Abstract

In conventional tunnelling under squeezing ground conditions, the choice of a suitable support concept is extremely important. Squeezing ground conditions are characterised by high ground stresses in combination with large time-dependent deformations. The use of yielding elements to create targeted flexibility of the sprayed concrete lining is internationally state of the art. The defined flexibility through the yielding elements leads to a different kinematic overall performance of the sprayed concrete lining compared to a plain sprayed concrete support. Decisive for the optimisation of the construction concept is the functional relationship between the time-dependent material behaviour of the sprayed concrete and the load-deformation behaviour of the yielding elements. Suitable calculation models must therefore take this into account. The aim of the present work is to analyse the basic relationships between the yielding elements and the system behaviour of the sprayed concrete lining in order to be able to make statements regarding a suitable support concept for squeezing ground.

To understand the interaction of the sprayed concrete lining with the yielding elements in squeezing ground, the individual components, i.e. sprayed concrete and yielding elements, are first experimentally investigated. At different complexity levels, they are then numerically merged to capture the interaction.

In detailed terms, the comparative investigations on the load-deformation behaviour of yielding elements and experimental investigations on the time-dependent material behaviour of sprayed concrete represent the basis for implementation in the calculation models. An empirical forecasting model for the determination of time-dependent sprayed concrete strength increase is developed based on in-situ and experimental data. The analytical and numerical models are created with the appropriate degree of detail and validated by means of a reference project for the various phases of the project stage. For the preliminary design, the convergence confinement method (CCM) is supplemented by the previously developed material models and implemented in a MATLAB calculation. A variation study with the CCM shows the influence of the geotechnical boundary conditions on the displacement development of the ground. A two-dimensional numerical model is created for use in the conceptual design. This model is used to analyse the influence of ground and system parameters on the load on the flexible sprayed concrete lining. The findings are translated into a three-dimensional model that analyses the kinematic behaviour of the overall system with a focus on the interaction between ground, sprayed concrete lining and yielding element.

Recommendations for the dimensioning of yielding elements are drawn from the findings, taking into account the time-dependent strength development of the sprayed concrete. In
addition, implementation strategies for the construction components, i.e. sprayed concrete and yielding elements, are presented in the respective calculation models, and an application for the corresponding project stage is recommended.