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TEMPERATURE EFFECTS ON STRENGTH AND STIFFNESS OF CLAY

P. KUNTIWATTANAKUL Graduate Student Univ. of Tokyo
I. TOWHATA Assoc. Professor ditto
K. OHISHI Undergraduate Student ditto

1 INTRODUCTION

The question whether the strength and stiffness of clay decrease or increase with an increase of temperature has been a prolonged argument for more than 20 years. The former was supported by Sherif and Burrous (1969), Hueckel and Baldi (1990), and others, whereas the later was confirmed by Laguros (1969), Houston et al. (1985) and others. Due to this apparent lack of agreement and because of the increased uses of clay in high temperature environment, it was decided to perform additional studies at the University of Tokyo to improve the knowledge in this area. This paper presents parts of the results of these studies which emphasize on the temperature effects on strength and stiffness of both normally consolidated (NC) and overconsolidated (OC) clay.

2 MATERIAL, APPARATUS, AND TESTING

All the samples used in this study were reconstituted samples consolidated from slurry of kaolin like clay powder and distilled water. The liquid limit and the plasticity index of the clay are 70 and 29% respectively. The slurry was prepared at a water content of 160% and consolidated in a consolidation tank under a pressure of 98 kPa. Test specimens were trimmed from the consolidated cake.

All the tests were isotropically consolidated undrained triaxial tests conducted in a temperature controlled triaxial apparatus. The temperature of the cell water could be controlled within an accuracy of ± 0.1 C. The tests were carried out using specimens of 5 cm in diameter and 10 cm in height. The specimens were wrapped with filter paper side drains. Moreover, lubricated sheets were put at both ends of the specimen. The shearing was carried out by a strain controlled apparatus with a strain rate of 5 % per hour. Heating of the specimens was done while the drainage valves were open, and volume of water drained from the specimen was monitored by a burette. The heating was considered to be complete when the rate of the water drained out was equal to the secondary consolidation rate. This process usually took 2 to 3 hours.

3 RESULTS AND DISCUSSIONS

In NC state, a heated specimen has higher strength and stiffness than those of an unheated specimen. This is illustrated in Fig.1: the top figure presents the results of the whole range of axial strain up to failure, whereas the bottom one enlarges the results between 0 to 1.0% axial strain. In obtaining this figure, four specimens were consolidated at 196 kPa. Then, one was sheared at room temperature, while the others were drained heated at 50, 70, and 90 C and then sheared. The figure clearly shows that the higher the temperature the higher the strength and stiffness.

In OC state, temperature does not have any significant effect on the strength, whereas it considerably affects the modulus at small strain (see Fig.2). This figure presents test results of specimens which were, first, consolidated at 196 kPa and, then, unloaded by increasing the back pressure to produce OCR of 2.2, 4, and 8. After that, one group of the specimens was sheared at room temperature, while the other was heated at 90 C and then sheared. From the figure, it is possible to conclude that (1) the strength is not significantly affected by the heating, (2) the modulus at small strain of heated specimens is higher than that of unheated specimens.

Fig. 3 shows plots of the initial secant modulus versus the temperature. The modulus was computed from the curves shown in the previous figures. The computation was based on an axial strain of 0.10%. For comparison, all the results were normalized by the modulus of the room temperature specimens. This figure clearly shows that the higher the heated temperature the higher the modulus. Further, the figure also indicates that the increase of the modulus caused by heating at 90 C of specimens with different OCR seems to be of the same order of magnitude, i.e., about 26 to 38%.

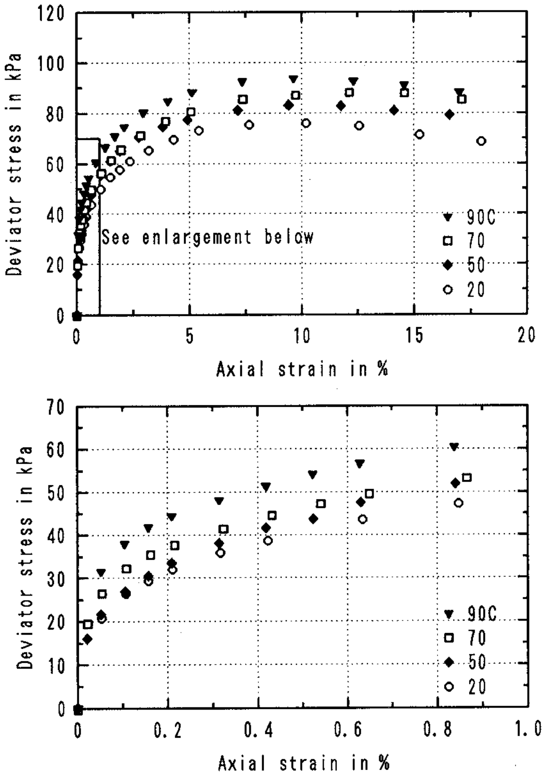

Fig. 1 Temperature effects on stress-strain curve of NC clay

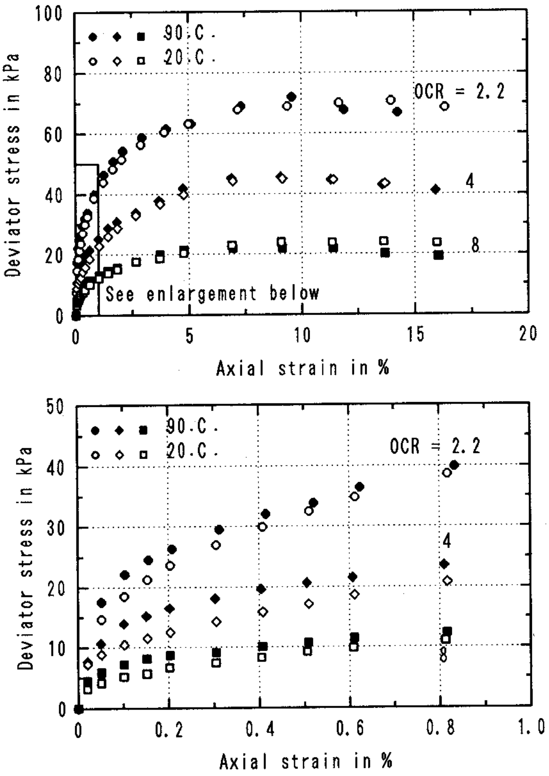

Fig. 2 Temperature effects on stress-strain curve of OC clay

4 CONCLUSIONS

With the results presented above, the following conclusions can be drawn. (1) For NC clay, heating causes increases of both strength and stiffness. (2) For OC clay, an increase of temperature induces an increase of the initial stiffness only: it does not have any significant effect on the strength. (3) The increase of initial secant modulus due to heating for both NC and OC clay seems to be of the same order of magnitude.

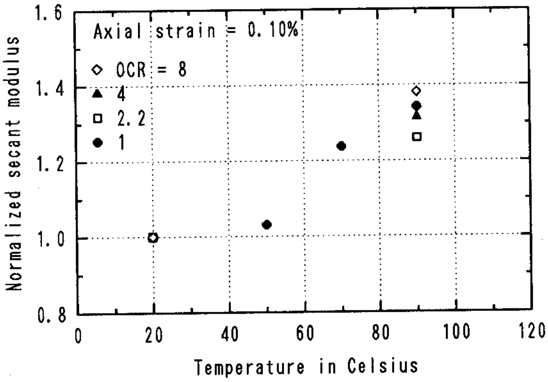

Fig. 3 Temperature effects on initial secant modulus

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