Ⅲ－4　Simple Ring Shear Test on Sand-mixed Soil

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1 Introduction

Use of a ring shear apparatus to estimate the strength of a soil is preferred especially when the soil strength is governed by higher shear deformations. Creeping landslides, for example, possess very high shear strains along the slip layer soil. The strength of the slip layer soils after sliding is thus governed by the creeping movement (i.e., extremely slow rate of shear) itself. Such a state of soil when its strength is governed by the shear movement is known as residual state, and in this state, the strength of a clay soil is always less than the peak strength (i.e., the strength due to static friction between the clay particles).

Ring shear apparatus, in general, is capable of shearing a soil sample for an infinite shear deformation without changing the area under shear. For the structural simplicity a ring shear apparatus in general use is based on direct shear principal, in which the soil sample is made to fail through a pre-located plane of shear. However, one widely experienced problem in this apparatus is effect of ring wall restriction on the movement of soil grains during shear. There is a great deal of effect on the shear movement of soil particles at pre-failure stage due to ring wall restriction. This effect can be minimized or theoretically reduced to zero if the direct shear is converted into simple shear, which is a state when all the soil particles in a certain layer are sheared with the same rate against the particles in the adjacent layers. For an easy understanding, the illustrations of direct and simple shear are made in Fig.1.

To determine the strength under minimized effect of ring wall restriction on the particle movement, a simple ring shear apparatus was developed, in which the soil sample could fail through the weakest horizontal plane in the entire depth of the sample. Several tests were carried out on sand mixed clay samples with the help of direct as well as simple ring shear apparatuses. Comparison of the results from the simple shear tests was made with those from the direct shear tests, and also studied was the drained strength behavior of clay soil when mixed with sandy particles.

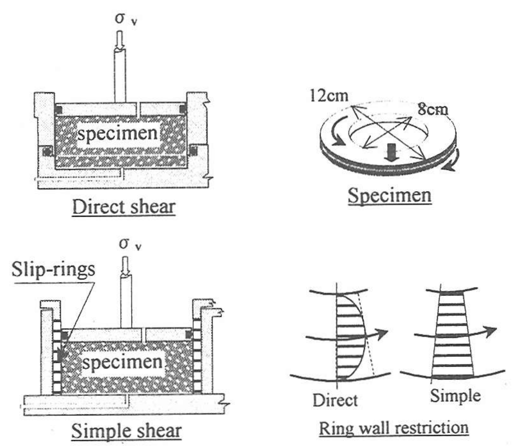

Fig.1: Soil specimen in direct and simple shear.

2 Tests and Results

A series of laboratory tests was carried out on a number of mix soil samples containing sand and landslide clay. The mix samples were prepared in 0/100, 10/90, 20/80, ………, 100/0 ratios.

2.1 Sample preparation

Three soil samples collected for preparing the test samples consisted of course sand, fine sand, and landslide clay. The coarse sand consisted of particles in a range of 2000 to 425 μ m, the fine sand consisted of Toyoura standard sand with particle size ranging from 200 to 75 μ m, and the landslide clay sample was prepared to contain silt and clay sized particles, i.e., particles below 75 μ m, only. A 50/50 mix of course and fine sands was then added to clay sample in 0/100, 10/90, 20/80, ………, 100/0 ratios to prepare a total of 11 test samples. The samples with extreme mix ratios are the pure landslide clay and pure sand. The physical properties of the individual samples are given in Table 1.

Table 1: Physical properties of mixed soil samples

Soil Sample	ρ_s (gm/cm³)	LL (%)	PL (%)	e_{max}	e_{min}	Particle size distribution (%)				
						<5 μ m	5~75 μ m	75~250 μ m	250~850 μ m	850~2000 μ m
Landslide clay	2.86	56.65	29.51			72	28	0	0	0
Toyoura sand	2.62	-	-	1.013	0.625	0	0	100	0	0
Coarse sand	2.58	-	-	0.928	0.706	0	0	0	34	66
Mixed sand	2.60	-	-	0.855	0.526	0	0	50	17	33

2.2 Ring Shear Tests

In addition to physical tests like solid density, relative density, liquid and plastic limits, particle size analysis, etc., all the mix soil samples were tested for shear strength in direct and simple ring shear apparatuses. Specimens formed in both the apparatuses assumed a shape of flat ring with a mean diameter of 10cm and width of 2cm, as shown in Fig.1. The thickness of the specimen, which could vary between 5 to 20 mm, however, was controlled at a minimum of 8mm so as to attain a sufficient gap between the largest sand particle (i.e., 2mm) and top and bottom of the shear ring. The shearing rate in both the apparatuses was maintained at 0.44°/min (angular speed), and all the test samples were sheared for three hours by which all them showed a constant state of strength against the deformation. The results thus obtained are presented in Figures 2 to 5.

Fig.2 and Fig.3 show the angles of shearing resistance of the mix soil samples in peak (ϕ_d) as well as residual (ϕ_r) state as functions of sand content determined by direct and simple shear methods respectively. Also presented in the same figures are volume occupied by clay particles (including voids inside the clay portion) and volume of voids (with respect to sand particles only) as percentage fraction of the volume of sand particles, represented respectively by V_{clay}/V_{sand} and $V_{void\text{-}s}/V_{sand}$.

Although, in both the methods, it can be seen that the strength of mix sample increases with the increase in sand content, after a certain state, i.e., around 80% sand content, the strength reaches a maximum and then drops. This strength of mix sample was found to be greater than that of 100% sand. One reason for this increase may be optimum intactness of the clay and sand particles. As shown in the figures, as the sand content increases, the volume of clay mass decreases in a parallel way with the decrease in voids in sand. However, when the sand content reaches 70-80% (i.e., 20-30% clay), the two lines are seen to have split, which means the volume of clay mass (including voids in it) is becoming lesser than that of voids in sand. It reduces the intactness of the soil particles, which results in reduced shear strength. In contrast, when the sand content is lesser, the mix sample is intact too but the strength being governed by clay content reduces with the reduction in sand percentage.

A direct comparison of the two methods (i.e., direct and simple shear methods) is made in Fig.4. It shows peak and residual shear strengths of all the samples tested. Although for smaller vertical stresses (i.e., σ_v) the strength by simple shear method is seen to have a higher value than that by direct method, the average line shows that they can be related as $\tau_{simple} = 0.91\ \tau_{direct}$, where τ is the shear strength of the soil.

Fig.5 shows a variation in strength of mix samples in terms of angles of shearing resistance with the content of sand particles bigger than 425 μ m. In most cases, physical as well as strength tests on remolded or disturbed soils are carried out with samples containing soil particles smaller than 425 μ m. Landslide soil, for example, is often sampled to contain particles smaller than 425 μ m while testing for shear strength. The actual slip layer soil, however, consists of a considerable amount of bigger sandy particles. Although the biggest sand particle mixed in the tested soil samples was 2mm, Fig.5 shows that even a minor percentage of the particles bigger than 425 μ m has a considerable effect on the strength of the mix soil.

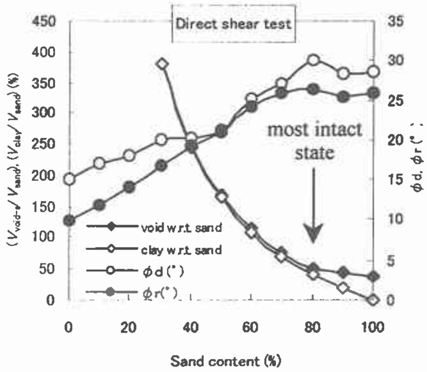

Fig.2: Results of direct ring shear tests

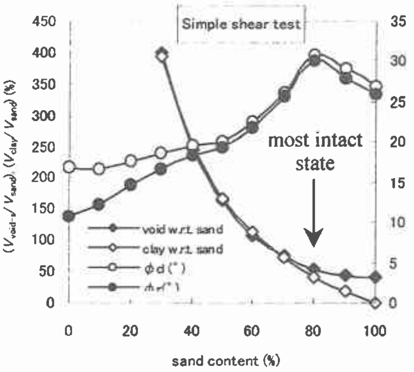

Fig.3: Results of simple ring shear tests

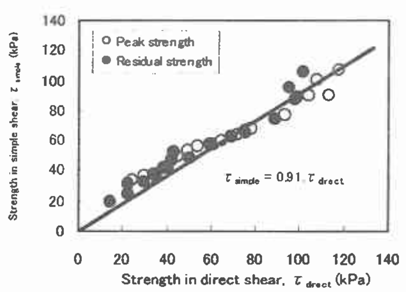

Fig.4: Comparison of strengths by direct and simple shear methods

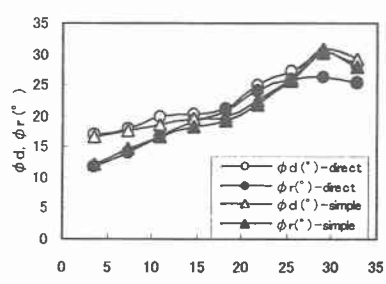

Fig.5: Variation of ϕ_d, ϕ_r with the content of particles bigger than 425 μ m

3 Conclusions

This study can be concluded at the following points.

- Both direct and simple shear tests showed a considerable increase in the strength of sand mixed clay soil. When the sand content reached around 70-80%, the increase in strength reached a peak and then dropped, which is because the mix sample reached an optimum state of particle intactness and behaved as a compacted soil.
- Comparison of shear strengths estimated by direct and simple shear methods showed that the strength in simple shear is slightly smaller than that in direct shear. The mean of all the values resulted in certain relation, in which strength in simple shear is about 90% of that in direct shear.
- In addition to a comparison of strength determined by direct and simple shear methods, the study revealed that the strength of a landslide soil estimated with a sample passing 425 μ m sieve is less than the actual one. There is a great deal of effect of bigger particles on the strength of a landslide soil because bigger particles do occur in a landslide soil sample.
- Although assumptions were made that the soil sample in simple ring shear apparatus was under simple shear, it needs a verification, which might be possible by observing the movement of slip rings. In addition, various sources of friction in this apparatus need to minimized.