Reinforcement mechanism of slope stability method with no cutting trees

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The study in this paper is the slope stability. Although many slopes are prone to collapse, countermeasures against slop failures have not been progressed yet in Japan. Most slope protection methods were to cover shotcrete on the slope in 1960's. However, the slope covered shotcrete have been deteriorating. Therefore, the slope failures frequently occur due to the natural disaster such as heavy rainfall and earthquake. It is important to develop an effective slope stability method. Moreover, it is necessary to consider environmental problems such as global warming. A new slope stability method to maintain natural environment on slopes is suggested in this paper. The method has advantage of the cost and construction. The rock bolts, the pressure plates and the unit nets as reinforcement are used in the method. The model shear test was conducted. The test sample is one collected from a slope. The experimental conditions on water content and the content for clay fraction were changed for each case. The objective of this study is to evaluate quantitatively the influence of ground physical properties on the reinforcement mechanism.

1. INTRODUCTION

A new slope stability method to maintain natural environment is suggested in this paper.
A Figure and a photograph of the slope made when this industrial method is constructed are shown in Figure.1 and Photo.1. The rock bolts, the pressure plates and the unit nets are used as reinforcement materials in the method. The method has an advantage of the cost and construction, because of the light materials. However, detailed design method has yet not been built up.
The purpose of this research is to estimate the deformation behavior and the stiffening effect quantitatively by implementing a shear test. There are three test samples, which are Toyoura sand, cohesive soil from Yamasaki fault and soil that mixed previously-noted two samples. As a result, the influence that differences of the ground conditions such as the ground physical properties and moisture content exercise the reinforcement mechanism is examined.

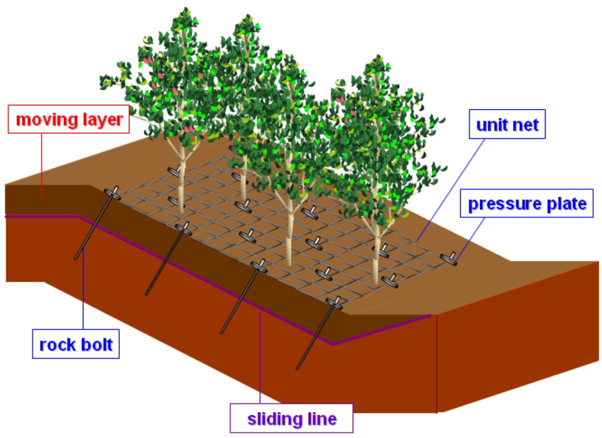


Fig.1 Concept of this slope stability method


Photo.1 Example of practical slope stability condition

2. REINFORCEMENT MECHANISM

Reinforcement mechanism of this slope stability method is shown in Fig.2. It is assumed that the

reinforcement mechanism changed gradually with the deformation of ground. The process for restraint against slope failure is described as follows.
First of all, sliding force that is a factor of a collapse by heavy rain and disintegration happens on the ground. The shear resistance brought by soil's own weight restrains the collapse at the stage of minute deformations of ground. When the deformation of the ground becomes one stage larger, the reinforcement effect of rock bolt arises as flexing resistance and pullout resistance. Next, the effect of stress dispersion appears due to the connection of rock bolts and unit nets with pressure plates. When the deformation of the ground progresses further, the reinforcement effect of hold-down of the ground that controlling deformation of ground level by unit nets and pressure plates arises.
It is the reinforcement mechanism of this method to attempt the stability of the slope as mentioned above.

3. CONCEPT OF SHEAR TEST

Fig.3 shows the outline of testing apparatus used in this research.
1/10 scales were assumed, and the size of the testing apparatus was 600mm in length, 500mm in width, and 350mm in the layer thickness. Then, the shearing transformation was given to the shearing box at constant speed (2.0mm/min) by an automatic load device.
The shear surface position was able to be a freely changed.

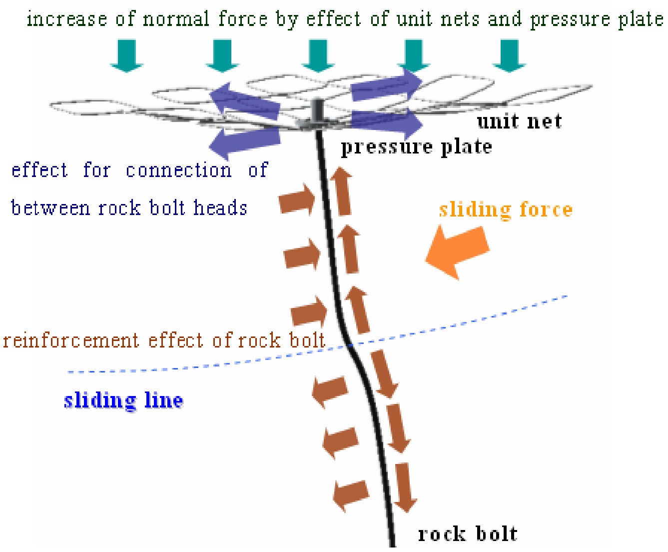


Fig.2 Reinforcement mechanism of this slope stability method

In this respect, the effect of reinforcement is achieved more efficiently, when the shear surface position is set to less than half length of reinforcement materials, according to the research in the past. Therefore, the shear surface position was fixed at 150mm in this paper.
Moreover, both of the rock bolts and the unit nets model were made of steel materials of SS400, and strain gauge was attached to both sides of them, and the stress calculation was done.
The bottom of the rock bolts were fixed to the test fixture, and two pressure plates (φ30mm) made of stainless steels used for the head of it, and was fixed connectedly with the unit net. The parameter of the test sample is shown in Table.1.

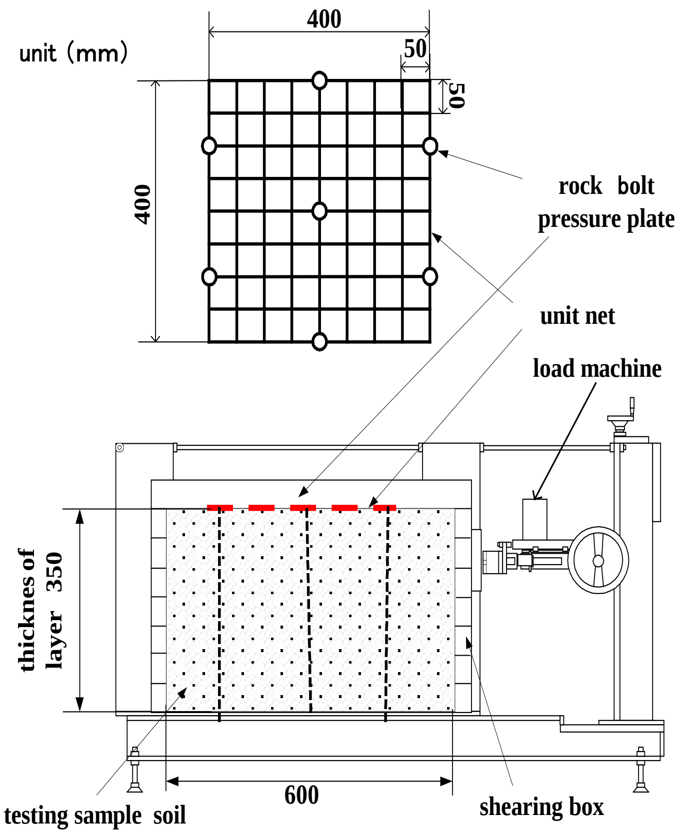


Fig.3 Outline of testing apparatus

Table.1 Physical properties of each testing sample

Clay fraction	Toyoura sand	Mixed sample	Cohesive soil
	0%	18%	28%
Wet density ρ t (g/cm^3)	1.54	1.76	1.77
Dry density ρ d (g/cm^3)	1.54	1.55	1.50
Moisture content w(%)	0.0	13.6	17.6

4. RESULTS OF THIS RESEARCH AND CONSIDARATION

Fig.4 shows relation between shear load (shear resistance strength) and shear displacement.

B, P, N and N' in explanatory indicates rock bolts, pressure plates, the grounded unit nets, and the non-grounded unit nets, respectively.

The shear load at B+P+N was the highest in the result of all samples as shown in Fig.4. It was confirmed that the sample containing clay obtained a comparatively high shear load even with no reinforcement. It is presumably because the more clay fraction grand contains, the higher cohesive becomes.

Fig.5 shows reinforcement effect distribution ratio of each sample calculated by shear resistance strength.

According to the result of the reinforcement effect distribution ratio in each sample, the distribution ratio of soil was larger, when higher clay fraction was contained. In addition, the distribution ratio of rock bolts was larger in the case that coarse-grained fraction was larger. Equations for computation(1)～(4) are shown each reinforcement effect distribution ratio.

$$R_h = (\tau_{(B+P+N)} - \tau_{(B+P+N')}) / \tau_{(B+P+N)} \times 100(\%) \qquad (1)$$

$$R_c = (\tau_{(B+P+N')} - \tau_{(B+P)}) / \tau_{(B+P+N)} \times 100(\%) \qquad (2)$$

$$R_B = (\tau_{(B+P)} - \tau) / \tau_{(B+P+N)} \times 100(\%) \qquad (3)$$

$$R_S = \tau / \tau_{(B+P+N)} \times 100(\%) \qquad (4)$$

τ () shows each countermeasure method and shear resistance strength.

R_h : Distribution ratio of hold-down of the ground

R_c : Distribution ratio of connection of heads

R_B : Distribution ratio of rock bolts

R_S : Distribution ratio of soil

Moreover, it is necessary that evaluate unit nets and pressure plates as a face of slope construction.

The most general evaluation index on the slope construction is reduction coefficient of supported slope. The equation (5) is a formula for calculation of reduction coefficient of supported slope.

$$\mu = T_0 / T_{max} \qquad (5)$$

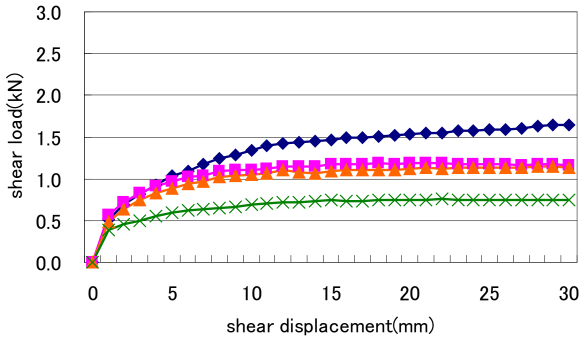
T_0: A pull force of reinforcement members that affects between the reinforcement members and the slope construction (kN per bolt)

T_{max}: The largest value of the pull force of reinforcement members (kN per bolt)

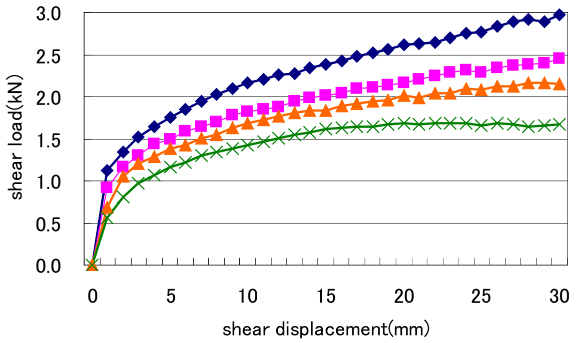
Fig.6 shows the reduction coefficient of supported slope in the countermeasure (B+P+N).

The result in the both cases when clay was contained and when it was not is shown.

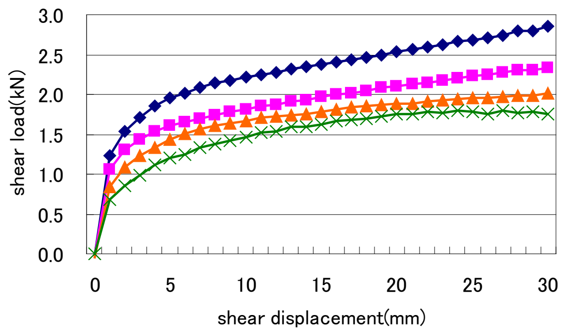
It was confirmed that the reduction coefficient of supported slope in early phase of the shear test has a high value in a sample containing clay(clay content of 18%) compared to the sample not containing it(clay content of 0%). It can also be understood that reinforcement effects of unit nets exerts from the early phase of the shear test on cohesive soil ground.



a)Toyoura sand(clay content of 0%)



b)Mixed soil(clay content of 18%)



c)Cohesive soil(clay content of 28%)

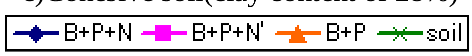
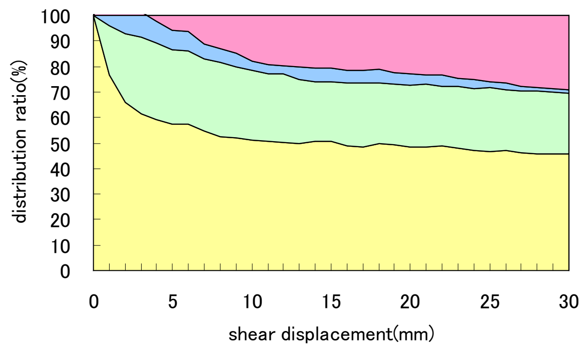
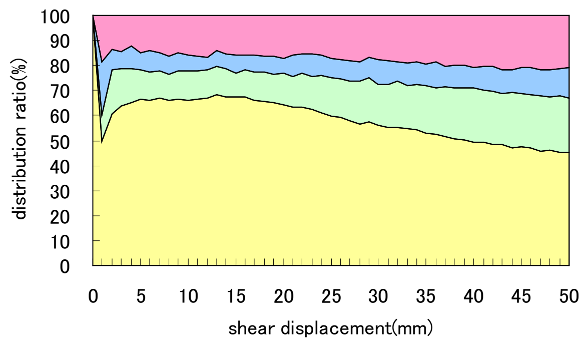


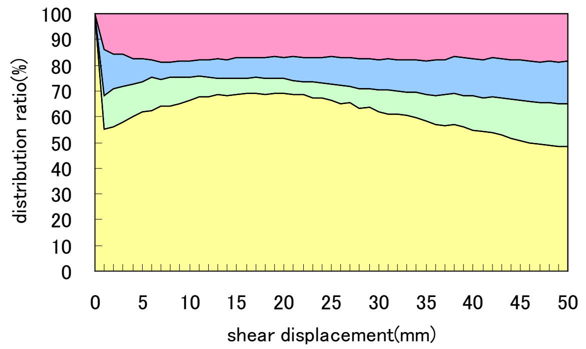
Fig.4 Relation between shear load and shear displacement



a)Toyoura sand(clay content of 0%)



b)Mixed soil(clay content of 18%)



c)Cohesive soil(clay content of 28%)

- effect of increasing normal force by unit nets
- effect of connection of heads by unit nets
- effect of rock bolts
- effect of soil

Fig.5 Relation between shear displacement and distribution ratio of each reinforcement effects

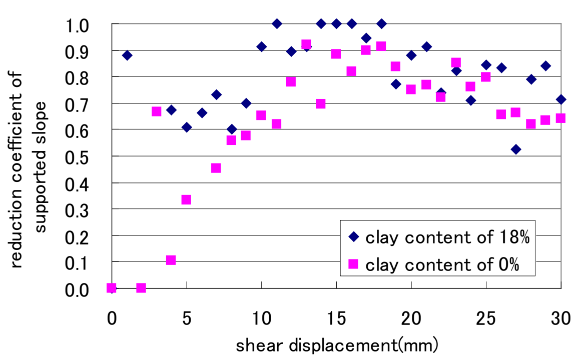


Fig.6 Relations between shear displacement and reduction coefficient of supported slope

5. CONCLUTIONS

We conducted the examination using three kinds of samples that the clay contents were different.
As a result of shear resistance strength, availability of countermeasure (B+P+N) was confirmed.
In the case of the sample containing clay, there was a difference between the countermeasure (B+P+N), (B+P+N') and (B+P), in shear resistance strength at early phase.
On the other hand, it was confirmed that there was no difference in the sample that did not contain clay.
In a word, the amount of clay influences the reinforcement effect of this method.
As a result, it was confirmed by the evaluation of the reinforcement effect distribution ratio and the reduction coefficient of supported slope, that the reinforcement effect of the unit nets was strongly demonstrated containing clay from the early phase.
A reduction coefficient of supported slope of this method was found to be about 0.6～0.8.

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