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Tunnelling in Squeezing Ground – Recent Improvements

By Wulf Schubert, Bernd Moritz, Peter Sellner and Manfred Blümel

Geological conditions in alpine areas in combination with high overburden in many tunnelling projects lead to squeezing behaviour. Main problems associated with such conditions are large deformations, overstressing of supports, and lack of face stability. Research on the Institute for Rock Mechanics and Tunnelling at the Technical University Graz since its beginning in 1992 are focused on tunnelling in squeezing ground. Based on problems encountered during the construction of the Inntaltunnel and Galgen-

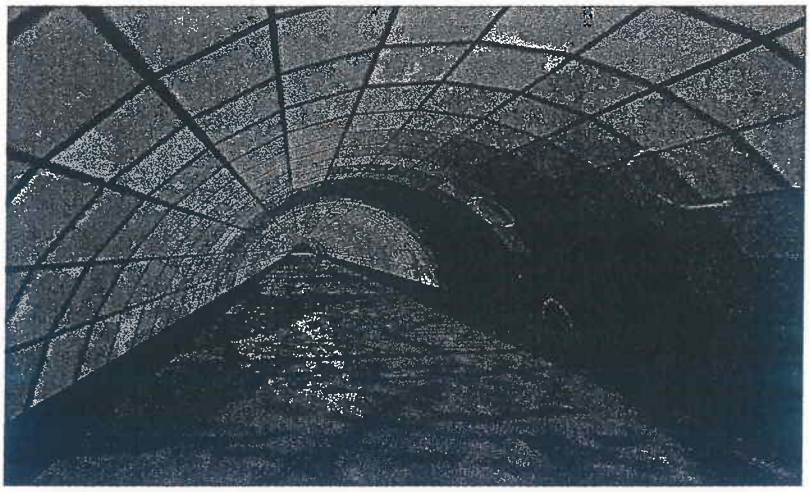

Fig. 1 Geotechnical situation and contour line plot of displacement vector orientation (L/S) at the "Hinterberg" fault zone, trend 5 m behind the face.

Bild 1 *Geotechnische Situation und Konturplot der Vektororientierung der Verschiebungen (L/S) in der Hinterbergstörung, Trend 5 m hinter der Ortsbrust.*

Tunnelbau in druckhaftem Gebirge

Beim Vortrieb von Tunnels in druckhaftem Gebirge tritt sehr oft die Problematik großer Verformungen, der Überbeanspruchung des Ausbaus oder der Instabilität der Ortsbrust auf. Um diese Probleme zu lösen, wurden bei Tunnelprojekten in den Alpen Forschungsschwerpunkte gesetzt. Die Ergebnisse dieser Forschungen sind einerseits die Möglichkeit einer kurzzeitigen Vorhersage des Verhaltens des Gebirges und der daraus resultierenden Verschiebungen sowie Verbesserungen des Ausbaus andererseits.

Tunnelling in squeezing rock can lead to several problems as large deformations and overstressing of support or a lack of face stability. During the construction of tunnels in Austria these problems occurred and research work was done to solve them. Short term prediction of rock mass behaviour and displacement forecast as well as improvements of tunnel support are the results of these research topics.

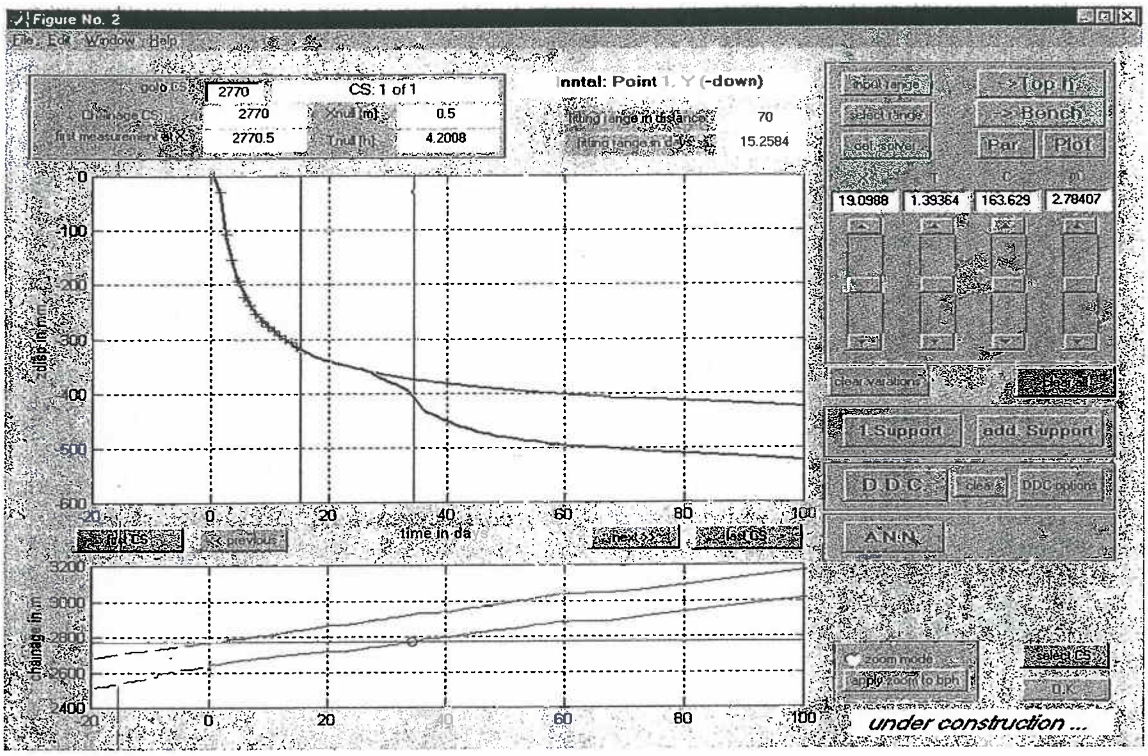

Fig. 2 Control window for displacement forecast for a sequential excavation.

Bild 2 *Steuerungsfenster der Verschiebungsberechnung für sequentielle Vortriebe.*

bergtunnel, a number of subjects has been investigated in detail, and solutions found for various problems.

Short term prediction and displacement control

A main problem when tunnelling in squeezing ground is the heterogeneity of fault zones. Prediction of rock mass behaviour, and thus proper choice of support, construction sequence, as well as determination of required overexcavation in heterogeneous rock mass is extremely difficult. Using data from 3D optical displacement monitoring, Budil (1) studied the phenomenon of longitudinal displacements, and found an interesting relation between displacement vector orientation and rock mass heterogeneity. This work was continued by Steindorfer (2), who in detail analysed the development of stresses and displacements in heterogeneous ground during tunnelling excavation.

Using the spatial displacement vector orientation (figure 1), the prediction of changes in rock mass stiffness ahead of the face is possible. An at least qualitative assumption about primary stress orientation seems to be possible with the procedure proposed by him. The findings have been implemented in commercial geotechnical monitoring software. In October 1998 he received the Leopold Müller award of the Austrian Society of Geomechanics for his thesis.

The problem of a more precise prediction of final displacements is currently tackled by Sellner (3). A poor estimate of final displacements in many cases leads to the requirement of extremely costly reshaping. Excellent functions have been developed by Guenot, Panet and Sulem (4) and modified by Barlow (5).

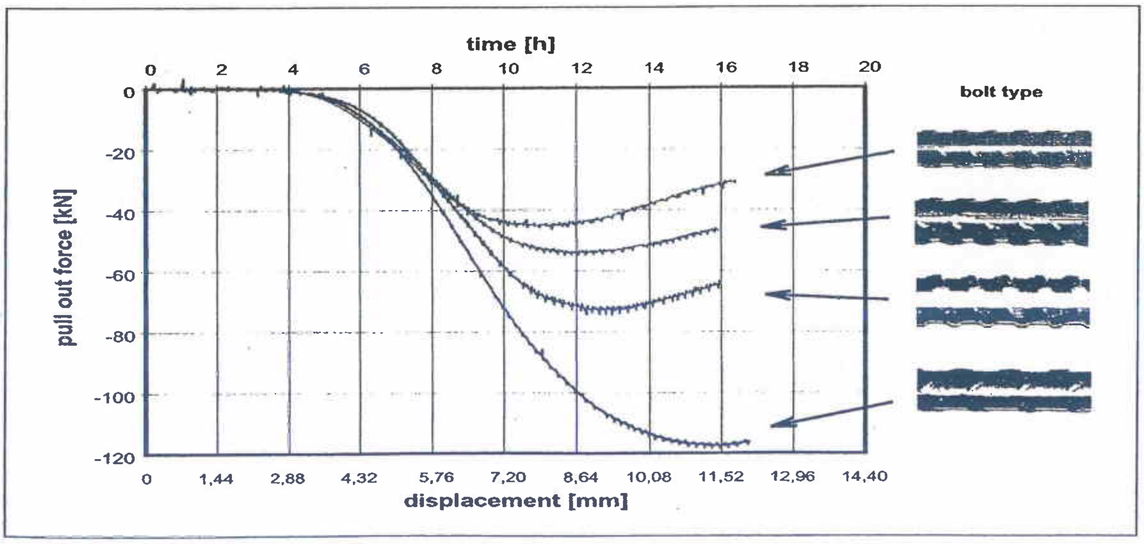

Fig. 3 Performance characteristic of one grout type with four different bolt types, displacement rate 0,72 mm/h.

Bild 3 *Arbeitslinien für vier verschiedene Ankerbauarten, Ausziehgeschwindigkeit 0,72 mm/h.*

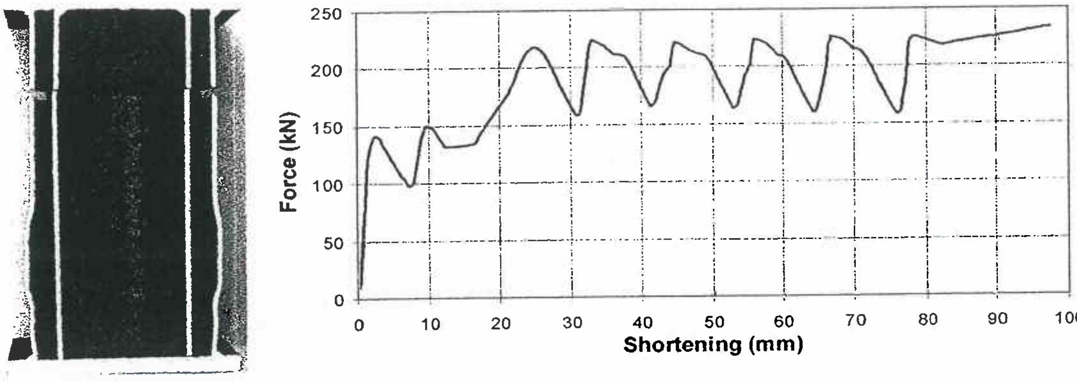

Fig. 4 Improved yielding element after laboratory testing (left), and load line (right).
Bild 4 *Verbessertes System im Labortest (links) und zugehörige Arbeitslinie (rechts).*

Function parameters are determined from the data base system DEST (6) and optical 3D monitoring results with the help of Artificial Neural Networks (ANN). First tests with the code, based on MATLAB are very promising (figure 2). Site tests are planned in near future.

Supports for tunnels in squeezing ground

Although rock bolts and shotcrete, occasionally supplemented by displacement gaps in many cases proofed to meet the requirements, there is still some room for improvement of supports for squeezing ground. Blümel investigated the bond between rockbolts and grout under squeezing conditions in numerous laboratory tests and FE simulations (7). This work yielded a recommendation for modified rib geometries, which considerably improve rock bolt performance (figure 3).

Squeezing conditions require strong and ductile supports. This has been a problem in the past, as most supports, such as steel sets or shotcrete do not provide enough ductility over the range of displacements encountered in squeezing rock. Moritz (8) improved a system first used at the Galgenbergtunnel (9). The basic idea is to integrate ductile elements into relatively stiff standard supports. The system consists of sets of concentrical steel cylinders, yielding a nearly bilinear load line. By varying number and dimensions of the so called "Lining Stress Controllers (LSC)", the system can be designed to the capacity of the linings used and displacements expected. Numerical simulations and field applications have shown the effectiveness of the system, which already is commercially available (figure 4).

Conclusion

A number of problems associated with tunnelling in squeezing ground have been studied during the past years. The solutions offered will contribute to a more economical and safe tunnel construction under such conditions. It showed, that efficient research on complex topics is possible only in a teamwork of specialists. A favourable environment for interdisciplinary co-operation has been found at the Technical University Graz. Equally important for a development is a good link between University and construction industry. Not only for the identification of problems, but also for the practical application of research results and developments, the co-operation of researchers, owners and contractors is essential. We have found considerable support from owners and contractors, readily supplying data, and providing sites as "field laboratories".

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