Ⅲ－149 Combined effects of cyclic prestarining and aging on elastic modulus of dry Toyoura sand

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INTRODUCTION

Effects of cyclic prestraining (CP) and consolidation time on the elastic modulus of granular materials are still poorly understood. Drnevich et al. (1970) showed that a large number of cycles with a large strain amplitude increases the shear modulus with the greater increase occurring at lower shear strains. Hardin et al. (1972) reported that shear modulus increases with consolidation period. Tokimatsu et al. (1986) showed that the elastic shear modulus G_{max} for an aged in-situ sand deposit can be reproduced in the laboratory by applying an appropriate amount of CP followed by consolidation for an appropriate period to 'undisturbed' samples that may have been disturbed during sampling, transportation, etc. However, some other researchers (DeAlba et al., 1984; Teachavorasinskun, 1992) showed that G_{max} of a clean sand is rather insensitive to CP.

TEST PROCEDURE

A specimen of Toyoura sand (7.5 cm in diameter and 15 cm in height) having 'regular ends' was reconstituted by air-pluviation. Equivalent Young's modulus, E_{eq}, versus single amplitude axial strain, $(\varepsilon_v)_{SA}$, relations and axial stress-dependency of the maximum Young's modulus, E_{max}, along the cyclic triaxial stress path during CP application were evaluated 'immediately before', 'immediately after' and 'long after' CP. E_{max} at the neutral stress state σ_c=0.8 kgf/cm^2, both prior to and after CP application, was evaluated at appropriate intervals. E_{max} and E_{eq} were obtained by applying cyclic load (CL) with $(\varepsilon_v)_{SA} \leq 0.002\%$ and varying $(\varepsilon_v)_{SA}$ in the range 0.001~0.035% in steps, respectively.

Prestraining cycles were applied symmetrically about the isotropic stress (σ_c=0.8 kgf/cm^2) with $(\varepsilon_v)_{SA}$=0.035% for a dense specimen and $(\varepsilon_v)_{SA}$=0.025% for the looser specimen at the frequency f=0.1 Hz to a number of cycles N=25000, which was considered enough to bring about considerable effects, if any, on E_{max}, E_{eq} and axial stress-dependency of E_{max} along CP stress path.

TEST RESULTS

Fig.1 shows the typical relations of axial stress, σ_v, versus axial strain, ε_v, for a small CL obtained initially and 'immediately before' CP, 'immediately after' CP as well as 'long after' CP. Responses were essentially linear and recoverable with the slope after CP differing from that before CP, indicating the influence of CP on E_{max}. The stiffness obtained using external gap sensor was slightly larger than that by LDTs, which would be due to that the specimen was denser at both ends. The difference is, however, very small. Elapsed time is defined as the cummulative time initialized at the begining of testing.

Fig.2 shows the effects of CP and post-straining consolidation on E_{eq}~$\log((\varepsilon_v)_{SA})$ relation. Due to CP, E_{eq} at a particular $(\varepsilon_v)_{SA}$ was observed to have decreased, with the maximum reduction at the smallest $(\varepsilon_v)_{SA}$. Partial recovery of stiffness damaged by CP was observed in the post-straining consolidation period, the maximum recovery occurring at the smallest $(\varepsilon_v)_{SA}$.

Effects of CP on the E_{max}~σ_v relation along the stress path during CP are shown in Fig.3— E_{max}~σ_v relation was shifted downward while keeping E_{max} at the peak axial stress during CP unchanged. This resulted in the decrease of the basic parameter E_1, where $E_{max}=E_1\sigma_v^m$, while increasing the value of exponent m. This behaviour may be called "CP-induced anisotropy", referring to inherent and stress-system induced anisotropies. 'Partial recovery' of E_{max} during the post-straining period can also be seen, which is larger at smaller σ_v.

Finally, Figs.4a and b show the variation of E_{max} at σ_c=0.8 kgf/cm^2 for the entire time history of the experiments for a medium dense and a dense specimens, respectively. The figures show: a) a marginal increase with some scatter in E_{max} prior to CP; b) a sudden drop (the maximum of about 20% in the looser specimen) of E_{max} by CP; c) like clay, thixotropic behaviour in the initial part of post-CP period, followed by a very slow increase in E_{max}. In these tests void ratio did not change largely as given in brackets.

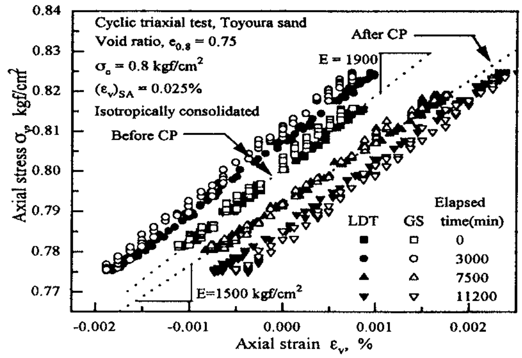

Fig.1: σ_v~ε_v relations of typical CL tests

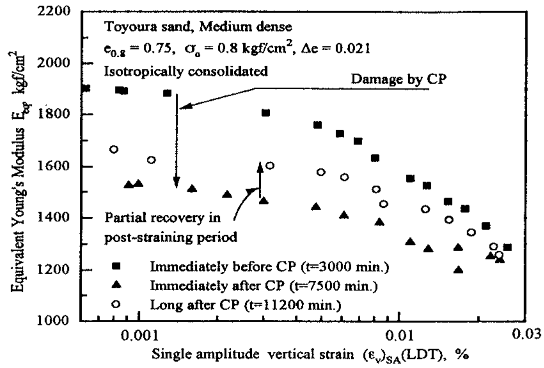

Fig.2: E_{eq}~Log$(\varepsilon_v)_{SA}$ variations at different times.

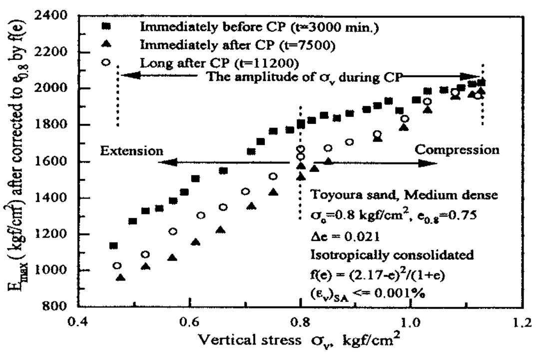

Fig.3: Variation of E_{max} along CP stress path.

CONCLUSION

The elastic Young's modulus E_{max} measured at the neutral stress state decreased noticeably by cyclic prestraining (CP) with $(\varepsilon_v)_{SA}$=0.025% and 0.034% for N=25000. This reduction is due to CP-induced anisotropy, since the E_{max} value at the peak axial stress applied during CP almost unchanged. The recovery in the E_{max} value at the neutral stress state during post-CP period is linked to gradual decrease in the effects of CP-induced anisotropy with time.

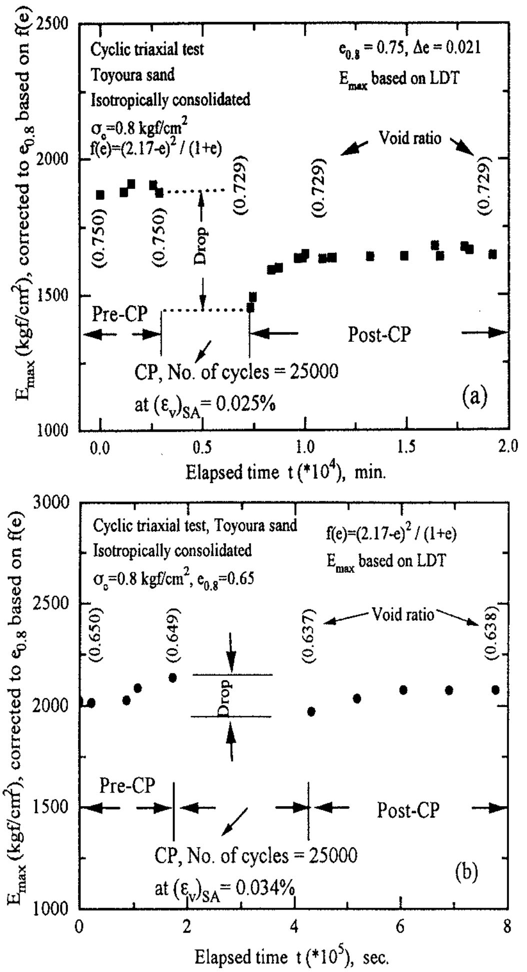

Fig.4: Variation of E_{max} at a neutral stress (σ_c=0.8 kgf/cm^2) with time for a) $e_{0.8}$=0.75, b) $e_{0.8}$=0.65.

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