AN ELASTOPLASTIC BOUNDING SURFACE MODEL FOR FIBROUS FINE-GRAINED SOILS

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Composite soils such as municipal solid wastes (MSW) and peats (organic soils) are mixtures of various materials with different properties. Their behaviour, as a whole, is affected by volume fraction and mechanical properties of each component separately. In general, these soils consist of two phases: “matrix phase” comprised of soil-kind maerials and “fiber phase” which are one-dimensional materials dispersed randomly in the matrix phase. As an important portion of composite soils, organic matters can be found in abundance in nature. With respect to the constituent materials and creation process, these soils have large void ratios and under loading experience large irreversible deformations. Hence, slope stability analysis for landfill of these soils, especially MSWs, has to be performed cautiously for environmental issues.

In this study, mechanical response of composite soils is simulated by assuming two individual phases: matrix and fiber. For each phase, an appropriate constitutive model is used. An anisotropic elastoplastic bounding surface model is used for matrix phase that could capture the nonlinearity and cumulative plastic strains in loading-unloading-reloading stress paths. The bounding surface expresses as Eq. 1 in general stress state space.

$$F = \frac{3}{2} \times \left(\sigma_{ij} - (1+\alpha_{ij})p'\right).\left(\sigma_{ij} - (1+\alpha_{ij})p'\right) - \left(M^2 - \left(\frac{3}{2}\alpha_{ij}.\alpha_{ij}\right)\right) \times (p' - p'_m)p' = 0 \quad (1)$$

where σ_{ij} is stress tensor, α_{ij} is fabric tensor that measure the anisotropy of soil, M is critical state value, p' is mean stress and p'_m defines the size of bounding surface.

Furthermore, an elastic semi-hardening Von-Mises type model is coded for fiber phase. The semi-hardening rule in this model governs the increments of elastic modulus with increase of confined pressure from unconfined state due to anchoring phenomena.

$$E = E_u + a_f \sigma_3 \quad (2)$$

where E_u is unconfined elastic modulus and σ_3 is confined pressure.

For mathematical and computational simplification, the developed model assumes that the fibers are continuous and aligned in 2-axis direction as shown in Figure 1. Acting strain or stress increments on the soil element must be decomposed into two separate increments for each phase by using volume averaging technique.

$$d\epsilon_i = A_i \times d\epsilon_0 \,; \quad i = f, m \quad (3)$$

where $d\epsilon_0$ is overall strain increments that soil element, as whole, has experienced; A_i is decomposition tensor for matrix (m) or fiber (f), and $d\epsilon_i$ is strain increments that decomposed into each phase (m or f). This technique was used for analysing metal-matrix with continuous elastic fibers by Dvorak and Bahei-El-Din (1982).

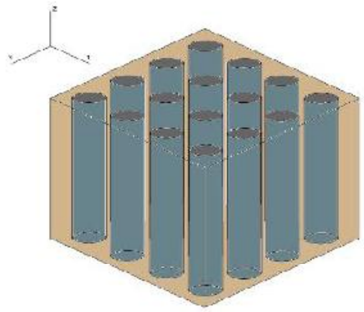

Figure 1. Continuous aligned fibers in a composite soil element

As illustrated in Figure 2, the model shows an appropriate approximation of experimental MSW behaviour in the triaxial compression tests in various confining pressure. The experimental results have been reported from Machado et al. (2002). As semi-hardening parameter of fibers, a_f, is associated with confining pressure which increases with this parameter.

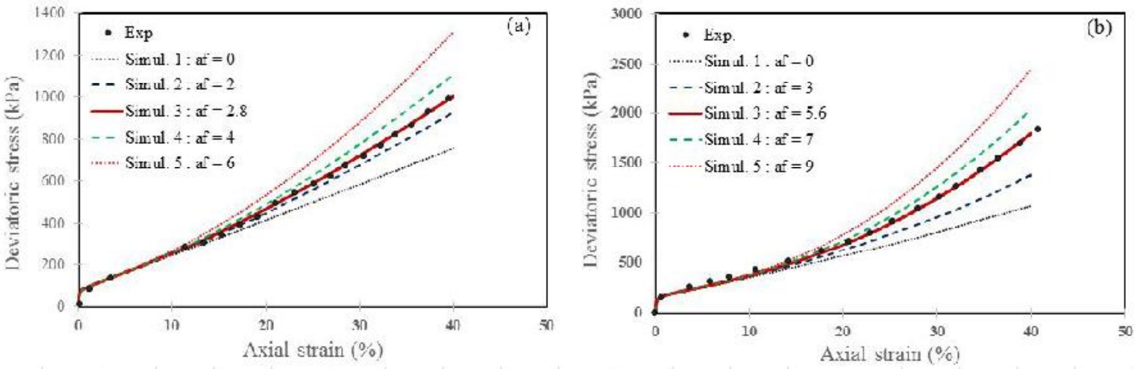

Figure 2. Comparison of experimental stress-strain behaviour with the numerical results with variations of model response due to changes of a_f; (a) $p'_m = 200\ kPa$,(b) $p'_m = 400\ kPa$

Assuming fibers as aligned continuous elements is in contradiction with texture of composite soils in the nature. Therefore, this simplification probably makes an over-estimation of the response of soil element. To overcome this problem, modifications due to discontinuity, miss-orientation and debounding of fibers from matrix, have been applied on the model by introducing equivalent elastic modulus for fiber phase. This study proposes a hybrid constitutive model for direct simulation of composite soils.

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