Algebra
Seminar

Effects of elastic shear modulus on soil liquefaction modelling and effective stress analysis

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Abstract: This research builds upon a well-established constitutive model for fully coupled effective stress analysis of liquefaction problems, the Stress Density Model (SDM). Recently, SDM has been calibrated based on semi-empirical relationships between liquefaction resistance and penetration resistance, and in this approach, SDM requires only CPT data as input. As traditionally SDM has been used with somewhat degraded initial elastic modulus, this study investigates in particular, the influence of the elastic parameter on the performance and calibration of the model. Elastic parameters have a complex role in liquefaction modelling because they simultaneously affect the dynamic response of the system and stress-strain behavior of the soil. When investigated these changes, specific attention is given to the development of parameters for a generic sand with the ability of the model to concurrently simulate the effects of density and confining stress on the liquefaction resistance and their effects on the rate of strain development during cyclic mobility.

First, the initial shear modulus G0 was obtained from literature for 41 clean sands tested at different densities and confining stresses. From each test, a value of A (i.e. SDM material parameter that defines the material constant in the relationship for the elastic shear modulus) was back-calculated. The shear modulus degradation curves for clean sands were scrutinised to quantify how the initial value of A changes at small strains so that a proper link between SDM and experimental data is established. Subsequently, the average value and dispersion of the data were computed. Secondly, a separate series of undrained cyclic laboratory tests on clean sand published in the literature were compiled and investigated to quantify the strain development during cyclic mobility (an aspect indirectly related to the elastic parameter A). Effects of relative density Dr and CSR (Cyclic Stress Ratio) on the strain-rate development were evaluated. As only Dr was found to correlate to the rate of deformation, mathematical expressions were developed to describe the effect of Dr on the deformation rate, both before and after achieving the selected liquefaction triggering criterion.

Incorporating the relationships resulting from the laboratory data scrutiny required a minor modification in SDM, as the identified initial value of A constraints excessively the development of shear strain during cyclic mobility, particularly for dense soils and relative low CSRs. This was the principal reason why in the original SDM, a degraded value for A was used. In this thesis, different alternatives were studied including to use A as a variable, which is justified in principle, as A is strictly speaking strain-dependent. At small strains, at the beginning of the simulation, the value of A was set as suggested by laboratory data, allowing more rigorous modelling of the elastic shear stiffness. Then, as the effective stress path approaches and enters cyclic mobility and the deformation increases, the value of A was degraded to allow for the development of larger strains.

Three types of representative relationships for sand were considered to evaluate the modification introduced in SDM and its calibration: (i) effects of soil density on the liquefaction resistance; (ii) effects of overburden stress on the liquefaction resistance; and (iii) effects of soil density on strain development during liquefaction and cyclic mobility. Once the simulation results were satisfactory at the element level, the modified model was evaluated in 1D effective stress analyses using the software FLAC. Two sites from Christchurch that liquefied during the 2010 Darfield (Mw=7.1) and 2011 Christchurch (Mw=6.2) earthquakes were the subject of 1D analyses. The input motion (deconvoluted record from the 2010 Darfield earthquake) was scaled to produce two levels of liquefaction response. The results were not entirely satisfactory, as a few anomalies (high dilation peaks) were noted in the acceleration time histories of the modified version. A detailed explanation of a plausible source of these peculiarities is provided regarding the interaction of the modified model and the selected numerical platform.

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