III-120 EFFECT OF BEDDING ERROR ON THE MEASURED HYSTERESIS DAMPING RATIO OF SAND

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INTRODUCTION: It has been experimentally proven that, in a monotonic loading triaxial test on sand, the bedding error can have an enormous effect on the measured stress-strain relationship. In the present study, the effect of bedding error, combined with the effect of cyclic prestraining, on the cyclic stress-strain relationship (Young's modulus and damping ratio) when porous stones are used at the specimen ends was investigated. In addition, the effect of bedding error on the damping ratio was analyzed based on a simple model. For the details of the apparatus and testing procedure, the reader is referred to Teachavorasinskun et al., 1991(a) and (b).

RESULTS AND DISCUSSION: Fig.1(a) and Fig.1(b) show the equivalent Young's modulus, E_{eq}, and the hysteretic damping ratio, h, plotted against the single amplitude axial strain, $d(\varepsilon_a)_{SA}$, of the virgin loose and dense Toyoura sand, respectively, while Fig.2(a) and Fig.2(b) show those of the prestrained loose and dense sand. In these figures, LDT and GS mean that the axial strain, ε_a, was measured locally on the lateral surface of specimen by means of LDT and externally from the movement of the cap of the specimen, respectively. It should be noted that ε_a by LDT does not include the bedding error. It may be seen that the bedding error has a discenible effect on the cyclic behavior. In particular, after the process of cyclic prestraining (Teachavorasinskun et al., 1991(a)), the effect of bedding error became more obvious and more important. Fig.3 compares the values of h by the two measuring methods at the same stage of test. It may be seen from Fig.1, Fig.2 and Fig.3 that, particularly for prestrained dense specimen, the values of h by GS are larger than those by LDT. This may be because a degree of the rearrangement of the relative positions of particles (plus densification in the case of loose sand) took place in the central part of the specimen, while the end friction prevented the zones next to the ends from that.

It is assumed that, adjacent to the ends of the specimen, loosened zones had been formed and they reduced the average Young's modulus. Supposing that the axial stress was uniformly distributed along the the vertical axis of specimen, the hysteresis loops, at a single amplitude deviatoric stress, q_{SA}, are illustrated in Fig.4. Curves **A** and **B** represent the stress-strain relationships of the loosened zones (near the ends) and the denser zone (center part) of the specimen, respectively, while the average relationship is denoted by the letter **C**. By assuming the volumes of the loosened end zones and denser center zone to be **aV** and **(1-a)V**, respectively (**V** is the total volume of specimen), the equivalent Young's modulus, and damping ratio averaged for the whole of specimen are obtained as:

$$\overline{E}_{eq} = \frac{q_{SA}}{d(\overline{\varepsilon}_a)_{SA}} = \frac{q_{SA}}{(aq_{SA}/E_A) + ((1-a)q_{SA}/E_B)} = \frac{1}{a/E_A + (1-a)/E_B} = \frac{E_B}{ax + (1-a)} \quad (1)$$

where
$d(\overline{\varepsilon}_a)_{SA}$ = the average single amplitude axial strain,
$\overline{E}_{eq}$ = the average equivalent Young's modulus (E_{GS}),
E_A = the equivalent Young's modulus of curve A
E_B = the equivalent Young's modulus of curve B (E_{LDT})
$x = E_B/E_A = d(\varepsilon_{aA})_{SA}/d(\varepsilon_{aB})_{SA} = W_A/W_B$ (for the same q_{SA})

$$\overline{h} = \Delta W/(2\pi W) = \frac{1}{2\pi}\left(\frac{a\Delta W_A + (1-a)\Delta W_B}{aW_A + (1-a)W_B}\right) = \frac{axh_A + (1-a)h_B}{ax + (1-a)} \quad (2)$$

where
$\overline{h}$ = the average damping ratio (h_{GS})
h_A, h_B = the damping ratio of curves A and B
W_A, W_B = the input energy of curves A and B
$\Delta W_A, \Delta W_B$ = the energy dissipated during a cycle for curves A and B ($\Delta W_A = 2\pi W_A h_A$ and $\Delta W_B = 2\pi W_B h_B$)

Rearranging Eqn.(2) by using Eqn.(1), we have the theoretical relationship between average damping ratio, $\overline{h} = h_{GS}$, and the locally measured damping ratio, $h_B = h_{LDT}$.

$$\overline{h} = h_B + \left(1 - (1-a)\frac{E}{E_B}\right)(h_A - h_B) \quad (3)$$

To obtain the parameter **a**, it was assumed that the damping and strain ralation be the same for the curves **A** and **B**. In the case of Fig.2(a), at Stage α, $\overline{h}$ starts increasing. It was considered that the strain in the loosened zones be already the strain in the central zone at Stage β, at which $h_{LDT} = h_B$ starts increasing. Then, we obtain

$$x \ at \ Stage \ \alpha = d(\varepsilon_{aA})_{SA}/d(\varepsilon_{aB})_{SA} = \frac{d(\varepsilon_{aB})_{SA} \ at \ Stage \ \beta(=\varepsilon_2)}{d(\varepsilon_{aB})_{SA} \ at \ Stage \ \alpha(=\varepsilon_1)} \quad (4)$$

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Then, the values of **a** was obtained from Eqn.(1) using the value of **x** obtained from Eqn.(4) and the measured values of $\overline{E}_{eq}$ $(=E_{GS})$ and E_B $(=E_{LDT})$ at Stage α. The theoretical relationships between $\overline{h}$ and $d(\overline{\varepsilon}_a)_{SA}$ shown in Fig.2(a) and Fig.2(b) were obtained from Eqn.(3) by using 1) the measured relationship between $\overline{E}_{eq}$ and $d(\overline{\varepsilon}_a)_{SA}$, 2) that between h_B and $d(\varepsilon_{aB})_{SA}$ and 3) the value of h_A at $d(\varepsilon_{aA})_{SA}$ which is equal to the value of h_B at **x** times the measured value of $d(\varepsilon_{aB})_{SA}$. It is seen that the calculated values of $\overline{h}$ fit fairly well the measured values of h_{GS}.

CONCLUSIONS: 1) The bedding error has a discernible influence on the cyclic behavior of triaxial specimen of Toyoura sand, in particular, the increase in the measured damping due to the bedding error is a new finding. And 2) a simple model Eqn.(1) through Eqn.(4) correctly predicted the effect of bedding error on the damping.

REFERRENCES: 1) Teachavorasinskun, S., Lo-Presti, D. C. S., Tatsuoka, F., and Shibuya, S. (1991(a)): "Effect of cyclic prestraining on stiffness of sands I, Testing method," Seisan Kenkyu, Institute of Industrial Sceince, University of Tokyo, Japan (to appear); 2) Teachavorasinskun, S., Lo-Presti, D. C. S., Ishii, Y., and Tatsuoka, F. (1991(b)): "Effect of cyclic prestraining on the stiffness and damping of sands," Proc. of 26th Annual Meeting of JSSMFE, Nagano, July (to appear)

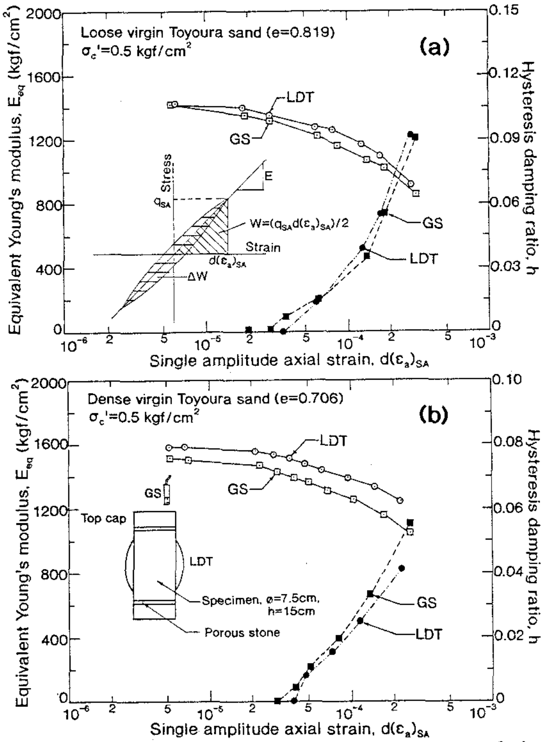

Fig.1(a) and (b) Young's modulus and damping of virgin loose and dense sand

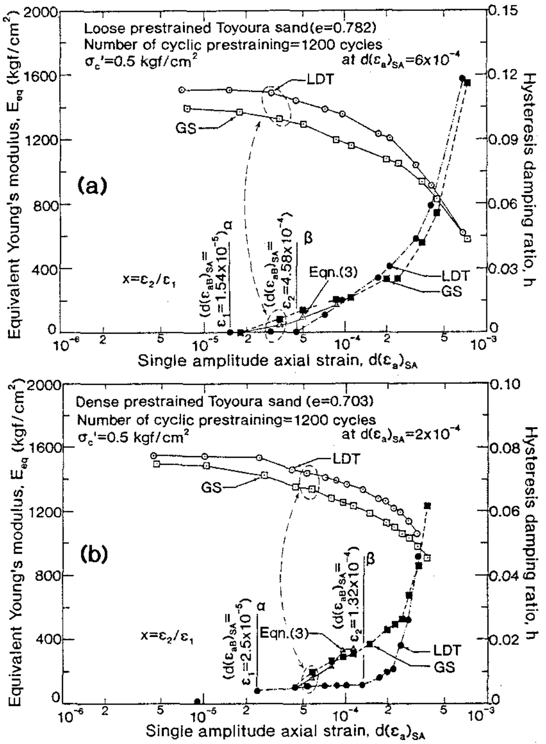

Fig.2(a) and (b) Young's modulus and damping of prestrained loose and dense sand

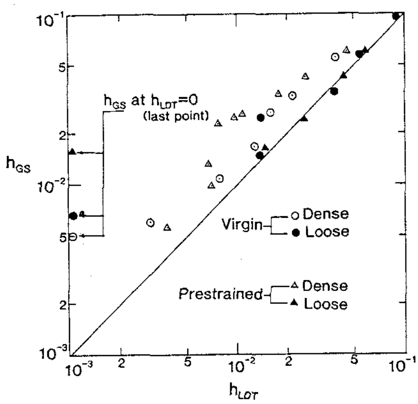

Fig.3 Relationship between h_{GS} and h_{LDT}

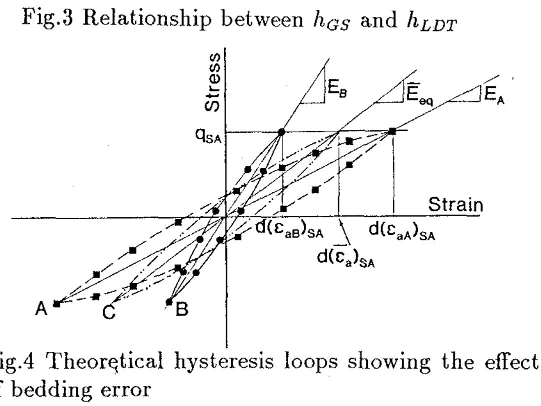

Fig.4 Theoretical hysteresis loops showing the effect of bedding error