Numerical Modeling of Earthquake-induced Permanent Deformations in Saturated Granular Soils

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ABSTRACT

Analysis of earthquake-induced permanent deformations in saturated soils is of great interest in computational geomechanics. Over the past two decades, significant progress has been reported on this subject. Many researchers have developed various computational techniques using advanced constitutive models for soil. Among the available methods, the fully-coupled "effective stress based" approach seems to be most versatile and has attracted more attention in recent years. The main components of this approach are a constitutive model for representing the stress-strain behavior of soil skeleton and a suitable means for coupling the pore water flow with the response of soil skeleton. The former is the subject of continuous developments, while the latter is based on a generalized form of Darcy's law for pore water flow in association with the equations of motion for the bulk of soil. Despite the significant progress in development of constitutive models for soils and the advances in numerical techniques for solution of the coupled equations of motion, an accurate estimation of permanent deformations in saturated granular soils that are subjected to severe shaking requires particular attention to a number of subtle features in the behavior of these soils. Among these features is the significant pore water pressure generation in reverse loading which is the outcome of the evolution of soil fabric in shear and the impact of this evolution on soil dilatancy. In addition, it has been observed that when granular soils are cyclically sheared to near zero effective stresses, the change of soil fabric may lead to substantial change of various soil properties such as dilatancy, frictional resistance, and hydraulic conductivity. Moreover, the choice of degrees of freedom for pore water pressure, pore water displacement and skeleton displacements in a finite element discretization, particularly near the interface of two dissimilar soils, plays an important role in accurate simulation of pore pressure which in turn affects the displacement predictions. This paper presents a comprehensive analysis of the role of the above features on estimation of the vertical and lateral displacements in saturated soil systems subjected to severe ground shaking.

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