the other hand, sand available as a construction material become short and its cost tend to be higher year by year.

According to the current criteria in BBA.(1983), FHWA(1974) and others, their recommendation is to use the soil which contains fines passing No. 200 sieve(75 μm) less than 15%. A survey shows that the grain sizes of the soils are greatly varied, 80% of which contain up to 50% fines. Without using those soils, the construction of reinforced earth structures in Korea would not be well developed due to the economical reason.

In order to expand the availability of the decomposed granite soils, it is necessary to understand the interaction between fine decomposed soils and the reinforcement used. This paper describes the properties of the decomposed soils and the interface shear strength between the fine decomposed soils and reinforcements. And then the possibility of using fine decomposed soils is discussed.

2 DISTRIBUTION AND PROPERTIES OF DECOMPOSED GRANITE SOILS

Geology of the Korean peninsula consists of various strata aged from Archiozoic to Cenozoic era. Gneiss and Schist complex of Archiozoic to Middle Proterozic age form the basement of the entire Korean peninsula, and granite was intruded during Mesozoic era throughout the peninsula. All the previous formations were severely deformed and were mildly metamorphosed to form granite gneiss. Sedimentary rocks are exposed in southeast corner of Korea with limited thickness. Thus, the most predominant rock types are granite and granite gneiss, which cover 65% of the total land, as shown in Fig. 1.

The rocks have been weathered through long geological history, and the upper 2 to 5 m are completely weathered. The soils distributed all over the country have been widely used as a construction material for earth structures.

Physical properties of the soil has been revealed throughout various construction works during last 20 years. Soil data of total 892 samples were collected and then classified them based on the grain size(Kim and Lee 1996). Classifying the soil into United Soil Classifica-

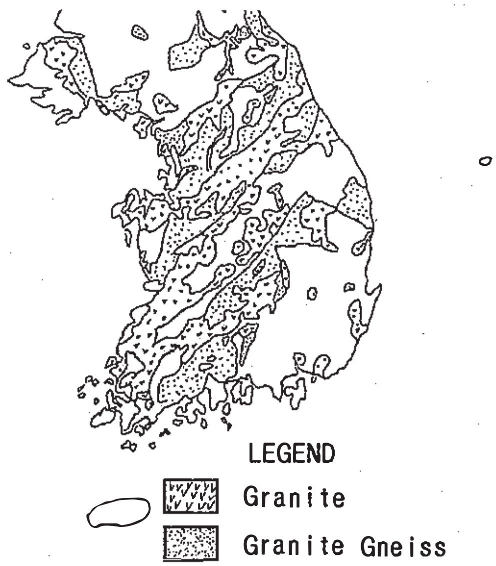


Fig. 1. Distribution of decomposed granite soils in South Korea

tion System, it is known that SM is dominant, as shown in Fig. 2. Current practice in using as backfill for earth reinforced structures is based on the contents of fines passing No.200 sieve(75 μm) or less than 15 μm. According to classification criteria of USCS, SM has fines more than 12%, and thus most of them would be unsatisfied with the guideline of less 15% fines.

Fig. 3 shows the frequency occurrence of fines passing No. 200 sieve for the decomposed granite soils. As shown in the figure, the distribution of soils coarser than 15% fines is only 15% of total samples. This means that the backfill for reinforced earth structures are not easily available when current practice is applied. It is noted, however, that if the soil containing up to 25% fines is used for the backfill, 35% of the decomposed granite soil is possible to use.

MOT of France(1980) recommends that 15 μm of the grain size shall be less than 10%. Based on the guideline, approximately 35% of the soils are available for backfill, as shown in Fig. 4. However, this still gives a limitation in using abundant decomposed soils. It is clear that the more fines is used as backfill, the less the construction cost becomes. For example, when the soil containing 40% fines is possible to use, 65% of the residual soils are available.

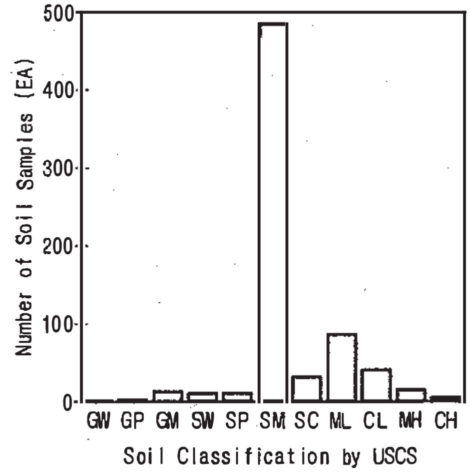


Fig. 2. Distribution of soils classified into Unified Soil Classification System.

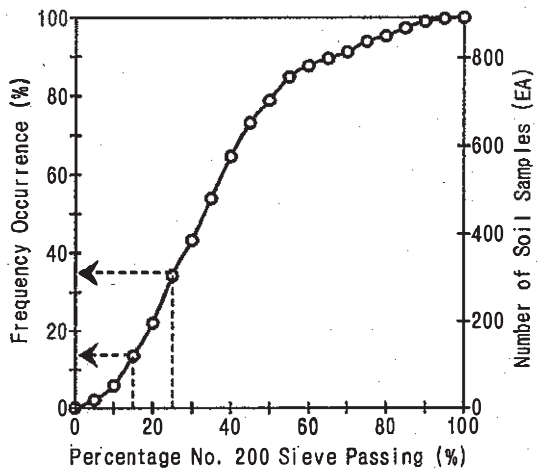


Fig. 3. Frequency occurrence of decomposed granite soils based on 75 μm (No. 200 sieve passing)

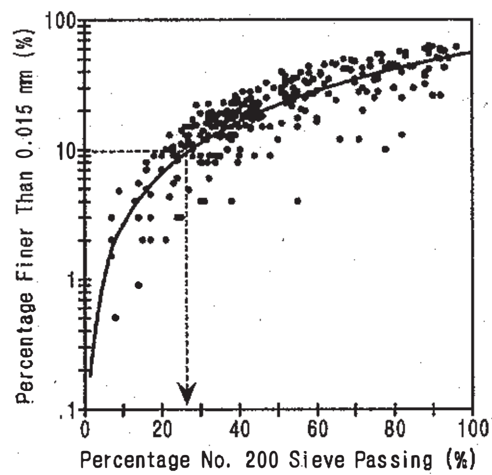


Fig. 4. Relationshiop between No. 200 sieve passing and 15 μm

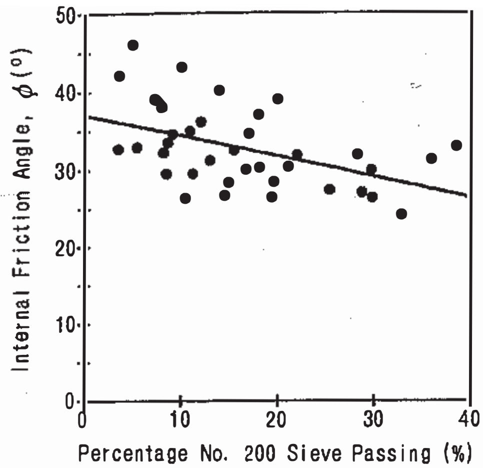


Fig. 5. Variation of friction angles with fine contents

Shown in Fig. 5 is the relationship between fine contents and drained friction angles for decomposed granite soils, which have been obtained from various sources. Plots are somewhat scattered but the figure shows a tendency that the friction angle decreases consistently with an increase of fines. When the soil contains 40% fines the friction angle drops.to 26 degrees.

3 FRICTION ON THE INTERFACE BETWEEN SOILS AND REINFORCE MENTS

In order to obtain parameters for design of reinforced earth structures, two different types of tests can be performed to simulate the behaviour of the structures. As shown in Fig. 6, the friction component is important near the surface(indicated as A in the figure) and in the other parts the pullout resistance is related to the stability(Kim and Lee 1996). Tests are herein performed only for the former case.

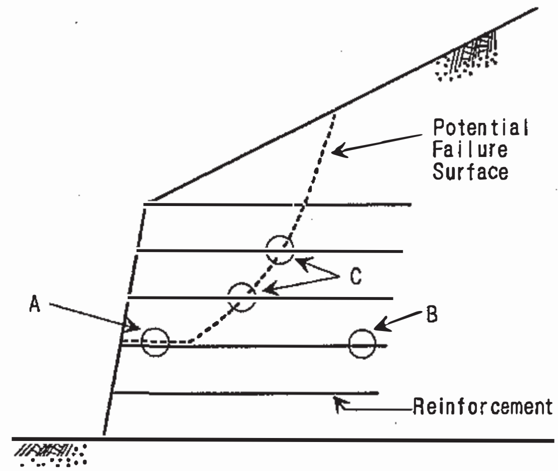


Fig. 6. Mechanism of stability in reinforced earth structures

3.1 Soils used

Tests are performed using three soils different in grain size. Sample "A" has 7% fines which is adequate for using as backfill, according to current practice. However, Sample "B" has fines slightly over 15%(19%) but the contents of 15 μm is less than 10%. As sample "C" has 36% fines and 15μm contents is over 10%, it is a problematic soil in terms of current practice. Gain size distribution of the

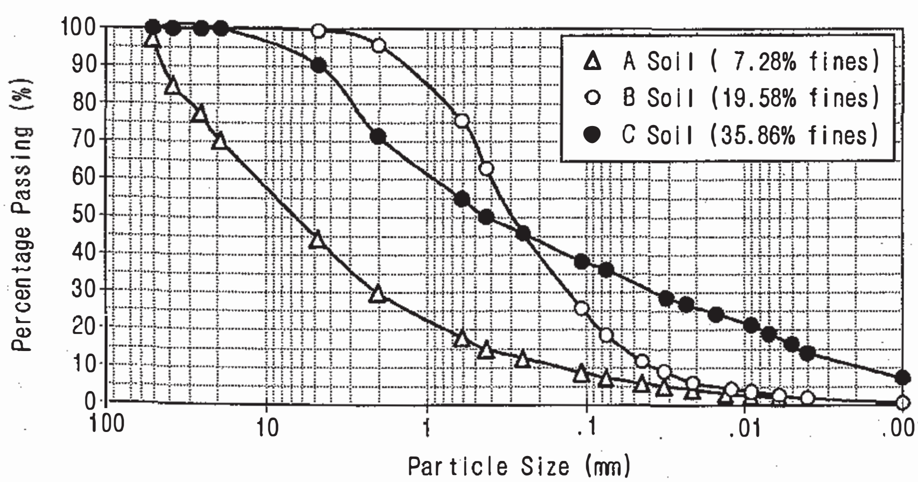


Fig. 7. Particle size distribution of the soils tested

three different soils is shown in Fig. 7. As the sample "A" has contained grains coarser than No. 4 sieve size, they are excluded in the test because of the limitation of the shear box size. Instead, the coarse materials over No. 200 sieve size are replaced by 60%.

3.2 Reinforcements used

Three kinds of reinforcements were selected for testing. The steel strip is of smooth surface and 4mm thick. Friction tie(Paraweb) is a material which comprises synthetic fibres encased in a polyethylene sheath. A 3mm thick woven geotextile consisted of polyester is manufactured by Kolon, a local company in Korea. Properties of the reinforcements are summarised in Table 1.

Table 1. Properties of reinforcements

Reinforcement	Surface	Material	Thickness (mm)	Manufactured by
Steel strip	Smooth	Steel	4.0	-
Friction tie	Textured	HDPE	3.5	Geco
Geotextile	Woven	Polyester	0.9	Kolon

3.3 Test apparatus

The size of shear box is 60mm x 95mm and the lower part is moved to shear a sample. The shear box is mounted on large container, in which water is filled in order to keep saturation during shear.

The lower box is filled with PVC, leaving the space of the reinforcement thikness, and then after cutting it to fit for the size of the shear box, it is put on the PVC. A woven geotextile is sticked to a thin iron plate with an adhesive agent so that it is not pushed during shearing.

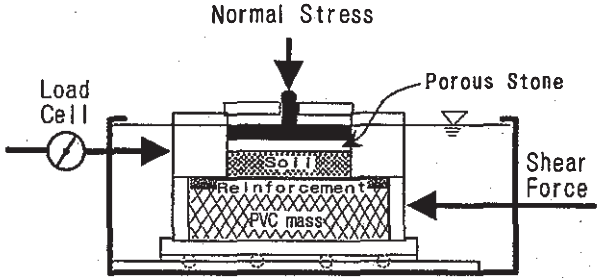


Fig. 8. Direct shear test apparatus

Soils contained in the upper box are compacted with the same dry density as that obtained from 95% modified Proctor. The sample is submerged into the water in outer box for 24 hours and then sheared with the speed of 1 mm/sec. The test procedure is identical to those recommended by MOT in France. A schematic diagram of the shear box is shown in Fig. 8.

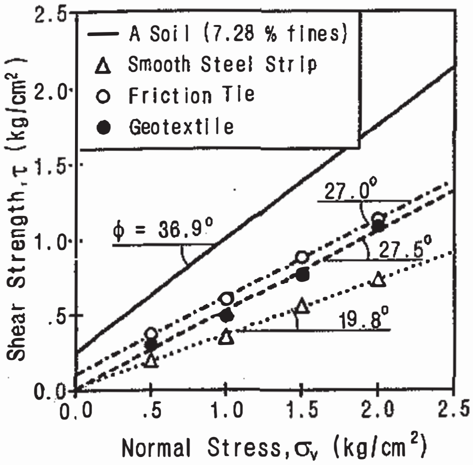
3.4 Results

Test results show that the friction between soils and reinforcement depends largely on the roughness of the reinforcement. The interface friction angle(δ) for smooth surface strip is remarkably low for all soils tested, compared with for other materials. Basically, there is no difference between the friction angles for friction tie and geotextile which have the rough surface. It is interesting to note that the interface friction angles are almost the same(27 to 29 degrees) regardless of fine contents(see Fig. 9).

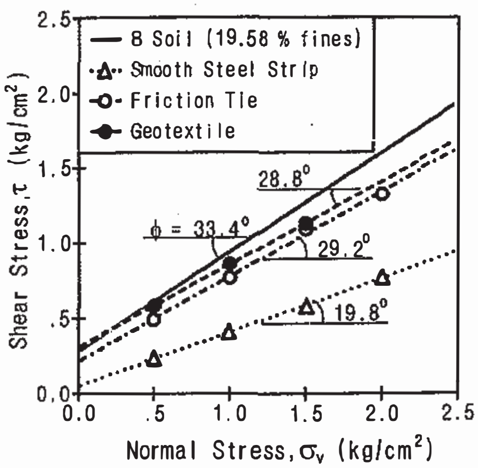
The interface cohesion component between soils and reinforcements are negligible for sample "A" containing only 7% fines, while finer sample exhibits considerable amounts of the components. For rough reinforcements, the values are approximately 50% or over of the cohesion of the soil.

The ratio of tan ϕ to tan δ is refered to the ratio of frictional coefficient, μ. The value of μ is useful in evaluating the quality of the backfill. The results show that the ratio tends to increase with an increase of fine contents. The values measured for smooth steel strip is as low as 0.48 to 0.58, while those for rough surface reinforcements is as high as 0.68 to 0.90, as shown in Fig. 10. As the ratio tends to increase with an increase of fine contents, the value is possible to reach unity when using much finer soils for the test. Milligan and Palmeira(1987) also predicted the possibility.

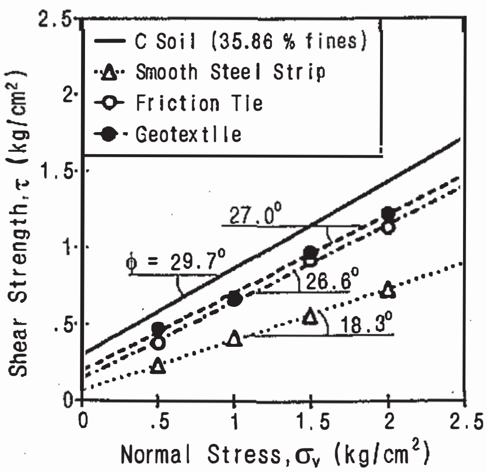
The increase of the ratio in fine grained soils can be explained by the formation of a shear plane. In coarse material, a shear plane in direct shear test is an interface between soil and reinforcement. Therefore the property of reinforcement greatly affects the interface friction angle. When much fine materials are involved, a shear plane, which is created by rolling and sliding of grains, is likely to move slightly up from the interface because some fine grains stick to the rough reinforcement(see Fig. 11).



(a) Soil Sample A (7.28 % fines)



(b) Soil Sample B (19.58 % fines)



(c) Soil Sample C (35.86 % fines)

Fig. 9. Strength parameters measured by direct shear test

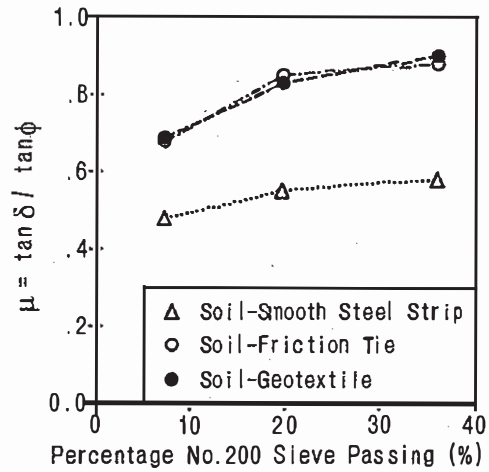


Fig. 10. Variation of friction ratio with different soil and reinforcement

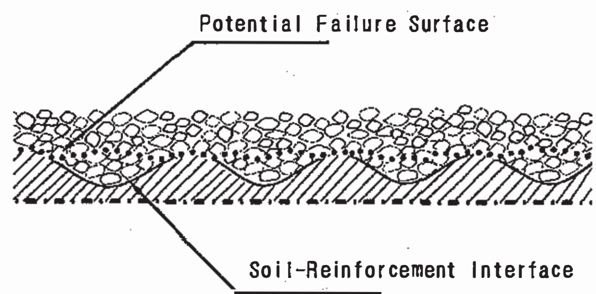


Fig. 11. potential shear plane for fine grained soils

4 DISCUSSION

Current practice for reinforced earth structures uses the friction component only. The cohesion component, however, play an important role in developing shear strength. As shown in Fig. 9, considerable amounts of cohesion intercept exhibited when fine soils are sheared on the interface of rough reinforcements. If this component is disregarded, it is clear that the current practice may be too conservative.

Furthermore, the strength parameters obtained in this test are for saturation condition. In field, however, full saturation is not usual for earth structures even when heavy rainfall is produced. A problem encountered in the fine backfill material is swelling when wetted. If swelling is not critical for the backfill, much fine materials can be used for reinforced structures. Therefore, further researches are needed for swelling behaviour of the Korean decomposed granite soils. When drainage facilities are provided, the problem may be eliminated.

Engineering practice so far have been based on saturated soil mechanics. Fredlend et al. (1978), Gan et. al.(1988) and others have studied shear strength and permeability for unsaturation condition. The research program to extend the availability of the decomposed soil includes the unsaturated soil mechanics for the Korean decomposed soil. When the results are applied to practice, current practice using only sandy soil less than 15% fines will be lifted.

5. CONCLUSIONS

The distribution and property of the Korean composite granite soils were reviewed. They are utilized in construction works as a backfill material but 85% of them have fines in which 75μm is more than 15%. In order to construct more economical earth reinforced structures, a research to utilise much finer materials is essential in Korean circumstances.

A series of direct shear tests was performed with soils having different fines and different reinforcements. The tests show that the interface friction angles are almost the same for rough reinforcements, regardless of fines contents. For a soil having 36% fines, the ratio of friction angles coefficients reached 0.9. This means that the interface friction angle approaches to the angle of shear resistance of the soil. In addition, the interface cohesion intercept was 50% or more of the cohesion of the soil.

Although current practice applies only friction component, the interface cohesion may be mobilized in stability of reinforced earth structures. Furthermore, as the backfill is usually not fully saturated in rainy season, the principle of unsaturated soil mechanics may be applied for the design of the reinforced earth structures. Considering those points, much fine decomposed soils are possible to be used as backfill. In that case, drainage facilities may be provided in order to eliminate the possibility of swelling due to an increase of water content.

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