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The effect of Kaolinite clay on the liquefaction resistance of the sandy soil; case study of the Gorgan city in north of Iran

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Abstract

In this paper by performing of a series of triaxial cyclic test the effect of adding fines on the liquefaction potential of sandy soil are studied, after sampling of the soil and doing basic geotechnical tests on the samples. The result of triaxial cyclic tests showed that pure sandy soil after 54 cycle of loading is liquefied which prove the studied soil is liquefaction prone. Moreover it can be inferred from the test results that in low fine percent liquefaction resistance is decrease that can be attributed to breaking the coarse grain's bond by fine particles. While by increasing the percent of the Kaolinite clay the soil liquefaction resistance is increase which can be explain by domination of the fine in soil structure and making soil more cohesive. This decreasing and increasing trend in soil resistance against liquefaction by adding fines is observed in several other studies which the percent of the fine that change the trend is named threshold fine amount. The result of the paper has been shown for studied sand of Noor city the threshold fine amount of Kaolinite clay is 12 weight percent.

***Key words**: Sandy soil, triaxial cyclic test, liquefaction, Gorgan city*

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Extended Abstract:

1. Introduction

One of the most important, interesting, complex topics in engineering geology and earthquake geotechnical engineering is liquefaction. The devastating effects of liquefaction in 1964 between the 9.2-magnitude Alaska earthquake known as the Good Friday earthquake and the 7.5-magnitude earthquake in Japan were reported. Both earthquakes provide unique examples of liquefaction-related damages, including slope instability, bridge and building failure, and flouting of buried structures (Kramer, 1996). Liquefaction is a term commonly used to describe abrupt and dramatically reduced resistance in sandy soils during seismic loading.

Regarding the widespread damage this phenomenon has caused in recent decades, numerous efforts have been made to estimate and analyze the potential of soil liquefaction. Several variables in soil properties (such as compaction, confining stress, particle size, and fine content) and their effect on liquefaction have complicated this issue (Seed and Idriss, 1971). Concerning the effect of fine particles on the liquefaction potential of sandy soils, it should be noted that the addition of clay or silt to the sand at different percentages can substantially alter the dynamic behavior of sand-clay mixtures. An extensive study in this area by Polito and Martin (2001) have been done. In addition to these laboratory studies, extensive field research has also been conducted to investigate the effect of fine on the liquefaction potential. The likelihood of liquefaction is likely to increase in soils with less than 10% fine also reported by Nguyen et al. (1991).

2. Materials and method

The sandy soil used in this paper is from an area north of Gorgan city in Golestan province. Samples obtained by exploratory drilling, this layer is composed of relatively poorly graded coarse-grained sand that is classified as SP in the unified classification. Mineralogically, about 90% of the grains consist of quartz and feldspar minerals. Also less than 10% of the carbonate minerals (calcite and dolomite) of iron oxides and hydroxides (hematite and limanite) are detectable in the grain texture. Kaolinite clay was sampled from the mines in East Azarbaijan province for preparation of fine aggregate.

Since the purpose of these experiments was to investigate the effect of fine addition on soil liquefaction resistance, the samples were mixed and prepared by dry deposition method because the homogeneity of the mixtures was of particular importance in this study and this method allowed the preparation of homogeneous samples.

In this study, stress-control undrained cyclic triaxial test based on ASTM D5311 standard was performed on various mixtures of sandy soil and kaolinite clay at 0, 5, 10 and 15 weight percent under 100 kPa confining pressure. Also, all samples were made at moderate relative density (Dr = 45%) and cyclic loading applied under 0.25 cyclic stress ratio.

3. Results and discussion

Study of the results of cyclic triaxial tests showed that the pattern of deformations in pure sand and its mixture with different percentages of kaolinite clay was almost similar. It should be noted that the liquefaction of samples is determined according to Ishihara's criterion (Ishihara, 1993). A closer look to the results can also show that pure sandy soil is liquefied at 54 cycles of loading. By adding 5% of kaolinite clay to this soil, it can be seen that the mixture is liquefied in cycle number 21, which is much less than pure sand. By increasing the percentage of kaolinite clay to 10%, the number of liquefaction loading cycles has increased to 29 cycles. Finally, the soil mixed with 15% kaolinite clay has liquefied after 86 cycles of loading (Fig. 1).

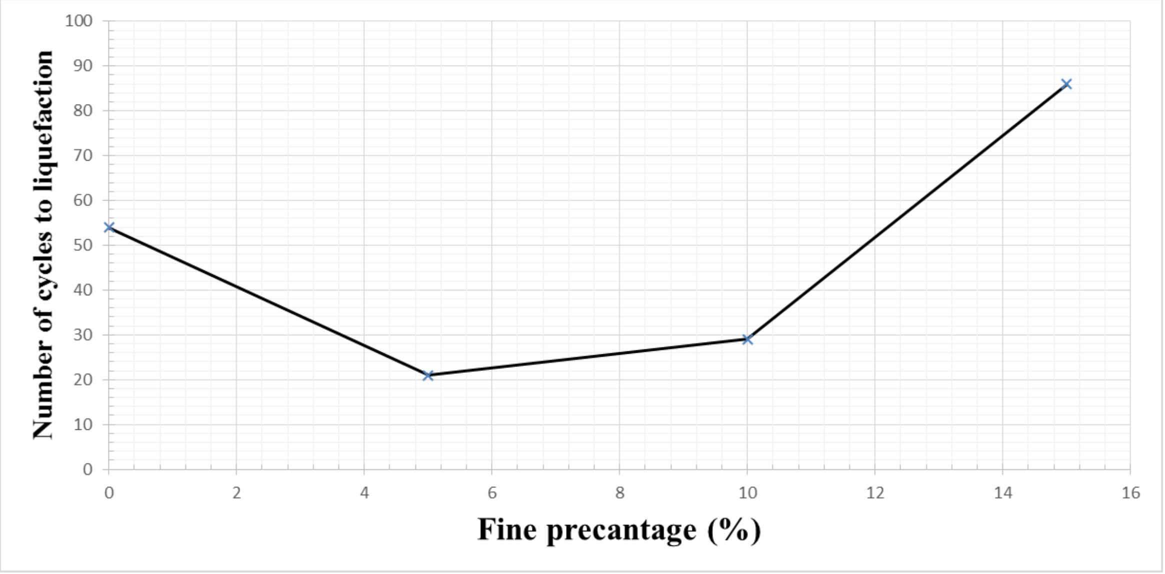

Fig. 1. Variation of liquefaction resistance of sandy soil with increasing of percentage kaolinite

Changes in pore water pressure during cyclic loading are shown that as the cyclic loading increases pore water pressure gradient increases gradually. A closer look at this results shows that, at this criterion, soil samples have been liquefied in approximately the same number of loading cycles.

The results of tests showed that the trend of change in the strength of the samples mixed with fine is in line with previous studies. As the percentage of fine additives is less than a certain value, the resistance to liquefaction decreases, but with the passage of fine particles from this threshold, the resistance to liquefaction increases. At a percentage below the limit, the fine grains are not actively involved in bearing, completely enclosed in the voids between the sand grains, reducing only the sample's total porosity. As clay content increases, clay particles gradually divide sand particles. In this fine percentage, the sand particles are surrounded by fines and this caused in removing the interlock between the sand grains, and with the sharp reduction in friction and locking, the energy required for breaking these locks greatly reduces and result in reducing the liquefaction resistance of the soil.

It is worth noting that some of the fine grains fill the cavities and do not affect the lock-in between sand grains (passive fine) but some fine grains are between sand particles and help break the soil structure (active fine grains).

4. Conclusion

The results of cyclic triaxial tests showed that the sandy soils of Gorgan were highly susceptible to liquefaction such that pure sand became liquefied during 54 cycles of loading. The results of this paper show that the amount of fine grains (threshold clay amount) for sand mix of Gorgan city with kaolinite clay is between 10% and 15%. Therefore, the amount of fine grains limit can be assumed to be 12% due to the trend of changes in porosity ratio and liquefaction resistance for kaolinite clay sand mixture.

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