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## 3D advanced modelling of TBM excavation in squeezing rock conditions

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### ABSTRACT

The design analysis of tunnels to be excavated with Tunnel Boring Machines (TBMs) requires the study of the complex interaction between the rock mass, the tunnel machine and its system components, and the tunnel support. A 3D advanced model which considers all these components, as recently developed by the Rock Mechanics and Rock Engineering Group at Politecnico di Torino, will be illustrated in this lecture. Modelling is carried out by using the Finite Element Method (FEM) and with reference to the specific advanced features of the Double Shield Universal TBM. As a case example, the excavation of the Lyon-Turin Base Tunnel when crossing the Carboniferous Formation in squeezing conditions is considered. Reference is made to the characterization studies and the suite of monitoring data obtained during the excavation of the Saint Martin La Porte access adit in the same rock formation. The application of the newly developed 3D simulator to such a case will be described and the results obtained in terms of the key design parameters will be illustrated.

### KEYWORDS

Mechanized excavation, Shielded TBMs, 3D modeling, Squeezing conditions, Lyon-Turin Base Tunnel, Carboniferous Formation

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### 1. INTRODUCTION

With the growing interest worldwide in the excavation of longer and deeper tunnels, as is the case in Europe of the new crossings of the Alps in the form of Base Tunnels (to a length of 57 km and up to a depth of 2500 m) [1], mechanized excavation with Tunnel Boring Machines (TBMs) is getting the most attention, also given the steps forward in technological developments that have recently been made. However, one is to recognize that the use of TBMs when major geological/geotechnical hazards are encountered, as is the case of severely squeezing rock conditions, is yet under discussion due to some negative documented cases that resulted in very low rates of advancement and even in standstills or complete loss of the TBMs.

Open TBMs have shown several limitations when meeting squeezing problems as the level of squeezing increases [2].

For shielded TBMs, the main hazards are machine trapping (including cutterhead and shield jamming), overstressing and failure of the tunnel lining. Furthermore, the occurrence of significant deformations (ovalization) or even horizontal or vertical shifting of the segmental lining may lead to jamming of the back-up equipment or to violation of the clearance profile as well underlined in [3].

For the analysis of the feasibility of TBM excavation in such conditions at the design stage, an appropriate simulation tool may play a significant role. One such a tool in the form of a 3D advanced numerical model (3D Simulator) has been developed by the Rock Mechanics and Rock Engineering Group at Politecnico di Torino and is briefly described in this lecture.