NUMERICAL MODELING AND SIMULATION OF EXCAVATION PROCESSES OF SOFT SOILS IN MECHANIZED TUNNELING

Doctoral defense by ABDIEL RAMON LEON BAL

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Shield-driven excavations using Earth Pressure Balance (EPB) Tunnel Boring Machines (TBMs), have emerged in recent years as a safe, cost- and time-effective method for the construction of tunnels in difficult and unstable soils. A central aspect of this tunneling method is the continuous excavation via the tools mounted at the cutting wheel of the TBM. The interaction developing between the cutterhead and the tunnel face induces the destructuration and subsequent failure of the ground, which is transported into the pressure chamber. Understanding this transient interaction is of paramount importance for machine driven tunneling, as it determines the efficiency of the excavation process and the lifetime of the excavation tools. Computational methods are helpful to provide further insight into the mechanics of deformation of the ground, the wear behavior, the torque and the energy requirements of the EPB machine during the excavation process.

Single- and coupled two-phase computational formulations, in association with a hypoplastic constitutive model, are proposed for the modeling of mechanized excavations in dry and partially saturated soft soils using the Particle Finite Element Method (PFEM). The global re-meshing strategy of the PFEM is further enhanced by means of a new adaptive mesh refinement strategy for the treatment of strain localization in the ground. The two-phase numerical formulation also features the Soil Water Characteristic Curve (SWCC) and the Kozeni-Carman model, which accounts for the porosity and granulometric properties of the soil in the estimation of soil permeability. Additionally, an extension to an hypoplastic viscous formulation, allowing for the improved modeling of rate-dependent effects in granular flows, is presented. The proposed computational strategy demonstrates robustness in the simulation of soft soil excavations, characterized by large deformations, evolving spatial boundaries and strong material non-linearities.

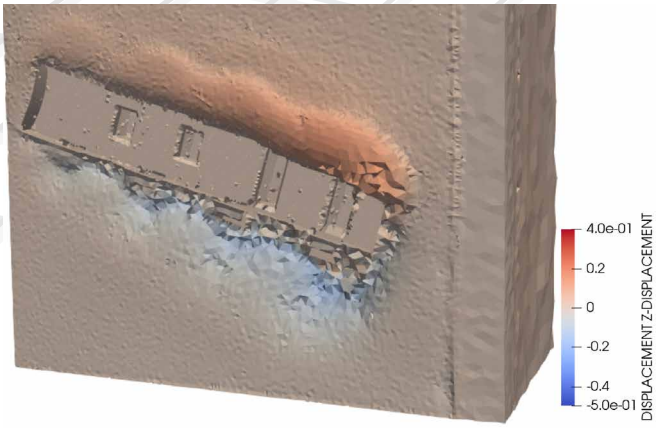

Fig: Mechanized excavations in dry granular soil

For the numerical investigation of tool-soil interactions in soft soils, two- and three-dimensional PFEM excavation models are developed. The evolution of the soil deformations, effective stresses, pore pressures and reaction forces on the tool generated during the excavation process are analyzed. Model predictions show a good agreement when compared to laboratory measurements obtained from an in-house excavation device as well as to numerical and experimental results available in the literature. Finally, simulations of EPB TBM excavation processes in dry and fully saturated soft soils are presented. Using a reduced-scale model of a TBM cutterhead equipped with excavation tools, different aspects of the excavation operation and the cutterhead-tunnel face interaction, including the ground deformations and the cutterhead torque, are analyzed and discussed. Further more, parametric investigations elucidating the influence of selected geotechnical parameters on the mechanized excavation process are also performed.

RUHR-UNIVERSITÄT BOCHUM Fakultät für Bau- und Umweltingenieurwissenschaften

Lehrstuhl für Statik und Dynamik
Prof. Dr. techn. Günther Meschke

Universitätsstr. 150
44780 Bochum

sd@rub.de
www.sd.rub.de