



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

Gh. A. Jafarzadeh Imanabadi, S. A. H. Naeini*, R. Ziaie Moayed

Faculty of Technical and Engineering, Imam Khomeini International University, Qazvin, Iran

Review History:

Received: Jul. 05, 2021
Revised: Oct. 18, 2021
Accepted: Dec. 10, 2021
Available Online: Jan. 01, 2022

Keywords:

Unsaturated soil
Particle size
Liquefaction potential
Cyclic triaxial test
Loose sand

ABSTRACT: In recent years, studies on strength characteristics of unsaturated soils due to the importance of suction in these types of soils have 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 under undrained conditions on three types of sand with different grain size distributions. 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 #131 Firoozkooh sand has the lowest liquefaction resistance in the 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 a reduction in the degree of saturation. An increase in the number of cycles to liquefaction and, consequently the liquefaction resistance of the studied sand samples due to a decrease in saturation, especially in sands with finer grains, is another result of this study.

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 in the 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 the reduction in the degree of saturation have been reported [5-9].

The review of previous researches shows the lack of studies about the 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 is SP according to the Unified Soil Classification System.

Sample preparation and testing procedure

In this paper, the 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 the 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.

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



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



Fig. 1. Unsaturated triaxial chamber and ceramic disk on the 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 CRR₂₀ values for #161, #131 and D11 sands are 0.255, 0.207 and 0.267, respectively. The reason for the difference between CRR₂₀ and the number of liquefaction cycles in the constant CSR for studied sands can be investigated in the difference in global void ratio after solidification (e_s), which is equal to the 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, a reduction in the degree of saturation increases the number of cycles to liquefaction and consequently the liquefaction resistance (CRR₂₀), but the rate of increase in #161 sand is higher than #131 and D11 sands. The reason for the greater effect of the degree of saturation on increasing the liquefaction

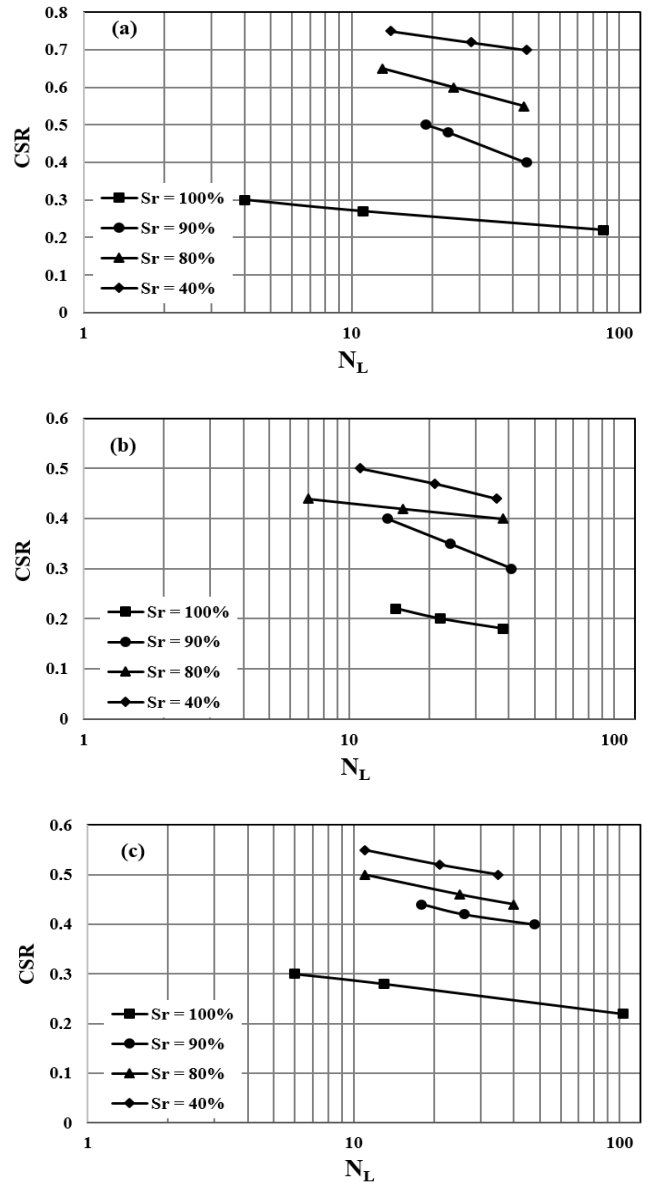


Fig. 2. The effect of degree of saturation on the variation of the number of liquefaction cycles under different CSR for (a) 161, (b) 131 and (c) D11 Firoozkooh sand

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 the degree of saturation because of limited matric suction to the surface tension between pore water and sand particles, which depends on the thickness of the shrinkage shell. At low saturation degrees, as the thickness of the shrinkage shell is almost constant, the effect of desaturation on increasing matric suction and liquefaction resistance decreases.



Fig. 3. Variation of CRR20 with the degree of saturation for used Firoozkooch 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 a significant role in the variation of liquefaction resistance so #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 the reduction in surface tension between pore water and sand particles.

Reduction in the 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.

References

References

[1] D.G. Fredlund, N.R. Morgenstern, R.A. Widger, The shear strength of unsaturated soils, *Canadian Geotechnical Journal*, 15(3) (1978) 313-321.

[2] Y.J. Cui, P. Delage, Yielding and plastic behaviour of an unsaturated compacted silt, *Géotechnique*, 46(2) (1996) 291-311.

[3] H. Toyota, K. Nakamura, N. Sakai, W. Sramoon, Mechanical properties of unsaturated cohesive soil in consideration of tensile stress, *soils and foundations*, 43(2) (2003) 115-122.

[4] F. Geiser, Ccedil, Oise, L. Laloui, L. Vulliet, Elastoplasticity of unsaturated soils: laboratory test results on a remoulded silt, *Soils and foundations*, 46(5) (2006) 545-556.

[5] S. Kimoto, F. Oka, J. Fukutani, T. Yabuki, K. Nakashima, Monotonic and cyclic behavior of unsaturated sandy soil under drained and fully undrained conditions, *Soils and foundations*, 51(4) (2011) 663-681.

[6] M. Vernay, M. Morvan, P. Breul, Influence of saturation degree and role of suction in unsaturated soils behaviour: application to liquefaction, *E3S Web Conf.*, 9 (2016) 14002.

[7] Y. Tsukamoto, Degree of saturation affecting liquefaction resistance and undrained shear strength of silty sands, *Soil Dynamics and Earthquake Engineering*, 124 (2019) 365-373.

[8] L. Mele, A. Flora, On the prediction of liquefaction resistance of unsaturated sands, *Soil Dynamics and Earthquake Engineering*, 125 (2019) 105689.

[9] K.H. Tran, S. Imanzadeh, S. Taibi, D.L. Dao, Liquefaction Behavior of Dense Sand Relating to the Degree of Saturation, in, *Springer Singapore*, Singapore, 2020, pp. 879-886.

[10] R.S. Ladd, Preparing Test Specimens Using Undercompaction, *Geotechnical Testing Journal*, 1 (1978) 16-23.

[11] K. Been, M.G. Jefferies, J. Hachey, The critical state of sands, *Géotechnique*, 41(3) (1991) 365-381.

HOW TO CITE THIS ARTICLE

Gh. A. Jafarzadeh Imanabadi, S. A. H. Naeini, R. Ziaie Moayed, *The effect of particle size and degree of saturation on liquefaction potential of sandy soil*, *Amirkabir J. Civil Eng.*, 54(7) (2022) 531-534.

DOI: 10.22060/ceej.2022.20238.7376



