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Shear strength behavior of two saprolitic soils

Résistance au cisaillement de deux sols saprolitiques

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ABSTRACT : The saturated and unsaturated shear strength behavior of a completely decomposed fine ash tuff and a completely decomposed granite from Hong Kong were studied using the direct shear and triaxial tests. The completely decomposed fine ash tuff is a fine- to medium-grained saprolite and the completely decomposed granite is a coarse-grained saprolite. Results show that matric suction provides some increase in the shear strength of both soils. The effect of matric suction on the shear strength was more pronounced on the fine- to medium-grained saprolite than on the coarse-grained saprolite. The contribution of matric suction to shear strength can be related to the soil-water characteristic curves of the soils.

RESUME : La résistance au cisaillement saturée et non saturée d'un cendre fin complètement décomposé, et d'une granite complètement décomposée de Hong Kong a été étudiée en utilisant les essais de cisaillement direct et les essais triaxiaux. Le cendre fin complètement décomposé est un saprolite à grain fin à moyen et la granite complètement décomposée est un saprolite à gros grain. Les résultats montrent que la succion matricielle entraîne une augmentation de la résistance au cisaillement dans les deux sols. L'effet de la succion matricielle sur la résistance au cisaillement était plus prononcé dans le saprolite à grain fin à moyen que dans le saprolite à gros grain. La contribution de la succion matricielle à la résistance au cisaillement peut être due au courbes de rétention d'eau des sols.

1. INTRODUCTION

Saturated and unsaturated shear strength tests on two saprolitic soils from Hong Kong were conducted using direct shear and triaxial equipment. These tests formed part of a study sponsored by the Geotechnical Engineering Office of Hong Kong (i.e., GEO) as part of their ongoing research on the shear strength of unsaturated, saprolitic soils.

The saprolitic soils involved in the study are a completely decomposed fine ash tuff and a completely decomposed granite. Both saprolitic soils possessed intergranular bonding, relict joints and are unsaturated in their natural state. The tasks of sampling and testing of these saprolitic soils are challenging.

2. SOILS

The grain size distributions of the completely decomposed fine ash tuff and the completely decomposed granite are presented in Figs. 1a and 1b, respectively. Both soils are heterogeneous, cemented and possess relict discontinuities.

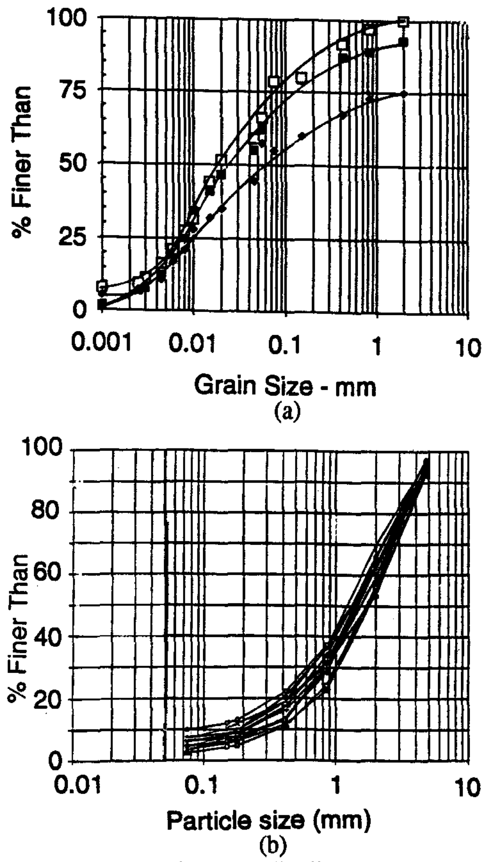

Figure 1 : Grain size distributions for (a) completely decomposed fine ash tuff, and (b) completely decomposed granite.

3. TESTING PROGRAM

Multistage, saturated and unsaturated direct shear tests were conducted on 50mm by 50 mm by 21mm specimens of the completely decomposed fine ash tuff.

For the completely decomposed granite, multistage saturated and unsaturated direct shear tests, single stage saturated triaxial tests and two-stage unsaturated triaxial tests were conducted. The saturated and unsaturated direct shear tests were conducted on 100mm by 100mm by 40mm specimens. The single stage saturated triaxial tests were conducted on 71mm diameter by 150 mm height specimens. The two-stage shear unsaturated triaxial tests were conducted using 84mm diameter by 150mm height specimen.

In the unsaturated direct shear tests and unsaturated triaxial tests, air and water pressures were controlled using the axis-translation technique in specially modified direct shear (Gan et al., 1988) and triaxial cells (Ho and Fredlund, 1982). For the unsaturated direct shear tests on the fine ash tuff, two sets of net normal stresses of 20 kPa and 100 kPa were used. For the decomposed granite, two series of unsaturated direct shear tests were conducted using a constant net normal stress of 20 kPa in both series. A net confining pressure of 20 kPa was used in the unsaturated triaxial tests on the decomposed granite.

4. TEST RESULTS

Shear strength results for the decomposed fine ash tuff and the decomposed granite are presented in Figs. 2 to 9.

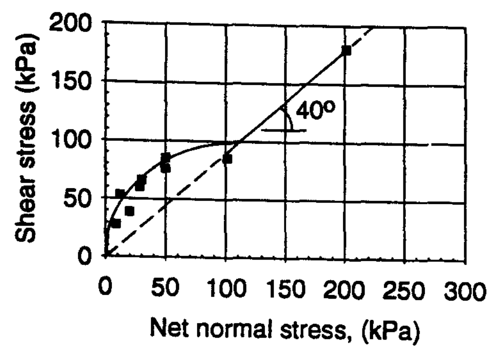

Figure 2 : Saturated peak direct shear strengths of completely decomposed fine ash tuff.

4.1. Decomposed Fine Ash Tuff

The peak shear strength envelope from the saturated direct shear tests (Fig. 2) is comprised of two segments, a curvilinear segment at low normal stresses followed by a linear segment at higher normal stresses. The linear segment has a slope of 40°. The transition from the curvilinear segment to the linear segment of the envelope occurs at a normal stress of about 110 kPa. The best-fit shear strength envelope for saturated direct

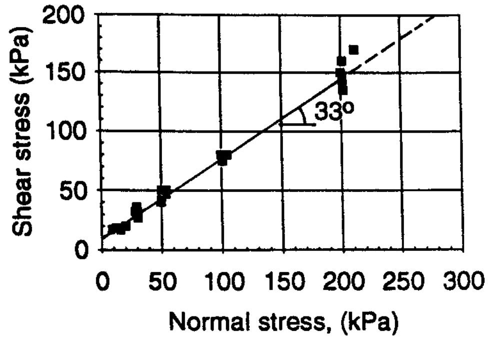

Figure 3.: Ultimate shear strength envelope from saturated direct shear tests on remolded specimens of decomposed fine ash tuff.

shear tests on remolded specimens gave a linear envelope with a slope of 33° and an intercept of 10 kPa (Fig.3).

The shear strength versus matric suction envelopes for the fine ash tuff (Fig. 4) show that the shear strengths of the decomposed fine ash tuff increase with matric suction The increase in the shear strength with matric suction appears to reach a limit at matric suctions greater than about 75 to 100 kPa.

4.2. Decomposed Granite

Results of saturated direct shear tests on the undisturbed decomposed granite (Fig. 5) show a bi-segment characteristic in the low normal stress range. The linear segment of the envelope has a slope of about 38°. Shear strength results from saturated direct shear tests on the completely remolded, specimens of the decomposed granite showed that the unbonded decomposed granite has an angle of internal friction of 35.5° (Fig. 6).

Results from unsaturated direct shear tests on the decomposed granite (Figs. 7a and 7b) show considerable scatter. Results from the two-stage unsaturated triaxial tests on the decomposed granite (Fig. 8) also show considerable scatter. A general trend of increasing shear strength with matric suction is quite evident, when the data are viewed in relation to the ϕ^b equal to ϕ' line shown Figs. 7 and 8.

The q' versus p' envelope from saturated triaxial tests (Fig. 9) is linear, with a slope of 32° and an intercept of 23 kPa. These values are equivalent to a ϕ' of 38.5° and a c' of 29 kPa.

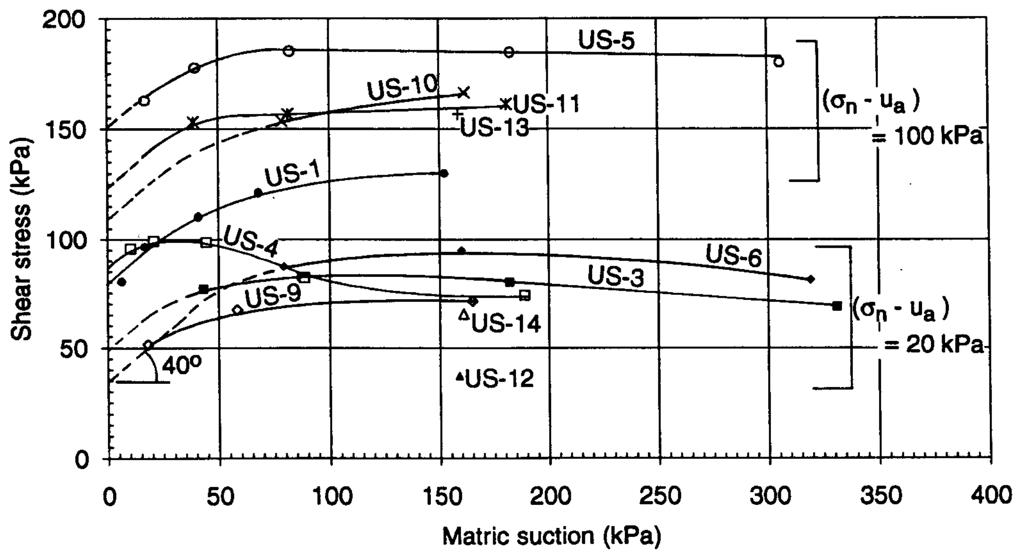

Figure 4 : Unsaturated direct shear strength results for completely decomposed fine ash tuff from multistage tests.

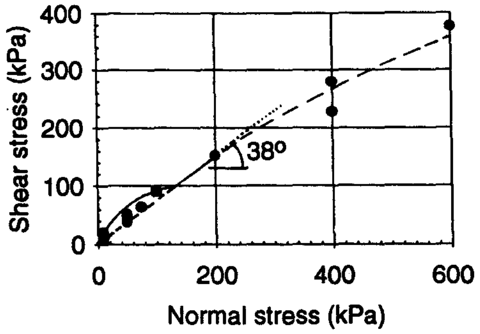

Figure 5 : Saturated peak direct shear strengths for completely decomposed granite.

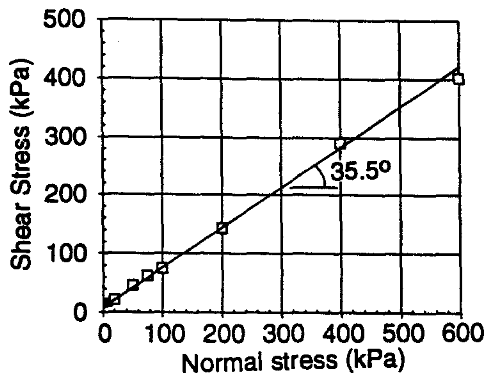

Figure 6 : Ultimate shear strength envelope from saturated direct shear tests on remolded, recompacted completely decomposed granite.

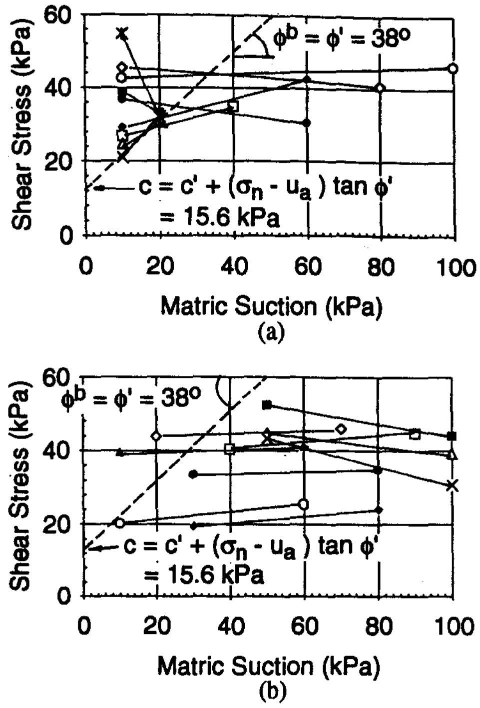

Figure 7 : Unsaturated direct shear results for completely decomposed granite (a) 1st series, and (b) 2nd series.

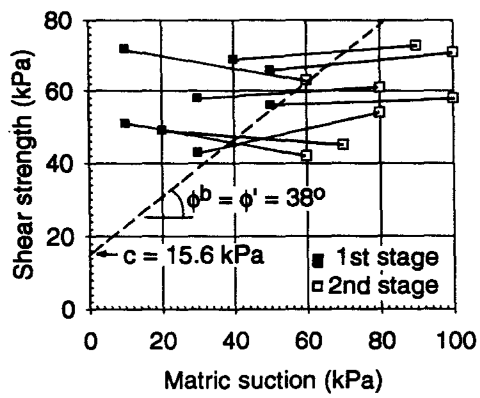

Figure 8 : Unsaturated triaxial results for completely decomposed granite

5. DISCUSSIONS

The peak strength envelopes for the saturated decomposed fine ash tuff (Fig. 2) and the saturated decomposed granite (Fig. 5) in direct shear have a bi-segment form (comprising of a curvilinear segment followed by a linear segment. The bi-segment envelope is similar to peak strength envelopes usually obtained for overconsolidated soils. The decomposed fine ash tuff and decomposed granite are not overconsolidated. In fact, the insitu densities of both soils are below the expected densities corresponding to the in-situ stress conditions.

Similar bi-segment shear strength envelopes for saprolitic soils from Hong Kong were reported by Irfan (1988), Massey et al (1989), Pun and Shen (1993) and Cheung and Greenway (1987). It was reported in these these previous studies that the normal stress corresponding to the transition of the bi-segment envelope coincide with the change over from a dilatant behavior to a compressive

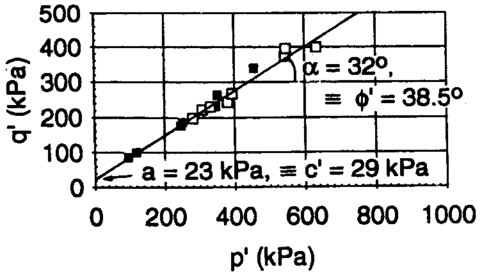

Figure 9 : Saturated triaxial results for completely decomposed granite

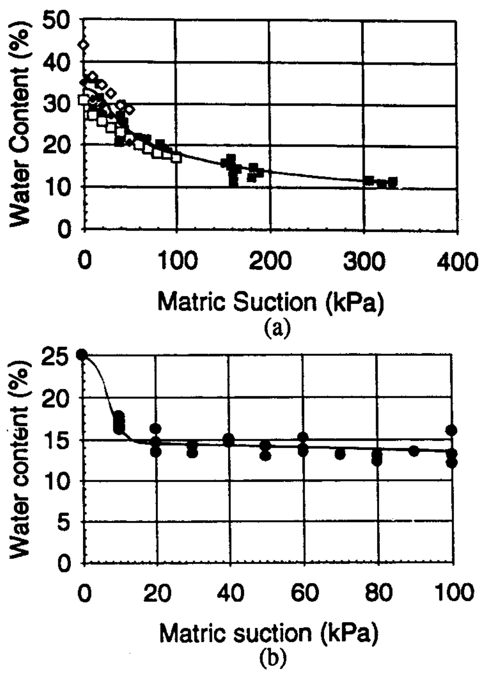

Figure 10 : Soil-water characteristic curves for (a) completely decomposed fine ash tuff, and (b) completely decomposed granite.

behavior during shear failure. Results from the decomposed fine ash tuff were found to be in agreement with this observation. Results from the decomposed granite were not as conclusive. For the decomposed granite the normal stress corresponding to the transition from the curvilinear to the linear segment of the envelope was found to be approximately defined by the "pseudo preconsolidation" pressure of the decomposed granite. The envelope from the results of saturated triaxial tests did not appear to exhibit similar bi-segmental characteristic. The saturated triaxial tests on the decomposed granite were conducted at higher confining pressures.

The unsaturated direct shear tests on the decomposed fine ash tuff (Fig. 4) show that matric suction, at low suction values, had the same effect on shear strength as net normal stress. The value of ϕ^b was equal to the value of ϕ' at matric suctions below about 30 to 40 kPa when the soil is close to saturation. The contribution of matric suction to shear strength decreases (i.e., ϕ^b decreases) as the soil desaturates. At matric suctions greater than about 75 to 100 kPa, the contribution of matric suction to shear strength levels off or in some cases declined, as the water content of the fine ash tuff is near its residual value (Fig. 10a).

Results of unsaturated direct shear tests and unsaturated triaxial tests on the decomposed granite show considerable scatter Figs 7a, 7b and 8). A trend of increasing strength with matric suction is, however, evident from the data. The scatter in the shear strength data can be attributed to the heterogeneity and the low water retention capacity of the decomposed granite (Fig. 10b). The decomposed granite reaches its reisdual water content for matric suctions greater than about 20 kPa. The contribution of matric suction to shear strength for a soil with low water retention capacity at the residual water content is difficult to determine. This is because the water phase in the dry state of the soil is easily disrupted by shear displacements.

CONCLUSIONS

1. Matric suction increases the shear strength of the completely decomposed fine ash tuff and the completely decomposed granite.

2. The effect of matric suction on shear strength is more pronounced in the fine-grained, completely decomposed fine ash tuff than in the coarse-grained, completely decomposed granite.

3. The nonlinear character of the shear strength versus matric suction relationship is related to the desaturation of the soil. In other words, the nonlinear character of the shear strength versus matric suction envelope is related to the soil-water characteristic of the soil. The ϕ^b value is equal to the ϕ' value when the soil is saturated. The value of ϕ^b decreases when the soil desaturates. At some low "residual" water content, the value of ϕ^b becomes constant, or may even becomes negative.

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