# Theme: Shear and compression behaviors for an unsaturated compacted soil

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***Introduction***

The safety factor of residual or compacted soil slopes with a deep groundwater table depends on, among other factors, the magnitude of the negative pore-pressure above the groundwater table which contributes to additional shear strength of the soil (Fredlund and Rahardjo, 1993). With precipitation, the pore-water pressure becomes less negative or even positive. As a result, the shear strength of the soil decreases and this may trigger landslides. Thus, it is important to understand the characteristics of pore-water pressure changes in soils due to water infiltration in order to predict the extent to reduction in shear strength under certain rainfall condition.

The objective of this study is to investigate the strength and deformation characteristics of the compacted soil during infiltration by the effects of loading history and shear level for soaking. The loading history of the compacted soil is represented using the compaction pressure, the vertical pressure and the matric suction. Shear tests on a compacted soil were conducted using modified direct shear apparatus.

***Description of the soil***

The non-plastic volcanic soils, Shirasu, less than 0.85 mm in particle size is used in this study. The preparation of the soil specimens which are "identical" in their initial conditions by controlling the initial water content and relative density are required to determine the collapsibility and shear strength parameters. The compacted soil specimens have a diameter of 60 mm and a height of 21 mm. The properties of Shirasu soil are shown in Table 1.

Table 1 Index properties of Shirasu soil

| Property | Shirasu |
|---|---|
| Specific gravity | 2.54 |
| Sand : Silt : Clay | 85 : 13 : 2 |
| Air-dried water content | 0.6%-1.3% |
| Optimum water content | 8.1% |
| $\gamma_{dmin}$, g/cm$^3$ | 0.954 |
| $\gamma_{dmax}$, g/cm$^3$ | 1.297 |

***Modified direct shear apparatus***

This research deals with the collapsible unsaturated soil, emphasizing on the collapsibility and shear strength properties. The direct shear testing is suitable and convenient to do as double consolidation test and to study on the shear strength parameters especially in low confining pressure. Due to some disadvantages of conventional direct shear box, this apparatus needs to be modified for measuring the water content and matric suction during soaking. The electrical sensors for water content measurement made by Theta probes is installed on the upper half of shear box near the shear plane. The detail of this apparatus has been reported by Hormdee et al. (2005). Measuring of the matirc suction, ($u_a$-$u_w$), requires making use of a high air entry ceramic disk for the water phase and a coarse disk for the air phase. Since the constant water content condition is believed to more appropriate to simulate the field condition when loading unsaturated soils (Habibagahi and Mokhberi).

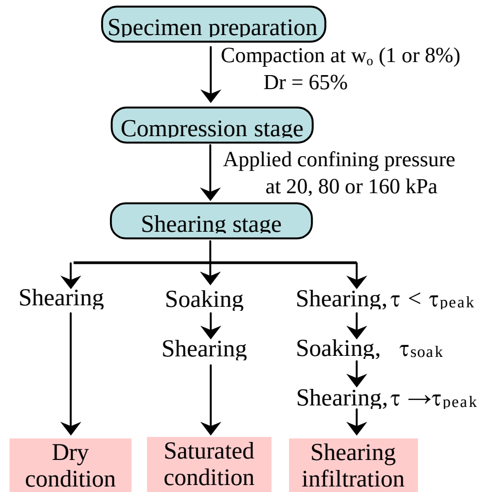


Fig.1 Steps of testing program

***Test procedure***

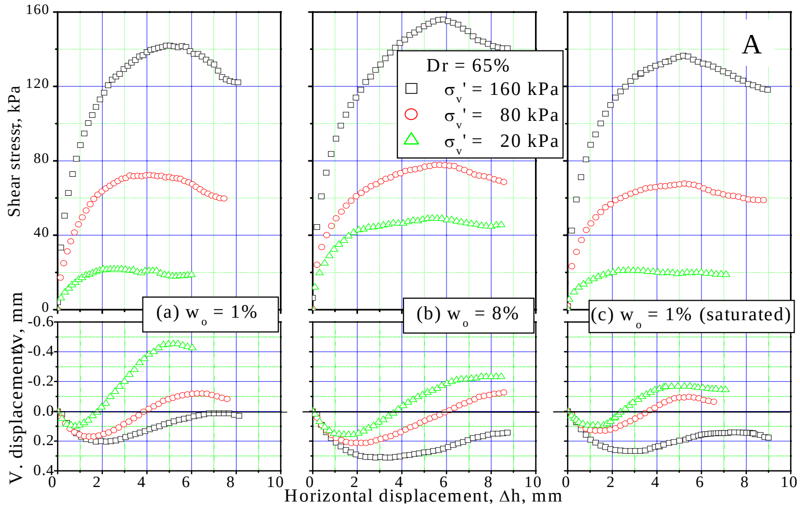
The testing program is divided into two parts: the first focuses on defining the shear strength at different net normal stress, and the second focuses on the effects of shear level infiltration.

The soil was compacted into the direct shear box with Dr=65% and initial water content of about 1% and 8%. Pore-air pressure, pore-water pressure, and net normal stress were applied to the soil specimens for a period to allow sufficient time to reach its equilibrium. Each specimen, therefore, had a constant net vertical stress of 20, 80, and 160 kPa throughout the pressure was maintained at atmospheric conditions through the ceramic base plate. The pore water was allowed to drain, or enter to specimen, as desired. The test procedure shows in Fig.1.

***Results of shearing under constant water content***

Figure 2-A shows shear stress and vertical displacement versus horizontal shear displacement curves for compacted soils at initial relative density, Dr=65% as referring to the compaction pressure and constant water content. The shear stress increased gradually with horizontal displacement and it showed an increase in strength due to the confining pressure. The shear strength of saturated soil is less than that of unsaturated soil at the same confining pressure due to the matric suction gaining more shear strength in soils. According to these series of tests produced the matric suction about 2-10 kPa, it is not much effect on the increasing value of unsaturated shear strength from saturated shear strength in this case as shown in Fig.2-B. However the slope, the angle of internal friction, is quite same that is about 40.6$^o$. One reason that the results in the case of $w_o$=8% gain more shear strength is the energy to prepare the specimens higher than $w_o$=1%.

In Fig.2-A, it also shows the lower of confining pressure applied; the more dilatancy but gaining the less peak shear strength. From those results, getting the relationship between the normalized of peak shear stress by net normal stress and the dilatancy index, -Δv/Δh, is one linear line as shown in Fig.2-C. That means although the effects for each different factor (i.e., initial water content, net normal stress) gain different shear strength in Fig.2-A, there is only unique line for quite good relationship between dilatancy index and normalized of peak shear strength. It means that the effect of different water content on the shear strength directly reflect to the changing of the dilatancy.



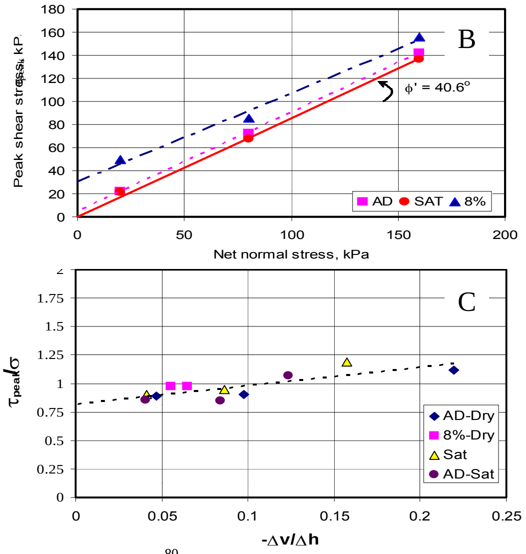




Fig. 2. Effects of net normal stress.

***Results of shearing infiltration***

In in-situ condition, the level of shear while the water content change is not recognized during designed stage. As the result of the shear strength of saturated condition lower than unsaturated condition, especially under having high matirc suction so the effect of shearing level for soaking is a key. Figure 3 shows the results from shearing infiltration test on soils after confining pressure under 80 kPa. The shearing infiltration test were conducted in order to observe the strength of soil when it failed due to water infiltration under relatively high shear stress condition. The program included testing of soils starting from both dry and saturated condition for initial state of Dr=65%. The soil specimen is not fail as the same results of Han (1997) that a shear stress level below 85% would not cause the specimens to fail during soaking even matric suction approach zero then continue shearing until it fails.

During soaking at any shear stress level, equalization stage to constant shear stress at specific horizontal displacement are required. In Fig.3, it shows that the mobilization in horizontal direction of lower shear stress level is lower than in higher shear stress level. This mobilization occurs due to reducing of the matric suction during infiltration, so shear force exert a displacement, repeatedly otherwise it would fail during soaking.

For collapsibility, the collapse means the decrease in height following wetting at a constant applied vertical stress. But when soaked under shear, it motivated horizontal movement. The higher level of shear infiltration, the lower settlement during soaking under constant confining pressure and shear level as shown in Fig.4. During soaking, the saturation degree slowly changes in first stage with rapid settlement because the collapse starts whenever the water comes to some part of soil even not reached the reading sensors. So the relationship on first part of Δv-ΔSr curve depends on void ratio, pressure of water for infiltration under the location of the water content reading sensor.

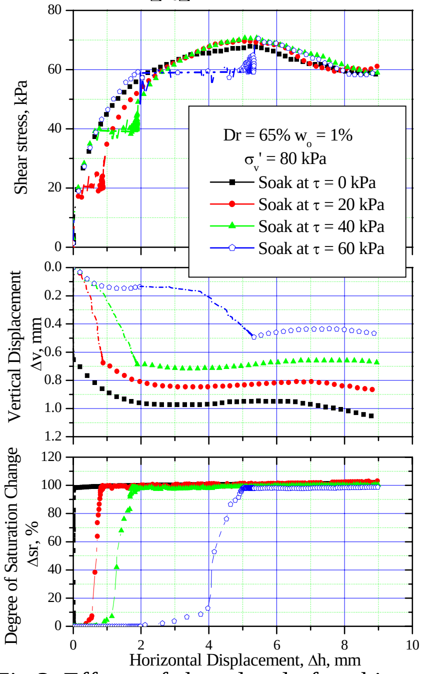



Fig.3. Effects of shear level of soaking

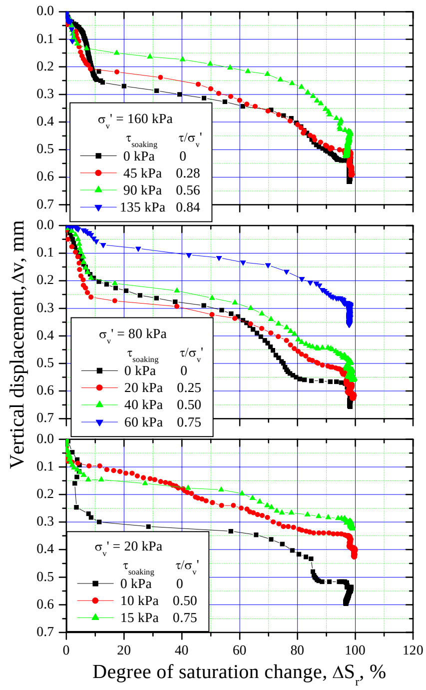



Fig.4. Relationship of Δv-ΔSr during infiltration.

***Conclusions***

To learn about the soil behaviors, the testing of collapsible sandy soil at low confining pressure is inevitable. It has to be modified in order to be able to measure the water content and matric suction close to shear zone. As in detail, found the quite unique relationship between dilatancy index and normalized of peak shear stress is not depending on the net normal stress and initial water content. It means that the effect of different water content on the shear strength directly reflect to the changing of the dilatancy. In term of collapse, even the collapsibility on the soil under shearing is less than on the same soil without shearing but it gains more horizontal movement at higher shear level of soaking. So to deal with the collapsibility under shear, need more attention on design.

***References***

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