A CONSTITUTIVE MODEL FOR FIBER-REINFORCED SOILS

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ABSTRACT

Fiber inclusion to improve the properties of compacted soil is becoming increasingly common in geotechnical engineering projects. However, the technique requires extensive testing on soil and fiber samples before it can be implemented. Although research performed over the last few decades has evaluated certain fiber-reinforced soil properties and formations, the development of constitutive models for fiber-reinforced soil has lagged. This dissertation aims to minimize testing requirements for fiber-reinforced specimens and thereby to encourage the implementation of fiber-reinforced soils in engineering.

Extensive testing on unreinforced and reinforced silty and Ottawa sand specimens was performed to develop and to validate a constitutive model for predicting the stress-strain-volume-pore pressure response of fiber-reinforced soils. Results showed that the effective friction angle and cohesion intercept increased significantly in consolidated-undrained ($\overline{CU}$) and consolidated-drained (CD) triaxial compression tests for both fiber-reinforced silty sand and Ottawa sand. The shear strength parameters of fiber-reinforced silty sand and Ottawa sand are strain dependent so more shear strain was needed to mobilize fiber resistance for specimens consolidated at higher effective stresses. Moreover, the laboratory results suggested that fiber-reinforcement provides both a deviatoric (q_f) and a hydrostatic (p_f) contribution to the stresses in the specimens.

However, the hydrostatic contribution of fibers varied according to different soil types and loading conditions.

The proposed constitutive model to predict the mechanical properties of fiber-reinforced soils is based on superposition of the response of unreinforced soil and the response due to fibers. Key assumptions in the model include: (1) fibers are uniformly distributed in the specimens. (2) f_{mob} accounts for the reductions in fiber strain due to relative slip between the fibers and the soil, and varies with effective consolidation stress, soil types, and loading conditions, (3) yielding is considered, (4) shear distortion (θ) is equal to triaxial shear strain (ε_q), (5) the total axial strain in the fibers (ε_t) is equal to 0.25 times axial strain plus 1.68 times volumetric strain from tests on unreinforced specimens, and (6) the initial p_{f0} and q_{f0} are used to account for the compaction, extrusion, and consolidation process.

The model was found to be capable of reproducing the deviatoric stress well for all reinforced silty sand and Ottawa sand. The predicted pore pressure and volumetric strain were all in a close agreement with the observed behavior up to large strains for both soils. However, the predicted volumetric strain behavior shows some tendency to over-predict the dilatancy of the reinforced silty sand specimens consolidated less than 20-psi (140-kPa). The predictions in fiber deviatoric and hydrostatic stresses in $\overline{CU}$ tests matched reasonably well and followed the same trends as the measured behavior, except for specimens consolidated at higher effective stresses. In CD tests, the deviatoric and hydrostatic stresses matched reasonably well and mimicked the measured behavior, but tended to deviate slightly from the observed response at large strains.