Optimal shear displacement amplitude for pore pressure generation in undrained cyclic loading ring shear tests: an energy approach

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1. INTRODUCTION

In recent decades, a new method, energy approach, has been proposed for the analysis of liquefaction potential of a site during earthquake. However, some factors, such as the frequency and the amplitude of cyclic loadings that may influence the dissipated energy, need more scrutinizing. Recently, a series of cyclic shearing tests has been conduced on a sandy soil by using a newly developed undrained ring shear apparatus. The liquefaction processes of sandy soils subjected to different types of shear loadings are examined basing on energy approach, and the test results are presented here.

2. SAMPLES & TEST PROCEDURES

A sandy soil, Osaka Formation, was used as the sample. These samples were taken from the headscarp of a landslide in Takarazuka golf course triggered by the 1996 Hyogoken-Nambu earthquake. To examine the effects of grain size on pore water pressure generation, silica sand no. 2, 4, and 8 were also used in this research.

In this research, ring shear apparatus DPRI-Ver.4 was used. Shear-displacement-controlled method was used to apply the cyclic loadings. Once the sample was saturated and consolidated, cyclic shearing was applied to the soil until the excess pore water pressure ratio was ≥ 0.95.

3.TEST PHENOMENA

Fig. 1 presents the results of a typical test. As seen, excess pore pressure was built-up to reach the normal stress within some cycles, and the shear resistance became almost zero consequently. Note that different tests showed differing pore-water pressure generation process. Here those differences are examined combining the dissipated energy at sliding surface during shearing i.e., energy approach (Fig. 2).

4. DISCUSSIONS AND CONCLUSION

Fig. 3 presents results of tests performed under almost the same shear displacement amplitude (Δl_{max}) and void ratio, but differing frequencies (from 0.01 to 0.20 Hz). As seen, the total dissipated energy W_{total}, the number of cycles (***N***), and the total experienced shear displacement (l_{total}) until liquefaction were almost the same for these tests and were independent of frequency.

Results of test at different Δl_{max} showed that pore water pressure generation is significantly dependent on the applied Δl_{max} during shearing. In Fig. 4, the total dissipated energy required for liquefaction (W_{total}) was plotted against Δl_{max}. It can be seen that with increase of Δl_{max}, W_{total} decreased until a certain value of Δl_{max} (about 0.5 mm) at which W_{total} reached the minimum value (approximately 100 J/m^2), and thereafter, W_{total} increased with further increase of the Δl_{max}. The existence of this optimal value of 0.5 mm probably is due to the fact that the Δl_{max} less than 0.5 mm is not effective for the rearrangements of particles, and then the energy is mostly spent on overcoming friction forces between adjacent particles; while the Δl_{max} greater than 0.5 mm could result in both rearrangement and breakage of particles. Breakage of particles consumes more energy.

Finally, it is noted that results of tests on silica sands revealed also the existence of this optimal value, and the optimal value of shear displacement amplitude seemed to be independent on the grain sizes (Fig. 4).

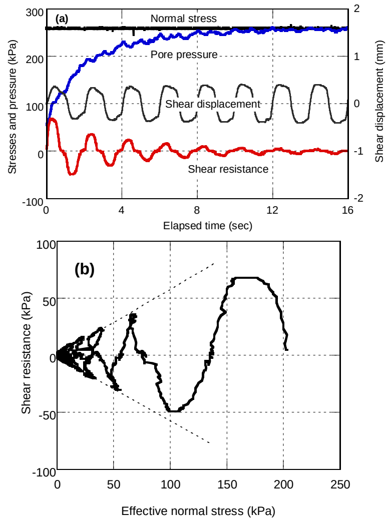

Fig. 1. Typical test results (a) time series data, (b) effective stress path (e=0.67; Δl_{max}=0.38mm, f=0.5 Hz)

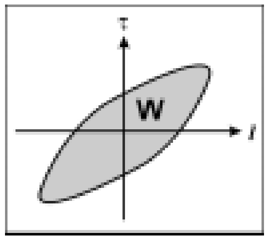

Fig. 2. Dissipated energy (W) in the soil subjected to cyclic loading in the ring shear test for one cycle.

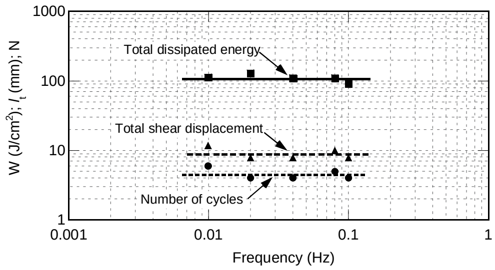

Fig. 3 Total dissipated energy (***W***$_{total}$), number of cycles (***N***), and total shear displacement required for liquefaction versus loading frequency (***f***) (Δl_{max} = 0.49-0.50 mm).

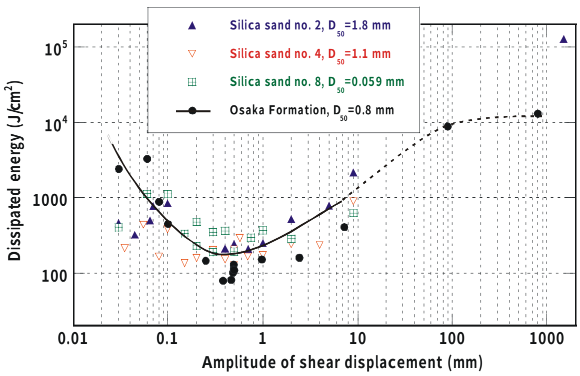

Fig. 4. Total dissipated energy (***W***$_{total}$) to liquefaction against shear displacement amplitude.