CERIS Civil Engineering Research and Innovation for Sustainability

Numerical modelling of non-displacement piles in sand. The importance of the dilatancy in the resistance mobilization

Summary

This thesis' focus is the response of non-displacement piles installed in sand when subjected to axialload, specifically in the relevance of soil's volumetric behavior on this response. At the soil-pile interface, when the soil is distorted by shear volumetric deformations (usually dilatation) occur, which causes asignificant variation in the stress state.

That is done with the support of finite element numerical models by adopting the elastoplastic ECPmodel, a realistic constitutive law for the soil and the soil-pile interface. This model, written in terms ofeffective stresses, is a multimechanisms model that takes into account important factors that influencesoil behaviour, such as non-linear elasticity, incremental plasticity or the critical state definition. Otherimportant aspects, such as the distinction between dilating or contractive behaviour, flow rule or densityindex, can be considered via the model parameters. Only with an advanced soil model, that capturesthe real behaviour of the soil, it is possible to model the involved phenomena.

One of the first steps of this work was to obtain parameters for the ECP rheological model that would describe the stress-strain behaviour of Toyoura sand (in loose, moderately dense and very dense states) in the current laboratory stress-strain paths. To achieve consistent parameters' sets for a wide range of stresses, a parameter identification strategy was developed, and the description of the model's critical state pressure as a function of void ratio was enhanced.

Afterwards, the numerical modelling of the pile-soil interface zone is addressed using simplified models using GEFDyn numerical code. Soil behaviour when the shear zone localizes is modelled using2D solid elements or 2D interface elements. Moreover, the effect of the surrounding soil rigidity is also taken into account. The response of the models under plane strain and axisymmetric conditions are studied to illustrate the effect of some key parameters on both laboratory and *in-situ* stress-paths. Also, some strategies to calibrate the interface element's constitutive model parameters which depend on the thickness of the shear zone developed at the soil-pile interface are described and discussed.

Finally, after calibrating the numerical models of 2D solid and interface elements, the evolution of the pile's shaft resistance during loading has been investigated by simulating physical centrifuge models presented in the literature. Even if reduced pile models present different responses from what is observed in real piles, these modellings highlight the influence of the density index and therefore the dilatancy on the stresses generated in the soil around the pile.

The links between the different phases of the study including the simplified 1D axisymmetric model and the complete 2D one are underlined under the light of the 2D model results to elucidate the pertinence of the adopted modelling options and simplifications.

Keywords

non-displacement pile under axial load, soil dilatancy, soil-structure interface, multimechanism elasto-plastic model, calibration strategy.

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