Landmarks in Earth Reinforcement, Ochiai et al. (eds),
© 2001 Swets & Zeitlinger, ISBN 90 2651 863 3

Countermeasure against the slope using difference of shearing mechanism on main slip layer

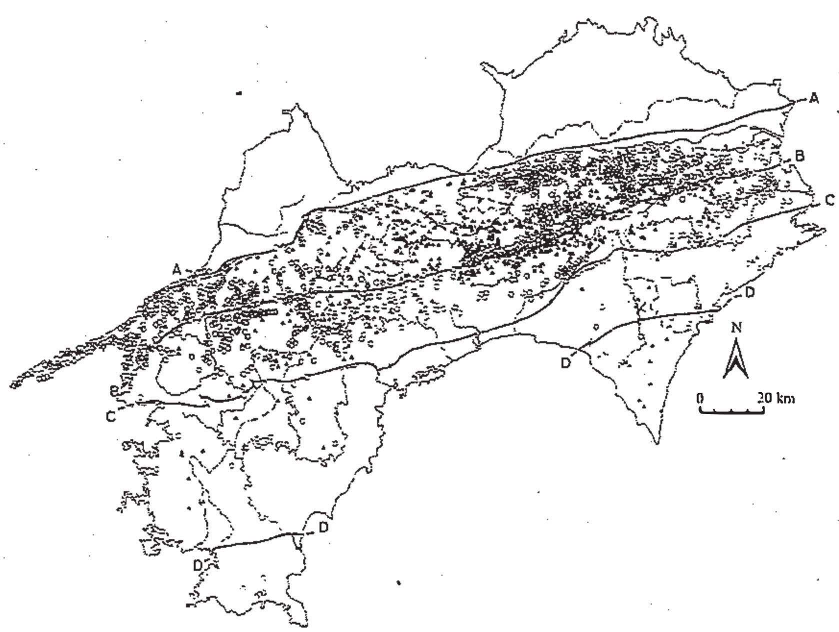
Mitsuhiko Mukaitani
Takamatsu National College of Technology, Kagawa, Japan

Masamichi Hori & Nobuyuki Kobayashi
Advanced course, Takamatsu National College of Technology, Kagawa, Japan

ABSTRACT: Most landslides and slope failures are caused by the shear strength on main slip layer. Then, the shearing mechanisms of landslide soils are important. This paper treats the modeling of slope by view point of topographic and geological studies and the peak and residual shearing resistance. These soil samples are artificial soils in the laboratory. Firstly, we considered topographic and geological studies on various types of slope stability and clarified the relation between the shearing resistance angle and type of slope. We suggested the idea for design of countermeasure considering difference of shearing mechanism on the slope. Finally, we investigated the effect of sand or gravel fraction on main and interslice slip surfaces of slope.

1 INTRODUCTION

This paper treats the shearing mechanism of landslide soil using artificial gravelly soil in laboratory. There are many landslides in fractured zone in Shikoku Island, Japan. The slip layer of these landslides has the gravel fraction including fine ones. In Japan, landslides are often classified for their geology into three groups, landslides in Tertiary deposit, landslides in fractured zone and landslides in solfataric soil. As shown in Figure 1, the Median Tectonic Line (called MTL) runs in east-west direction in Shikoku Island. MTL is the active fault. Same tectonic line runs in Kyushu Island, too. The fractured zone spreads at the southern part of the MTL. In this zone, many landslides take place in the weathered slopes of black green and other rocks. MTL is not only main factor of earthquake problems, but also landslide ones.



○: landslide, ▲: slope failure of large scale
A-A line: Median Tectonic Line, B-B: Mikabu Tectonic Line
C-C: Butsuzo Tectonic Line, D-D: Aki Tectonic Line

Figure 1. Shikoku Island and the fractured zone. (Takahashi, 2000)

Then, disturbed samples of artificial soils were obtained in laboratory. Ring shear tests were carried out on these samples under drained condition. The test results are discussed from the viewpoint of shearing mechanism with comparing to landslide at in-situ.

2 TOPOGRAPHIIC CLASSIFICASIONS OF LANDSLIDE

Many factors effect on safety factor of the landslide. Landslides are divided into four groups in topographic classifications. It is very important that strength parameters is connected with the factors by another study area. In slope designing, stability analysis is the most remarkable work. In stability analysis, it is necessary to calculate using the strength parameters and the present shape of slope which is not affected by the historical movement. The schematic diagram of slope is shown in Figure 2. The relation between classifications and profiles of landslide is shown in Figure 3.

(1) It is assumed that the main slip surface and the inter slice surface are mobilized the peak strength ϕ' at the primary slide in landslide soil mass movement.

(2) In latent slide, the inter slice surface is mobilized the peak strength and the main slip surface is intermediate between the peak strength and the residual strength ϕ_r.

(3) In active slide, the inter slice surface is mobilized intermediate between the peak strength and the residual strength and the main slip surface is ϕ_r.

(4) In ancient slide, the main slip surface and the inter slice surface are mobilized ϕ_r.

3 GEOLOGICAL CLASSIFICASIONS OF LANDSLIDE

Okuzono (1987) suggested the geological classifications of landslide from the view point of collapsible structure as shown in Figure 4. The main target of this figure is the artificial cut slopes. Slope failures can be classified into three groups, which are rock fall, surface failure and landslide. The relation between classifications and ϕ' is shown in Figure 4.

(1) circular slip by clayey soil: These failures are occurred by homogeneous clayey soil. If the soil mass of slope is made by sandy clay or decomposed granite soil, slope failure occurs. In this case, only main slip surface affects the stability of soil mass. The main slip surface is mobilized intermediate between ϕ' and ϕ_r. The interslice surface is mobilized ϕ'.

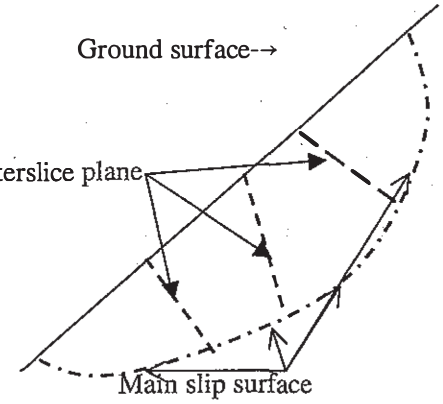


Figure 2. Description of interslice and main slip surfaces.

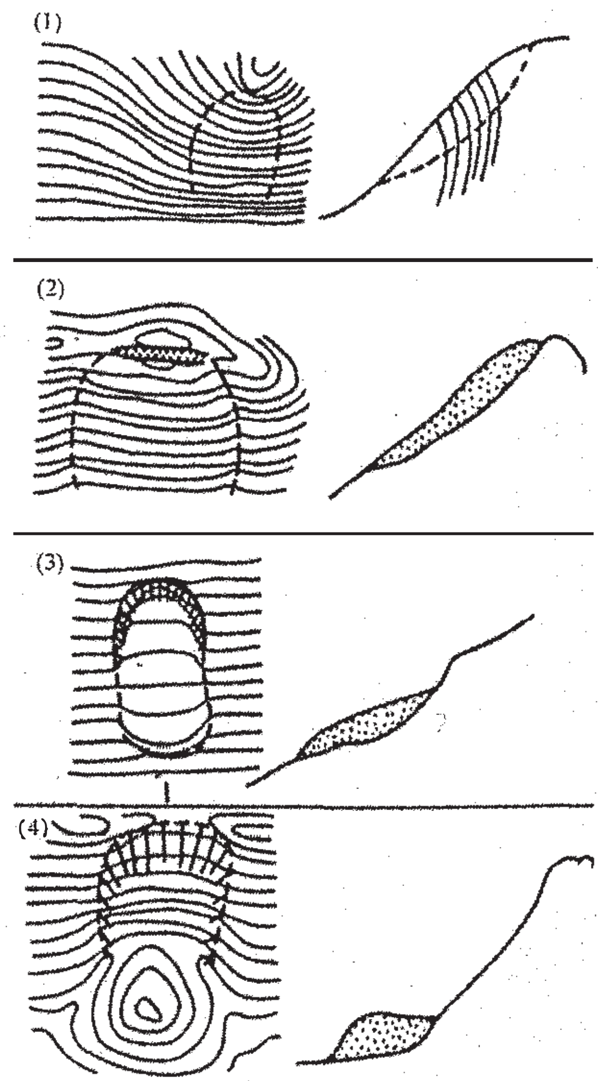


Figure 3. Schematic diagram of topographic classifications c landslide. (Ueno, 1997)

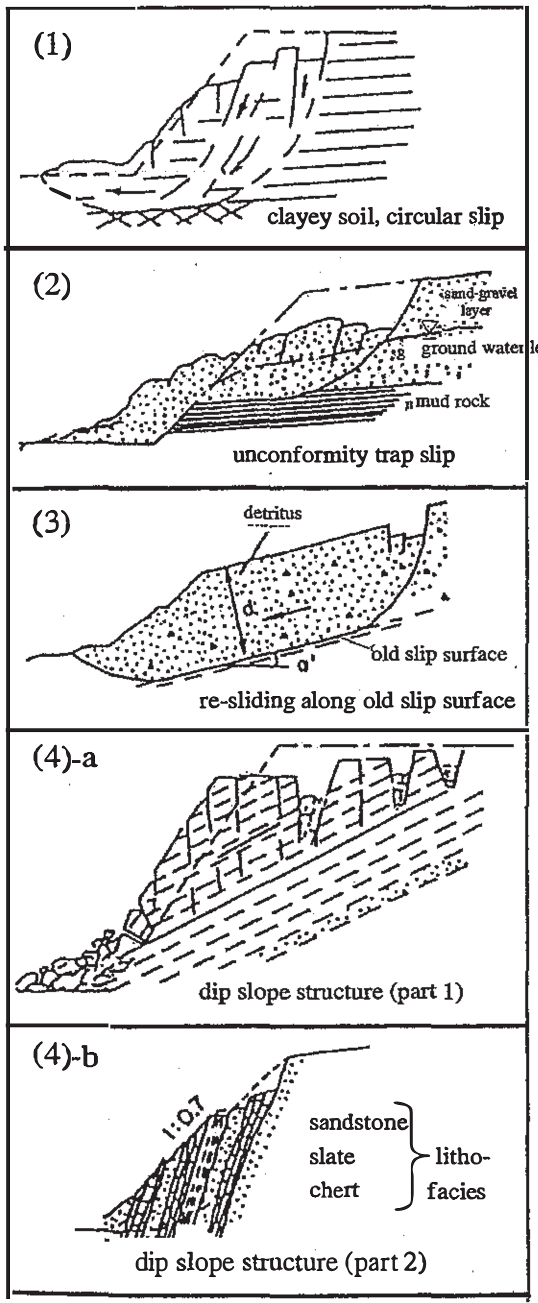


Figure 4. Schematic diagram of geological classifications of landslide. (Okuzono, 1987)

(2) unconformity trap slip by difference of permeability: If porous soil mass of slope is on base rock which has low permeability, slope failure occurs with piping of seepage ground water. The main slip surface is mobilized intermediate ϕ_r. The inter slice surface is mobilized intermediate between ϕ' and ϕ_r.

(3) re-sliding along old slip surface: This failure occurs along the old slip surface and another slip surface whose scale is small. The main slip surface is mobilized ϕ_r. The interslice surface is mobilized intermediate between ϕ' and ϕ_r.

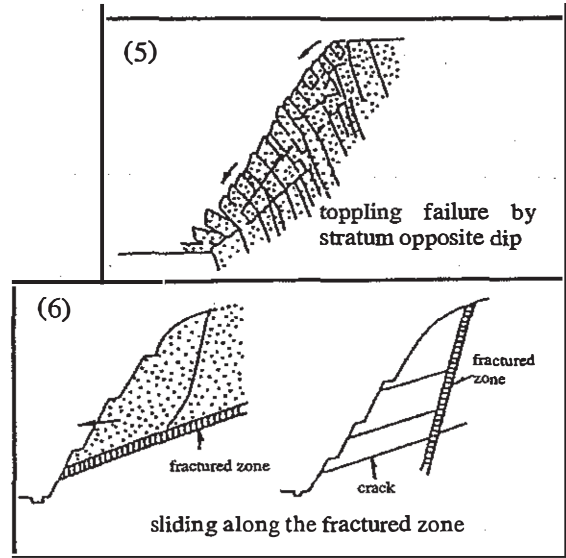


Figure 4. (continued) Schematic diagram of geological classifications of landslide. (Okuzono, 1987).

(4) dip slope structure: In this case, movement soil mass of slope has the alternation strata of sandstone and shale. Even if the shale layer is very thin, main slip surface is on between these layers. The unconformity, schistosity and joint are included into this group from geological view point. The main slip surface is mobilized ϕ_r. The interslice surface is mobilized intermediate between ϕ' and ϕ_r.

(5) toppling failure by stratum of opposite dip: The development of fault, unconformity, schistosity and joint affects the stability of slope. If these weak layers are connected together, slope failure occurs called 'creep type failure', 'toppling' and 'wedge failure'. The main surface is mobilized intermediate between ϕ' and ϕ_r. The interslice slip surface is mobilized ϕ_r.

(6) sliding along the fractured zone: The shear strength of the slope with fractured zone is low value. So, slope failure occurs very easily. If the thickness of fractured zone is thin layer, failure pattern is similar to above mentioned type 5. The main slip surface is mobilized ϕ_r. The interslice surface is mobilized intermediate between ϕ' and ϕ_r.

4 EFFECT OF SHEAR MECHANISM ON SHEARING RESISTANCE ANGLE

The maximum angle of shearing resistance ϕ' in terms of effective stress is corresponding to the peak strength by triaxial test. The minimum angle of shearing resistance ϕ_r in terms of effective stress is to the residual strength by ring shear test. Yagi et al. (1985) made two kinds of ring shear apparatus. One is a box shear type (called Bishop type) in which a specimen is sheared along the one plane thickness as shown in Figure 5(a). Figure 6 shows the schematic diagram of direct shear and similar failure mode at in-situ. Another is a simple shear type in which a specimen is sheared uniformly throughout the thickness as shown in Figure 5(b). The reason why they made the simple shear type ring shear apparatus is that a slicken side is not always found in a sliding layer but a slip band is formed in above mentioned many case. Figure 7 shows the schematic diagram of simple shear and similar failure mode at in-situ.

The influence of difference of shearing mechanism using two kinds of ring shear test is to evaluate the condition of main and interslice slip surfaces. The effect of shear mechanism on shearing resistance angle is observed in Figure 8 on ϕ_r of remoulded landslide clayey soil obtained by the triaxial compression test. The soil was weathered serpentine obtained by Shimotsu, Wakayama prefecture, Japan. The soil samples were obtained by mix-

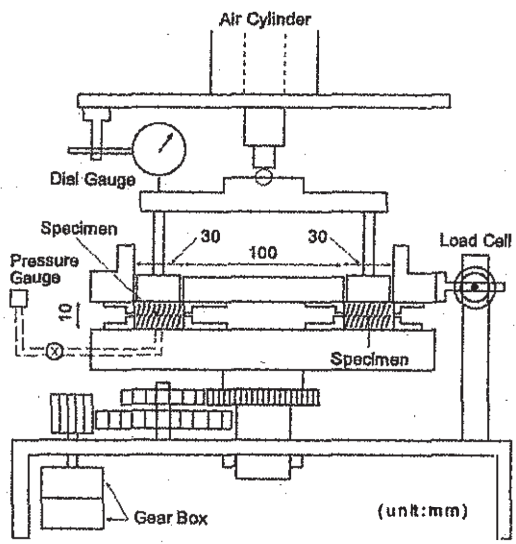


Figure 5(a). Direct shear type ring shear apparatus.

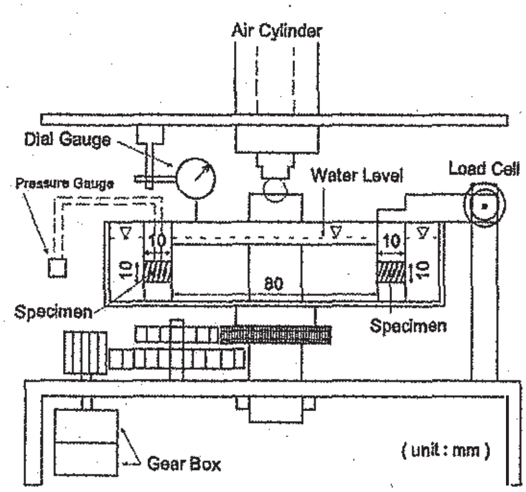


Figure 5(b). Simple shear type ring shear apparatus.

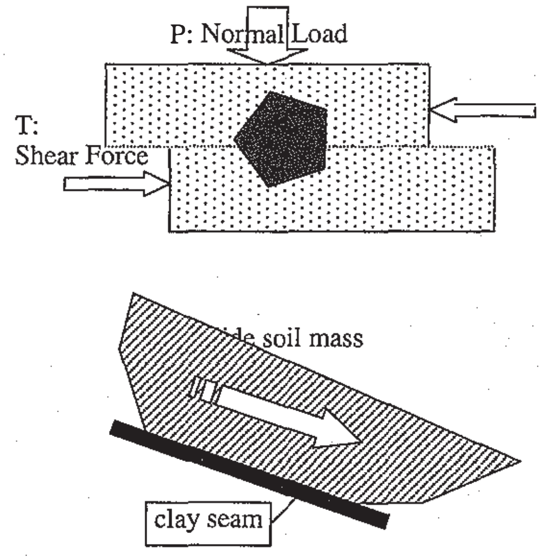


Figure 6. Schematic diagram of direct shear and similar failure mode at in-situ.

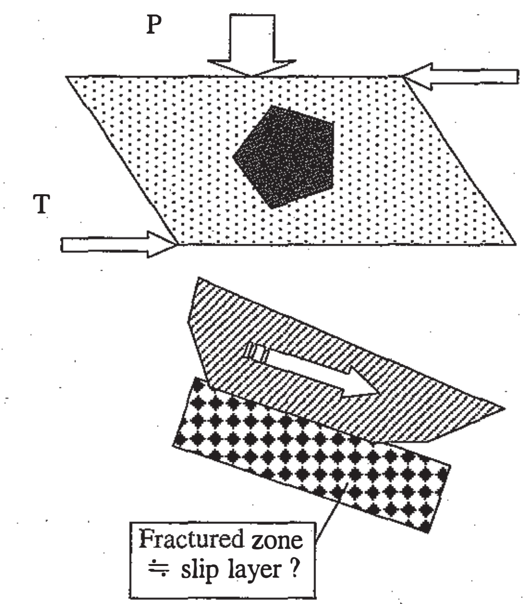


Figure 7. Schematic diagram of simple shear and similar failure mode at in-situ.

ing clay fraction and gravel fraction in various ratios. In Figure 8, the ϕ_r increases gradually with increase of gravel fraction.

However, as mentioned above, the difference of test apparatuses on restriction for slip surface, can be also observed. Figure 8 shows the relation of ϕ_r and sand or gravel fraction for the same samples, but obtained by newly developed "simple shear" type ring shear test apparatus shown in Figure 5. The slip surface is not made before shear and is freely selected. In Figure 8, the ϕ_r does not increase until greater than 50% of gravel fraction.

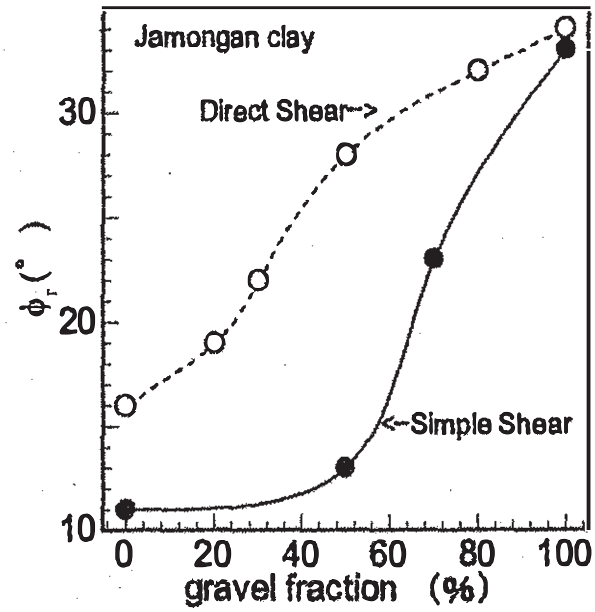


Figure 8. Effect of shearing mechanism on ϕ_r.

These results indicate that ϕ_r is influenced by the large grain size fraction, but the influence depends on the test apparatus or the restriction for the slip surface.

5 DESIGNING FLOW CONSIDERING DIFFERENCE OF SHEAR MECHANISM

In designing, the choice of ϕr affects the safety factor and the countermeasure with cost. If the slip surface of landslide is observed as very thin plane of a few mm thickness, we must use ϕr by ordinary type ring shear tests. These slip surfaces are called by 'slicken side' at in-situ.

If the slip surface of landslide is observed as the layer of a few cm thickness or fractured fault zone, we must check the possibility of ϕr by simple shear type ring shear tests. These landslides are including initially movement slope in topography.

In sand or gravel material, void ratio is most important factor. In clay material, water content is most important factor. The clayey soil including sand or gravel is needed the new viewpoint. Figure 9 shows the relation of eg and ϕ' by triaxial compression tests. For eg less than 3, the apparent ϕ' is nearly equal to that of sand or gravel, but for less than 3, ϕ' is equal to that of clay. The eg is void ratio in terms of sand or gravel and defined as following equation (1).

$$e_g = (V_w + V_{clay})/(V_{sand\ or\ gravel}) \qquad (1)$$

The new factor of eg has possibility of explanation of state for slip surface condition of landslide soil including sand or gravel.

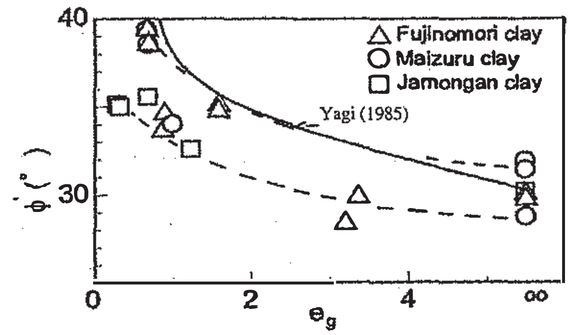


Figure 9. Relation between e_g and ϕ'.

6 APPLICATIONS FOR DESIGNING OF COUNTERMEASURE

We discussed the relation between topographic and geological view points and the variation from peak strength to residual one. Nevertheless, a few factors are considered to calculate the safety factor on the slope. We must decide the proper strength parameters based on laboratory tests, topographic and geological studies.

The infinite slope method is most simply consideration on stability problem seen in Figure 10. The stability of the only one soil's block is related with the Coulomb's failure criterion. This method is able to predict the effect of countermeasure on the slope based on the equilibrium of forces without analytical calculations.

(1) drainage of main slip surface: The stress condition on main slip surface must be decrease the value of horizontal distance against the apparent failure criterion seen in Figure 11.

(2) shear resistance type of pile work: The stress condition on main slip surface must be decrease the vertical distance, which is equal to the force using pile or other techniques par unit area, against the apparent failure criterion. seen in Figure 12.

(3) anchoring: The stress condition on main slip surface must be decrease the combined force seen in Figure 13, which is equal to the force using anchoring par unit area, against the apparent failure criterion.

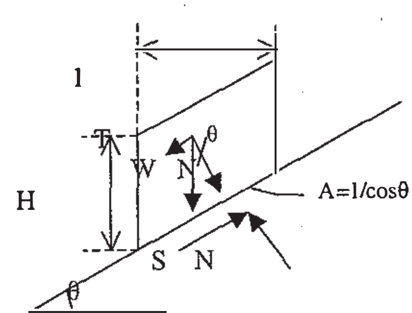


Figure 10. Schematic diagram of finite slope model.

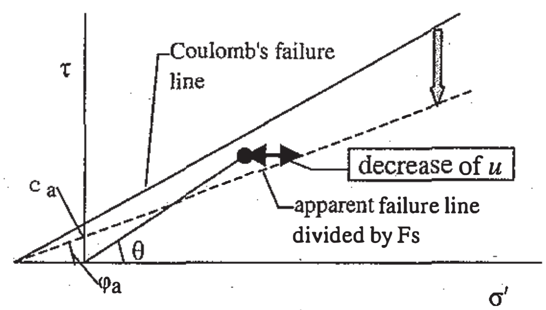


Figure 11. Estimation of drainage value on relation between σ' and τ.

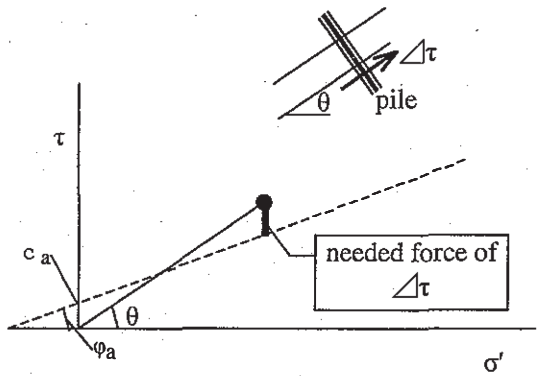


Figure 12. Estimation of needed force value on relation between σ'and τ.

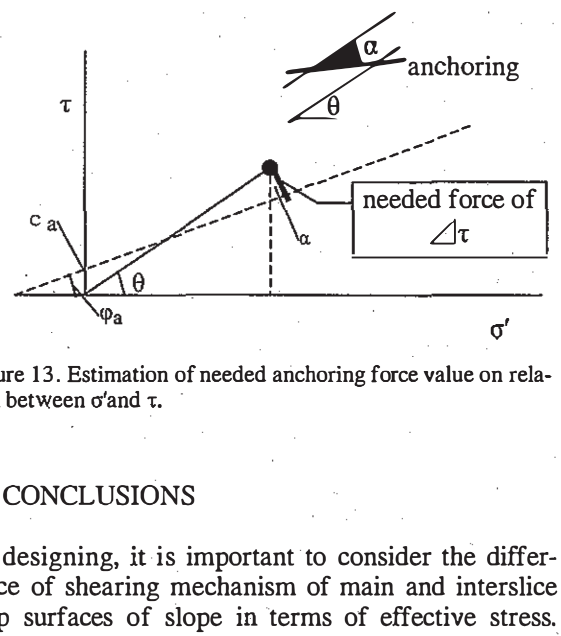


Figure 13. Estimation of needed anchoring force value on relation between σ'and τ.

7 CONCLUSIONS

In designing, it is important to consider the difference of shearing mechanism of main and interslice slip surfaces of slope in terms of effective stress. The effective stress concept may be applicable to slope regardless of the contact mode of slip surface (ϕ': triaxial compression test, ϕ_r: direct shear type or simple one). The $\phi'$and ϕ_r are influenced by the grain size of sample, but the influence depends on the test apparatus.

8 ACKNOWLEDGEMENTS

The authors would like to express their gratitude to undergraduate students in Takamatsu N.C.T. for their help in the preparation of this paper. This research was partially supported by the Ministry of Education, Science, Sports and Culture, Grant-in-Aid for Encouragement of Young Scientists, No. 11750448, 1999-2000.

REFERENCES

Enoki Meiketsu, Yagi N. and Yatabe R. 1989. The mechanism of reinforcement in tension in sand. *Memories of Faculty of Engineering. Ehime university*. Vol. 11. No. 4: 441-449. (In Japanese)

Enoki Meiketsu, Yagi N. and Yatabe R. 1991. Stability Analysis Method of Natural Slope. *Memories of Faculty of Engineering. Ehime university*. Vol. 11. No. 2: 425-432. (In Japanese)

Gray D. H. 1974. Reinforcement and stabilization of soil by vegetation. ASCE. *Journal of Geotechnical engineering division*. Vol. 100. No. GT6: 695-699.

Ishii Tomonori, Yatabe R., Yagi N. and Yokota K. 1999. Influence of clay minerals on strength characteristics of landslide clay in Mikabu. *Proceedings of the international symposium on slope stability engineering*: 697-700. Japan.

Takahashi Jiro. 2000. Mass movement and erosion cycle, *Proceedings of conf. on Landslide and Slope failure*: 49-54.(In Japanese)

Ueno Shouji. 1996. The method of application of topographical and geological information for geothechnical engineers, (part 5) Landslide. *Journal of JGS*. Vol. 44. No. 6: 51-56.

Ueno Shouji. 1997. Study of configuration, scale and distribution of landslides for countermeasure. *Text of regional geothechnical investigation in Siga pref.* 7-27. (In Japanese)

Ueno Shouji. 1999. Study of configuration, scale and distribution of landslides. *Proceedings of the international symposium on slope stability engineering*: 175-180. Japan.

Yagi Norio and Yatabe R. 1985. A Microscopic Consideration on Shearing Characteristics of Decomposed Granite Soil. *Journal of JSCE*. No. 364: 131-141. (In Japanese)

Yagi Norio, Enoki M. and Yatabe R. 1992. Reinforcing Mechanism of Sandy Soil by Roots of Plans. 1991. *Proceedings of 27th Annual Conference of Soil Mechanics and Foundation Society of Japan*: 1865-1866. (In Japanese)

Yagi Norio, Yatabe R. and Enoki M. 1994. The Effects of Root Networks on Slope Stability. *Proceedings of Int. Conf. on Landslide, Slope stability and Safety of Infra-structure*: 387-392. Malaysia.

Yamashita H, Saga M., Fujita H., Yokota K. and Yatabe R. 1999. The characteristics of landslides caused by the hydrothermal metamorphic clay. *Proceedings of the international symposium on slope stability engineering*: 693-696. Japan.

Yatabe Ryuichi, Yagi N. and Enoki M. 1991. Consideration from effective stress about strength parameters of slip layer clay of landslide. *Journal of the Japanese Society of Landslide*. Vol. 28. No. 2: 20-26. (In Japanese).