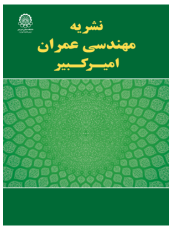

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Investigation of Loading Rate Effect on the Shear Strength of Clay-Sand Mixture in Triaxial Test

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ABSTRACT: The strength behavior of soil is affected by strength parameters including soil cohesion and its internal friction angle. These parameters are influenced by factors such as soil density, soil type, loading rate, moisture content, confining pressure and Etc. In this paper, the effect of loading rate on the shear strength behavior of clay-sand mixtures is investigated using the triaxial test. In this research, 8 types of "clay:sand" composite materials with weight ratios of 100:0, 80:20, 60:40, 40:60, 30:70, 20:80, 10:90 and 0:100 were used. To investigate the effect of loading rate, samples were subjected to non-uniform loading rates of 0.1, 1, and 5 mm/min with a defined load pattern. In this study, three confining pressures of 100, 300, and 500 kPa were used. The results of this study show that, depending on the amount of confining pressure, the sudden change in loading rate has different effects on the strength of samples with different percentages of clay-sand combination. Deviator stress variations, as well as the slope of the stress-strain curve, depending on the amount of sand at the moment of a sudden change in loading rate. In other words, changes in deviator stress and slope of the stress-strain curve are directly related to the amount of sand from one limit to the next. This limit of sand is 40% for low confining pressure (100 kPa) and 20% for higher confining pressure (300 and 500 kPa).

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1. Introduction

Changes in the two parameters of the angle of internal friction and cohesion of the soil change the strength behavior of the soil and are influenced by factors such as soil compaction, soil type, loading rate, moisture content, confining stress, etc. Among these factors, little attention has been paid to the effect of loading rate on soil strength behavior.

Some full-scale field case histories showed paramount importance of time effects on the stress-strain behavior of granular materials, for example, long-term settlements of shallow foundations, the time-dependent bearing capacity of driven piles, residual settlements of high earth structures, such as rockfill dams and high highway embankments [1-3]. The time effects on the stress-strain behavior of geomaterials comprise i) the aging effects in the material intrinsic stress-strain properties due to time-dependent inter-particle bonding and weahering and others, and ii) the loading rate effects due to the material viscous properties. Therefore, a proper understanding of not only the aging effect but also the viscous properties of geomaterials is then essential for the practical implications mentioned above [4, 5].

Reappraisal of loading rate effects on sand behavior in view of seismic design for pile foundation, Watanabe and Kusakabe have found that with increasing strain rate, soil strength and angle of internal friction and deformation modulus increase [6]. Yamamuro and Abrantes have studied the behavior of sand under a high strain rate by an undrained triaxial apparatus. Their results show that as the strain rate increases, the samples become more resistant [7].

Previous studies have shown that most studies have focused on the effect of loading rate on mainly pure sand or pure clay soils and have not been investigated for mixed soils with different sand and clay compositions. Therefore, in this study, the effect of loading rate on the strength behavior of "clay-sand" mixed soil by a triaxial device is investigated.

2. Methodology

In this study, a triaxial device (UU) with specimens with a diameter of 38 mm and a height of 76 mm was used. Mixed soil from 8 types of sand-clay composites with weight ratios of 0: 100, 20:80, 40:60, 60:40, 70:30, 80:20, 90:10 and 100:0.

All samples were prepared in three layers with 5% moisture and 60% constant relative density with 38 and 76 mm diameter and height. And to ensure a uniform distribution of moisture, each specimen was kept in a plastic container for about 24 hours after applying moisture, and then the specimens were made. The method of triaxial testing is as strain control and loading of 8 types of specimens by the applied load pattern according to Fig. 1. Thus, from every 2% of the axial strain, a sudden change in loading speed is applied to the specimens. All eight samples under this load pattern were tested under three types of confining stresses with values of 100, 300, and 500 kPa.

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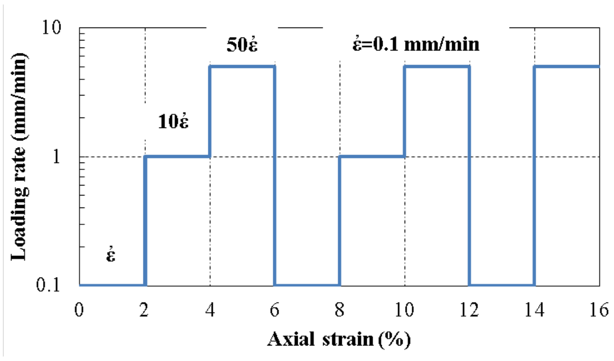

Fig. 1. Loading pattern of specimens

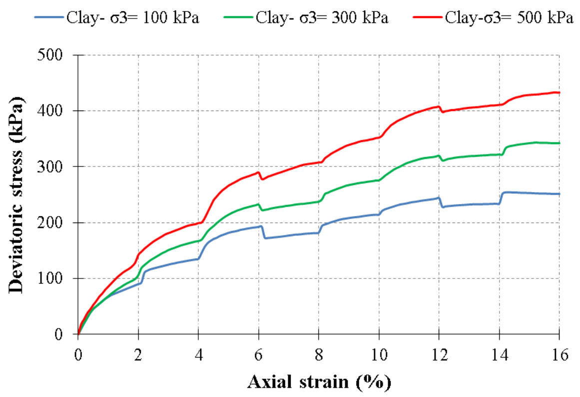

Fig. 2. Stress-axial strain curves for pure clay

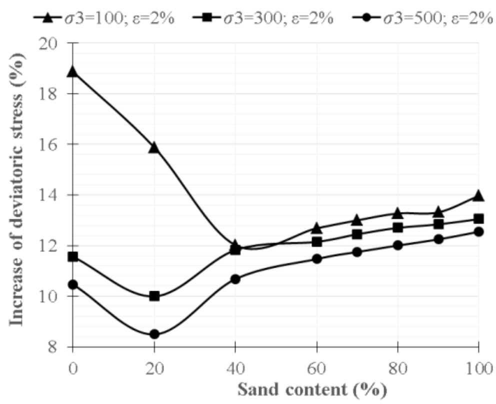

Fig. 3. Variation of increased deviatoric stress versus percentage of sand in soil at strain of 2%

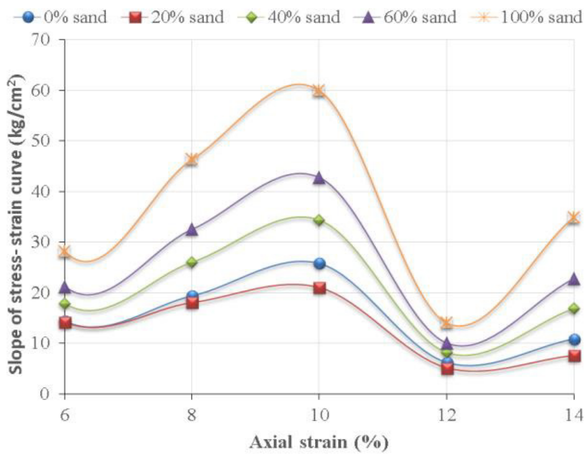

Fig. 4. Variation of curves slope versus axial strain at confininig stresses of 500 kPa

3. Results and Discussion

The deviatoric stress–axial strain variation for pure clay under confining pressure of 100, 300, and 500 kPa with the defined loading pattern (Fig. 1) have been shown in Fig. 2.

As shown in Fig. 2 the curve becomes steeper as the loading speed increases, and the curve drops steeply as the speed decreases.

The values of increasing the deviatoric stress at the moment of increasing the loading rate versus sand contents are shown in Fig. 3. The curves shown in Fig. 3 show that by increasing the percentage of sandy soil up to 20% in samples with 300 and 500 kPa confining stress, the rate of stress increase first decreases and then increases with increasing sand content. Vallejo and Mawby showed when the concentration by weight of the sand in the mixtures was >75%, the shear strength was governed mainly by frictional resistance between the sand grains. When the sand concentration was <40% by weight, the shear strength of the mixtures was entirely dictated by the strength of clay [8].

The slope of the stress-strain curve was calculated at each strain interval where the loading rate varied. For example, Fig. 4 shows the slope variation at different loading rates for different soil compositions under confining stress of 500 kPa.

The results show that the slope of the stress-strain curves is directly related to the loading rate. Other researchers have also observed this behavior. The results of Watanabe and Kusakabe showed that increasing of loading rate increases the secant modulus by 30 to 150% [6]. Also with increasing loading rate, a 115% increase in the secant modulus at 1% axial strain was obtained in the studies of Yamamuro et al. on dry sand [9].

4. Conclusions

To investigate the effect of loading rate on the strength behavior of soil mixed with different sand-clay weight ratios, standard compressive triaxial tests (UU) were performed under 100, 300, and 500 kPa confining stresses. The results are presented as follows:

The percentage of increase in deviatoric stress at the moment of increasing loading rate is directly related to the amount of loading rate and inversely related to the confining stress. Deviator stress variations, as well as the slope of the stress-strain curve, depending on the amount of sand at the moment of a sudden change in loading rate. In other words, changes in deviator stress and slope of the stress-strain curve are directly related to the amount of sand from one limit to the next. This limit of sand is 40% for low confining pressure (100 kPa) and 20% for higher confining pressure (300 and 500 kPa).

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