



Experimental investigation of the effect of relative densities and type of loading on sand liquefaction under irregular earthquake loading

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ABSTRACT: The cyclic triaxial test has been widely used to evaluate the liquefaction potential of soil over the past few decades. When a specimen is subjected to repeated shear loading, the sand particles tend to rearrange their stacking into a denser state. While drainage is prevented, pore pressure generation and loss of effective stress have resulted. This paper presents a systematic experimental investigation into the liquefaction behavior of saturated sand subject to seismic loading with various relative densities such as 30, 50 and 70 percent. Dynamic triaxial tests were run on saturated firozkooh sand using irregular time history loads that were recorded during the 1999 Chi-Chi earthquake in Taiwan. The records could be classified as shock and vibration type waveforms. The effect of each type of waveform and relative densities of sand samples on the liquefaction potential of sand was also evaluated in order to compare these results with previous studies, some cyclic tests have been done with various relative densities 30, 50 and 70 percent. The triaxial test results indicate that the pore pressure generation and liquefaction resistance of sand are influenced by the relative densities and the type of irregular loadings. Also, with the increasing duration of the records in the same PGA, the vibration waveform have more liquefaction potential than the shock waveform.

1- Introduction

Liquefaction is a soil mechanics problem that often influences structures supported on saturated sand deposits. Seed and Idriss [1] proposed an equivalent approach and evaluated the equivalent uniform cyclic stress as 65% of the maximum stress in random loadings. Recent research has evaluated sand behavior under random loading [2-6]. However, the previous researches show that the most studies have been carried out on the specimens subjected to uniform cyclic loading because of the lack of ability of the facilities to apply the irregular loading on the specimens. Furthermore, the effects of cyclic loading forms on the specimens with various densities have not been considered.

In this paper, the effects of irregular loading of strong ground motions, including two patterns of shock and vibration ground motion, are applied to the sand specimens then the liquefaction potential and pore water pressure characteristics of Firoozkuh #161 in various densities are compared with those results which obtain from the same specimens subjected to harmonic sinusoidal cyclic loading.

2- Methodology

The 6 records of the Chi-Chi earthquake are considered at different stations. In terms of appearance, the records

at stations 4, 5 and 6 were classified as shock loading and records at stations 1, 2 and 3 were vibration waveforms.

Cyclic triaxial test specimens 50 mm in diameter and 100 mm in height were prepared in watertight rubber membranes with porous stone and filter paper on each end. The wet tamping method has been used for sampling. The specimens had consolidation stress of = 100 KPa.

The experiments performed in this research were at relative densities (D_r) of 30%, 50%, 70%. All tests were performed at a similar relative density and all samples were prepared using the method described above.

3- Results and Discussion

the variation of pore-water pressure values of all irregular tests are presented in Figure 1. It is noteworthy that no loading is done in parts of the graphs shown in the dotted line.

Figure 1 portrays that with increase relative densities 30 to 70%, the diagram tends to go to the right as last research, the specimen needs more ($q/2\sigma'_c$) to liquefy.

In order to investigate soil behavior under shock and vibration waveform more precisely, the variation of excess pore pressure at different PGA that occurred liquefaction, in the relative densities 30, 50 and 70 percent are plotted in Figure 2.

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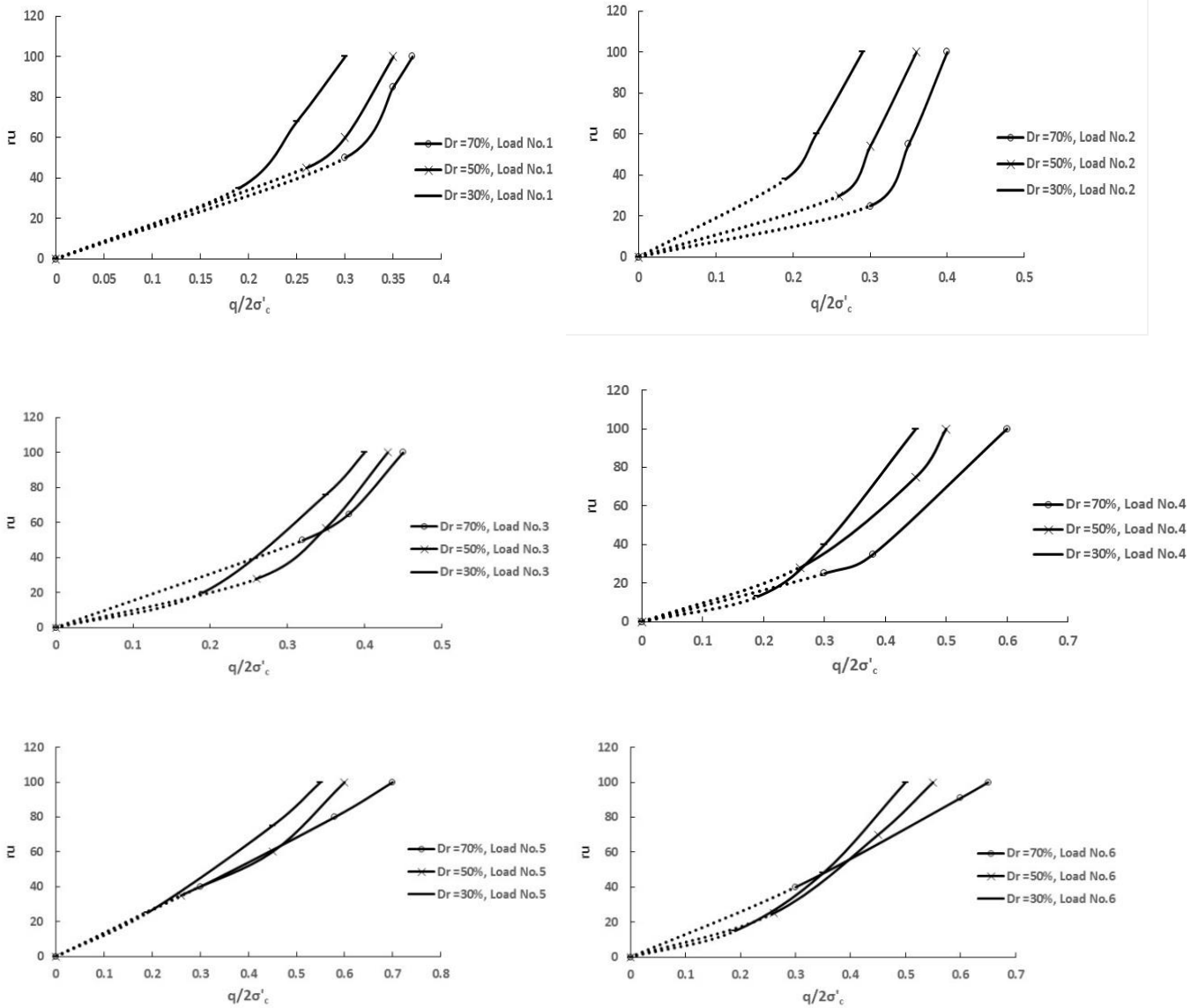


Fig. 1. The variation of pore-water pressure values of all irregular tests

According to Figure 2, by increasing the relative density of specimens, the PGA of record that leading to liquefaction has increased. Samples under the relative density of 70% require about 20% higher PGA values for liquefaction. Thus, relative density has a major role in defining the dynamic behavior of cohesionless soils.

4- Conclusion

A comparison of soil behavior indicated that a higher stress ratio for liquefaction occurred during shock loading than vibration loading.

In cyclic uniform loading, by increasing the relative density of the specimens from 30% to 70%, the pore-water pressure increased; meanwhile, with the increase in the density of the specimens, the Stress correction coefficient increased.

At a similar PGA, due to the number of acceleration cycles that reached to 0.65PGA in vibration waveform is more than shock waveform and the high value of the effective duration of them so, the shock records have less liquefaction potential than vibration one.

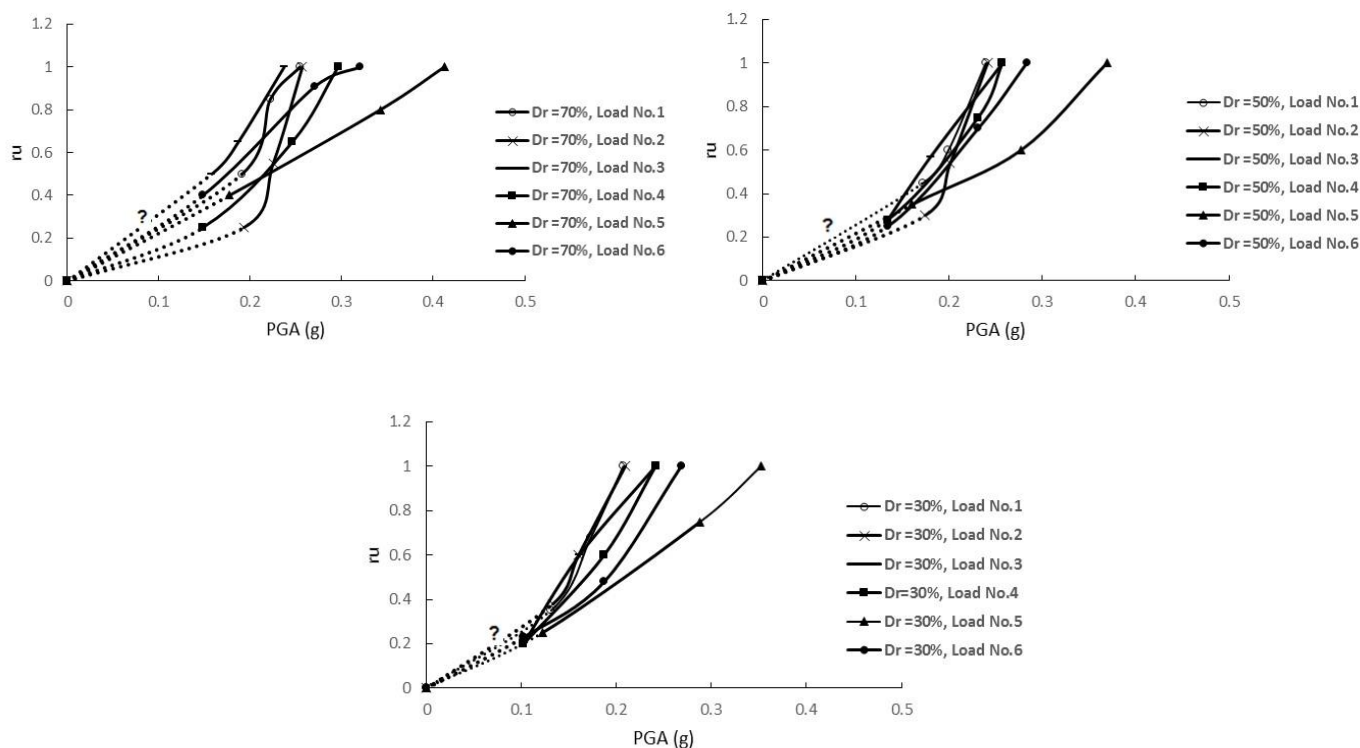


Fig. 2. The variation of excess pore pressure at different PGA that occurred liquefaction

References

[1] H.B. Seed, I.M. Idriss, Simplified procedure for evaluating soil liquefaction potential, *Journal of Soil Mechanics & Foundations Div*, (1966).

[2] S.S. Kumar, A. Dey, A.M. Krishna, Response of saturated cohesionless soil subjected to irregular seismic excitations, *Natural Hazards*, 93(1) (2018) 509-529.

[3] K. Pan, Z. Yang, Evaluation of the liquefaction potential of sand under random loading conditions: Equivalent approach versus energy-based method, *Journal of Earthquake Engineering*, (2017) 1-25.

[4] K. Pan, Z. Yang, Effects of initial static shear on cyclic resistance and pore pressure generation of saturated sand, *Acta Geotechnica*, 13(2) (2018) 473-487.

[5] J. Qiu, X. Wang, J. Lai, Q. Zhang, J. Wang, Response characteristics and preventions for seismic subsidence of loess in Northwest China, *Natural Hazards*, 92(3) (2018) 1909-1935.

[6] S. Sağlam, S. Bakir, Models for pore pressure response of low plastic fines subjected to repeated loads, *Journal of Earthquake Engineering*, 22(6) (2018) 1027-1041.

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