(Ⅲ－8)　　　　　塑性コンクリートに適する一つの損傷モデル

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INTRODUCTION

Plastic concrete is composed of cement, water, clay, sand, gravel and bentonite etc.. It has advantages over common concrete in building cutoff wall under earth-rockfill dams. Its main mechanical properties are: as the confining pressure increases, the strength and the strain at peak stress increase tremendously; the stress-strain relations change from strain-softening to strain-hardening and the volumetric strain changes from dilatation to contraction, but the initial modulus changes little. Based on the previous study on the mechanical properties of plastic concrete, a damage model for plastic concrete is constituted using the unified form with one set of parameters in the frame of the continuous damage theory.

CONSTITUTION OF THE DAMAGE MODEL

The basic assumptions are: (1) the strength of plastic concrete is composed of the structural strength and the frictional resistance strength, and both of them satisfy the Mohr-Coulomb strength criterion; (2) the stress-strain relations of the both parts are hyperbolic. Whereas the damage variable is defined as the ratio of the area bearing frictional resistance stress to the total area of a certain surface.

From the above assumptions, we can get

$$\sigma_{ij} = (1-r)\sigma_{ij}^s + r\sigma_{ij}^f,\ \ d\sigma_{ij} = (1-r)d\sigma_{ij}^s + rd\sigma_{ij}^f + (\sigma_{ij}^f - \sigma_{ij}^s)dr \quad (1)$$

where σ, σ^s and σ^f are the total stress tensor, structural stress tensor and frictional resistance stress tensor, respectively.

It can also be derived that the tangent moduli of the both parts are,

$$E_t^s = \left\{1-[(1-\sin\phi^s)(\sigma_1-\sigma_3)^s]/(2c^s\cos\phi^s + 2\sigma_3^s\sin\phi^s)\right\}^2 E_{i0},$$

$$E_t^f = \left\{1-[(1-\sin\phi^f)(\sigma_1-\sigma_3)^f]/(2c^f\cos\phi^f + 2\sigma_3^f\sin\phi^f)\right\}^2 E_{i0} \quad (2)$$

where ς and ϕ_s, c_f and ϕ_f are the parameters of the Mohr-Coulomb strength criterion, E_t^s and E_t^f are the tangent modulus for the structural part and the frictional resistance part, respectively, and E_{i0} is the initial tangent modulus.

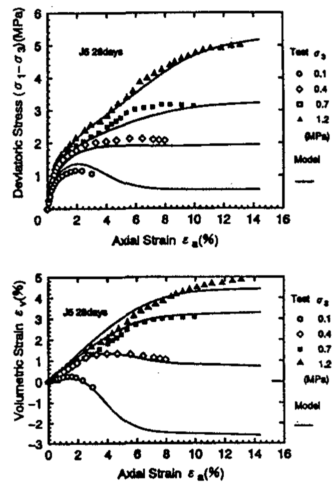

Fig.1 Fitting and test curves of $(\sigma_1\text{-}\sigma_3)\sim\varepsilon_a$ and $\varepsilon_v\sim\varepsilon_a$

The Poisson's ratio of plastic concrete has such features: (1) the higher the lateral pressure, the less the initial Poisson's ratio; (2)along with the increase of lateral pressure, the volumetric strain changes from dilatation to contraction; (3) the volumetric strain will not change(μ=0.5) after a certain large shear strain. In this paper, we adopt the hypothesis of strain equivalence. Therefore, the Poisson's ratios of the structural part, the frictional resistance part and the total sample are the same. On the basis of the above-mentioned features, the following equation is constructed to express the Poisson's ratio,

$$\mu = \mu_0/[(\sigma_3/P_a)^{n_1}(1-r)] + r(1-r)/[a_1 + a_2(\sigma_3/P_a)^{n_2}] + 0.5r \quad (3)$$

where μ_0, n_1, n_2, a_1 and a_2 are the material parameters.

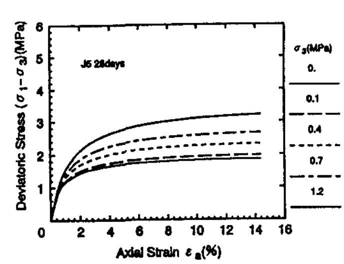

Fig.2(a) Stress-strain curves of the structure parts

The damage variable is expressed as,

$$r = 1 - \exp(-\eta_1 \bar{\varepsilon}^{\eta_2} \xi) \quad (4)$$

where $\xi = q^s / p^s$, q^s is the octahedral shear stress and p^s is the mean stress of the structural part. $\bar{\varepsilon}$ is the octahedral shear strain, and η_1, η_2 are the material parameters.

The relation between $d\sigma_{ij}$ and $d\varepsilon_{kl}$ is,

$$d\sigma_{ij} = D_{ijkl} d\varepsilon_{kl} \quad (5)$$

where D_{ijkl} is the stiffness tensor of the typical element in the sample which is expressed as,

$$D_{ijkl} = (1-r)D^s_{ijkl} + C_2 R_{ij} L_{mn} D^s_{mnkl} + rD^f_{ijkl} + C_1 R_{ij} T_{kl} \quad (6)$$

where D^s_{ijkl} and D^f_{ijkl} are the stiffness tensor of the structural part and the frictional resistance part, respectively. $e_{ij} = \varepsilon_{ij} - \delta_{ij}\varepsilon_v / 3$, $C_2 = \eta_1 (1-r)\bar{\varepsilon}^{\eta_2}$, $C_1 = \eta_1 (1-r)\eta_2 \bar{\varepsilon}^{\eta_2 - 1}\xi, L_{ij} = (1/p^s)^2 [(3/2)(p^s/q^s) - q^s \delta_{ij}/3]$.

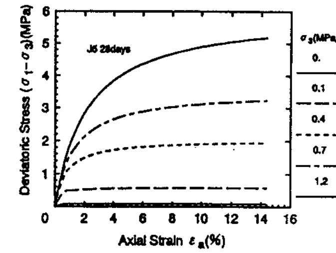

Fig.2(b) Stress-strain curves of the friction resistance parts

REFLECTION OF THE MODEL TO THE MECHANICAL PROPERTIES

The comparison between the fitting and test curves of curves of (σ_1-σ_3)~ε_a and ε_v~ε_a (sample J5, E_i=270MPa, c^s=0.65MPa, ϕ^s=22.9°, c^f=0.02MPa, $\phi^f = 45.3°$, $\mu_0 = 0.39$, n1=0.36, a_1=0.55, $a_2 = 0.55$, n_2=4.2, η_1=350, η_2=2.2)is shown in Fig.1.

Fig.2(a)(b) show the stress-strain curves of the structure part and the friction resistance part when they are mobilized individually. When the deformation is relatively small, the structural stress is dominant, but in the residual stage, all the total stress is carried by the frictional resistance stress. Such stress transformation is shown in Figs.3, and the evolution of damage variable is shown in Fig.4.

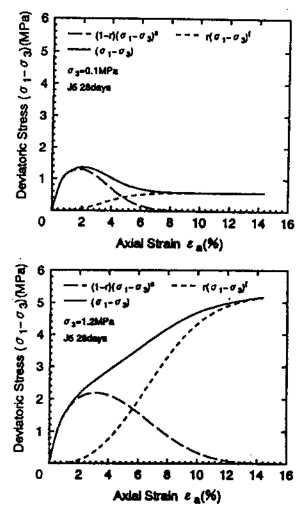

Fig.3 Decomposition of the stress

When the confining pressure is low(e.g. σ_3=0.1Mpa), the strength of the frictional resistance part is much lower than that of the structural part and in the process of deformation the frictional resistance stress is lower than the structural stress. Along with the evolution of damage, the value of $[(\sigma^s_{ij} - \sigma^f_{ij})dr]$ is negative. When $(1-r)(\sigma_1 - \sigma_3)^s$ reaches its peak value, the total stress strain curve begins to show strain softening. On the other hand, when the confining pressure is high(e.g. σ_3=1.2Mpa), the value of $[(\sigma^s_{ij} - \sigma^f_{ij})dr]$ is positive and the total stress strain curve will not show strain softening.

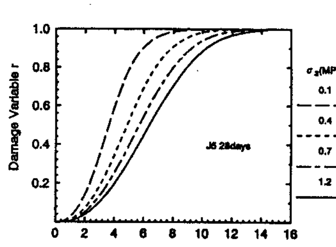

Fig.4 The evolution of the damage variable r

In Eq.(3), μ_0 represents the initial Poisson's ratio at $\sigma_3 = P_a$ (0.1MPa) and n_1 reflects the change of the initial Poisson's ratio with the confining pressure. a_1, a_2 and n_2 reflect the change of the Poisson's ratio with the confining pressure in the process of the progressive damage. The change of the Poisson's ratio for sample J5 during the process of loading is shown in Fig.5 and the corresponding volumetric strain curves are shown in Fig.1. It can be seen that Eq.(3) can reflect the effect that the volumetric strain curves change from dilatation to contraction as the confining pressure increases.

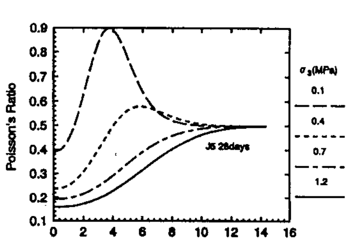

Fig.5 Transition of the Poisson's ratio