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Parameter design of yielding layers for squeezing tunnels

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ABSTRACT

Tunneling in a soft rock mass under high in situ stress often results in squeezing deformation. Supports that use yielding layers are suggested to address the squeezing deformation of tunnels. However, feasible design methods for the yielding layer have not been proposed, especially for the determination of the yielding stress P_s and thickness d. In this study, a laboratory test is conducted to verify the effect of the yielding support. The test results show that the pressure of the secondary lining is reduced with the installation of the yielding layer. The comparisons between the laboratory test and uniaxial tests of confined and unconfined conditions showed that the whole stress–strain curve of the yielding layer can be obtained by its confined compression tests. The whole stress–strain curve of the yielding layer can be divided into three stages: elastic stage, yielding stage and failure stage. Compared with other yielding lining, a polyurethane (PU) yielding layer with density (70–100) is more suitable for the yielding layer as it has high deformation capacity and adjustable yielding stress. A design method of a PU yielding layer considering its density is proposed, and the key parameters of the yielding layer for a squeezing tunnel are determined.

1. Introduction

Large deformation due to weakness and rheological properties of squeezing rock is a great challenge for tunnel engineers. The deformation can converge several tens of centimeters or even more, leading to severe damage of the support system (Schubert, 1996; Mahmutoglu et al., 2006). Two approaches are applied to solve this problem in squeezing tunnels: a rigid support system based on the “resistance principle” (Kovári, 1998) and a yielding support system based on the “yielding principle” (Anagnostou and Cantieni, 2007; Ramoni and Anagnostou, 2010). However, efforts to prevent large deformations via a rigid support system often result in spectacular shear failures of the shotcrete lining (Schubert, 1996), which lead to brittle failure of the rigid support, the increase in concrete thickness and costly repairs during the operation period. In this case, yielding supports have been proposed to solve the large deformation in recent decades (Kimura et al., 1987; Cantieni, 2009; Rodríguez and Díaz-Aguado, 2013; Tan et al., 2017). There are two basic options available for yielding supports (Cantieni, 2009; Ramoni and Anagnostou, 2010; Mezger et al., 2018): radially deformable linings (installing a yielding layer between the primary support and secondary lining, Fig. 1a) and tangentially deformable segmental linings (inserting a yielding element between the circumferential segments divided by shotcrete lining, Fig. 1b). In yielding support systems, the tangentially deformable linings are used to prevent the failure of the shotcrete lining, while the radially deformable linings are designed to absorb the time-dependent deformation of rock and protect the secondary lining.

Tangentially deformable linings incorporating special compressible concrete, steel or plastic elements are inserted into the circumferential segments of the shotcrete lining (Mezger et al., 2018). In this condition, the primary support is allowed to accommodate more deformation to avoid its shear failures. Many researchers have studied the characteristics of tangentially deformable linings by field and laboratory tests. As early as 1950, timber elements were first used to provide sufficient deformation capacity (Rabcewicz, 1950; Schubert, 1996), and the different types of timber used depended on the required ductility and resistance (Schubert, 2008). Yielding steel elements were developed in 1995 and successfully used at the Galgenberg tunnel (Schubert, 1996; Schubert and Moritz, 1998). Subsequently, with the construction of a number of tunnels in recent years, the applications of yielding elements

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