III-364 Effect of Cyclic Prestraining on The Stiffness of Sand

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Tests performed: The effect of cyclic prestraining on the deformation modulus of sand was investigated in the torsional shear apparatus. The hollow cylindrical specimens of Sengenyama sand were prepared by so-called 'under-water vibration' method. First, dry sand was spooned through water into the hollow cylindrical molds, then, vibration was applied to the side of the outer mold. The sample was prepared in 4 layers, each of 5 cm thick. The saturated specimens were subjected to monotonic and static cyclic loadings. The systems were the same as those used by Pradhan et al.,1989 and by Kato et al., 1989 for the monotonic and cyclic tests, respectively.

Two dense specimens were consolidated along a K-constant line until the axial stress of 2.0 kgf/cm^2 and the radial stress of 0.75 kgf/cm^2 were attained. These stresses were kept constant during the subsequent shearing stage.

i) Test No.1: The specimen was monotonically sheared until failure (the monotonic loading test on virgin specimen, ML-VS).

ii) Test No.2: This sample was sheared in three stages. It was first cyclically sheared up to a single amplitude shear strain, $d(\gamma_{at})_{SA}$ of about 0.5 %. The shearing procedure was the same as that used by Kato et al., 1989. A total of 15 cycles was applied at each controlled stress amplitude (the cyclic loading test on virgin specimen, CL-VS). Second, the same shearing procedure was re-applied to the specimen (the cyclic loading test on prestrained specimen, CL-PS). Finally, the specimen was monotonically sheared (the monotonic loading test on prestrained specimen, ML-PS).

The initial conditions and some results of these tests are presented in Table 1.

Discussion: The relationships between the shear stress ratio, τ_{at}/σ_a' and the shear strain, γ_{at} (Fig.1(a)) and also between τ_{at} or $d(\tau_{at})_{SA}$ and γ_{at} or $d(\gamma_{at})_{SA}$ are shown in Fig.1(b). The following points may be seen. **(1)** the effect of cyclic prestraining was obvious in that the skeleton curve of the cyclic test (CL-VS) stiffer than the stress-strain curve for ML-VS. This means that Masing's second rule is not valid for the virgin specimens. **(2)** the stress-strain relationship of the ML-PS is stiffer than that of ML-VS. This may be due mostly to the cyclic strain hardening effect that was induced by the previous cyclic loading. In relation to the skeleton curve of the cyclic test (CL-VS), Masing's second rule was applied and the reloading stress-strain curve was calculated. This curve was plotted in Fig.2, and appears to be similar with the prestrained monotonic stress-strain (ML-PS) relationship. This means that Masing's second rule can be applied to cyclically prestrained specimen (but not to virgin specimen). **(3)** Fig.3 shows the relationship between the normalized secant shear modulus, $G_{sec}/f(e)$, and shear strain, γ_{at}, for the monotonic loading tests, or the normalized equivalent shear modulus, $G_{eq}/f(e)$, and the single amplitude shear strain, $d(\gamma_{at})_{SA}$, for the cyclic loading tests. The function *f(e)* accounts for the variations of void ratios from test to test. It shows that the shear modulus obtained from the CL-PS is slightly lower than that obtained from the CL-VS. **(4)** There are negligible differences in the moduli obtained between the two monotonic loading tests on the VS and on the PS at strains less than 0.0001 (before the point A), whereas the difference increases for higher shear strain levels (see also Fig.2). Fig.4 shows the relation between the shear modulus and the number of cycles for the CL-VS. It can be seen that the effect of the number of cyclic loadings on the shear modulus is very small.

Conclusions:

1) For the virgin specimens, the skeleton curve obtained from the cyclic loading test is stiffer than the stress-strain curve of the monotonic loading test.

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2) Due to cyclic straining, the stiffness during the subsequent monotonic loading does not change at $\gamma_{at}<10^{-4}$, while at $\gamma_{at}>10^{-4}$, it becomes larger than that for the virgin specimen. However, cyclic straining does not increase the stiffness for the subsequent cyclic loading.

References:

1) Kato, H., Wakasa, S., Teachavorasinskun, S., Tatsuoka, F., Murata, O., and Tateyama, M.,(1989) "Shear Modulus and Damping of Sand at Low Pressures by Torsional Shear Test," Proc. Jap. Ann. Symp. SMFE.

2) Pradhan, T. B. S.(1989) "The Behavior of Sand Subjected to Monotonic and Cyclic Loadings," Ph.D Thesis, Kyoto University.

Table 1 Summarize of the initial conditions and some results

Test No.	$e_{0.05}$ 1)	e_{CON} 2)	σ_a' 3)	σ_r' 3)	G_{max} 4)	τ_{max} 3)
1	0.670	0.660	2.0	0.75	750	0.71
2	0.611	0.607	2.0	0.75	900	-

1) Void ratio measured at σ_C' = 0.05 kgf/cm²
2) Void ratio measured after consolidation
3) in kgf/cm²
4) $G_{max} = (\tau_{at}/\gamma_{at})_{\gamma_{at}\to 0}$

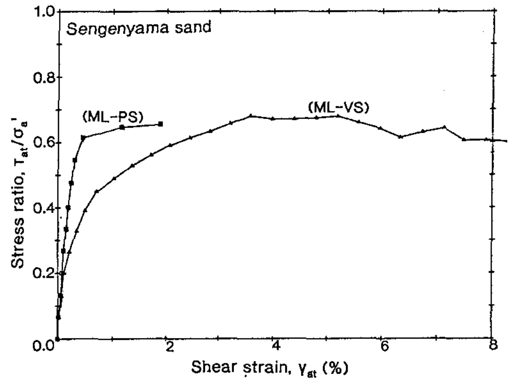

Fig.1(a) Stress ratio and shear strain

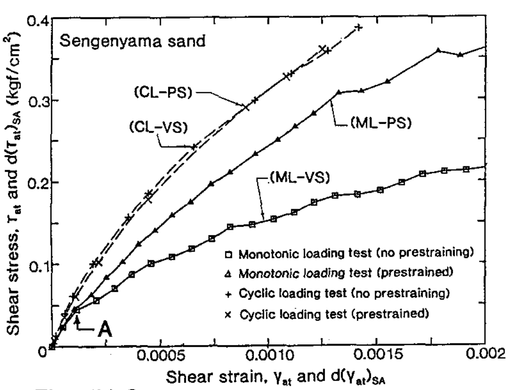

Fig.1(b) Stress-strain relationships of cyclic and monotonic loading tests

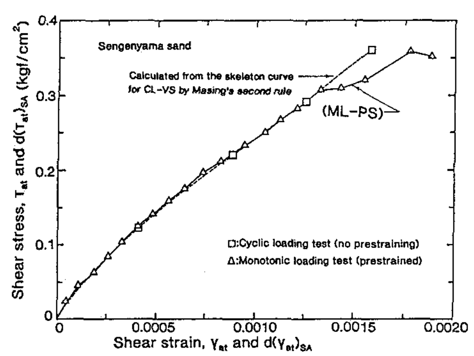

Fig.2 Application of Masing's second rule to the skeleton curve of CL-VS

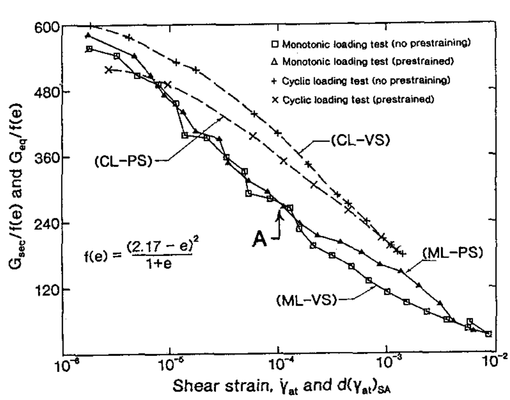

Fig.3 Shear modulus obtained from cyclic and monotonic loading tests

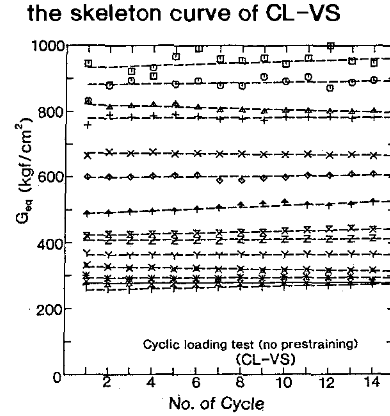

Fig.4 Shear modulus of CL-VS at each cycle