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Untersammelsdorf Tunnel – Challenges, Special Measures and use of Special Shotcrete for Tunneling in Lacustrine Clay

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SHOTCRETE FOR UNDERGROUND SUPPORT XIV, NOVEMBER 2019, PATTAYA

UNTERSAMMELSDORF TUNNEL –

CHALLENGES, STATE-OF-THE ART MEASURES AND USE OF SPECIAL SHOTCRETE FOR TUNNELING IN LACUSTRINE CLAY

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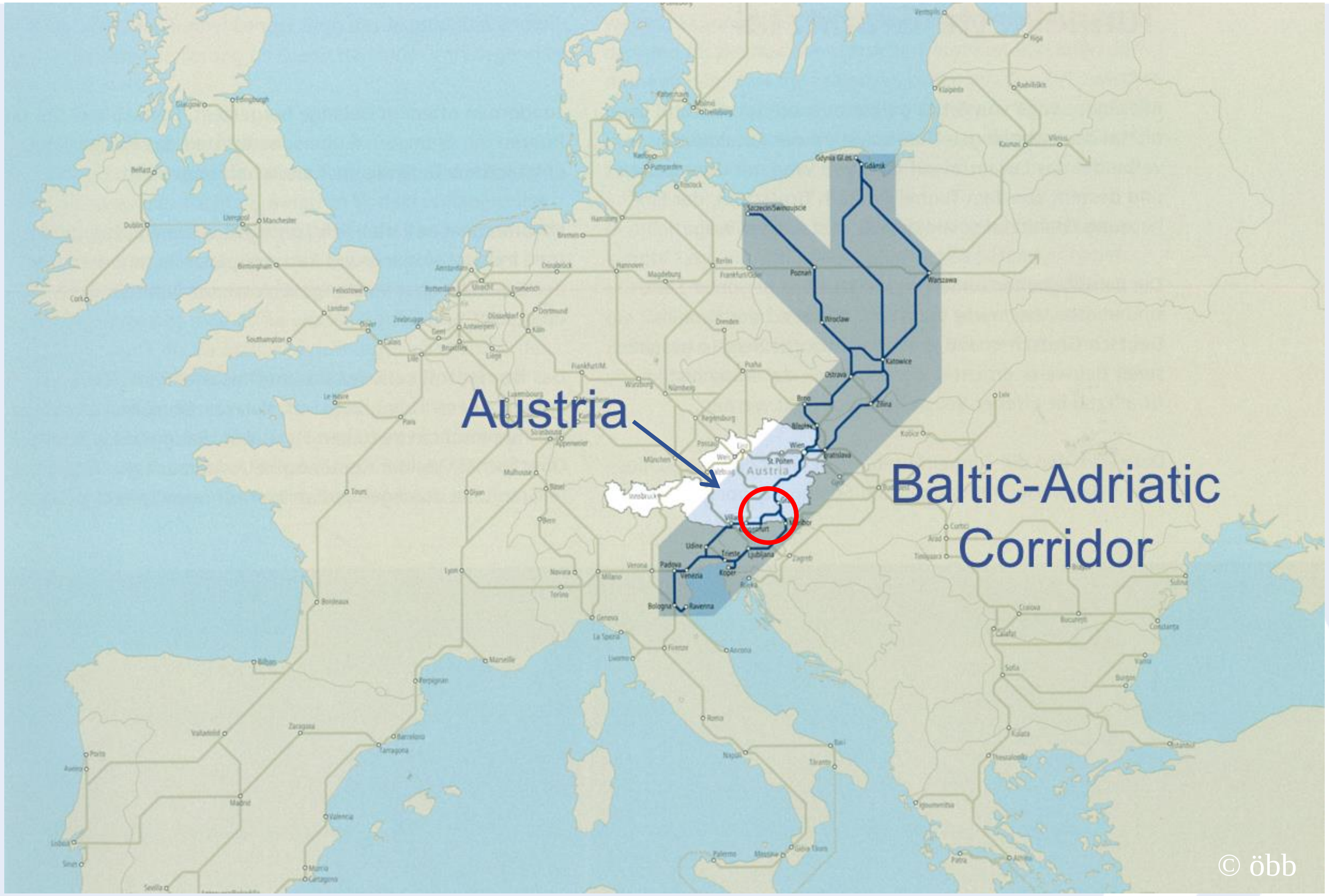
ECI

TUTG Thailand Underground &Tunnelling Group

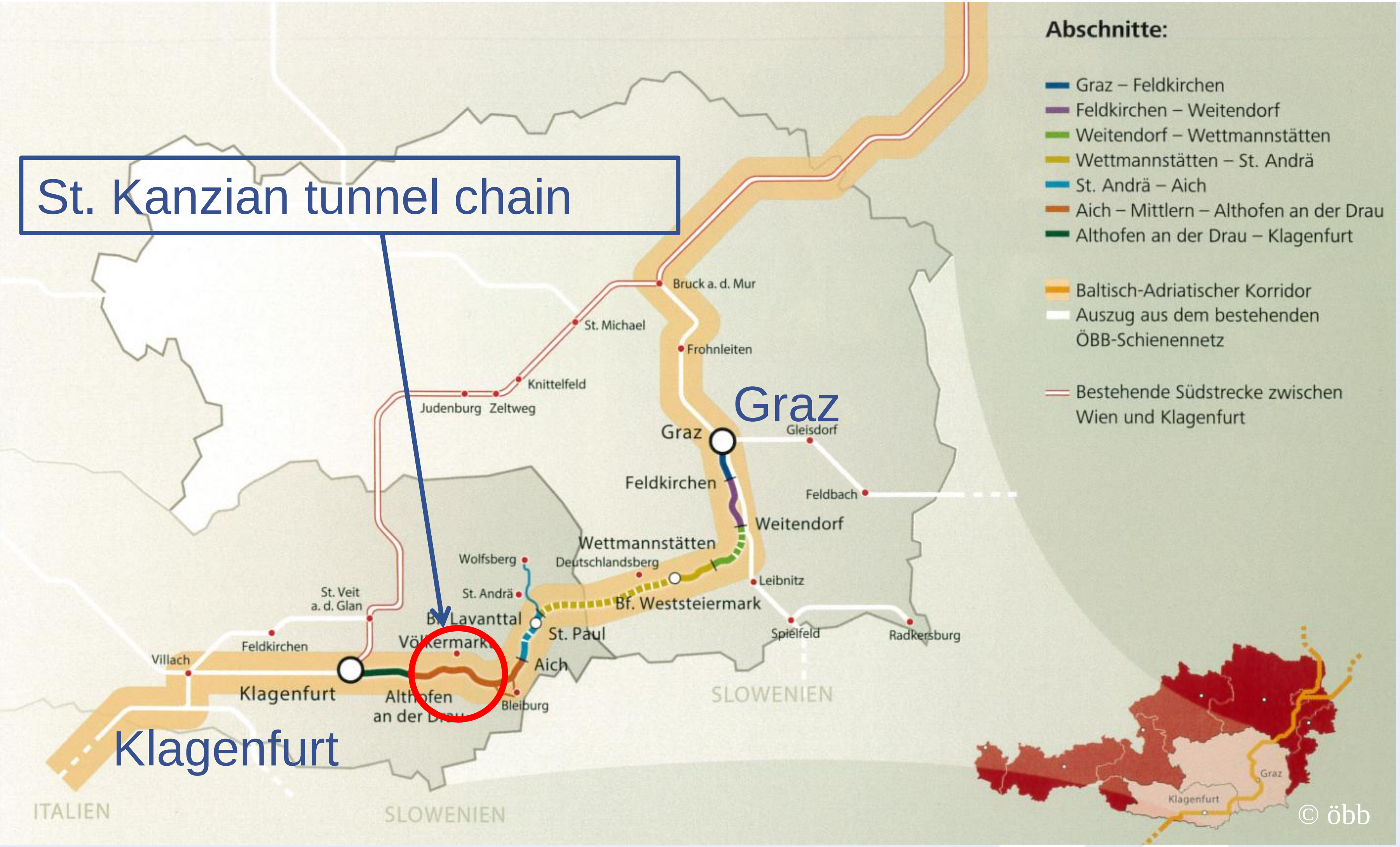
ITA AITES

STUVA

INTRODUCTION – PROJECT OVERVIEW

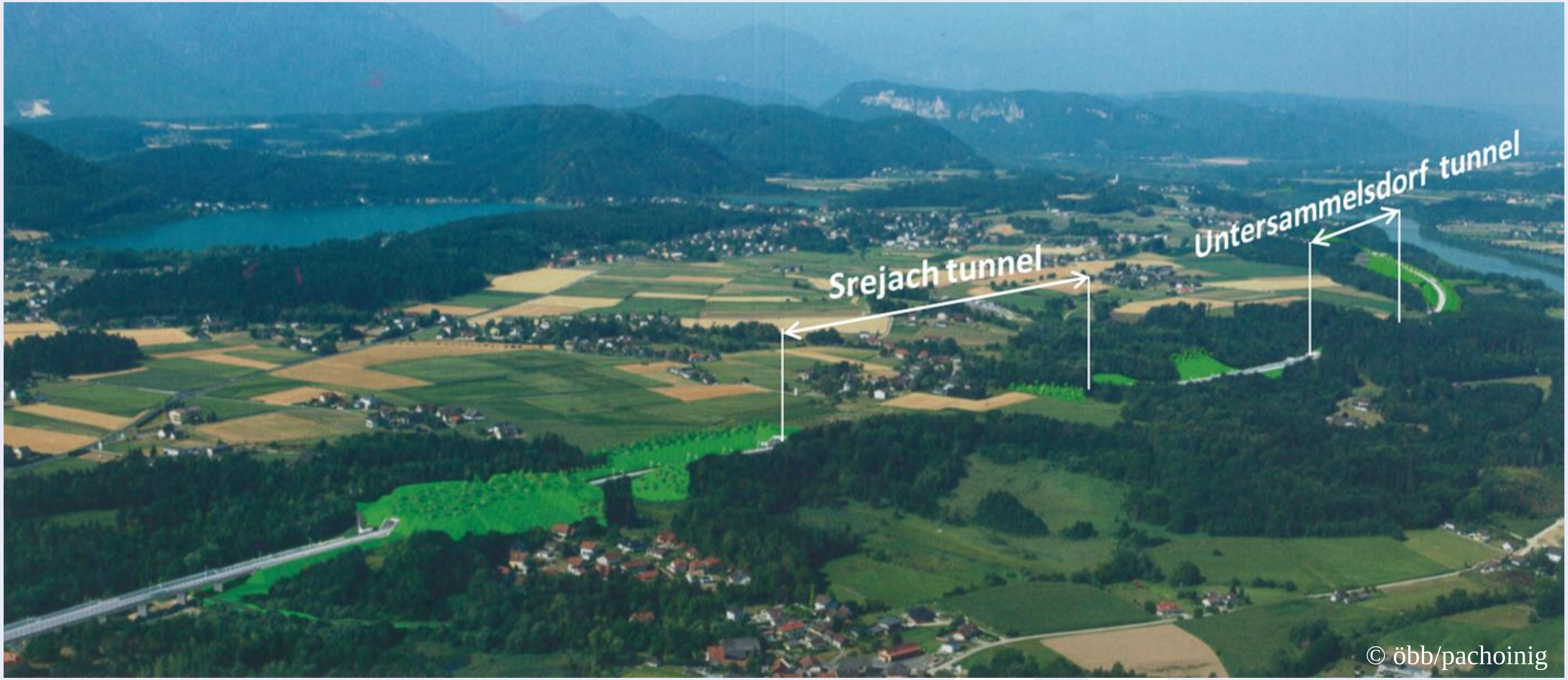


INTRODUCTION – PROJECT OVERVIEW



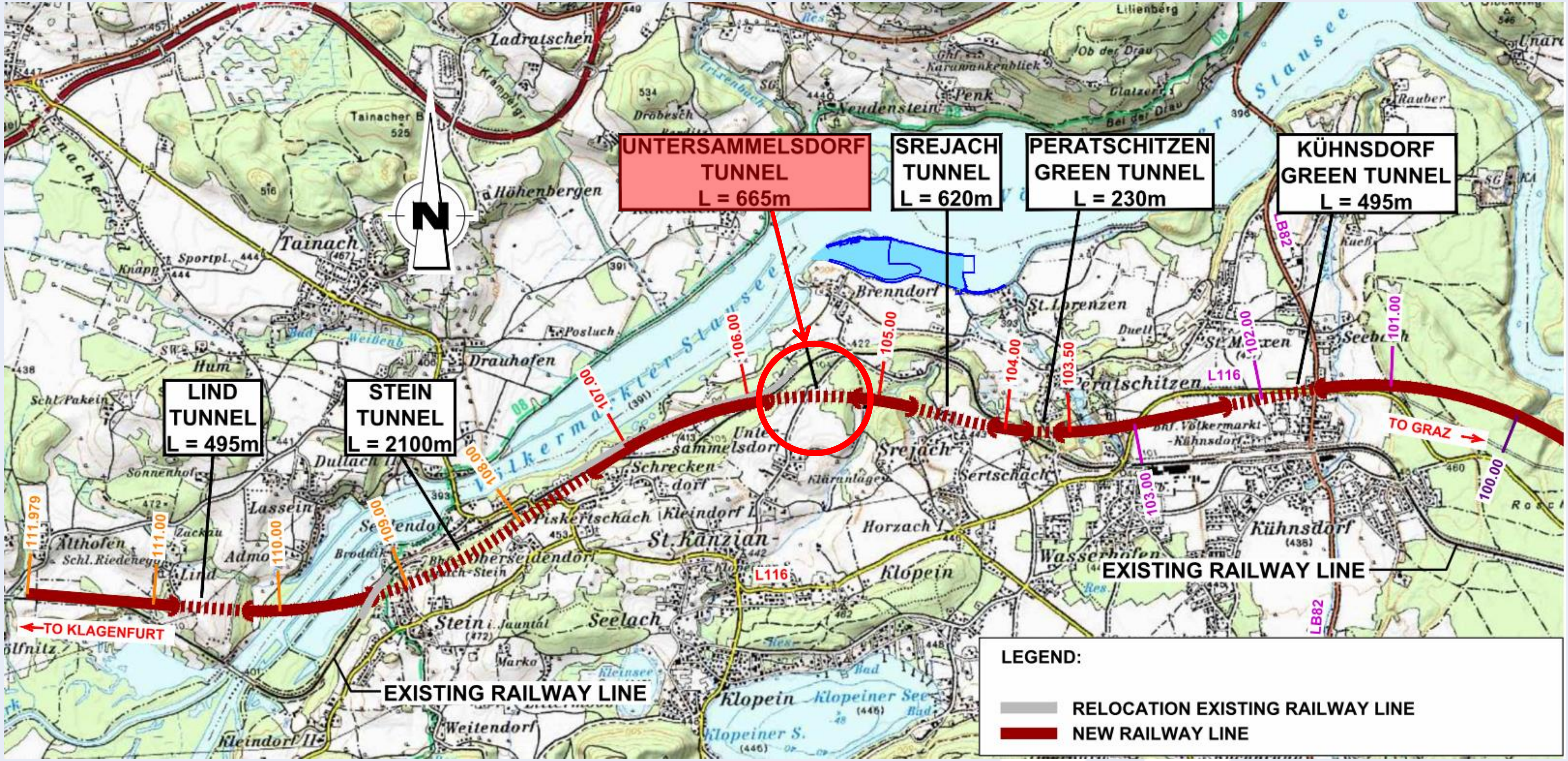
INTRODUCTION – PROJECT OVERVIEW

Visualization St. Kanzian tunnel chain:

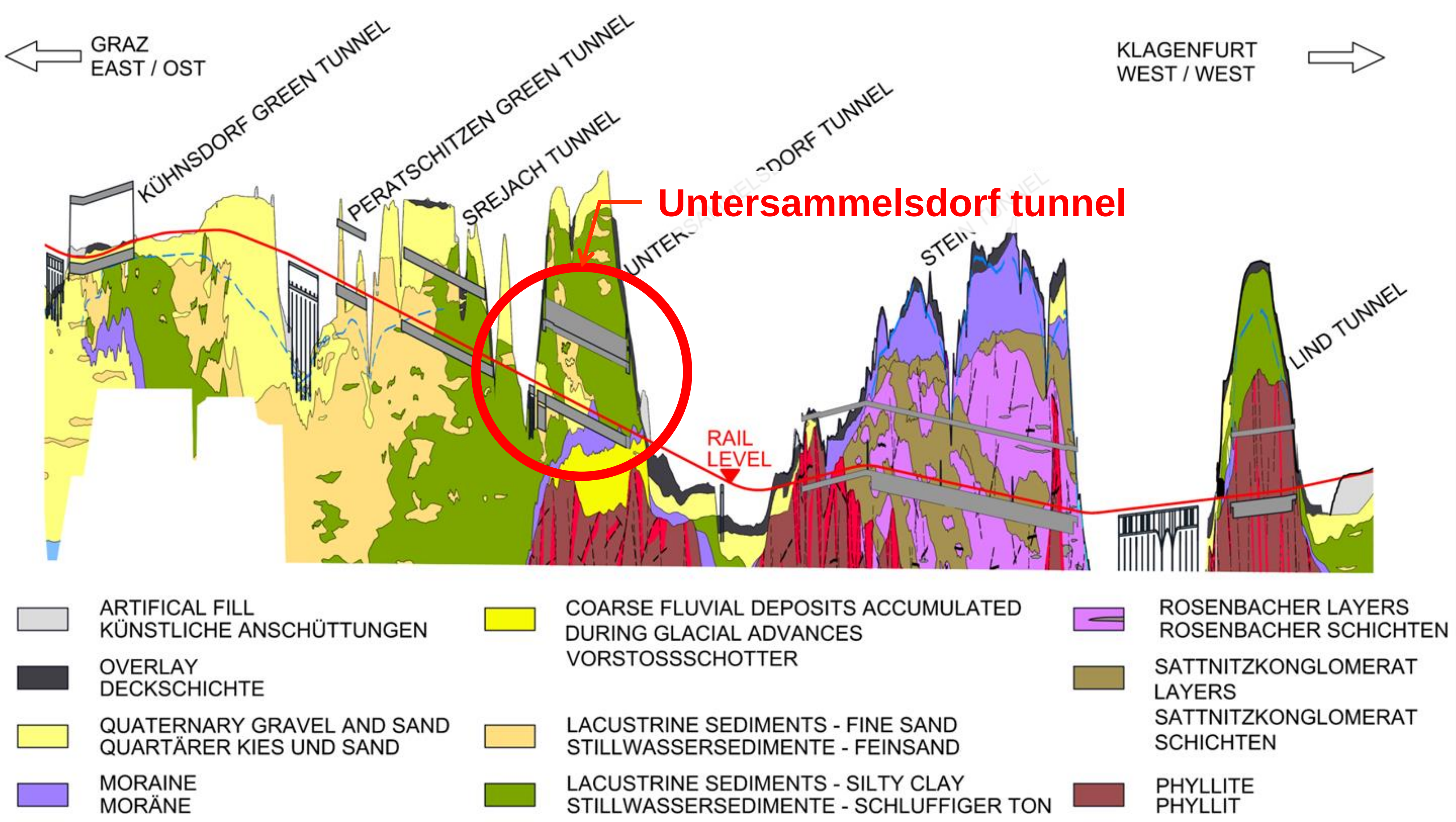


INTRODUCTION – PROJECT OVERVIEW

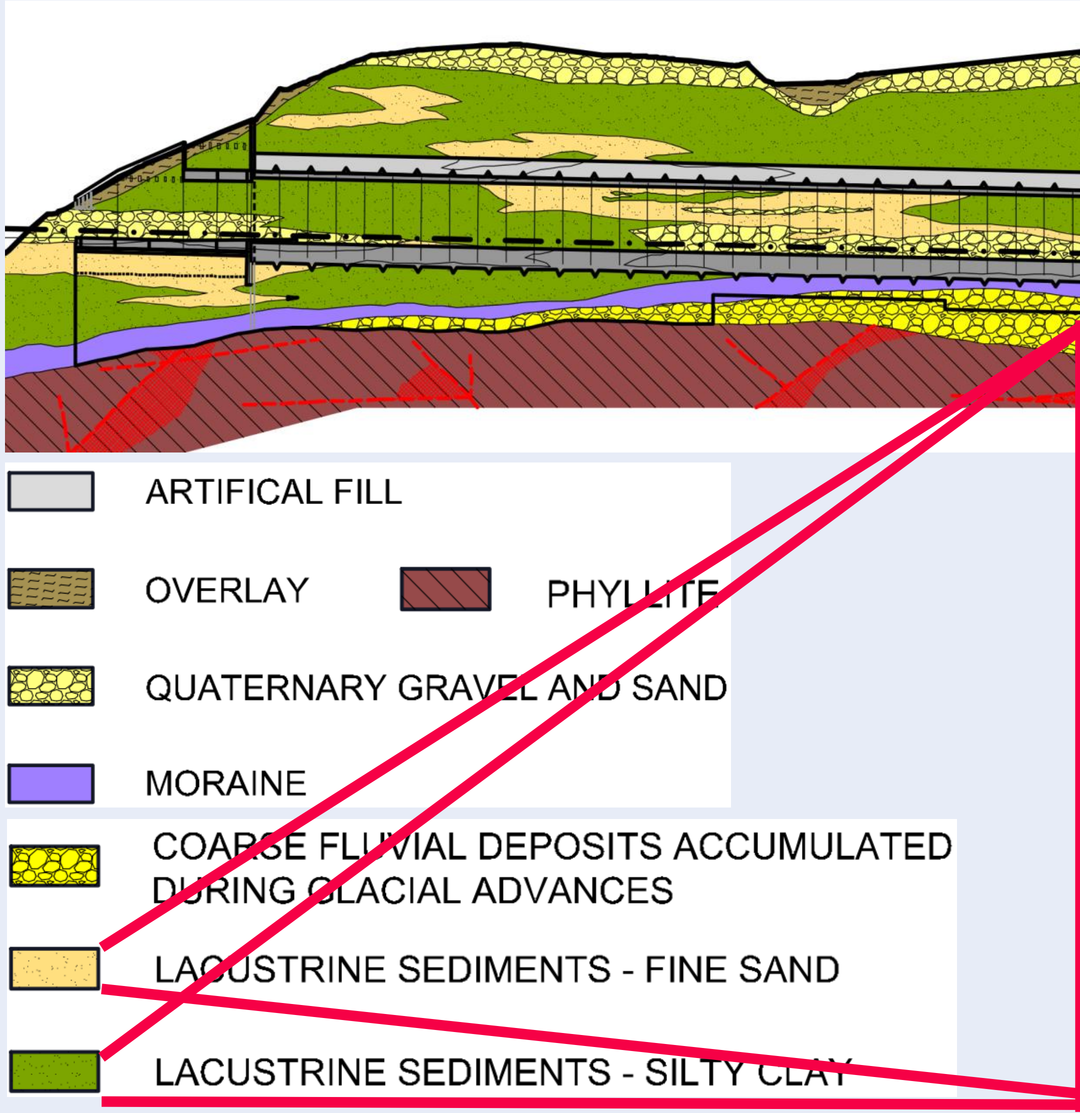
Layout St. Kanzian tunnel chain:



GEOLOGICAL OVERVIEW



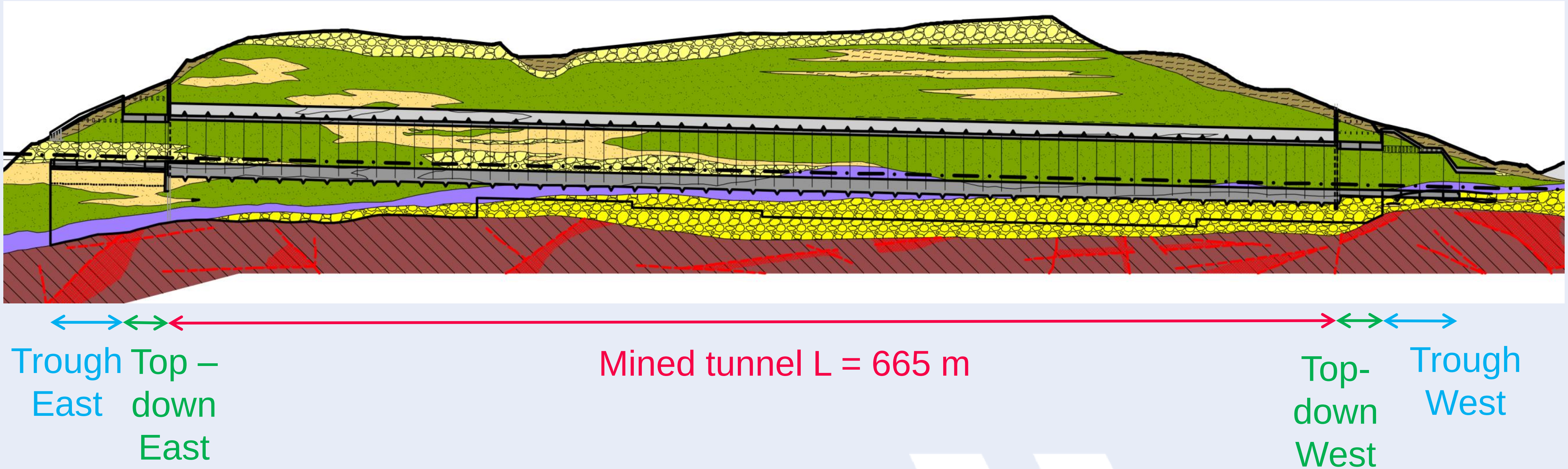
GEOLOGICAL LONGITUDINAL SECTION



Lacustrine Sediments – Silty Clay:

- mainly medium plastic to very plastic silts and/or silty clays
- locally stiff or very soft

GEOLOGICAL LONGITUDINAL SECTION

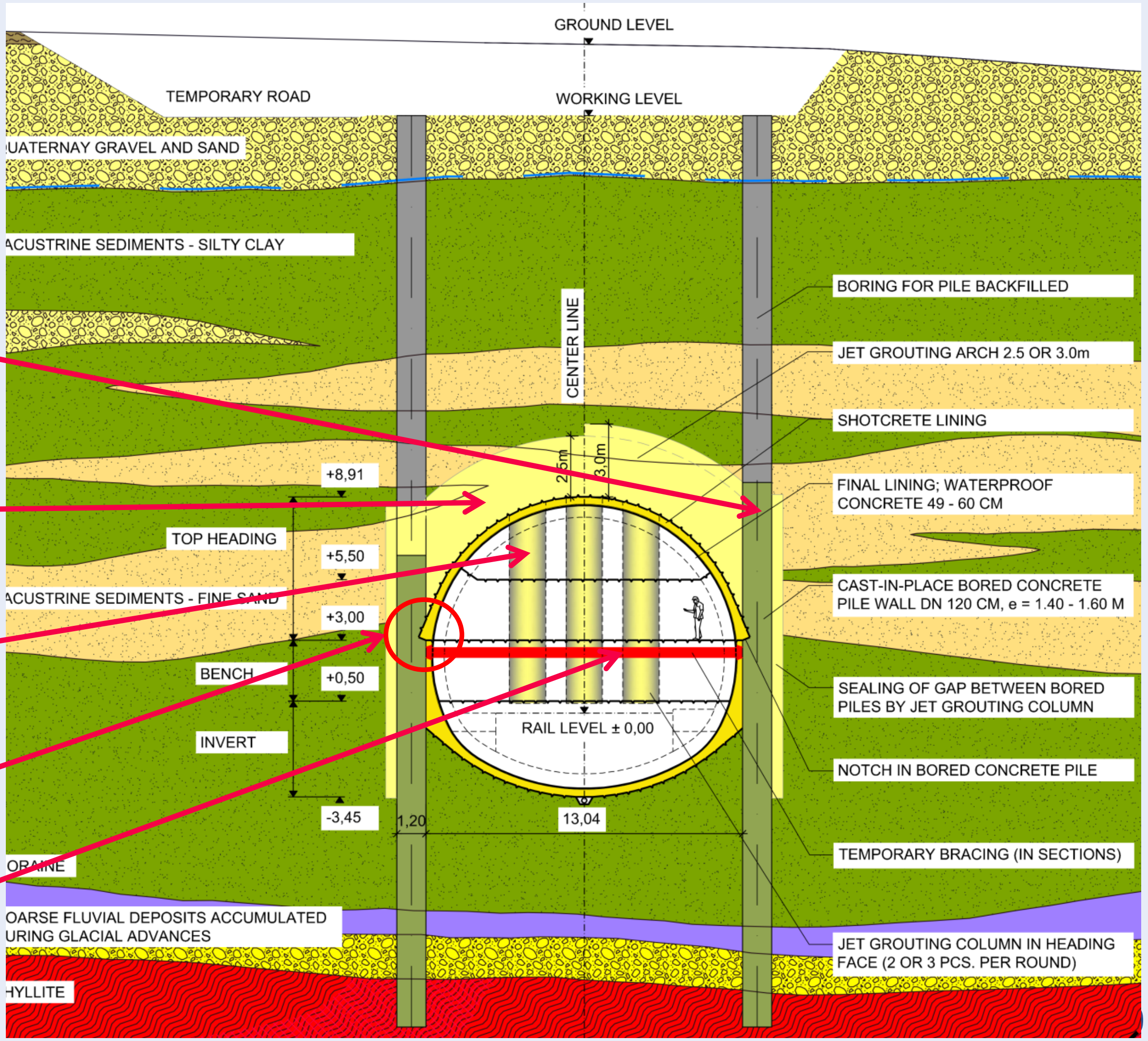


- **Heading permanent in lacustrine sediments**
- **Bench / invert in western tunnel section in quaternary gravel and sand as well as moraine**
- **Overburden up to 33 m over rail level**

CONCEPT TUNNEL EXCAVATION – CROSS SECTION

MINED TUNNEL WITH :

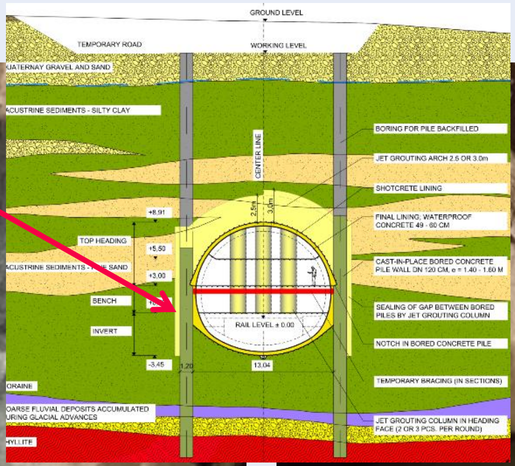
- caste - in - place bored concrete pile wall, DN 120 cm, e = 1.40 m – 1.60 m
- jet grouting arch 2.5 m or 3.0 m thick interfingerd with pile wall
- jet grouting columns in heading face (2 or 3 pcs per round)
- Shotcrete lining with connection to bored concrete pile
- temporary bracing (in sections)

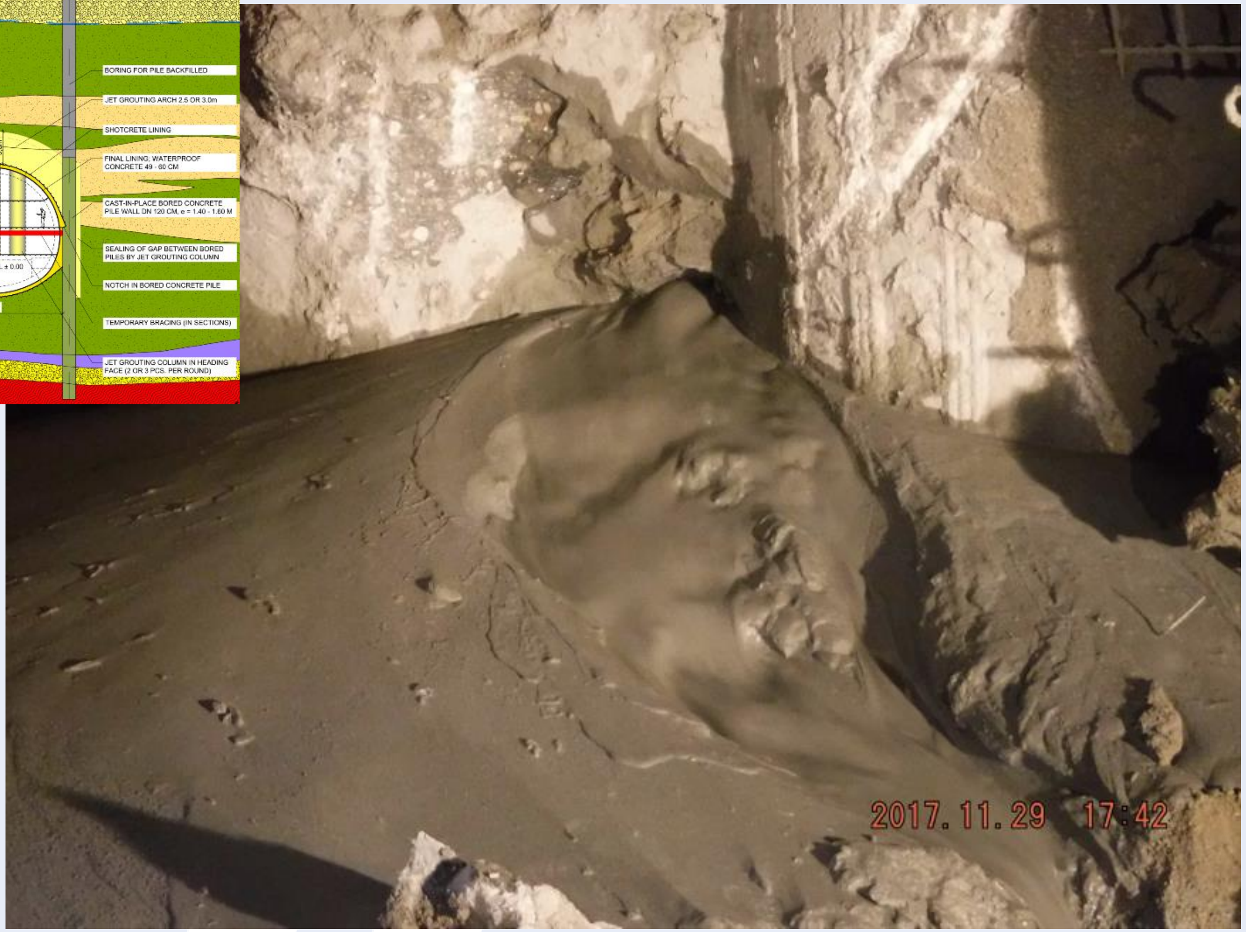


INCIDENTS AND POSSIBLE FAILURES DURING CONSTRUCTION

Cast - in - place bored concrete pile wall,
DN 120 cm, e = 1.40 m – 1.60 m

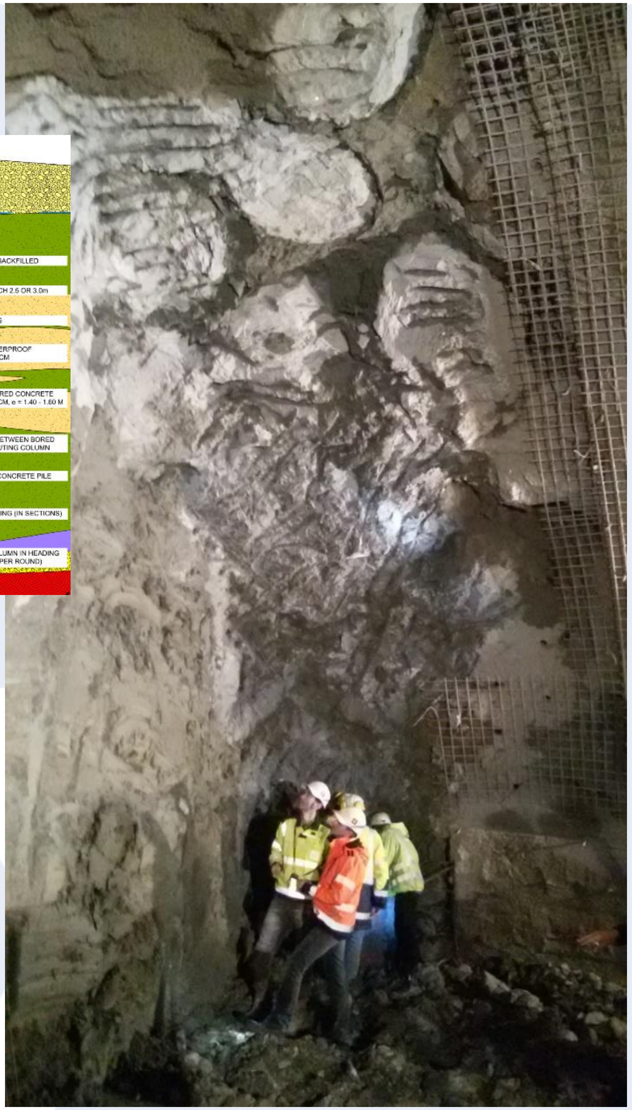
⇨ **Ingress of water and Lacustrine Sediments**



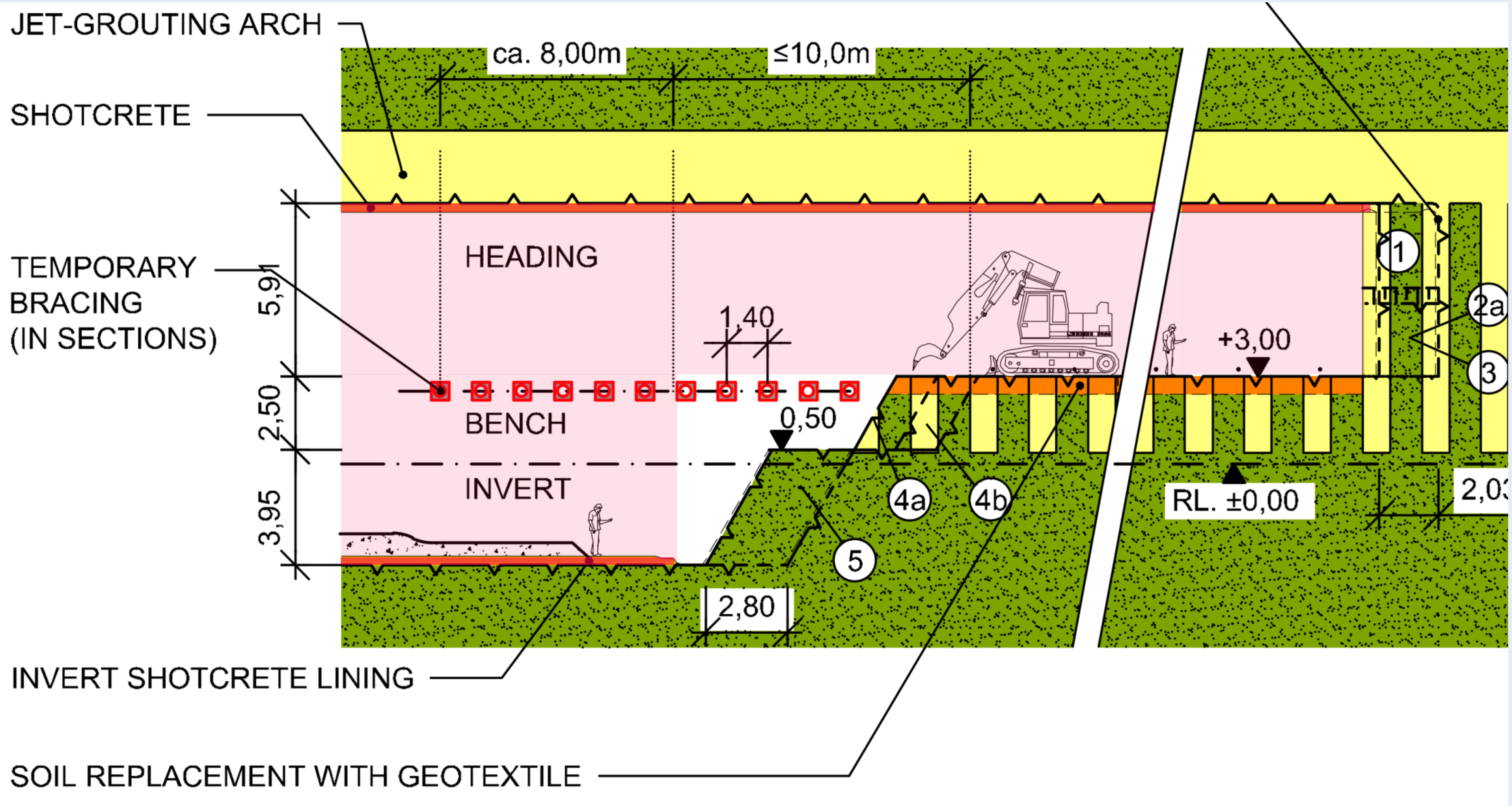


INCIDENTS AND POSSIBLE FAILURES DURING CONSTRUCTION

Defective areas in tunnel crown (due to reduced diameter of jet grouting columns)

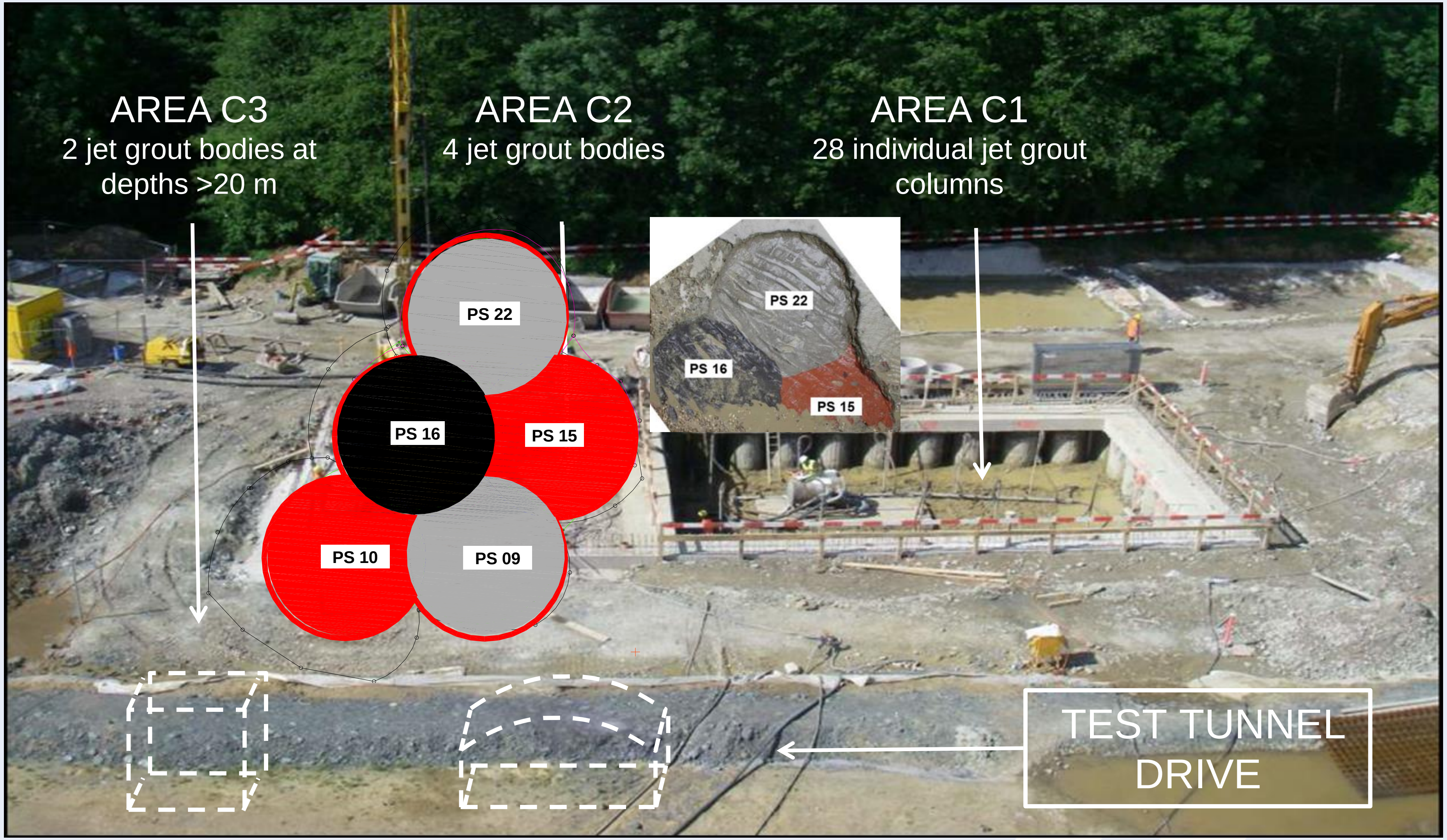


CONCEPT TUNNEL EXCAVATION – LONGITUDINAL SECTION



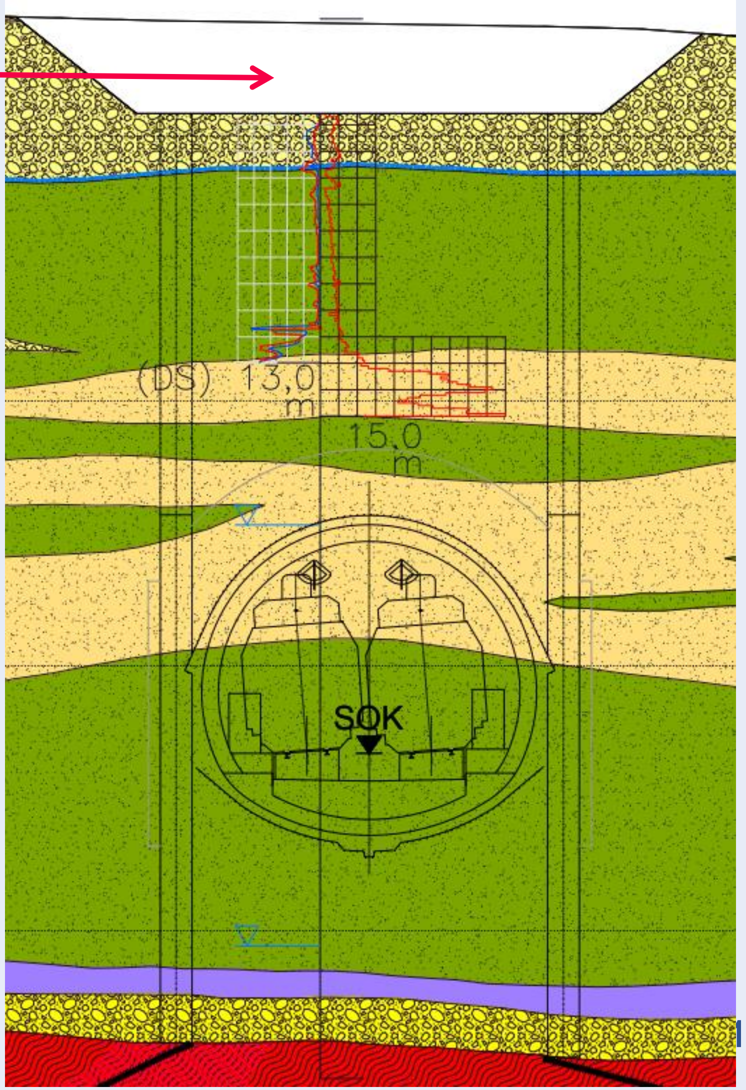
TEST PIT FOR SOIL STABILIZATION TESTS

TEST FIELD – AREAL VIEW



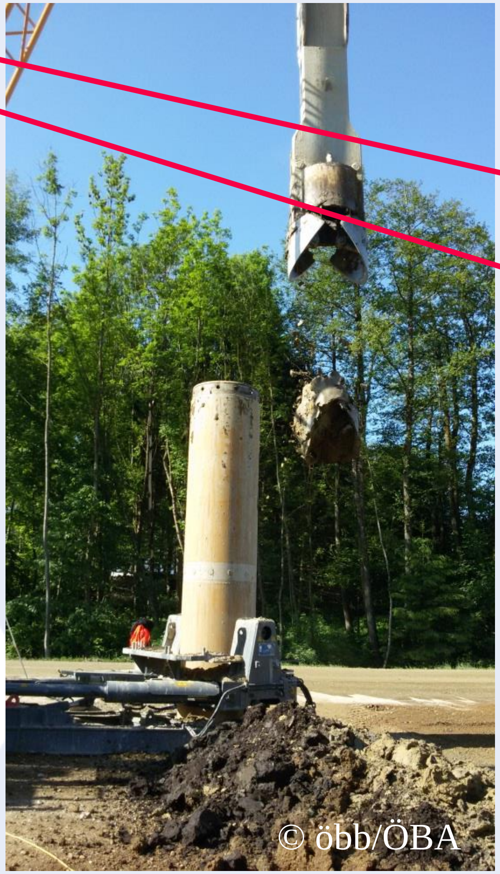
CONSTRUCTION SEQUENCE – STEP 1

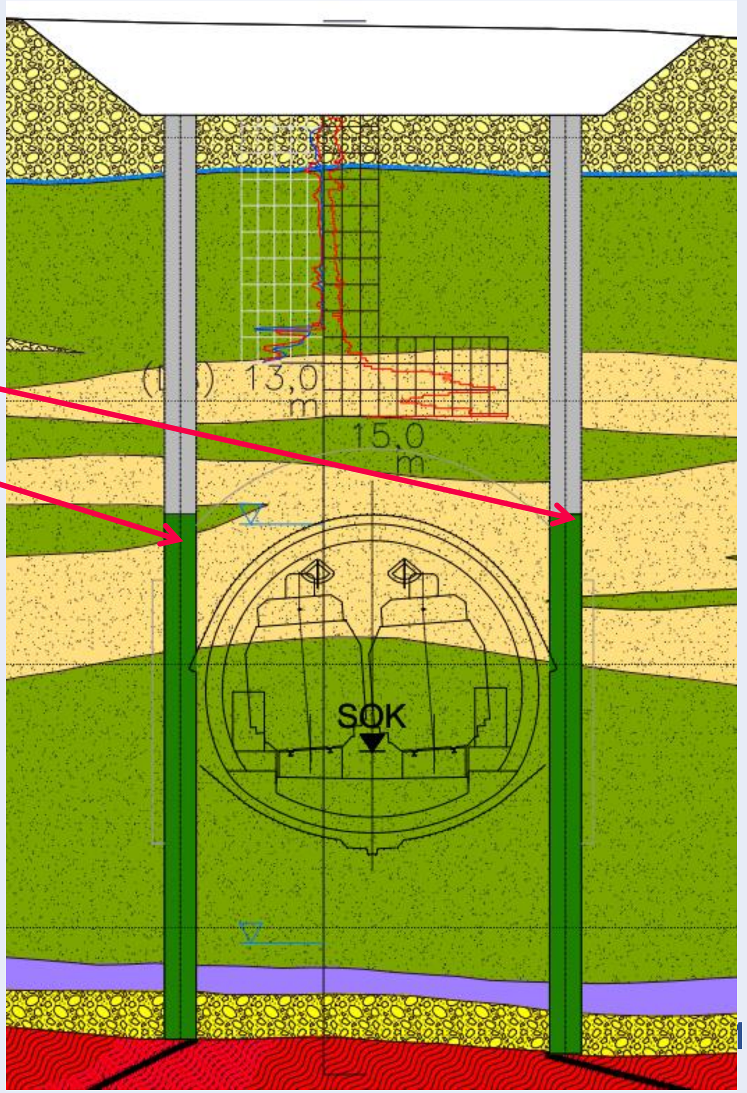
- precut



CONSTRUCTION SEQUENCE – STEP 2

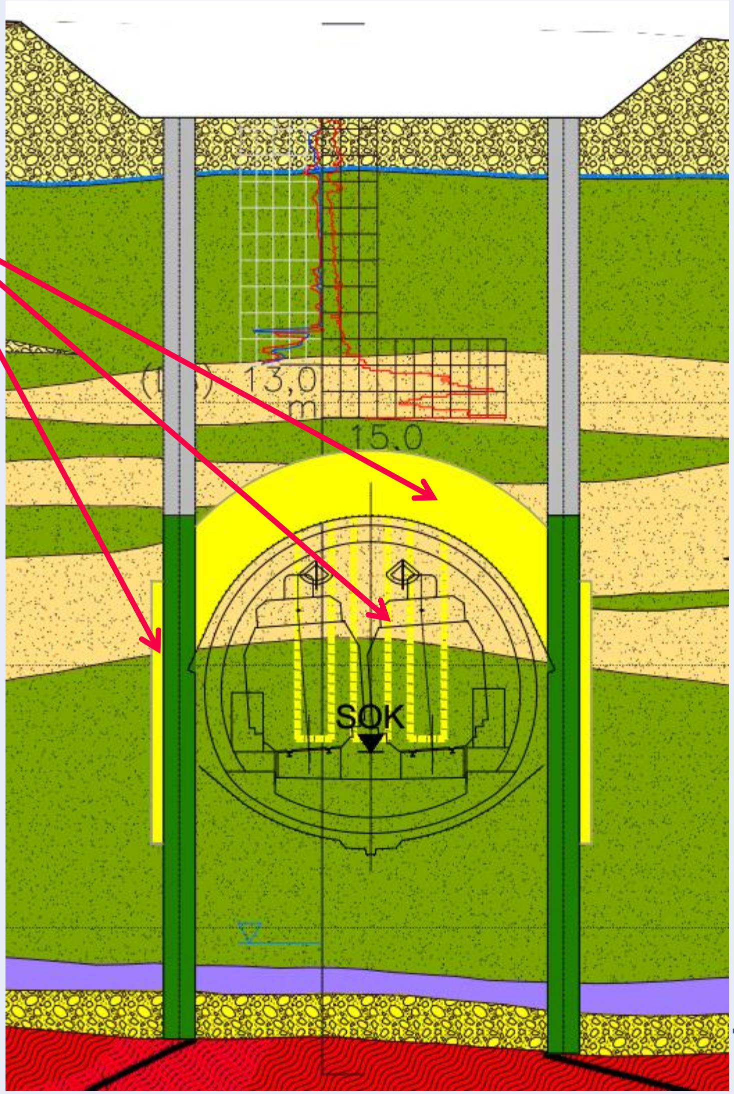
- precut
- bored concred piles



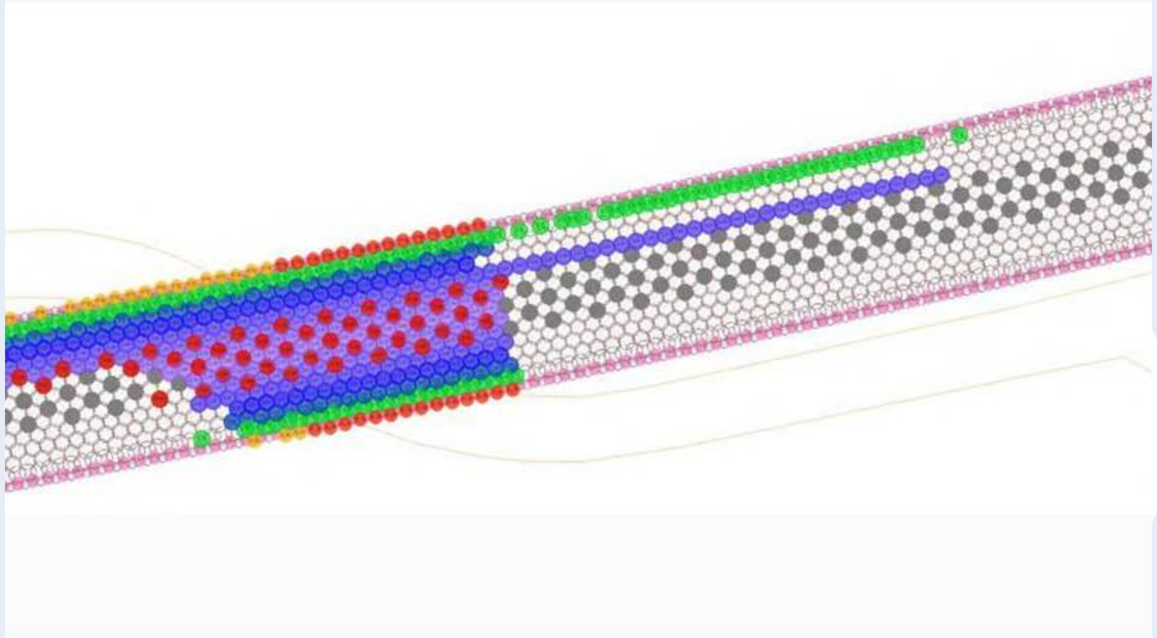


CONSTRUCTION SEQUENCE – STEP 3

- precut
- bored concred piles
- Jet grouting arch, jet grouting face columns and jet grouting for sealing gap between bored piles

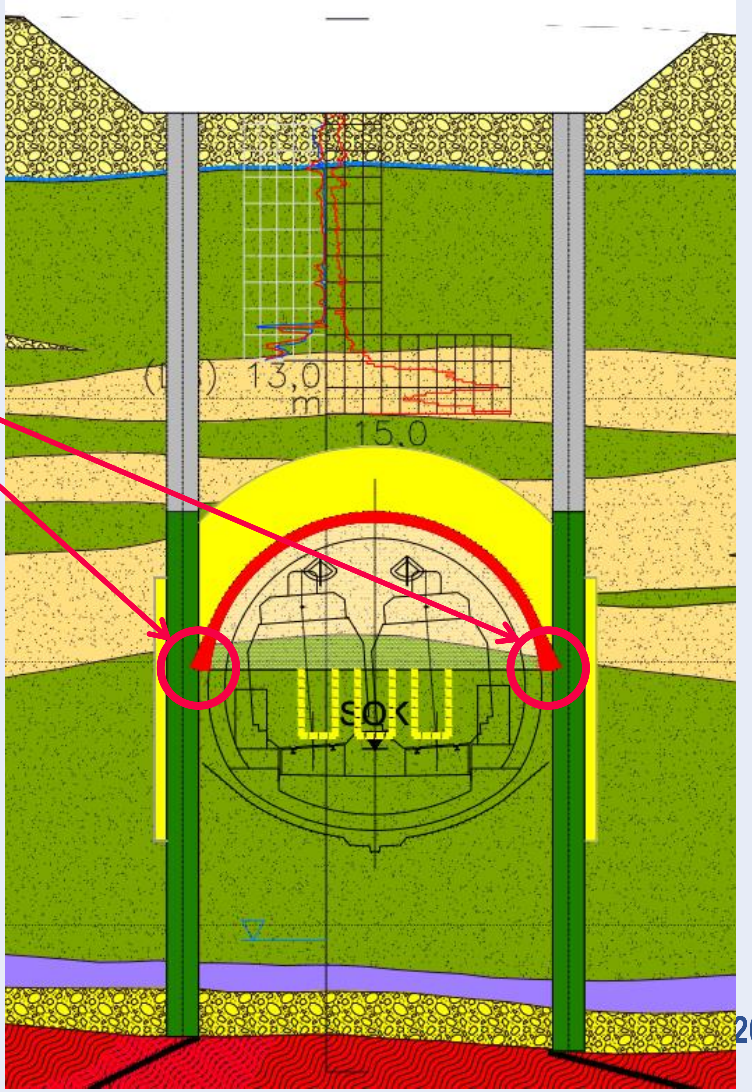


CONSTRUCTION - JET GROUTING COLUMNS



CONSTRUCTION SEQUENCE – STEP 4

- precut
- bored concred piles
- Jet grouting arch, jet grouting face columns and jet grouting for sealing gap between bored piles
- advance of heading with connection of the shotcrete to the bored piles by a notch



CONSTRUCTION SEQUENCE – STEP 5

- precut
- bored concred piles
- Jet grouting arch, jet grouting face columns and jet grouting for sealing gap between bored piles
- advance of heading with connection of the shotcrete to the bored pile by a notch
- temporary bracing at bench level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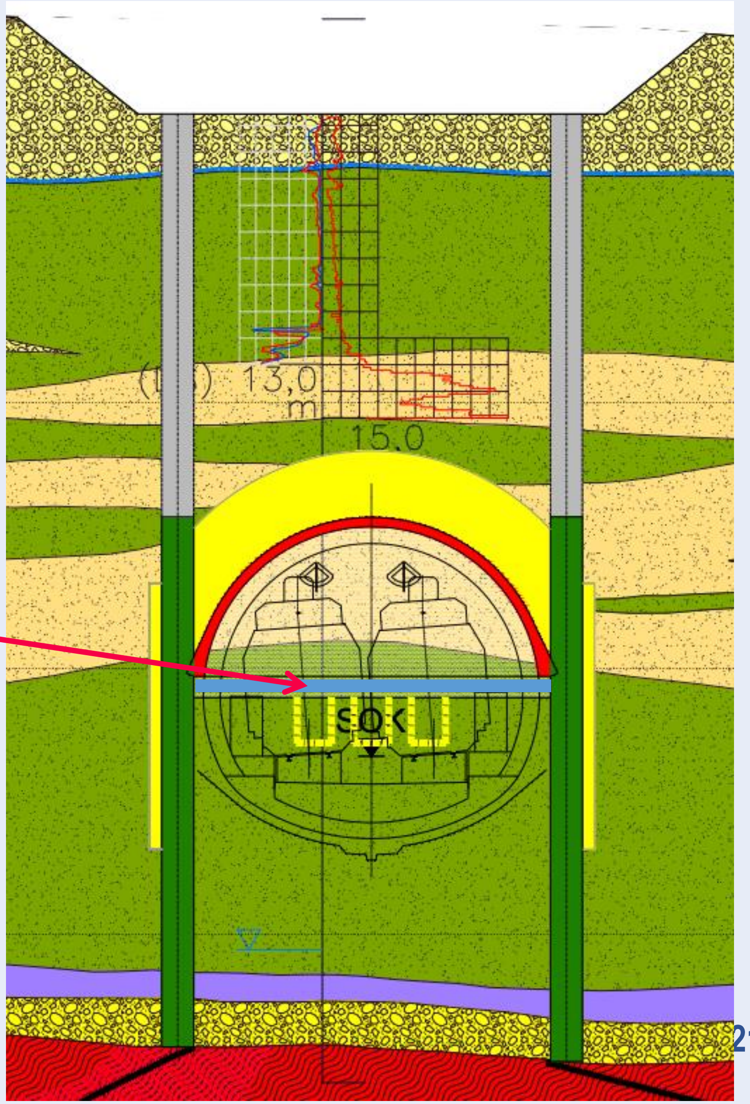
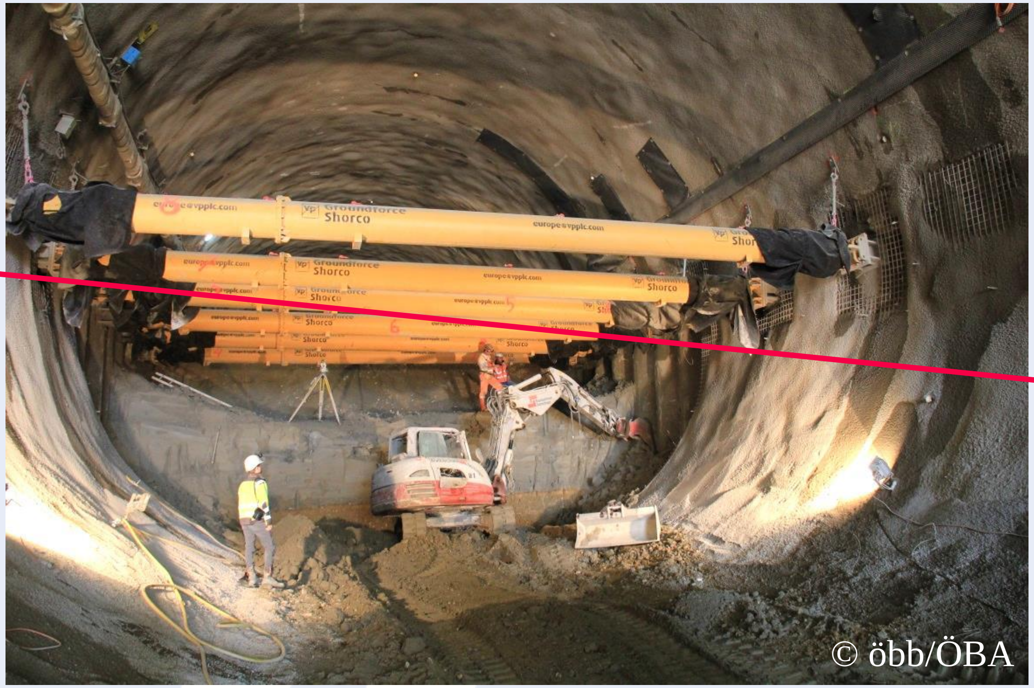
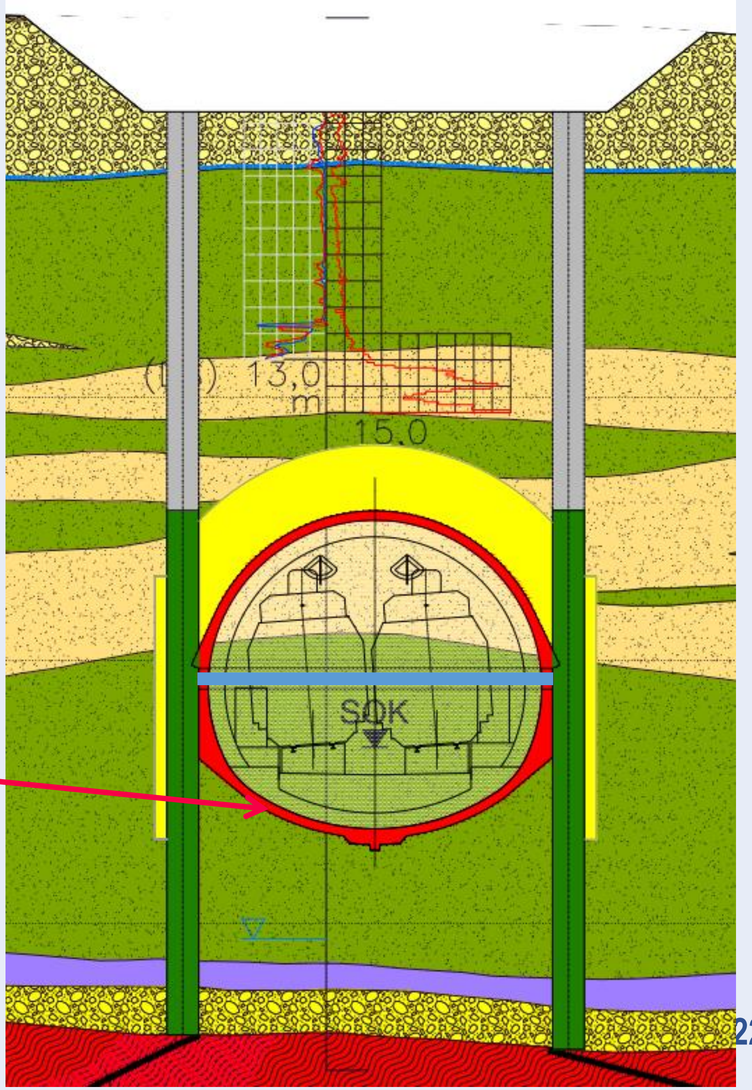


CONSTRUCTION SEQUENCE – STEP 6

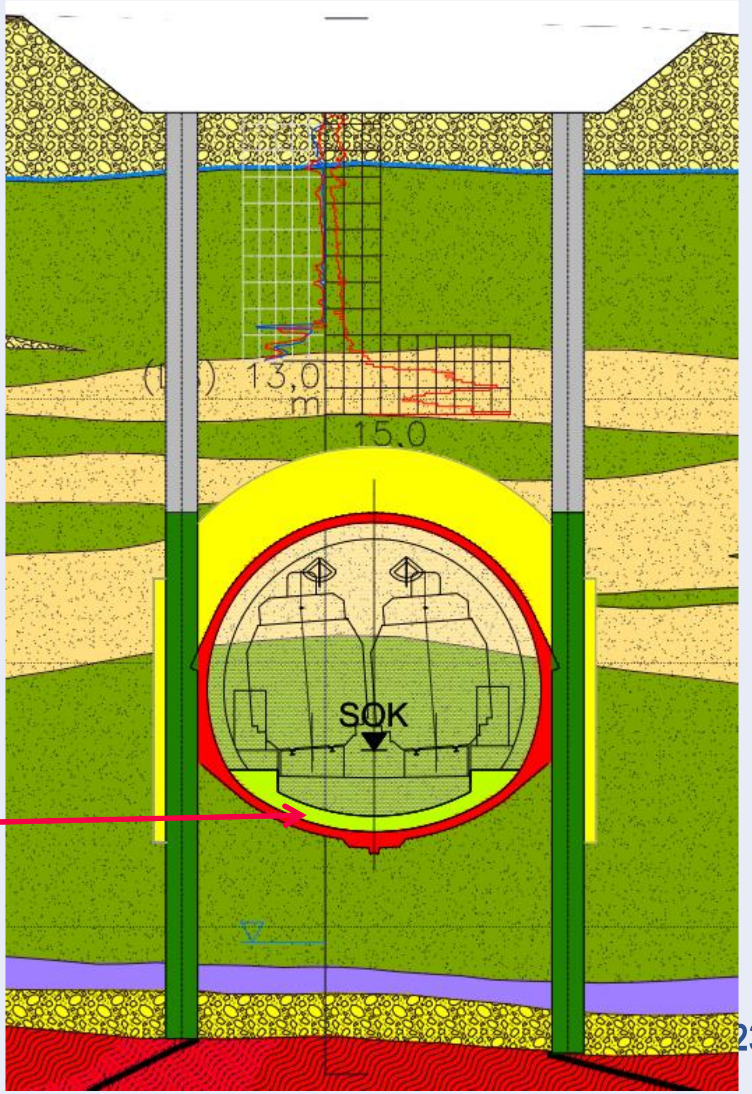
- precut
- bored concred piles
- Jet grouting arch, jet grouting face columns and jet grouting for sealing gap between bored piles
- advance of heading with connection of the shotcrete to the bored pile by a notch
- temporary bracing in bench level
- advance of bench and invert with rapid ring closure





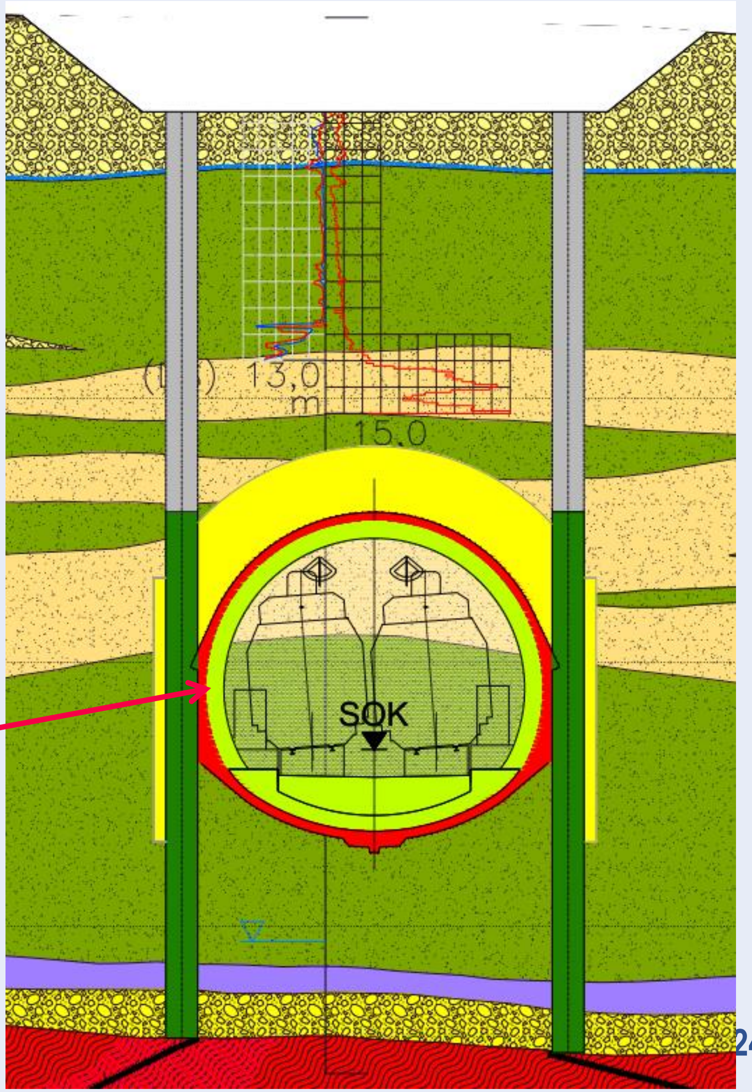
CONSTRUCTION SEQUENCE – STEP 7

- precut
- bored concred piles
- Jet grouting arch, jet grouting face columns and jet grouting for sealing gap between bored piles
- advance of heading with connection of the shotcrete to the bored pile by a notch
- temporary bracing in bench level
- advance of bench and invert with rapid ring closure
- concrete lining invert



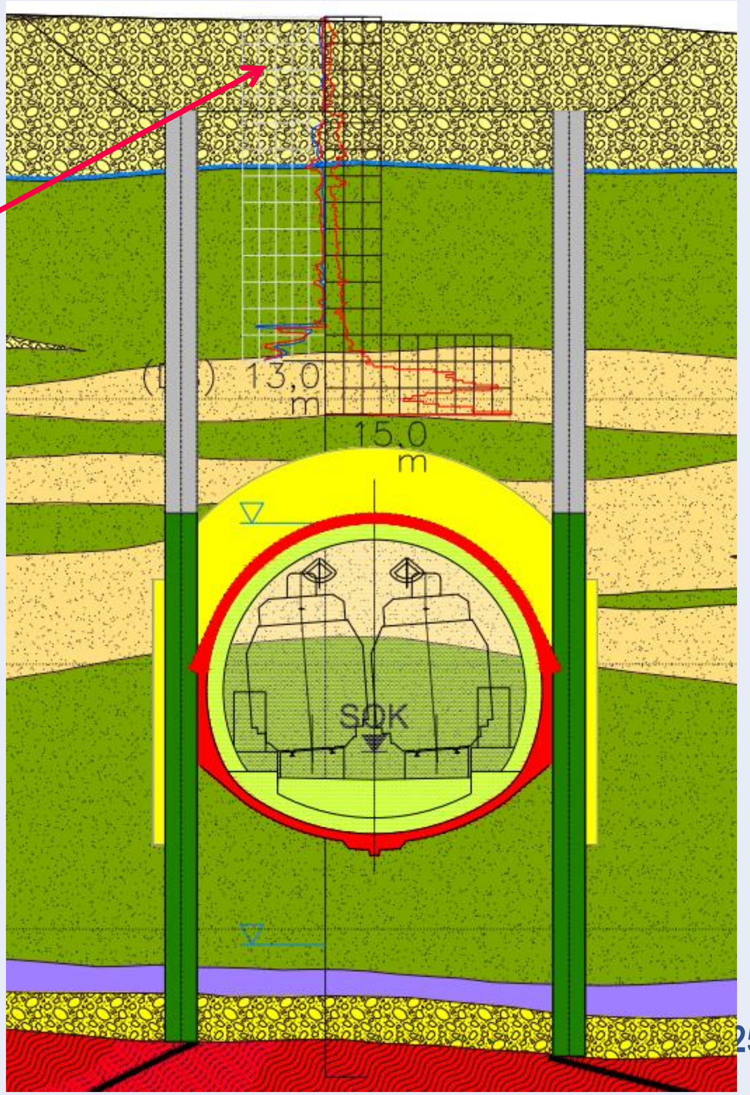
CONSTRUCTION SEQUENCE – STEP 8

- precut
- bored concred piles
- Jet grouting arch, jet grouting face columns and jet grouting for sealing gap between bored piles
- advance of heading with connection of the shotcrete to the bored pile by a notch
- temporary bracing in bench level
- advance of bench and invert with rapid ring closure
- concrete lining invert
- concrete lining profile



CONSTRUCTION SEQUENCE – STEP 9

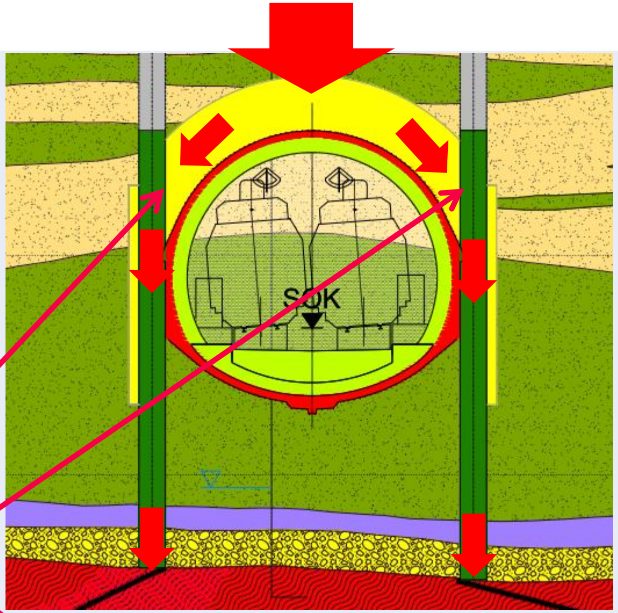
- precut
- bored concred piles
- Jet grouting arch, jet grouting face columns and jet grouting for sealing gap between bored piles
- advance of heading with connection of the shotcrete to the bored pile by a notch
- temporary bracing in bench level
- advance of bench and invert with rapid ring closure
- concrete lining invert
- concrete lining profile
- refilling of precut



DESIGN DETAIL: SHOTCRETE IN NOTCH OF BORED PILES

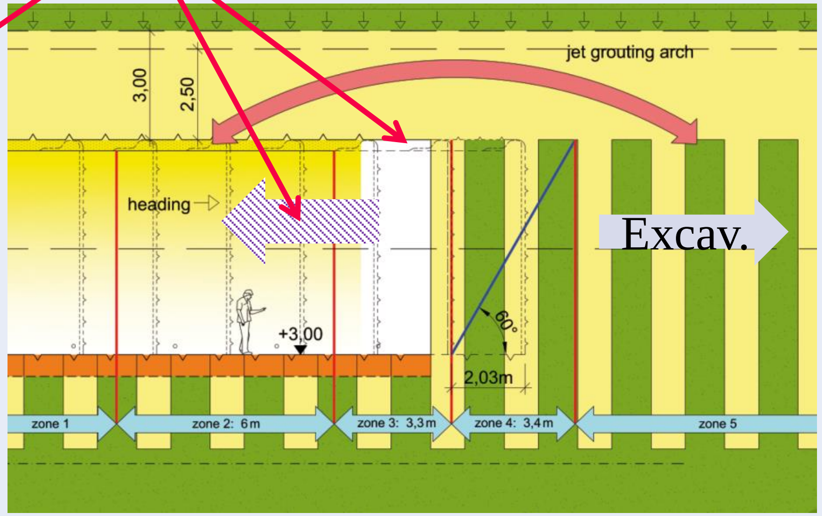
Load bearing system:

- entire ground load of up to 6,000 kN/m lies on the jet grouted arch (in area of excavation)
- due to the high stiffness of loadbearing system, small displacements and accordingly sudden system failure had to be expected after slight exceedance of the loadbearing capacity
- danger of local failure in area of excavation with a zip effect in long. direction



Decisive question:

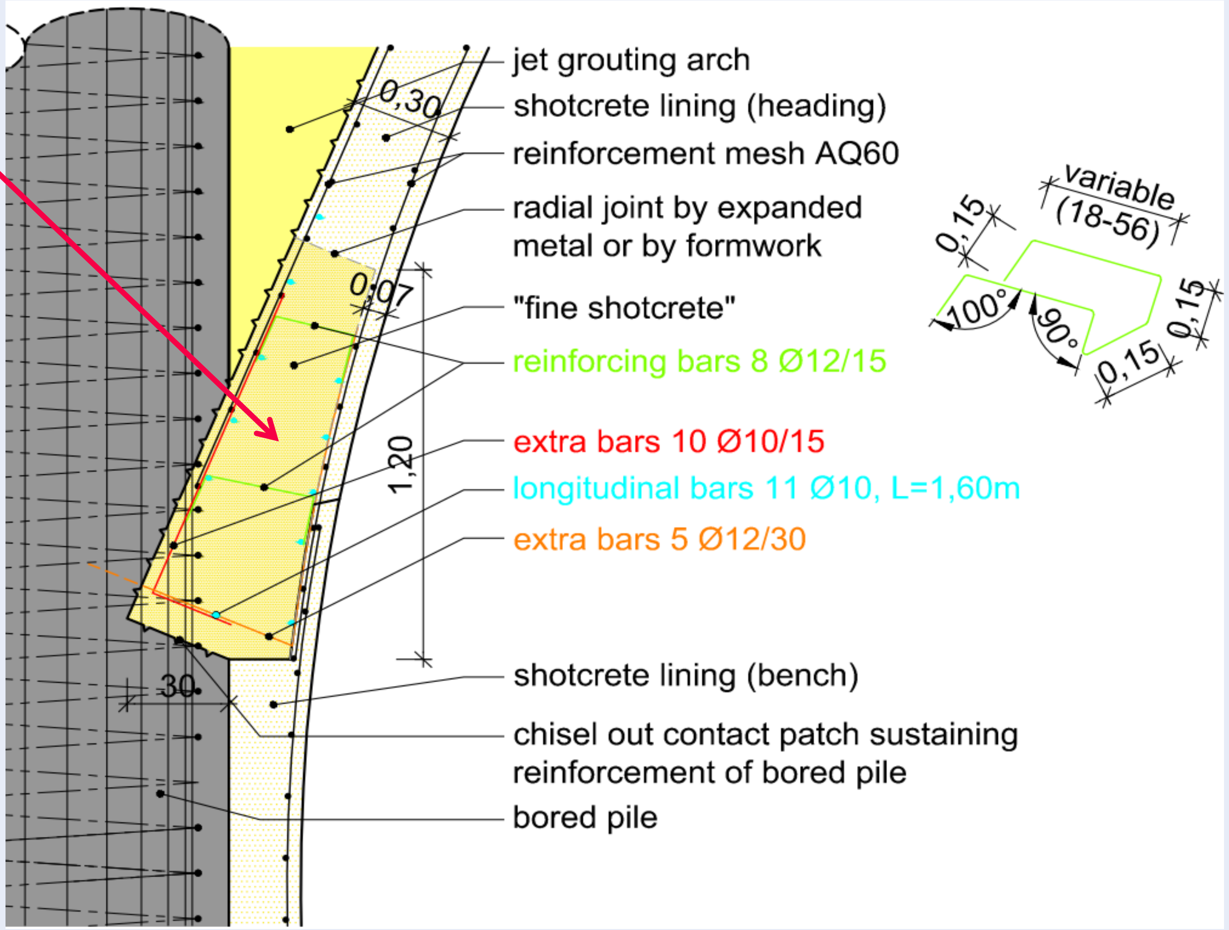
- parameters for friction and cohesion in the joints between jet grouted arch and bored piles
- ⇨ lack of reliable values for these parameters
- ⇨ Additional measure: load transfer from the shotcrete support layer through notches in the bored piles



DESIGN DETAIL: SHOTCRETE IN NOTCH OF BORED PILES

Two main goals for production of “fine shotcrete” in notch:

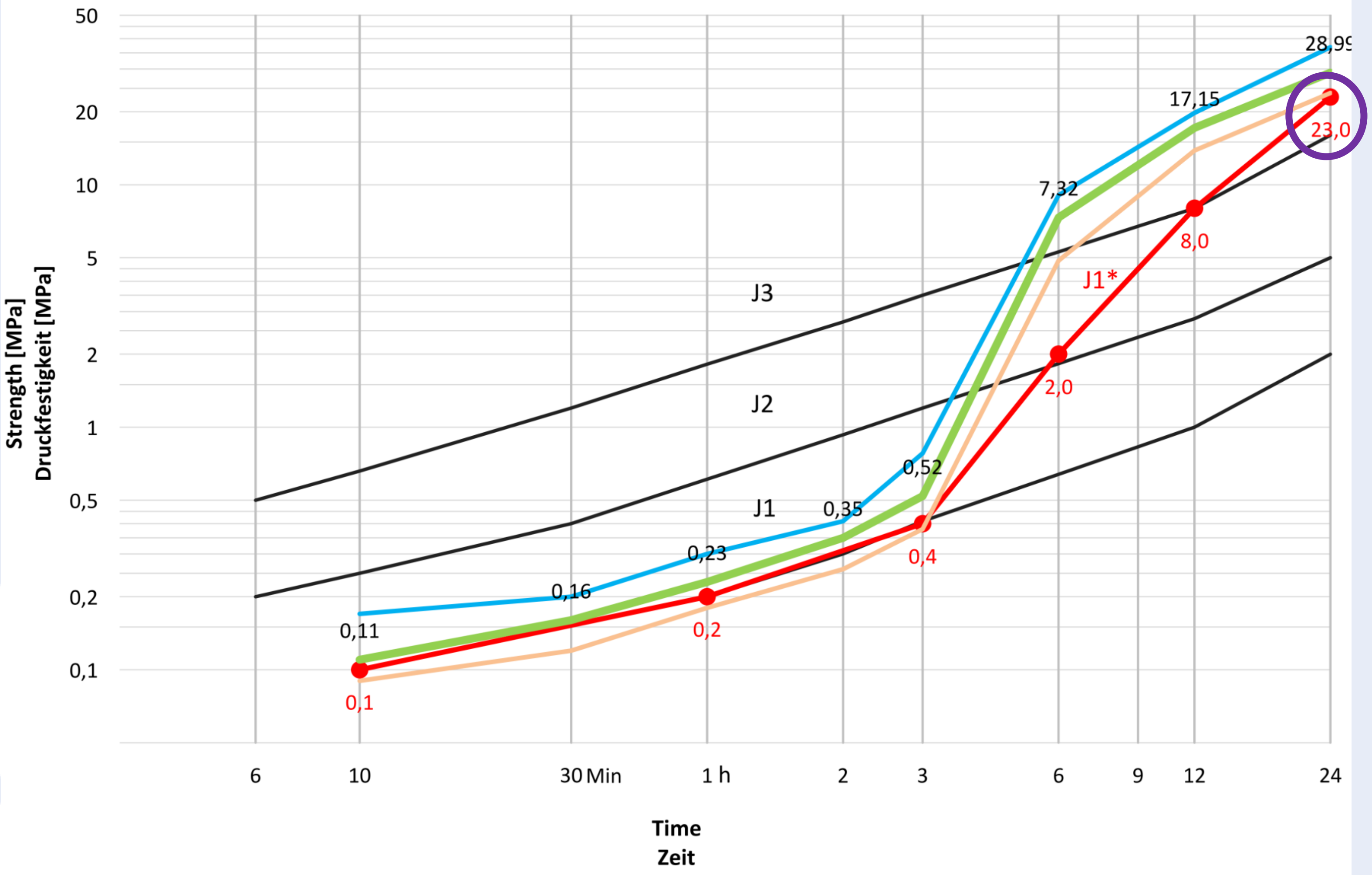
- high 24 h strength of “fine shotcrete”
- shotcrete structure without spraying shadows



DESIGN DETAIL: SHOTCRETE IN NOTCH OF BORED PILES

Shotcrete formula for C25/30/II/XC3/XF4:

Contents	kg/m³
CEM I 52,5 R SpB	450
sand 0/4 (dry)	1.639
water-reducing admixture: LZSP20W	3,60
retarder	1,80
W/Z - factor	0,47



DESIGN DETAIL: SHOTCRETE IN NOTCH OF BORED PILES

- over 50 tests
- Variation of capacity from 0,5 to 25,5 [m³/h]
- Variation of accelerator for solidification from 2% to 8% of the binder content

Shotcrete - machine	Mai2Pump Taurus	ALIVA TYP 263	SPM 500 Putzmeister
Capacity [m³/h]	0.5 - 2.0	2.5 - 4.0	4.0 - 25.5
accelerator solidification	2% - 8%	2% - 8%	2% - 8%

DESIGN DETAIL: SHOTCRETE IN NOTCH OF BORED PILES

Findings:

- **accelerator content** strongly affected the **development of compression strength within the first 3 hours**
- **after 3 hours** the chemical reaction of the **cement** and the **water / cement ratio of 0.47** were decisive for the development of compression strength
- **Compression strength of 23 N/mm² after 24 h** could be reached in all tests
- **Best results** were delivered through a **combination of the highest pumping rate (25.5 m³/h)** with the **lowest accelerator content (2 %).**
- This resulted in **wet fine shotcrete with a plastic consistency.**
  Trapping of rebound or **spraying shadows behind the reinforcing bars** could be **avoided.**

UNTERSAMMELSDORF TUNNEL – CHALLENGES, SPECIAL MEASURES AND USE OF SPECIAL SHOTCRETE FOR TUNNELING IN LACUSTRINE CLAY

Summary of conclusions:

Untersammelsdorf tunnel represented an unique and highly challenging tunnel project, requiring state of the art design and construction methods.

Different construction methods had to be used **simultaneously** to sucessfully cope with specific conditions and problems.

- ⇨ **careful preparation and planning (e.g. Untersammelsdorf test field),**
- ⇨ **inovative solutions (construction method, „fine shotcrete“),**
- ⇨ **further developments in heavy construction (jet grouting)**

ensured the project execution on-time and within the budgeted costs.

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THANK YOU FOR YOUR ATTENTION!

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