World Tunnel Congress & Exhibition

WTC 2019

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NAPLES 2019

TUNNELS AND UNDERGROUND CITIES: ENGINEERING AND INNOVATIONMEET ARCHAEOLOGY, ARCHITECTURE AND ART

Società Italiana Gallerie
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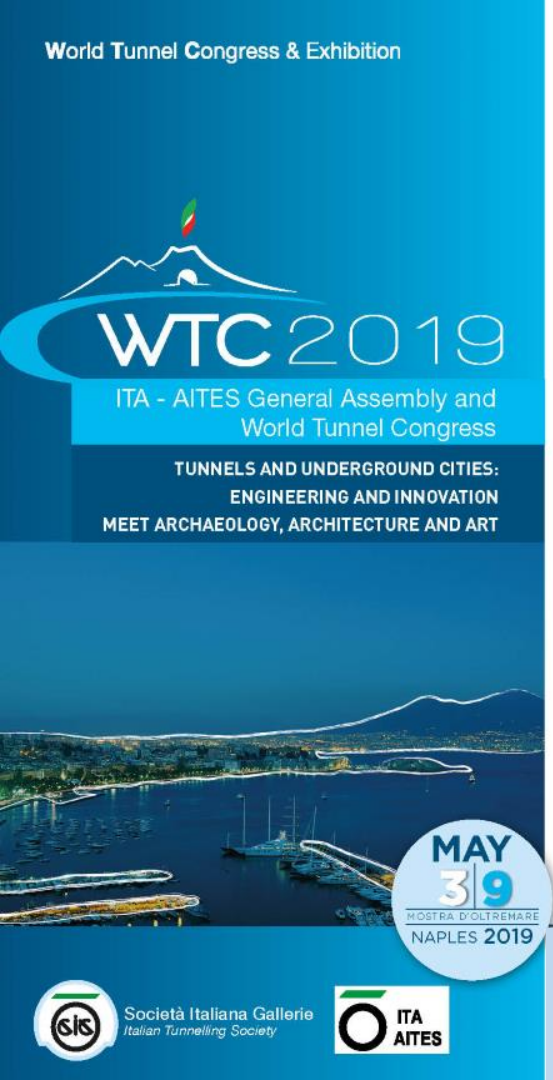

Brenner Base Tunnel – Interaction between underground structures, complex challenges and strategies

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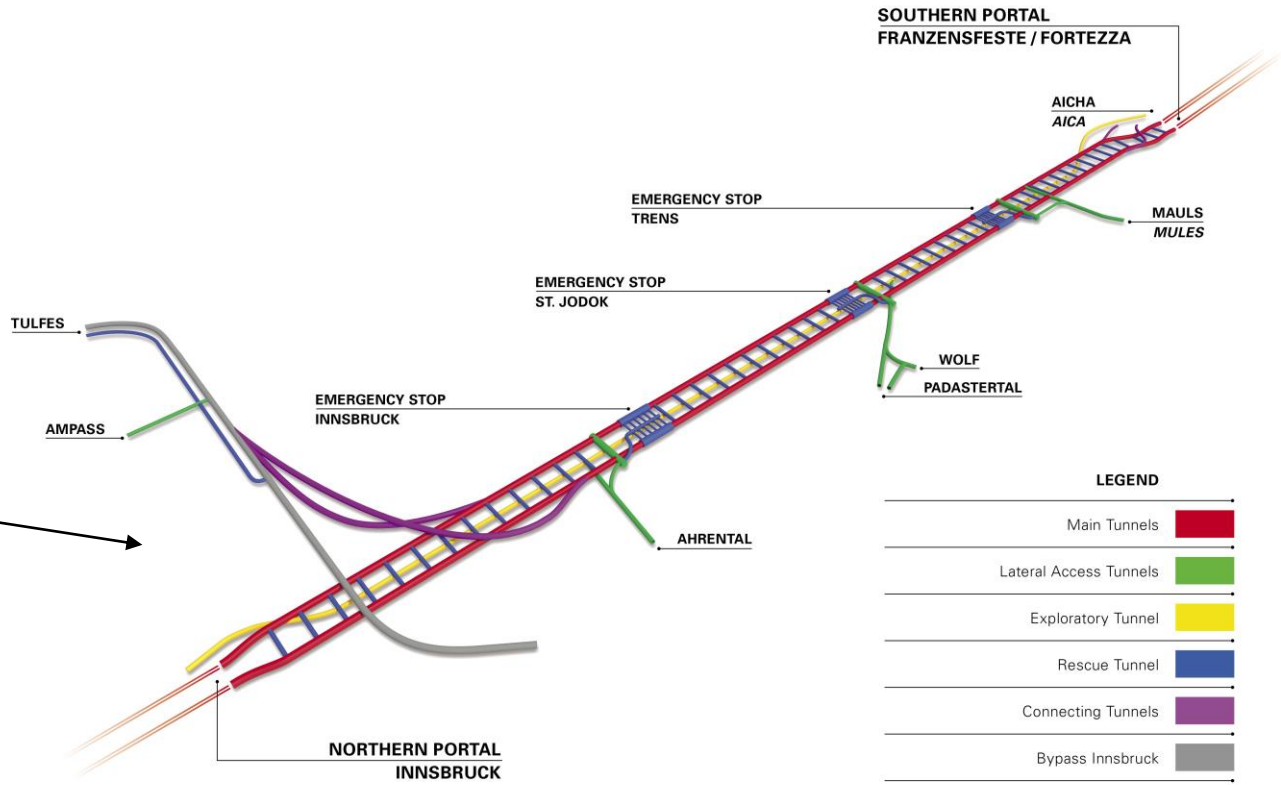
Romed Insam / Gerd Wieland

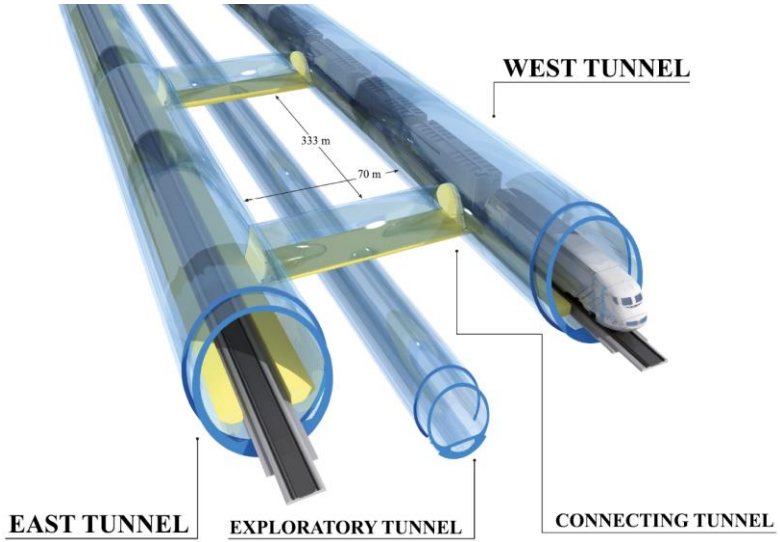
Outline of presentation

- Project overview and status of the works
- Construction lot H51 “Pfons-Brenner”
- Geotechnical design and interaction between the structures at construction lot H51
- Conclusions

Brenner Base Tunnel – Overview

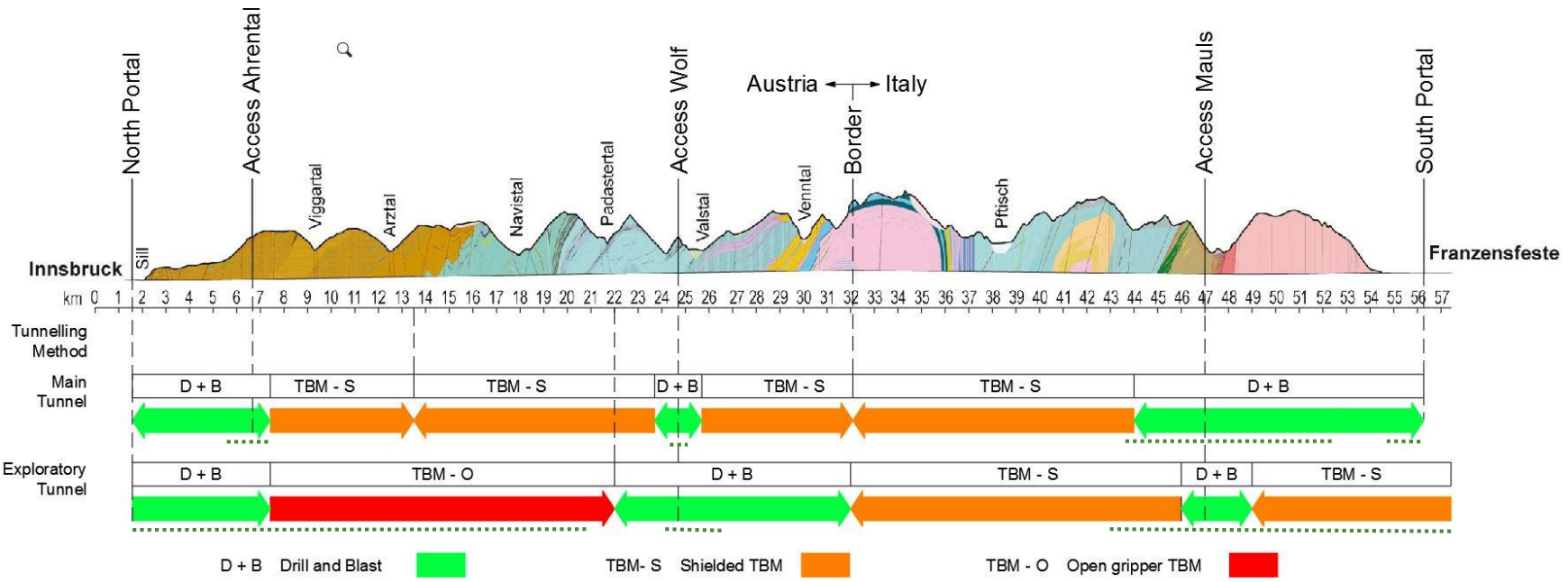


Brenner Base Tunnel – Tunnel system



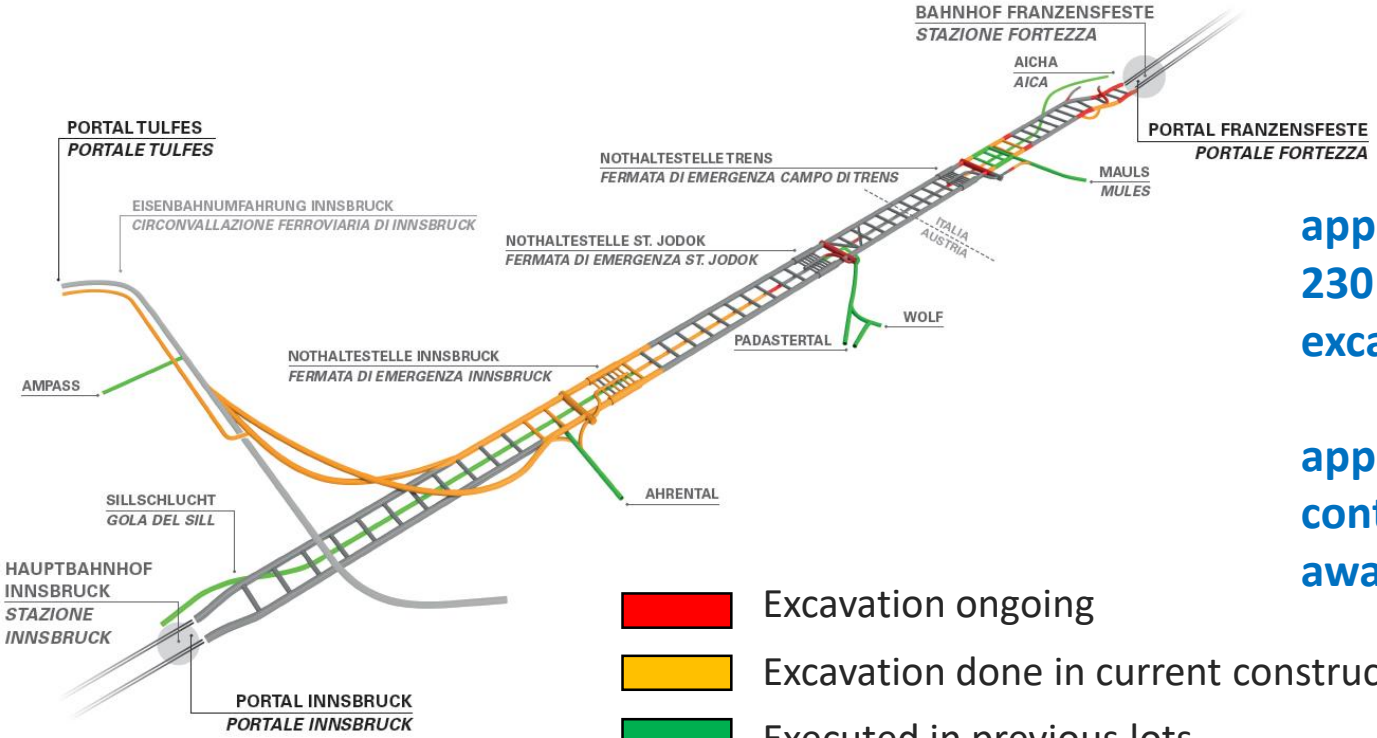
- Lenght BBT: 55 km
  (with the existing Bypass of Innsbruck: 64 km)
- 2 main tunnels (single-track) + 1 exploratory tunnel
- Cross passages every 333m
- Total length of the tunnel system: ca. 230 km
- Max. Overburden: ca. 1.800 m
- Velocity:
  Freight trains: 120 km/h, passenger trains: 250 km/h
- Ballast-free track
- Traction current: 25kV / 50Hz
- Command & Control: ETCS LEVEL 2

Brenner Base Tunnel – Tunneling Methods



approx. excavated to date .....

Brenner Base Tunnel – Status of the works

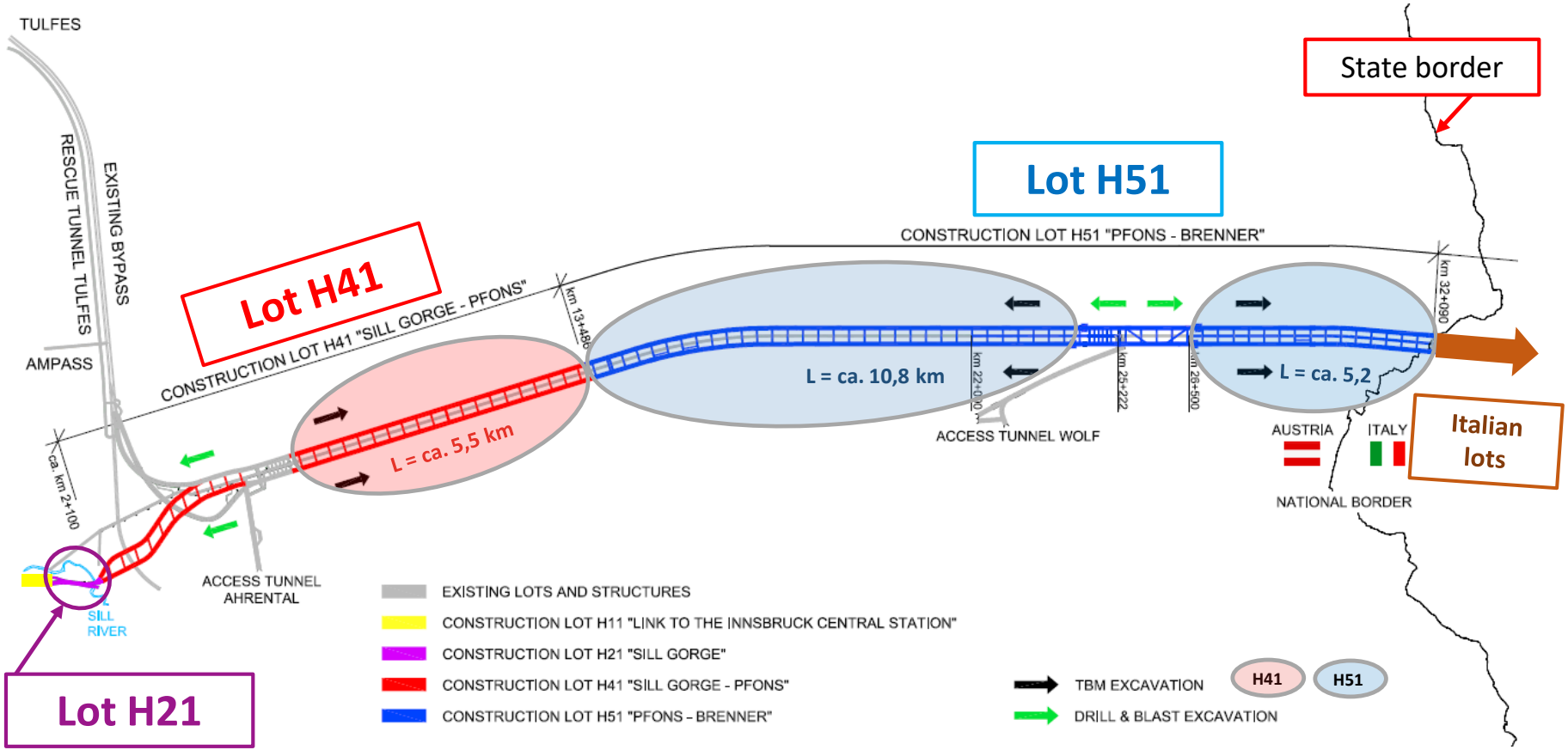


approx. 100 km of the total 230 km tunnel have been excavated

approx. 80 % of all contractual work have been awarded to contractors

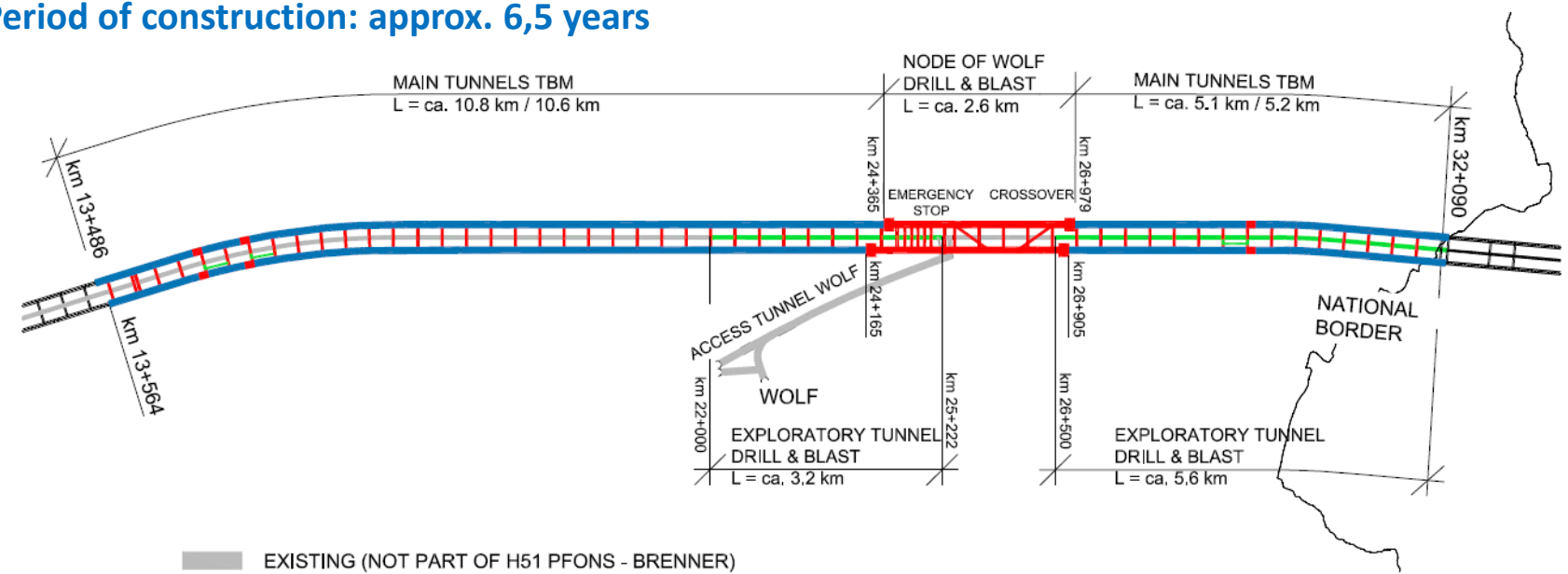
- Excavation ongoing
- Excavation done in current construction lots
- Executed in previous lots

Brenner Base Tunnel – Main Construction lots Austria

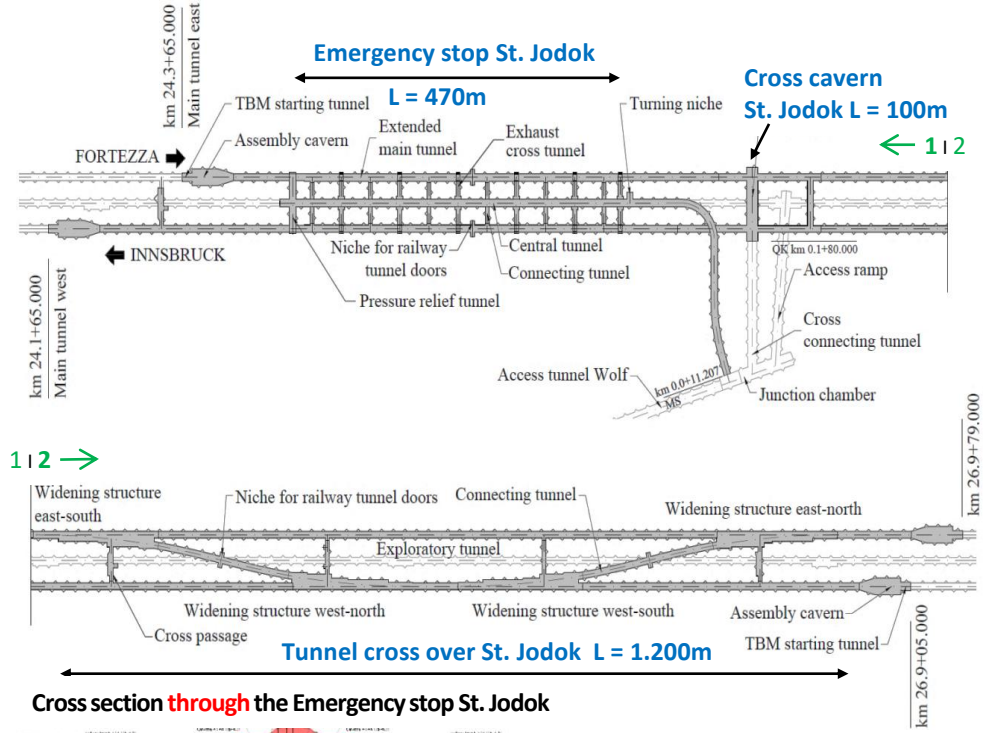


H51 “Pfons - Brenner” Construction lot – Overview

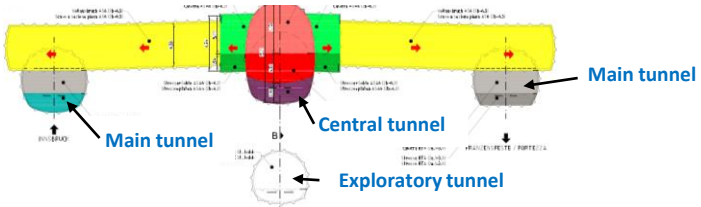
km 13,486 – km 32,090
Start of construction: 19/11/2018
Period of construction: approx. 6,5 years



H51 “Pfons - Brenner” Construction lot – „Node of Wolf“



Cross section through the Emergency stop St. Jodok

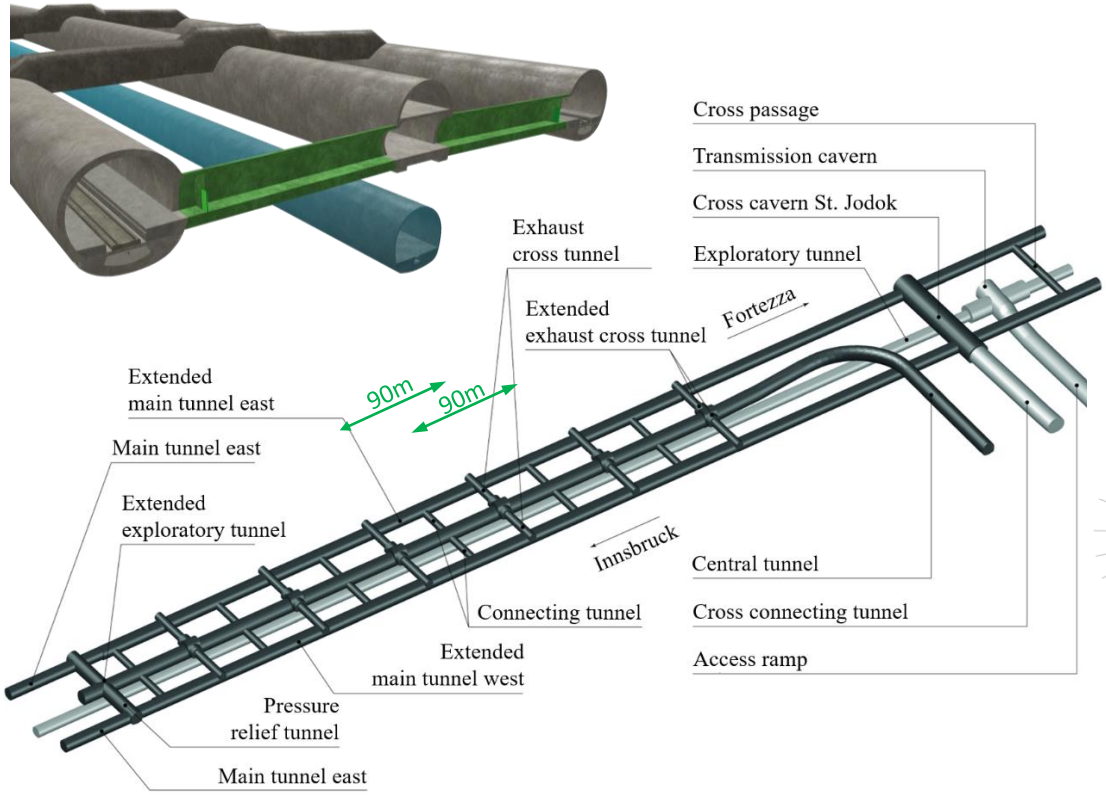


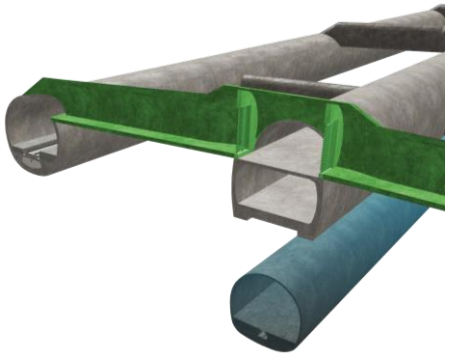
Cross cavern St. Jodok / Main tunnel tubes:
St. Jodok cross cavern, length: **100 m**, excavation area: approx. **230** m²
East tunnel, length: **2,6 km**, excavation area: approx. **90** m²
West tunnel, length: **2,7 km**, excavation area: approx. **90** m²

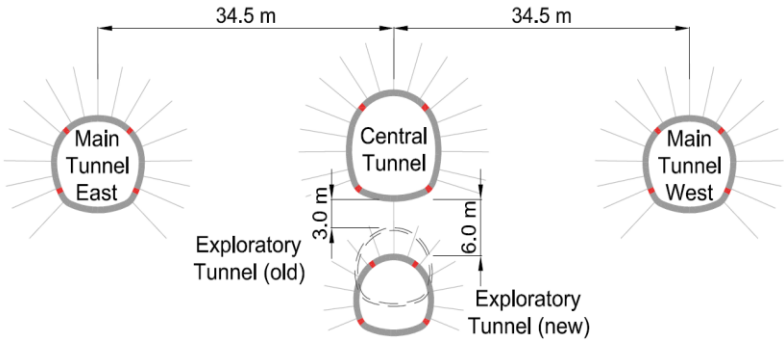
Emergency stop St. Jodok:
Extended main tunnel tube in the emergency area, length: **470** m, excavation area: approx. **100** m²
1 central tunnel, length: **900** m, excavation area: approx. **116** m²
6 exhaust cross tunnels, length: **60** m, excavation area: approx. **41** m²
6 connecting tunnels, length: **60** m, excavation area: approx. **38** m²
1 pressure relief tunnel, length: **60** m, excavation area: approx. **116** m²
1 turning niche

Tunnel cross over St. Jodok, total length: 1.200 m:
4 widening structures with excavation areas of up to approx. **300** m²
2 connecting tunnels, excavation area: **90** m²
2 niches for the railway tunnel doors
4 assembly caverns and TBM starting tunnels with excavation areas of up to approx. **300** m²

H51 “Pfons - Brenner” Construction lot – Emergency Stop







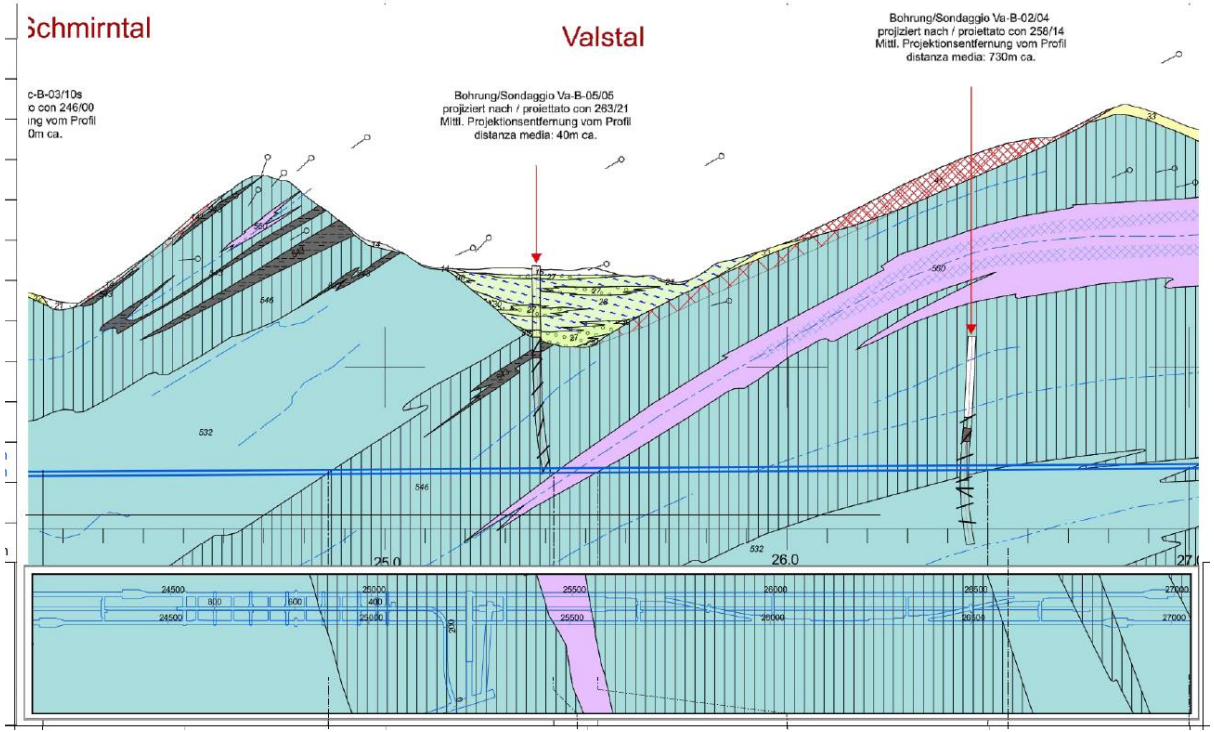
Emergency Stop St. Jodok
with the underlying exploratory tunnel

Predicted geological conditions for the Node of Wolf

- Predominately calcareous and non-calcareous Bünder schists
- Secondary black phyllites, chlorite schists, rauhwacke, calcareous marbles and fault zones
- Overburden 400-900 m

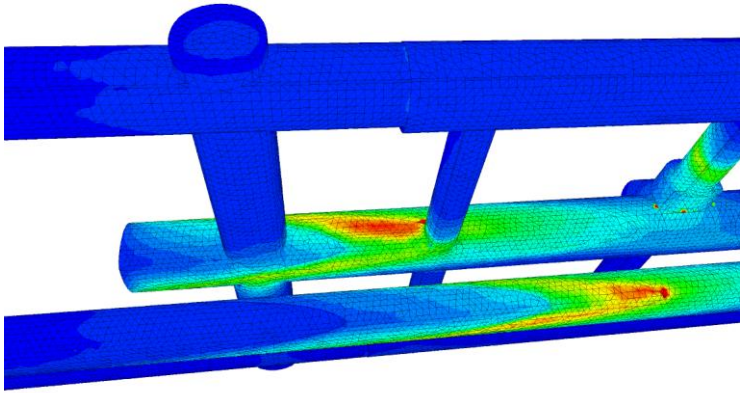
Calcareous Bünder schists

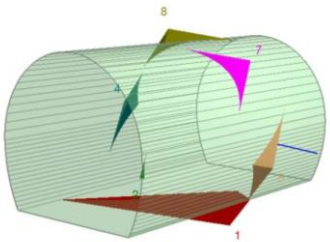
Black phyllite

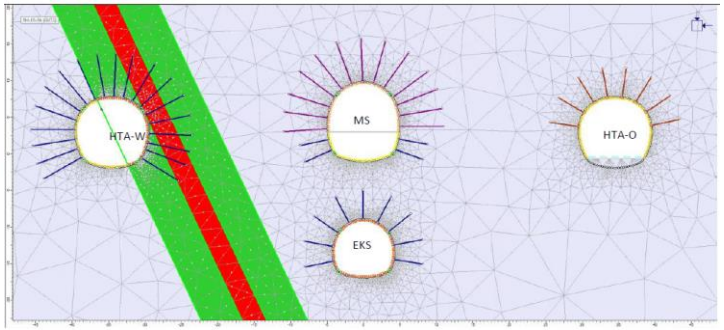


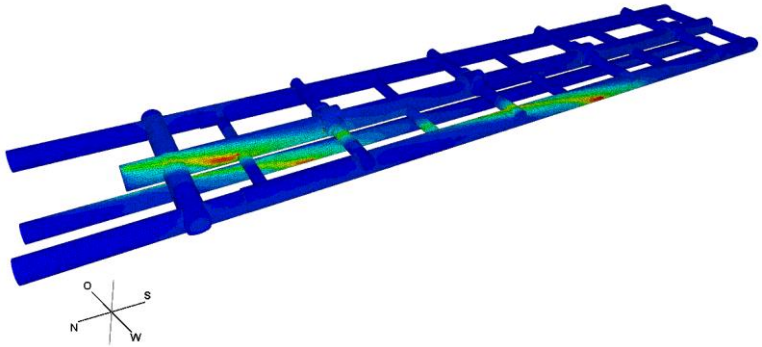
Geotechnical design – system behavior

- Geotechnical design according to the guideline for "*Geotechnical Design of Underground Structures with Conventional Excavation*" from the Austrian Society for Geomechanics
- Methods to analyse the system behavior:
  - Wedge analysis
  - Numerical 2D and 3D analyses considering the entire tunnel system and the construction process



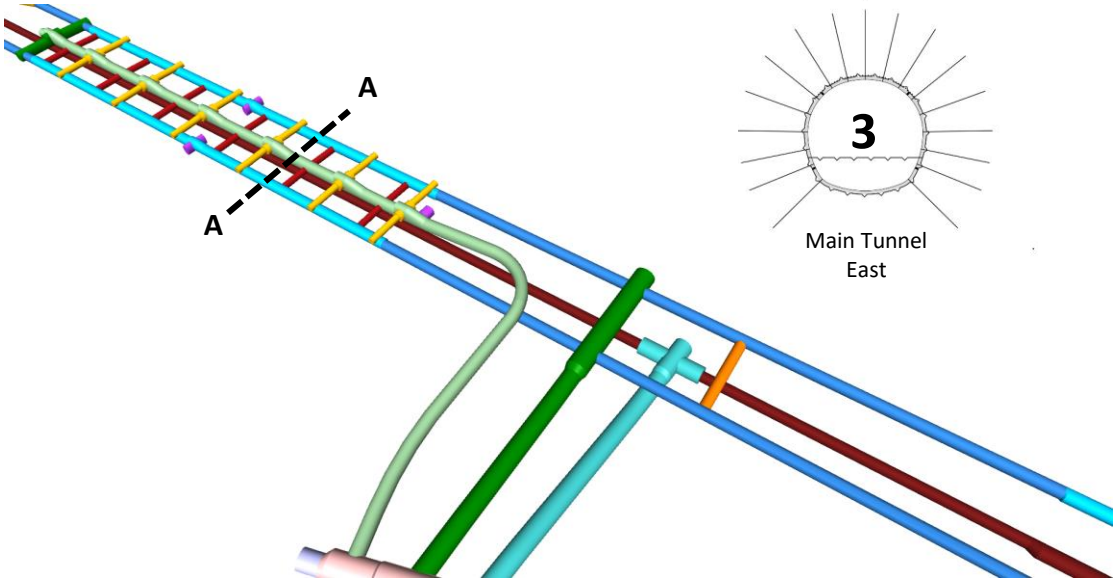




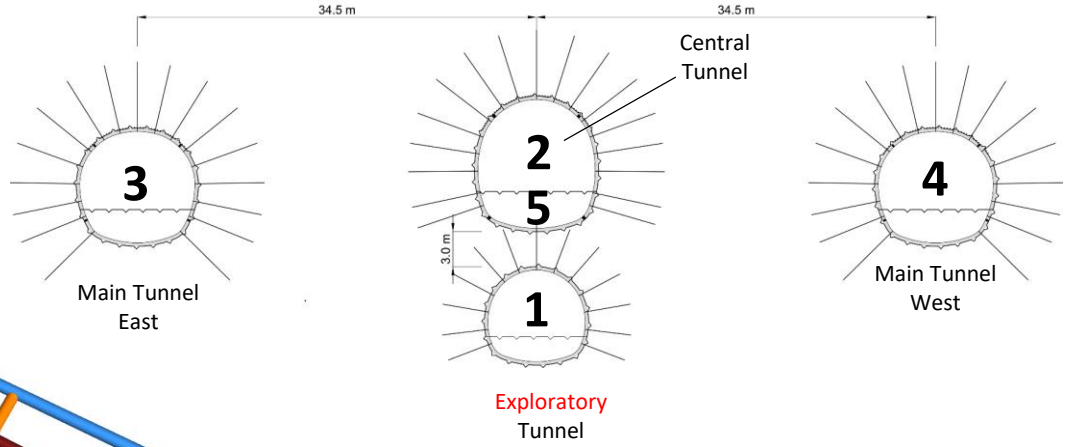


Geotechnical design – system behavior

- Construction sequence of the Emergency Stop St. Jodok

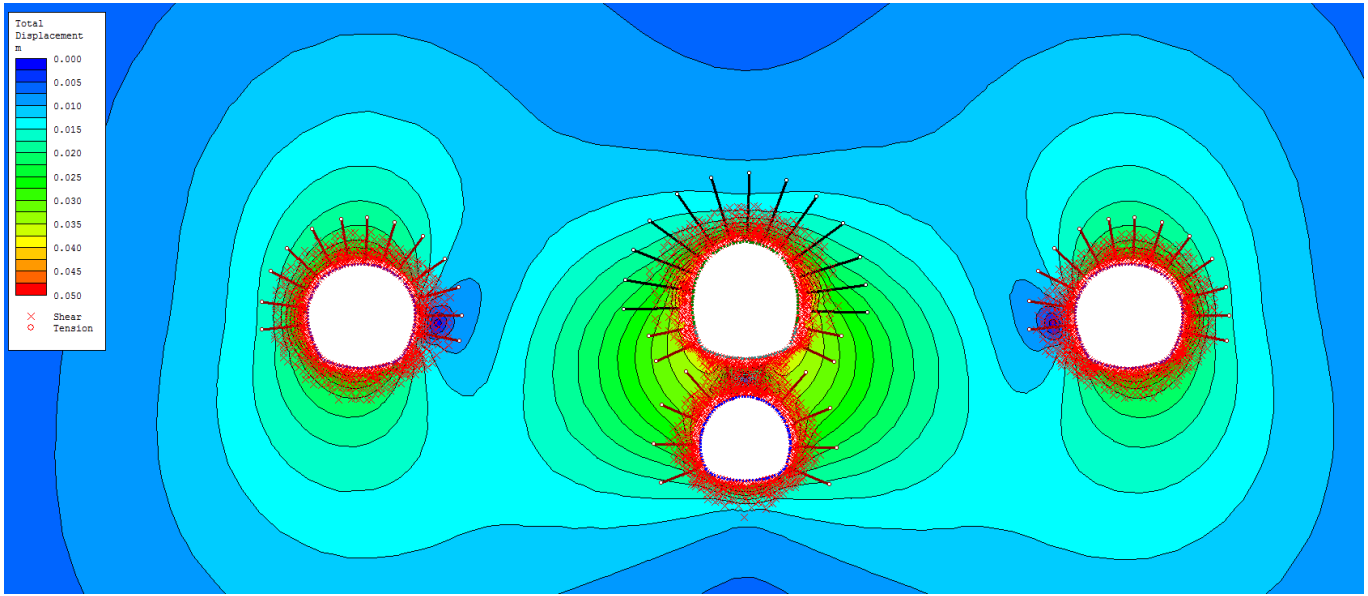


Section A-A



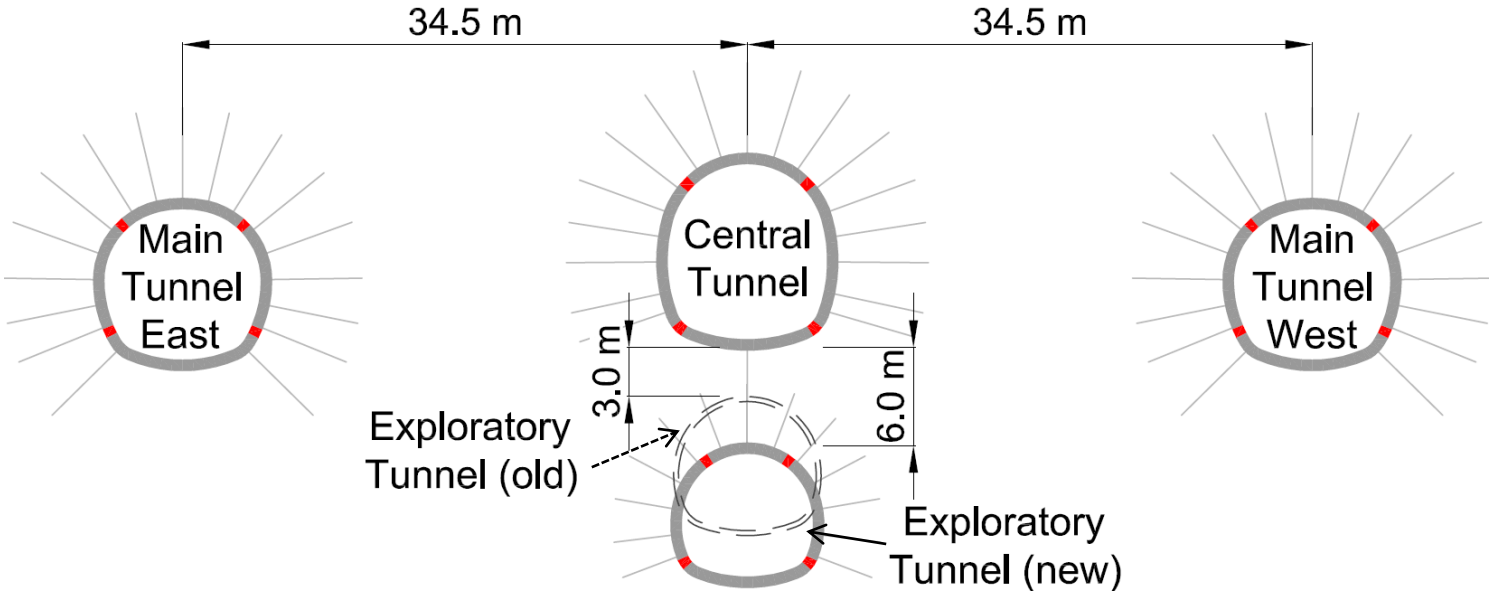
Geotechnical design – mutual interactions

- Numerical analyses have shown significant mutual interactions between adjacent underground structures
- Overloading of the rigid shotcrete lining in the previously excavated exploratory tunnel caused by stress redistribution of subsequently excavated adjacent structures



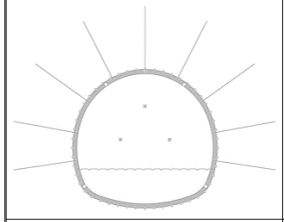
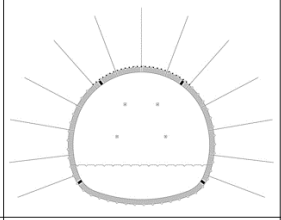
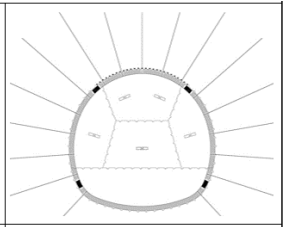
Geotechnical design – mutual interactions

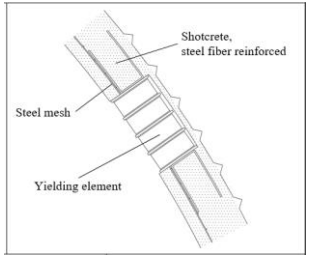
- Measures to prevent overloading of the rigid support in the exploratory tunnel
  - Lowering the exploratory tunnel
  - Ductile rock support in the exploratory tunnel

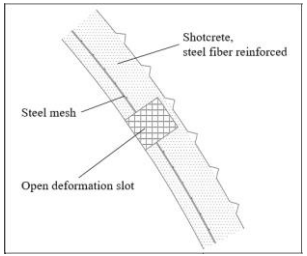


Geotechnical design – mutual interactions

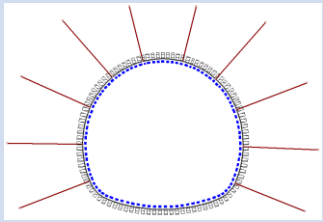
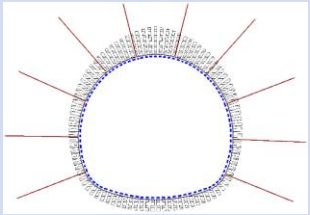
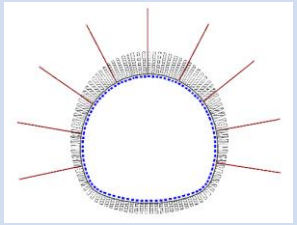
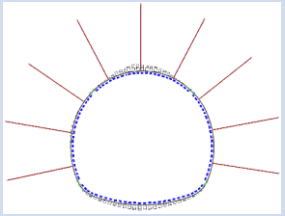
- Ductile Rock support:
  - Open slots for relatively good rock mass conditions where small deformations are expected
  - Yielding elements for relatively poor rock mass conditions where large deformations are expected

		
Round length Top heading: 1.7 m Invert: 3.4 m **Shotcrete lining** ds = 25 cm steel fiber reinforced with one layer steel mesh **Systematic bolting:** SN rock bolts 250 kN, L=4 m bolt pattern: 1.7 m x 2.0 m **4 Rows of open deformation slots**	**Round length** Top heading: 1.3 m Invert: 2.6 m **Shotcrete lining** ds = 30 cm steel fiber reinforced with one layer steel mesh and lattice girder **Systematic bolting** SN rock bolts 250 kN, L=4 m bolt pattern: 1.3 m x 1.5 m **Spiles umbrella** **4 Rows of yielding elements**	**Round length** Top heading: 1.0 m Invert: 2.0 m **Shotcrete lining** ds = 30 cm steel fiber reinforced with one layer steel mesh and lattice girder **Systematic bolting** Self-drilling rock bolts 350 kN, L=6 m bolt pattern: 1.0 m x 1.3 m **Spiles umbrella** **4 Rows of yielding elements**



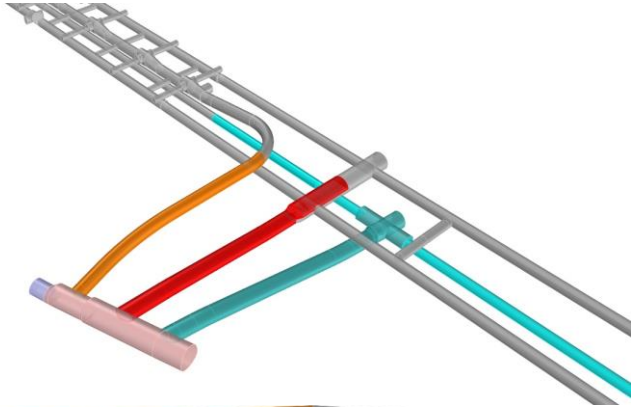


Geotechnical design – mutual interactions

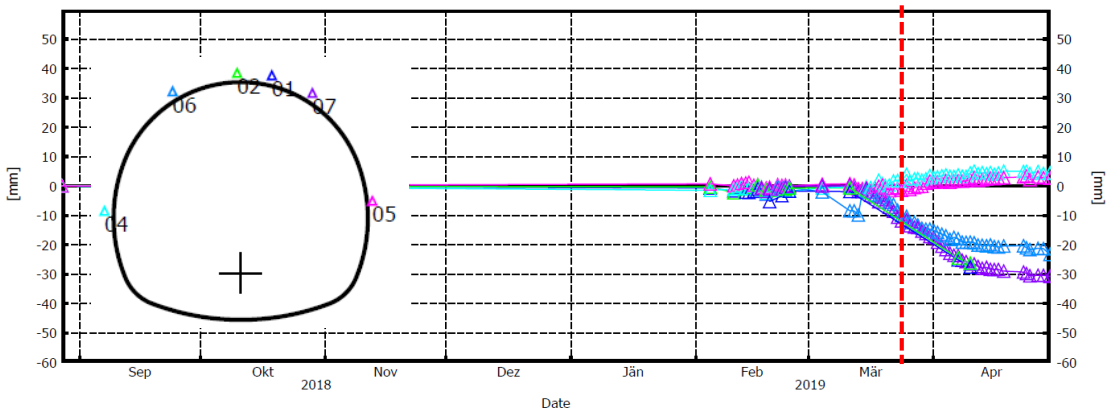
Comparison of measures to reduce the loading of the shotcrete lining in the exploratory tunnel				
Mutual interaction between structures	NO	YES	YES	YES
Support concept	Rigid rock support: Systematic bolting Shotcrete ds = 25 cm	Rigid rock support: Systematic bolting Shotcrete ds = 25 cm	Rigid rock support: Systematic bolting Shotcrete ds = 25 cm	Ductile rock support: Systematic bolting Shotcrete ds = 25 cm 4 deformation slots
Min. distance between structures	-	3m	6m	6m
Degree of utilization of the shotcrete lining	**35%**	**490%**	**310%**	**12%**
Normal Force shotcrete lining				

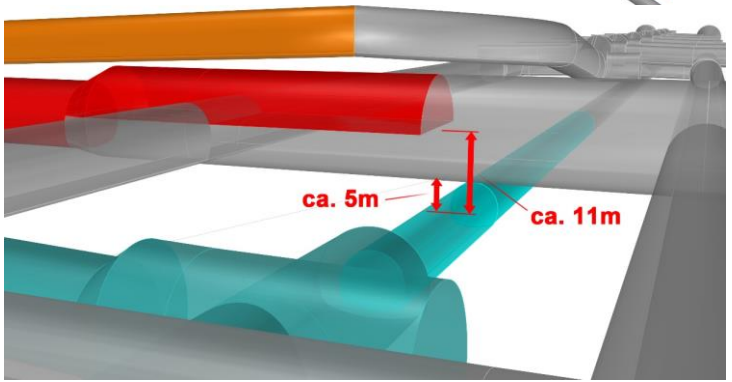
Experiences from the construction site

- Status of works on 22.03.2019
- Additional deformations up to 3 cm in the exploratory tunnel due to the top heading in the cross cavern
- No damages on the ductile rock support in the exploratory tunnel



Vertical displacements in the exploratory tunnel





Experiences from the construction site

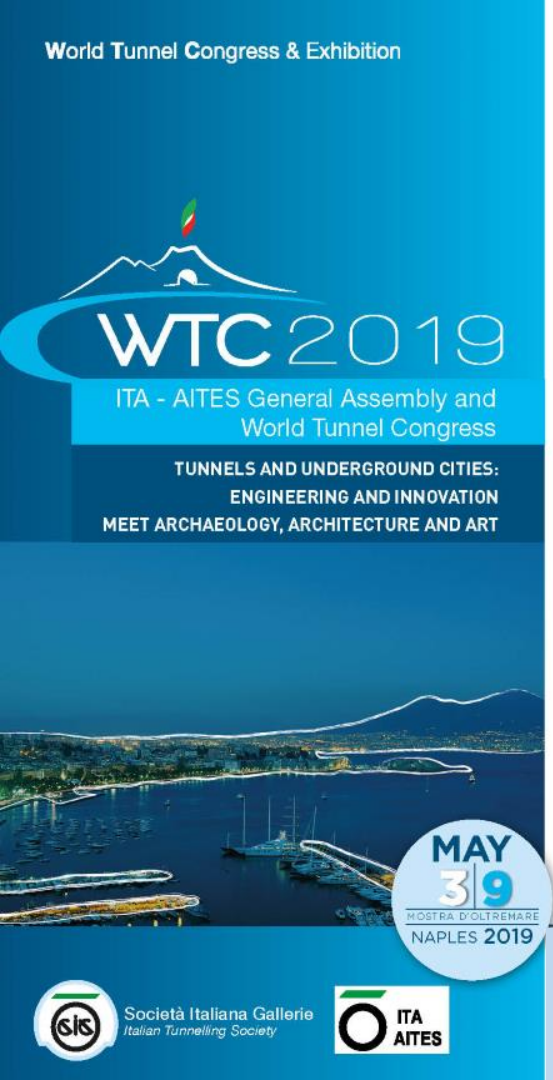
- Top heading and bench excavation of the cross cavern St. Jodok

Conclusions

- The design of the individual tunnels were performed considering the **entire tunnel system** and the **construction processes.**

- The interaction between the different structures (main tunnels, cross passages, exploratory tunnel, emergency stop) could already be observed in several construction lots of the BBT.

- The **support concept** ("rigid" / "ductile") depends on the geological conditions, the stress state, the geometry and distance between the structures as well as the construction processes.



Thank you for your attention !