

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

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ABSTRACT

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 is 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 ratios 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 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 the silty sand specimens. Also, with increasing the confining pressure, the soil liquefaction resistance increases in all silt percentages.

KEYWORDS

Cyclic behavior, simple shear tests, non-plastic silt, volume constant, shear strain.

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1. Introduction

Although 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 increase in liquefaction resistance. Also, some studies have shown that the liquefaction resistance of silty sands is more depends 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 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 Firuzkooch sand, using a cyclic simple shear test at constant volume condition. The resulting are compared and the possibility of predicting the liquefaction potential of the samples depended on type of the soil is discussed.

2. Testing procedure

In the laboratory experiments 161 Firuzkooch sand was used as the base sand and crushed silica firuzkooch 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 (σ'_{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 Firuzkooch sand). Figure 1 shows the cyclic response of loos sand. The specimen had a void ratio of 0.79 and the relative density (D_r) 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) shows a very good correlation in terms of the number of loading cycles and the sample became liquefied in the third cycle.

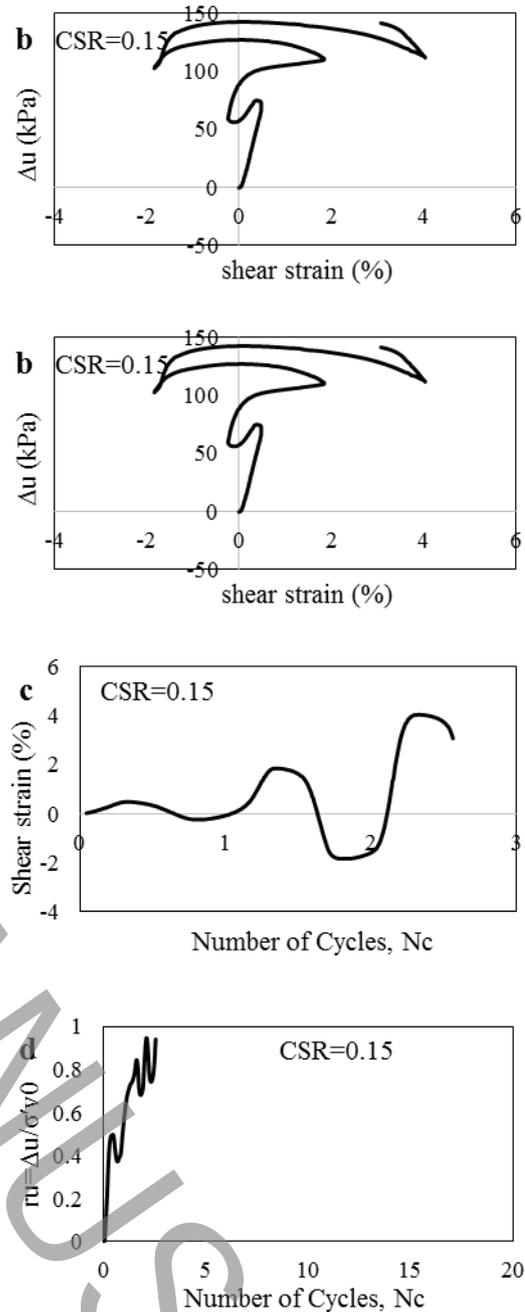


Figure 1. Cyclic stress-strain response, b) Pore water pressure changes - shear strain, c) Shear strain versus number of cycles to liquefaction, d) Excess pore water pressure ratio versus number of cycles for Clean sand soil sample ($e = 0.79$ and $D_r = 29\%$) and $\sigma'_{vc} = 150$ kPa, (CSR = 0.15)

Experiments were also performed on silty sand specimens. Samples were tested with a consolidated void ratio of 0.71 and a relative density (D_r) of 31%. It was observed in clean sand that the soil liquefied in less

number of cycles and 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 occur. However, the silty sand specimens made with the same void ratio and in loose conditions liquefied at lower shear strain than clean sand, so that 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 occur 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.

5. References

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