



Segmental linings for hydraulic tunnels

Dr. Alois Vigl

Trondheim 04.11.2019



Segmental linings for hydraulic tunnels

- How the story began
- Focussing upon the main goals
- Specific lining features
- Field of successful applications
- How the story ends

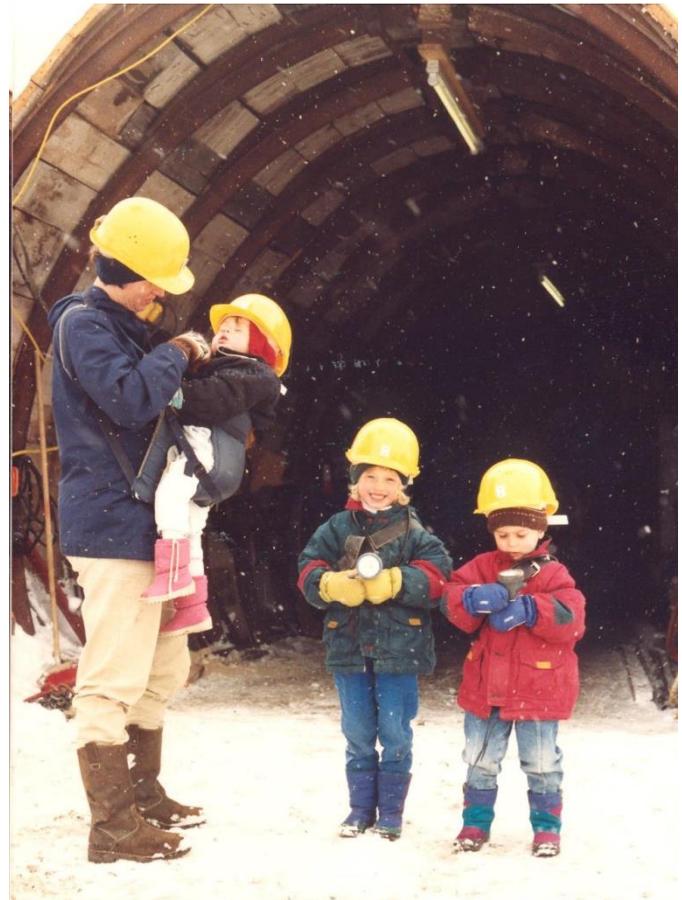
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How the story began ...

- The **Evinos Tunnel** design 1991 – water supply for 4 Million people in Athens
- **30 km hydraulic tunnel** with different TBM- types and different lining technologies
- Background of tunnelling for **high head hydropower schemes**



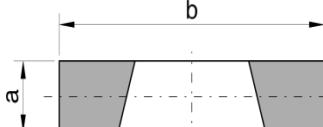


Focussing upon the main goals for hydraulic tunnel linings

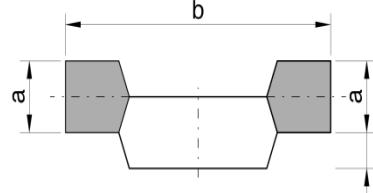
- Suitable segmental lining system?
- How to deal with internal and external water pressure?
- Suitable joint design?
- Suitable structural design?
- Economical reinforcement & production?
- Economical installation & sealing?
- Final treatments required?



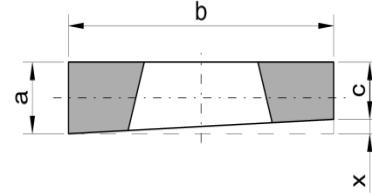
Which segmental lining system



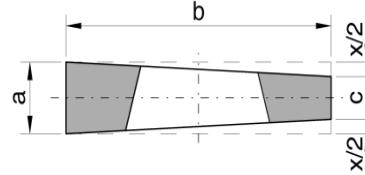
Parallel Ring-
System +
Keystone



Parallel Ring-
System
Honeycomb



Tapered Ring-
System L/R +
Keystone

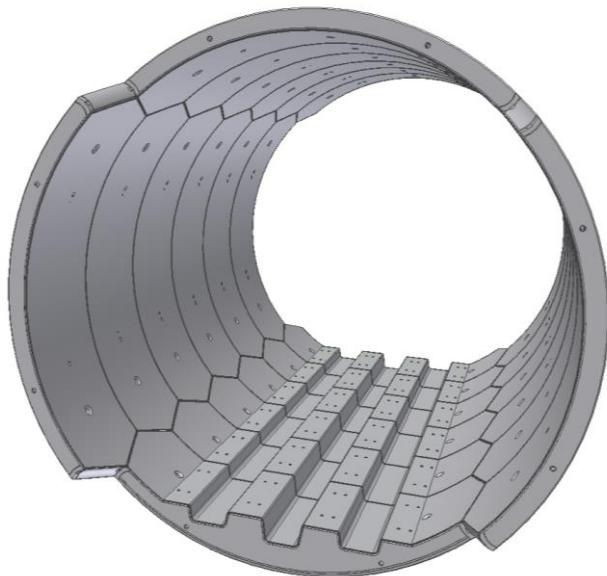


Universal Ring-
System +
Keystone

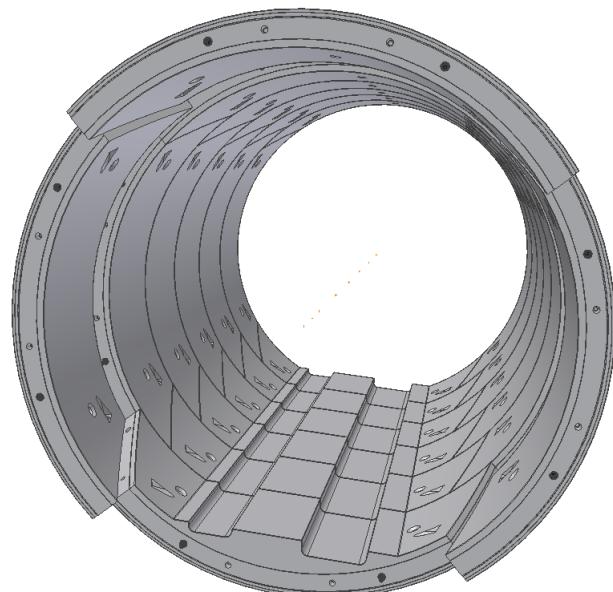




Which segmental lining system



Honeycomb

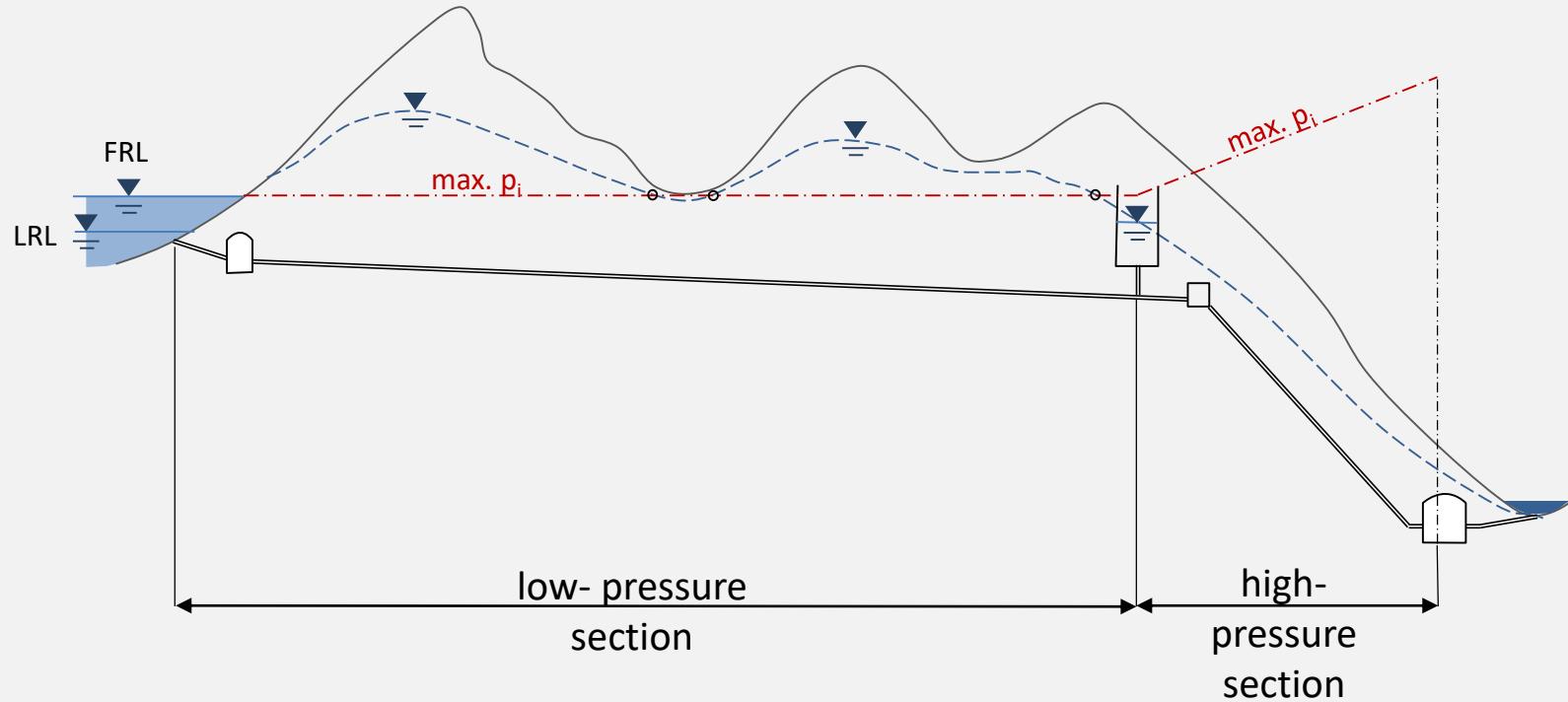


Parallel Ring System

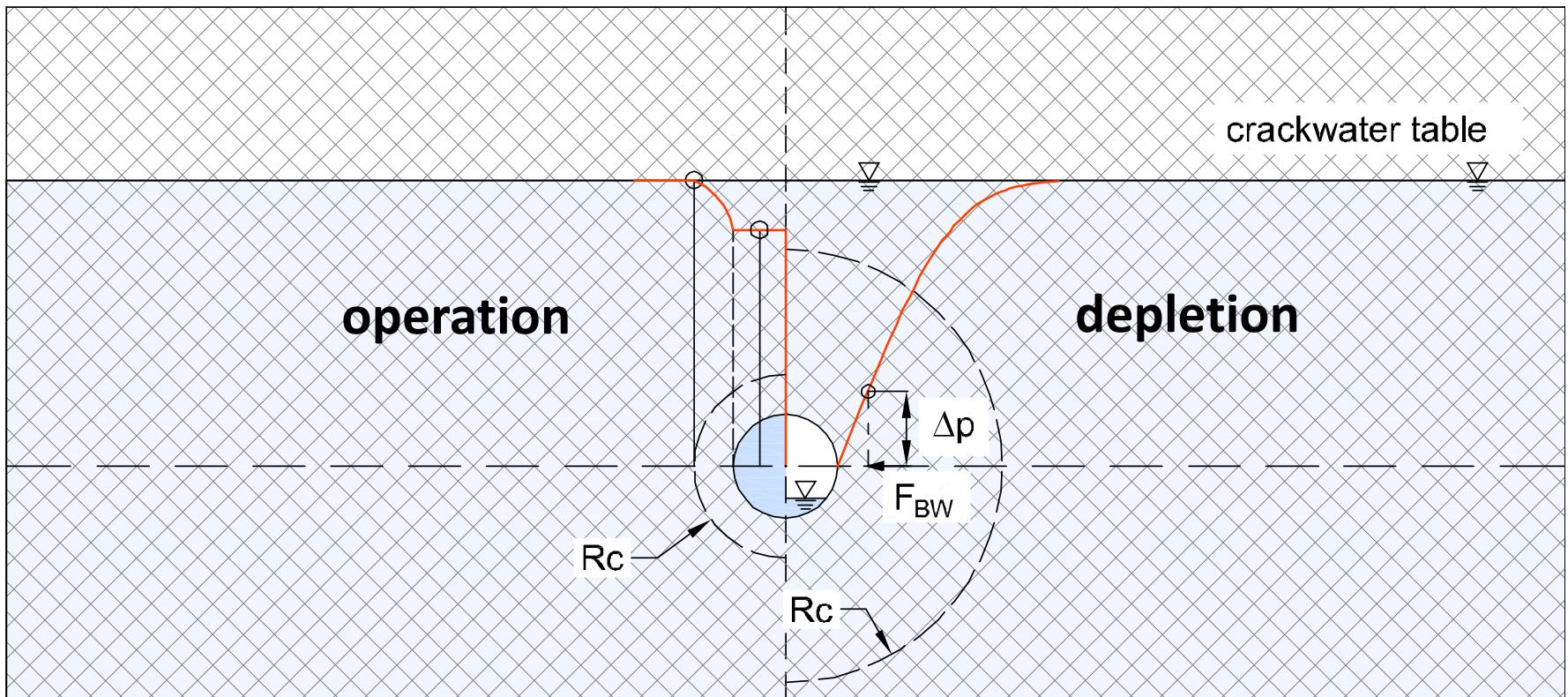
or

Rhomboidal

internal and external water pressure?



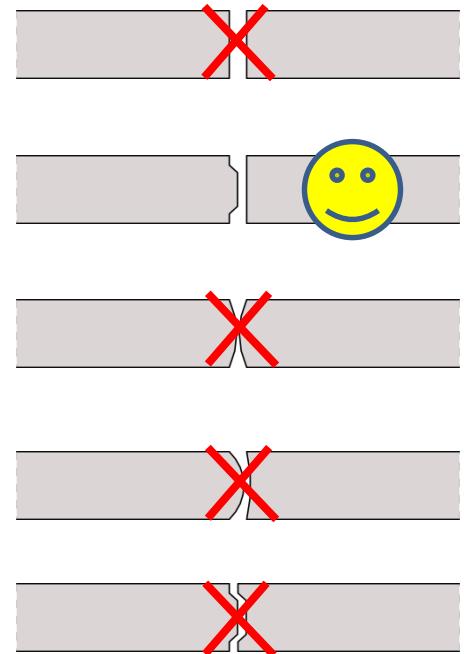
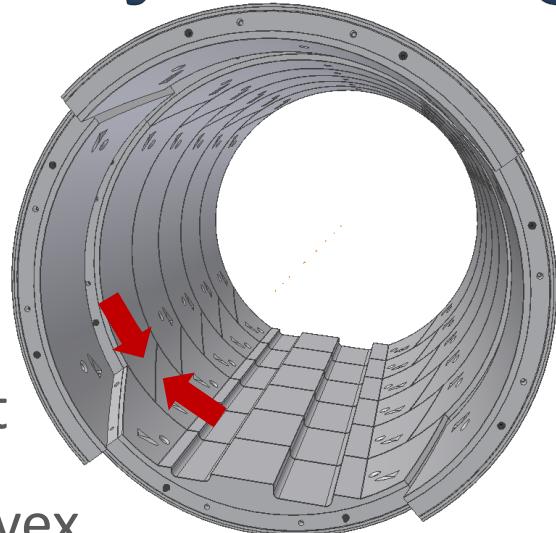
internal and external water pressure?





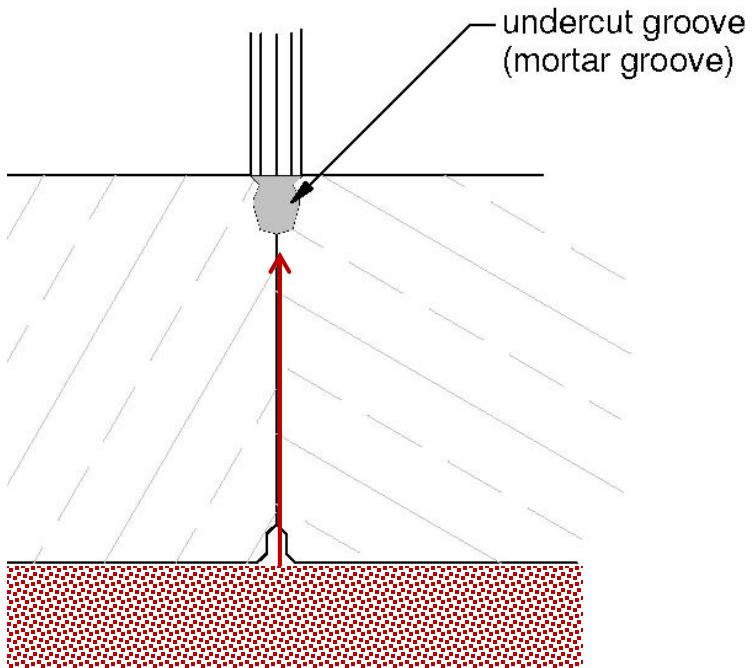
suitable joint design

- Flat & fullface contact
- Flat & partial face contact
- Knuckle Joint convex/convex
- Knuckle Joint convex/concave
- Centring groove with partial contact

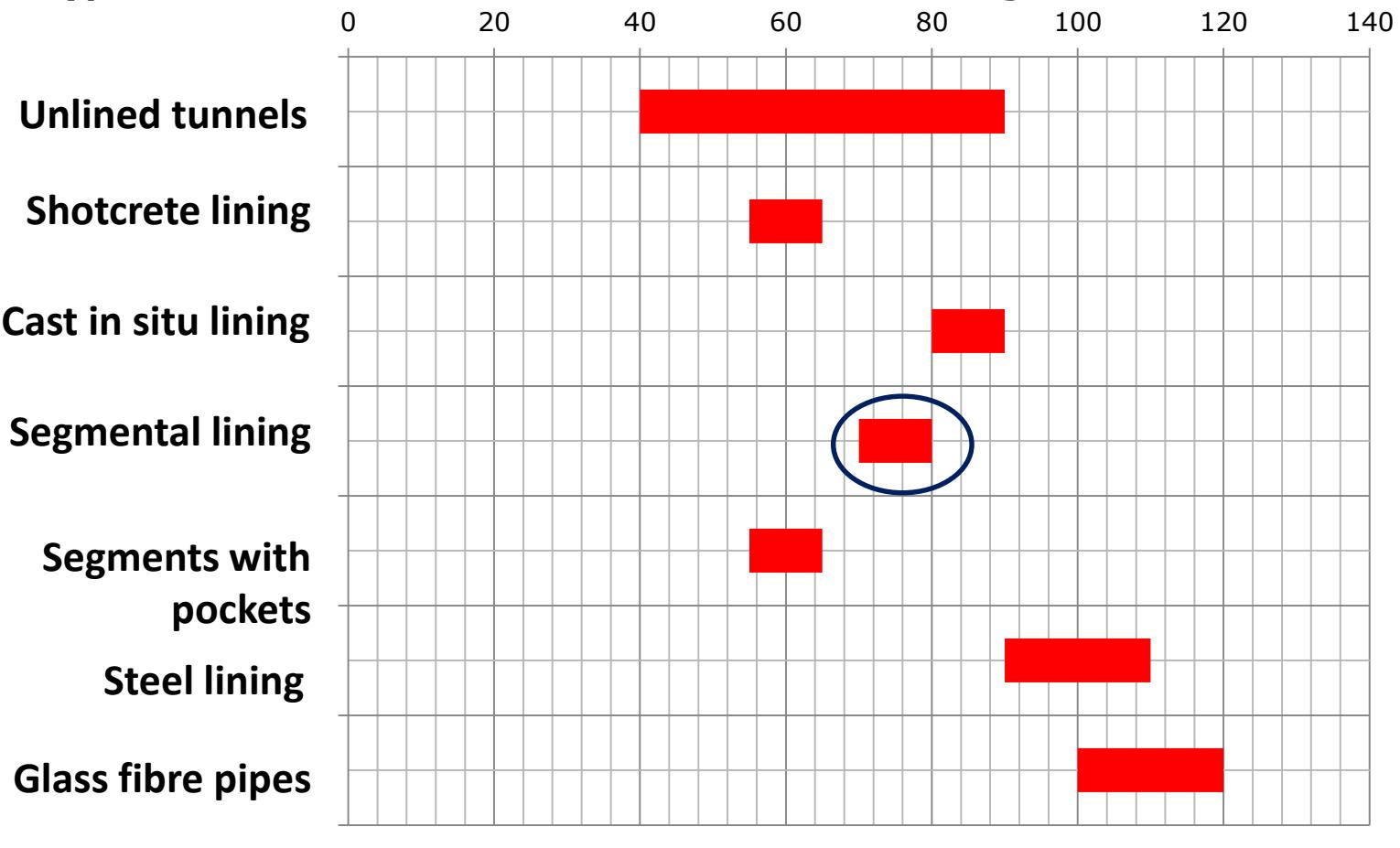




suitable joint design



Typical friction coefficients for tunnel / shaft linings



Hydraulic friction coefficients according Strickler k_{St} [$\text{m}^{1/3}\text{s}^{-1}$]



suitable structural design



- Steel fibre reinforcement
- Conventional reinforcement

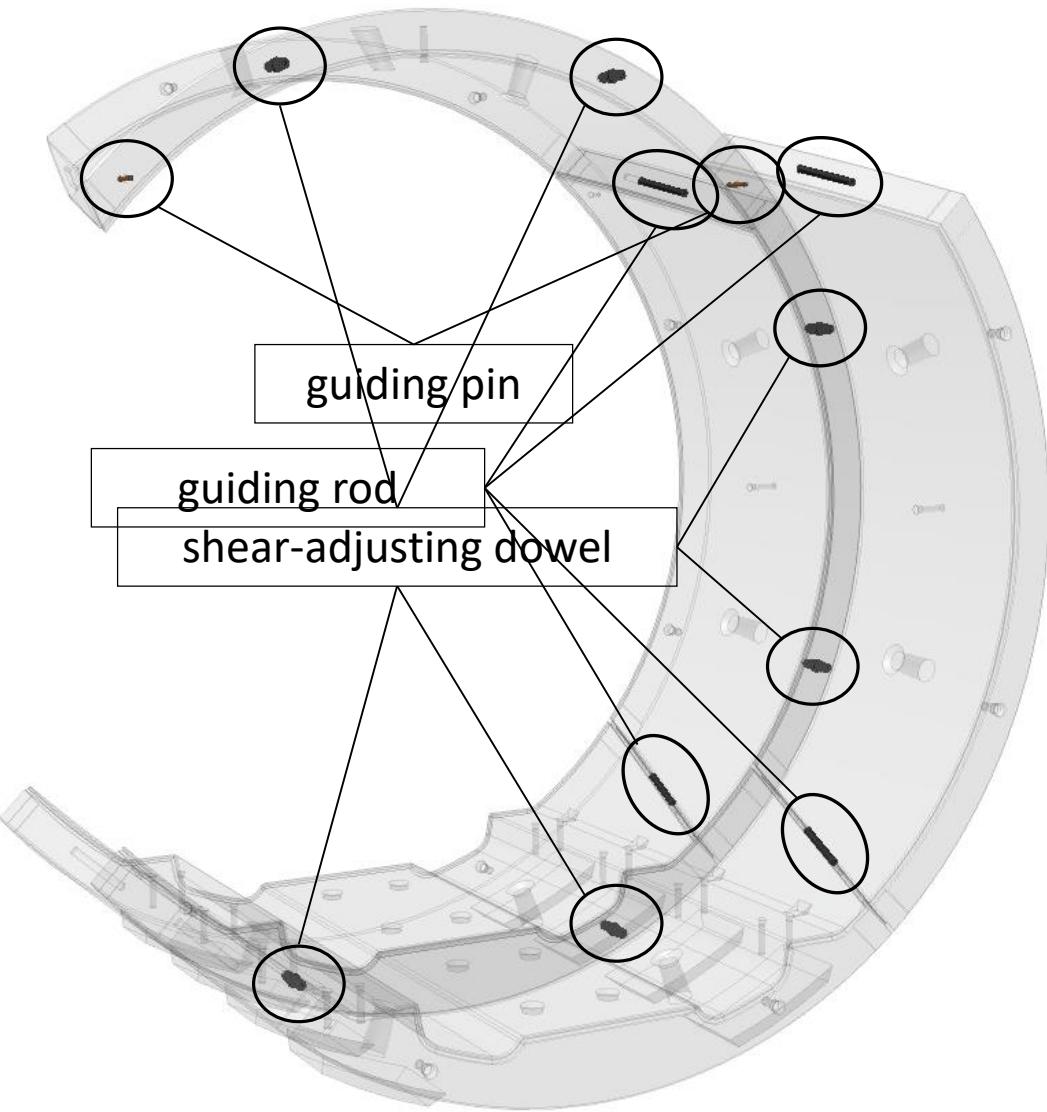


Economical reinforcement & production



Produktion
Storage
Manipulation
Installation

Economical & accurate installation





guiding rod
Longitudinal joints

**Shear & adjusting
dowel rod
circumferential
joints**





guiding pin
Overlapping edges



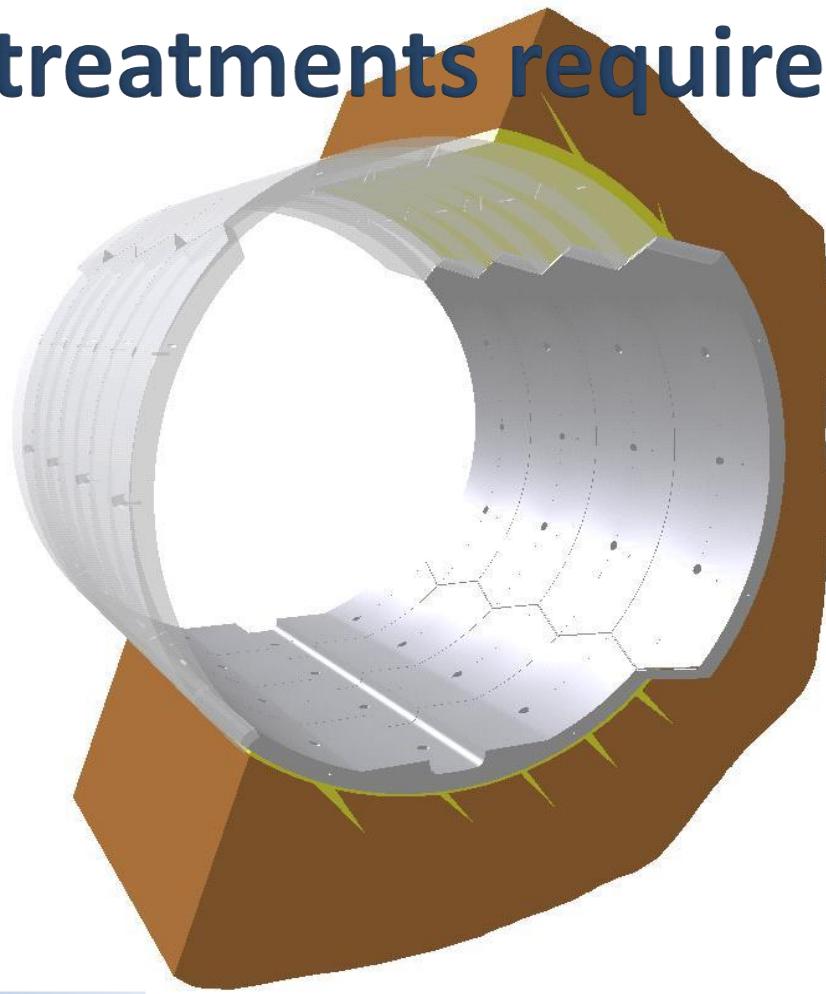


Segment features & details

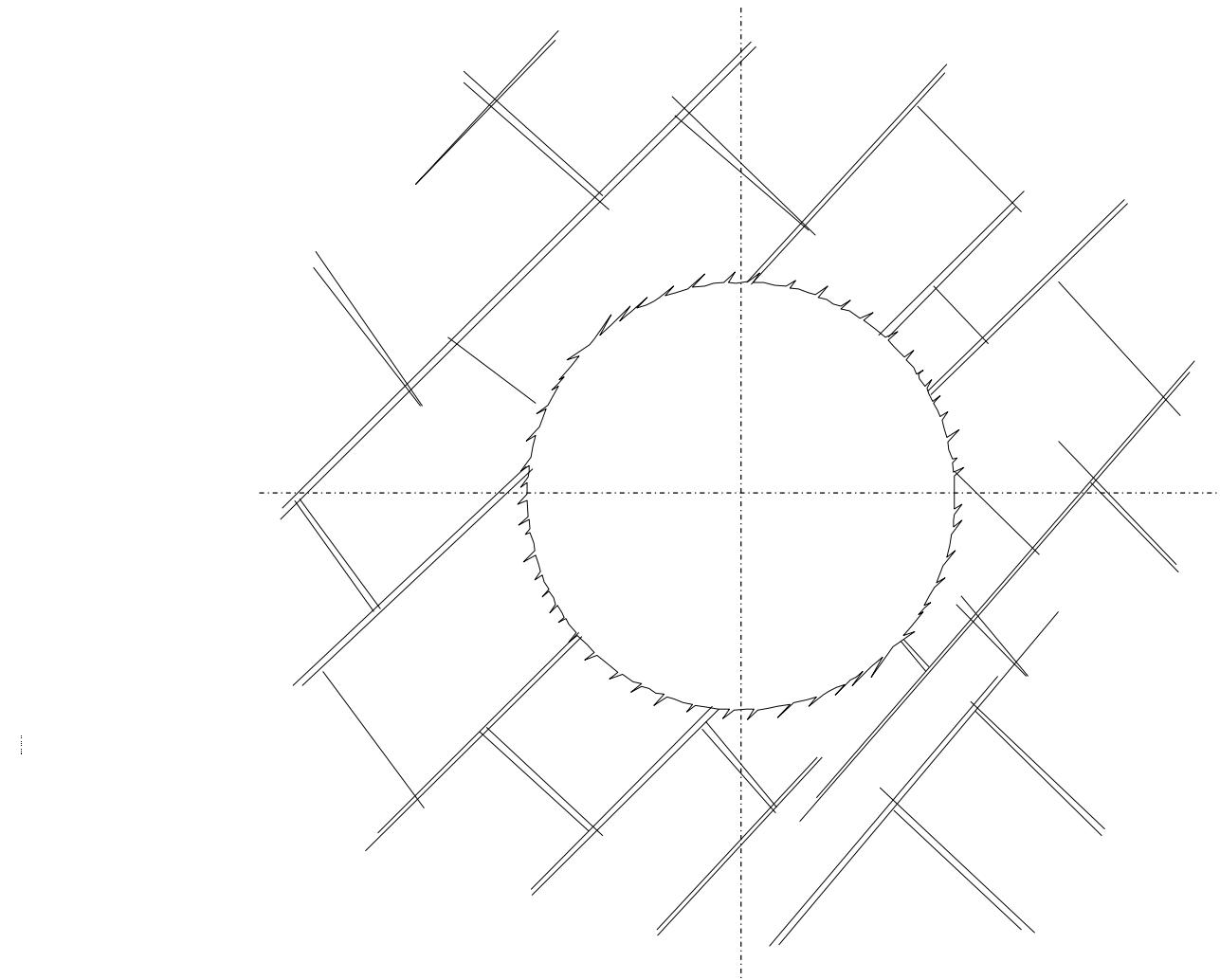




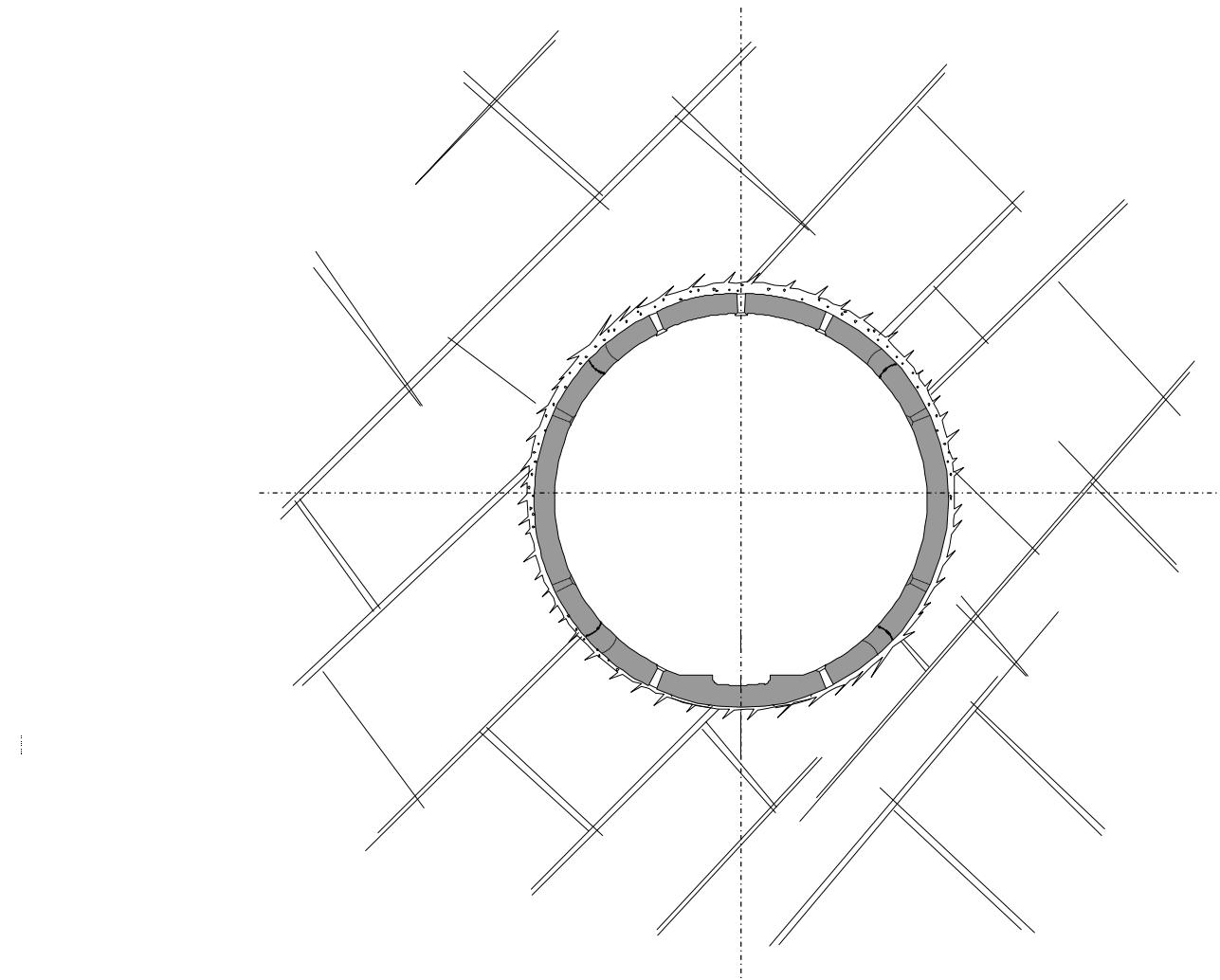
Final treatments required



Excavated tunnel

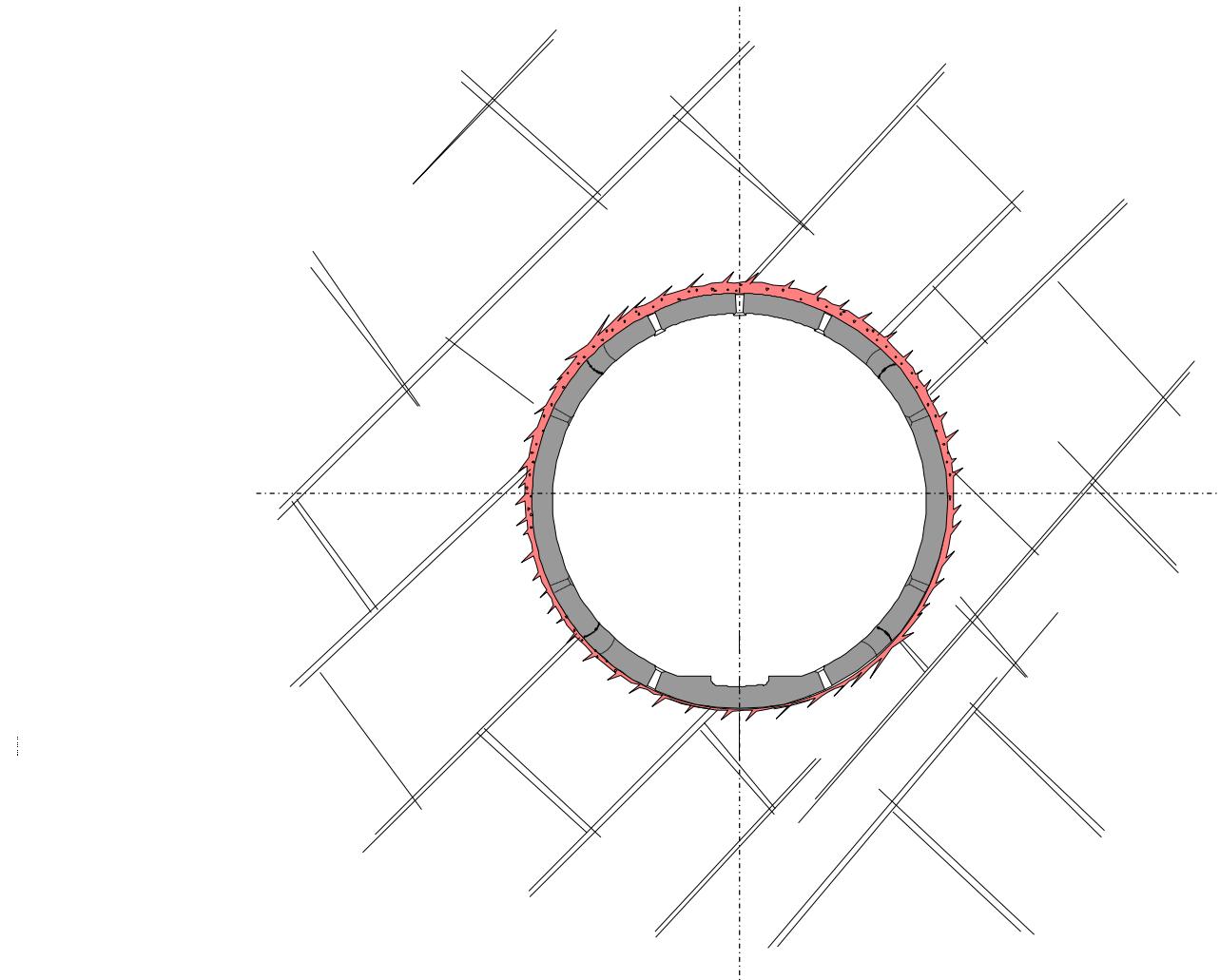


Segmental lining bedded with Pea gravel



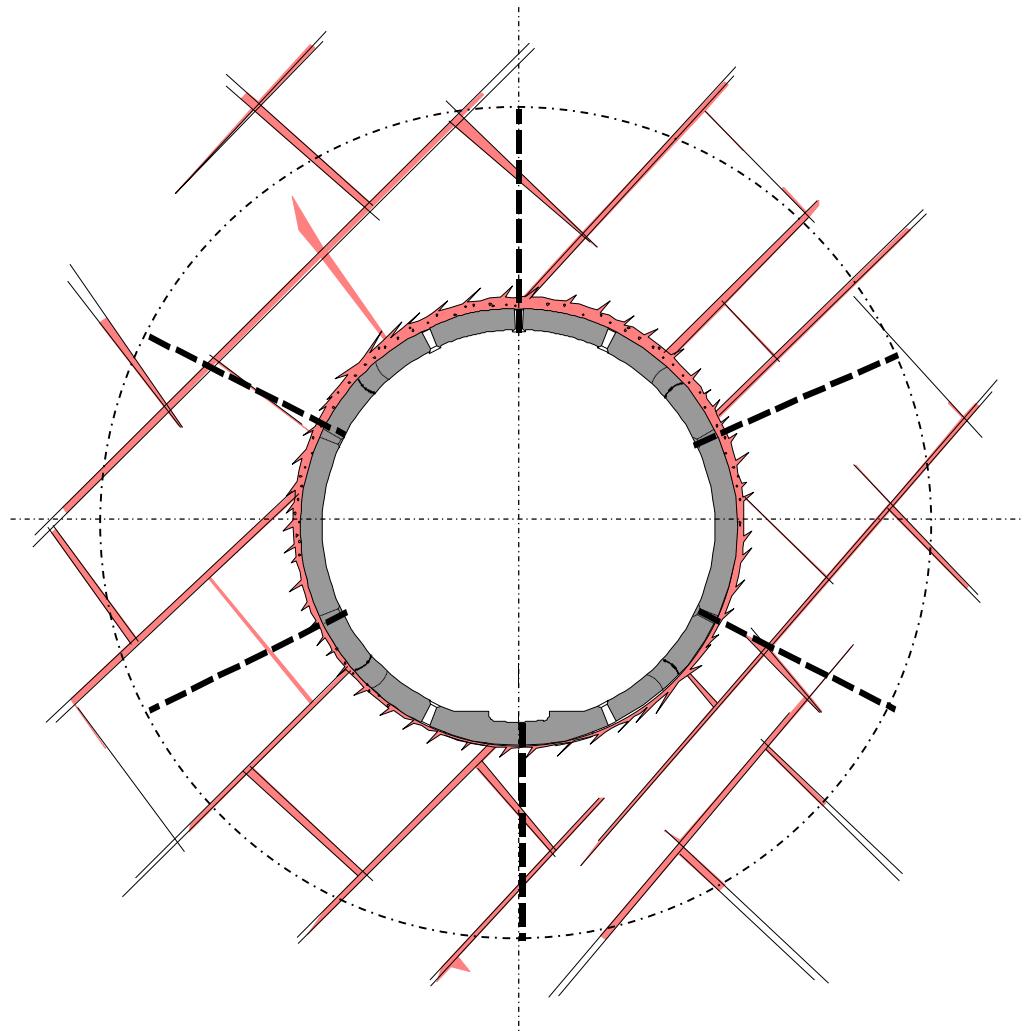


Contact grouting of the Pea gravel





consolidation & sealing grouting















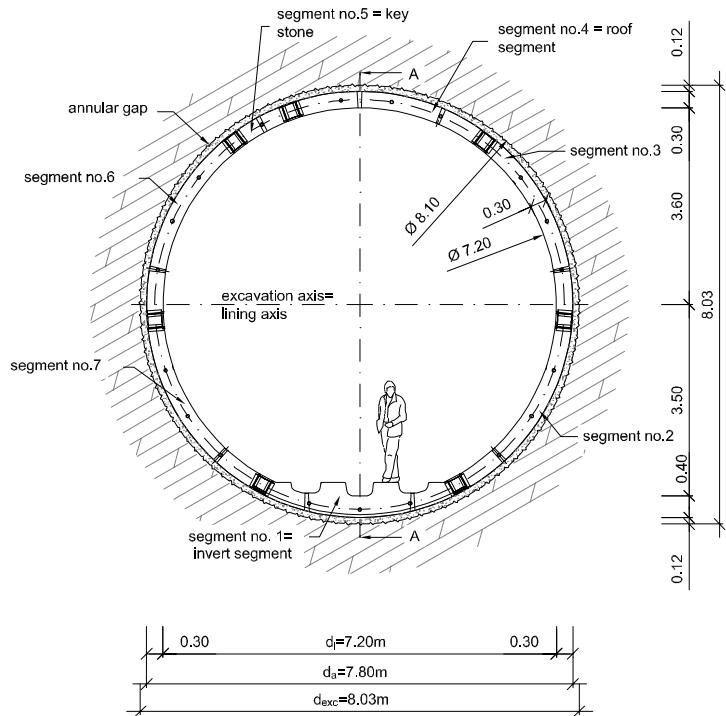
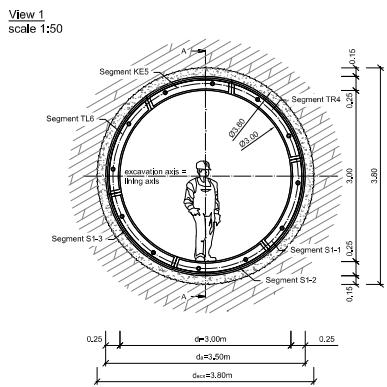
Specific lining features for hydraulic tunnels

- **Parallel ring system** – versus exact tapered system
- “open” lining system – versus gasket sealed lining
- Curve & correction management with **joint spacing**
- Flat surface **without pockets** – versus bolted system
- Joint sealing & segment repair within one step
- Little reinforcement and segment cracking allowed
- Pea gravel bedded and treatment by **systematically grouting**
- Local special measures to improve the system where required (inner lining rings)

Field of successful applications

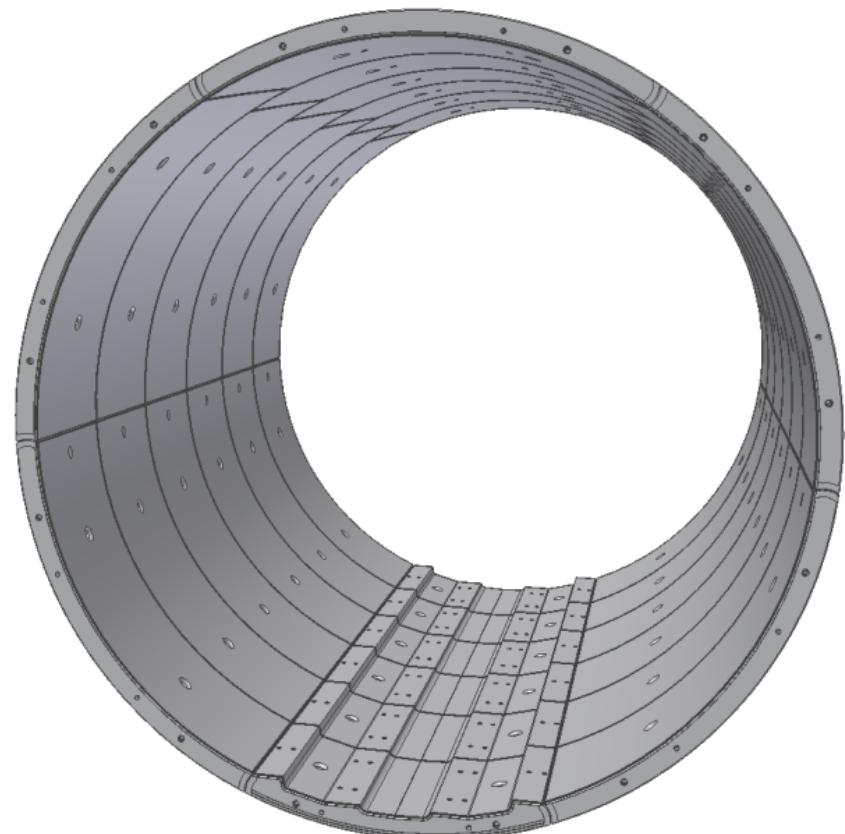
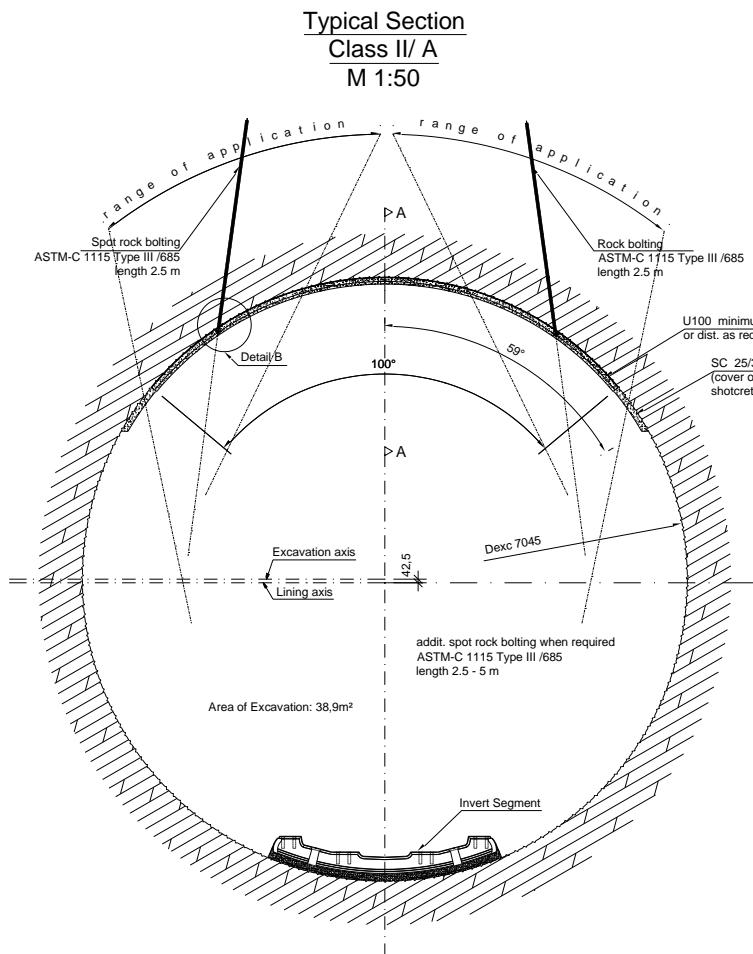
Typical Section
view in heading direction
scale 1:100

- ~ 365 km hydraulic tunnels
- $D_i = 3,0\text{m} - 9,2\text{m}$

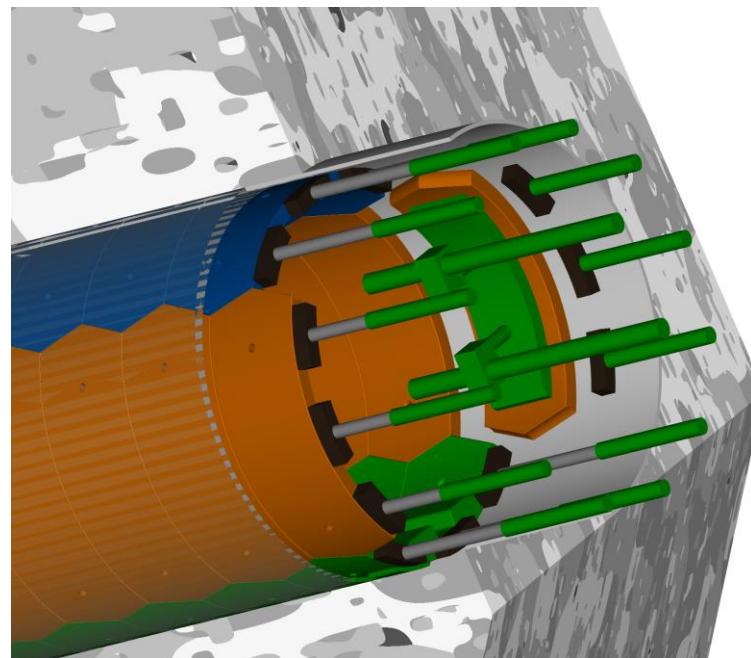
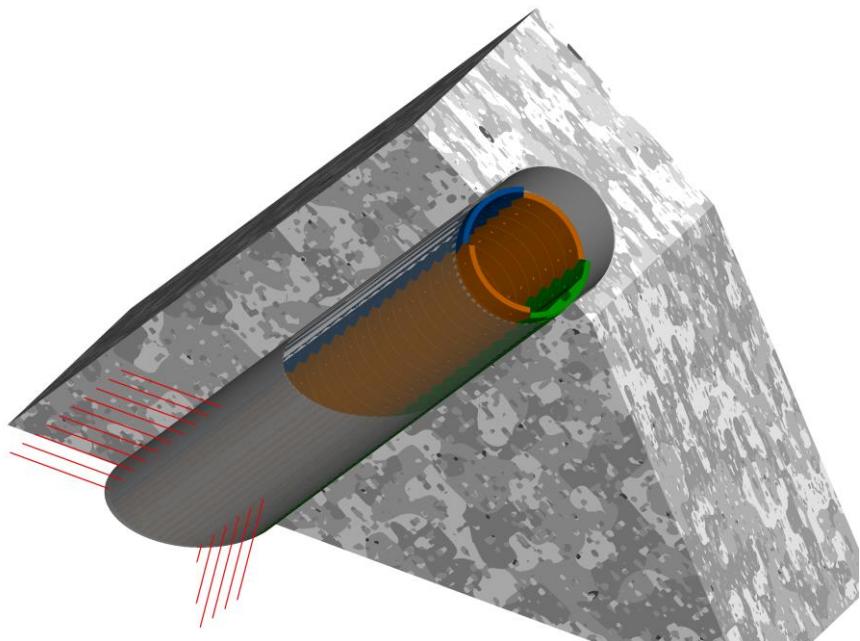


HRT lining design lined / unlined with invert segment

San Francisco HPP - Ecuador

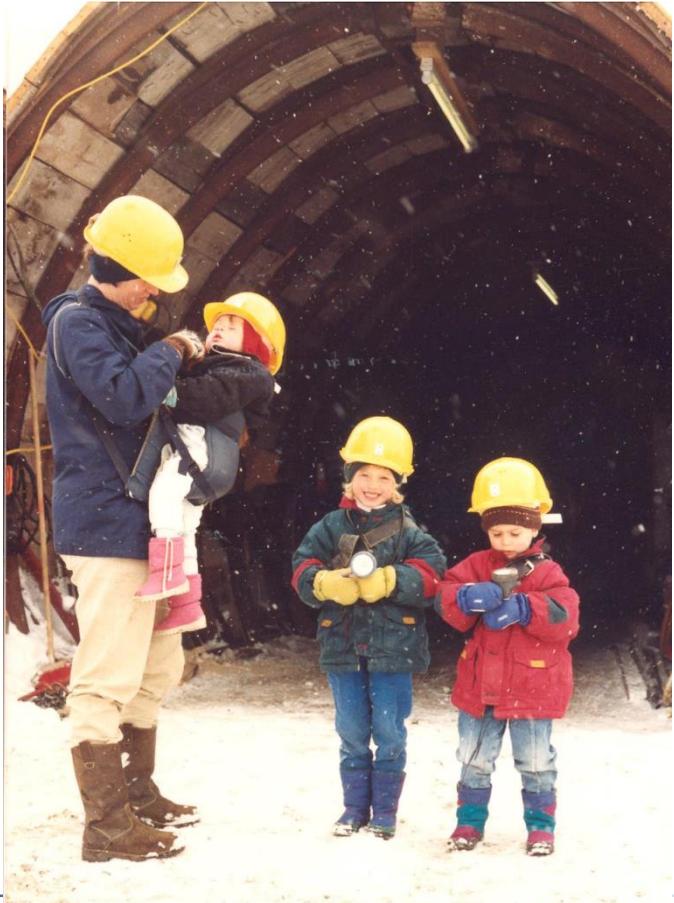


Inclined shaft lining – Parbati - India





How the story ends



1991 – 2019



trondheim, 04.11.2019 © dr. a. vigl – „www.vigl-zt.at“



Thank you for listening that story!