Amirkabir Journal of Civil Engineering

Amirkabir J. Civil Eng., 52(8) (2020) 481-484
DOI: 10.22060/ceej.2019.15768.6021

Investigation of the Effect of Temperature on the Undrained Shear Strength of Kaolinite

A. Cheshomi[1,*] , F, Mohammadi[2] , A.M. Rajabi[3]

[1] University of Tehran/ College of Science/ School of Geology
[2] University of Tehran/ College of Science/ School of Geology
[3] University of Tehran/ College of Science/ School of Geology

ABSTRACT: Investigation of the effect of temperature on soil strength is one of the issues which has been considered by many researchers in recent decades. In this study to investigate the effect of temperature on the undrained shear strength (Cu) of clay soils, a cell with the capability of both changing and keeping fixed the temperature of sample, was designed and constructed. After determining the index properties of samples for Kaolinite clay soil, undrained shear strength (Cu) test was carried out on saturated clay soil at 10, 20, 30, 40, 50, 60 and 70 ° C. Repeatability of the results was confirmed by repeating tests on samples with the same properties a given temperature. The results showed that by increasing the temperature, the Cu values decreased so that, as the temperature raised from 10 ° C to 70 ° C, the values Cu were reduced from 26.6 to 10.94 kPa. Accordingly, in the studied temperature range, an empirical relationship between temperature and Cu (with R^2= 0.96) was proposed. The general shape of the stress–strain curves of the samples in different temperature was the same and in strain level of 20% was linear. Increasing the temperature caused to decline in the range of elastic deformation and enhancement in the range of plastic deformation of the samples; in addition, by increasing the temperature, the angle of the failure plane was decreased. The measurement of axial expansion stress (A_{ES}) indicated enhancement of the stress by increasing the temperature.

Review History:

Received: 2019-02-03
Revised: 2019-04-07
Accepted: 2019-04-08
Available Online: 2019-04-29

Keywords:

Temperature
kaolinite
undrained shear strength
clay soil
failure

1. INTRODUCTION

Physical and mechanical properties of soil are significantly affected by temperature. In recent decades, several studies have been done on how clay behaves at different temperatures. the first research on the effect of temperature on the soil in the 1960s was carried out by Campanella and Michel (1968) at a temperature range of 0°C to 60°C. In addition to studying the effect of temperature on soil properties, it was shown that variations in pore volume and pressure dependent on temperature variation in saturated soils can be explained by the thermal expansion of soil components, compressibility and its physicochemical effects [1]. Afterwards, many researchers have studied the strength of soils at different temperatures and have taken different results. Kuntiwattanakul et al., 1995; Graham et al., 2001; Cekerevac and Laloui, 2004; Abuel-Naga et al., 2007 showed shear strengths of the clays was reduced by increase of temperature [2, 3, 4, and 5]. Houston et al., 1985; Hueckel and Baldi, 1990 showed that the strength of the clays was decreased with increasing temperature [6, 7]. Burghignoli et al., 1992 witnessed independence of soil strength to the thermal situation [8]. Differences in mineralogy of clay, physical properties, different test conditions and temperature range are the main factors of the different results.

Due to the different results of the effect of temperature on the strength of clays, in the current study, specimens with a completely identical physical characteristics were made and to determine the effect of temperature on the undrained shear strength, soil strength at different temperatures were measured. For this purpose, a device with the ability to change and maintain the specimens' temperature during loading was designed and constructed. Then, by examining the repeatability of the results of the experiments, the effect of temperature change on the undrained shear strength of the kind of kaolinite was investigated.

2. DATA AND METHODS

In this study, in order to investigate the effect of temperature on the undrained shear strength of clays, a device was designed and constructed. In this study a clay sample with the dominant mineral which is kaolinite has been used. Based on the identification of the soil, the Gs, LL, PL and PI are 2.64, 47, 27 and 20 respectively. In this study, undrained shear strength (Cu) test was performed on saturated specimens of kaolinite clay at 10, 20, 30, 40, 50, 60 and 70 °C.

3. RESULTS AND DISCUSSION

Stress-strain curve for different temperatures are presented

*Corresponding author's email: a.cheshomi@ut.ac.ir

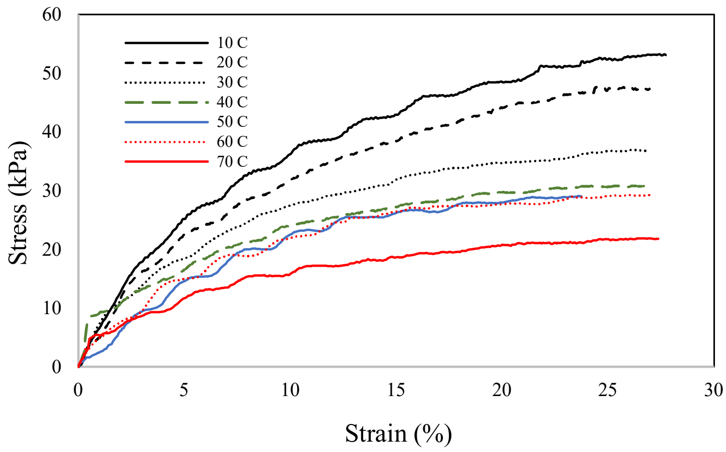

Fig 1. Stress - strain curve of kaolinite for different temperatures

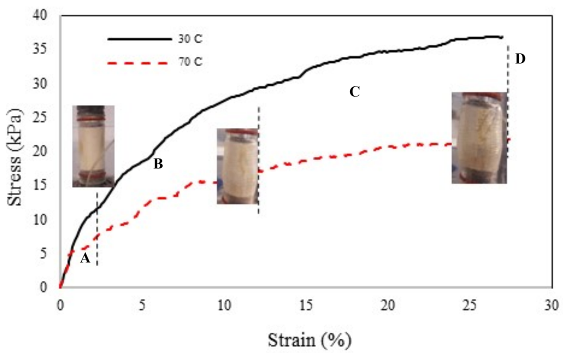

Fig 2. Stress-strain curve for specimens at a temperature of 30 °C and 70 °C, separating the different behavioral ranges of the sample at different strain levels

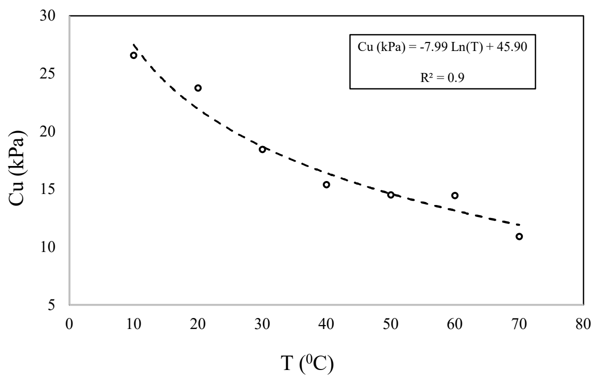

Fig 3. Changes in undrained shear strength (Cu) versus temperature for kaolinite

in Fig. 1. According to the Fig. 1, the temperature curves are similar, but their maximum points are different.

To analyze the curves of Fig. 1, the samples were selected at temperature of 30 °C and 70 °C, and compared in Fig. 2. In this curve, 4 sections A, B, C and D can be distinguished by different slopes. At the beginning of the test, the specimen showed high strength and, therefore, showed a fairly steep gradient and elastic behavioral pattern (Section A). After this step, the specimen still exhibits high strength, but due to the formation of fine cracks, the slope of the curve is reduced and the specimen enters the plastic stage (Section B). As the loading increases, the strain increases and the surface of the major breakdowns are created by the addition of fine cracks. This situation leads to the reduction of the slope of the curve and strength of the specimen (Section C). After the occurrence of the main fractures, the deformation of the specimen is maintained at a constant level of stress and the slope of the stress-strain curve is minimized (Section D). Generally, the temperature ranges of the elastic deformation decreased with increasing temperature, and the specimen entered the plastic deformation zone more quick. Changes in Cu are plotted in Fig. 3.

According to Fig. 3, with increasing temperature, Cu decreases, so that its value from 26.6 kPa at 10 °C reach to 10.94 kPa at 70 °C. In other words, by increasing the temperature of the sample, Cu value has decreased by 2.5 times

The reduction of Cu by increasing the temperature in the specimens is due to a change of two factors. The first factor relates to the forces between the plane in the clay structure and the other is the pore pressure of the specimen.

4. CONCLUSION

In this study, to investigate the effect of temperature variation on kaolinite Cu, saturated samples of soil with constant physical properties were prepared and tested for determination of Cu at different temperatures of 10, 20, 30, 40, 50, 60 and 70 °C. The results show that the undrained shear strength decreases with increasing temperature, so that for kaolinite the Cu value is about 26.6 kPa for 10 °C to 10.9448 K kPa at 70 °C. The reason of the reduction of Cu is the increase in pore water pressure due to the increase of temperature and reduction of the bond between the mineral planes of clay. Also, examination of samples during loading and failure times shows that the angle of the fracture surface of the samples decreases with increasing temperature. The angle of the failure plane in the tested samples at 10 °C and 70 °C are generally 70 ° and 45 °, respectively.

5. REFERENCES

[1] Campanella, R.G., Mitchell, J.K., 1968. "Influence of temperature variations on soil behavior". *Journal of Soil Mechanics & Foundations Div*.

[2] Cekerevac, C. Laloui, L., 2004. "Experimental study of thermal effects on the mechanical behavior of a clay". *International journal for numerical and analytical methods in geomechanics*, 28(3), pp. 209-228.

[3] Abuel-Naga, H.M., Bergado, D.T., Bouazza, A., 2007. "Thermally induced volume change and excess pore water pressure of soft Bangkok clay". *Engineering Geology*, 89(1-2), pp. 144-154.

[4] Graham, J., Tanaka, N., Crilly, T., Alfaro, M., 2007. "Modified Cam-Clay modelling of temperature effects in clays". *Canadian geotechnical journal*, 38(3), pp. 608-621.

[5] Kuntiwattanakul, P., Towhata, I., hishi, K., Seko, I., 1995. "Temperature effects on undrained shear characteristics of clay". *Soils and Foundations*, 35(1), pp. 147-162.

[6] Houston, S.E., Houston, W.N., Williams, N.D., 1985. "Thermo-mechanical behavior of seafloor sediments". *Journal of Geotechnical Engineering*, 111(11), pp. 1249-1263.

[7] Hueckel, T., Baldi, G., 1990. "Thermoplasticity of saturated clays: experimental constitutive study". *Journal of geotechnical engineering*, 116(12), pp. 1778-1796.

[8] Burghignoli, A., Desideri, A., Miliziano, S., 1992. "Deformability of clays under non isothermal conditions". *RIG*, 4.

HOW TO CITE THIS ARTICLE

A. Cheshomi, F. Mohammadi, A.M. Rajabi, Investigation of the Effect of Temperature on the Undrained Shear Strength of Kaolinite, Amirkabir J. Civil Eng., 52(8) (2020) 481-484.

DOI: 10.22060/ceej.2019.15768.6021