Introduction to *RS*^{2} Hardening Soil Constitutive Model through a Case Study of Deep Excavation in Berlin Sand

Abstract

Due to the limited supply of land, nowadays more buildings are constructed on sensitive soils, such as soft soils. Soft soils usually have higher water content and plasticity, and thus more complicated behaviors than stiff soils. Although elastic-perfectly-plastic material models, such as the Mohr Coulomb, work well for initial estimations, more advanced material models are required for accurate simulations where soft soils are present in the problem. This article focuses on the application of one such material model, the Hardening Soil model, and a case study on a deep excavation in Berlin, Germany.

The Hardening Soil Model

For soft soil, material yielding starts at the very early stages of loading and Young's modulus changes with the level of stress. The Mohr Coulomb model assumes a single constant Young's modulus and is an elastic-perfectly-plastic model, and thus it is lacking accuracy. In comparison, the Hardening Soil model introduces three stress-dependent Young's moduli (E', E'_{50}, E'_{oed}) and has hardening rules for the continuous yielding of the material. Another advantage of the Hardening Soil model over the Mohr Coulomb model is its formulation of the flow rule which can capture the initial compaction of the material at the initial stages of shearing, as well as the dilation that could happen at later stages of loading.

Site Characteristics

The investigated case study is a deep excavation in the M1 pit from the VZB tunneling project in Berlin. The pit was excavated underwater to a depth of 20 meters, and supported by a diaphragm wall.

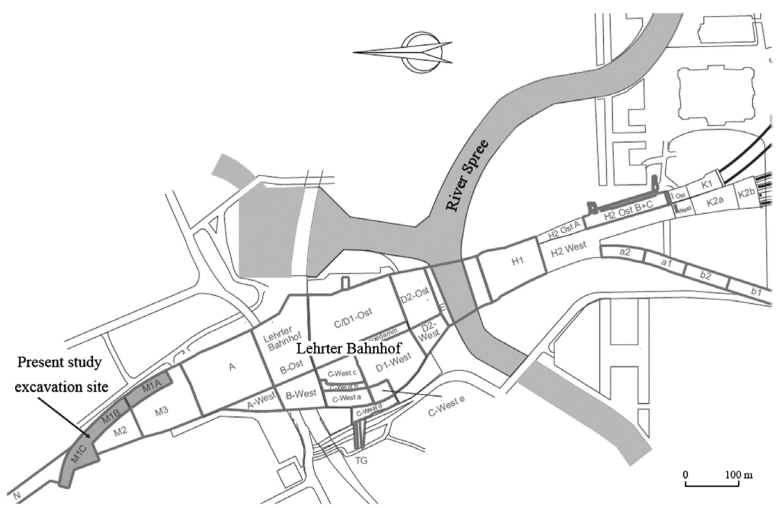

Figure 1 - M1 pit deep excavation location (Nikolinakou M. A., Whittle, Savidis, & Schran, 2011)

The soil (Berlin sand) is characterized as saturated glacier deposits from three different deposition periods. Typically, the vertical soil profile consists of one fill layer (3-4m thick) overlying three layers of sandy tilts, including S0 (6m thick with 1-m-thick organic soil), S1 (10m thick) and S2 (below the depth of 22m) (Nikolinakou M. A., Whittle, Savidis, & Schran, 2011). The soil samples were tested in the lab and modelled by the Hardening Soil model.

Model Setup in *RS²*

This *RS²* model includes three primary layers of sand depositions, excluding secondary fill and organic soil. A 1.5-m-thick diaphragm wall extends to 28.7 meters below the ground soil, and it is supported by a row of pre-tensioned tiebacks. The water table is at 2-m depth.

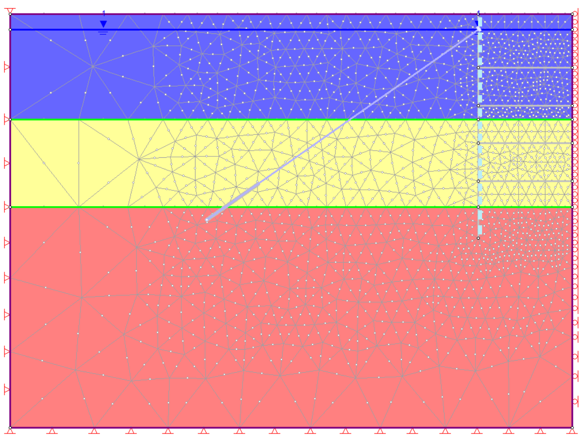

Figure 2 - Initial Stage

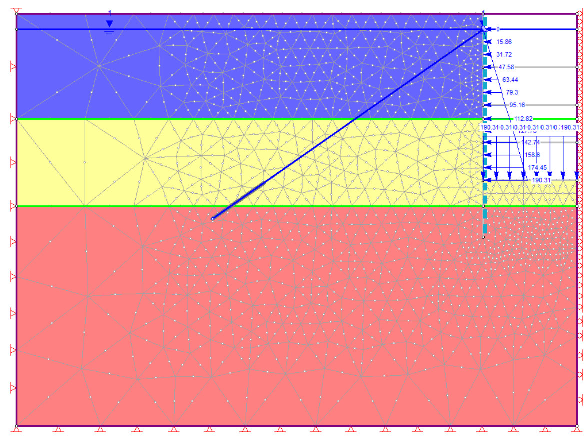

Figure 3 - Final Stage Excavation

The Hardening Soil model is developed in *RS²* as a User-Defined material model. The material properties and the input dialog for S0 sand are presented in Figure 4 and 5.

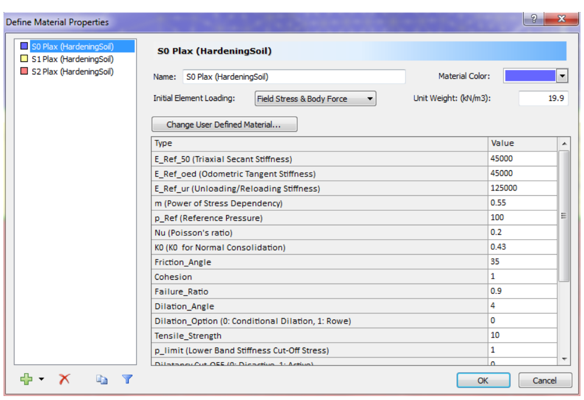

Figure 4 – Hardening soil material model for the S0 sand layer

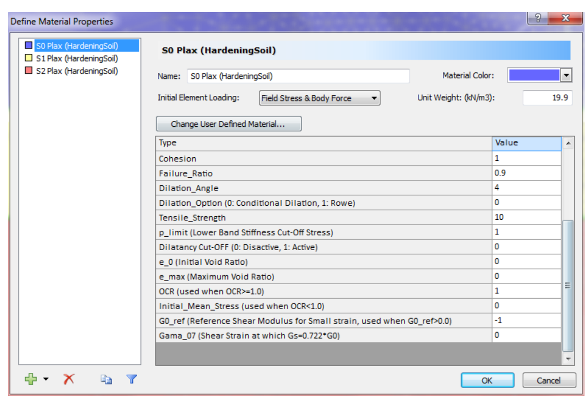

Figure 5 – Hardening soil material model for the S0 sand layer (continued)

Results and Discussions

The horizontal displacement of the diaphragm wall was measured after the bolt installation and after the final stage of excavation. In Figures 6 and 7 the measured wall deflection are compared with the simulation results from the *RS²* Hardening Soil model as well as with simulation results from the *Plaxis* Hardening Soil model (Plaxis HS) (Nikolinakou M. A., Whittle, Savidis, & Schran, 2011).

Figures 6 and 7 show the the results after intallation of the the bolt, and after the final stage of excavation respectively. The simulation results from *Plaxis* and *RS*[2] are in good agreement, and both are in good agreement with the observed behavior. Figure 8 and 9 show the contours of horizontal displacement in the domain after installation of the bolt and after the final stage of the excavation.

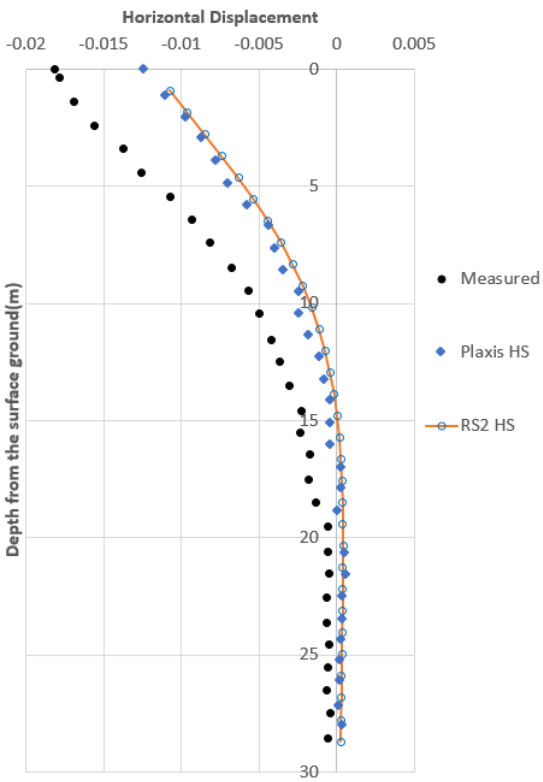

Figure 6 - Horizontal displacement of the diaphragm wall after tensioning the bolt

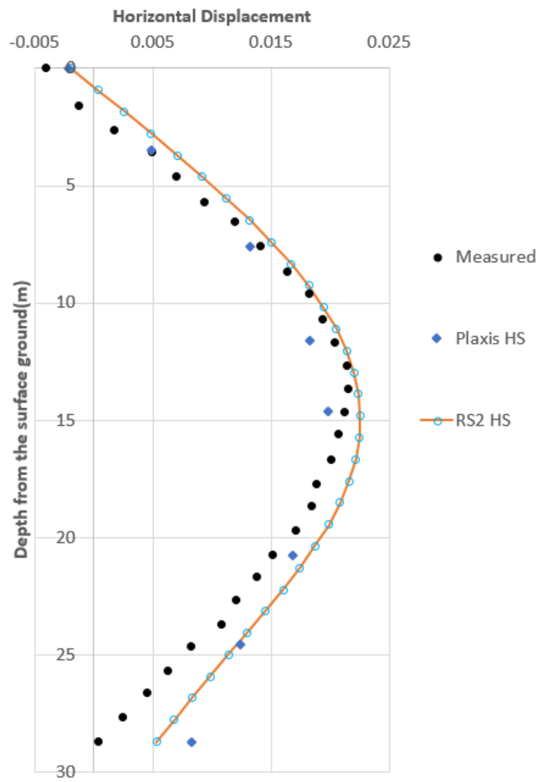

Figure 7 - Horizontal displacement of the diaphragm wall at the final excavation stage

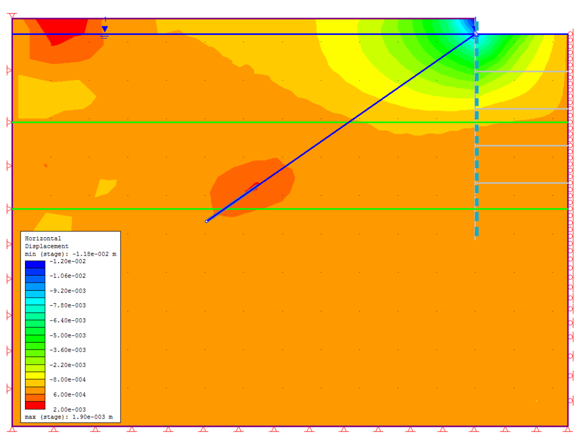

Figure 8 - Horizontal displacement result in *RS*[2] after tensioning the bolt

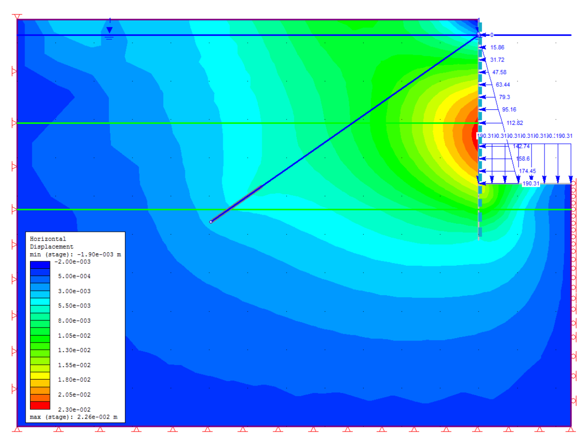

Figure 9 - Horizontal displacement result in *RS*[2] after the final excavation

Conclusion

This article introduces the hardening soil model in *RS*^{2} as one of the new advanced material models, developed as a User-Defined constitutive model. Through the modeling of the deep excavation in Berlin sand, it has been shown that the hardening soil model provides reliable predictions for soft soil behaviors.

References

Nikolinakou, M. A., Whittle, A. J., Savidis, S., & Schran, U. (2011). Prediction and Interpretation of the Performance of a Deep Excavation in Berlin Sand. *Journal of Geotechnical and Geoenvironmental Engineering*, 1047-1048.

Zain, M., Ahmad, J., Ashaari, Y., Shaffie, E., & Mustaffa. (2011). Modelling of Lateral Movement in Soft Soil Using Hardening Soil Model. *UKSim 13th International Conference on Modelling and Simulation*, 195.