III-257 EFFECT OF CYCLIC LOADING PERIOD ON THE BEHAVIOR OF CLAY UNDER UNDRAINED TORSIONAL SIMPLE SHEAR

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1. Introduction

Period of loading cycle or frequency of cyclic loading has been reported to impose some effect on the cyclic behavior of the soil. However, researches on this phenomenon are not many and mostly concentrated on the effect on cyclic shear strength of clays, for instants by Fischer et al (1976), Ishihara (1980), Procter & Khaffaf (1984)... Recently, in a study by Matsuda & O-Hara (1990) the effect of frequency on the generated excess pore pressure and cyclic induced settlement have been discussed. To clarify the reported results, the effect of frequency on the cyclic behavior of clay, including the generation of excess pore pressure, cyclic shear strain, shear modulus and post-cyclic recompression, is investigated in this study using torsional simple shear apparatus on hollow cylindrical specimen (TSS test).

2. Tested Clay and Testing Procedures

The clay used in this study was obtained from Tokyo Bay and preconsolidated one-dimensional at stress of 0.5 kgf/cm² . The basic properties are: LL 80%, PI 40%. For TSS test, clay specimen in hollow cylindrical form was anisotropic consolidated at maximum vertical stress 1.84 kgf/cm² to get to normally consolidated state. In order to introduce an overconsolidation history, the specimen was then unloaded one-dimensionally to a prescribed stress level. After consolidation, clay of certain OCR was directly subjected to undrained torsional cyclic simple shear under stress control condition. Accumulated excess pore pressure (E.P.P) was allowed to dissipate after cyclic loading and the volume change was measured.

3. Results and Discussions

Total of 13 TSS tests have been performed on clay of OCR 1, 2, and 4. Four different frequencies, 0.05, 0.1, 0.2, and 0.5 Hz were selected to be applied in each series of 4 tests of the same stress ratio SR (τ_{cy}/σ'_{vc}) as 0.2, 0.34 and 0.5 for OCR 1, 2 and 4, respectively. The effect of frequency on the cyclic behavior of clay are discussed hereafter.

a) Excess Pore Water Pressure (E.P.P.)

Results from all test series showed that within the selected range of frequency (0.05-0.5 Hz) the E.P.P. generated during undrained cyclic loading at a certain number of cycles increased with decreasing frequency. The required number of cycles, N, to cause a certain value of E.P.P. for various frequencies are shown in Fig. 1 for OCR 1 and 4, respectively. It has been observed that, with the number of cycles upto more than 100 in case of NC clay and 200 in case of OC clay, the increase in E.P.P. due to decreasing frequency still continued without converting to a stable level for all frequencies. It means within this range the rate effect on the behavior of E.P.P. is still essential not only for NC, but also for OC clay.

However, it seemed that if the shear stress ratio is small, the effect of frequency become less and at some level it might be erased as observed in case of SR=0.33 for OCR 4 and illustrated in Fig. 2.

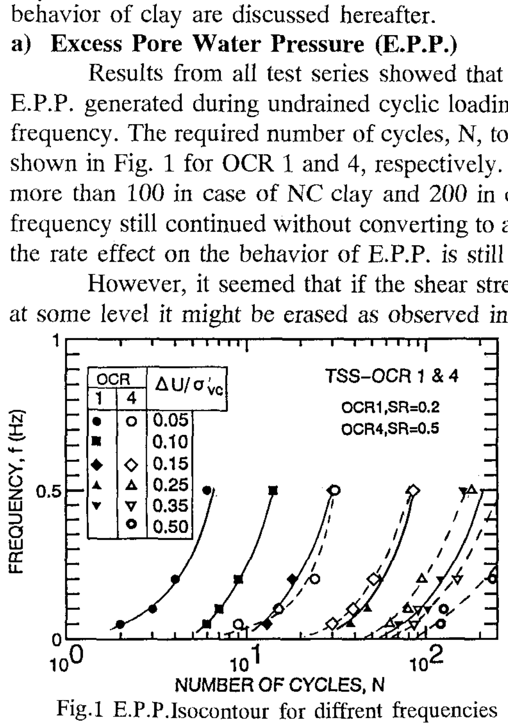

Fig.1 E.P.P.Isocontour for diffrent frequencies

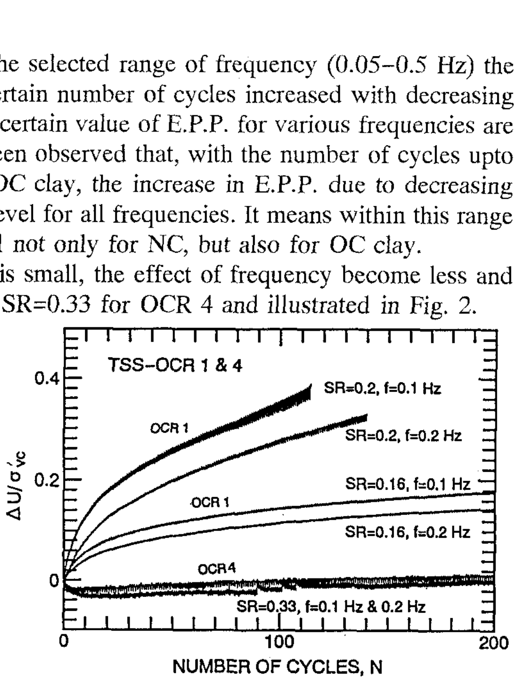

Fig.2 Effect of SR on E.P.P. at different frequencies

b) Cyclic Shear Strain and Shear Modulus

The effect of frequency on the development of cyclic shear strain is presented in Fig. 3 in terms of required number of cycles to cause a certain level of double amplitude cyclic shear strain, γ_{DA}. However, a correlation between the E.P.P. and the γ_{DA} appeared not to be affected by frequency, that all the data points from tests of different frequencies for each OCR were arranged in almost one line as can be seen in Fig. 4.

Clearly, with decreasing frequency the increase in cyclic shear strain means a decrease in shear modulus at a certain number of cycles. However, a correlation between equivalent shear modulus, G_{eq}, and single amplitude cyclic shear strain, γ_{SA}, has been found to be independent of frequency. In Fig. 5, three separated curves are represented for OCR 1, 2, and 4, where different marks show different frequencies.

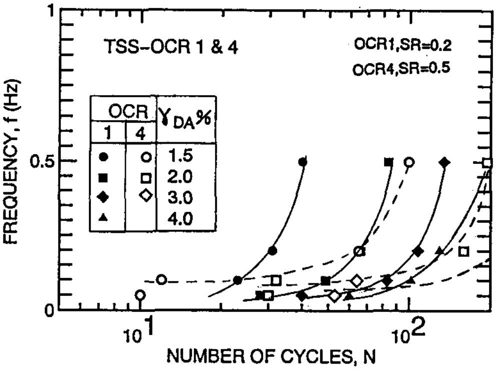

Fig.3 Shear Strain Isocontour for different frequencies

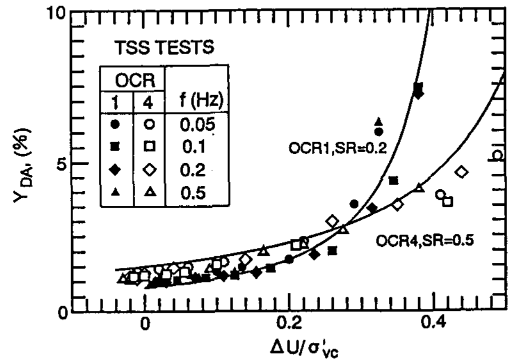

Fig.4 Relationship between γ_{DA} and E.P.P.

c) Post-cyclic Recompression

Dissipation of the build-up pore pressure leads to recompression of clay. The recompression index, C_r*, determined as the slope of the consolidation curve in e–log σ'plot, was found to be independent of frequency. As can be seen in Fig. 6, data from tests of diffrent frequencies (different marks) of each OCR are arranged around the line representing an unique relationship between the value of C_r* and the value $[1/(1-\Delta U/\sigma'_{vc})]$ despite of frequency.

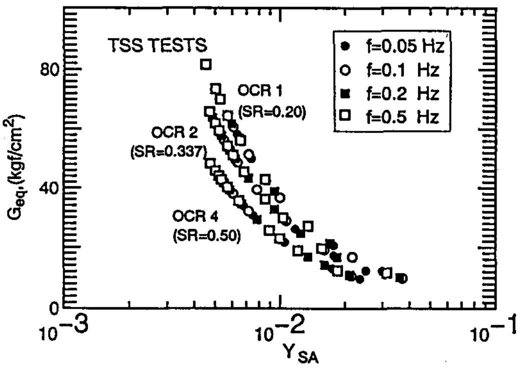

Fig.5 Relationship between G_{eq} and γ_{SA}

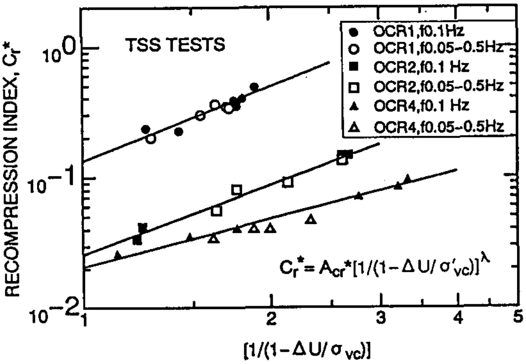

Fig.6 Relationship between C_r* and E.P.P.

4. Conclusions

Results from this study allow to yield following conclusions:

1) Within the selected range from 0.05–0.5 Hz the effect of frequency on the generation of excess pore pressure and on development of cyclic shear strain seem not to be neglegible for both NC and OC clay.

2) The correlations between parameters such as: a)the excess pore pressure and the cyclic shear strain; b)the equivalent shear modulus and the cyclic shear strain; and c)the recompression index and the amount of build–up pore pressure appeared to be independent of frequency.

References

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Proctor, D.C., and Khaffaf, J.H., 1984: Cyclic Triaxial Tests on Remolded Clays. Journal of the Geotechnical Engineering Devision, ASCE 110,(10), pp 1431–1445