Abstract

A wide range of geotechnical structures are subjected to episodes of cyclic loading. Among them, we can for example mention onshore and offshore foundations subjected to environmental loadings, pavements subjected to traffic loading, filling-emptying cycles on silos and water tanks, among many others. In order to develop constitutive models or numerical tools that accurately reproduce the soil behavior on the aforementioned geotechnical problems, a deep understanding on how soil behaves under cyclic loading is necessary. This behavior is, however, not trivial since non-linearity, small strain stiffness, stiffness degradation, cyclic hysteresis and recent stress history play a significant role.

This dissertation presents some contributions to the experimental evidence and numerical description of soil cyclic behavior. It begins with comprehensive experimental databases on Malaysian kaolin and Zbraslav sand. In each database, several monotonic and cyclic tests were performed and analyzed considering a wide range of initial conditions and loading characteristics. In particular, the influence of the deviatoric stress amplitude, soil plasticity, initial stress ratio, drained cyclic preloading and sequence of packages of cycles with different deviatoric stress amplitudes was investigated on Malaysian kaolin. On Zbraslav sand, the influence of the deviatoric stress amplitude and different types of drained or undrained cyclic preloadings was investigated. The experimental databases will be freely available at the soilmodels.com website.

The thesis further presents a detailed analysis and comparison of the prediction capabilities, advantages and limitations of some of the most well-known and advanced constitutive models for cyclic loading on fine-grained soils: Anamnesis, anisotropic hypoplasticity with ISA, SANICLAY-B and three surface kinematic hardening model. Subsequently, the characteristic limitations of four advanced constitutive models for coarse-grained soils: hypoplasticity with intergranular strain, hypoplasticity with ISA, SANISAND and SANISAND-MSf are detailed and discussed. The aforementioned works remark the main components of the models that require improvements and provide discussion and analysis of them, which are of great value both for practical applications (to know under which conditions the models predict reliable results) and for future developments. The results suggest a huge success in the reproduction of monotonic loading but several issues in many simulations under cyclic loading. Among them, poor prediction capabilities when the model simulates conditions different to the ones in which it was calibrated, overshooting effects, improper accumulation of plastic strains, spoiled dilatancy-contractancy characteristics, or in general, poorly reproduced stiffness.

An improved version of the intergranular strain model by Niemunis and Herle is further presented. It presents improved capabilities in the prediction of strains and/or pore water pressure accumulation under cyclic loading. Finally, two case studies consisting of a monopile and a tripod subjected to multiple episodes of cyclic loading were simulated. The analyses focus on their deformation mechanism and the capabilities of the considered constitutive models to reproduce the centrifuge results.