Long-term behavior of lined tunnels excavated in squeezing ground

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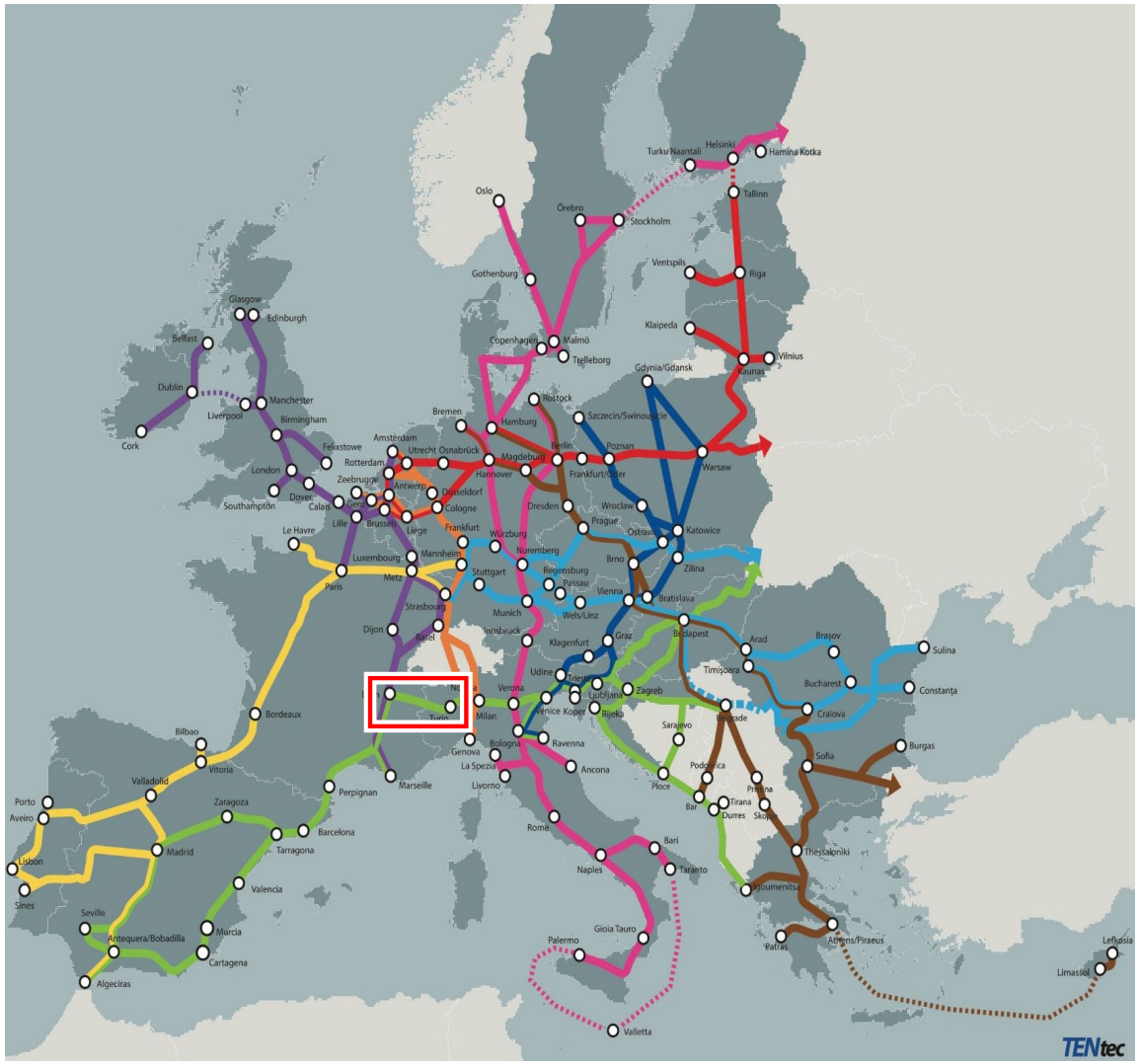
Outline

1. Background
2. Numerical modeling
3. Results and discussion
4. Conclusions and outlook

1. Background

Trans-European Transport Network (Ten-T) project

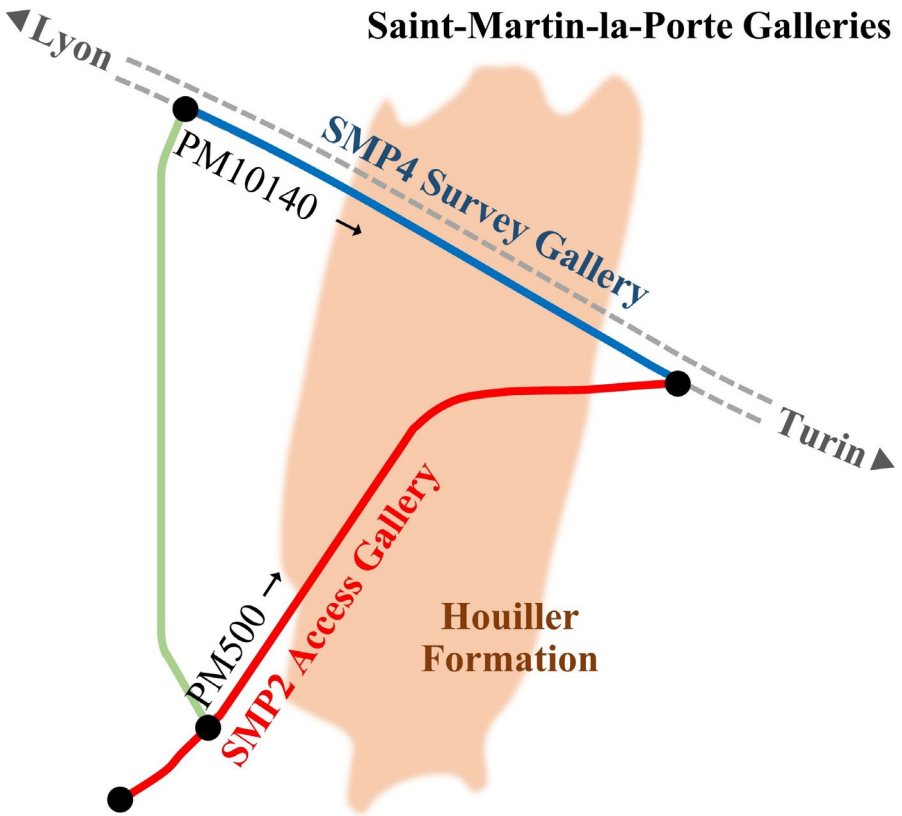


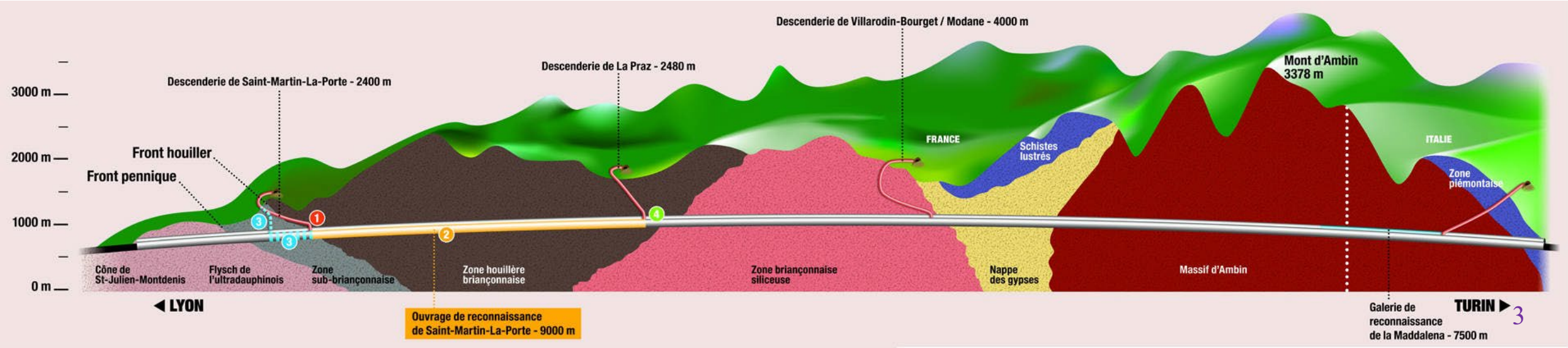
Lyon-Turin railway link

57.5 km twin-tube base tunnel

(45 km on the French side and 12.5 km on the Italian side)

Saint-Martin-la-Porte access gallery (SMP2) : $R \sim 5.5\ m$

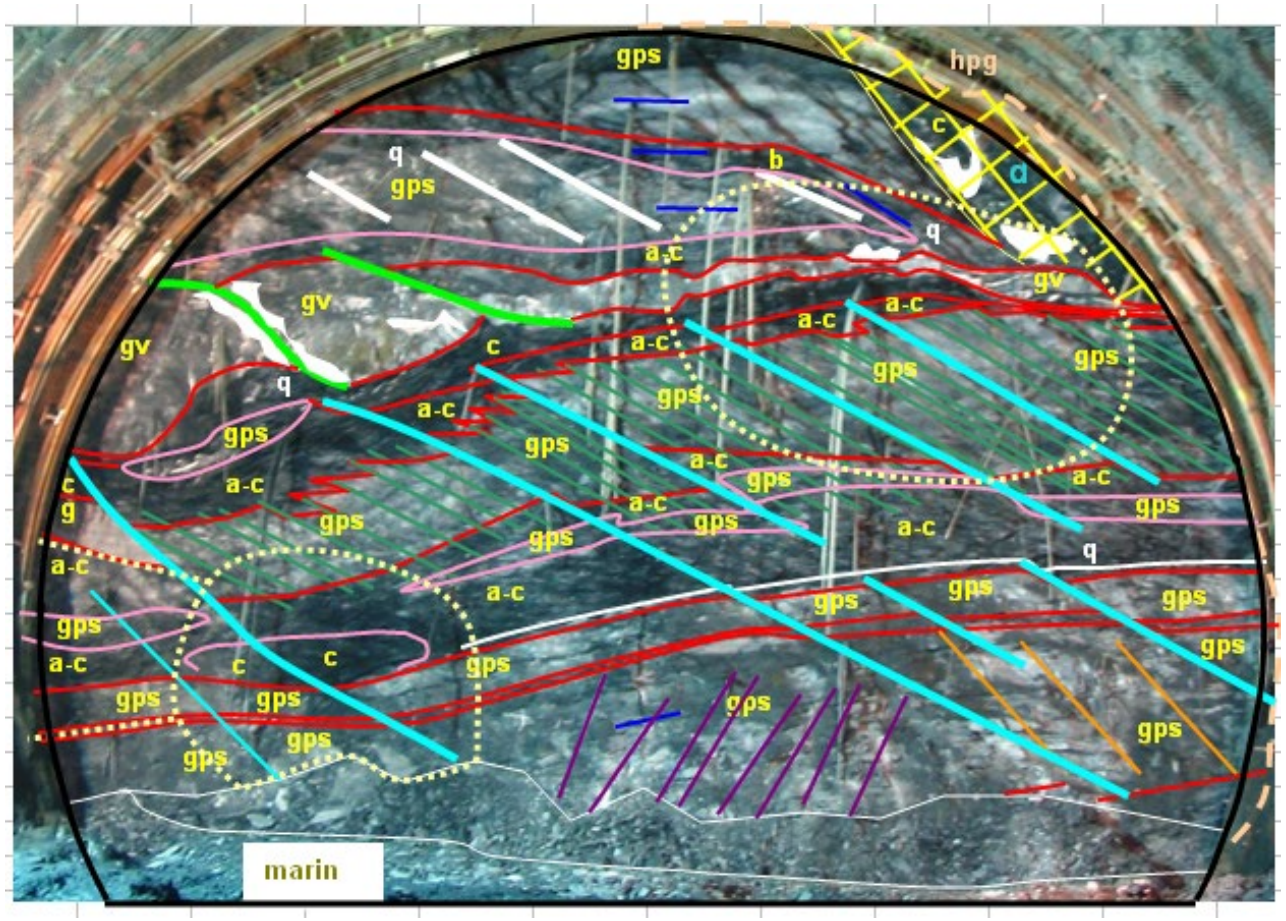


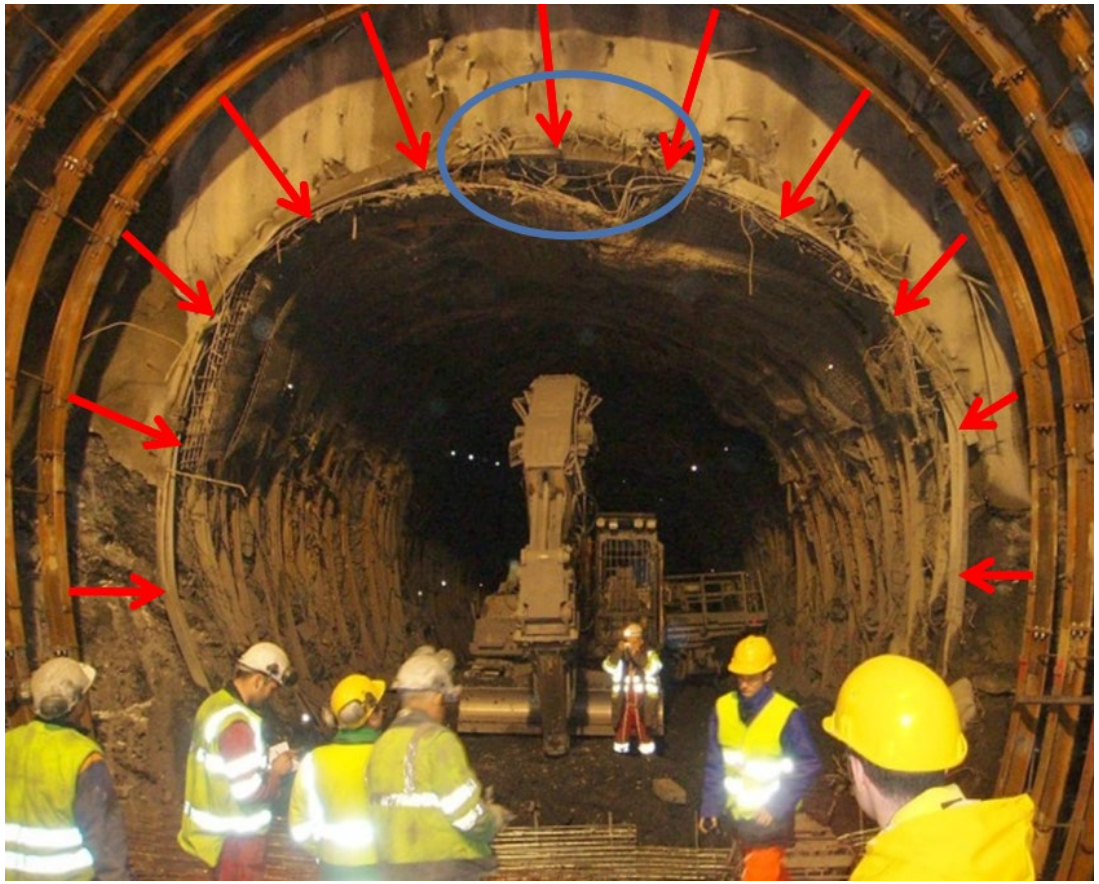


Geological context

Productive Houiller at a depth of 300 m: highly tectonized structure (schists, sandstone, coal …)

Evidence of squeezing behavior: anisotropic and time-dependent convergences

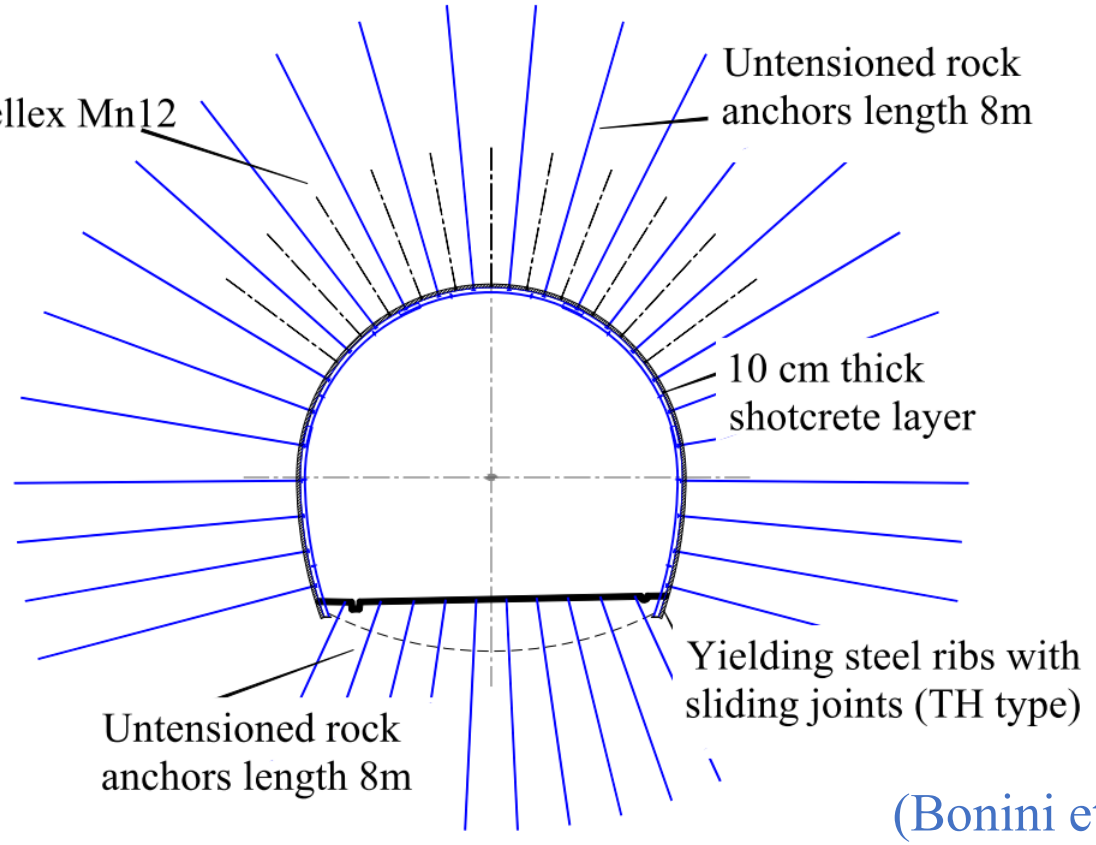




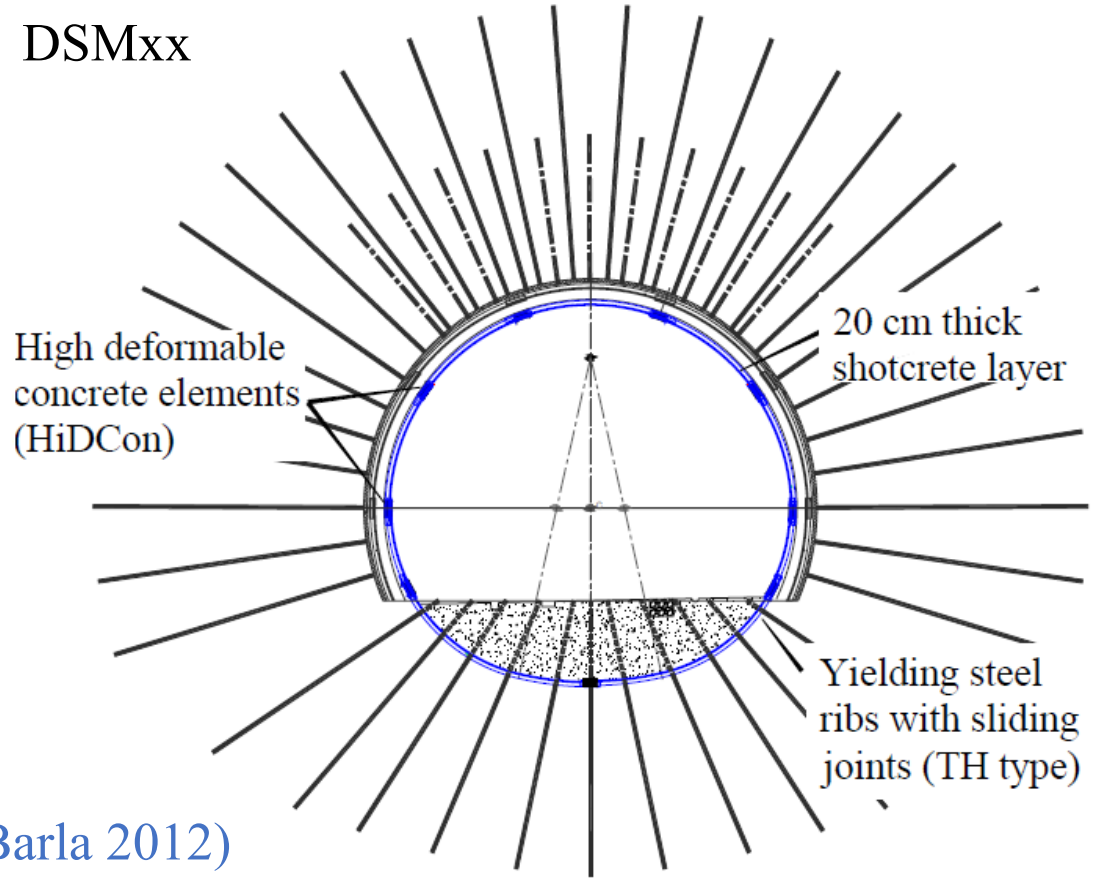
(Mathieu 2008; Barla et al. 2012)

Support systems

P7-3



DSMxx



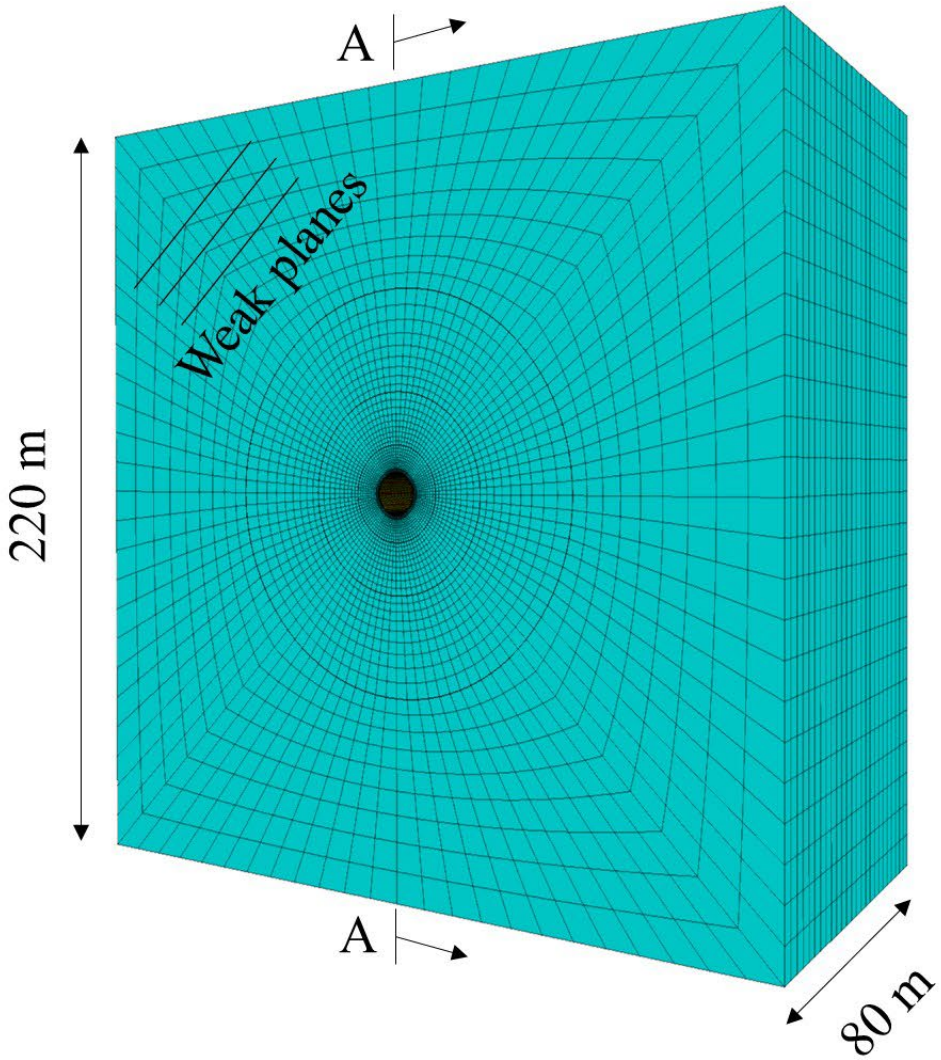
(Bonini et Barla 2012)

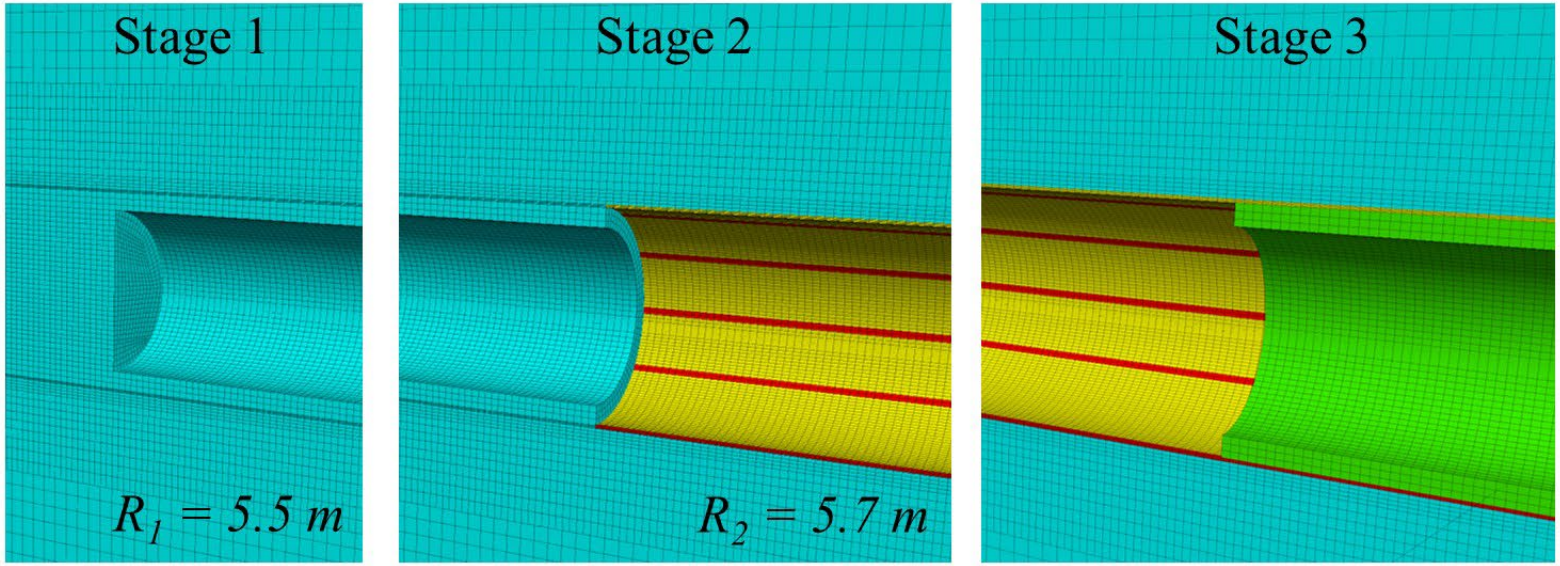
Objective

Modeling of long-term response of SMP2 (chainage 1383 m) considering the specific support method and the re-profiling process

2. Numerical modeling

FLAC3D simulation in large-strain mode (σ_0 = 8.5 MPa)

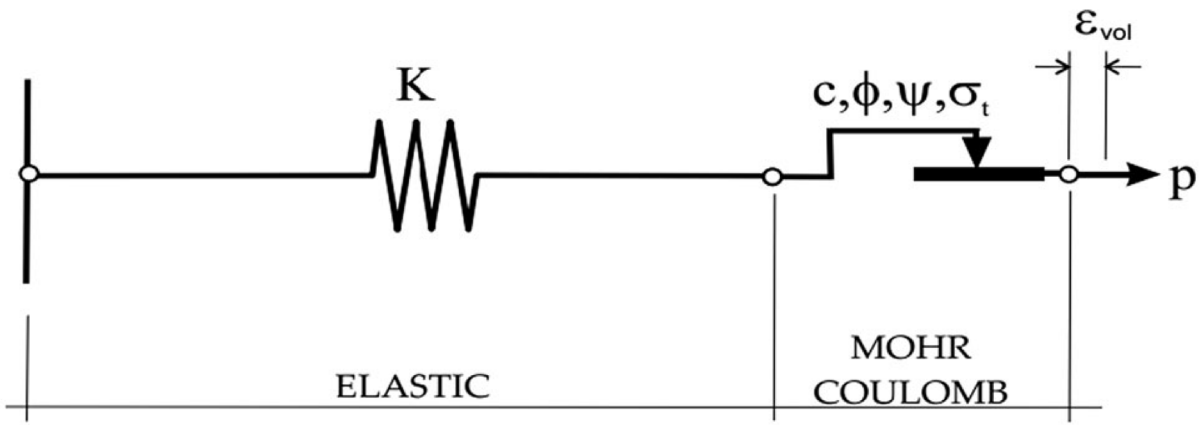




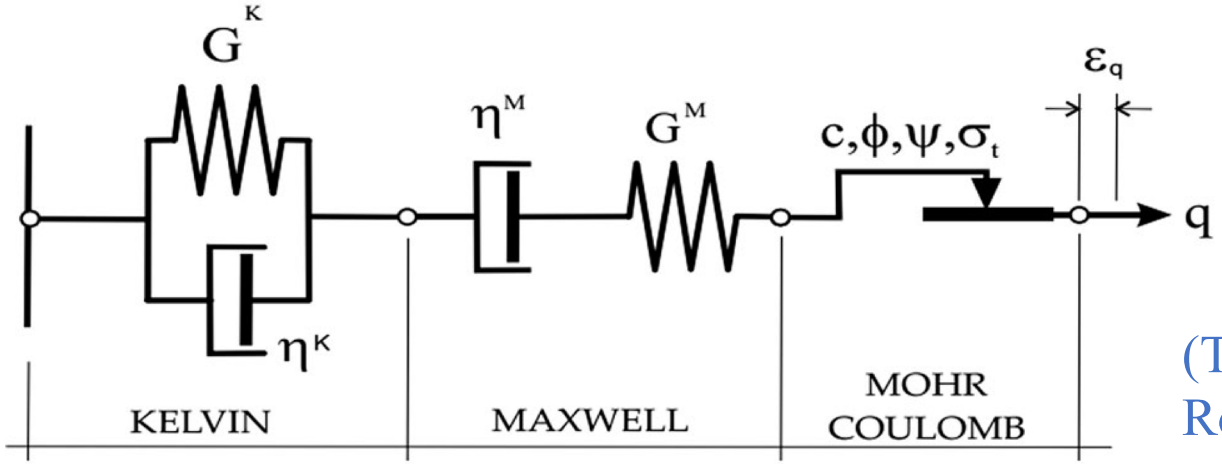
Side view of the cutting plane A-A

- Ground
- Shotcrete (thickness: 20 cm)
- Highly deformable concrete element (thickness: 20 cm)
- Coffered concrete ring (thickness: 90 cm)

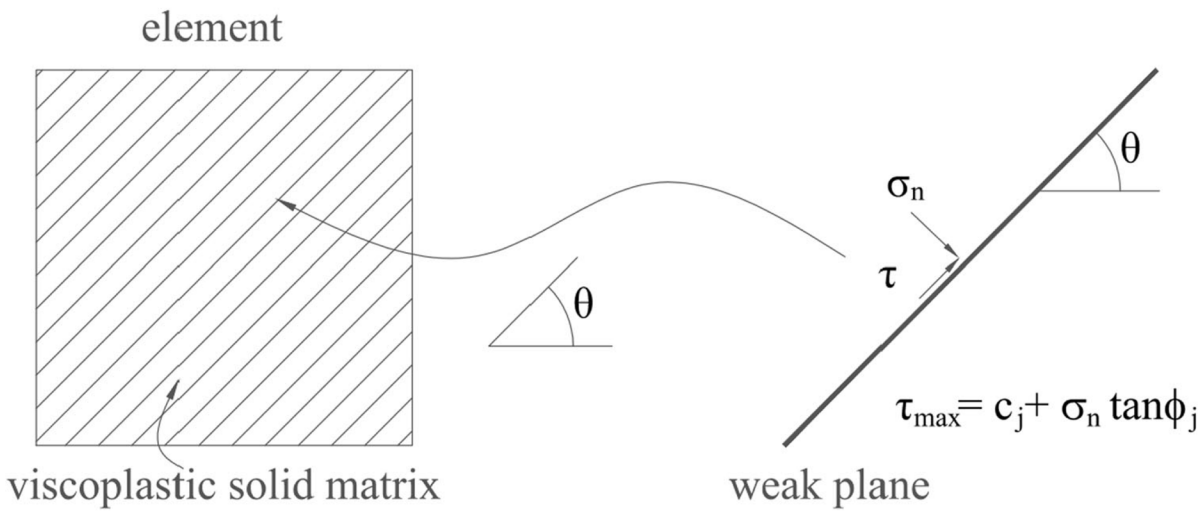
Modeling of the ground: CVISC model and ubiquitous-joint approach



CVISC model: volumetric behaviour.

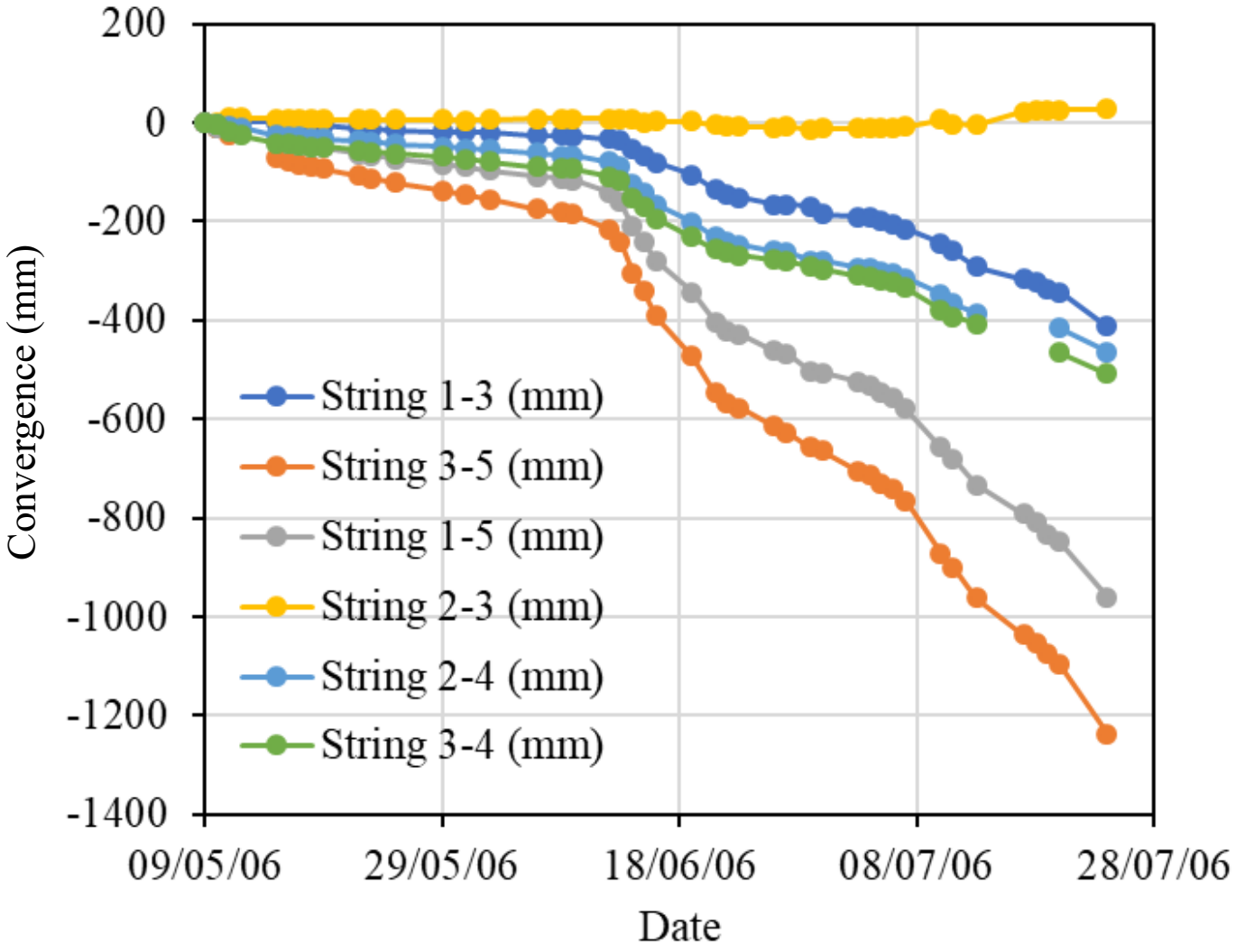


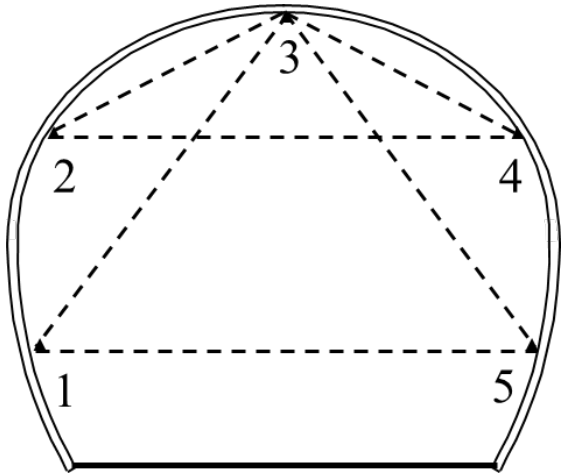
CVISC model: deviatoric behaviour.

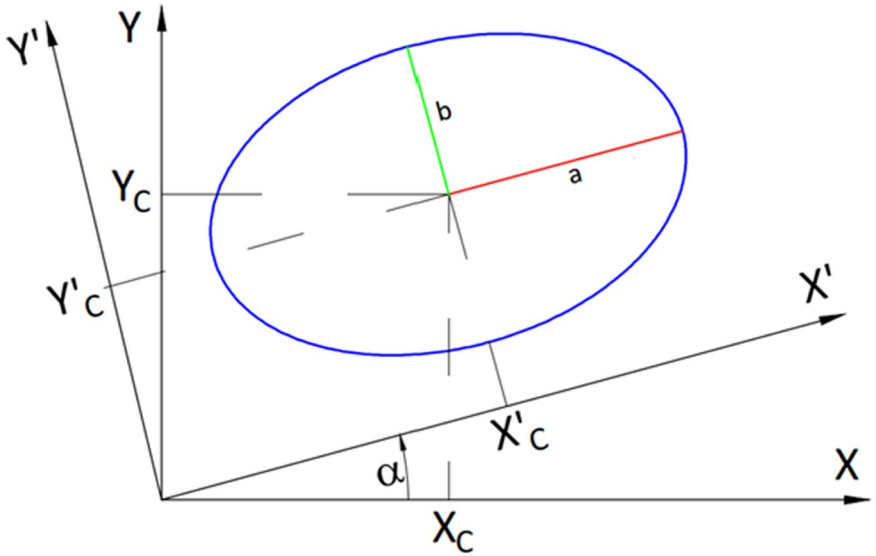


(Tran-Manh, H., Sulem, J., Subrin, D., & Billaux, D. (2015). Rock Mechanics and Rock Engineering, 48(6), 2301–2317.)

Convergence measurements



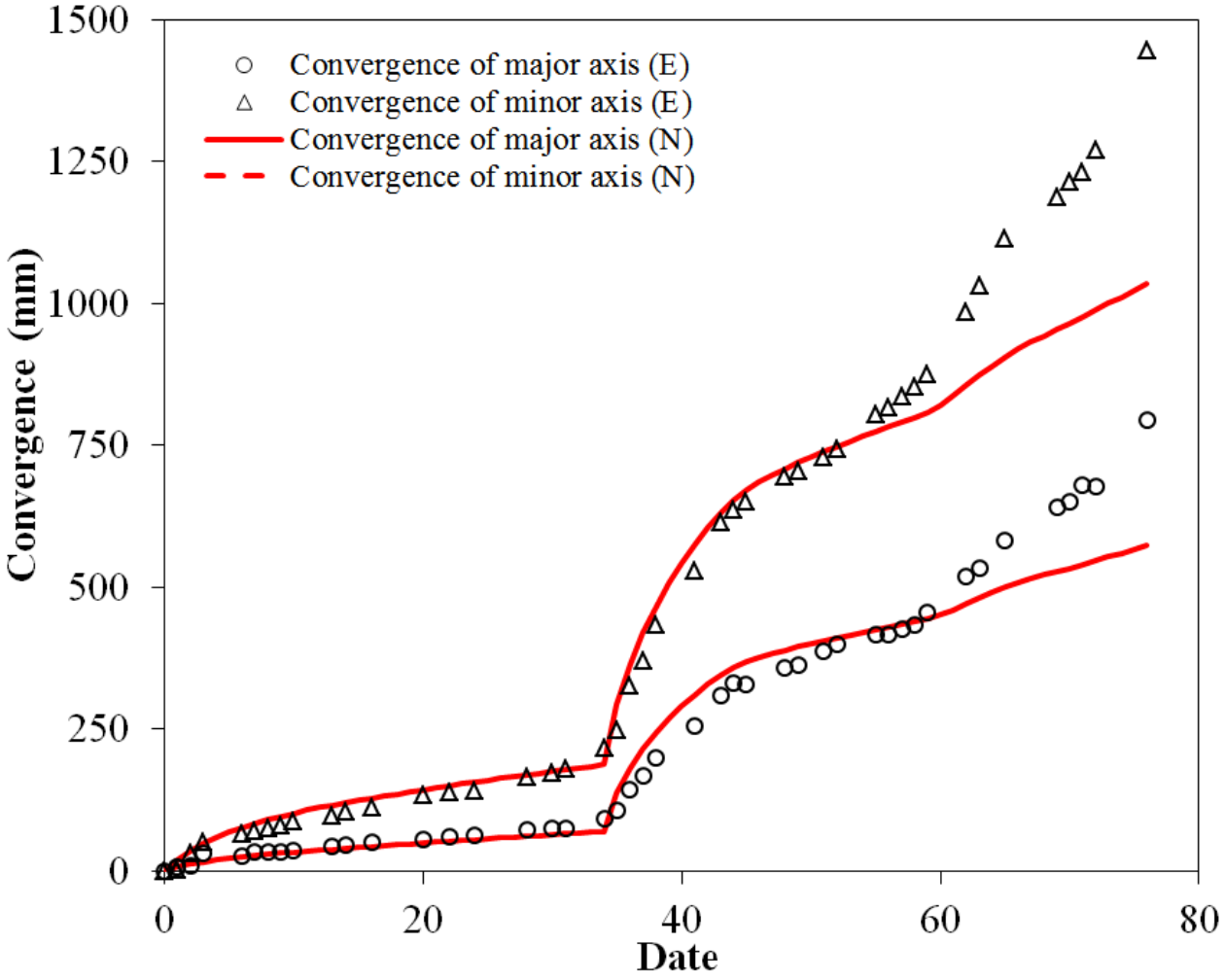




(Tran-Manh, H., Sulem, J., Subrin, D., & Billaux, D. (2015). Rock Mechanics and Rock Engineering, 48(6), 2301–2317.)

Calibration of the rock mass parameters from convergence data of the unlined tunnel (Chainage 1384 m)

Solid matrix		
E	(MPa)	650
ν	()	0.3
G^K	(MPa)	550
η^K	(GPa.day)	2.2
η^M	(GPa.day)	13.75
c	(MPa)	1.20
φ	(°)	26
σ_t	(kPa)	8.5
ψ	(°)	0
Joint		
c_j	(MPa)	0.42
φ_j	(°)	23
σ_j	(kPa)	8.5
ψ_j	(°)	0

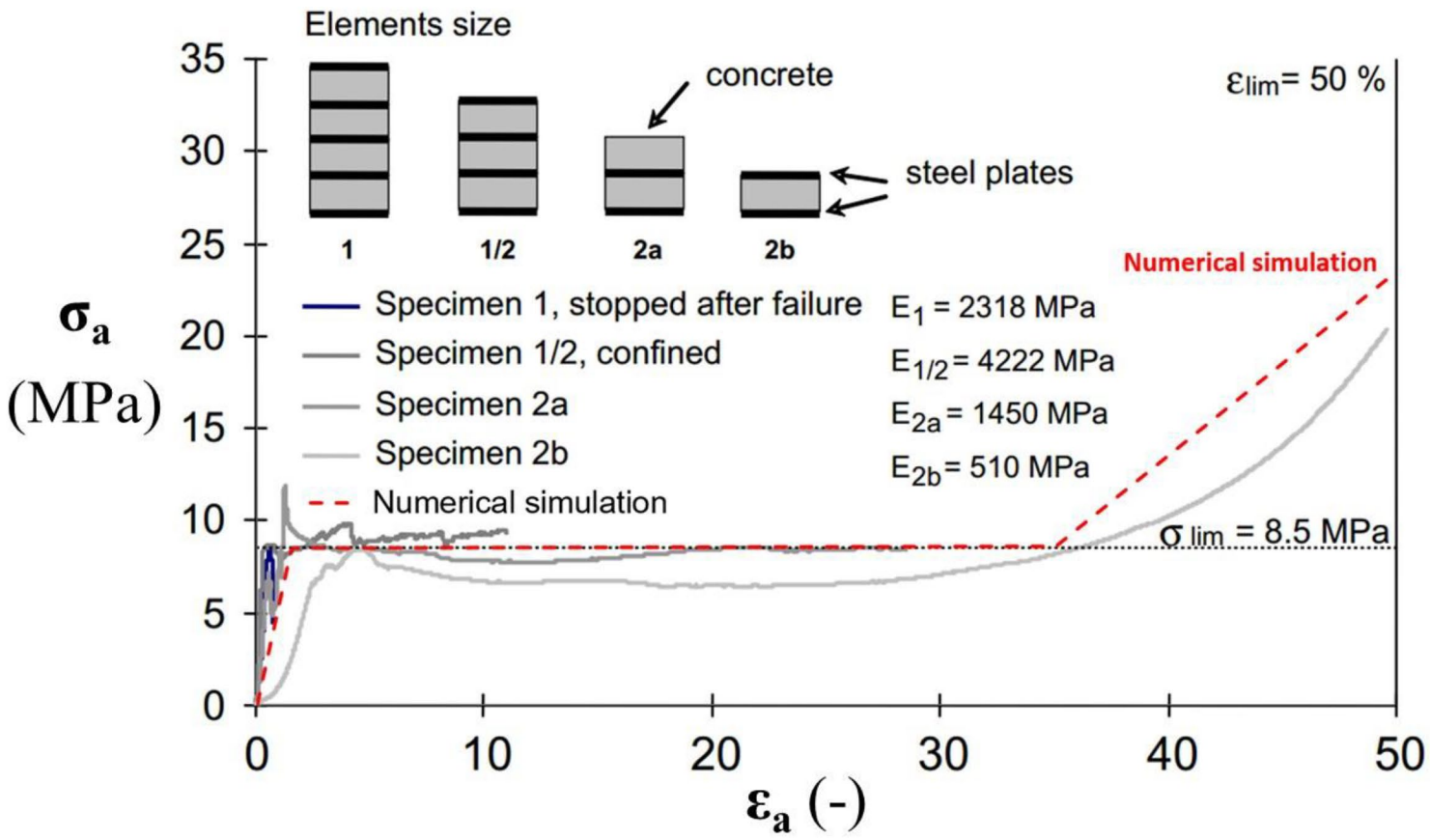


(Tran-Manh, H., Sulem, J., Subrin, D., & Billaux, D. (2015). Rock Mechanics and Rock Engineering, 48(6), 2301–2317.)

Highly deformable concrete (HiDCon) elements: Double-Yield Model

Young's modulus	(MPa)	550	Poisson's ratio	()	0
Cohesion	(MPa)	1e20	Tension limit	(KPa)	0
Multiplier	()	1000			

e^{pv} (-)	0	1,00	1,41
p_c (MPa)	2,83	2,86	8,33



Shotcrete: elastic

Young's modulus 10 GPa

Poisson's ratio 0.2

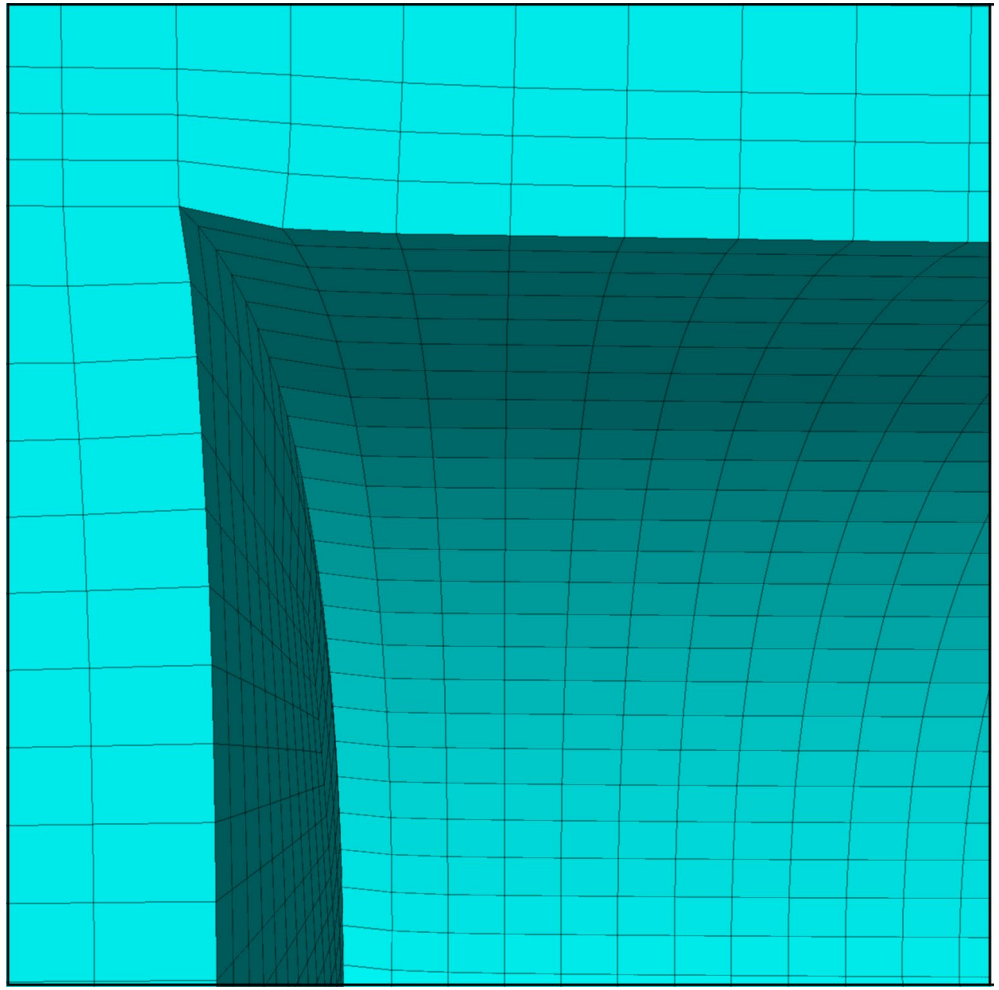
Concrete ring: elastic

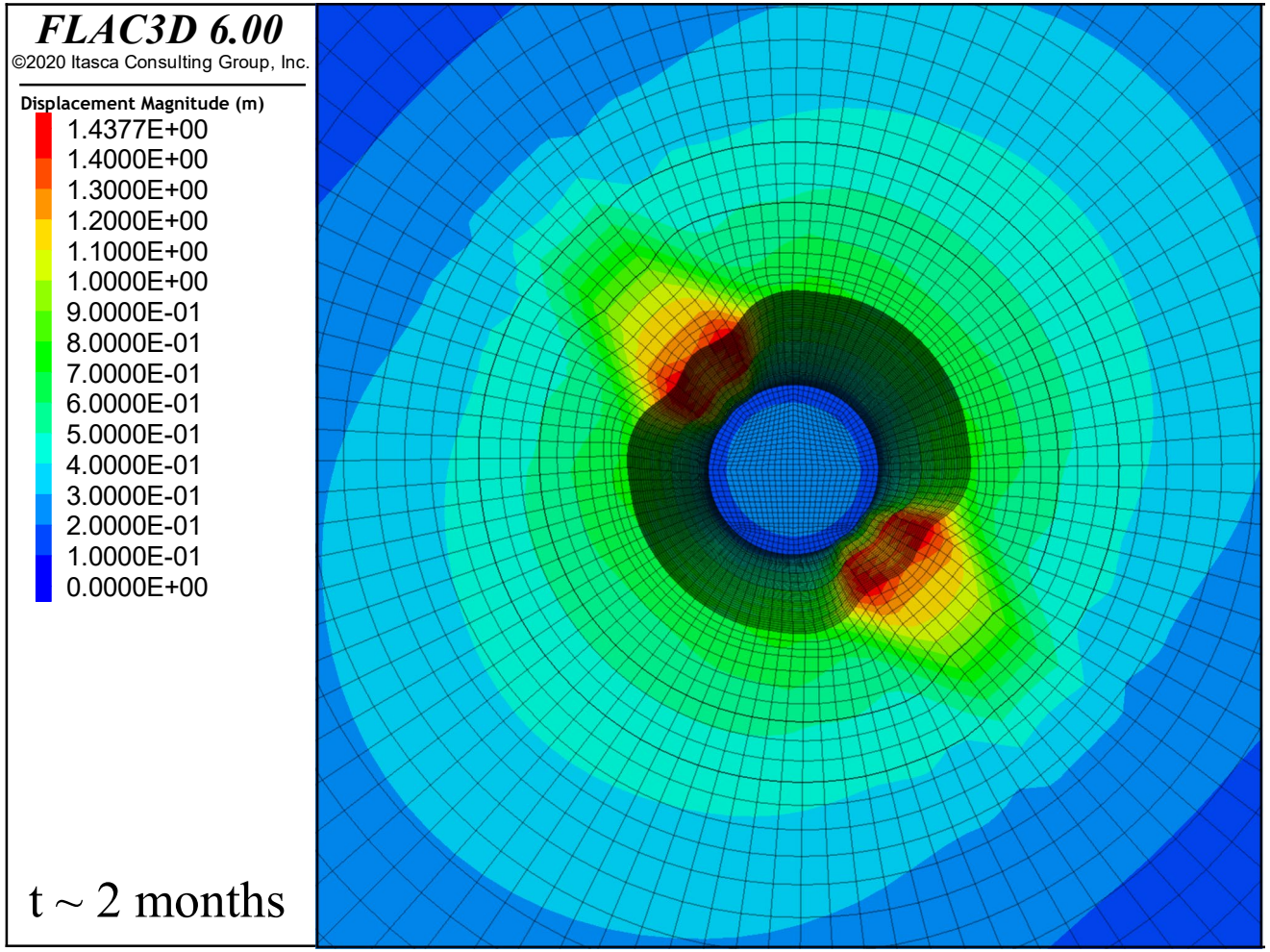
Young's modulus 20 GPa

Poisson's ratio 0.2

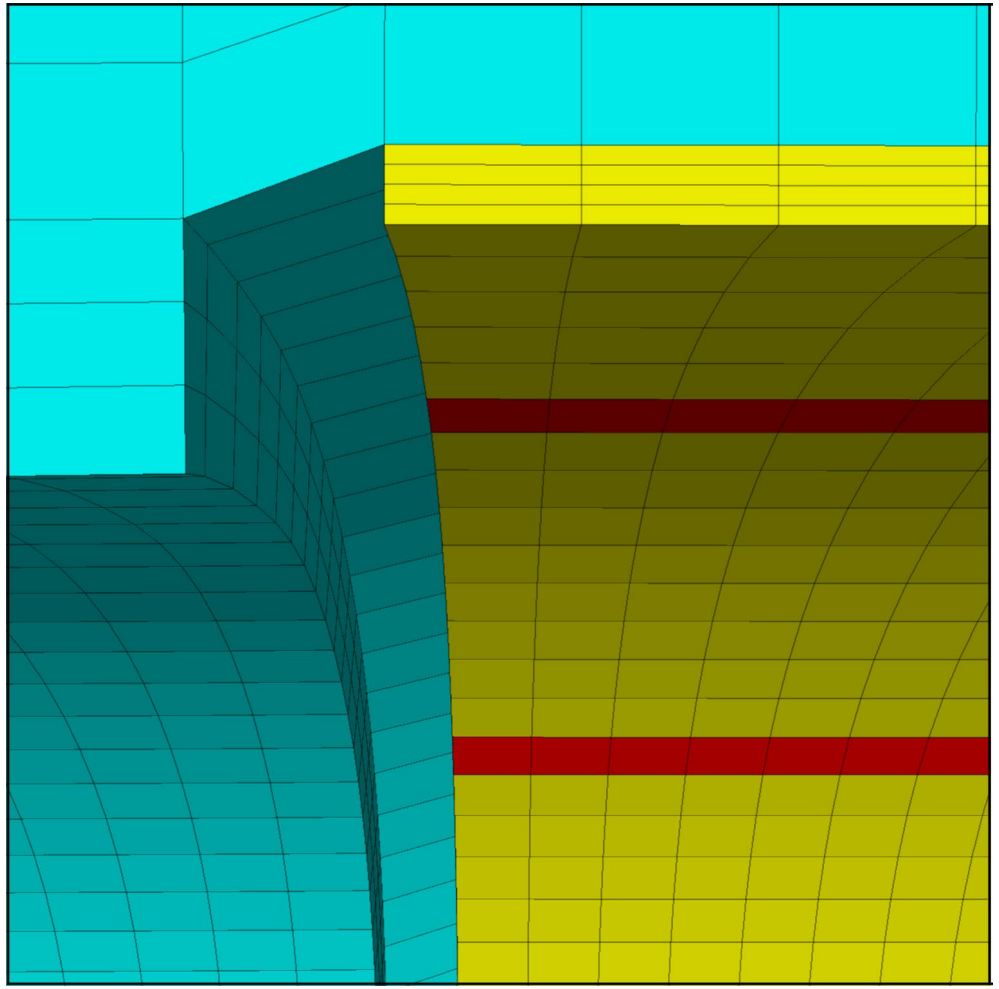
3. Results and discussion

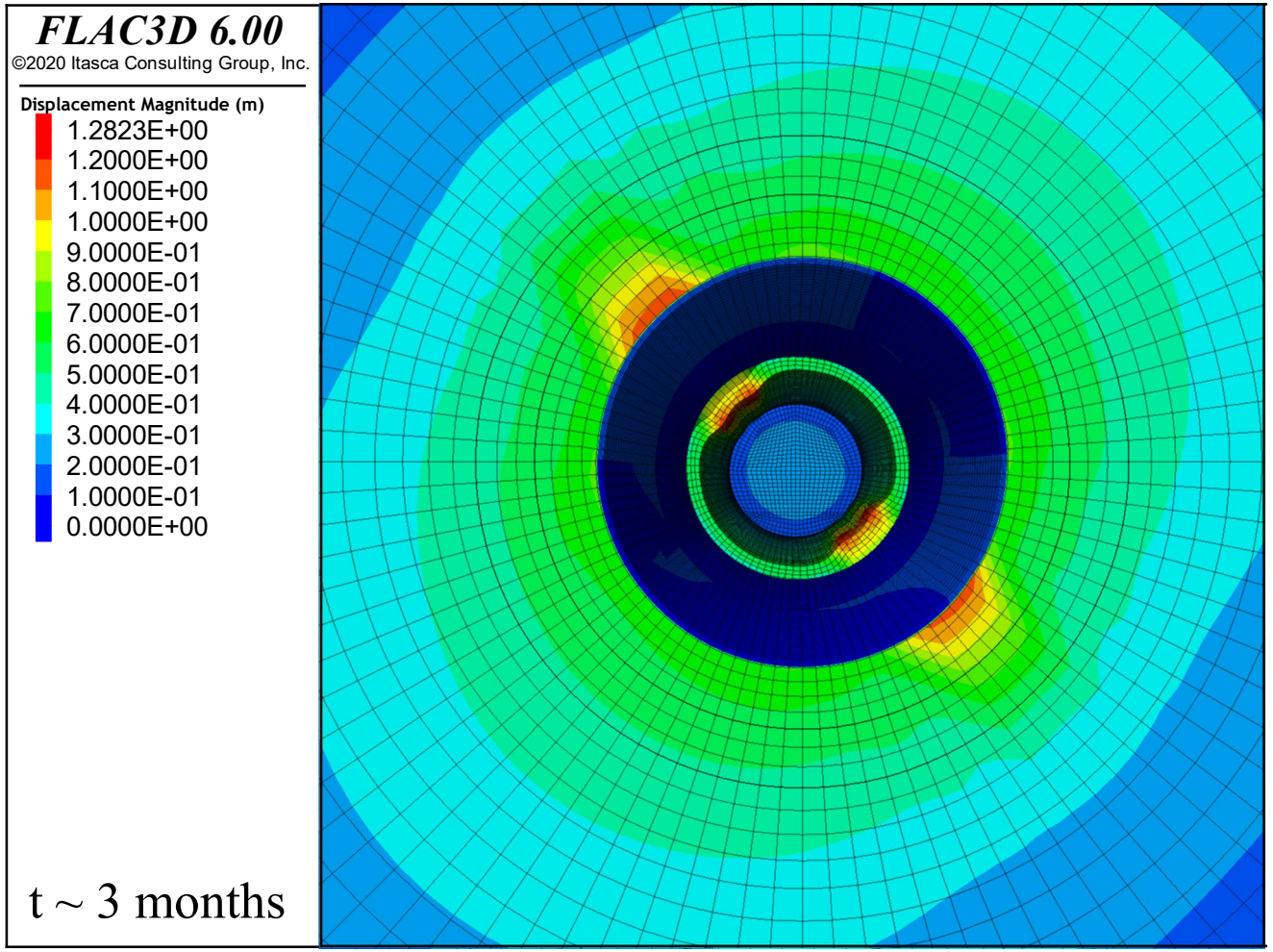
Stage 1: excavation



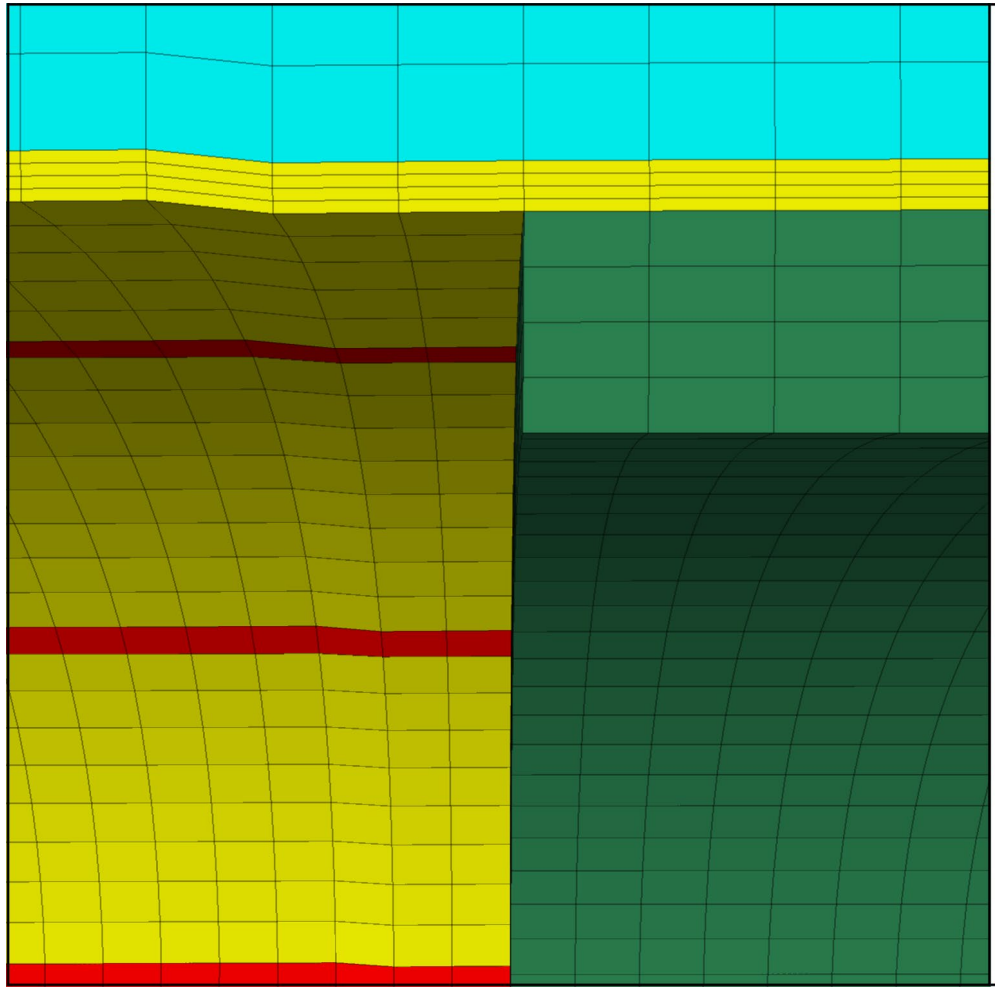


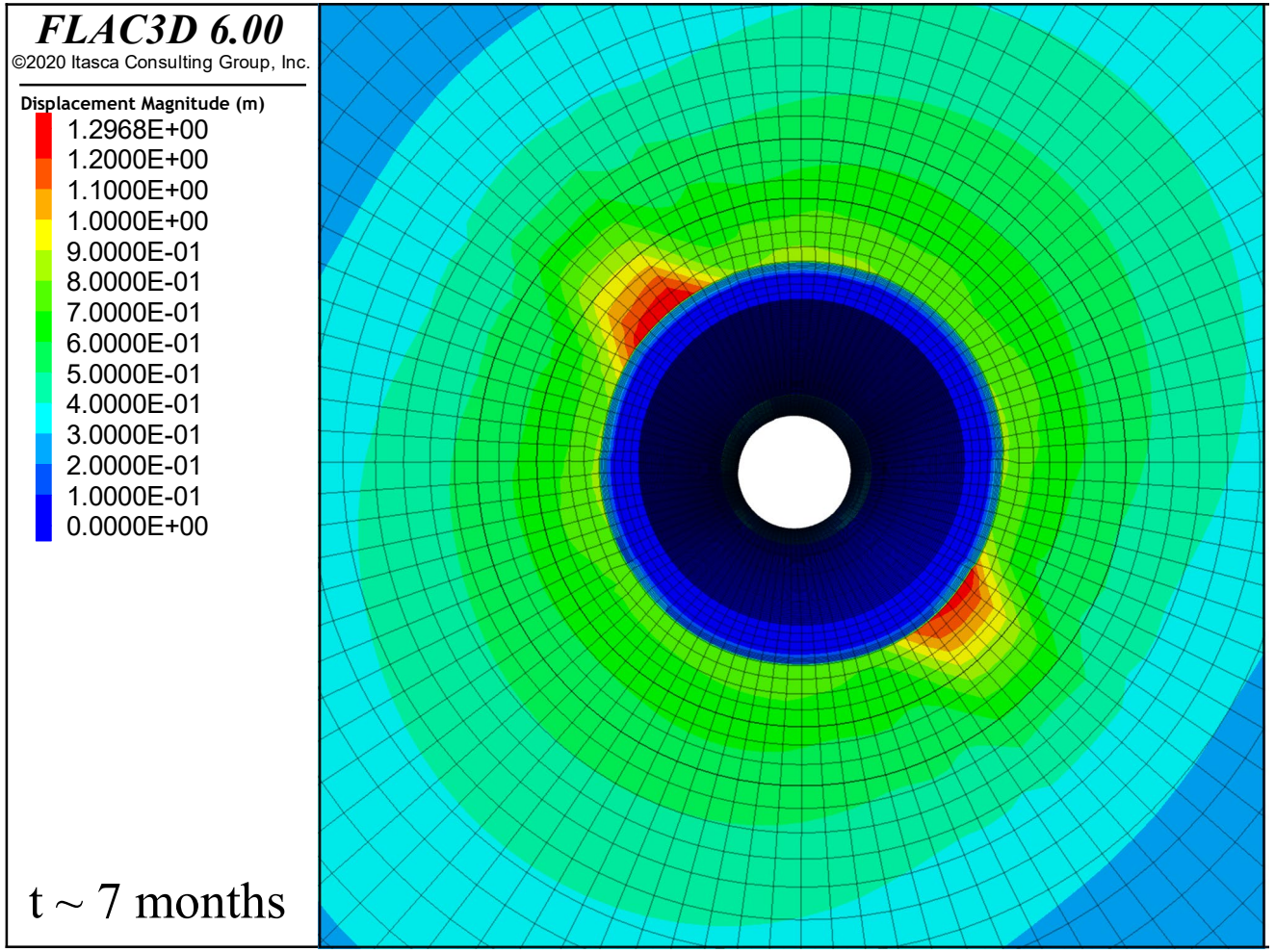
Stage 2: re-profiling and installation of the support system





Stage 3: installation of the final lining

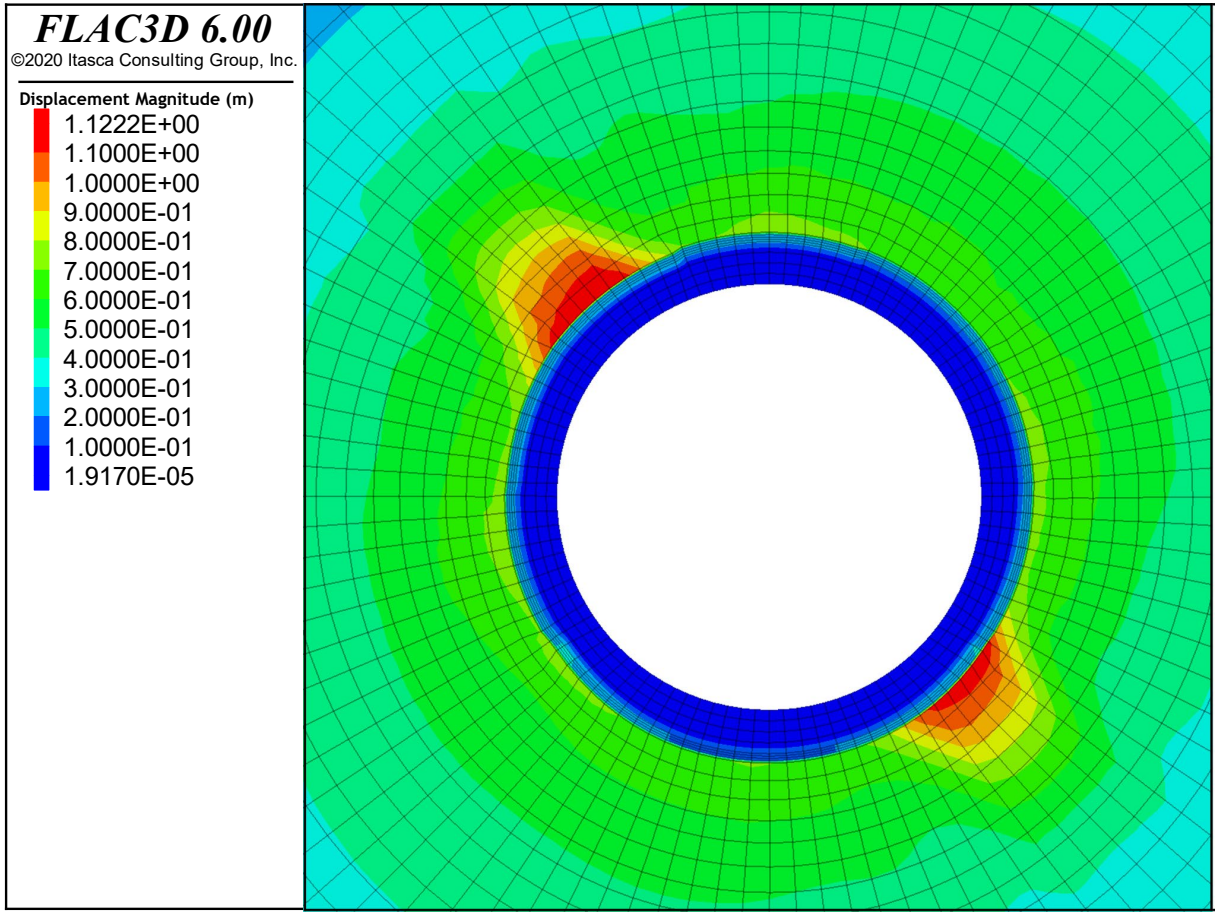


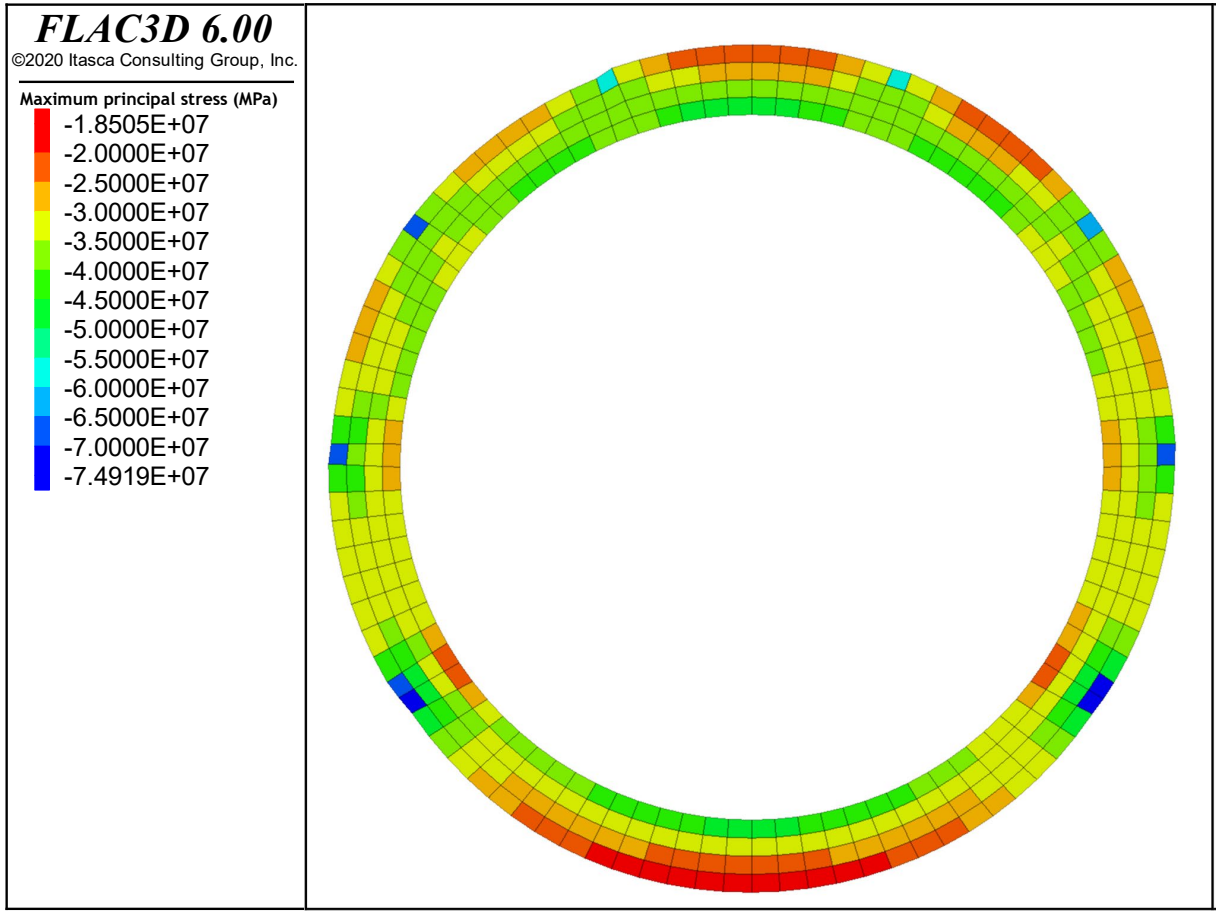


Displacement of the rock mass and stress in the final lining

t ~ 10 years

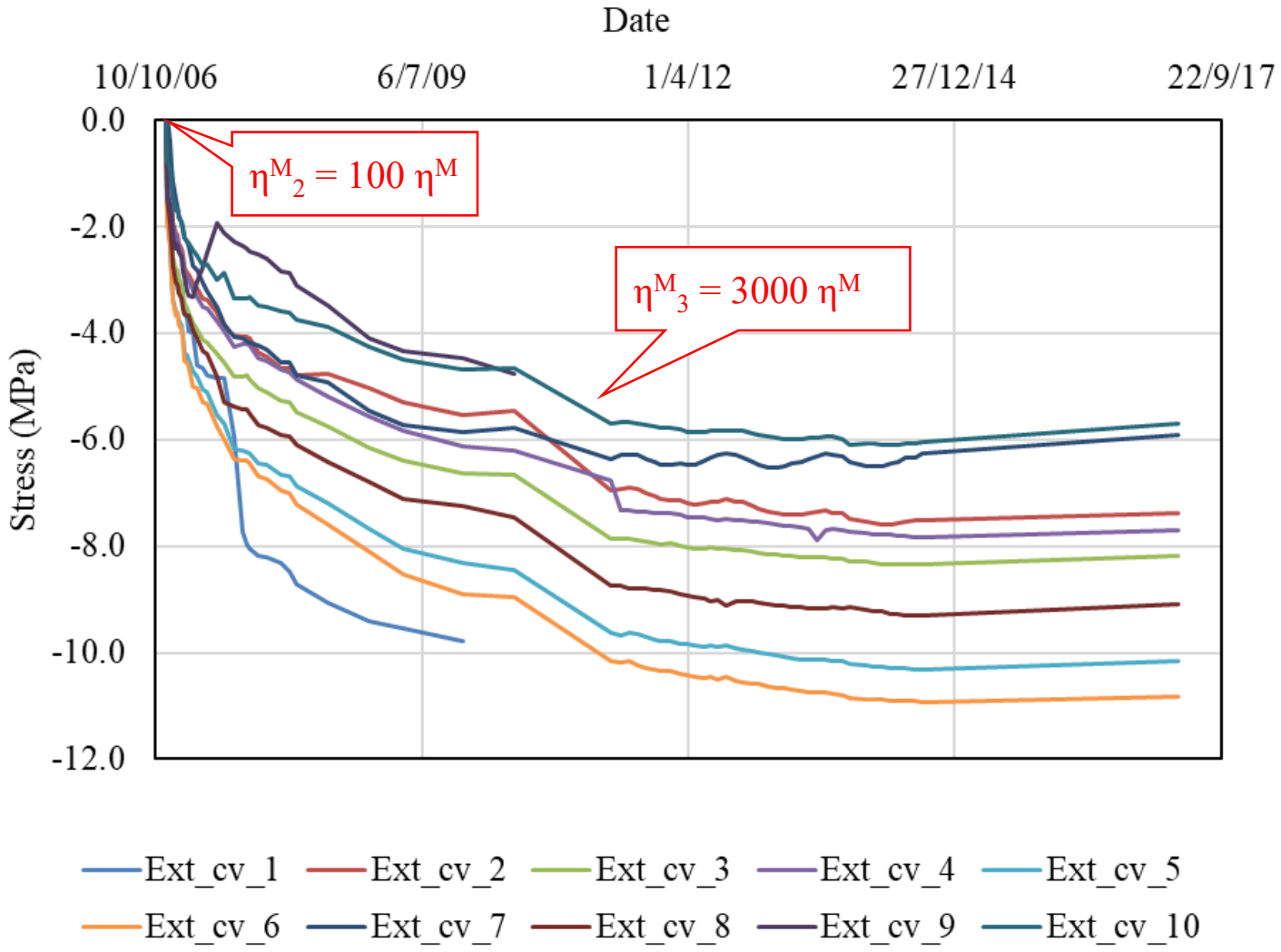
Stress ~ 40 MPa

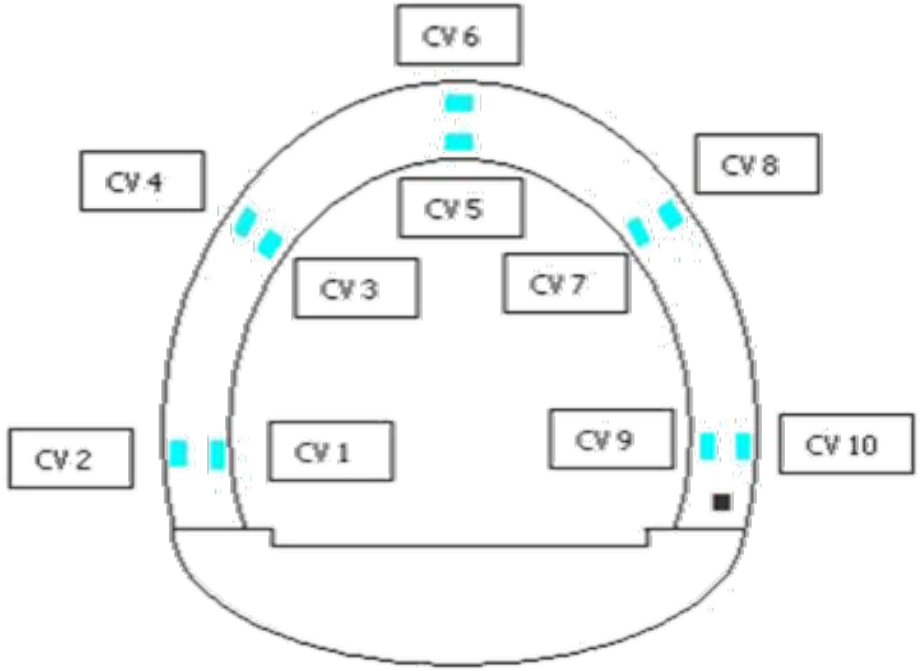




Stress measurement in the final lining up to 2017

Overestimation of the stress in the final lining

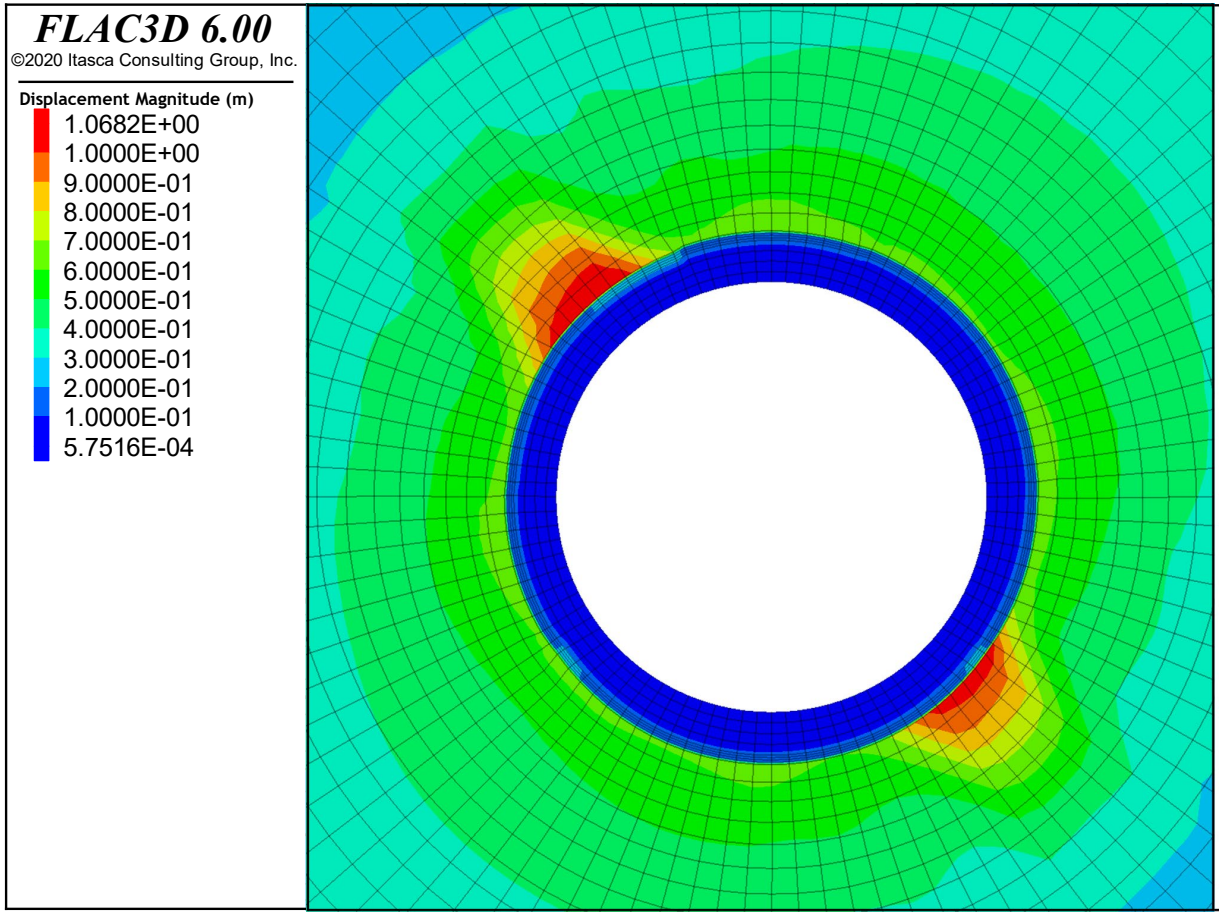


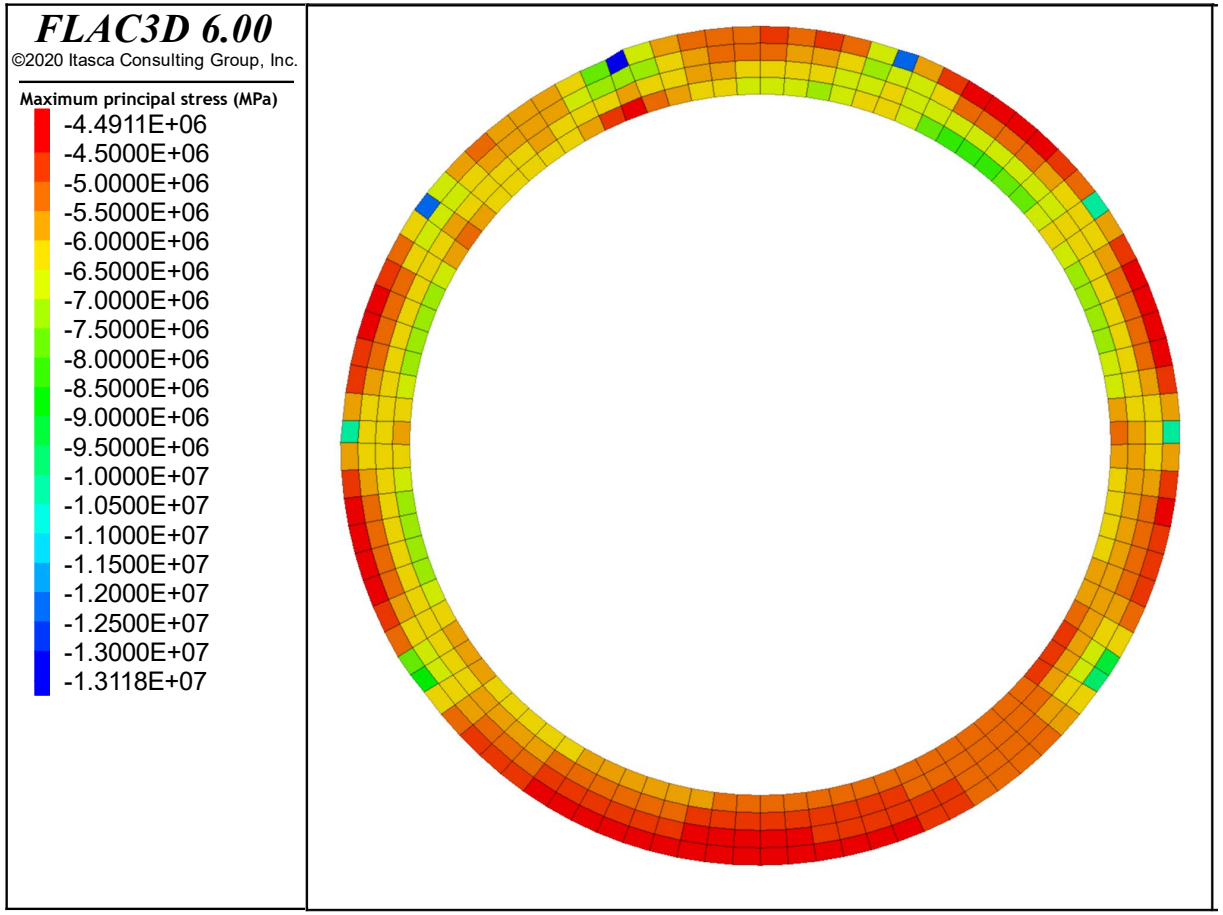


Displacement of the rock mass and stress in the final lining

t ~ 10 years

Stress ~ 8 MPa





4. Conclusions and outlook

Conclusions

The different excavation stages, the re-profiling process and the specific support system are simulated by using the FLAC3D code.

CVISC constitutive law and the ubiquitous-joint approach permit to describe the time-dependent and anisotropic behavior of squeezing rock masses as encountered during the excavation of SMP2 gallery.

The strong convergence observed during the excavation of the tunnel can be correctly reproduced .

The Maxwell element in the CVISC model leads to an increasing convergence until the stabilization of the system. In order to simulate the observed stabilization of stress in the final lining, the increase of the viscosity of Maxwell element η^M with time needs to be introduced.

Outlook

The model will be applied to simulate the response of SMP4 survey gallery excavated at 600 m depth.

Thanks for your attention !

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