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From advance exploration to real time steering of TBMs: A review on pertinent research in the Collaborative Research Center "Interaction Modeling in Mechanized Tunneling"

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Abstract

This paper reports on planning and construction related results from research performed at the Collaborative Research Center "Interaction Modeling in Mechanized Tunneling" at Ruhr-University Bochum, Germany. Research covers a broad spectrum of topics relevant for mechanized tunneling in soft soil conditions. This includes inverse numerical methods for advance exploration and models for the characterization of the in situ ground conditions, the interaction of the face support and the tail gap grouting with the porous soil, multi-scale models for the design of fiber reinforced segmental linings with enhanced robustness, computational methods for the numerical simulation of the tunnel advancement, the soil excavation and the material transport in the pressure chamber, logistics processes and risk analysis in urban tunneling. Targeted towards the continuous support of the construction process, a concept for real-time steering support of tunnel boring machines in conjunction with model update procedures and methods of uncertainty quantification is addressed.

Keywords: Mechanized tunneling; Computational simulation; Tunnel reconnaissance; Tunnel linings; Face support; Tail void grouting; Real-time analysis; Abrasion; Process simulation

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1. Introduction

Mechanized Tunneling has proven itself as an economical and flexible construction method that continues to undergo a dynamic evolution process; shield diameters are constantly increasing, and the range of scenarios in which tunnel boring machines are deployed is continuously expanding, from clays to granular soils to highly fractured or monolithic rock masses, from partially to fully saturated ground, and from alpine mountain ranges with high overburden pressures to sensitive urban areas with low overburden. Today, the application range of tunnel boring machines is being extended to an ever increasing variety of geotechnical conditions (see, e.g. ITA Working Group, 1989; Koyama, 2003; Maidl et al., 1996; Robbins, 1987). In order to maintain low settlements, and to ensure an economically feasible as well as environmentally friendly construction process, realistic numerical models are required to provide reliable prognoses during the planning and construction stages in modern mechanized tunneling. These models become especially critical in difficult geotechnical environments as well as under special boundary conditions, such as driving under existing constructions. A prerequisite for a reliable numerical prognosis is the accurate assessment of the interactions between the components involved in mechanized tunneling, the surrounding site, the ground, and any pre-existing structures. Heterogeneous geological conditions and often only approximated ground parameters create, in contrast to other engineering projects, special demands. This and the constant expansion of the range of deployment of shield-supported tunneling as well as the tendency to ever larger shield diameters necessitate new insights to new problems that can only be effectively solved through truly interdisciplinary research. Open problems demanding fundamental research arise in almost all aspects of the mechanized tunneling process. Examples are the actual distribution of the face support pressure in Earth Pressure Balanced (EPB) shields, the actual mechanism in which the face supporting and the grouting fluids infiltrate the porous ground, the relationship between the excavation at the tunnel face and cutter head wear, the effectiveness of measurements with respect to the quality of prognosis, the real-time support of the tunneling processes through continuously updated process-oriented numerical models, the optimization of logistics processes or the robustness of segmental lining and the effectiveness of the grout between the lining and the ground. In this context, the German Research Foundation (DFG) established the Collaborative Research Center "Interaction Models for Mechanized Tunneling" (SFB 837) at Ruhr-University in Bochum since 2010. Collaborative Research Centers are interdisciplinary scientific research groups in which cooperative research is conducted under the umbrella of a central research theme. Within 15 subprojects, design concepts, numerical models and new excavation technology concerning mechanized tunneling are being developed. The research goals of the SFB 837 are concerned with relevant planning and construction aspects of the many components of the mechanized tunneling process. They are organized into four project areas (Fig. 1). Project area A is concerned with the characterization and modeling of the in situ ground and the disturbed ground conditions in the vicinity of the

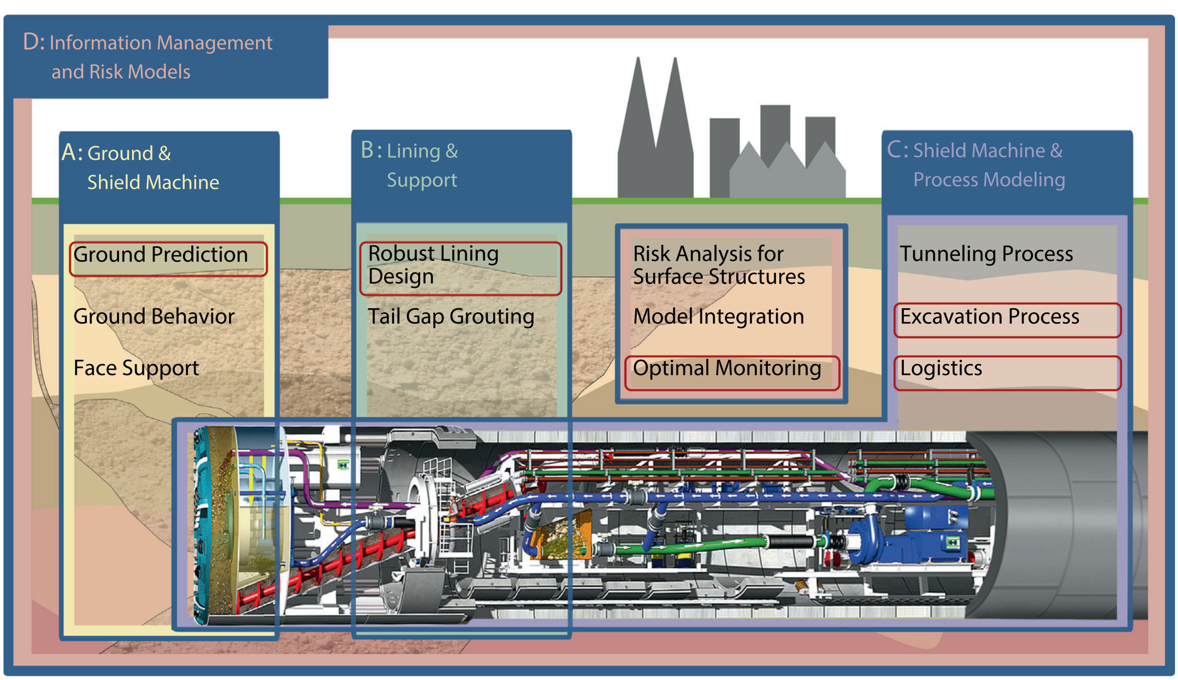

Fig. 1. Components and processes involved in mechanized tunneling and their representation within four project areas in the SFB 837. The topics addressed in papers of the Special Issue are highlighted.

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