III-204 EFFECT OF STRESS HISTORY ON THE STIFFNESS OF SAND IN SIMPLE SHEAR

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INTRODUCTION :Although most sand deposits are considered to be a normally consolidated, there are a large amount of evidence shown that some natural sands exhibit an overconsolidated behaviour. Due to the difficulty in knowing the stress history of in-situ sand deposits, it is important to find out how the stress history has affected the response, espiacially, in the aspect of stiffness. This means that the pattern of reduction in stiffness both of normally consolidated, NC, and overconsolidated, OC, sands should be investigated more in detail. In this paper the stiffness of NC and OC dense Toyoura sand was examined, under drained simple shear conditions, for a range of shear strain between 5×10^{-6} and 10^{-1}.

CONSOLIDATION HISTORY APPILED: Five drained monotonic torsional simple shear tests were performed on Toyoura sand. The datails of the test procedures and the apparatus have been reported by Pradhan et al.(1988) and Teachavorasinskun(1989). These tests can be devided into two groups in terms of the consolidation history. Referring to Fig.1, the first group of three tests were normally consolidated; tests MTS06 and MTS09 along the anisotropic stress path with $K_O=0.52 \times e_{O.O5}$(O-kochi,1984) and test IMS01 along the isotropic stress path (K=1.0). In the second group, the samples were first consolidated along the anisotropic stress path ($k_O=0.52 \times e_{O.O5}$) and then unloaded to the desired overconsolidation ratio, OCR, of two for OMS03 and four for OMS05. The OCR is defined as the ratio of the maximum axial stress ($(\sigma_{am}')_{past}$) experienced to the current axial stress (σ_a'). The unloading path for OC specimens is calculated from an empirical formula shown in Fig.1 (O-kochi, 1984). The initial conditions and some results are summarized in Table 1.

TEST RESULTS: The variation of secant shear modulus, $G_s=\tau_{at}/\gamma_{at}$, for OMS05 is shown in Fig.2, together with the $\tau_{at}\sim\gamma_{at}$ relation when $\gamma_{at}<7\times10^{-6}$. τ_{at} and γ_{at} represent the shear stress and the shear strain in simple shear. It is clear that the linear range appears up to γ_{at} around 7×10^{-6}. As a result of this, the maximum shear modulus of each test is defined as the slope of the $\tau_{at}\sim\gamma_{at}$ relation when $\gamma_{at}<7\times10^{-6}$.

The solid lines in Fig.3 represent the $G_s\sim\log(\gamma_{at})$ relation of the NC specimens while the dashed curves show those of the OC tests. In a comparison between OMS03 and MTS06, the mean effective stress, p', is larger in test OMS03 than in test MTS06. This may contribute to the larger value in the maximum shear modulus, G_O, of test OMS03, though the two tests share the same axial stress, σ_a'. Comparing G_O of tests OMS05 IMS01 and MTS06, the maximum shear modulus is not affected by the stress history(i.e. by OCR) as long as p' and the void ratio are the same. This matches the testing results reported by Iwasaki, Tatsuoka and Yoshida (1977). Fig.4 shows the $G_s/G_O\sim\log(\gamma_{at})$ relationships in which the solid line is the average curve for the NC sand (Teachavorasinskun, 1989). As implied by Fig.3 and 4, the pattern of reduction in stiffness of the sand depends on the stress history. The results indicated that, for the scope of γ_{at} between 7×10^{-6} and 10^{-3}, the OC sand is stiffer than the NC sand.

An examination of the effect of consolidation path on the stiffness can be noticed by comparing the results of tests IMS01 and MTS06 (Fig.3). For NC sand, the effect of pre-shearing is negligible.

CONCLUSIONS: 1) the initial stiffness which defined as G_s at $\gamma_{at}<7\times10^{-6}$ is not affected by the stress history(=OCR) as long as the initial mean effective stress, $p'=(\sigma_a'+2\times\sigma_r')/3$, and the void ratio are the same. 2) The reduction in stiffness is more obvious in NC sand than that in OC sand, however the stiffness curve will merge together again at a larger shear strain level of 10^{-3}. 3) The low dependency of stiffness on the consolidation path was observed for the NC sand.

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REFFERENCE:

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3) Pradhan, T.B.S., Tatsuoka, F., Horii, N. (1988): "Simple shear testing on sand in a torsional shear apparatus," Soils and Foundations, Vol.28, No.2, pp.95-112

4) Teachavorasinskun, S., Shibuya, S., Tatsuoka, F. (1989): "Stiffness of sand in simple shear," Proc. of 24th national convention of JSSMFE in Tokyo, June 1989

Table 1. Summary of results

Test No.	$e_{0.05}$	$K^{1)}$	$OCR^{2)}$	$p'^{3)}$	σ_a'	$G_0^{4)}$
MTS06	0.690	0.36	1.0	0.57	1.0	930.7
MTS09	0.696	0.36	1.0	1.15	2.0	1301.9
IMS01	0.681	1.00	1.0	0.48	0.5	900.0
OMS03	0.702	0.57	2.0	0.71	1.0	1145.5
OMS05	0.695	0.96	4.0	0.48	0.5	873.3

1) $(\sigma_r'/\sigma_a')_{initial}$
2) $(\sigma_a')_{max}/\sigma_a'$
3) $[(\sigma_a'+2\times\sigma_r')/3]_{initial}$
4) (τ_{at}/γ_{at}) at $\gamma_{at}<7\times10^{-6}$

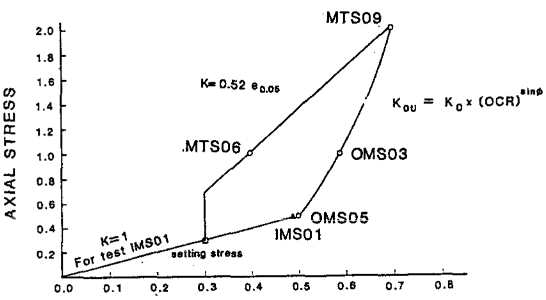

Fig.1 The stress condition before strarting of shear

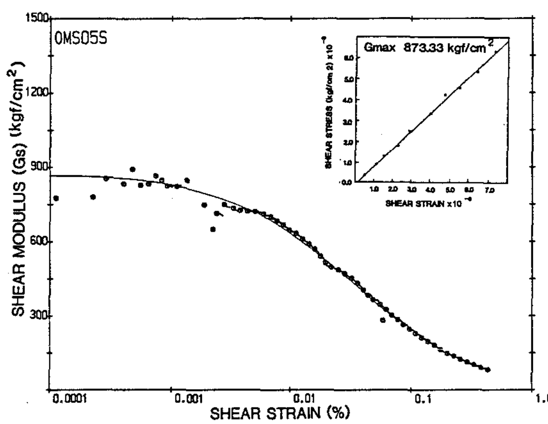

Fig.2 Relationship between Gs vs. shear strain and the definition of Gmax

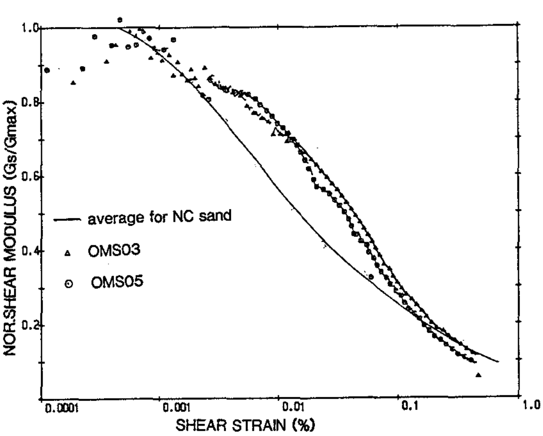

Fig.4 The relation between the normalized stiffness and shear strain

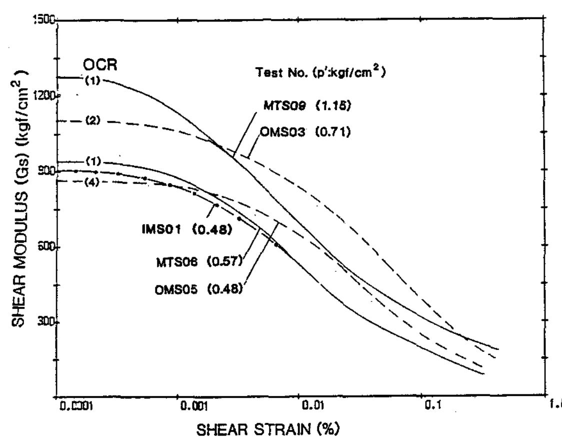

Fig.3 The average stiffness curve
(solid lines:NC sand & dashed lines:OC sand)