The effect of particle size and degree of saturation on liquefaction potential of sandy soil

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ABSTRACT

In recent years, studies on strength characteristics of unsaturated soils due to the importance of suction in these types of soils has been more focused on cohesive fine-grained soils or compacted sandy soils and limited research on liquefaction of loose unsaturated sandy soils and the effect of particle size on this behavior have been done. In this paper, it has been aimed to investigate the effect of particle size and degree of saturation on liquefaction resistance of loose unsaturated sandy soils by performing a series of cyclic triaxial tests at undrained conditions on three types of sand with different grain size distribution. The results show that variation of pore water pressure and liquefaction resistance in studied sands are largely dependent on particle size and intergranular void ratio, so that #131 Firoozkooh sand has the lowest liquefaction resistance in saturated state due to its higher intergranular void ratio. Also, according to the obtained results, increasing the size of sand grains reduces the matric suction created in the soil mass due to reduction in degree of saturation. Increase of number of cycles to liquefaction and consequently the liquefaction resistance of the studied sands samples due to decrease of saturation, especially in sands with finer grains, is another result of this study.

KEYWORDS

Unsaturated soil, Particle size, Liquefaction potential, Cyclic triaxial test, Loose sand.

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1. Introduction

The dependency of unsaturated soil behavior on suction in soil mass under different drainage conditions, including drained air and water, constant suction, undrained air and water has been investigated in several studies which resulted increase of liquefaction resistance and undrained shear strength of soils [1-4]. In recent years, a few studies have been conducted on the cyclic behavior of unsaturated medium and dense sandy soils in which the increase of cyclic resistance and reduction in liquefaction potential by reduction in degree of saturation have been reported [5-9].

The review of previous researches shows the lack of studies about liquefaction of unsaturated loose sandy soils due to low suction and difficulty of prototyping of this type of soils. On the other hand, no study has been done on the effect of particle size on the liquefaction of unsaturated sands. For this purpose, in this study, by considering three types of unsaturated loose sands with different grain sizes, in addition to investigating the effect of saturation degree on the liquefaction resistance of sand, the effect of particle size in this field has been investigated by conducting a series of undrained cyclic triaxial tests at saturated and unsaturated states.

2. Materials and methods

2.1. Materials

The soils used in this study are 161, 131 and D11 Firoozkooh sands with physical properties presented in Table 1. As shown in table 1, the type of studied soils are SP according to Unified Soil Classification System.

Table 1. Physical properties of used Firoozkooh sands

Property	Value		
	#161	#131	D11
D_{50} (mm)	0.22	0.68	1.36
C_u	1.71	1.88	1.63
C_c	0.86	0.97	1.22
e_{max}	0.855	0.897	0.856
e_{min}	0.559	0.580	0.538
Soil classification	SP	SP	SP

2.2. Sample preparation and testing procedure

In this paper, under-compaction method according to relations of Ladd [10] and Been et al. [11] has been used to make homogeneous loose cylindrical specimens with a diameter of 5 and a height of 10 cm and relative density after consolidation of approximately 30%. After saturation of specimen in unsaturated triaxial chamber show in Figure 1, the saturated specimens were consolidated and then desaturated under differential pressure between air pressure and back pressure from the bottom of ceramic disk. After draining the specific water content to reach the considered degree of saturation, the water outlet is closed and the specimen is kept in the same position for 24 hours. Then, the unsaturated specimen is subjected to undrained-unexhausted cyclic triaxial test under net pressures of 100 kPa at loading frequency of 0.01 Hz.

Figure 1. Unsaturated triaxial chamber and ceramic disk on bottom pedestal

3. Results and discussion

As shown in Figure 2, for saturated #131 sand liquefaction occurs in fewer cycles and CSRs than #161 and D11 sands. Also, as can be seen in Figure 2, the CRR_{20} values for #161, #131 and D11 sands are 0.255, 0.207 and 0.267, respectively. The reason for difference between CRR_{20} and the number of liquefaction cycles in the constant CSR for studied sands can be investigated in the difference of global void ratio after solidification (e_c), which is equal to intergranular void ratio (e_{sc}) due to the absence of fine grains. As e_{sc} decreases, the contacts between sand particles and consequently effective stress increases, liquefaction resistance of saturated sand decreases.

It is obvious in Figures 2 and 3 that, at constant CSR, reduction in degree of saturation increases the number of cycles to liquefaction and consequently the liquefaction resistance (CRR_{20}), but the rate of increase in #161 sand is higher than #131 and D11 sands. The reason for the greater effect of degree of saturation on increasing the liquefaction resistance of #161 sand can be stated in the higher suction created in this sand due to its higher specific surface area than other sands. Also, as shown in Figure 3, the rate of increase in liquefaction resistance decreases with reduction in degree of saturation, because of limited matric suction to the surface tension between pore water and sand particles, which depends on thickness of shrinkage shell. At low saturation degrees, as the thickness of shrinkage shell is almost constant, the effect of desaturation on increasing matric suction and liquefaction resistance decreases.

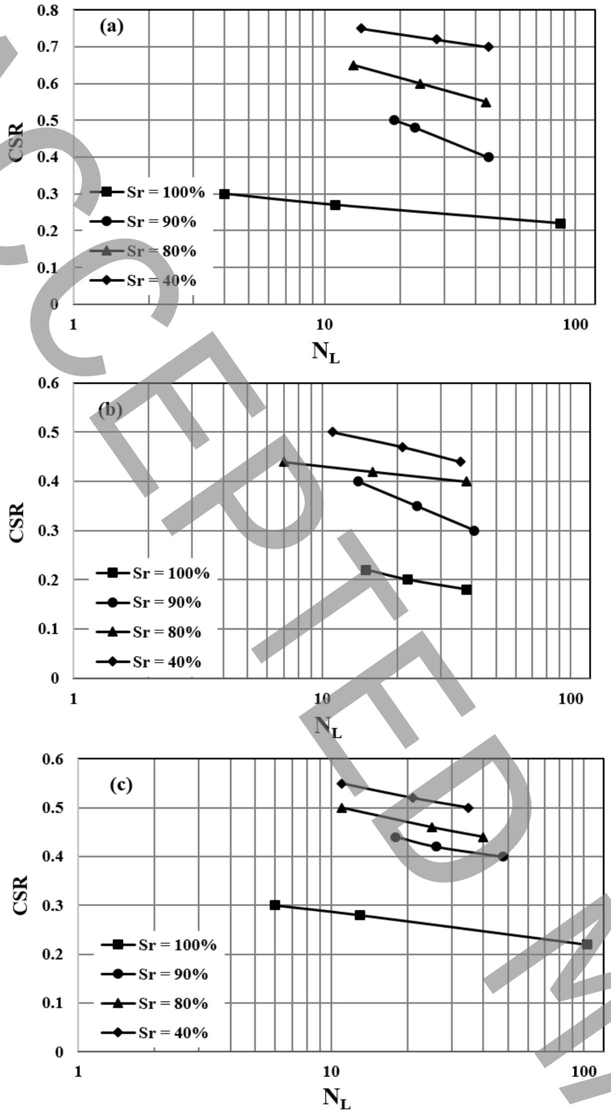

Figure 2. The effect of degree of saturation on variation of number of liquefaction cycles under different CSR for (a) 161, (b) 131 and (c) D11 Firoozkooh sand

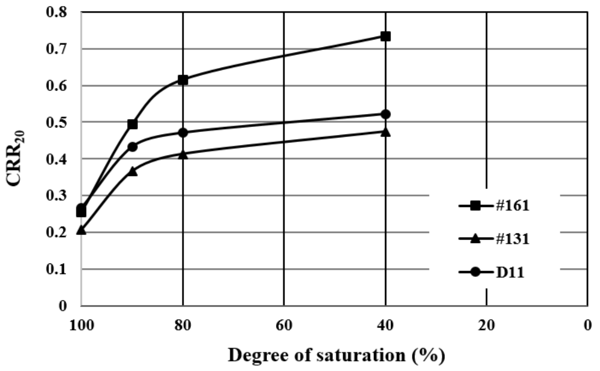

Figure 3. Variation of CRR_{20} with degree of saturation for used Firoozkooh sands

4. Conclusions

In this study, the effect of particle size and degree of saturation on liquefaction resistance of saturated and unsaturated loose sands. The main results obtained in this research are as follows.

- The intergranular void ratio (e_{sc}) has significant role in variation of liquefaction resistance, so that #131 sand has the lowest liquefaction resistance at saturated state due to the higher intergranular void ratio.
- By increase of particle size, the matric suction decreases due to reduction in thickness of the shrinkage shell, revealed to reduction in surface tension between pore water and sand particles.
- Reduction in degree of saturation increases the number of cycles to liquefaction and consequently, increase of liquefaction resistance, but the rate of this increase in #161 sand is higher than #131 and D11.

5. References

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