The flow behaviour of soil-foam mixtures, used as support medium in closed mode tunnelling with EPB shields, is an essential factor for the operation of the TBM. On the one hand, a rather soft consistency is required providing a homogeneous face support pressure transfer to the tunnel face. High accuracy in face support regulation is crucial for settlement control, especially in sensitive environments, such as urban areas. On the other hand, a rather stiff consistency is preferable concerning transportation and disposal of the excavated ground in order to avoid additional treatments for landfilling, tipping or sewage management. Outside the classical application range for EPB shields, which is formed by clayey and silty soils, the addition of conditioning agents is necessary to generate appropriate consistencies, particularly in cohesionless soils below the groundwater table. In such ground conditions, foam is injected to the excavated ground to generate a face-supporting muck and to control water inflows at the tunnel face.

So far, the flow behaviour of soil-foam mixtures has been investigated by index tests. Most notably, the slump test, known from concrete technology, is widely applied on soil-foam mixtures. However, flow is actually a non-static phenomenon and cannot be expressed by a single parameter, which is derived from an equilibrium-state condition at rest. Therefore, this thesis focuses on the rheology of soil-foam mixtures aiming at an extended understanding of the flow behaviour and of the influences the individual components have on it. An experimental programme was elaborated, which dealt with two main scopes: a discussion on the slump test and its value as index test for the flow behaviour of soil-foam mixtures and secondly, the application of rheometer tests to soil-foam mixtures. The method in sample preparation, test conduction and temporal restraints were strictly defined for all tests, ensuring reproducibility and comparability. The initial water content was derived from foam penetration tests depending on the residual (foam-)water content that occurs during excavation.
A large number of slump tests was executed providing information on the slump and spread of the mixture samples when altering the different shares of the sample composition (soil, water, foam). These were evaluated with analytical approaches enabling a derivation of rheological properties from slump tests. The application of the analytical models is dependent on the geometry of the slumped sample. For an application to soil-foam mixtures, the models had to be partially adjusted. The value of the slump test and the applicability of the models to soil-foam mixtures were discussed based on the results.

Rheological tests on various scales were performed with a variety of soil-water-foam mixtures in order to determine flow curves and thus to characterise their flow pattern. Rheometers were equipped with cylinder and ball measuring systems. The findings have been compared with flow curve data from literature determined in micro-scale investigations on particle-foam mixtures. Due to their grain-size, real soil-foam mixtures cannot be investigated in such precise rheological setups. From this multi-scale analysis, it can clearly be shown that the flow behaviour of soil-foam mixtures is very dependent on the particular shearing condition. Each scale provides its own informative value on rheology. On the micro-scale, flow curves of particle-foams could be well described by the Papanastasiou-Herschel-Bulkley model, whereas in macro-scale experiments using a ball measuring system, the results were dominated by yield-stresses, slip effects and the destructive behaviour of foams. Nonetheless, the material possesses a particular behaviour and differences in results from different mixture compositions could be detected. Finally, the findings from slump and ball rheometer tests have been compared to establish a comparable basis between both approaches. Thus, it becomes possible to relate the results of both experiments to each other.

This thesis provides information on the interaction between soil, water and foam during the excavation process in EPB tunnelling. Therefrom, optimisation strategies can be derived in order to design the soil conditioning process with foam more effectively. Moreover, suggestions are presented for an implementation of the ball measuring equipment in the excavation chamber of an EPB-TBM for live analysis of the flow behaviour and the conditioning process.