Amirkabir Journal of Civil Engineering

Amirkabir J. Civil Eng., 54(6) (2022) 437-440
DOI: 10.22060/ceej.2021.19963.7302

Investigation of Cyclic Behavior of Silty Sand Soils Using Cyclic Simple Shear Test Under Constant Volume Conditions

E. Khavaninzadeh, R. Ziaie Moayed*

Department of Civil Engineering, Imam Khomeini International University, Qazvin, Iran

ABSTRACT: The study of the cyclic behavior of sandy soils during seismic loading has been one of the most important geotechnical issues in previous decades and is still one of the most geotechnical challenging aspects among researchers. In the earthquake, the soil is under initial constant normal stress and the shear stresses change direction regularly; as a result, the directions of main effective stresses on the soil sample are changed. In the present study, cyclic simple shear responses for different mixtures of clean silica sand and non-plastic silt have been evaluated. The laboratory experiments were performed at a constant cyclic stress ratio of 0.15 (CSR = 0.15) and effective confining pressures of 50, 100 and 150 kPa. A series of constant volume cyclic simple shear tests on silty sand samples have shown that by increasing the non-plastic fines up to 30%, the shear strain decreases and then with an increment of silt content to 40% the shear strain increases, but the shear strain of the sand with 40% silt is less than the clean sand. The results also indicate that the liquefaction resistance of clean sand under the same conditions is higher than that of silty sand specimens. Also, with increasing the confining pressure, the soil liquefaction resistance increases in all silt percentages.

Review History:

Received: Apr. 28, 2021
Revised: Aug. 21, 2021
Accepted: Nov. 01, 2021
Available Online: Nov. 09, 2021

Keywords:

Cyclic behavior
Simple shear tests
Non-plastic silt
Volume constant
Shear strain

1- Introduction

Although the triaxial test is the most common and widely used test to evaluate the shear strength of soils, the shear tests such as torsional shear and simple shear tests use a stress path that creates more realistic loading conditions in the event of an earthquake. Some researchers believe that with increasing non-plastic fine content, the liquefaction resistance of silty sand increases; others have reported a decrease in the liquefaction resistance, and some have reported a decrease and then an increase in liquefaction resistance. Also, some studies have shown that the liquefaction resistance of silty sands is more dependent on the void ratio of the sand skeleton than the fine content [1-6].

While significant research has been done on the cyclic behavior of clean sandy soil using a simple shear apparatus at constant volume conditions [7, 8] but there is a lack of information about this type of behavior in sandy soil with non-plastic fine content. The main purpose of this study is to investigate the effect of non-plastic fine content on the liquefaction potential of 161 Firuzkooh sand using a cyclic simple shear test at constant volume condition. The results are compared and the possibility of predicting the liquefaction potential of the samples depending on the type of soil is discussed.

2- Testing procedure

In the laboratory experiments, 161 Firuzkooh sand was used as the base sand and crushed silica firuzkooh silt was used as the non-plastic fines. To produce a sequence of sand of sand-silt mixtures, the quantity of crush silica fines was varied from 0,10,20,30 and 40% by mass

All specimens were prepared by the moist tamping method and were tested under effective vertical stresses ($\sigma\rangle_{vc}$) of 50, 100 and 150 kPa. During the cyclic loading phase, shear stresses from uniform sinusoidal cycles (τ_{cy}) were applied at a cyclic stress ratio of 0.15 (i.e. $\tau_{cy}/\sigma'_{vc} = 0.15$) at a frequency of 0.1 Hz.

3- Results and discussion

Drained constant volume cyclic simple shear tests were performed on clean sand samples (161 Firuzkooh sand). Figure 1 shows the cyclic response of loose sand. The specimen had a void ratio of 0.79 and the relative density (Dr) after consolidation was 29%.

The clean sand sample shows a significant softening strain after the second cycle. The general pattern of changes in pore pressure also, shows dramatic deviations with shear strain. The changes in the excess pore pressure ratio (r_u) show a very good correlation in terms of the number of loading cycles and the sample became liquefied in the third cycle.

*Corresponding author's email: Ziaie@eng.ikiu.ac.ir

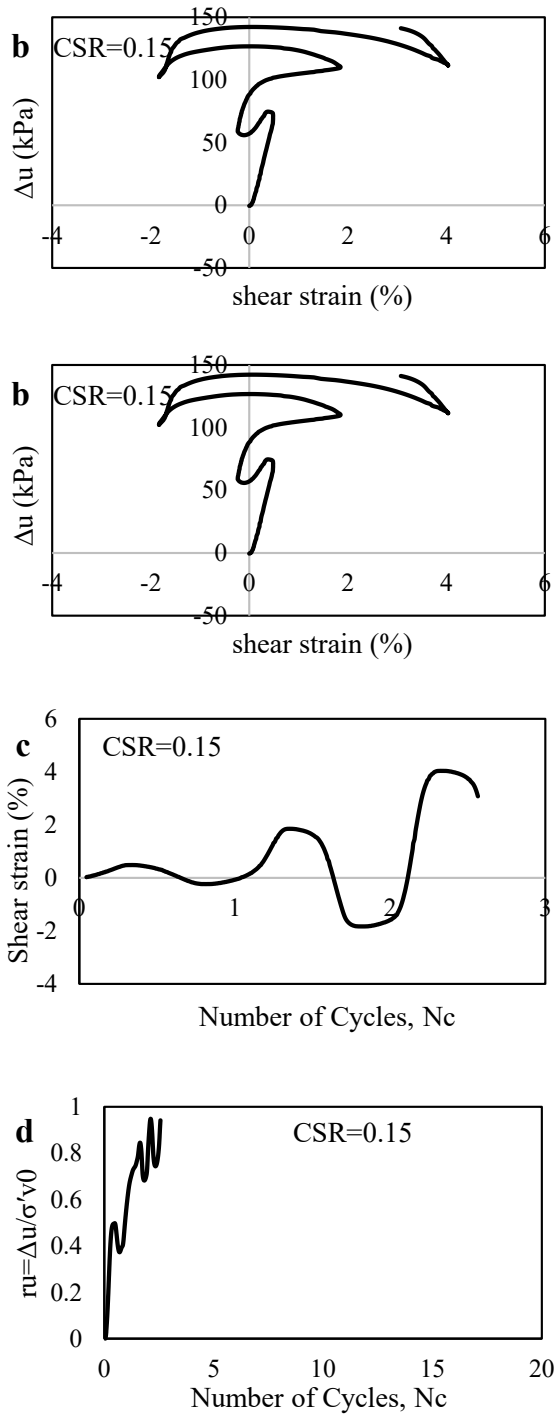

Fig. 1. Cyclic stress-strain response, b) Pore water pressure changes - shear strain, c) Shear strain versus the number of cycles to liquefaction, d) Excess pore water pressure ratio versus the number of cycles for Clean sand soil sample (e = 0.79 and Dr = 29%) and σ′vc= 150 kPa, (CSR =0.15)

Experiments were also performed on silty sand specimens. Samples were tested with a consolidated void ratio of 0.71 and a relative density (Dr) of 31%. It was observed in clean sand that the soil liquefied in less number of cycles and had higher shear strain (-2 to +4%). The results showed that with increasing the non-plastic fine content up to 30%, the specimens liquefied in less shear strain (-1.7 to +2.2%) and a higher number of cycles needed than clean sand.

4- Conclusion

In the present study, the results of cyclic simple shear tests on different sand-silt mixtures were considered in order to investigate the effect of non-plastic fine content on the cyclic behavior of silica sand. Drained constant volume cyclic simple shear tests were carried out on sandy samples in stress control conditions.

Experiments on clean sand showed that, in a small number of cycles (N = 3), a softening and liquefaction behavior at high shear strain occurs. However, the silty sand specimens made with the same void ratio and in loose conditions liquefied at lower shear strain than clean sand, so by increasing the silt percentage to the threshold of 30%, the samples become liquefied in less shear strain than clean sand, but after this percentage, by increasing the non-plastic fine content, the liquefaction occurs in the larger shear strains. The obtained data showed that the liquefaction resistance of clean sand under the same conditions is higher than silty sand. Also, with increasing confining pressure, the soil liquefaction resistance increases in all silt percentages.

References

[1] L.P. Kaufman, N.-Y. Chang, Percentage silt content in sands and its effect on liquefaction potential, in: Computational Methods and Experimental Measurements, Springer, (1982), pp. 447-459.

[2] S. Thian, C. Lee, Undrained response of mining sand with fines contents, International Journal of Civil & Structural Engineering, 1(4) (2011) 844-851.

[3] S. Yang, S. Lacasse, R. Sandven, Determination of the transitional fines content of mixtures of sand and non-plastic fines, Geotechnical Testing Journal, 29(2) (2006) 102-107.

[4] R. Salgado, P. Bandini, A. Karim, Shear strength and stiffness of silty sand, Journal of geotechnical and geoenvironmental engineering, 126(5) (2000) 451-462.

[5] J. Troncoso, Seismic response of tailings dams built with cohesionless soils to different types of ground motions, in: International symposium on safety and rehabilitation of tailings dams, 1990, pp. 82-89.

[6] M.J. Khosraviyani, O. Bahar, S.H. Ghasemi, Laboratory study to investigate the effect of density and type of loading on the liquefaction behavior of sands under irregular earthquake loading, Amirkabir Journal of Civil Engineering, 53(2) (2019) 717-730 (in persian).

[7] D. Porcino, V. Diano, Laboratory study on pore pressure generation and liquefaction of low-plasticity silty sandy soils during the 2012 earthquake in Italy, Journal of Geotechnical and Geoenvironmental Engineering, 142(10) (2016) 04016048.

[8] M.M. Monkul, C. Gültekin, M. Gülver, Ö. Akın, E. Eseller-Bayat, Estimation of liquefaction potential from dry and saturated sandy soils under drained constant volume cyclic simple shear loading, Soil Dynamics and Earthquake Engineering, 75 (2015) 27-36.

HOW TO CITE THIS ARTICLE

E. Khavaninzadeh, R. Ziaie Moayed, Investigation of Cyclic Behavior of Silty Sand Soils Using Cyclic Simple Shear Test Under Constant Volume Conditions, Amirkabir J. Civil Eng., 54(6) (2022) 437-440.

DOI: 10.22060/ceej.2021.19963.7302