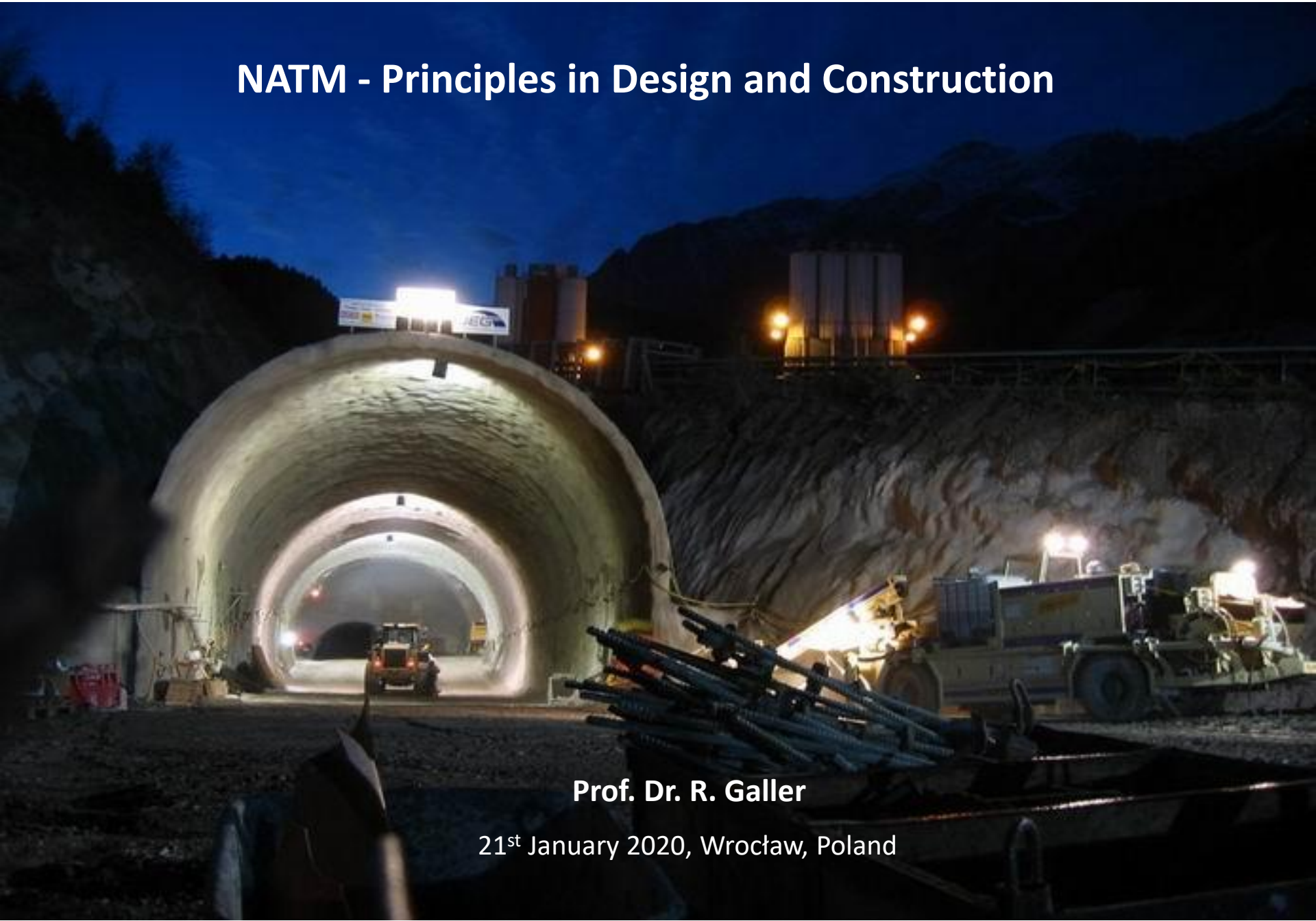
NATM - Principles in Design and Construction



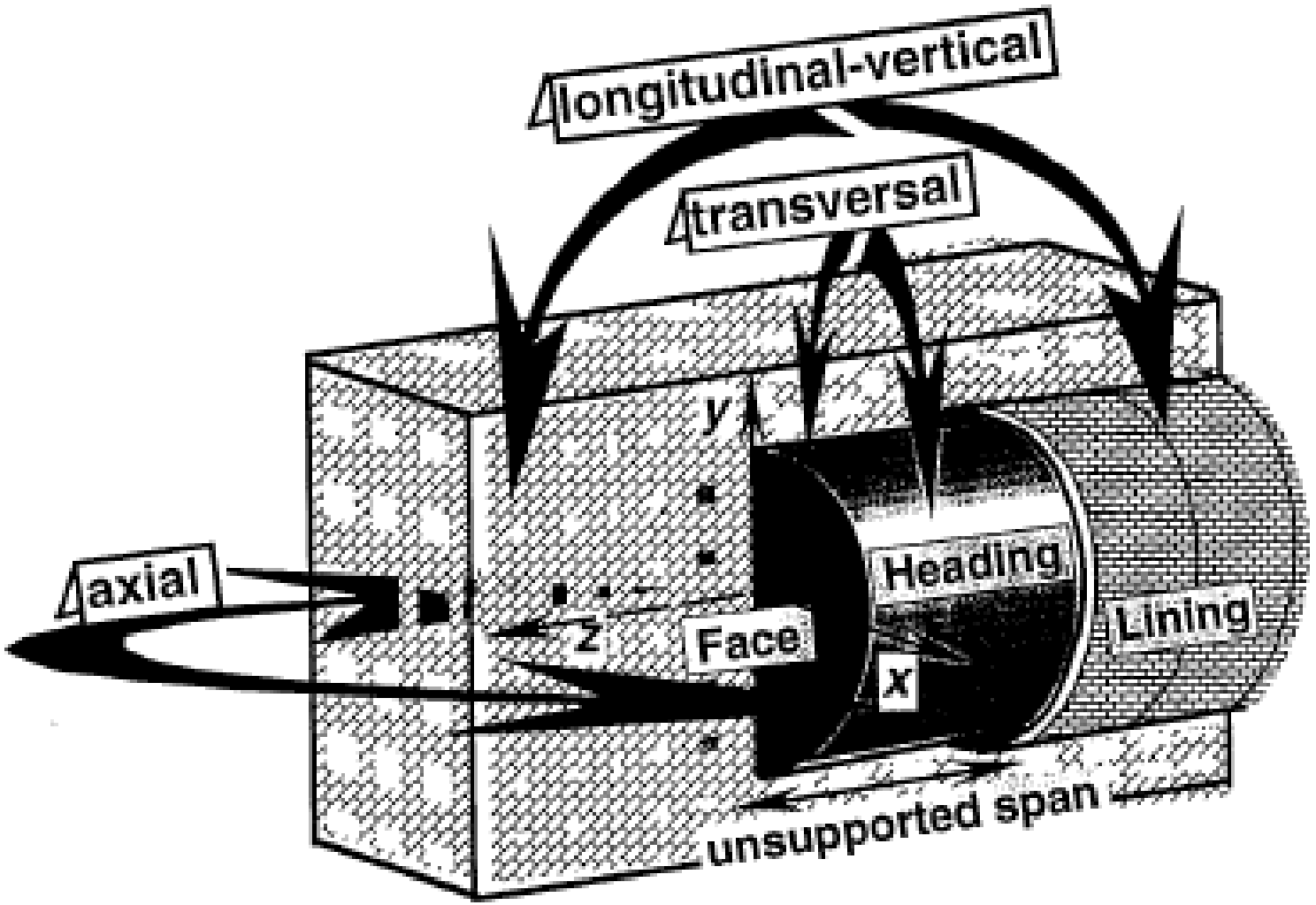
Prof. Dr. R. Galler

21st January 2020, Wrocław, Poland

NATM - Principles in Design and Construction

- NATM forsees **immediate and joint decisions by both partners** within the contractual frame work. This ensures an immediate and **effective response** to **changes in ground conditions**.
- NATM needs **qualified** and **experienced owners**, **designers** and **contractors**, qualified and authorised engineers on site, as well as a qualified and experienced workforce and a suitable contractual model.
- An important feature of the NATM is to **ensure a good cooperation between all parties** to a contract.
- Technical questions regarding **safe, fast and economical tunnelling** take priority over contractual considerations. This approach is of general **benefit to all parties**. It is based on a profound technical expertise and the willingness to compromise.
- As a rule NATM in Austria is executed on the basis of **unit price contracts**.

3-dimensional stress transfer

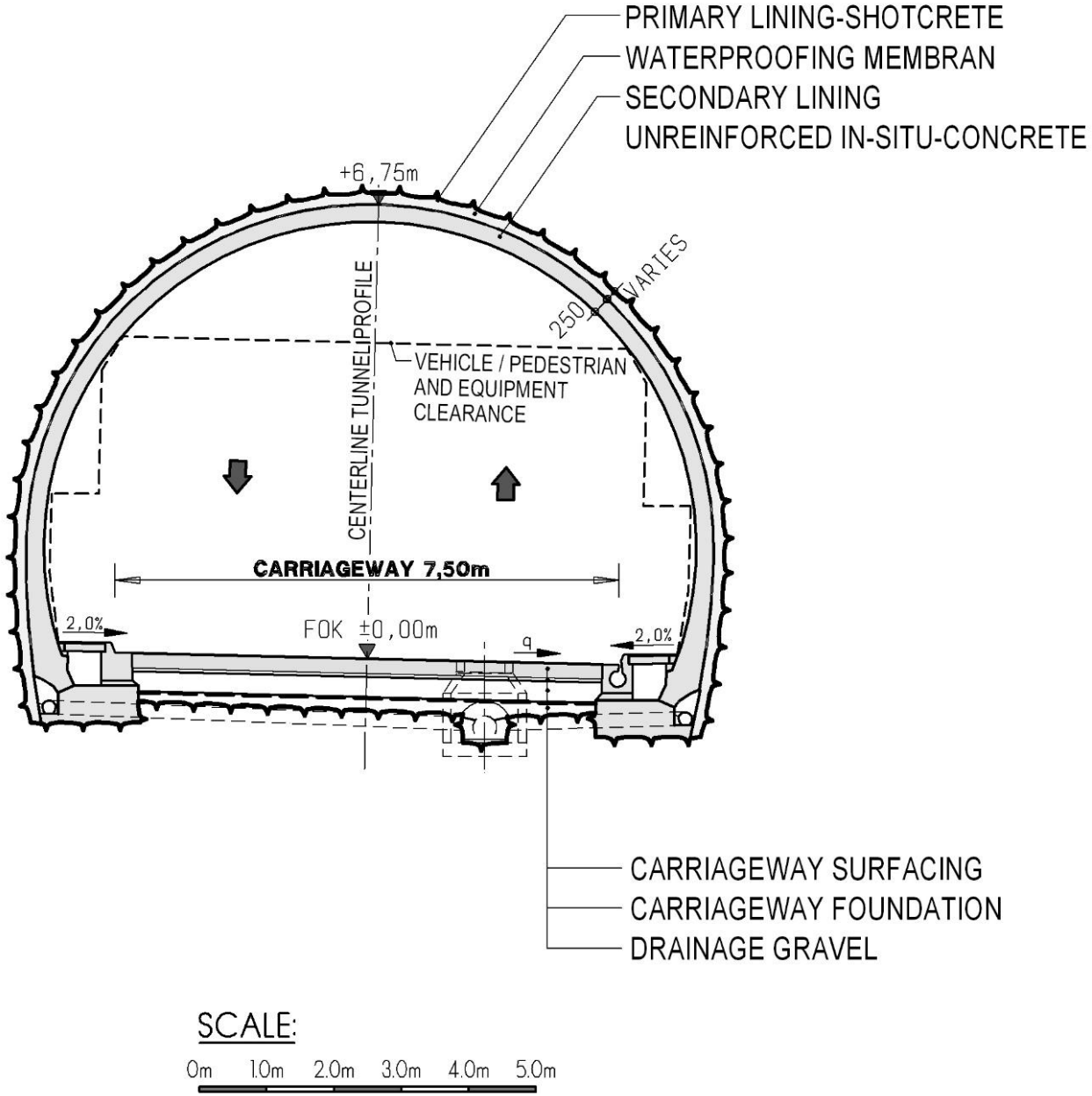


HARD ROCK CONDITIONS

- The typical sequence for conventional excavation is subdivided into top **heading – bench – invert**.
- The top half of the tunnel cross section is excavated first, the **bench follows simultaneously a few hundred meters behind**. A ramp is maintained on one half side of the cross-section to enable access to the top heading.
- The **invert** is prepared at quite **some distance to the bench** excavation.
- An **invert arch** is **only** installed, where a **ring closure** is required by the prevailing rock conditions. The invert arch construction is also split into two halves to maintain access to the tunnel face at any time.

HARD ROCK CONDITIONS

horse shoe shape



SQUEEZING ROCK CONDITIONS

- As a reaction to failure of the shotcrete lining occuring during excavation due to large deformations **longitudinal slots** were left open in order to allow displacements without damaging the shotcrete.

- This approach was accompanied by a dense **rock bolting** to **increase the shear strength** of the rock mass and to reduce deformation of the tunnel.

- In the late nineties, **yielding elements** were developed, which have been integrated into the shotcrete lining. By limitation of the normal forces in the shotcrete lining overstressing is prevented and the support capacity is maintained.

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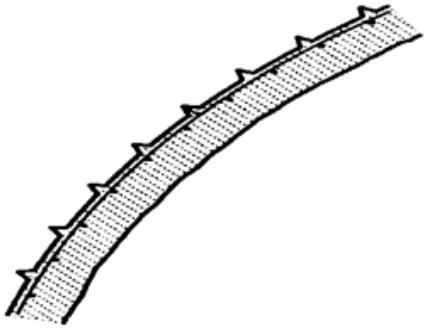
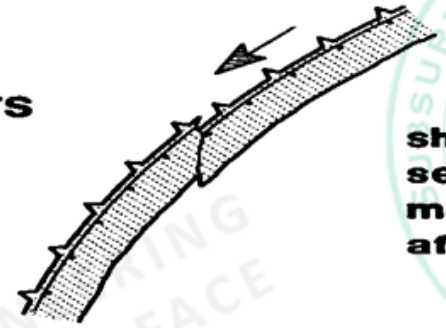
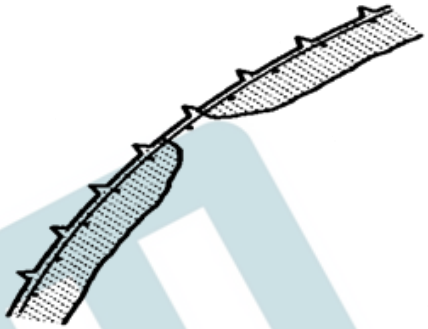
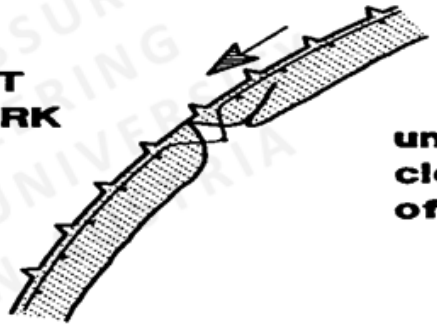
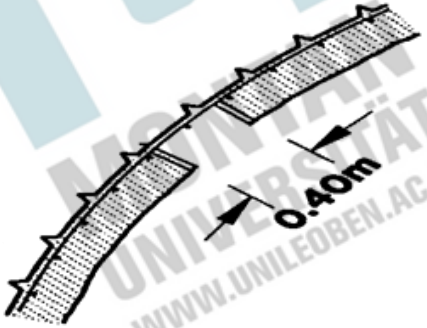
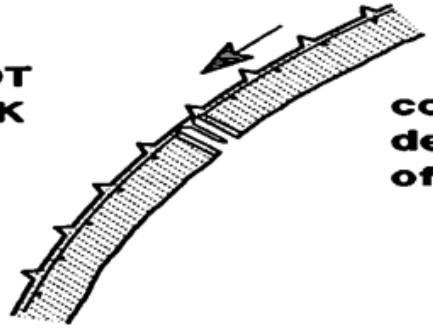
SHOTCRETE APPLICATION		SHOTCRETE AFTER DEFORMATION
	**SHOTCRETE WITHOUT SLOTS**	 shearing with roof settlements of more than 50mm after 1 day
	**SHOTCRETE SLOT WITHOUT FORMWORK**	 uncontrolled closure of the slots
	**SHOTCRETE SLOT WITH FORMWORK**	 controlled deformation of slots

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SQUEEZING ROCK CONDITIONS

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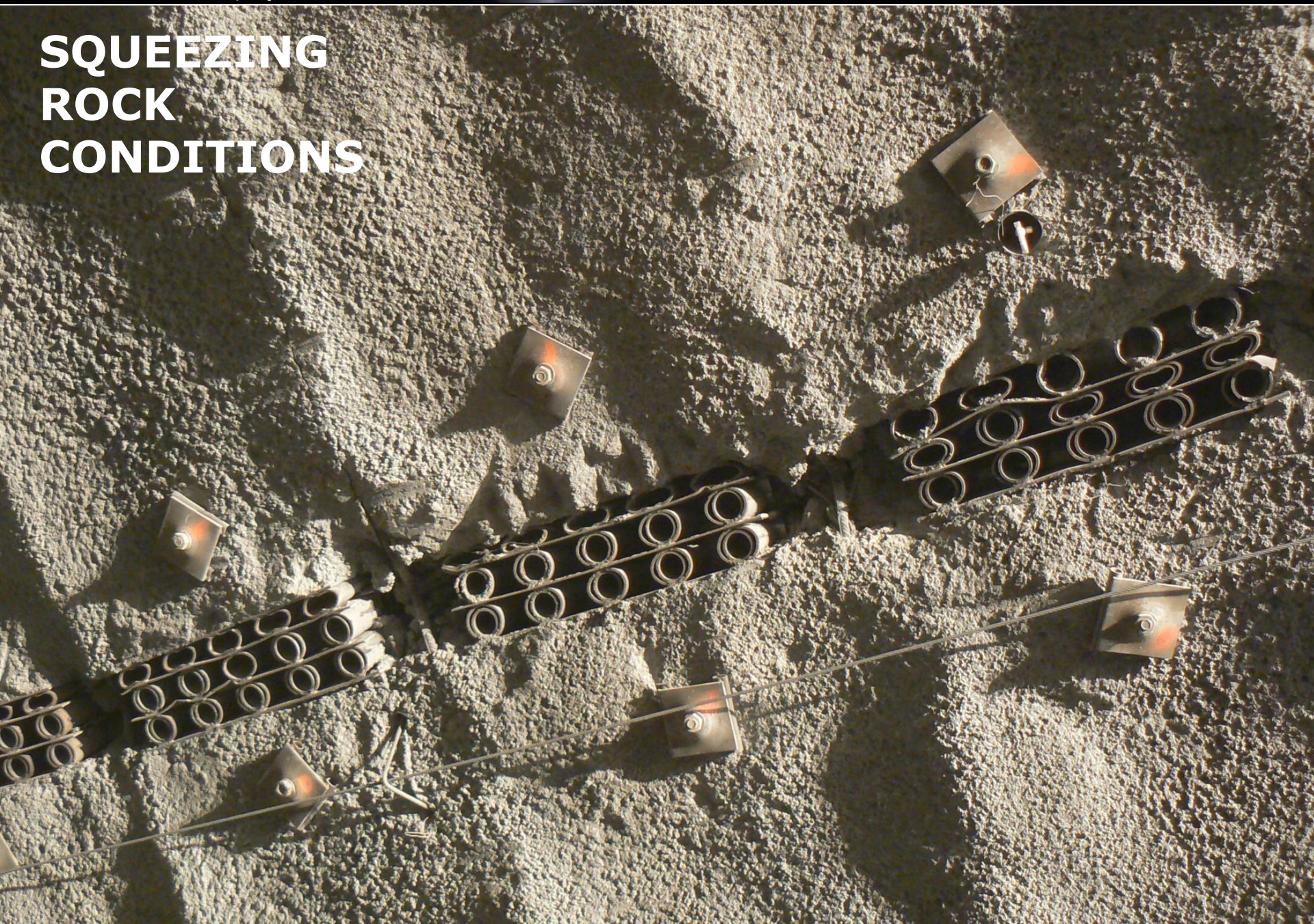

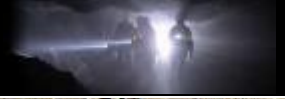

SQUEEZING ROCK CONDITIONS

SOFT GROUND CONDITIONS

- Typical ground conditions for this example consist of **sandy, silty gravel** with interbedded layers of silt.
- The typical cross-section is similar to the cross-section of a hard rock tunnel, however an **invert arch** consisting of reinforced or unreinforced concrete is arranged in the **standard case** throughout.
- In contrast to a deep rock tunnel, the **thickness of the secondary lining is adjusted to the depth of overburden** and the lining is reinforced as required to cope with the substantial ground loads.

SOFT GROUND CONDITIONS

- Typically the length of **excavation rounds** in this example is **limited to 1.0 m** at a maximum and the **closure of the invert follows after 5.0 m**. The advance rate is restricted to **4.0 m in 24 hours** to limit deformations of the young shotcrete primary lining.

- To allow excavation of a typically 60 m² double-track tunnel, the groundwater level is lowered by a system of external wells. The tunnel cross section is **excavated in small portions** when tunnelling in gravel which comprises flowing layers of soil.

- Massive **support of the excavation face** with shotcrete and face anchors or even ground treatment by grouting ahead of the face is occasionally required to provide safe tunnelling conditions.

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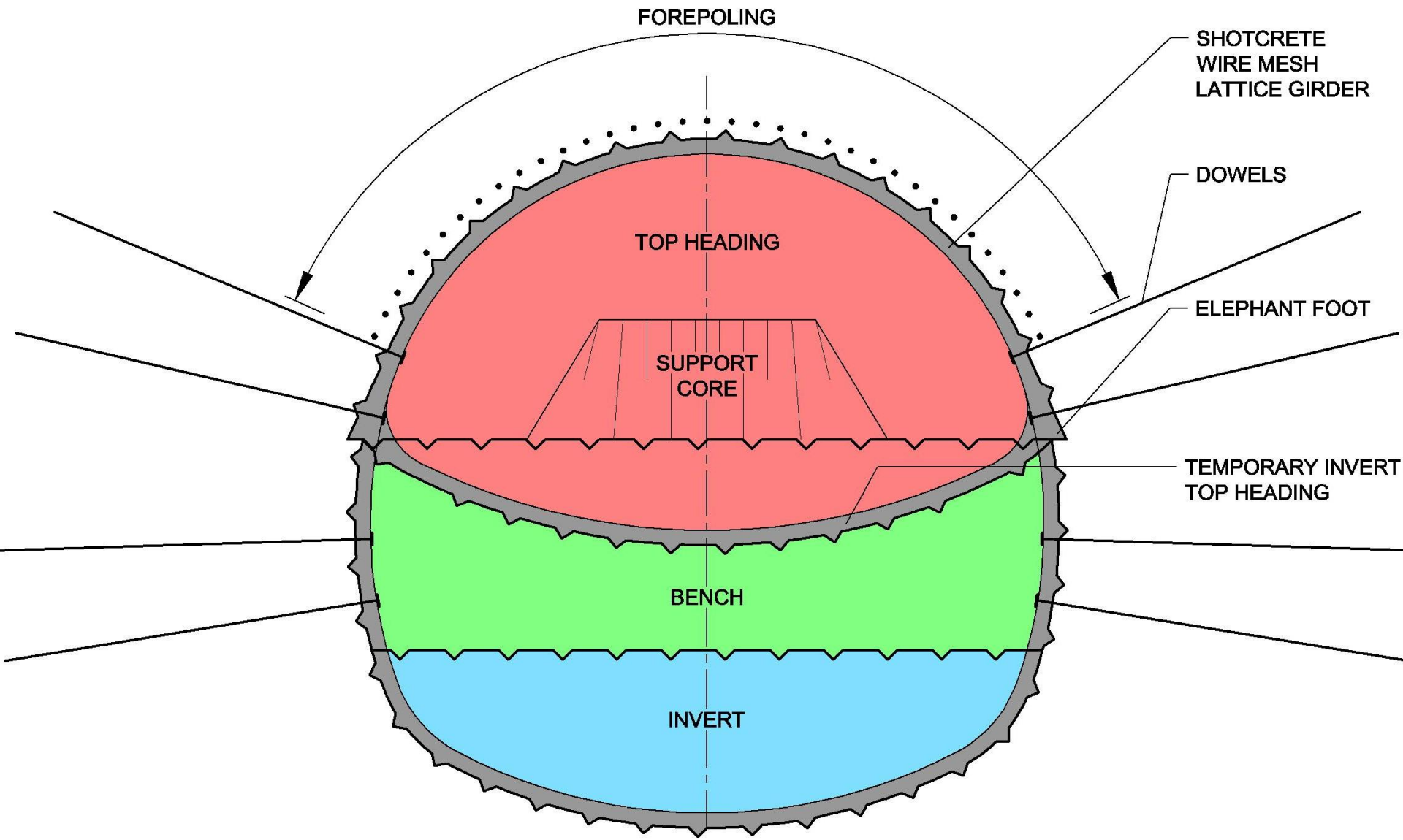

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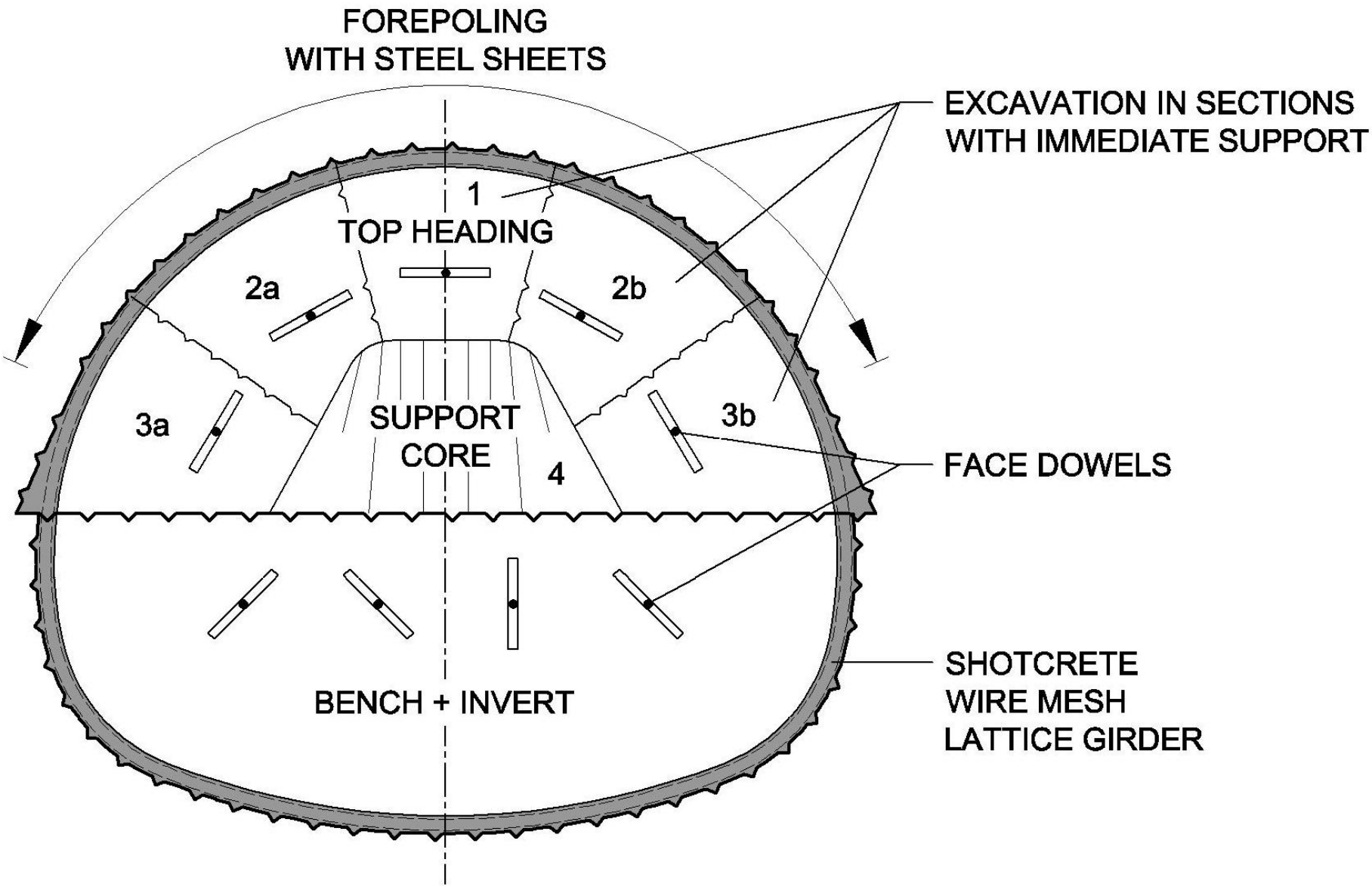

partial excavation with top heading+bench+invert

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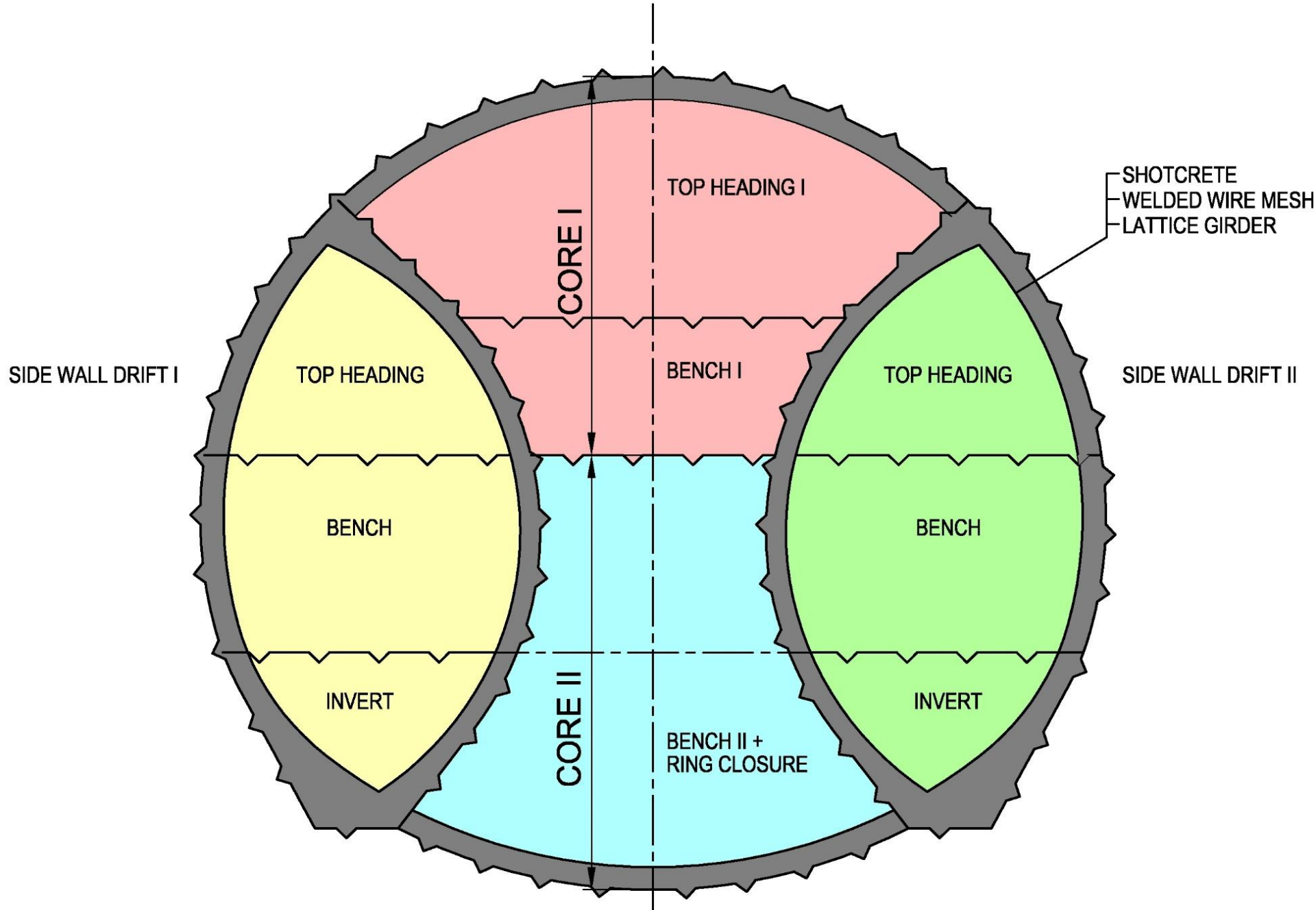

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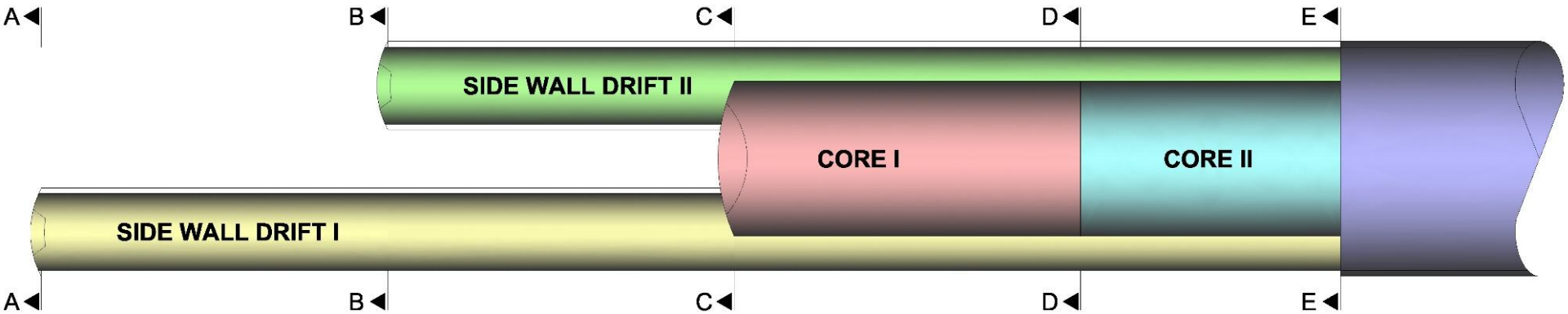

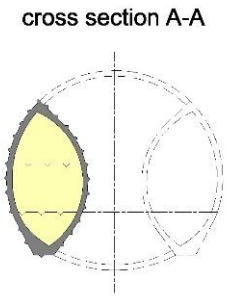

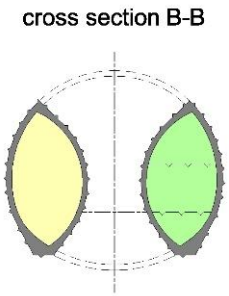

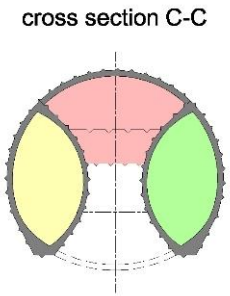

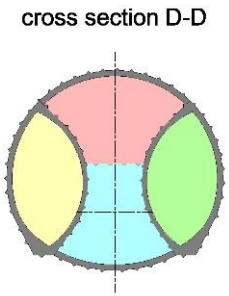

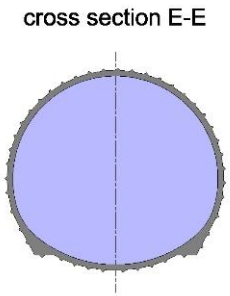

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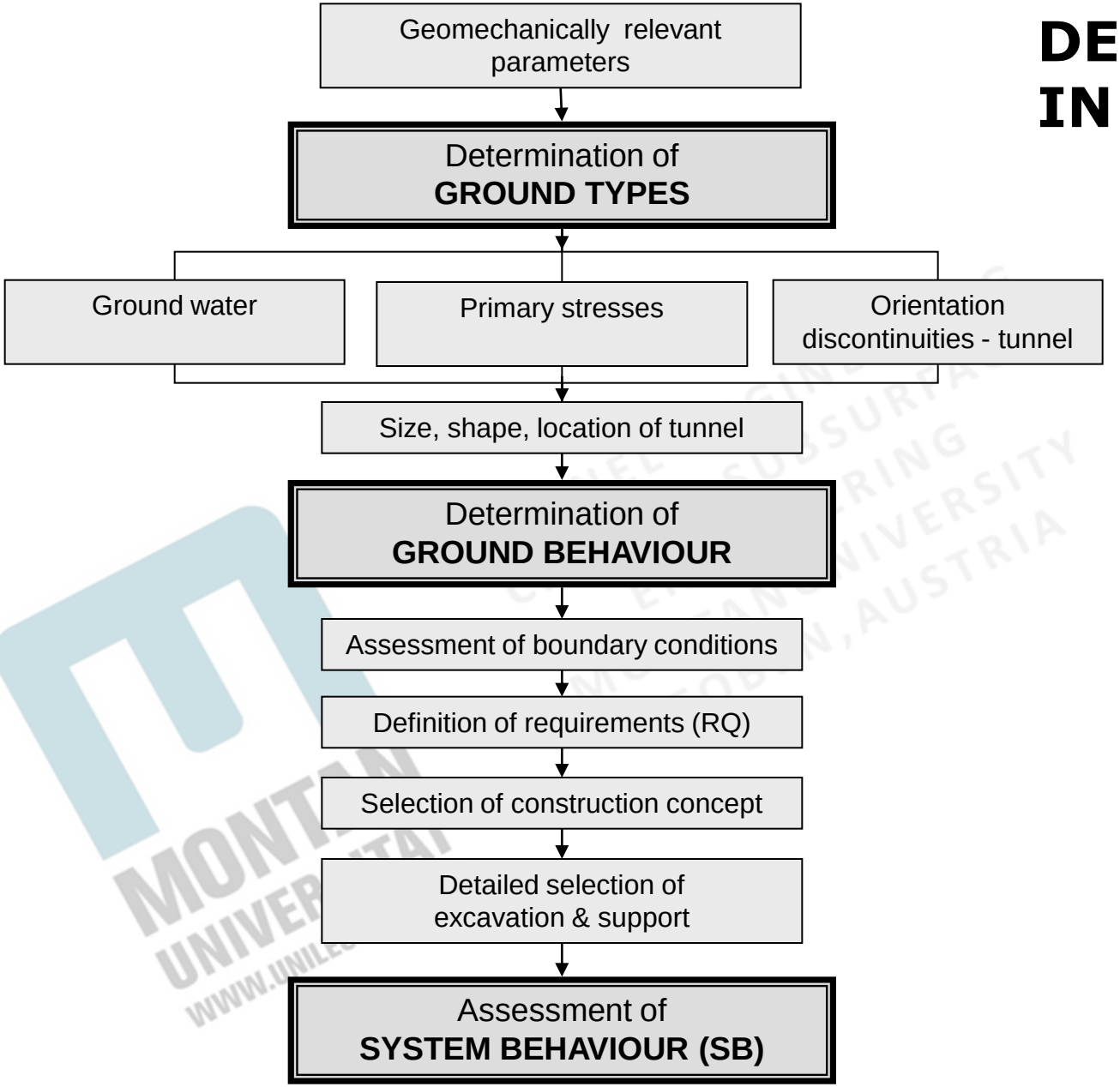
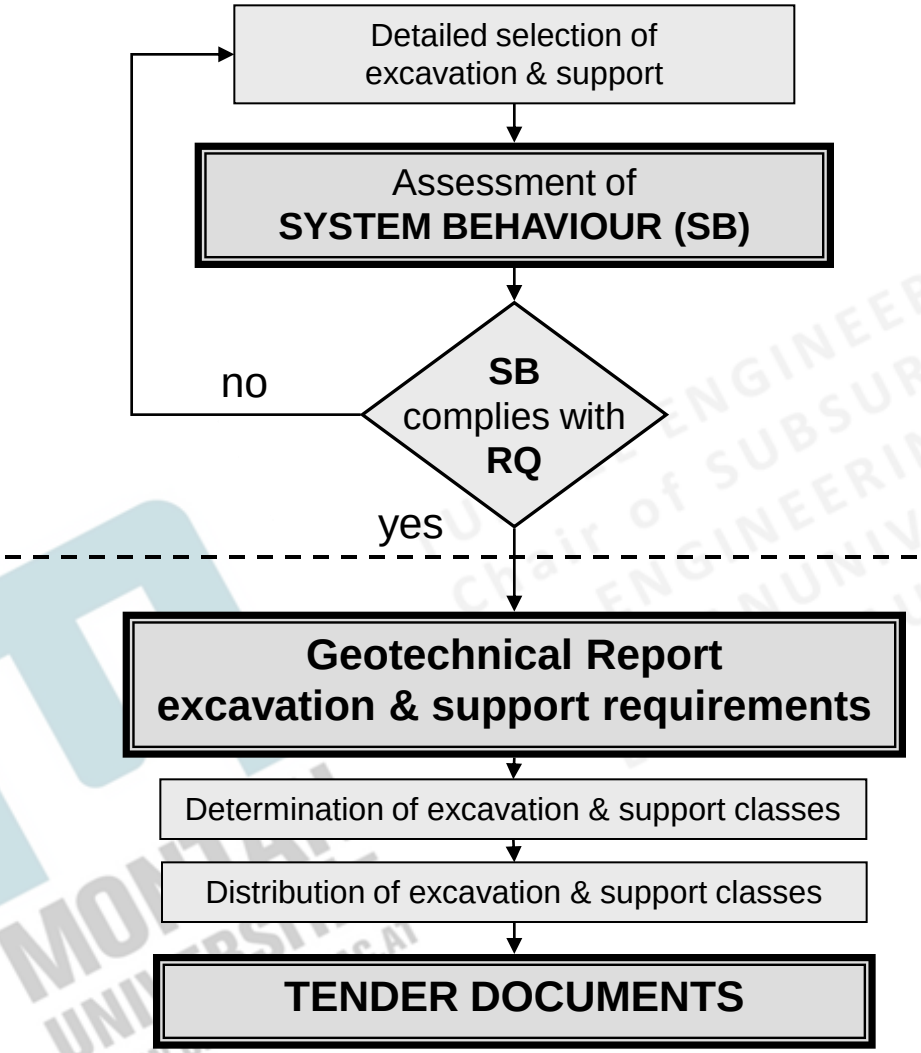
DESIGN STAGES IN NATM (1)



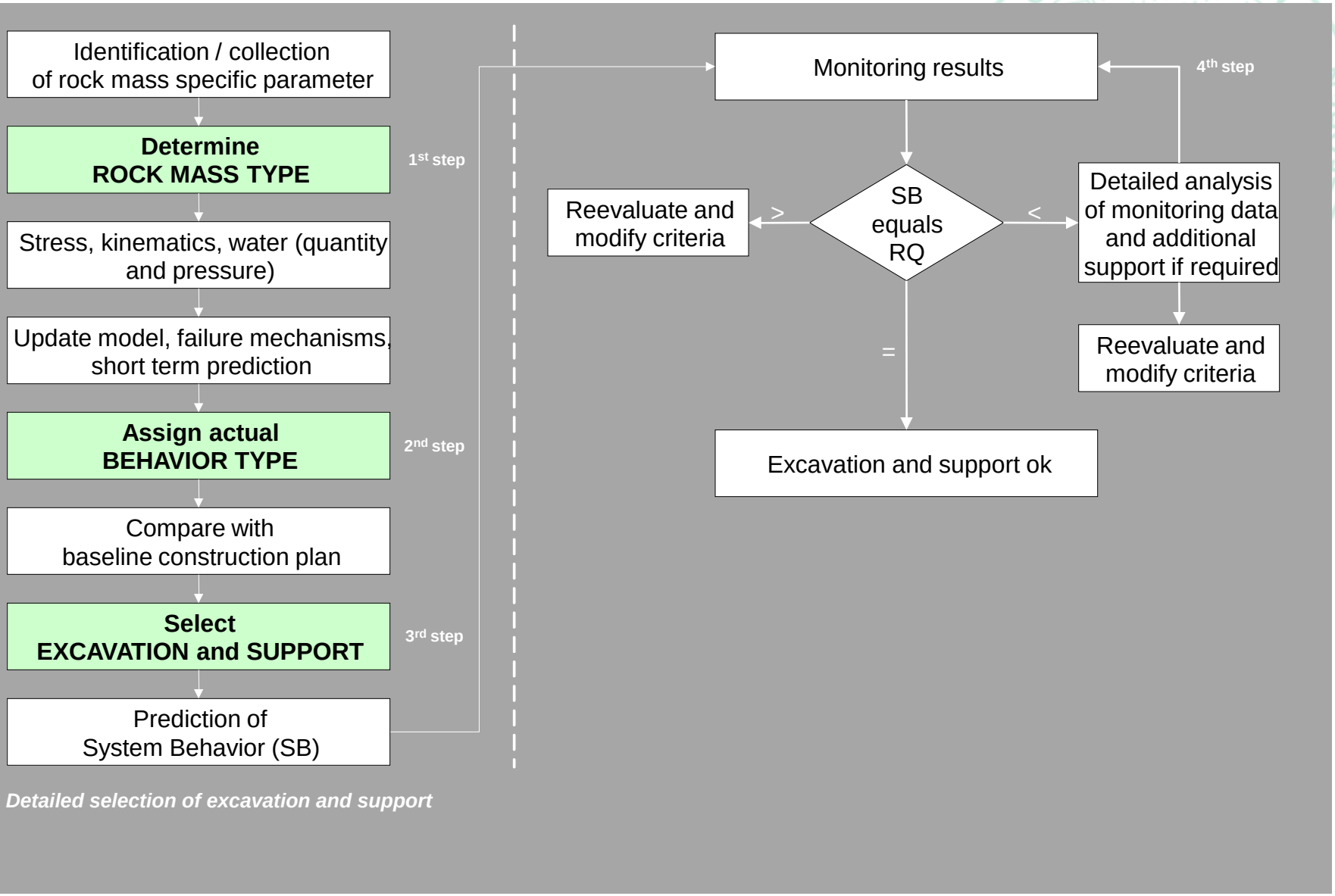
Determination of excavation and support

DESIGN STAGES IN NATM (2)



Specifications
contractual obligations

DESIGN PROCESS during construction (PHASE 2)

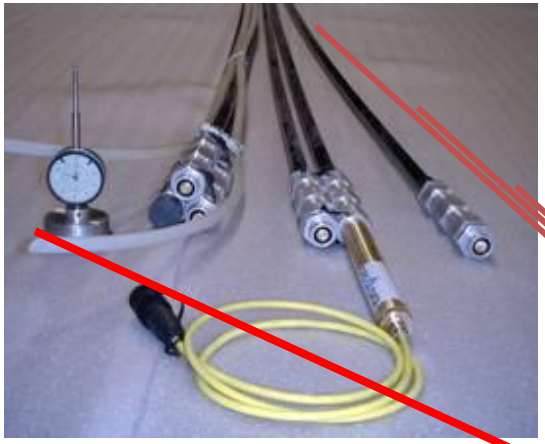


Continuous geotechnical monitoring and interpretation during tunnel construction is one of the key features in NATM! WHY?

- Limits in accuracy of a geological model
- Lack of rock and rock mass parameters
- Limited knowledge of in-situ stress
- Uncertainties and simplifications in the mathematical models used for design
- to verify the applied rock classification
- to control the tunnel stability
- to optimize the support
- to optimize the construction sequence

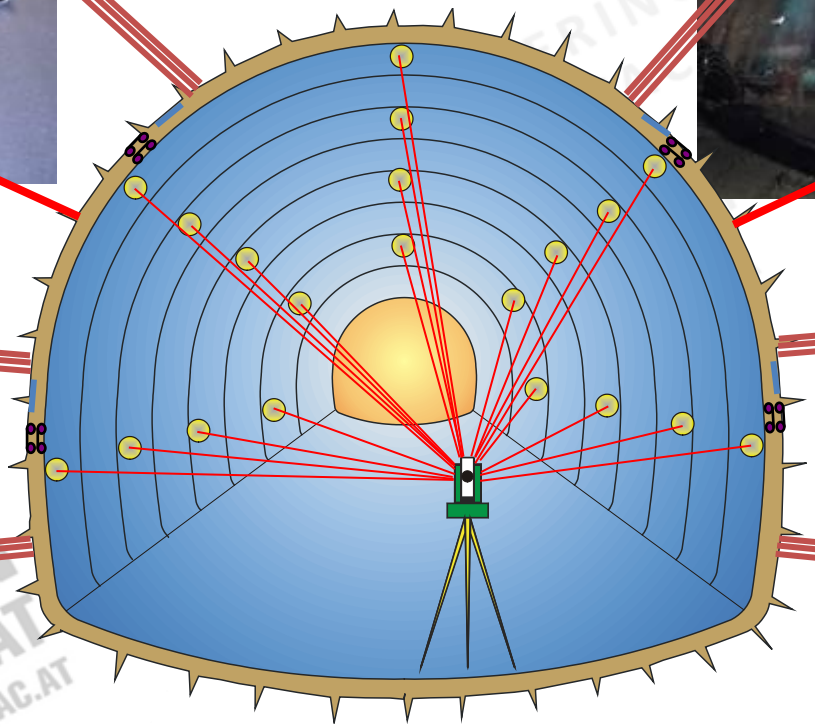
The inaccuracy of the design calls for an OBSERVATIONAL APPROACH to allow a safe and economical construction!

Monitoring

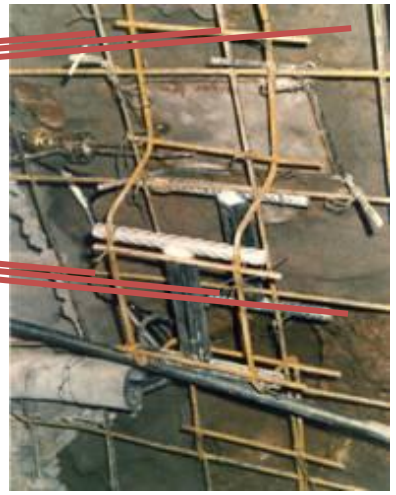


3D-displacement-targets

Extensometers



Measuring anchors



Strainmeters
Pressure cells

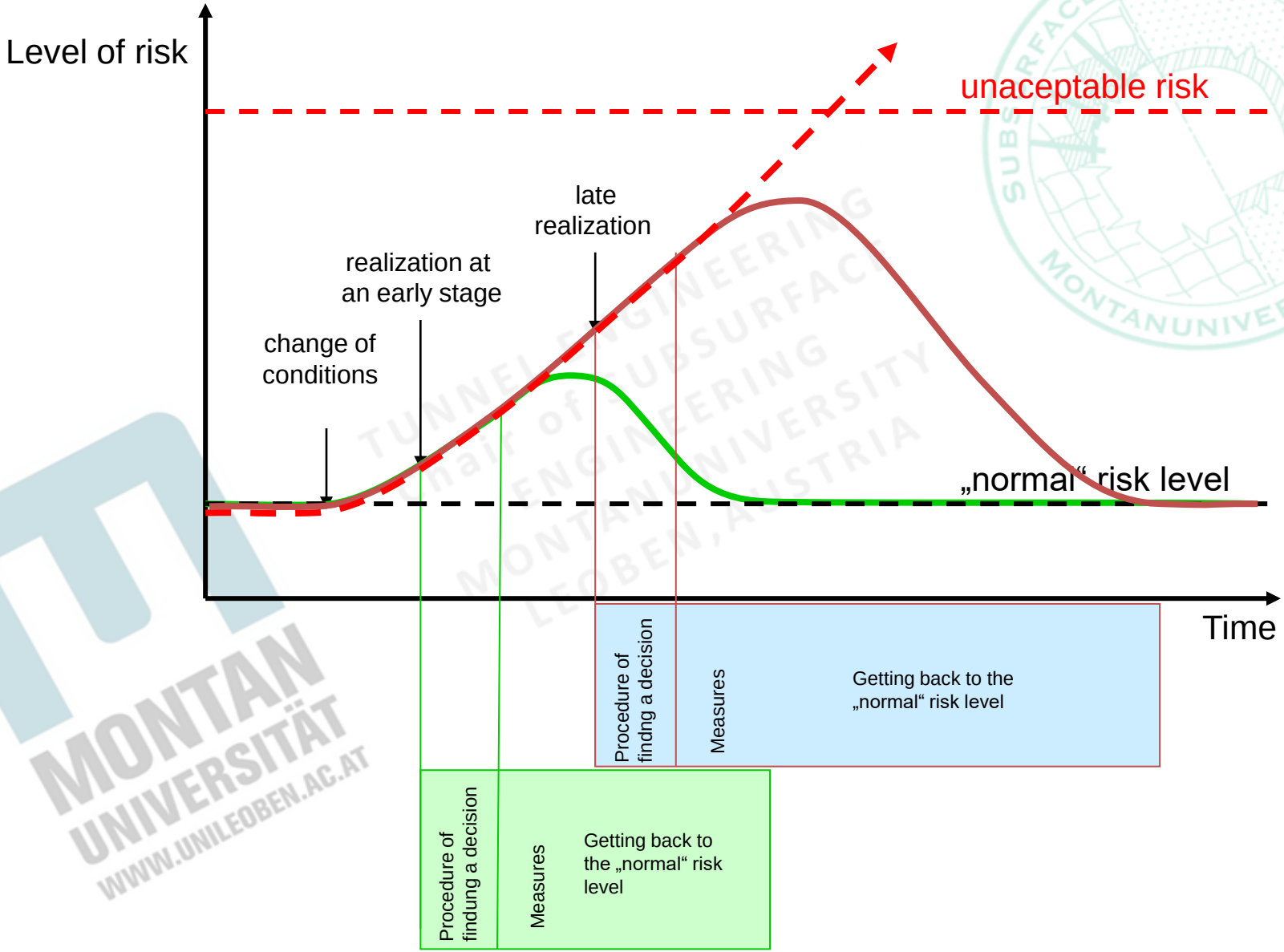
What should be specified to be able to modify the construction on site

The design should specify information to be collected on site during construction:

- geological records of the tunnel face
- results of advance probing
- qualitative observations
- monitoring results
- Criteria for the selection of excavation
- criteria for support or auxiliary measures

A management concept with all technical and organisational provisions to allow a **timely decision-making process** during construction

Risk management during Construction



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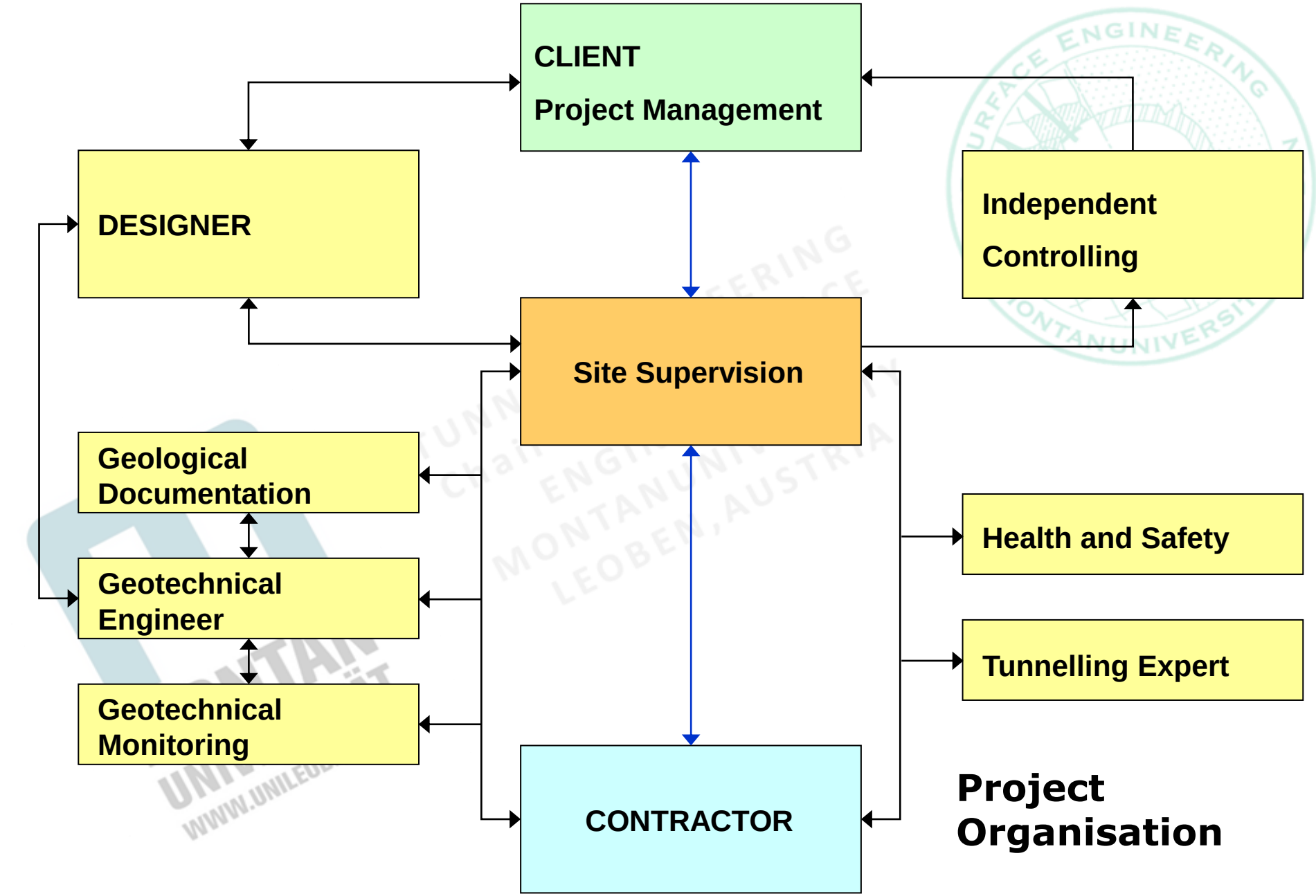

Project Organisation

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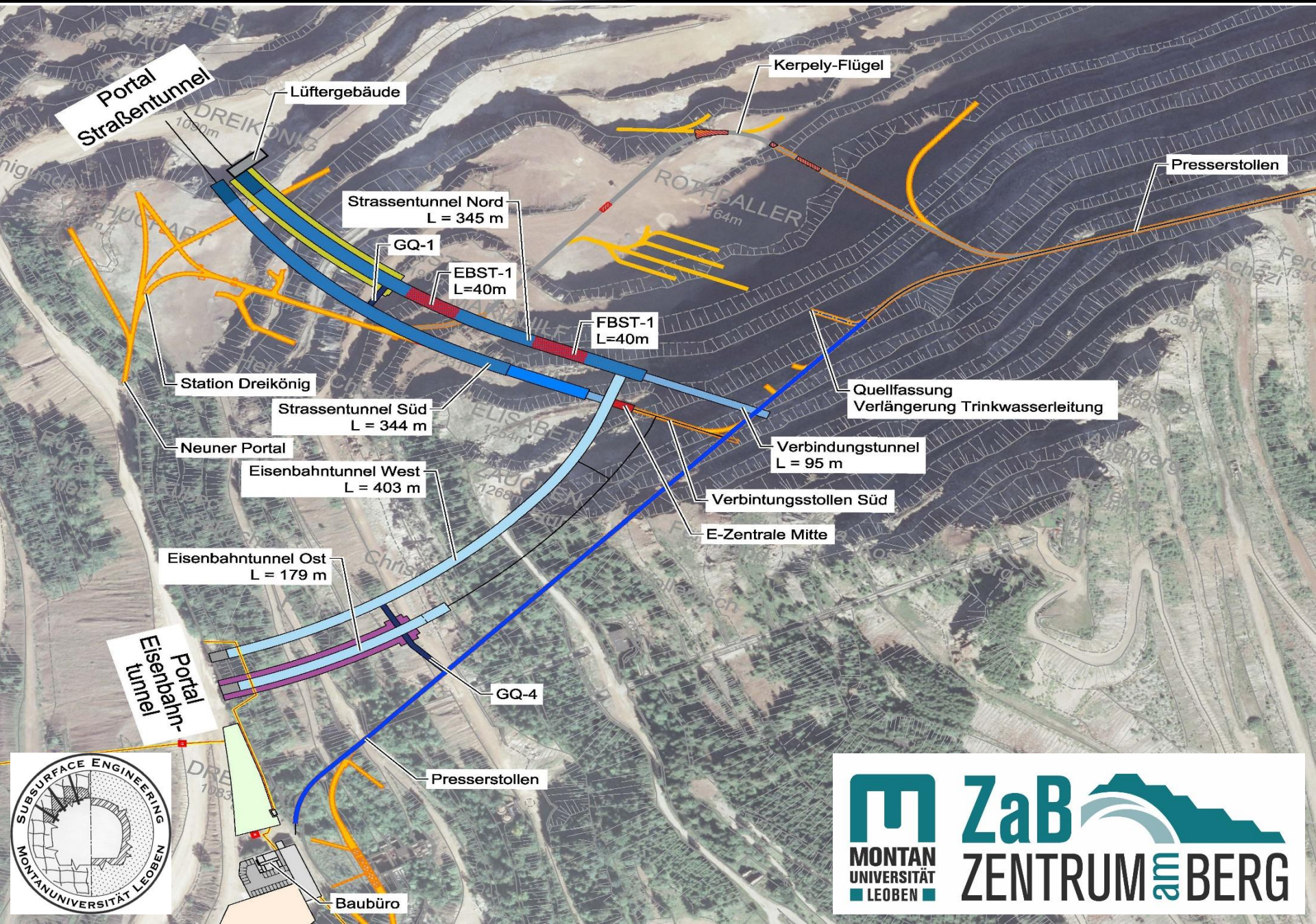

Portal area motorway tunnels

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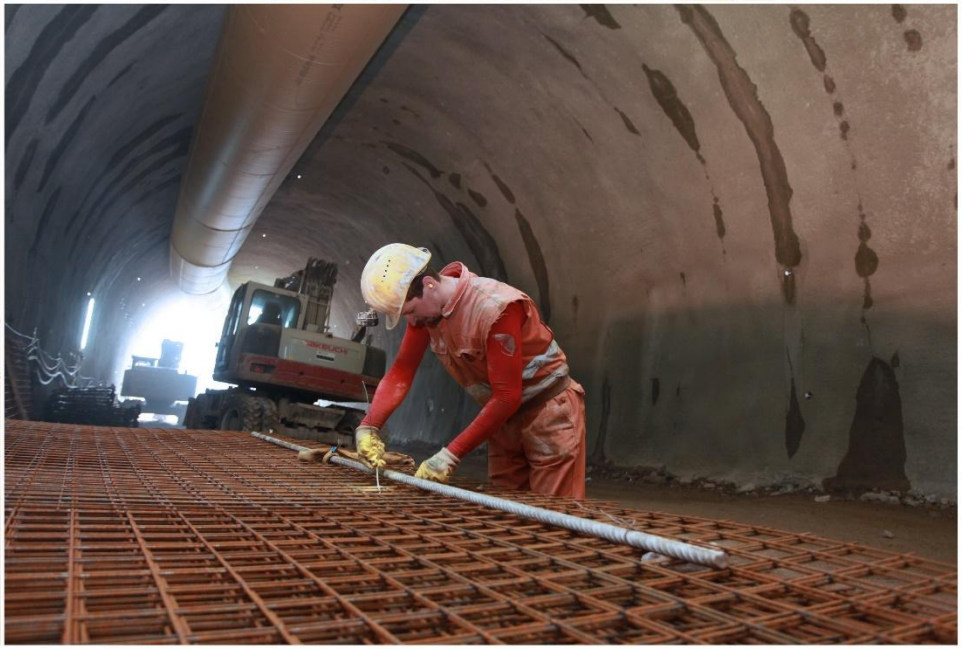

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NATM

New Austrian Tunneling Method

Master of Engineering

Welcome to a fruitfull cooperation!

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