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Discussion on the state parameter for gravel

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Introduction: The previous study on dense gravels (AnhDan et al., 1999) showed that even when the gravel is continuously yielding, all strain components that occur between two stress states are noticeably stress history-dependent. Therefore, none of them is suitable to be used as the stress history-independent hardening parameter. One type of energy function that is shown below is the state parameter for gravel, which is unique for a given stress state.

Theory background:

Irreversible strain increments can be obtained as:

$$d\varepsilon^{ir} = d\varepsilon - d\varepsilon^{e}$$

where $d\varepsilon$ is the total strain increment and $d\varepsilon^{e}$ is the elastic strain increment. The elastic strain increments can be obtained based on the anisotropic hypo-elasticity model proposed by Tatsuoka and Kohata, 1995 as:

$$d\varepsilon_v^e = \frac{d\sigma_v}{E_v} - 2\nu_{hv}\frac{d\sigma_h}{E_h} \qquad d\varepsilon_h^e = \frac{(1-\nu_{hh})d\sigma_h}{E_h} - \nu_{vh}\frac{d\sigma_v}{E_v}$$

where $E_v = E_{v0}(\frac{\sigma_v}{\sigma_0})^m \quad E_h = E_{h0}(\frac{\sigma_h}{\sigma_0})^m \quad \nu_{vh} = \nu_0(\frac{\sigma_v}{\sigma_h})^{m/2} \quad \nu_{hv} = \nu_0(\frac{\sigma_h}{\sigma_v})^{m/2}$

When based on the model described above, the elastic strain energy between two stress points is stress history-independent (Puzrin and Tatsuoka, 1998). Consequently, the stress history-dependency of the total energy W, if it exists, is solely due to the stress history-dependency of irreversible energy W^{ir}.

Test results:

The irreversible energies $W^{ir} = \int(\sigma_1 * d\varepsilon^{ir}_1 + 2\sigma_3 * d\varepsilon^{ir}_3)$ under triaxial compression conditions were calculated for the results of isotropically and anisotropically consolidated monotonic loading tests as reported in detail by AnhDan et al., 1999. The stress paths in these tests are shown in Fig. 1. A crushed sandstone was used (Chiba gravel with D_{50}=8mm, D_{max}=40mm). The density of the triaxial specimens (60cm high times 23cm*23cm in cross-section) ranged from 2.23g/cm^3 to 2.28 g/cm^3. Values of W^{ir}, defined as zero at state S (Fig. 1), are plotted against the effective mean principal stress p' for two series of tests in Figs. 2 and 3. For

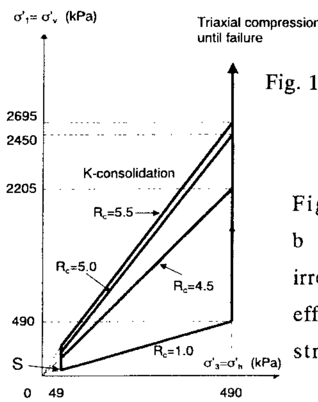

Fig. 1: Stress paths

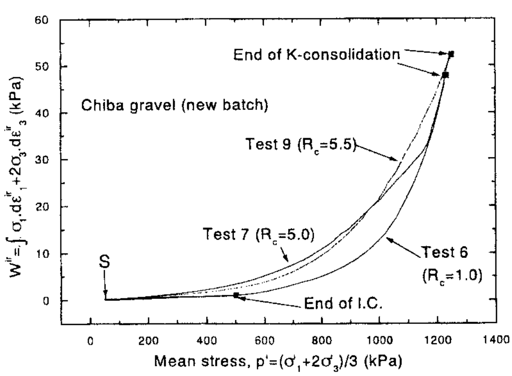

Fig. 2: Relationships between irreversible energies and effective mean principle stress (for new batch)

Keywords: Gravel, stress history-independent, energy function

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different stress paths, the values of W^{ir} are nearly the same for the same stress states, but not for different stress states with the same p'. Poorooshasb et al. (1967) suggested that yield loci for sand were of constant stress ratio $q/p'=\eta=constant$. As this yield locus cannot explain the yielding during K-consolidation with constant value of $R_c=1/K=\frac{\sigma_v}{\sigma_h}$, a modified form of yield function, $\eta+r*ln(p'/p_a)=constant$, was also proposed also by Poorooshasb (1971), where r is a material parameter and p_a is the reference stress set equal to 98kPa in the present study. We found that the relationships between W^{ir} and $\eta+r*ln(p'/p_a)$ for different stress paths nearly overlap with r=1.1 for a new batch and r=1 for the old batch, giving a unique relationship irrespective of different stress paths (Figs. 4 and 5). It is quite possible that the value of r is different for different batches of soils. This paper only suggests an existence of a suitable state parameter that is stress history-independent. However, the plastic potential functions for shear and volumetric yielding will have to be established to make use of it.

Conclusion: The energy function may be used as the stress history-independent hardening parameter in elasto-plastic models, that is a function of the stress parameter $\eta+r*ln(p'/p_a)$.

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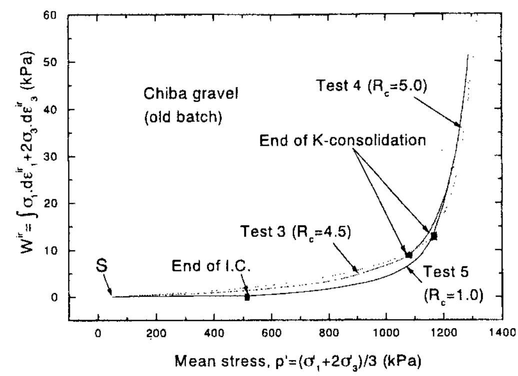

Fig. 3: Relationships between irreversible energies and effective mean principle stress (for old batch)

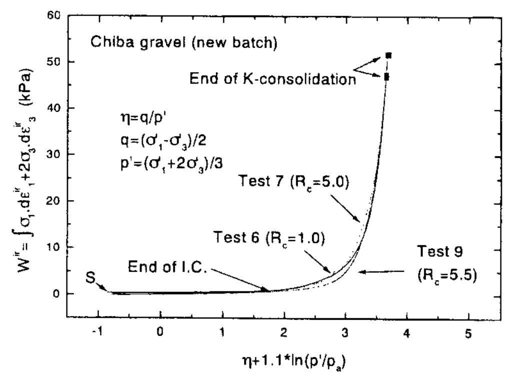

Fig. 4: Relationships between irreversible energies and stress parameters $\eta+r*ln(p'/p_a)$ (for new batch)

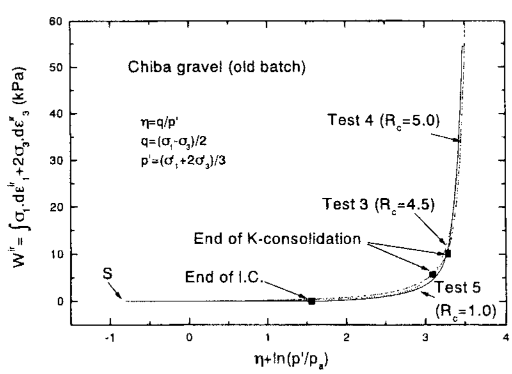

Fig. 5: Relationships between irreversible energies and stress parameters $\eta+r*ln(p'/p_a)$ (for old batch)