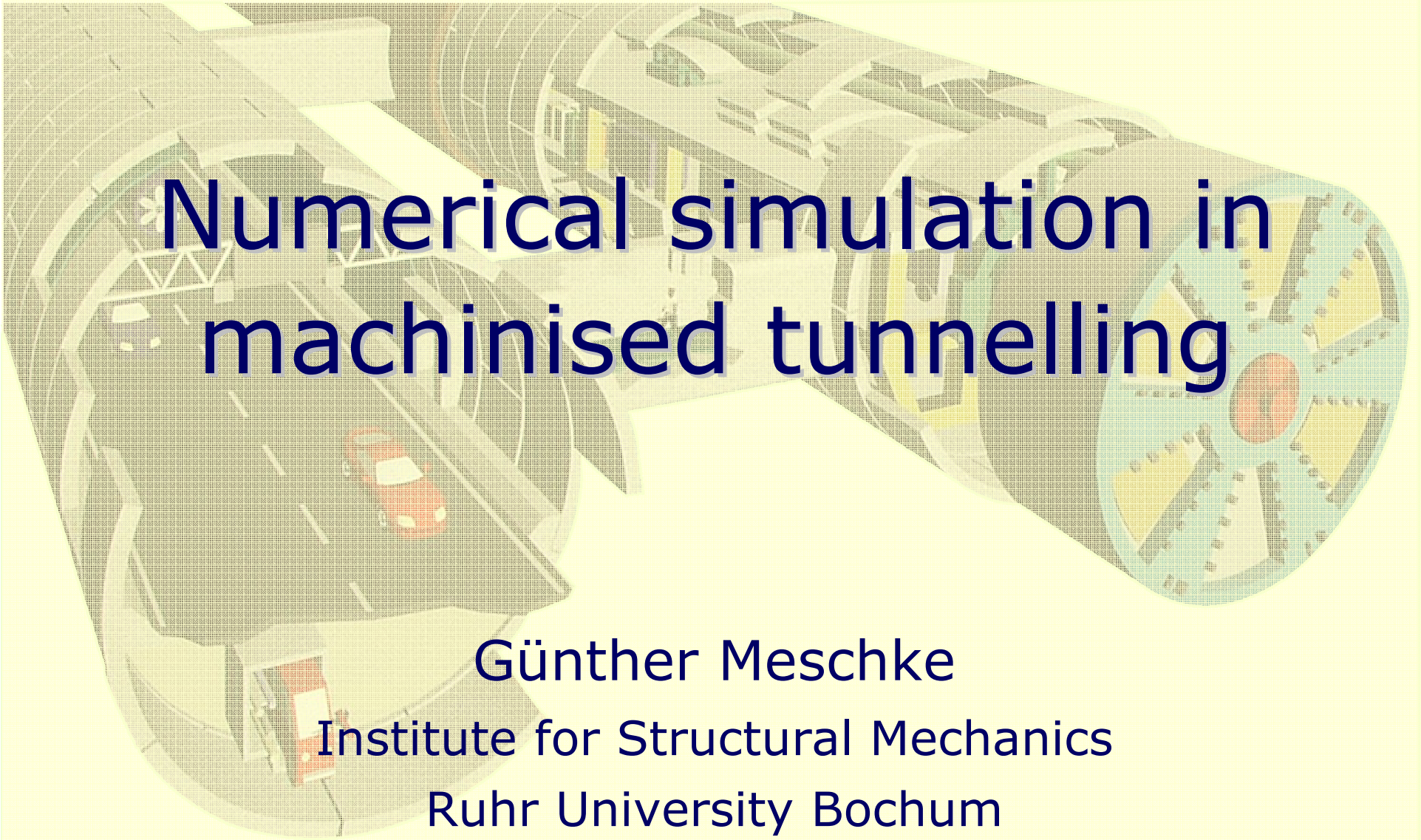


Numerical simulation in machinised tunnelling

Günther Meschke

Institute for Structural Mechanics

Ruhr University Bochum

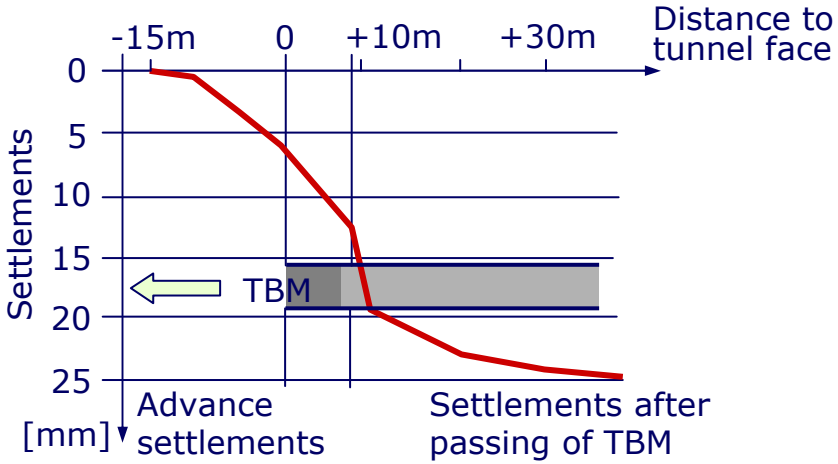
IKT Pipe Jacking Symposium 2007

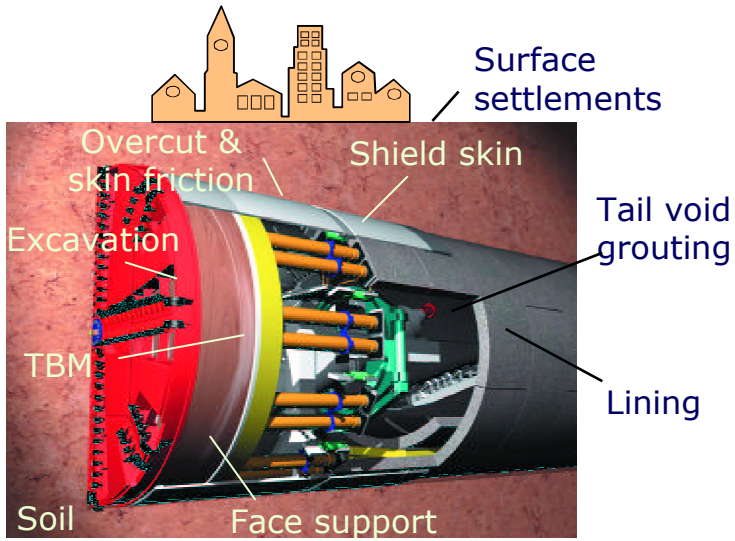
February 14th, 2007

Gelsenkirchen

STRUCTURAL MECHANICS

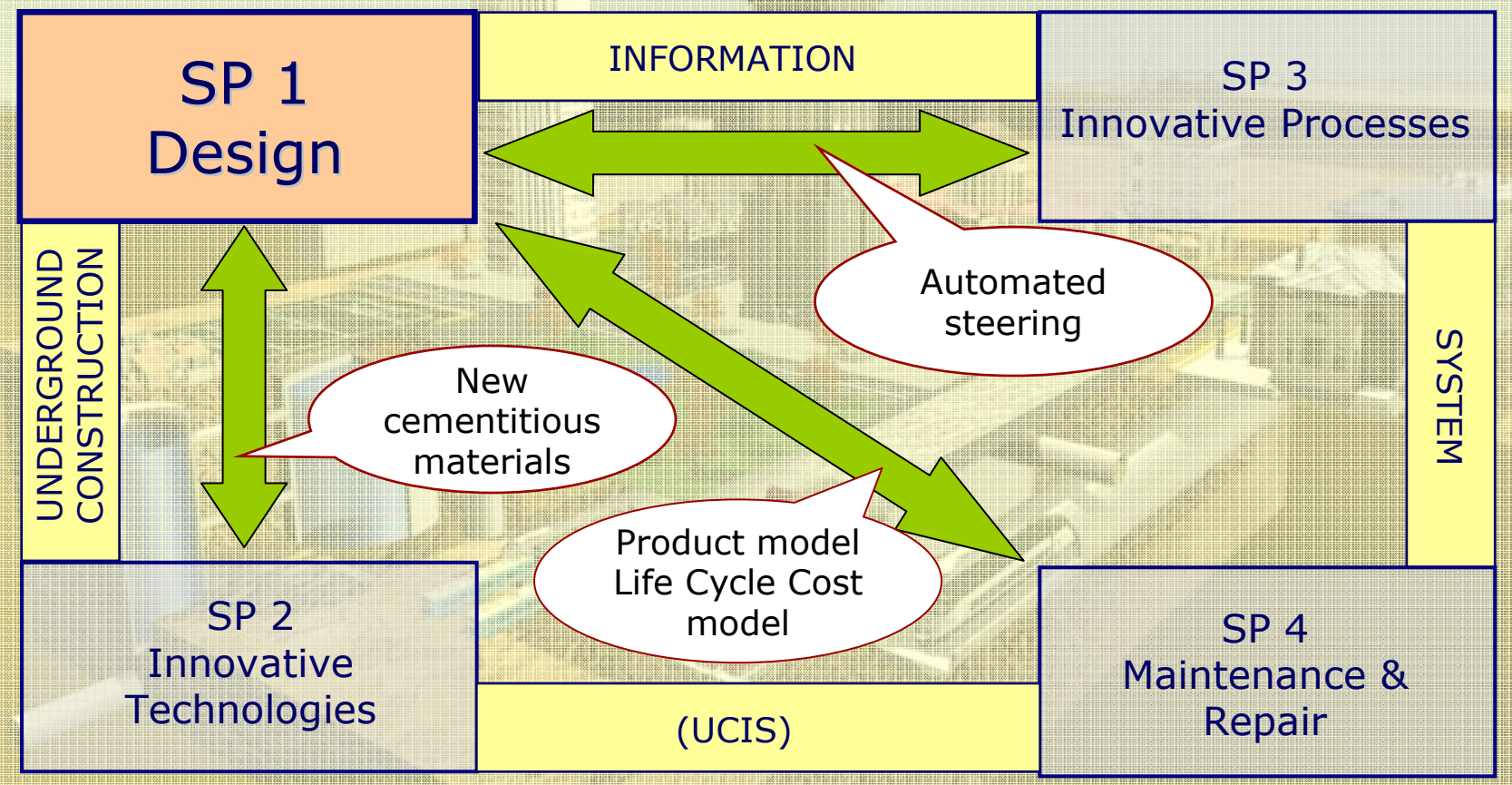
3D Simulations in TBM tunnelling





- ✓ Reliable prognoses of settlements (in particular in sensitive urban areas), stresses in tunnel lining etc.
- ✓ Insight into interacting mechanisms between individual components
- ✓ Sensitivity studies: Evaluation of influence of selected parameters
- ✓ Investigation of difficult soil conditions, identification of critical situations, failure of tunnel face
- ✓ Basis for optimization of design of tunnel excavation

European Research Initiative TUNCONSTRUCT



European Research Initiative TUNCONSTRUCT

Subproject 1: Design of Underground Construction

SP1
Design of underground structures

Günther Meschke (RUB-ISM)

16 partners

3 Companies
6 SME
7 HE

WP 1.1: Virtual underground construction
George Exadaktylos (TUC)

WP 1.2: Expert knowledge basis
Felix Amberg (Amberg)

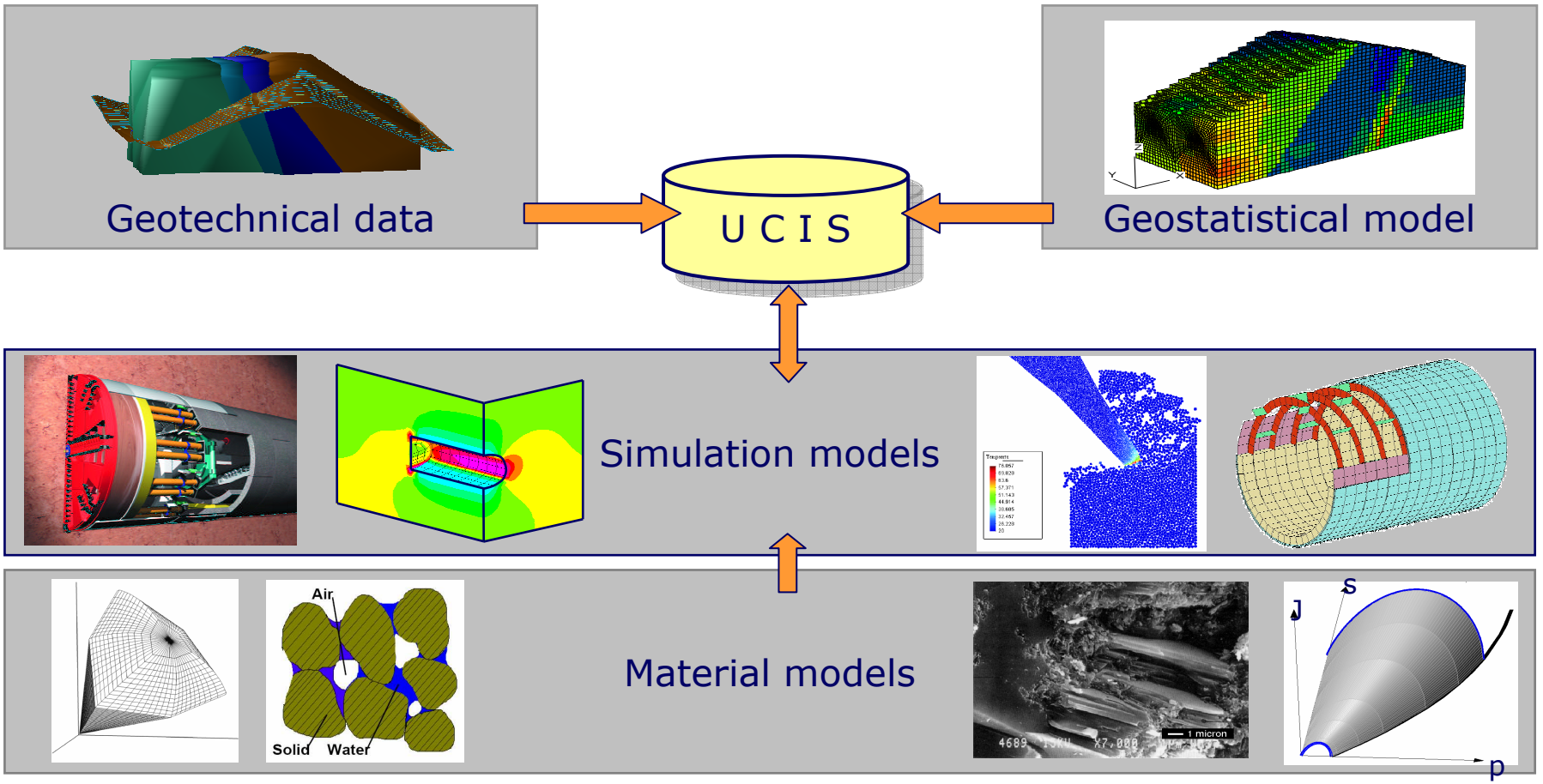
WP 1.3: Design support system
Wulf Schubert (TUG-IRMT)

WP 1.4: Integrated Optimization Platform
Dietrich Hartmann (RUB-ICE)

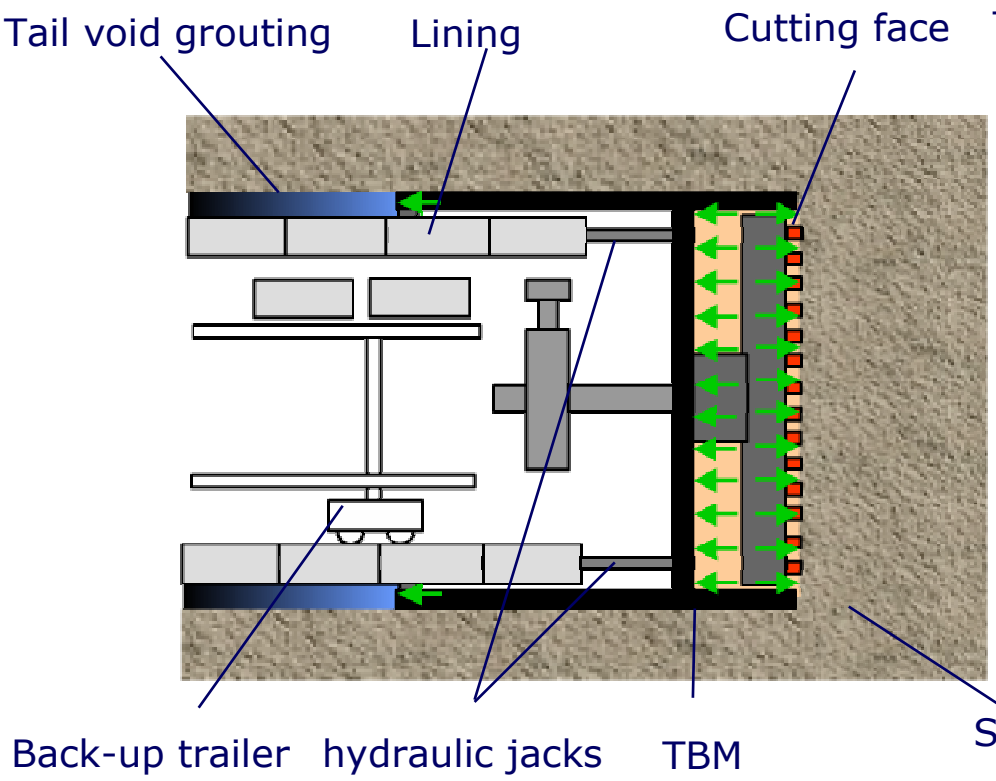
- Amberg (CH)
- Bouygues (F)
- C3M (SL)
- CIMNE (ES)
- Geodata (A)
- Maidl & Maidl (Ger)
- NCC (S)
- Univ. Bochum (Ger)
- TNO (NL)
- TU Crete (GR)
- TU Graz (A)
- TU Vienna (A)
- Univ. Barcelona (ES)
- Züblin (Ger)

European Research Initiative TUNCONSTRUCT

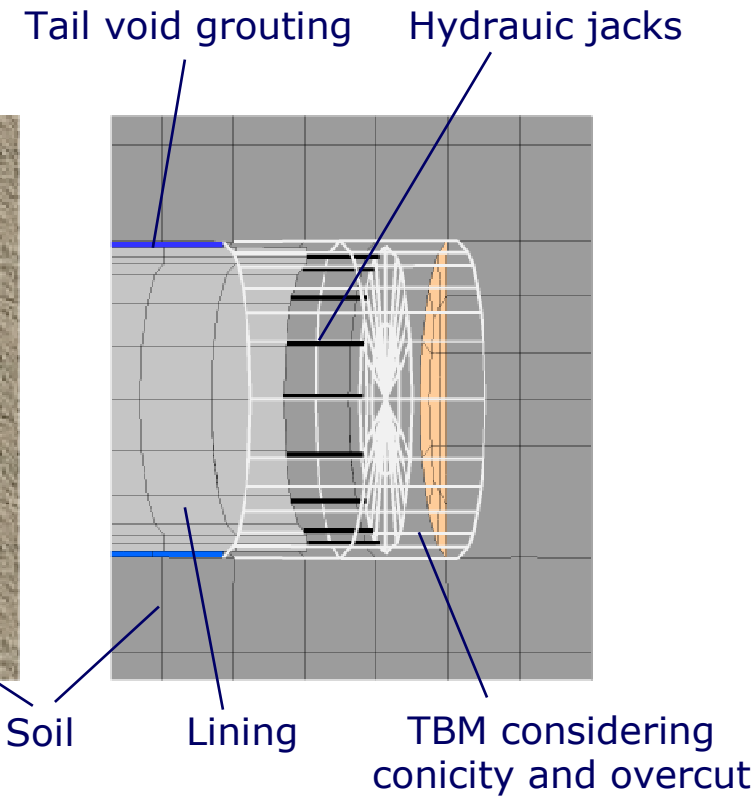
Integrated Concept for Numerical Simulation in Tunnelling



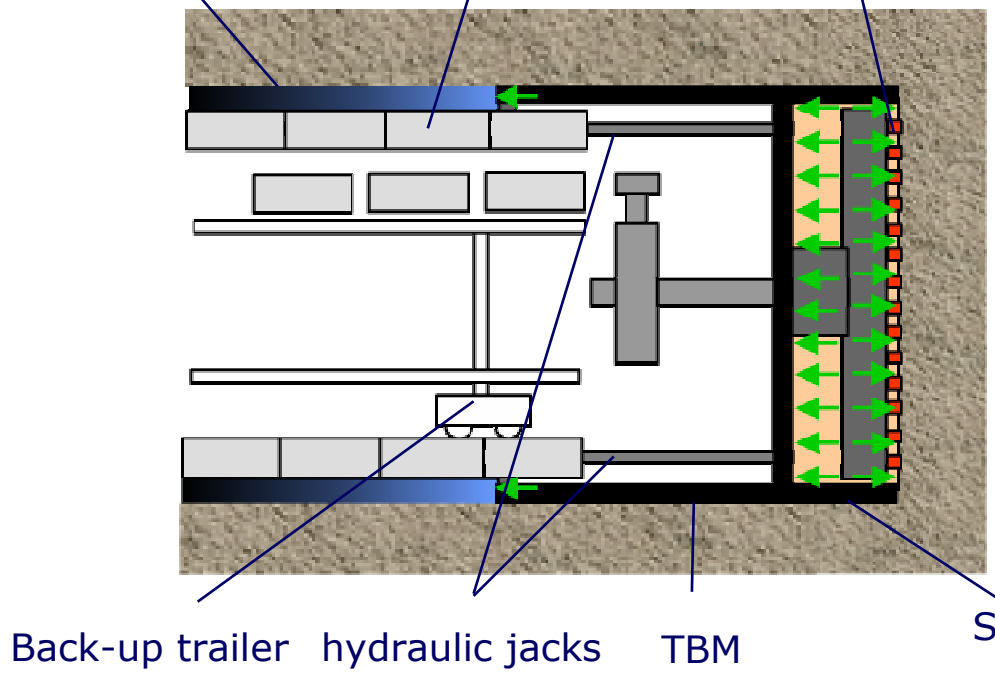
Construction process



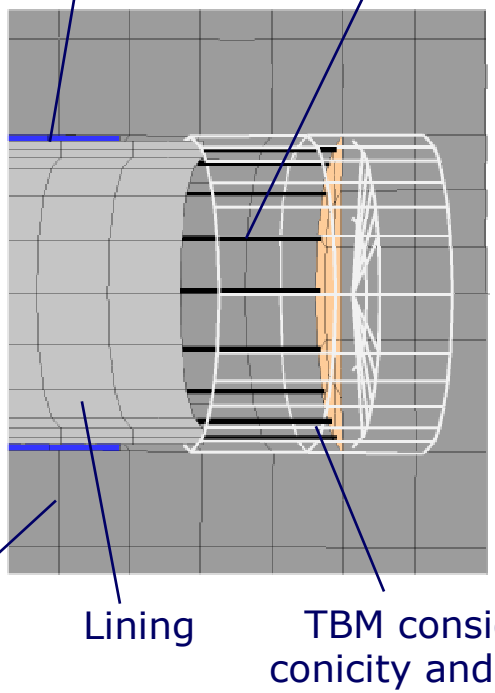
Simulation



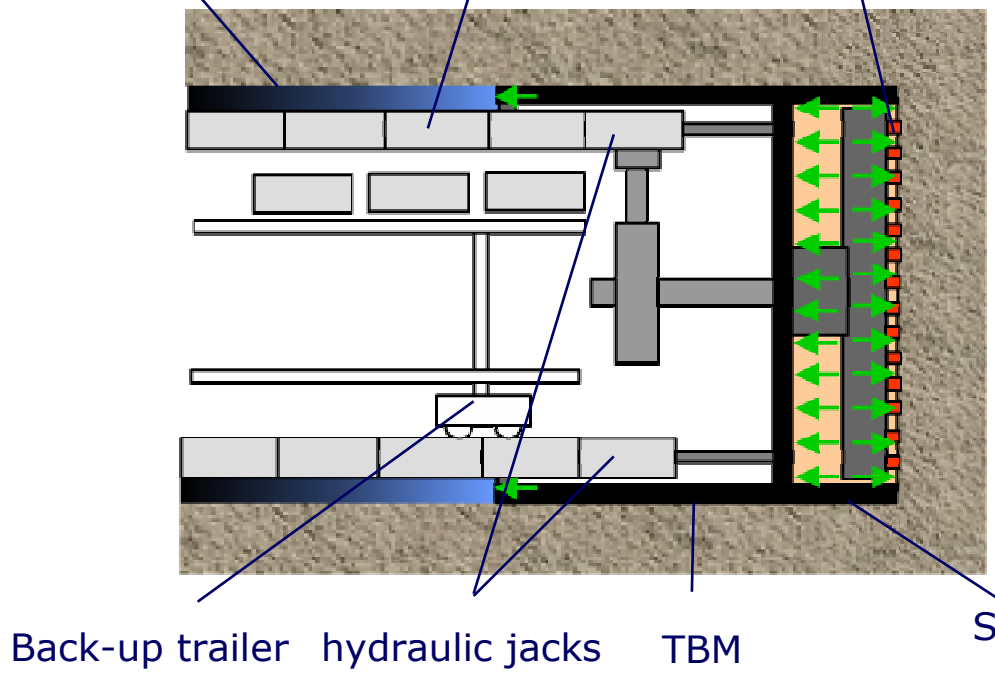
Construction process



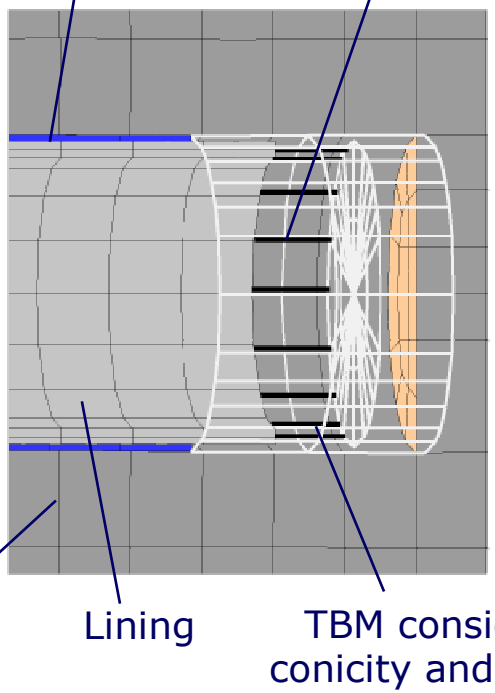
Simulation

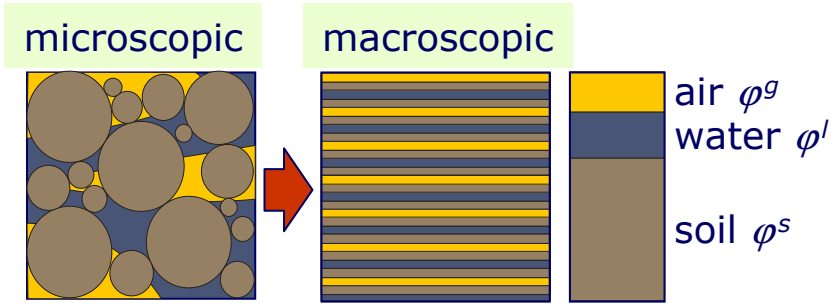


Construction process

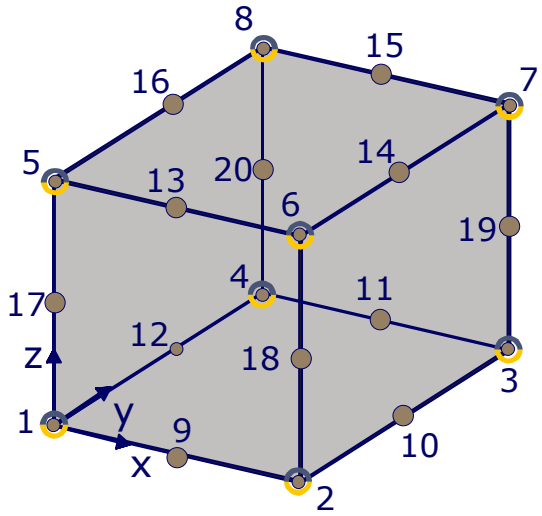


Simulation





Mixture theory for 3-phase materials



- Displacements $\mathbf{u}_s$
- Gaseous & liquid pressure p^l, p^g

Modelling of partially saturated soils

Balance of momentum

$$\operatorname{div}\boldsymbol{\sigma} + \rho\mathbf{b} = 0$$

Balance of mass of gaseous phase

$$\frac{\partial \phi^g \rho^g}{\partial t} + \phi^g \rho^g \operatorname{div}\mathbf{w}^g = 0$$

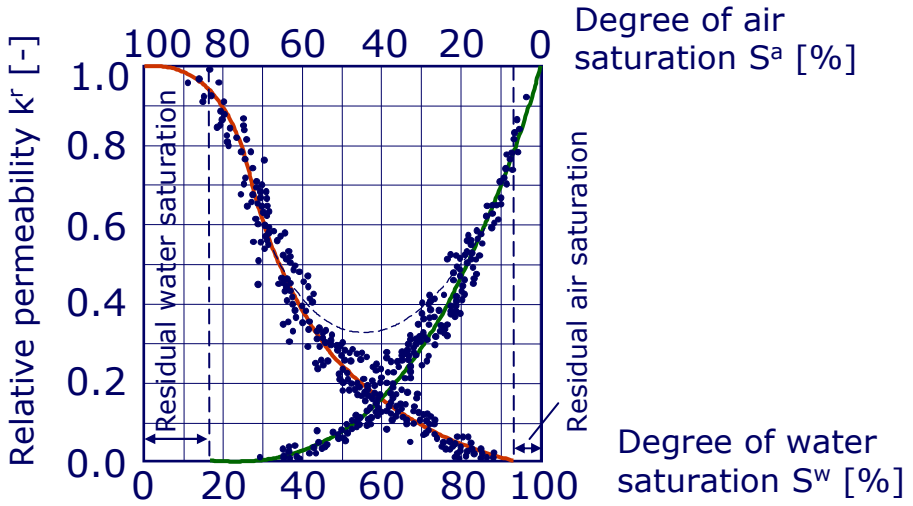
Balance of mass of liquid phase

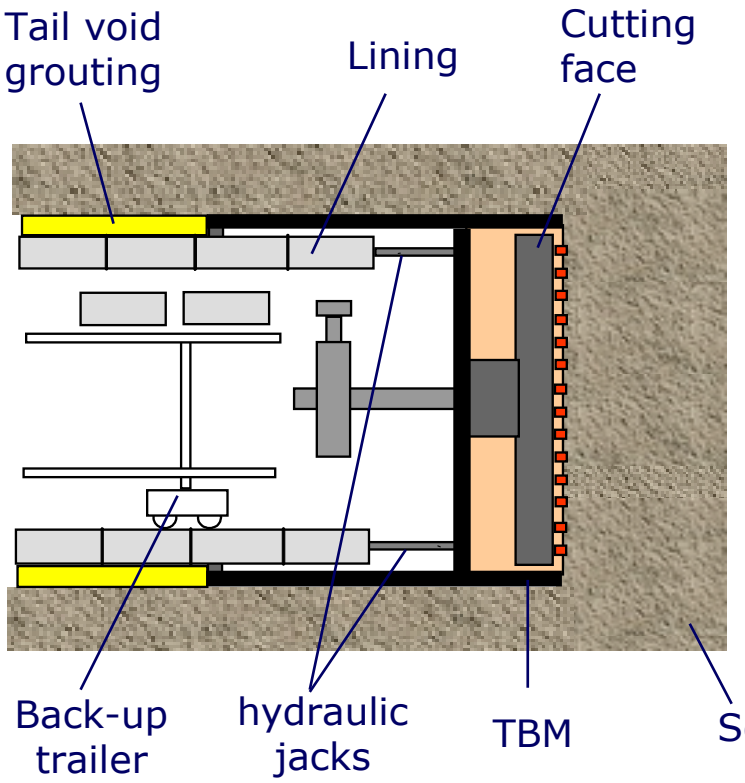
$$\frac{\partial \phi^l}{\partial t} + \phi^l \operatorname{div}\mathbf{w}^l = 0$$

DARCY – law for fluid phases

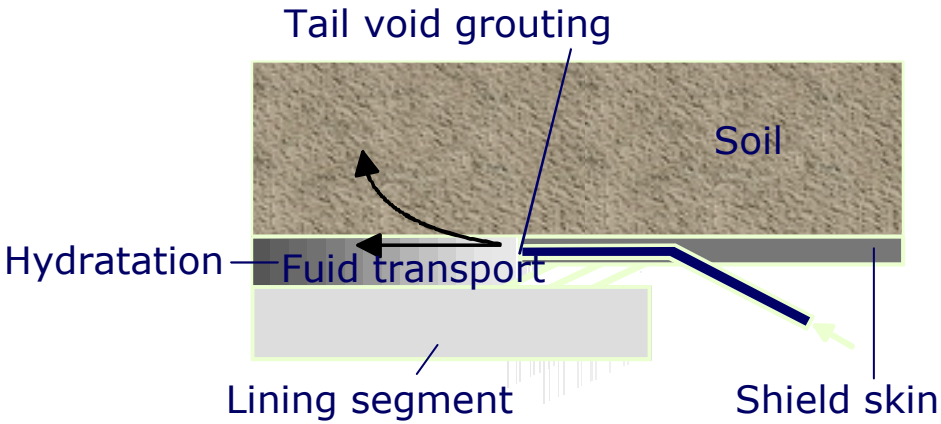
$$\mathbf{q}^\beta = \frac{k^\beta}{\mu^\beta}\left(-\nabla p^\beta + \rho^\beta \mathbf{g}\right)$$

Relative permeabilities k^g and k^l according to VAN GENUCHTEN (1985)

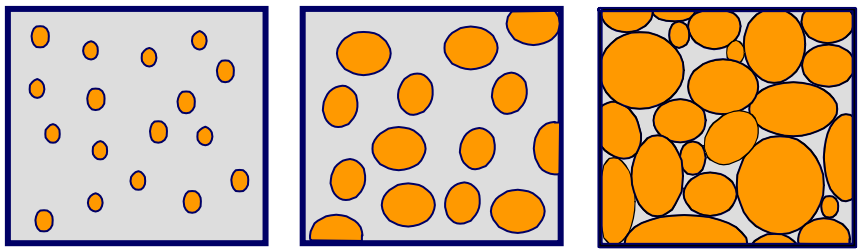




Modelling of tail void grouting

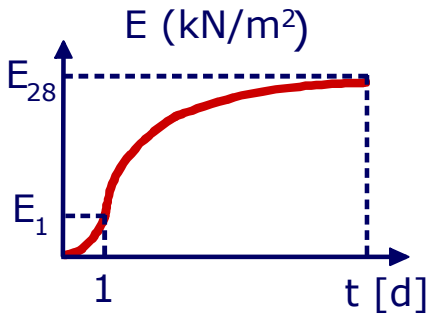


2-phase material with hydratation-dependent stiffness and permeability

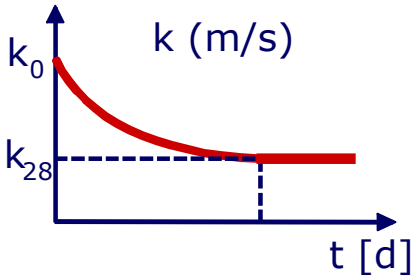


$t = 0,\ \nu_s \sim 0$ $\qquad$ $t > 0,\ \nu_s > 0$

Accounts for interactions between grout and soil

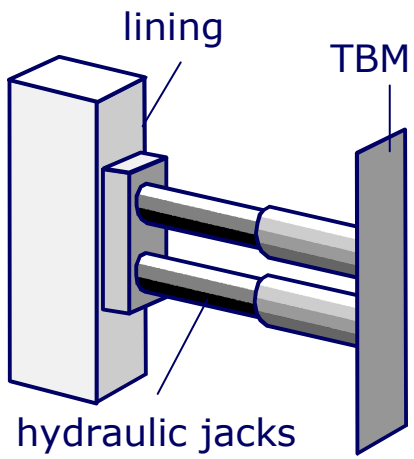


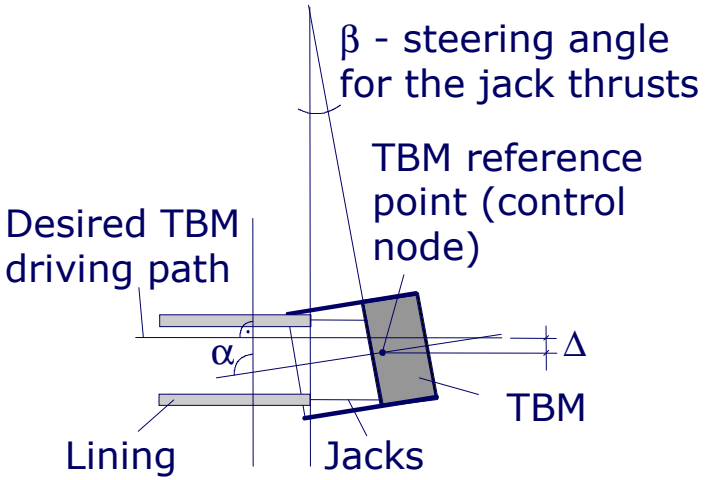
Elasticity modulus



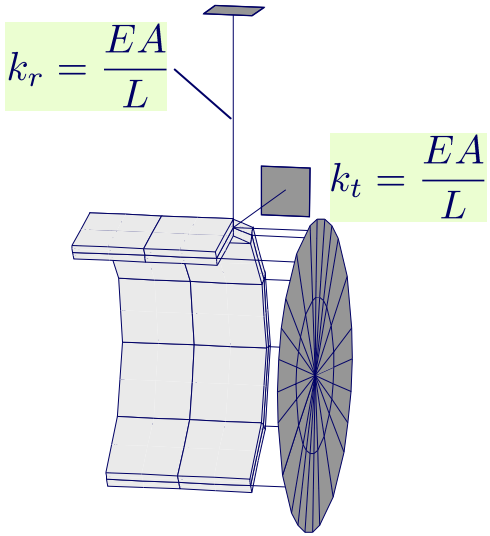
Permeability

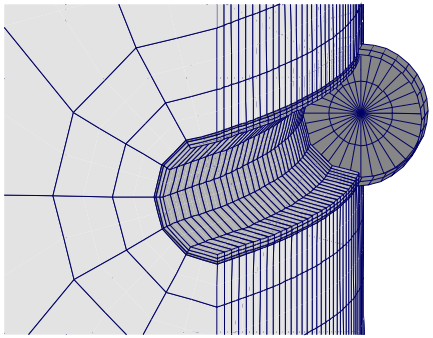
Construction

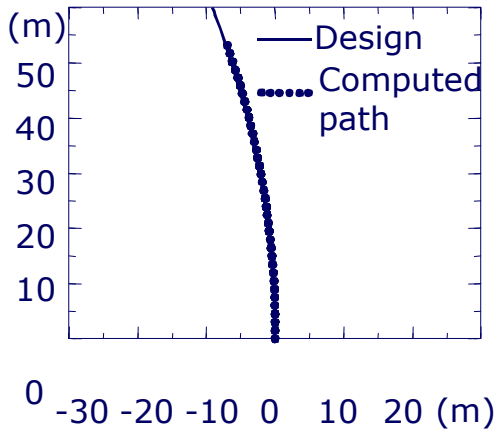




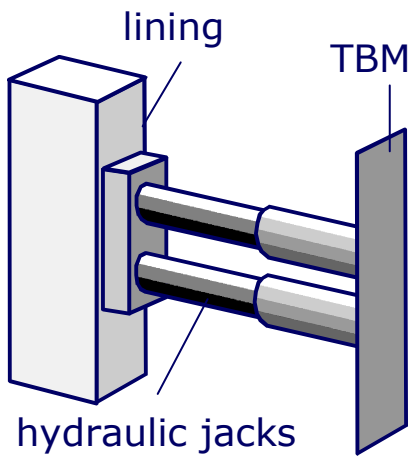
Simulation

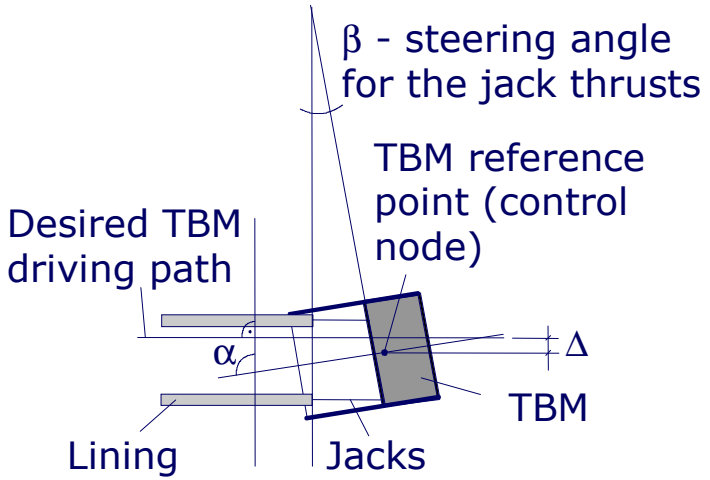




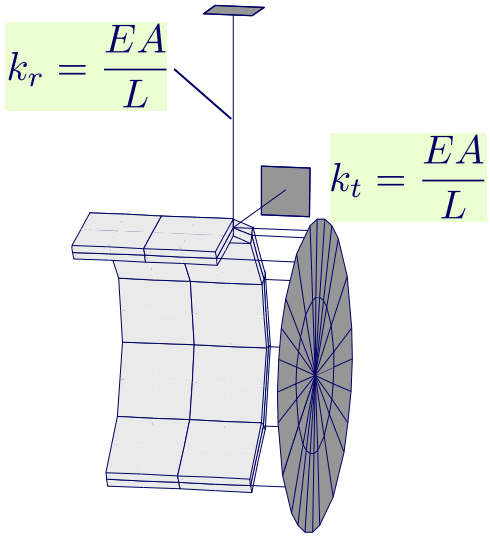


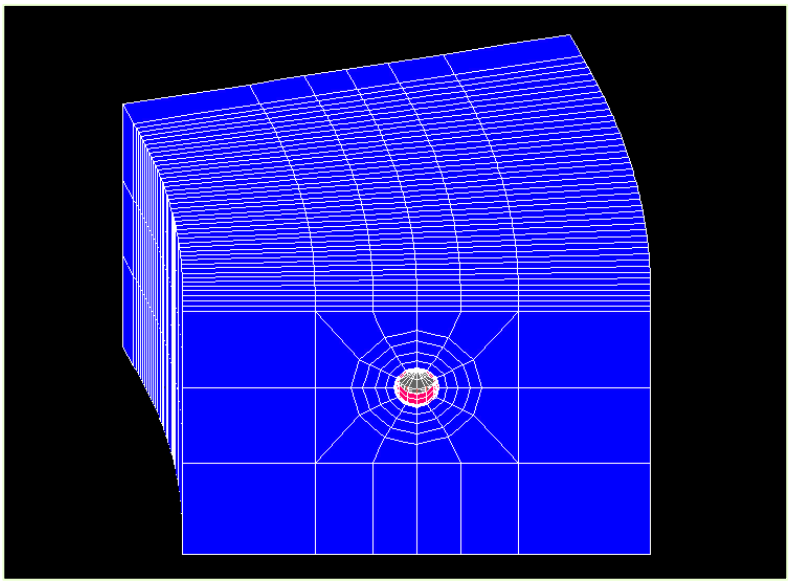
Construction



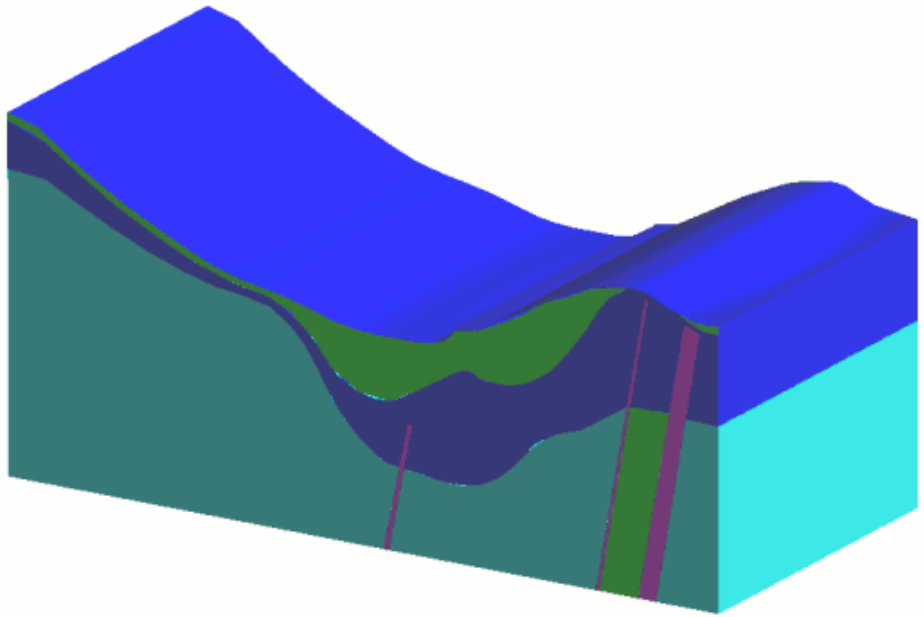


Simulation

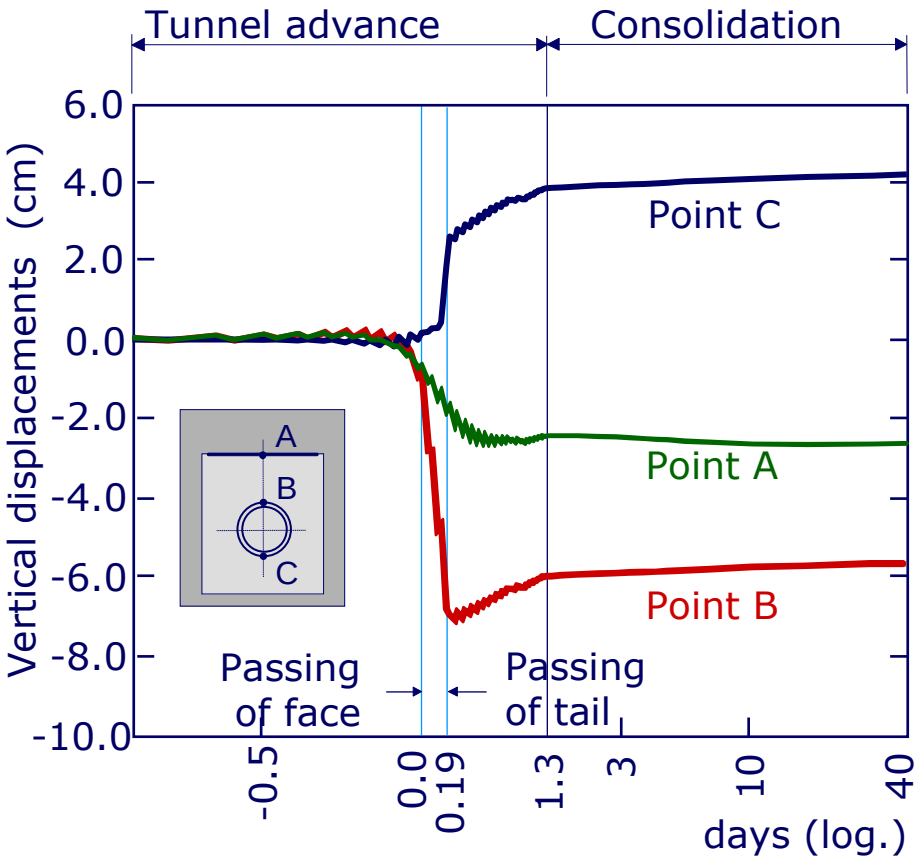


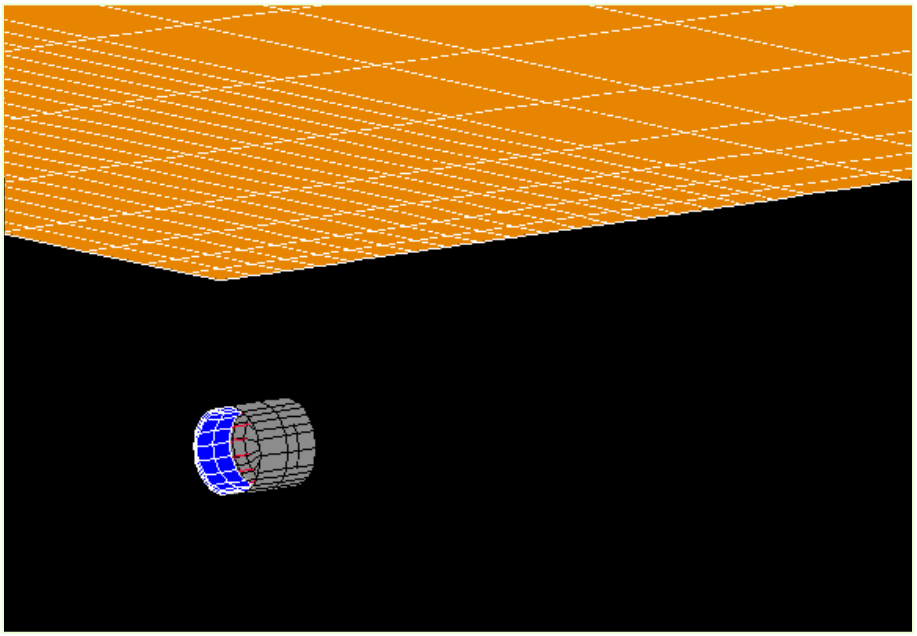


Integration of geological, geotechnical and simulation model

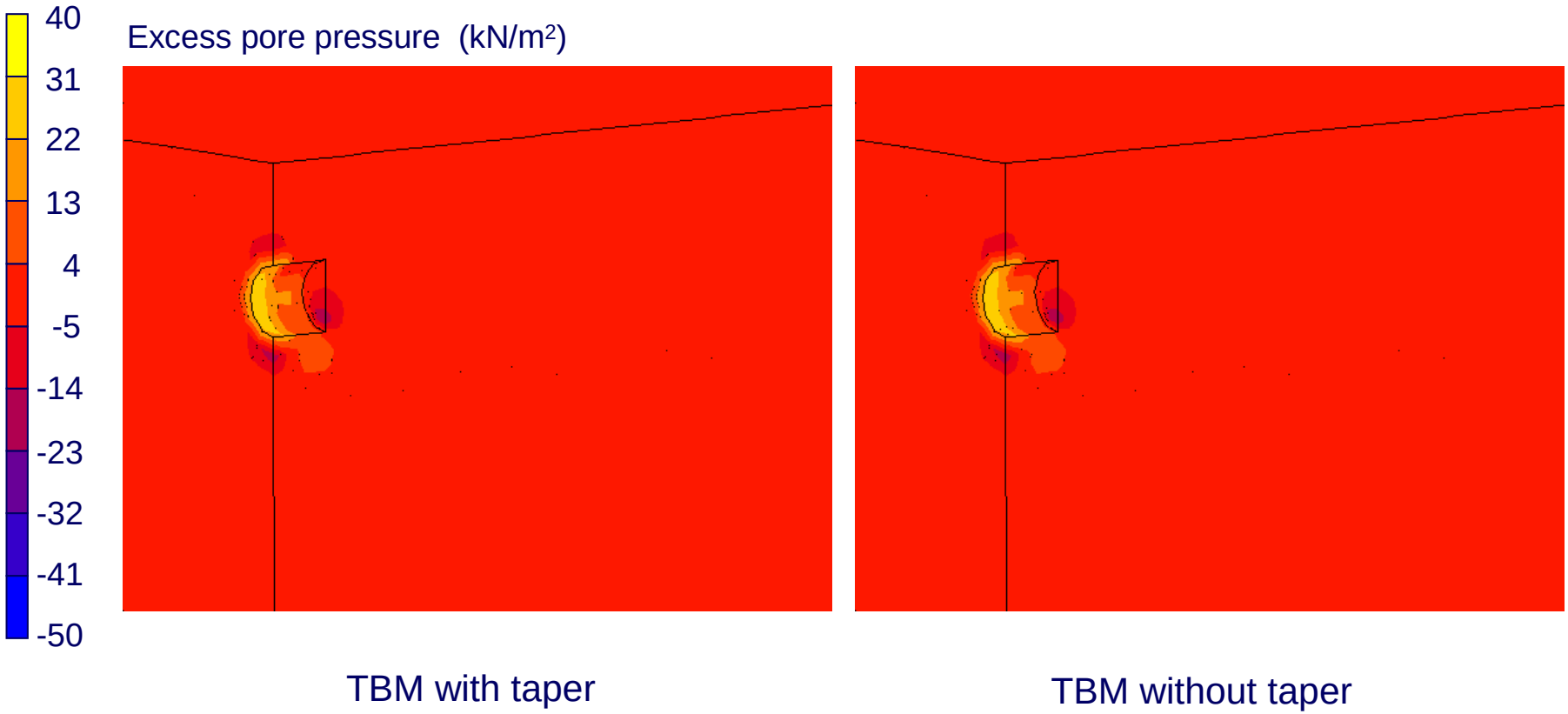


Prognosis of settlements

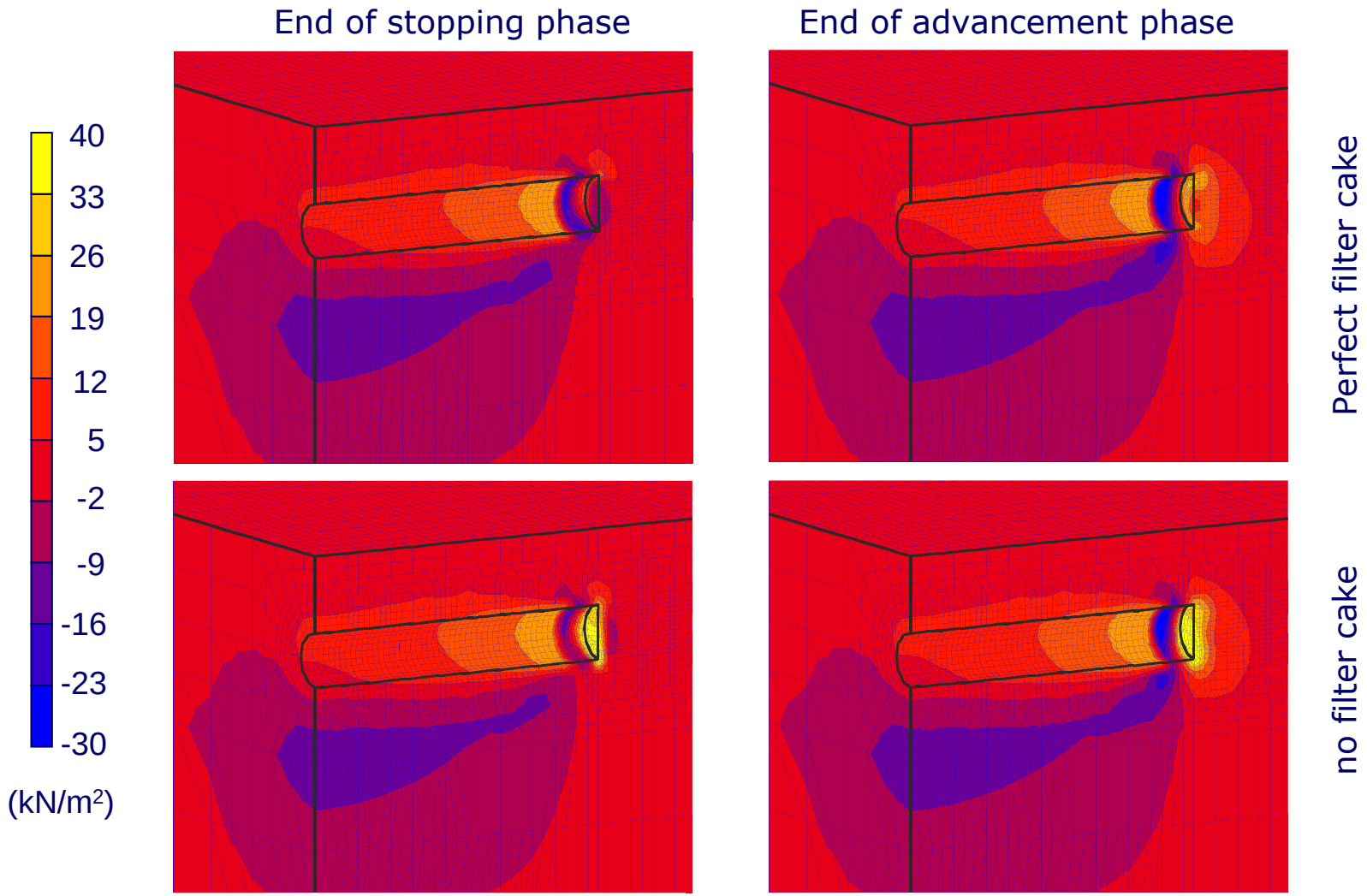




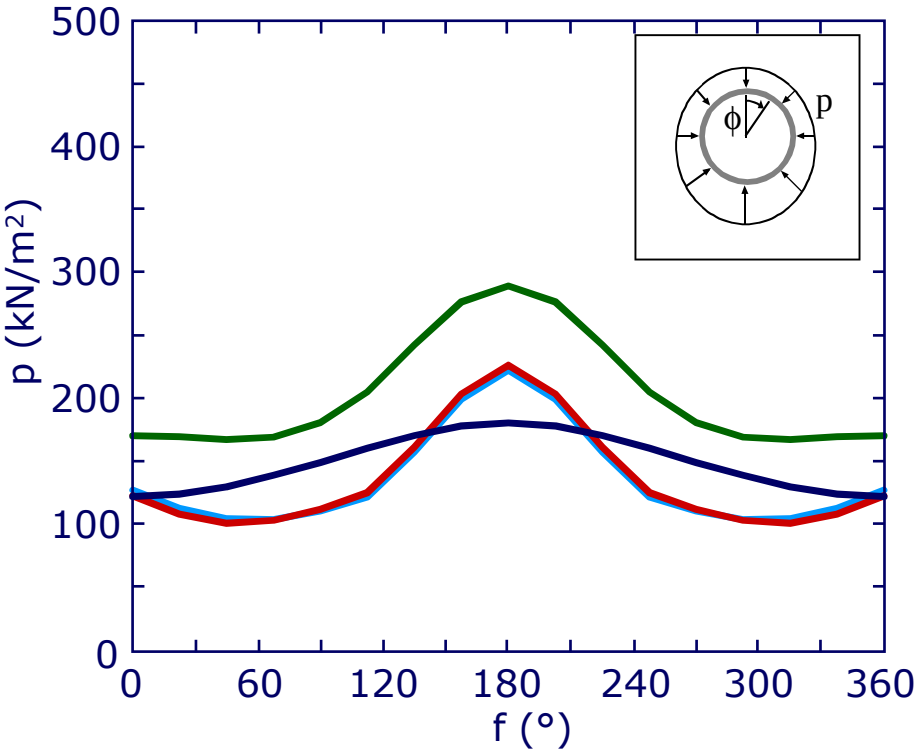
Computed excess pore pressures during the tunnel advance



Computed excess pore pressures during tunnel advance – Influence of filter cake



Computed lining pressure in the monitoring section



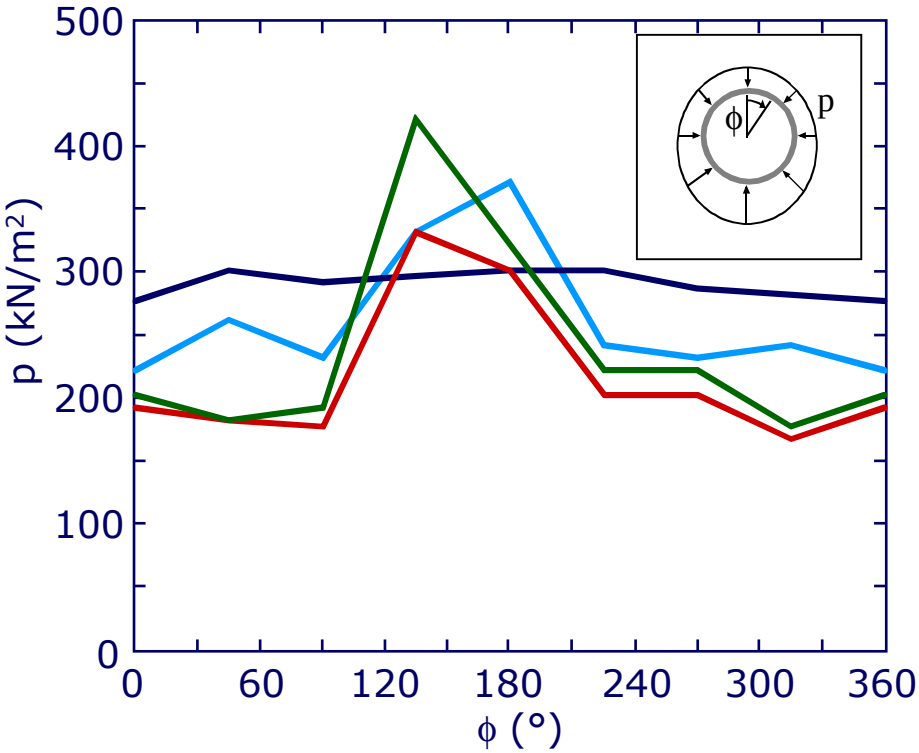
— At TBM tail

— 27 m behind shield t = ∞

— 5 lining rings behind shield

— Initial earth and pore pressure

Measured lining pressure on a tunnel in Japan [HASHIMOTO 2002]



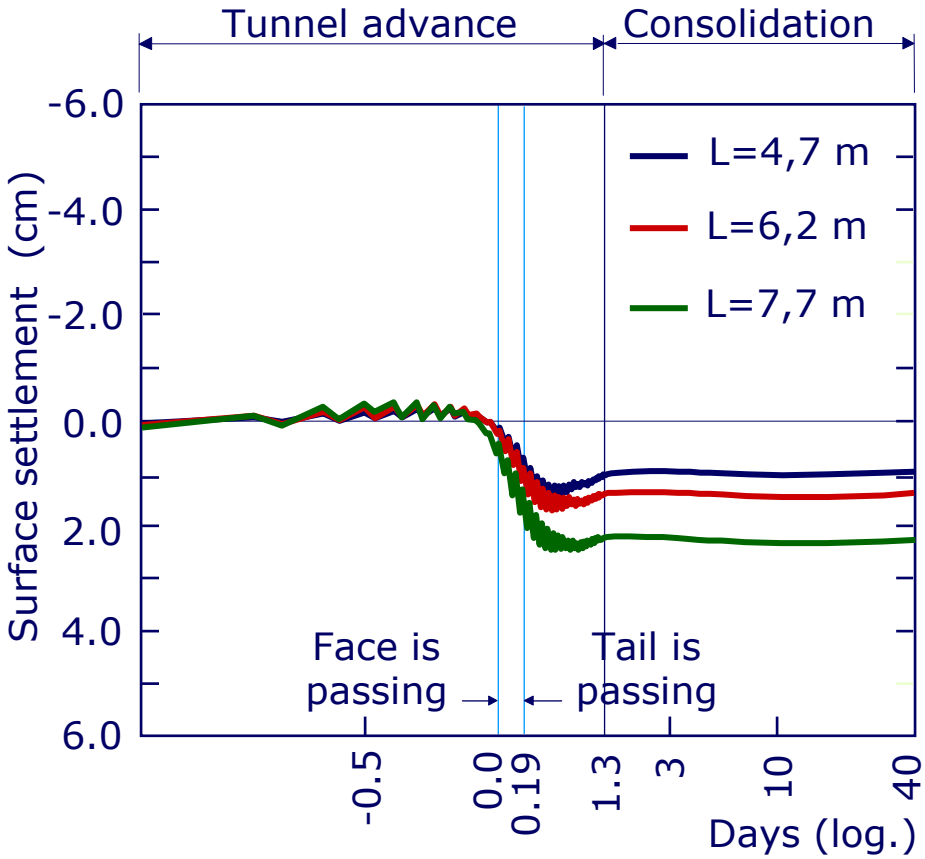
— At TBM tail

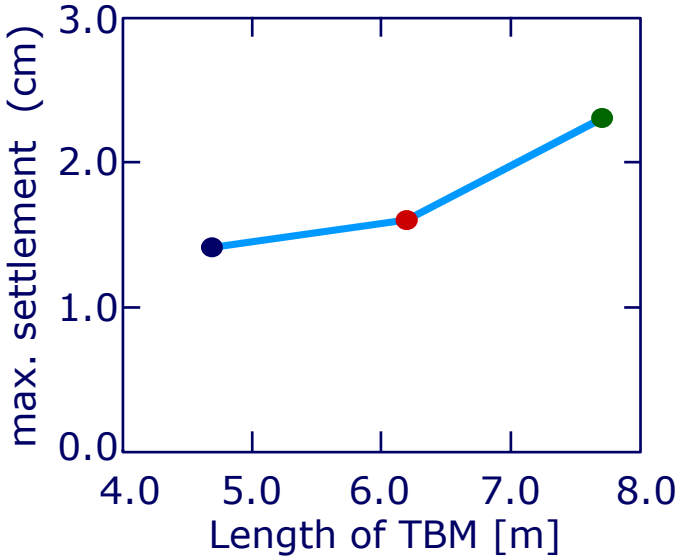
— 1 month after passing of tail

— 5 lining rings behind shield

— 6 months after Passing of tail

Geometry-related parameters: Influence of length of TBM





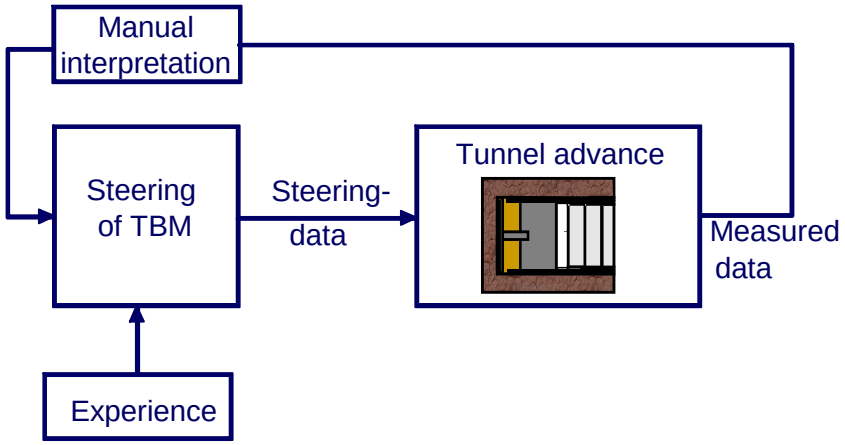
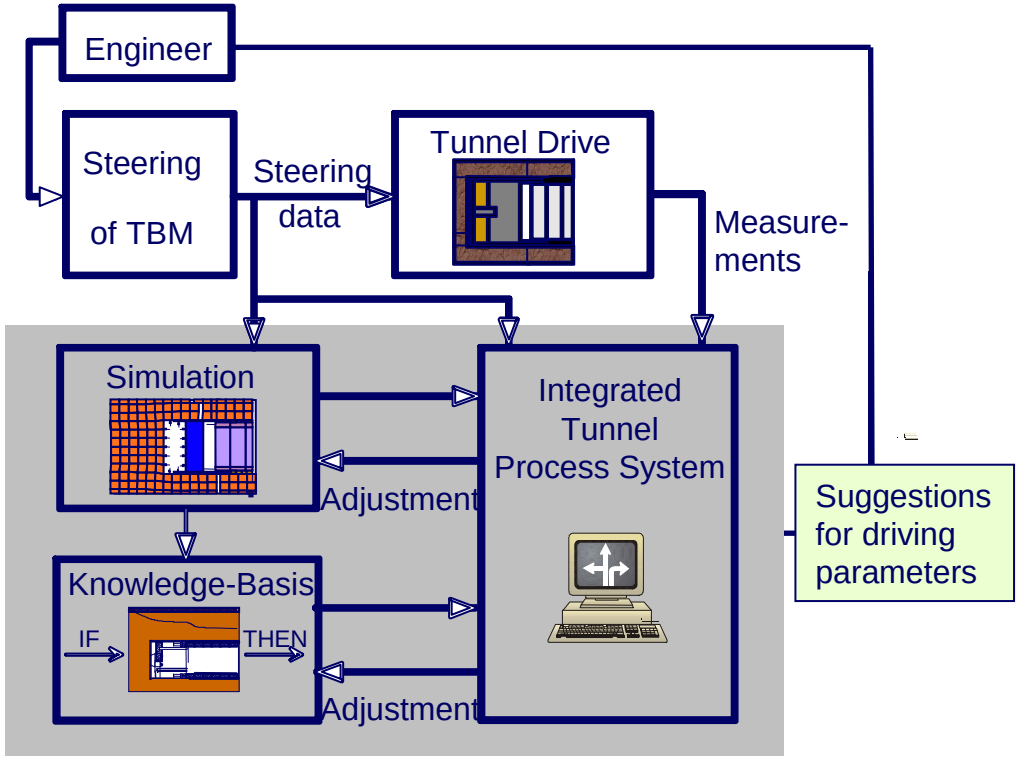
Influence on surface settlements

European Research Initiative TUNCONSTRUCT

Decision Support System for steering of TBM's

- Support of tunnel excavation by means of information and process management system
- Integration of numerical simulation and Methods of Computational Intelligence in real time

Current state



Mid-term perspective