Development of a new natural slope stability method without cutting trees

Shohei Hiroto [1], Harushige Kusumi [2], and Katsumi Teraoka[3]

[1] Graduate school of Kansai University
E-mail: k036660@kansai-u.ac.jp
[2] President, Kansai University
E-mail: kusumi@kansai-u.ac.jp
[3] Daika Co. Ltd
E-mail: teraoka@daika-net.co.jp

In recent years, about 1000 slope failures occur every year in Japan, and about 90% of them are superficial slope failures that occur within 3 meters from the surface. Therefore this research suggests a new natural method for the slope stability. It takes environment and landscape into consideration, and can prevent superficial slope failures from occurring. Reinforcement members used in this method are rock-bolts, unit-nets, and pressure-plates. And we tried to preserve existing trees as much as possible. The purpose of this research is to establish more accurately designed method, and so the shearing test by the model of 1/10 scale was conducted. We made a model ground with reinforcement materials in shearing box and made it sheared by automatic load machine. Then we measured shear load with loadcells measures shear load and strain gauges attached to rock-bolt and unit-net. In the past research, we made it clear how the change of the effect of diameter of pressure plates gave to reinforcement mechanism in this method on sandy soil ground. The result was that enlarging diameters of pressure plates increases reinforcement effect comprehensively in this method. Shearing test was carried out on cohesive soil ground in addition to sandy soil ground in this research, and we examined how the difference of the grain size made the effect to the reinforcement mechanisms. As a result, it was clarified that the depression effect of transformation became bigger as the diameters of pressure plates was longer also in the mixed soil ground.

1. INTRODUCTION

Figure.1 and Photo.1 show the outline of a new slope stability method that can maintain natural shape. Rock bolts, pressure plates and unit nets are used as reinforcement members in the method. The method has an advantage of the low cost and easy construction, because they are light materials. However, any detailed designing 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. Especially, to evaluate the effects that pressure plates have on reinforcement mechanism in this method, the examination uses three kinds of pressure plates in two kinds of soils.

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

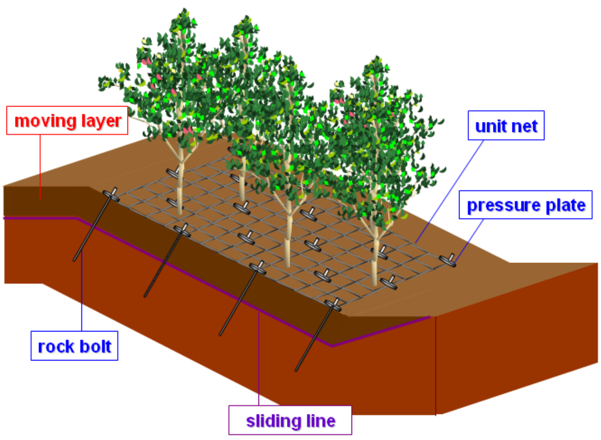


Fig.1 Concept of this slope stability method

Photo.1 Example of practical slope stability condition

collapse happens by heavy rain and disintegration 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 more 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, with unit nets and pressure plates, the reinforcement effect controlling deformation of soil mass on the ground level occur.

The reinforcement mechanism of this method is to stabilize the slope in a compound way as mentioned above.

3. DETAILS OF THE TEST

Fig.3 shows the outline of testing apparatus used in this research.

With the assumption of 1/10 scales, the size of the testing apparatus was 600mm in length, 500mm in width, and 350mm in depth. The test sample was Toyoura sand and compound soil (Toyoura sand and Yamazaki cohesive soil). Then, the shearing transformation was given to the shearing box at a constant speed (2.0mm/min) by an automatic load device.

The shear surface position was able to be a freely changed.

The past research showed that the reinforcement effect worked more effectively, when the shear surface position was set to less than half the length of reinforcement members. Therefore, the shear surface position was fixed at 150mm in this study.

Moreover, both of the rock bolts and the unit nets model were made of steel members of SS400, and strain gauge was attached to both sides of them in the stress calculation. The pressure plates are made of the stainless steels, and the diameters are 30 mm, 45 mm and 60 mm. Table.1 shows an experiment conditions in shearing test. The bottom of the rock bolts were fixed to the test fixture, and using two pressure plate of the same size, the head of the rock bolts was fixed with the unit net. B, P, 1.5P, 2P and N in explanatory drawing indicates rock bolts, pressure plates (ϕ 30mm, ϕ 45mm, ϕ 60mm) and unit nets respectively.

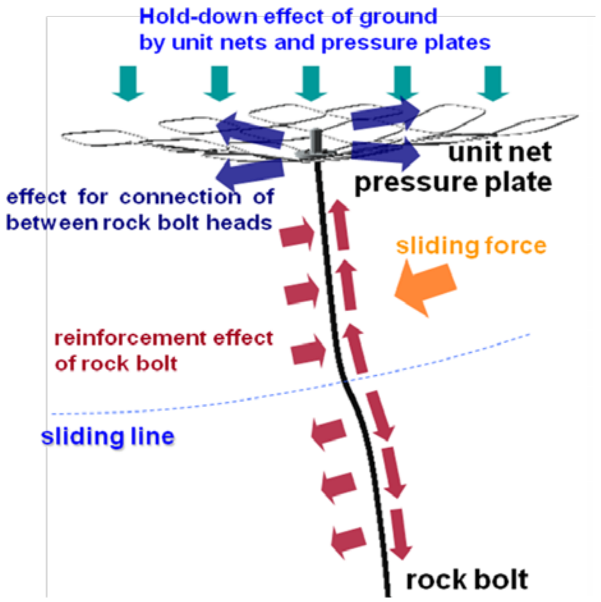


Fig.2 Reinforcement mechanism of this slope stability method

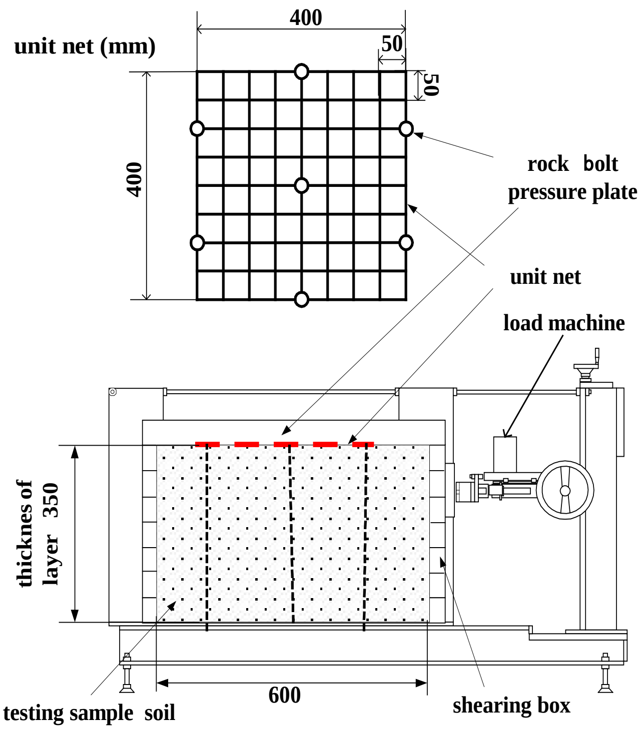


Fig.3 Outline of testing apparatus

Table.1 Experiment cases in shearing test

Experiment Case	Pressure Plate	Test Sample
No Reinforcement	–	Toyoura Sand, Mixed Soil
B	–	Toyoura Sand, Mixed Soil
B+P	ϕ=30mm	Toyoura Sand, Mixed Soil
B+1.5P	ϕ=45mm	Toyoura Sand
B+2P	ϕ=60mm	Toyoura Sand, Mixed Soil
B+P+N	ϕ=30mm	Toyoura Sand, Mixed Soil
B+1.5P+N	ϕ=45mm	Toyoura Sand
B+2P+N	ϕ=60mm	Toyoura Sand, Mixed Soil

4. RESULTS OF THIS RESEARCH AND CONSIDERATION

(1) Shear load

Fig.4 shows the result of shear pressure (shear resistance). The shear load value of composite soil was overall higher than that of Toyoura sand. In Toyoura sand, the shear load in B+P+N increased respectively by 24% and by 55%, when the size of the pressure plate became 1.5 times and twice. In mixed soil, in B+P+N the shear load increased by 27%, when the size of pressure plate became twice. Furthermore, the shear loads of measures with unit nets showed the increasing tendency at the time of the end of the shearing while shear loads of other cases settled. This is thought to attribute to an increase in hold-down effect of pressure plates and unit nets.

(2)Reduction coefficient index on the slope construction

Moreover, it is necessary to evaluate unit nets and pressure plates as a slope stability worker. The most general evaluation index on the slope stability worker is a reduction coefficient of supported slope.

Formula(1) is to calculate the reduction coefficient on the slope

$$\mu = T_0/T_{max} \quad (1)$$

T_0: A pull force of reinforcement members that affects connections of 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.5 shows the reduction coefficient of supported slope in each case. The average value of reduction coefficient of supported slope is 0.81, 0.73 and 0.61 respectively in case of B+2P+N, B+1.5P+N and B+P+N in Toyoura sand. The average value of reduction coefficient in mixed soil is 0.71 and 0.41 respectively in case of B+2P+N and B+P+N.

(3)Reinforcement effect distribution ratio

Fig.6 and Fig.7 shows reinforcement effect distribution ratio of each cases and each samples calculated by shear resistance strength. In Toyoura sand, the distribution ratios of pressure plates and unit nets increased by enlarging the diameter of pressure plates. In mixed soil, only the distribution ratio of pressure plate increased by enlarging the diameter of pressure plates.

The calculation formulae of the distribution ratio of each plate are shown in the formula (2)~(5).

$$R_N = (\tau_{B+P+N} - \tau_{B+P}) / \tau_{B+P+N} \times 100(\%) \quad (2)$$

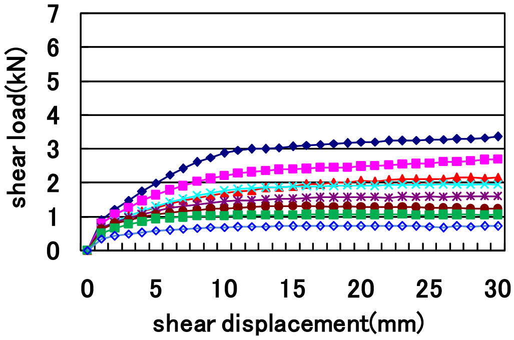
$$R_P = (\tau_{B+P} - \tau_B) / \tau_{B+P+N} \times 100(\%) \quad (3)$$

$$R_B = (\tau_B - \tau) / \tau_{B+P+N} \times 100(\%) \quad (4)$$

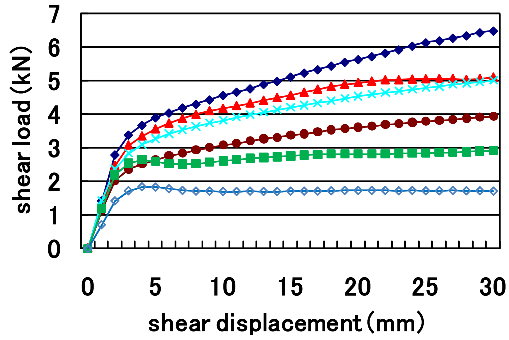
$$R_S = \tau / \tau_{B+P+N} \times 100(\%) \quad (5)$$

And τ () shows each measure's shear load.

R_N, R_P, R_B, and R_S indicate distribution ratio of unit net, pressure plate, rock bolt, and sample. In the same way, other measures are calculated respectively.



a) Comparison in Toyoura sand



b) Comparison in mixed soil

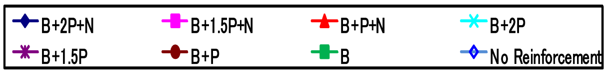
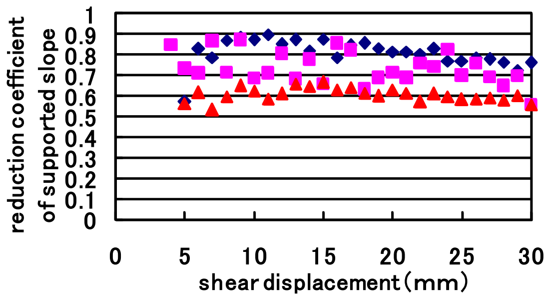
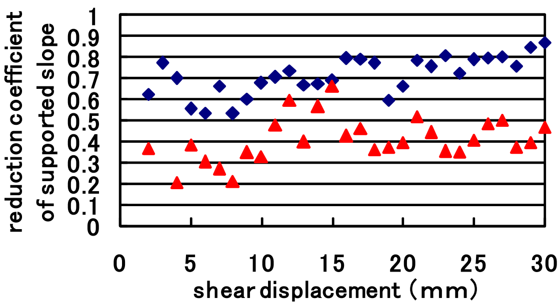


Fig.4 Relation between shear load and shear displacement



a) Comparison in Toyoura sand



b) Comparison in mixed soil

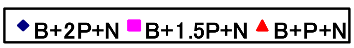
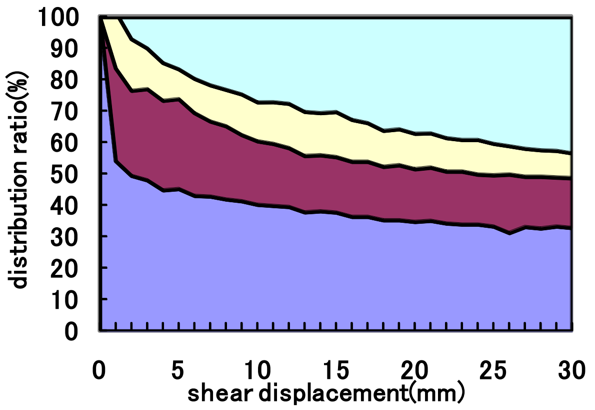
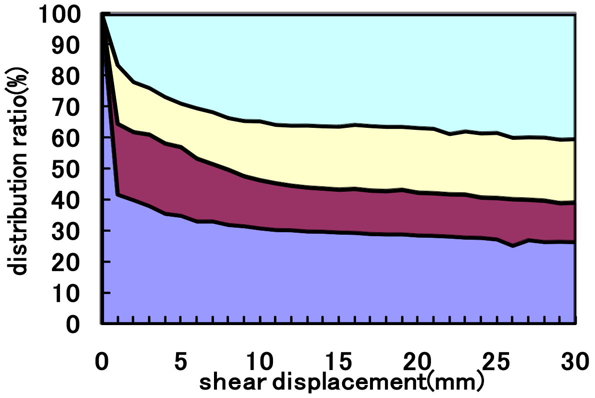


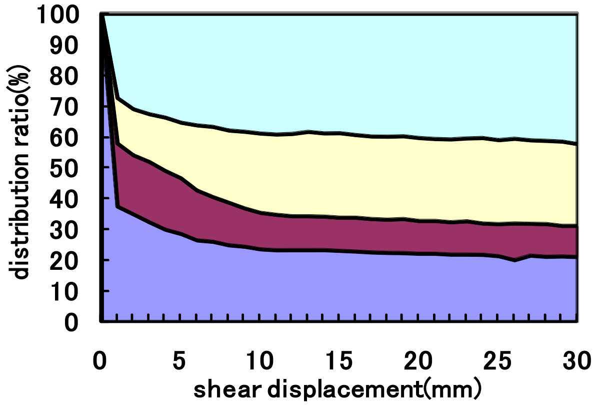
Fig.6 Relations between shear displacement and reduction coefficient of supported slope



a) The distribution ratio of measure B+P+N

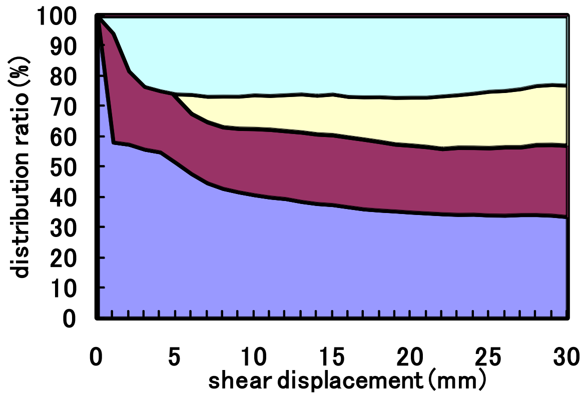


b) The distribution ratio of measure B+1.5P+N

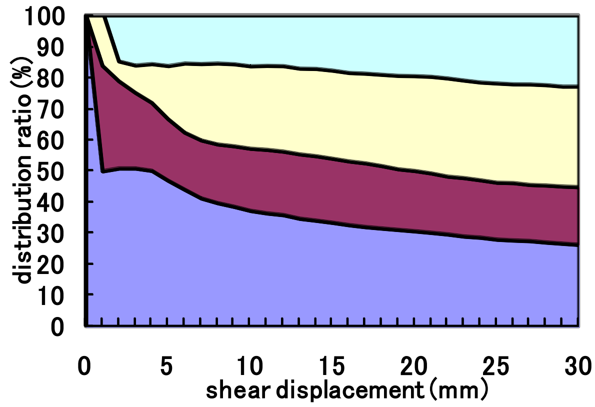


c) The distribution ratio of measure B+2P+N

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



a) The distribution ratio of measure B+P+N



b) The distribution ratio of measure B+2P+N

Fig.6 Relation between shear displacement and distribution ratio of each reinforcement effect in mixed soil

5. CONCLUSION

To clarify the influence that pressure plates give to the reinforcement mechanism of this method, we changed the size of pressure plates and carried out shearing test. In Toyoura sand, the shear load increased respectively by 24% and by 55% as the diameter of pressure plate enlarged 1.5times and twice. In mixed soil, the shear load increased by 27% because the diameter of pressure plate enlarged twice. Furthermore, from the result of reinforcement effect distribution ratio, distribution ratios of pressure plate and unit net increased when the diameter of pressure plate doubled in Toyoura sand and composite soil. It can be assumed that the effect of controlling the ground deformation increased by enlarging the diameter of pressure plate. Then, from the result of reduction coefficient index on the slope stability worker, it was confirmed that comprehensive reinforcement effect of this method increased by enlarging the size of pressure plates.

REFFERENCES

H. Kusumi at all, Slope stability method maintained natural environment by rock bolt and unit net, Ground and fundamental, The Japanese Geotechnical Society, Vol.53, No.9, pp.6～8, 2005 (in Japanese)

Japan Highway Public Corporation, Suggested method of reinforcement, designing and construction for cutting slope, pp.50, 2002(in Japanese)

Y. Chikata, H. Kusumi, and K. Teraoka Reinforcement mechanism of slope stability method with no cutting trees, EIT-JSCE Joint International Symposium on Rock Engineering 2008