# 不飽和土の力学的特性に対する温度依存性について
# Temperature effects of mechanical properties in an unsaturated soil

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## 1. Introduction

Research interest in the thermo-hydro mechanical behavior of soils is growing as a result of an increasing number of geomechanical problems involving thermal effects. The thermal effect is dominant in some applications such as geothermal structures where heat exchanger loops are used for permitting the circulation of a heat carrier fluid to exchange heat with the ground. The several heat exchanger loops, usually linked to a heat pump, permit the extraction of heat energy from and to the ground to satisfy in winter and in summer. Other applications include high-level nuclear waste isolation, petroleum drilling, and improvement of soft clay characteristics by thermal stabilization and zones around buried high-voltage cables.

In our research project, we investigated various thermal effects mainly due to ground source heat pump systems. There are few research works in which thermal mechanical effects to unsaturated soils were investigated (Uchaipichat, 2005). So the major aim of this study is to observe the thermal effects on mechanical properties of an unsaturated soil.

## 2. Materials and methods

In this study, a silty soil named DL clay was used as a test material. The physical properties of DL clay are shown in the Table 1. After water contents of the soil samples were adjusted to 17% and kept them in plastic bags at least for more than 24 hours. The necessary amount of soil is taken out from the bag and compacted in a greased split mold with 50 mm in diameter and 100 mm in height. Number of uniform rolled layers in each specimen is five. The target condition of the specimens is also shown in Table 1. After the compaction, the specimen was set in the triaxial cell. The triaxial compression apparatus as shown in Fig.1 is specially designed at which temperature and pressure can be controlled. It consists of four main parts; pressure and temperature controlling system, loading chamber, and auto data logging system. The tests were conducted under consolidated and drained condition. The constant three temperatures: 20, 30, and 40°C, and constant suction values: s = 0, 20, 50 kPa were employed. The confining pressure was 150kPa and the shearing speed was 0.02 %/min.

Fig.1: Modified triaxial compression apparatus

**Table 1. Silty soil, DL clay properties and sample initial condition**

| Soil particle density $\rho_s$ | Particle size distribution | | | Sample | |
|---|---|---|---|---|---|
| 2.65 | Sand | Silt | Clay | Water content | Dry density (g/cm$^3$) |
| | 0.1% | 96.6% | 3.31% | 17% | 1.3 |

## 3. Result and discussion

**(I) Shear strength behavior of soil sample** Figure 2 shows the stress- strain relationship at constant suction and various temperatures. According to the results, we can say that the effect of temperature differences (20, 30 and

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40°C) on the shear strength of soil sample is extremely small. Meanwhile the suction values remarkably influenced the shear strength values. That is the larger suction values the higher shear strength values.
The yield stresses seem to be affected by the temperatures and increase as an increase in temperatures. This tendency was opposite with the results obtained by Uchaipichat.

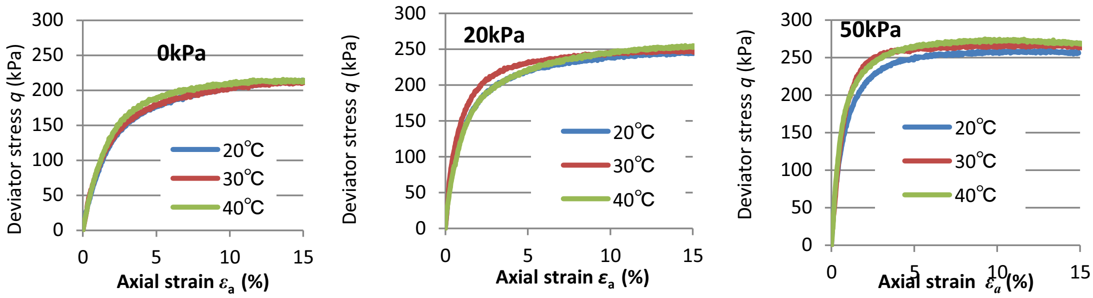

Fig. 2: Stress strain relationship at constant suction and different temperatures

**(II) Volume change behavior of soil sample-** Figure 3 shows the volumetric strains vs. axial strains relationships of the soil sample under constant suction and various temperatures. There is temperature effect on the volume change behavior of the soil sample. However we can't see clear trend of the volume change behavior of soil sample between different temperatures. The effect of suction to volume changes is obvious and the larger suction values the smaller volume changes. This tendency was consistent with the results obtained by Kohgo (1995).

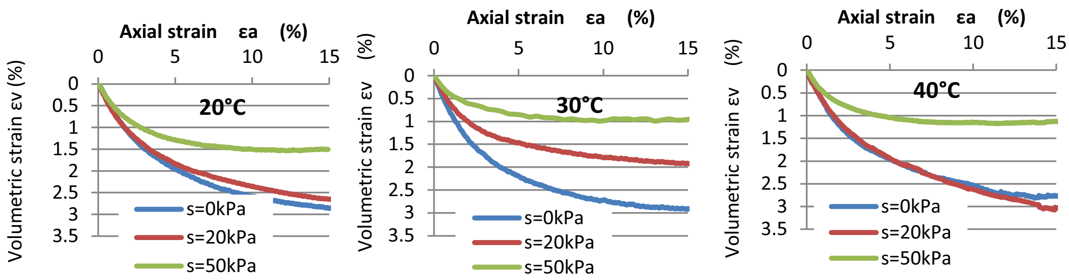

Fig 3: Strain relationship at constant temperature and various suctions

## 4. Conclusion

It can be concluded that the higher suction values the smaller amount of volume change. This property did not depend on the temperature differences. We could not see the significant different temperature effects between 20, 30 and 40°C for shear strength values at every suction values. To get the clear trend of temperature effect on the shear strength and volume change behavior of sample, we need to continue with other temperature level and various confining pressures.


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