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Effect of Soil Structure on G_{max} of Clays

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Introduction

The stress-strain variation of soil is continuously nonlinear at higher strain levels, but at very small strain of 10^{-3} % or less, shear modulus value is maximum and constant. The role of small strain shear modulus (G_{max}) becomes prominent for cases involving very small strains such as in pre-failure deformation studies and earthquake response studies. In this paper the G_{max} is evaluated by using laboratory bender element method. Assuming elastic behavior at very small strains, this method applies shear wave propagation principle through elastic medium. The equation used is

$$G_{max} = \rho V_s^2 \tag{1}$$

ρ = bulk density, V_s = shear wave velocity.

The study of undisturbed soil is needed to know the in-situ soil behaviour under different loading conditions. It is also equally important to know the behavior when the samples are disturbed and natural soil structure is completely removed by reconstituting. The reconstituted soils are more or less uniform, isotropic and devoid in soil structure attained with aging as in in-situ soils. The property differences between them also infer the amount of change in G_{max} in case of sample disturbance.

Test Method and Soil

In the test, well known Ariake clay from Japan and Louiseville clay from eastern Canada was used. Reconstituted and undisturbed soil specimens of both soils were tested in simple consolidometer cell instrumented with bender elements. Specimen size used was 60 mm diameter and 40 mm in height. The properties of undisturbed clays are shown on the Table 1.

Table 1. Physical properties of the tested clays

Name	w_L (%)	w_P (%)	I_P (%)	w_n (%)	G_s	Sensitivity	OCR	Clay % less than 5 μm
Ariake Clay	100	50	50	150.9	2.62	29	1.1	63
Louiseville Clay	71.4	22.5	48.9	69.7	2.77	18	3.2	65

Micro-structural aspect

The degree of bonding of the natural soil mass is governed by physiochemical interactions and cementation between particles, 3D arrangement of soil particles with void space and geologic processes of formations. In present study, clay properties are also tried to view from the micro-structural aspect. The photographs taken by Scanning Electron Microscope (SEM) for both of the clays are shown in Fig. 1.

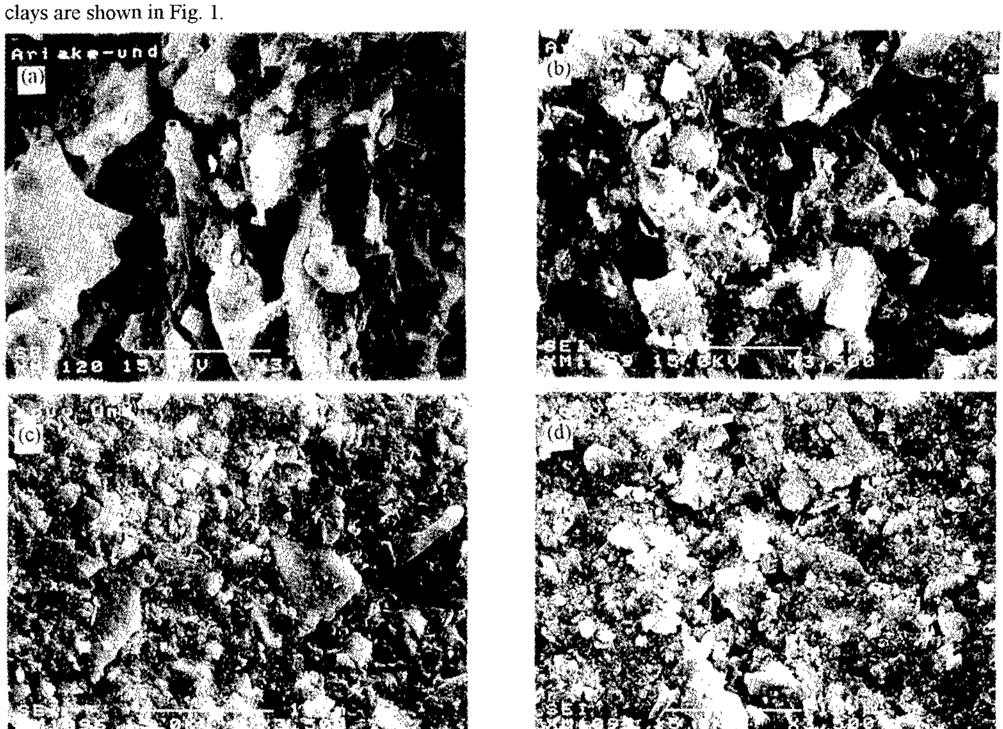

Fig. 1 SEM Image of (a) Undisturbed Ariake Clay (b) Remolded Ariake Clay (c) Undisturbed Louiseville Clay (d) Remolded Louiseville Clay

To prepare the remolded sample for SEM viewing, soil was thoroughly hand mixed to disturb the soil structure, if any. Looking on Ariake soil microstructure, the soil particles, which are mostly flaky and elongated, seem to be crushed and turned to relatively denser state after remolding. Microfossils are abundantly found and might have affected the Ariake clay behavior. Whereas for the Louiseville clay, as the soil particles are very small, little crushing is seen but the soil mass is loosened. The loss in strength in remolding might however be explained as the result of breaking of existing bonds between particles.

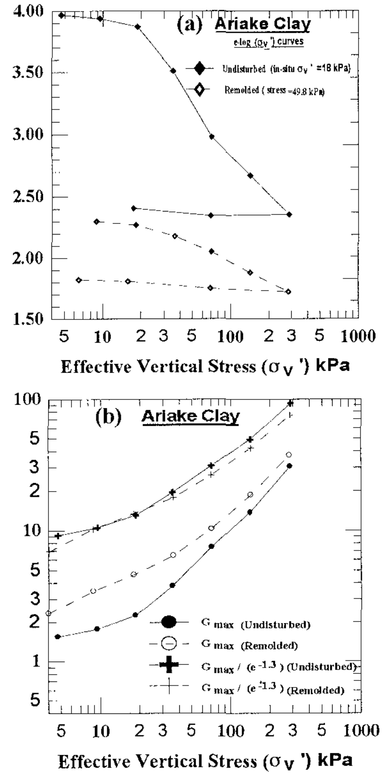

Fig. 2 Ariake Clay (a) e-log σ_v' curve (b) G_{max} and $G_{max}/e^{-1.3}$ variation.

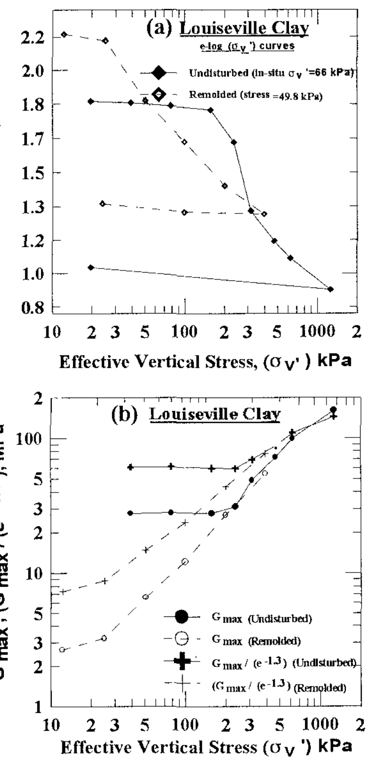

Fig. 3 Louiseville Clay (a) e-log σ_v' curve (b) G_{max} and $G_{max}/e^{-1.3}$ variation.

Test Results and Discussions

The results of one-dimensional consolidation of the clays are shown in Fig. 2 and Fig 3.

As G_{max} values are primarily dependent on void ratio (e) and effective stress, it is necessary to normalize with e to see the stress effect. The void ratio function $f(e) = e^{-1.3}$, as in Jamiolkowski et al. (1995) is used for the interpretation using equation (2) below, so any effect due this function is included in the interpretation.

$G_{max} = S_{vh}\, f(e)\, \sigma_v'^{\,n}$ (2)

where, S_{vh} is material constant showing the effect of in-situ soil structure and n is modulus exponent.

The plots show that during recompression stage of loading, the G_{max} for undisturbed soils increase by very small amount with effective vertical stress (σ_v'). Those values are very high in comparison to those for reconstituted condition as is very clear in Fig 3 (b). At normally consolidated condition (NC), $G_{max}/f(e)$ - σ_v' plot for reconstituted and undisturbed case very similar for both clays with undisturbed one on slightly higher side. This infers that the stress level dependency of both remolded and undisturbed soil is similar in NC portion. The important point to be noted here is that these results are from the soils with very different void ratios. The e-log (σ_v') curves of undisturbed soils show higher slope immediately after the preconsolidation pressure and decreases at large stress. The higher slope mentioned above might be due to the various factors causing apparent increase in overconsolidation with aging (Schmertmann, 1991).

Conclusion

The G_{max} at NC condition of the undisturbed sensitive soils, as used in the tests, can very well be represented by laboratory reconstituted soil with little margin of error. The difference in G_{max} is very high prior to preconsolidation stress, so those values may not be extrapolated from the reconstituted as well as disturbed samples. This higher G_{max} value is the combined effect of soil structure and overconsolidation of soil. The modulus exponent n (Eq. 2) obtained is 0.70 and 0.71 for Ariake clay and 0.78 and 0.61 for Louiseville clay in reconstituted and undisturbed condition respectively. The above result clearly shows that n value is not always 0.50, considered ordinarily. The same conclusion with n value of 0.60 was obtained by Lohani in his previous research on Bangkok Clay and the variation range of n from 0.40 to 0.68 is mentioned by Shibuya et al. (1997) too. Further studies with sufficient number of tests and on various clays are needed for drawing more general conclusion.

References

1. Jamiolkowski M., Lancellotta, R. and Lo Presti, D.C.F., 1995. Remarks on the Stiffness at Small Strains of Six Italian Clays. *IS-Hokkaido-1994. Prefailure Deformation of Geomaterials, Balkema.* Vol. 2, pp 817-836.
2. Schmertmann J. H., 1991. The Mechanical Aging of Soils. *Journal of Geotechnical Engineering Division* vol.-117, no-9, pp 1288-1330.
3. Shibuya S., Hwang S.C. and Mitachi T., 1997. Elastic Shear Modulus of Clays from Shear Wave Velocity Measurement. *Geotechnique 47.* no. 3, pp 596-601.