A Hypoplastic Macroelement for Single Piles in Sand

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ABSTRACT

The paper presents the theoretical formulation and the FE implementation of a novel hypoplastic macroelement model for single vertical piles in sand, in which the incremental nonlinear constitutive equations are defined in terms of generalized forces, displacements and rotations at the pile head. A series of nonlinear 3d FE simulations and small-scale model tests under artificial gravity have been performed to investigate such fundamental features of the pile-soil system as the size and shape of the failure locus and the stiffness properties of the system under several relevant loading paths – from very small displacement levels up to failure – under monotonic and cyclic loading conditions.

The information thus gathered has been used to construct the hypoplastic macroelement model following the same approach adopted by Salciarini and Tamagnini [1] for the case of shallow footings. In order to reproduce the soil-pile system behavior under cyclic loading conditions, the macroelement incorporates a suitably modified version of the "inergranular strain" concept proposed by Niemunis and Herle [2]. Analytical and numerical strategies are provided for the calibration of the macroelement constants. The proposed macroelement model allows a dramatic increase in computational efficiency in SFSI analyses, if compared to full 3d FE simulations. At the same time, its mathematical formulation based on hypoplasticity provides a superior accuracy in reproducing the nonlinear and irreversible pile response under complex loading programs with respect to conventional (nonlinear) uncoupled winkler spring approaches.

Comparison of the predicted model performance with experimental results from centrifuge tests shows that the hypoplastic macroelement is capable of correctly reproducing the experimentally observed response of single piles subjected to one-way and two-way cyclic loading conditions. The proposed macroelement model could therefore represent a significant step forward towards high fidelity modelling of SFSI problems for structures founded on isolated piled foundations, such as bridges and viaducts under seismic loading conditions.

REFERENCES

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