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Elastic Properties of Undisturbed Clayey Gravel Subjected to Monotonic Loading

Balakrishnaiyer Kandasamyiyer, University of Tokyo.
Junichi Koseki, IIS, University of Tokyo.

Introduction: The elastic properties at small strain level and the overall stress strain behavior of clayey gravel were studied by large scale triaxial tests with undisturbed samples[1] subjected to monotonic loading. The change in elastic properties with stress level was found significant, especially a reduction of Young's modulus at high stress level possibly due to damage to the soil structure.

Test Procedure: Two series of drained triaxial compression tests using the automated large scale triaxial testing apparatus were performed as summarized in Table 1, on cylindrical samples of dimension 60cm in height and 30cm in diameter. In the first series of tests[1], both the isotropic consolidation and the triaxial compression were performed with monotonic loading whereas large cyclic loading was applied in the second series of tests[2]. The results of first series and the initial loading behavior of the second series were considered in this paper. In both series of tests small vertical cyclic loading was applied at various stress levels in order to evaluate the equivalent elastic Young's modulus Eeq, as typically shown in Fig.1.

Table 1: initial condition of samples & stress paths applied

test series	depth & sample No.	grading (gravel/ sand/clay) in %, initial void ratio, e_o, water content w (%)	isotropic consolidation stress path	shearing stress path
			$\sigma_h = \sigma_v$ (kgf/cm^2)	q (=σ_v-σ_h) (kgf/cm^2)
1st series	5m-No.1	65 / 25 /10 e_o = 0.346 ; w = 10.9	0.5	0 to 3.5
	5m-No.2	65 / 24 / 11 e_o = 0.327 ; w = 10.4	0.5 to 1.0	0 to 5.5
	5m-No.3	63 / 25 /12 e_o = 0.342 ; w = 11.2	0.5 to 2.0	0 to 6.2
	5m-No.4	57 / 29 / 14 e_o = 0.347 ; w = 11.5	0.5 to 5.0	0 to 6.0
	10m-No.1	68 / 25 / 7 e_o = 0.285 ; w = 9.7	0.5 to 4.0	0 to 11.0
	10m-No.2	69 / 23 / 8 e_o = 0.379 ; w = 10.1	0.5	0 to 3.3
	10m-No.3	67 / 26 / 7 e_o = 0.378 ; w = 10.6	0.5 to 1.0	0 to 5.1
	10m-No.4	56 / 36 / 8 e_o = 0.361 ; w = 10.6	0.5 to 5.0	0 to 11.7
	10m-No.6	65 / 28 / 7 e_o = 0.365 ; w = 10.6	0.5 to 2.0	0 to 6.4
2nd series	5m-No.5 /case1	65 / 25 / 10 e_o = 0.372 ; w = 10.7	0.4 to 2.0 (initial loading)	0 to 2.5 (initial loading) σ_h=2.0; q_{pk}=8.2
	5m-No.6 /case2	52 / 25 / 23 e_o = 0.408 ; w = 9.5	0.4 to 7.0 (initial loading)	——
	10m-No.5 /case3	68 / 20 / 12 e_o = 0.333 ; w = 8.2	0.5 to 7.0 (initial loading)	0 to 5.0 (initial loading) σ_h=5.0; q_{pk}=21.1

Test Results & Discussion: The Eeq values, evaluated from small cyclic loading, were corrected[3] for a single amplitude axial strain ($d\varepsilon_{SA}$) of 10^{-5} and then normalized by void ratio function $f(e)=(2.17-e)^2/(1-e)$, where e is the current void ratio. The normalized corrected equivalent elastic Young's modulus (Eeq_C) was assumed as a function of the corresponding vertical stress applied (σ_V) as follows;

$$Eeq_C/f(e) = E_O * (\sigma_V / \sigma_O)^m \quad \text{................(1)}$$

where E_O & m are independent of the current stress level and σ_O is a reference stress(=1 kgf/cm^2). During isotropic consolidation, the $Eeq_C \sim \sigma_V$ plot on log-log scale (Fig.2), almost agree with the assumed relation(Eq.1), except at high stress level showing no increase in Eeq_C. A tendency of higher m values for smaller E_O values was also observed as shown in Fig. 3. During shearing, with increasing σ_V, most of the cases show a reduction in elastic property, possibly due to the damage of the soil structure(Fig.4).

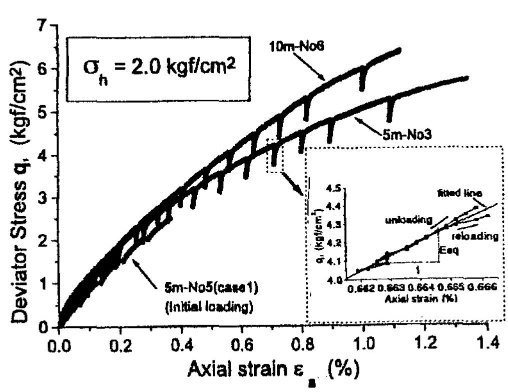

Fig.1: Typical stress ~ strain relationship for 3 cases

Key words : Gravel, Elasticity, Triaxial Compression, Soil Structure Damage

Institute of Industrial Science, 7-22-1, Roppongi,Minato-Ku,Tokyo 106. Tel: 03-3402-6231;Fax: 03-3479-0261

Higher degree of damage was noticed in the cases with high confining pressure possibly due to the difference in the degree of overconsolidation. The stress level for each case where the initialization of damage to elastic property could be observed, as the reduction of Eeq_C values, either during isotropic consolidation or during shearing was plotted, on the $q(=\sigma_v-\sigma_h)$ Vs $p'(=(\sigma_v+2\sigma_h)/3)$ plane. A reasonable circular/parabolic curve, which could be considered as the damage boundary for vertical Young's modulus, was obtained as shown in Fig.5. The maximum deviator stress q_{max} ~p' plot, which shows the shear failure envelop, was also added to Fig.5 in order to study the damage boundary pattern more clearly. Though the sampling depth, grading of material and the initial void ratio etc., were not the same in all cases, their independent effects on the Eeq_C values were not very clear.

Conclusion: 1) During isotropic consolidation the vertical Eeq_C can be assumed as a unique function of stress level, as given in Eq.1, except at high stress level. 2) During shearing there is a reduction in Eeq_C values due to soil structure damage, especially at high stress level. 3) The damage boundary for vertical Young's modulus was obtained as shown in Fig.5, for this undisturbed clayey gravel.

References: 1) Yukawa, Y. et.al., (1996), "Deformation Properties of Clayey Gravel by Triaxial Compression Test Part 1", The 51st annual meeting of JSCE (in Japanese). 2) Balakrishnaiyer, K. and Koseki, J., (1997) "Elastic Properties of Undisturbed Clayey Gravel Subjected to Large Cyclic Loading", The 32nd annual conference of JGS. 3) Jiang, G., (1996), "Small Strain Behavior and Deformation and Strength Characteristics of Gravel by Large Triaxial Tests", Doctoral Thesis, University of Tokyo (in Japanese).

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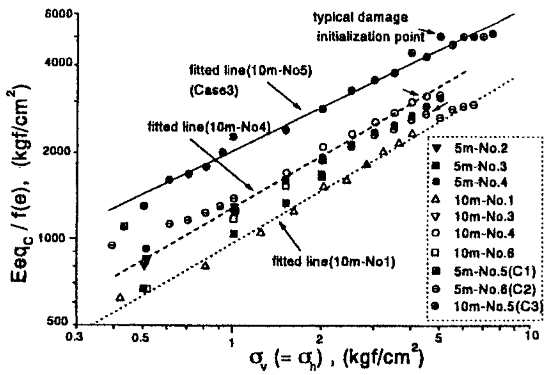

Fig.2: $Eeq_C \sim \sigma_v(=\sigma_h)$ relationship for isotropic consolidation

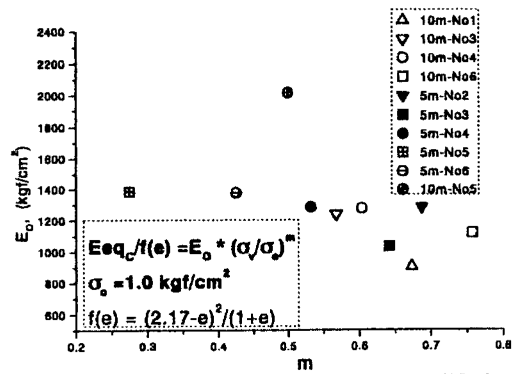

Fig.3: $E_0 \sim m$ variation during isotropic consolidation

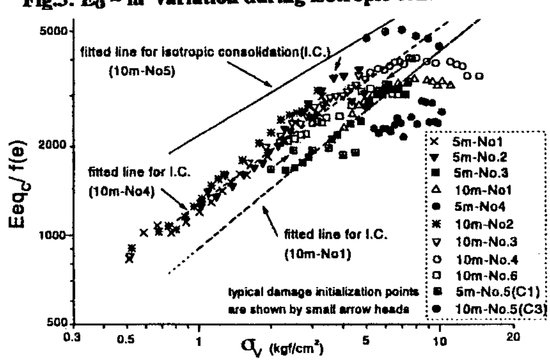

Fig.4: $Eeq_C \sim \sigma_v$ relationship during shearing

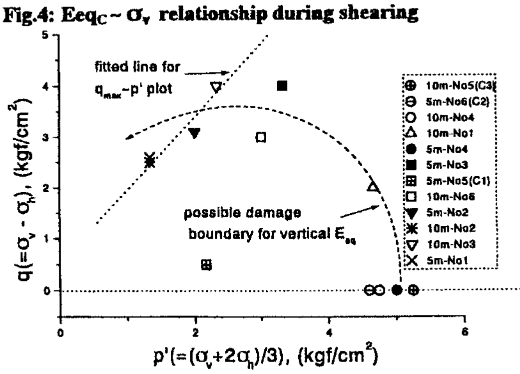

Fig.5: q ~ p' relationship for the initialization of structure damage