Development of natural slope stability method considered environment and landscape

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In this paper the study is slope stability. 70% of national land of Japan is mountain district, but countermeasures of slopes with the potentiality of collapse have not been progressed yet. Therefore, many slope failures occur caused by heavy reins or earthquakes in these years. Most slope protection methods were to cover shotcrete on the slope in 1960's. However, the slope covered shotcrete have been deteriorating. Therefore, it is important to develop an effective slope stability method. Furthermore, 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. In the method, existing timber is hardly cut down. The method has advantage of cost and construction. Reinforcement materials of the method are rock-bolt, pressure-board and unit-net. The direct shear test was conducted. To get higher slope stability efficacy, the test was conducted with 2 types of the diameter of pressure-board. The objective of this study is to evaluate quantitatively the influence of pressure-board 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.Rock bolts, pressure plates and 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. Especially, to evaluate the effects that pressure plates have on reinforcement mechanism in this method, the examination uses two kinds of pressure plates.

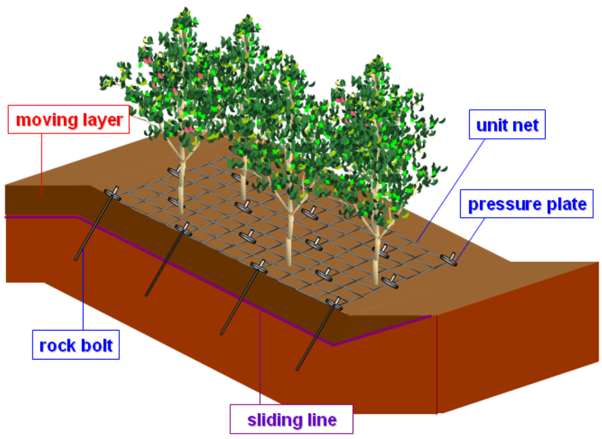


Fig.1 Concept of this slope stability method


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. 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 controlling deformation of soil mass on the ground level by unit nets and pressure plates arises.

The reinforcement mechanism of this method is to attempt the slope stability in a complex way as mentioned above.

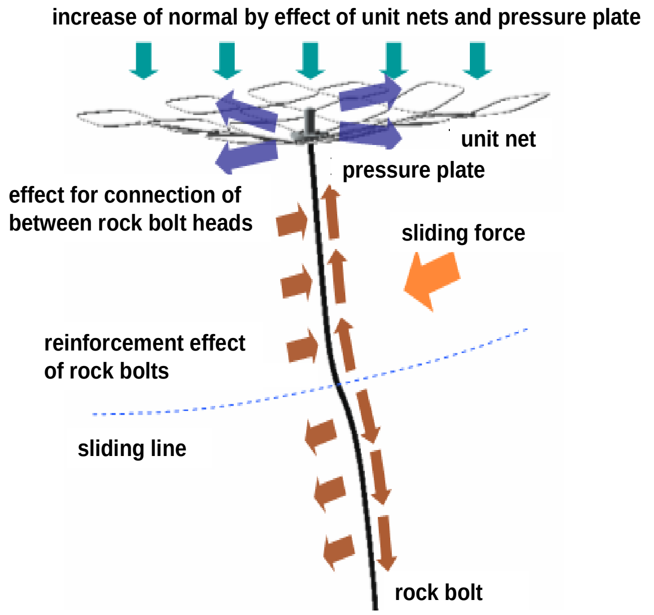


Fig.2 Reinforcement mechanism of this slope stability method

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 the layer. The test sample was Toyoura sand. 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.

In this respect, according to the research in the past, when the shear surface position was 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 in the stress calculation.

The pressure plates are made of the stainless steels, and the diameters are 30㎜ and 60㎜. 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 connectedly with the unit net.

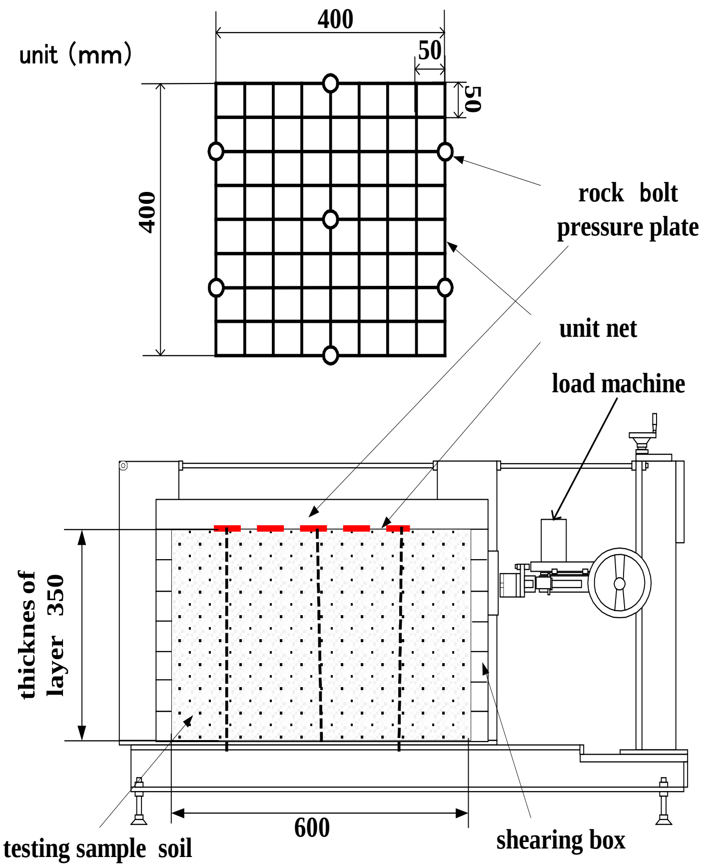


Fig.3 Outline of testing apparatus

4. RESULTS OF THIS RESEARCH AND CONSIDERATION

Fig.4 shows the relation between shear load (shear resistance strength) and shear displacement. B, P, 2P and N in explanatory indicates rock bolts, pressure plates(φ30 ㎜), pressure plates(φ60 ㎜) and unit nets respectively.

As for measures B+P+N and measures B+P, the shear load increased respectively by 53% and by 36% because the size of the pressure plates doubles. Furthermore, only the shear load of measures B+2P+N shows the increasing tendency at the time of the end of the shearing while shear loads of other measures settle. This is thought to attribute to an increase in hold-down effect of pressure plates and rope nets.

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

Comparing distribution ratios of measures B+2P+N with measures B+P+N, the distribution ratios of rope nets and rock bolts increase.

$$R_N = (\tau_{B+P+N} - \tau_{B+P}) / \tau_{B+P+N} \times 100(\%) \quad (1)$$

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

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

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

$$R_N' = (\tau_{B+2P+N} - \tau_{B+2P}) / \tau_{B+2P+N} \times 100(\%) \quad (5)$$

$$R_P' = (\tau_{B+2P} - \tau_B) / \tau_{B+2P+N} \times 100(\%) \quad (6)$$

$$R_B' = (\tau_B - \tau) / \tau_{B+2P+N} \times 100(\%) \quad (7)$$

$$R_S' = \tau / \tau_{B+2P+N} \times 100(\%) \quad (8)$$

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

R_N: Distribution ratio of rope nets in measures B+P+N

R_P : Distribution ratio of pressure plates in measures B+P+N

R_B: Distribution ratio of rock bolts in measures B+P+N

R_S: Distribution ratio of sand in measures B+P+N

R_N': Distribution ratio of rope nets in measures B+2P+N

R_P' : Distribution ratio of pressure plates in measures B+2P+N

R_B': Distribution ratio of rock bolts in measures B+2P+N

R_S': Distribution ratio of sand in measures B+2P+N

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

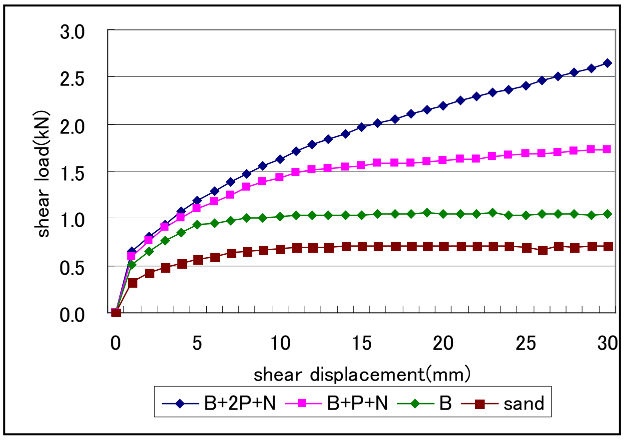
$$\mu = T_0 / T_{max} \quad (9)$$

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

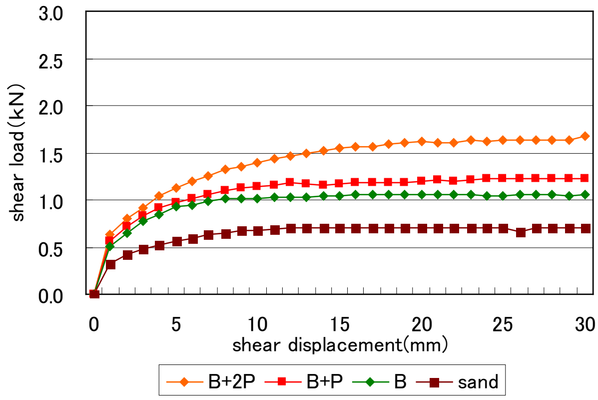
T_{max}: The largest value of the pull force of reinforcement members (kN per bolt)

Fig.6 shows the reduction coefficient of supported slope in measures B+2P+N and B+P+N.

The average value of reduction coefficient of supported slope is 0.79, and 0.61 respectively in each measures B+2P+N and B+P+N. It was also confirmed that the value of measures B+2P+N and B+P+N parallels from the first stage of the shearing. From this result, it is understood that the size of pressure plates influence the hold-down effect of rope nets and pressure plates.

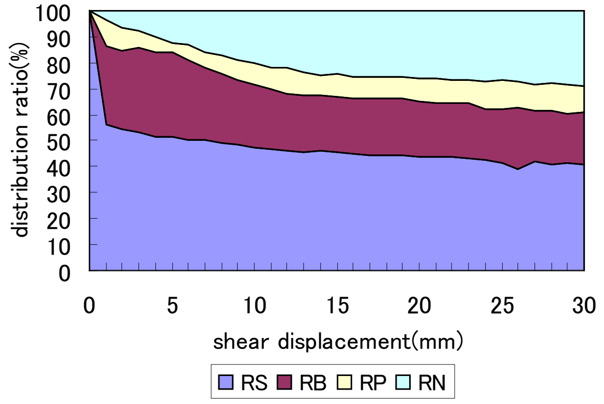


a) Comparison between measures B+2P+N and B+P+N

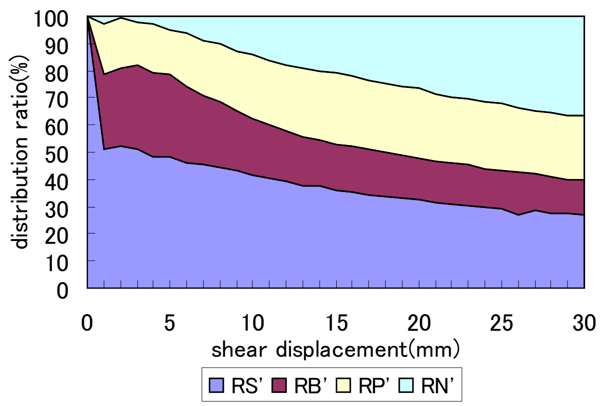


b) Comparison between measures B+2P and B+P

Fig.4 Relation between shear load and shear displacement



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



a) The distribution ratio of measures B+2P+N
Fig.5 Relation between shear displacement and distribution ratio of each reinforcement effects

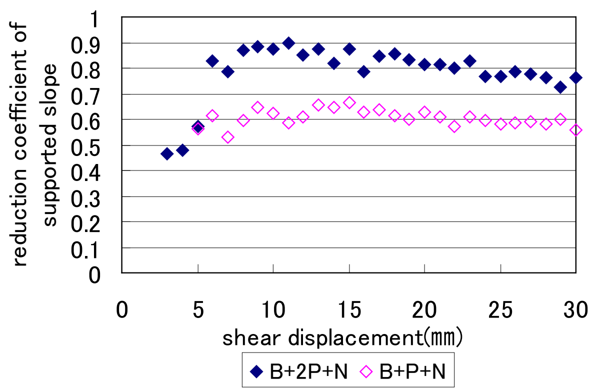


Fig.6 Relations between shear displacement and reduction coefficient of supported slope

5. CONCLUSION

To clarify the influence that pressure plates give to the reinforcement mechanism of this industrial method, we changed the size of them and conducted shearing test. As for measures B+P+N and measures B+P, the shear load increased respectively by 53% and by 36% because the size of pressure plates doubles.

As a result, it was confirmed that the size of pressure plates influenced an increase in the effect of reinforcement of them and the effect of the hold-down of the rope nets.

Additionally, the effect of reinforcement of pressure plates is demonstrated from the first of the shearing, and it is confirmed to exceed the effect of reinforcement of rock bolts from the result of distribution ratio.

The average value of the reduction coefficient of supported slope is 0.79, and 0.61 respectively of each measures B+2P+N and B+P+N.

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