



El evento del Cemento, el Concreto y los Prefabricados



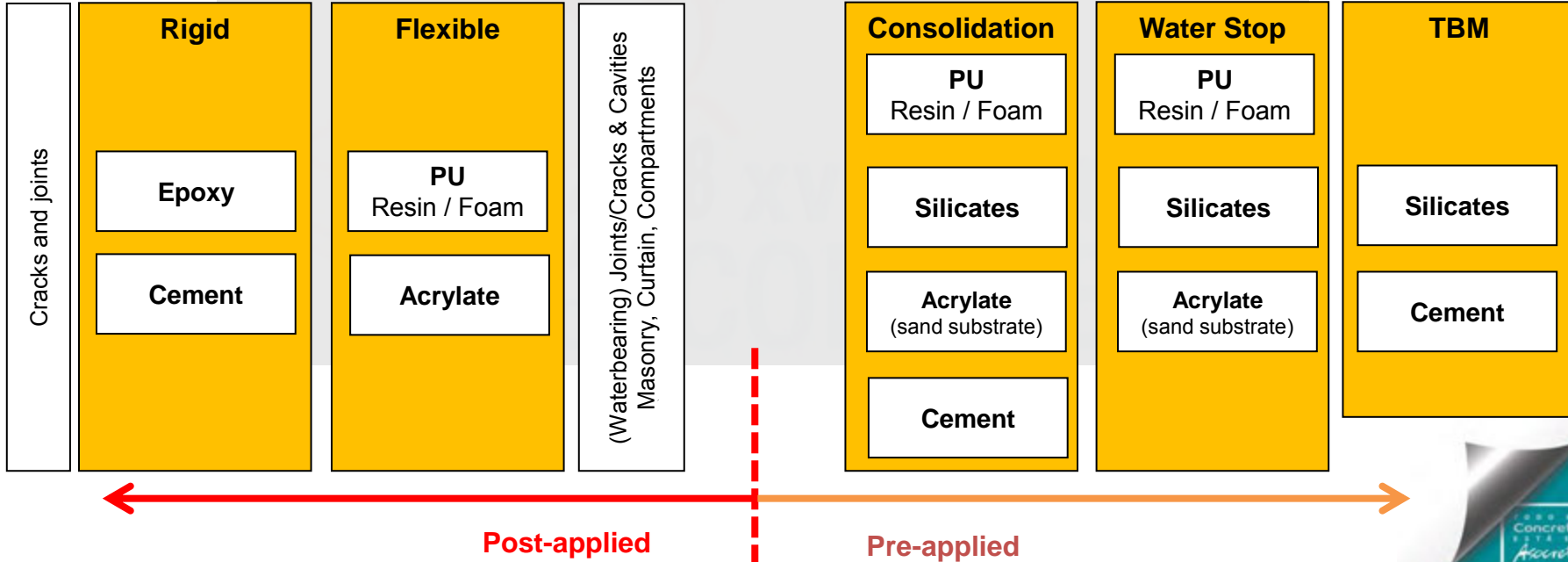
Materials, Equipment, Application & Procedure in Tunneling and Mining

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Injection Materials

Concrete Structure
Repair Work / Waterproofing

Tunnel & Mining
Soil/Rock/Sand



Problems with Ground Conditions

Problems with Geology:

- Unstable Rocks
 - Rock burst / failure
 - convergences
 - settlement on the surface
- Cavities
- Water
 - ingress
 - leakage

Possible Action:

- Stabilize
 - Waterstop
 - Backfill
- or
- Rock Bolting
 - Shotcrete

Why Injection works

→ SAFETY, ENVIRONMENT & COST (delays, downtimes)

Safety, Environment & Cost (water ingress)

Safety

Largest problems in tunnels → uncontrolled water ingress

Immediate flooding

Ground collapse with water ingress

Reduce risk of accidents / Improve working safety

Environment

More and more important in the world

Contaminated water has to be managed

Lowering of groundwater has to be prevented (Avoid environmental misshape)

Cost

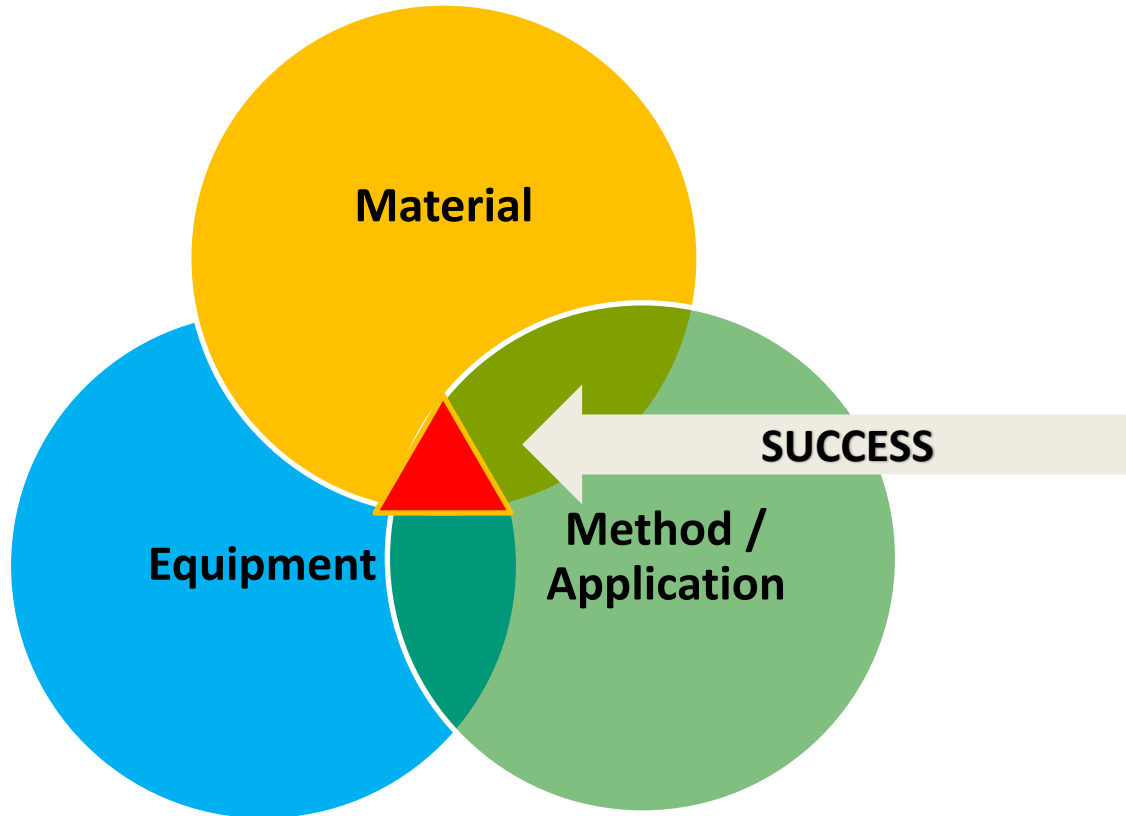
Pumping water → huge cost

Reduced tunnel production vs. total construction time reduction

DOWNTIMES: Stop the whole tunnel for shorter or longer periods

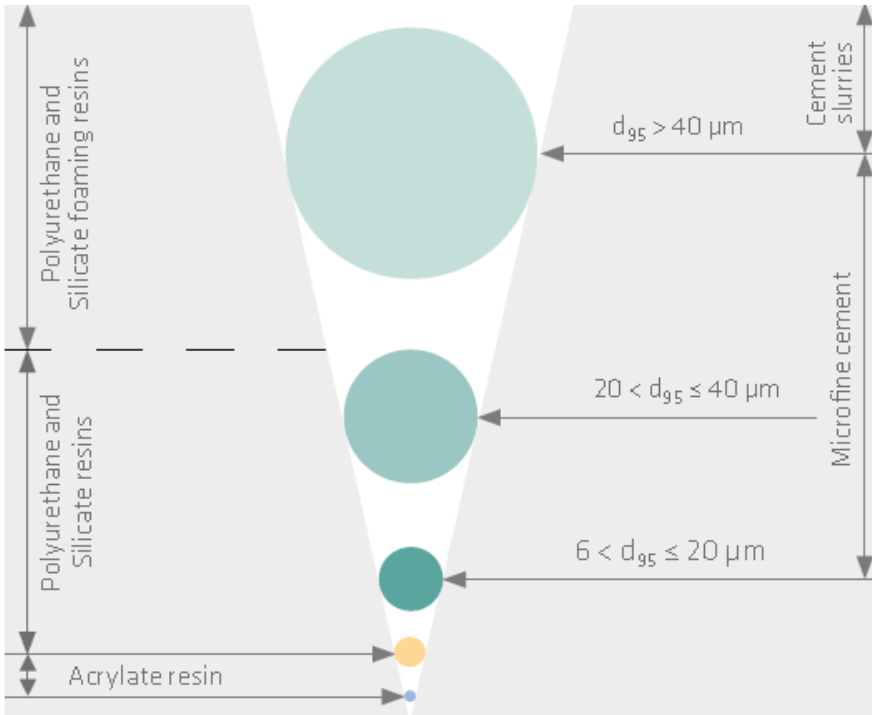
Right focus: Not kg price, but time consumption

Key Success Factors Injections



Injection material

why various technologies are needed



- Cements are the most economical material but cannot be used for all applications (curing time, flowing water).
- flowing water in the ground requires fast setting chemical injections
- Fast curing also reduces downtimes (e.g. anchors, bolts, wind energy)
- For application with TBM, silicate material shall be used in order to avoid difficulties with the TBM
- The smaller the particles, the better the penetration into difficult grounds such as sandy substrates

Injection material technologies and use

Cements

- Portland cement
- Microfine cement

Local solutions available

Silicate foams & resins

- Foaming Silicate Res for filling of big cavities and stabilizing of loose rock in front of TBM
- Non-foaming Silicate Resin, Umbrella injection in front of TBM
- Fast Anchoring / Bolting

Polyurethane (PU) foams & resins

- Non-foaming Polyurethane Resin for consolidation of unstable soil and rock
- Stopping unexpected high water inrushes

Acrylate resins (gels)

- Acrylate injection resins for consolidation of soil with low permeability

Injection material microfine cements

injection cement based on Portland cement max particle size (d95) is 20 μm .

low-alkali injection cement based on Portland cement max particle size (d95) is 16 μm .

low-alkali injection cement based on Portland cement max particle size (d95) is 12 μm .



Injection material Polyurethane Resins

PU Resin

(2 comp. // 1 : 1)

quick-reacting (45 sec) resin with short reaction times and *high final strength* 80 N/mm²

- Expands after watercontact (~3 times)
- Modular System: acc, foaming agent, retarder
- Accelerator & Foaming (<10 sec, ~25 times)

Use:

- for consolidation of unstable soil and rock
- Stopping of unexpected high water ingress underground



Injection material Silicate Foams

Silicate Foam

(2 comp. // 1 : 1)

quick foaming (30-fold) resin with short reaction times (15 sec.).

- Reacting with itself, in case of water no change of technical properties
- *Low reaction temperature (important for mining ~100°C)*
- *Cured foam is cuttable and plannable*
- *Cheaper, more mixing energy required compared to PU*

Use

- Stabilizing of disintegrated rock e.g. with high cavity content
- filling of big cavities
- TBM Heading consolidation



Injection material Silicate Resins

Compact Silicate (2 comp. // 1 : 1)

- non-foaming, non-flammable resin with short reaction times (40 sec.)
- *Very good adhesion even on damp surfaces*
- Reacting with itself, in case of water no change of technical properties
- *Low reaction temperature (important for mining ~100°C)*
- *Cured material is cuttable and plannable*

Use

- Stabilizing dry, moist, wet → soil & rock
- For anchor & bolt injections
- TBM Injection



Injection material Acrylate

Acrylate

(2 comp. // 1 : 1)

- quick-reacting resin with extremely low viscosity (5 mPa*s) with short adjustable reaction times (sec-min)
- Slight swelling factor up to 10%
- Cleaning with water only

Use

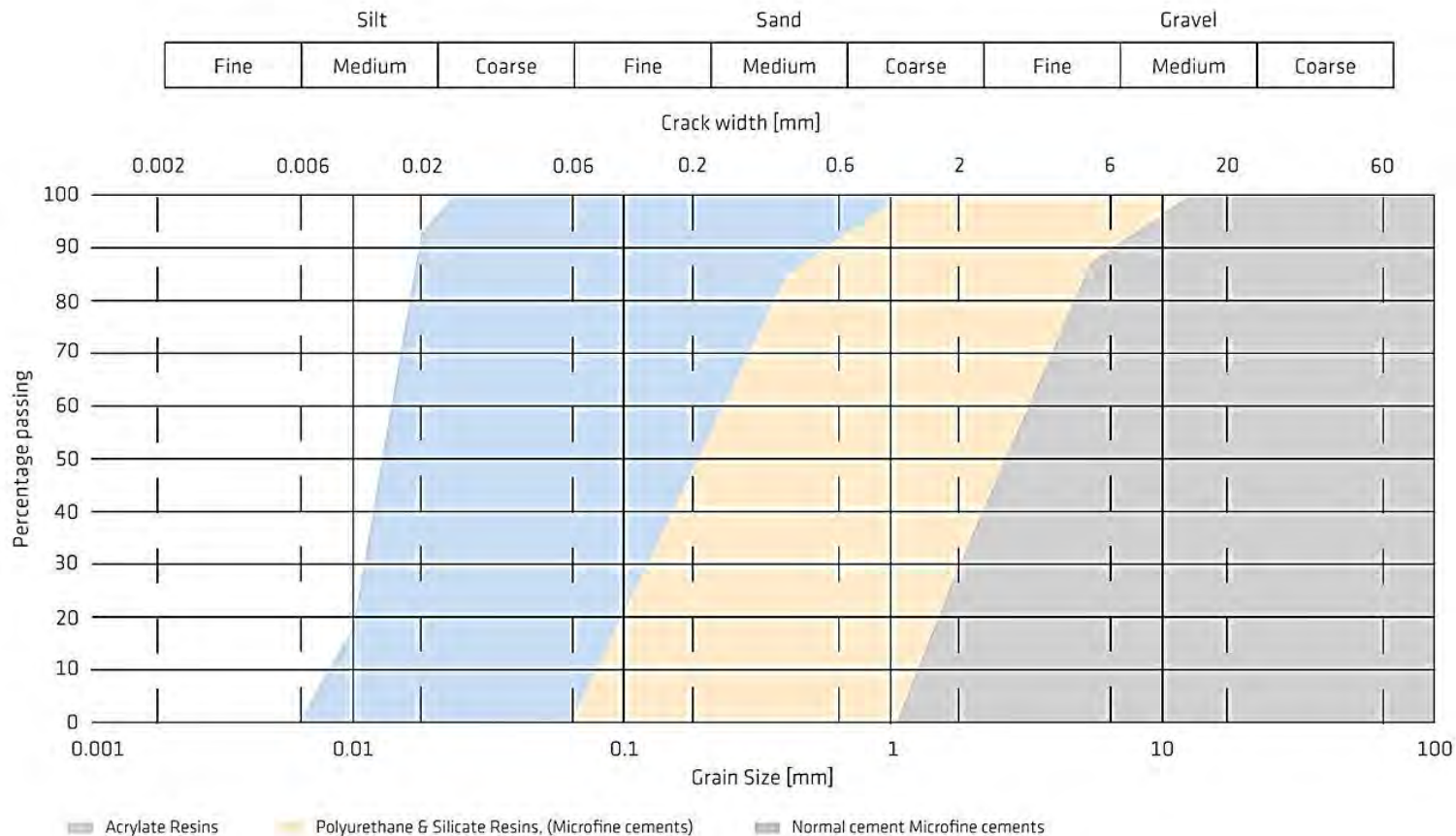
- Sealing of layers with low infiltration rates
- soil consolidation where is low permeability
- Sealing of fine cracks, fissures and voids well below $\ll 0.2$ mm

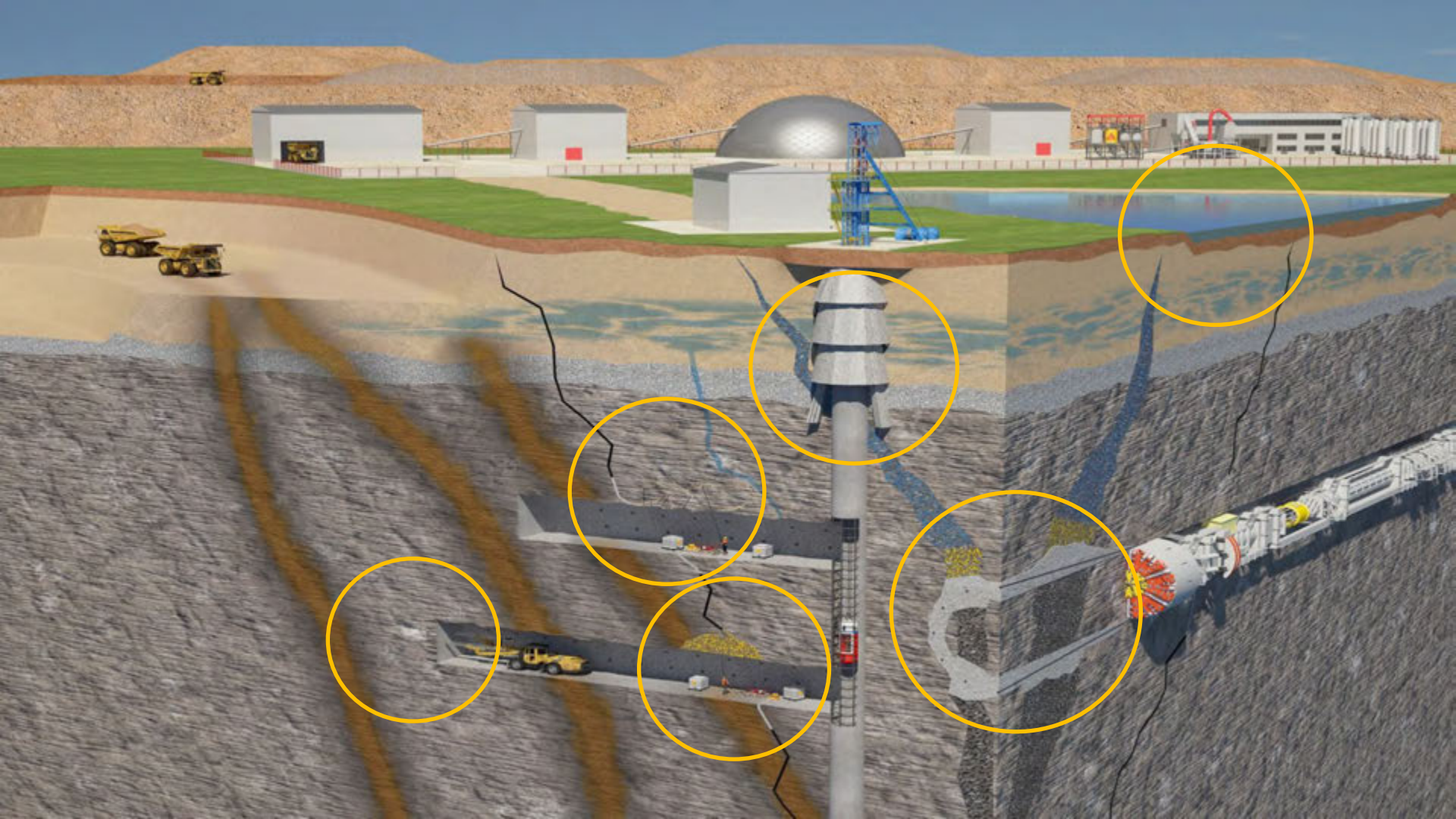


Injection material Acrylate



Selection Chart Consolidation





Equipment and accessories Common packers



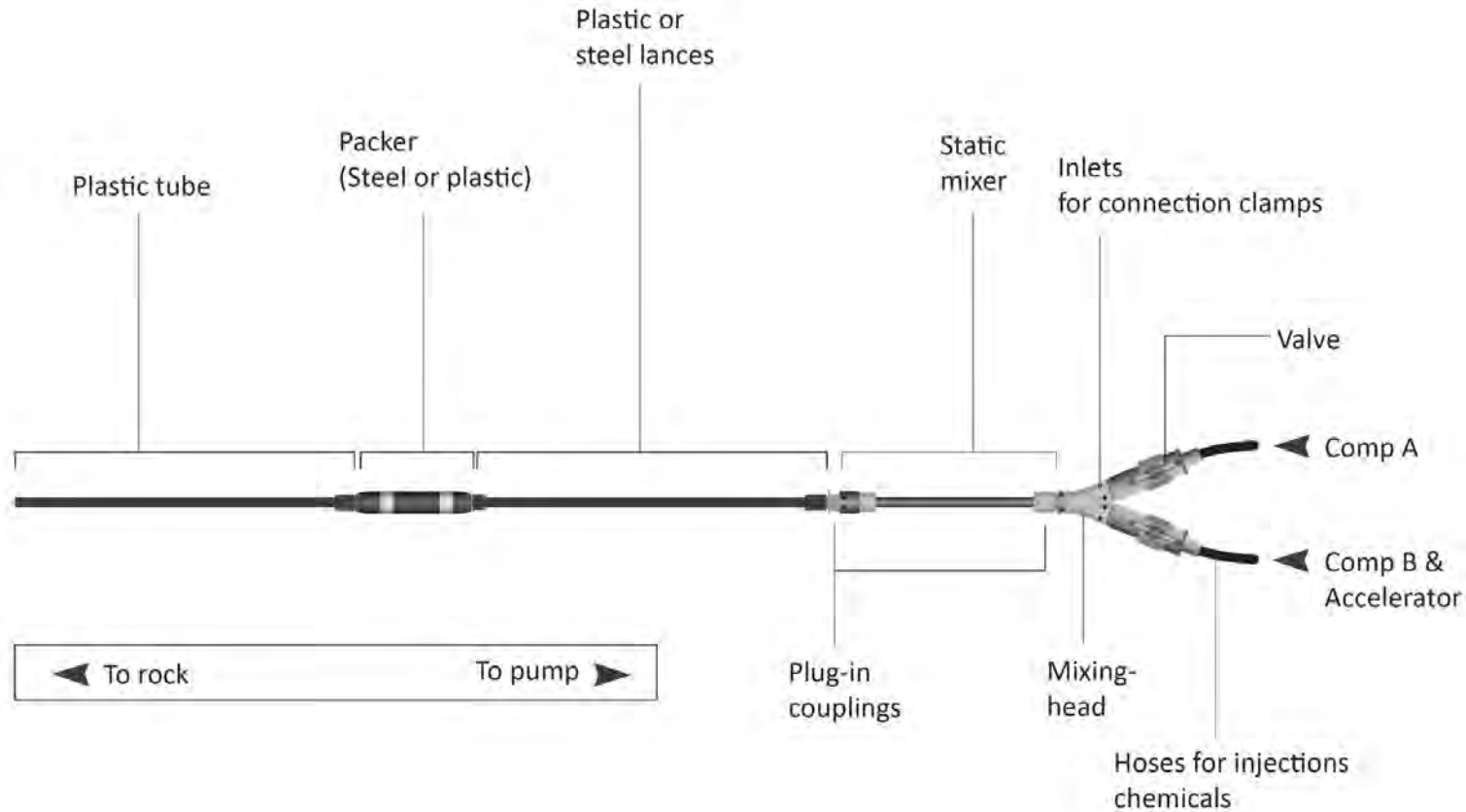
Inflatable packers

Inflating Packers

Material	Plastic core with rubber tube alternatively steel core
Diameter	ø 40 mm
Maximum expansion	ø 65 mm
Length	approx. 325 mm
Max. flow rate	19 l/min
Opening pressure	approx. 30-40 bar



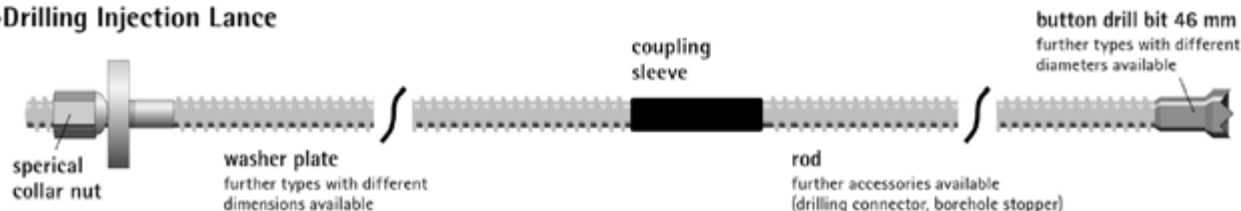
Packer System set-up



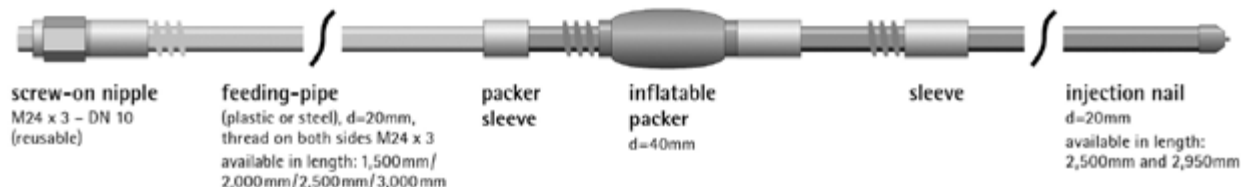
Injection packers & lances

Injection packers and lances e.g.

Self-Drilling Injection Lance



Inflatable Packer



Manchette Tube



Injection through packer systems



Injection through packer systems



Injection through packer systems



Injection through packer systems



Pumps for PU/Silicate 2-Component

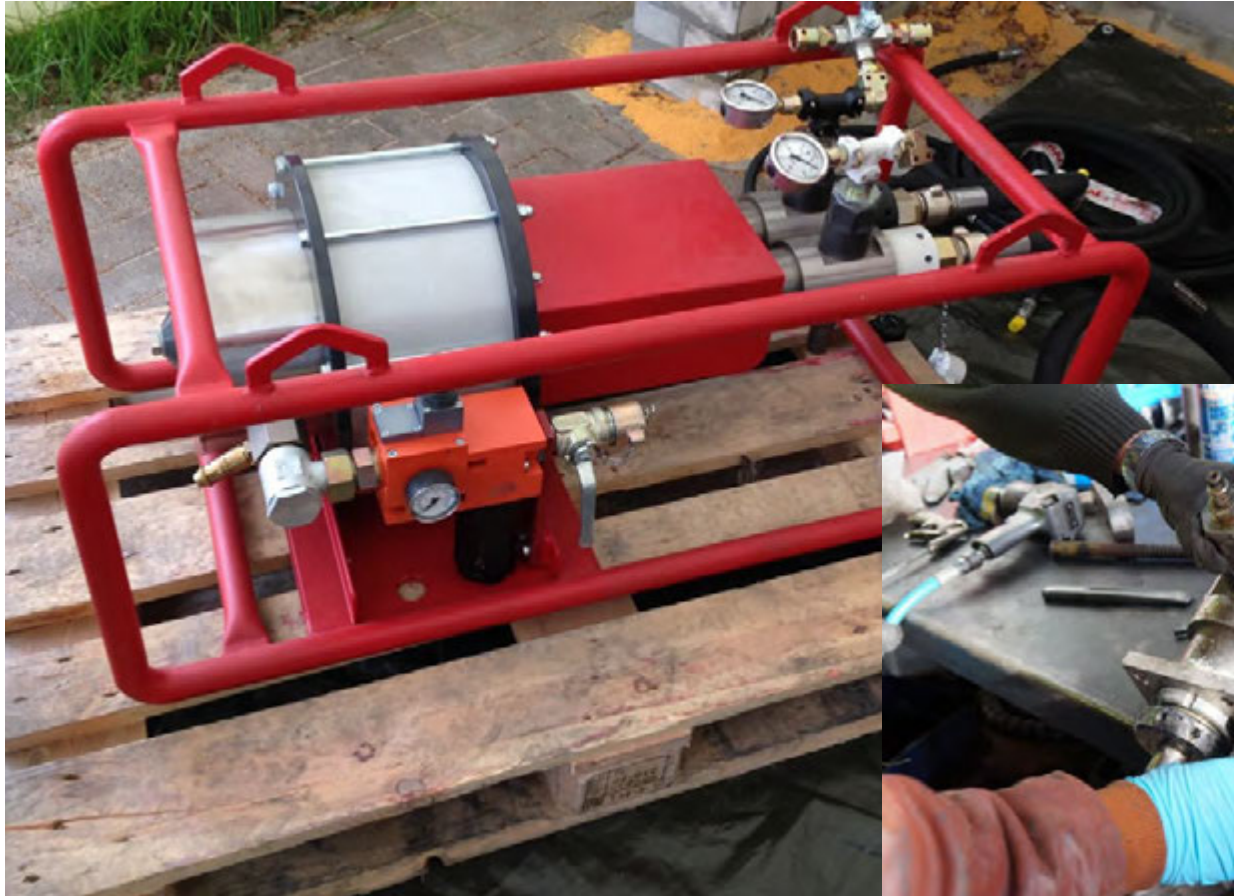
- This type is an air-driven, 2-comp. injection pump with a fixed mixing ratio (1:1 parts by volume).



Physical properties	
Injection pressure	up to 240 bar
Pump capacity	approx. 13 l/min
Air requirement	6 m ³ /min
Weight	approx. 118 kg
Suitable for	PU / SIL

Complete w. special mixing head, hoses. etc

Pumps for PU/Silicate 2-Component



- Do not switch type of injection resins before **PERFECTLY CLEANING!**



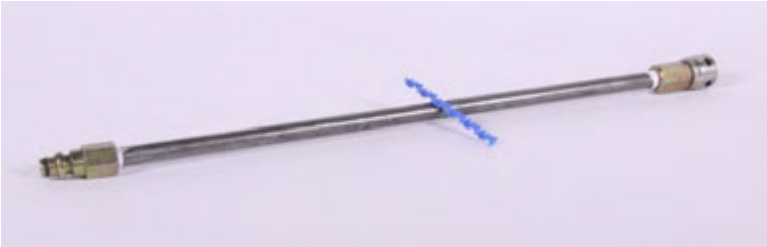
Pumps for PU/Silicate 2-Component



Pumps for PU/Silicate 2-Component



- **Polyurethane static mixer**



- **Silicate static mixer**
- Higher mixing energy is necessary for Silicate Technology
- Pipe is longer and thinner

Injection Methods for Tunneling and Mining

Application

Pre-Injection

- In front of the tunnel face

Tunnel



Post-Injection

- Somewhere behind the tunnel surface

Tunnel



Pre- vs Post Injection

- Post-injection alone is very difficult, costly and sometimes impossible
- Pre-injection can solve almost all problems
- Pre-injection target of 100% sealing is not realistic
- Post-injection as a supplement is very effective

Pre- vs Post Injection

Pre-Injection

- Dominated by cementitious injection
- Pre-injection is like an insurance, to avoid problems in the future

Benefits of pre-injection

- Minimal risk of uncontrolled water intrushes
- Substantially improved stability through poor ground
- «Dry» working conditions in the tunnel
- No, or little influence on the surroundings

Post-Injection

- Dominated by chemical injections
- Almost all tunnels require some kind of post-injection works either with micro-cements, PU or acrylates for leak sealing, repair or ground stabilization methods
- It is much easier to achieve good results with Post-Injection if the tunnel has been Pre-Injected

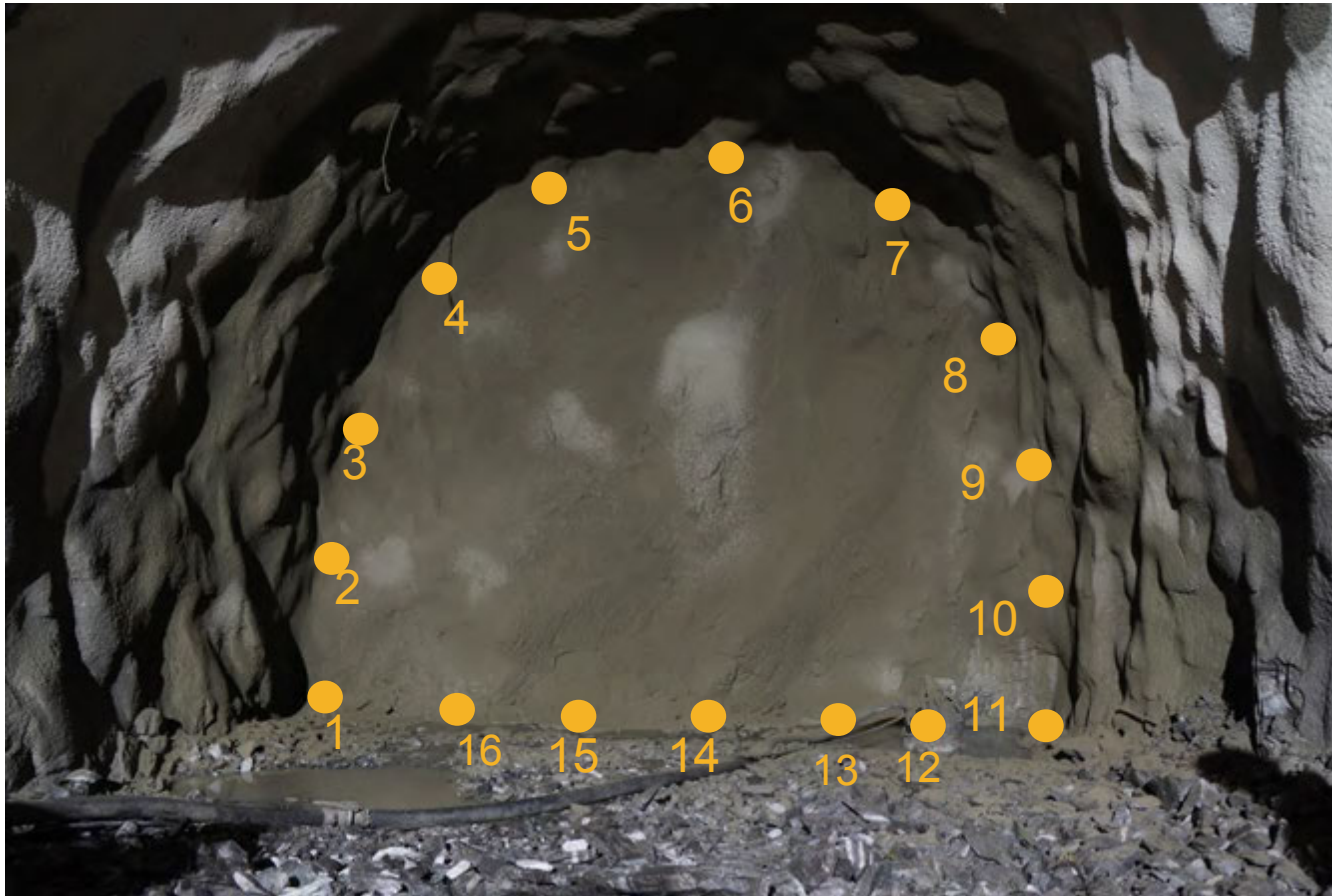
Drilling Injection



Typical drilling lengths
in hard rock:

- Exploratory holes:
25-30 m
- Grouting holes in Rock:
18-24 m
- Chemical Injections
against hydrostatic
waterpressure:
2-9 m

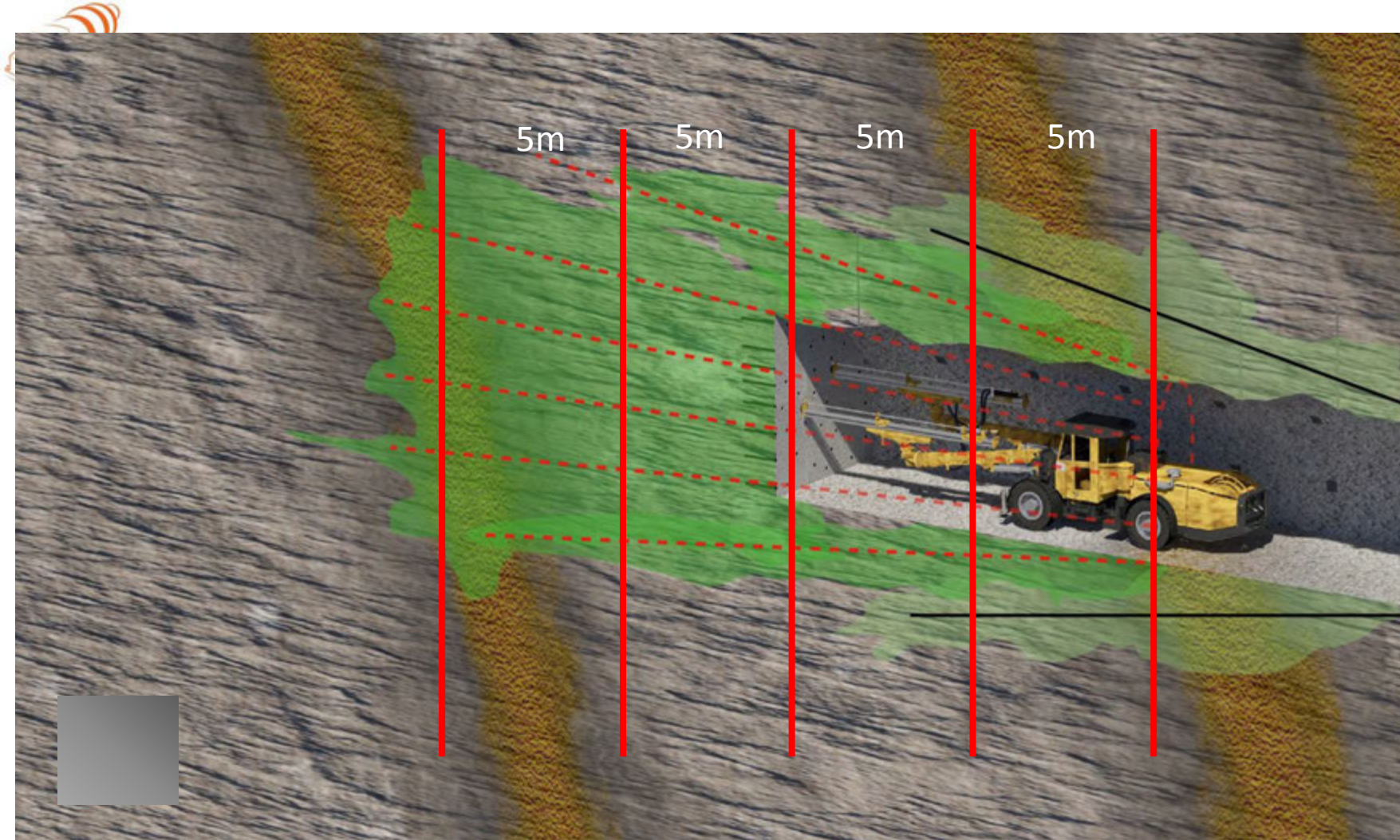
Pre-Injection drilling pattern

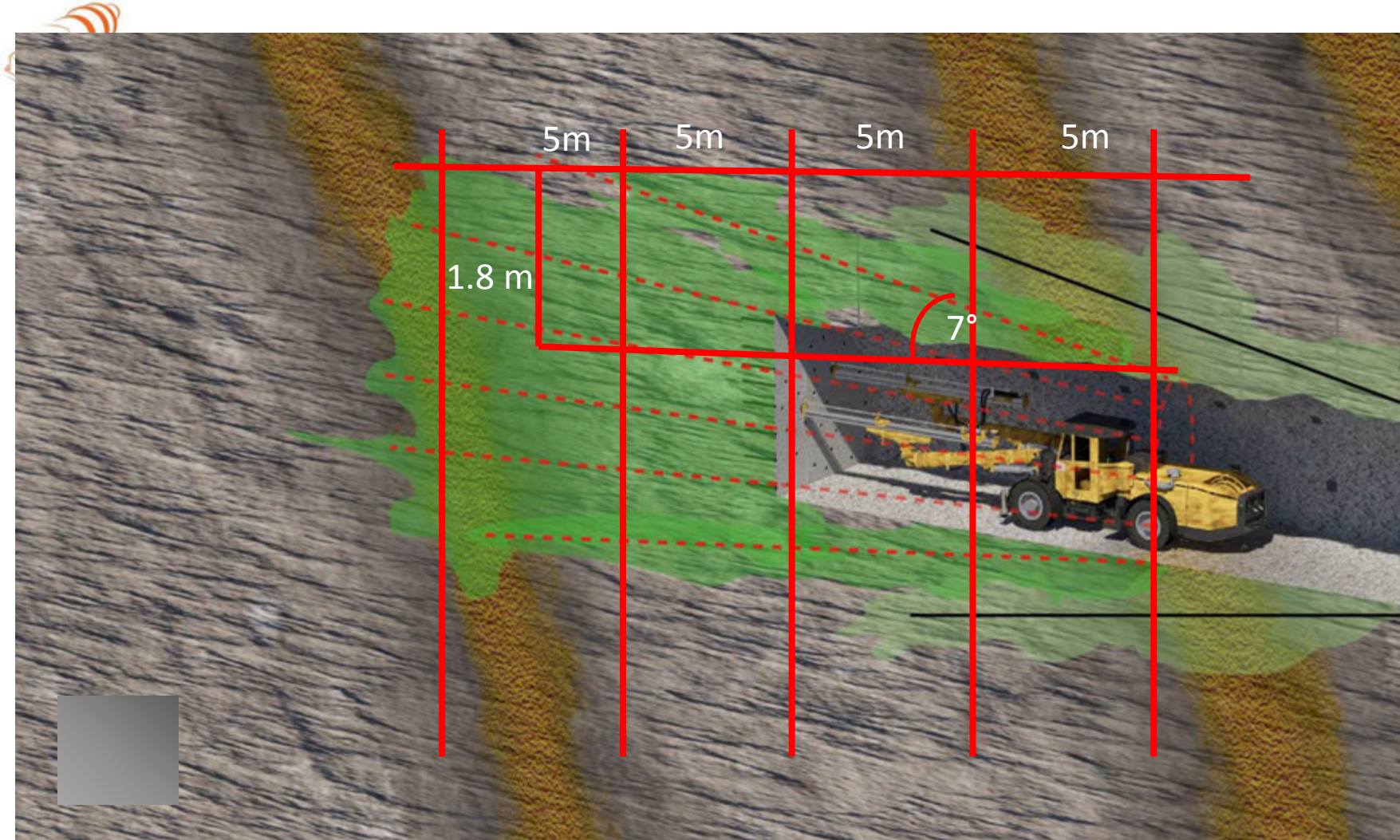


- Grouting holes in Rock:
18-24 m (4 x times multiple length of blasting)
- Spacing
0.5 to 1.5 m
- Angle
 $\sim 7^\circ$
- Documentation is very important
- Stop criterias

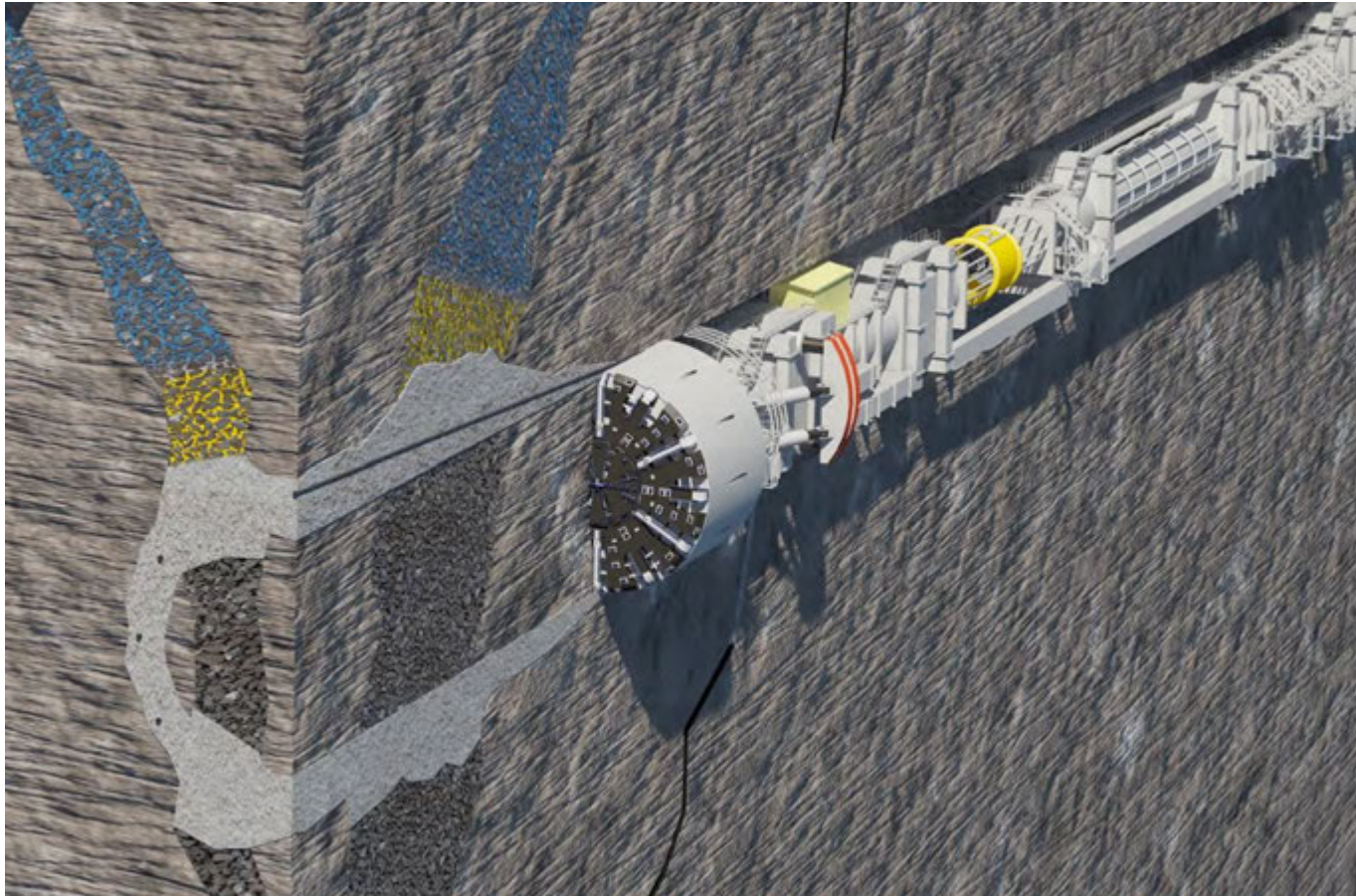
Injection pressure
Injection volume





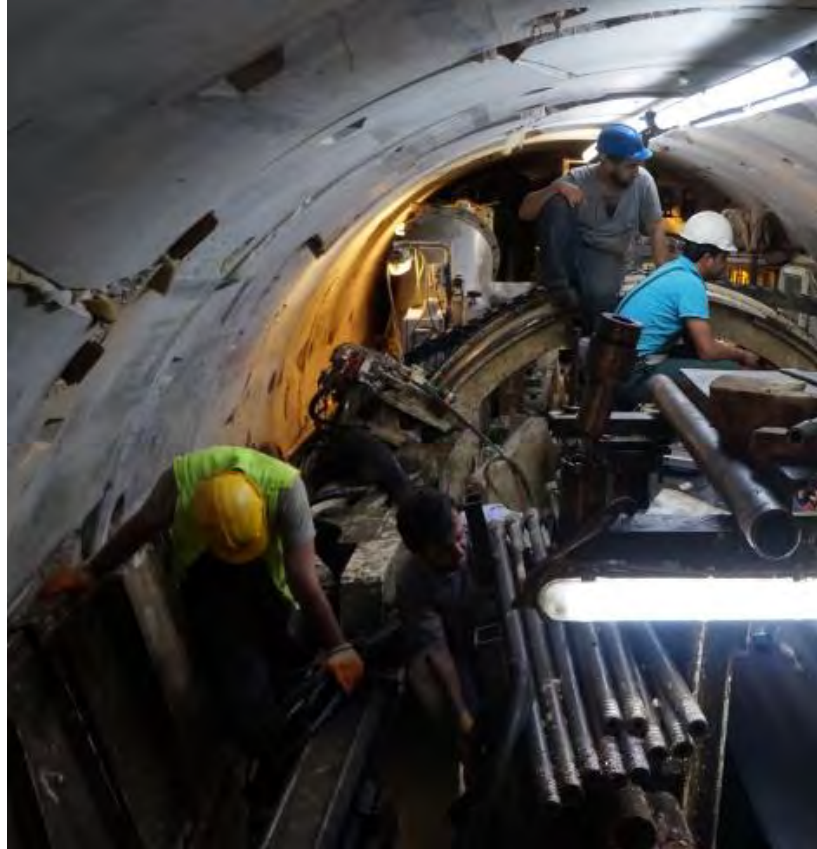


Example Pre-injection TBM injection above crown



Example Pre-injection TBM silicate injection

- For TBM: depending on the amount of water present, a foaming or non-foaming, compact silicate resin is used
- Cured resin is sliceable by the cutter-heads of the TBM
- In case of low soil permeability in front of the TBM a low viscosity Acrylate Resin has to be chosen.



Example Pre- / Post-injection high water inrush



Example Pre- / Post-injection high water inrush



Example Pre- / Post-injection high water inrush

Polyurethane

- Backfilled material has high infiltration rates
- Water ingress at only few points
- High water inrush
- PU resin
- + extra acceleration and expansion will solve this case



How does it work Post Injection

- Holes and injection shall be made in an angle of perpendicular to the water-bearing structures.

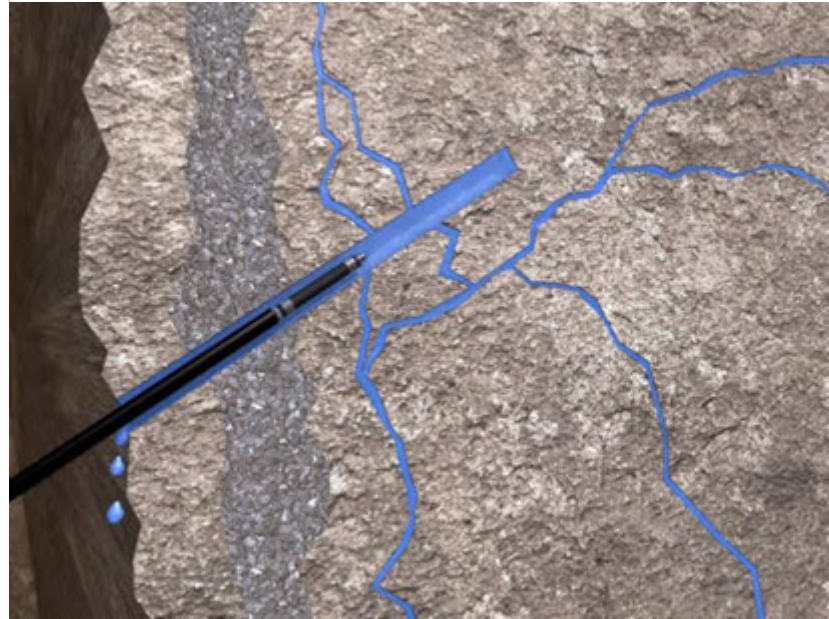
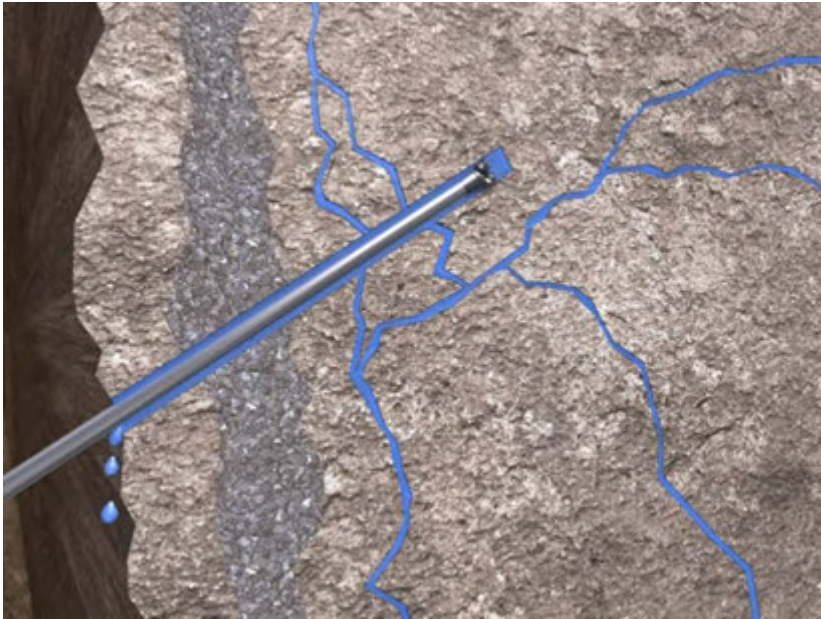


How does it work Post Injection



How does it work Post Injection

- Drill
- Place injection lance incl. packer



How does it work Post Injection

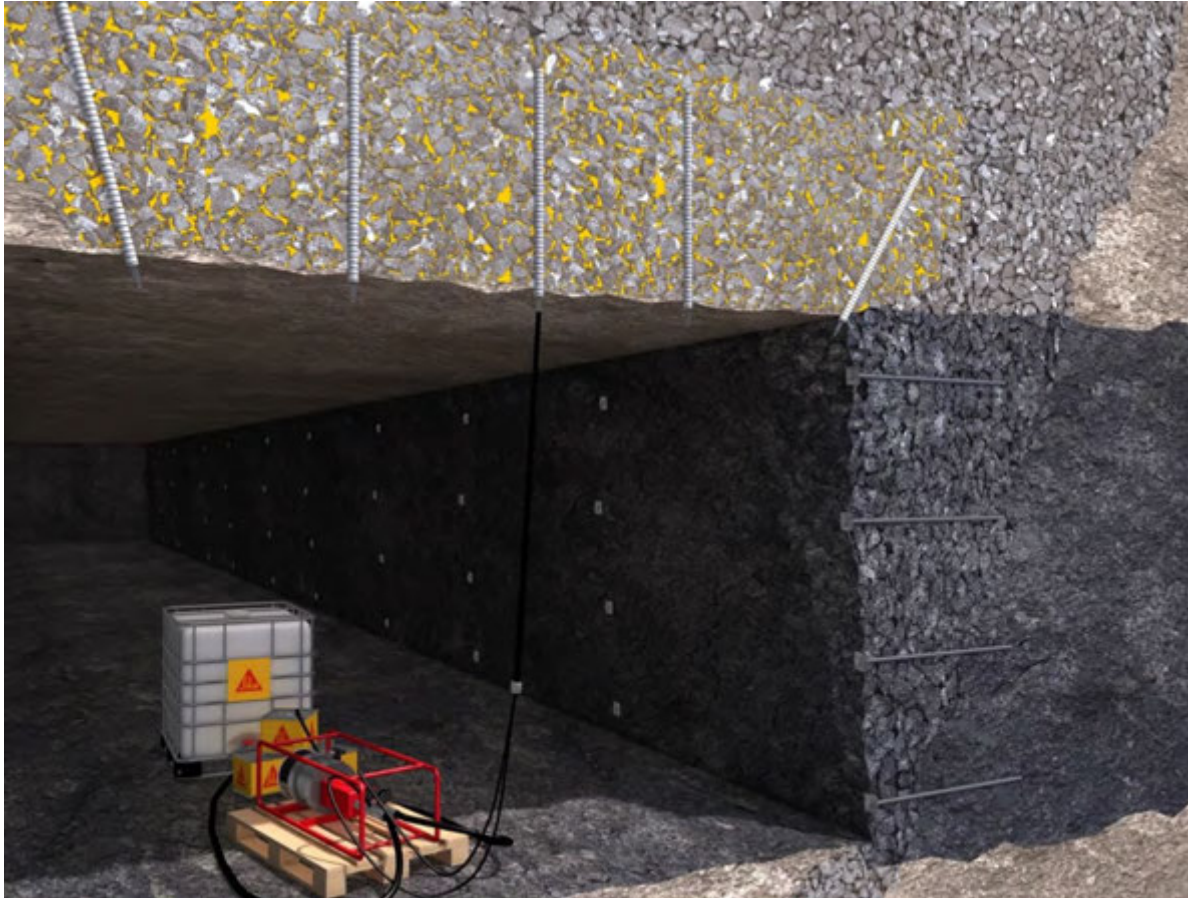
- Start pumping: Resin blows up the packer and enters the fault zone
- Resin starts to react and blocks water



Wrong packer placing

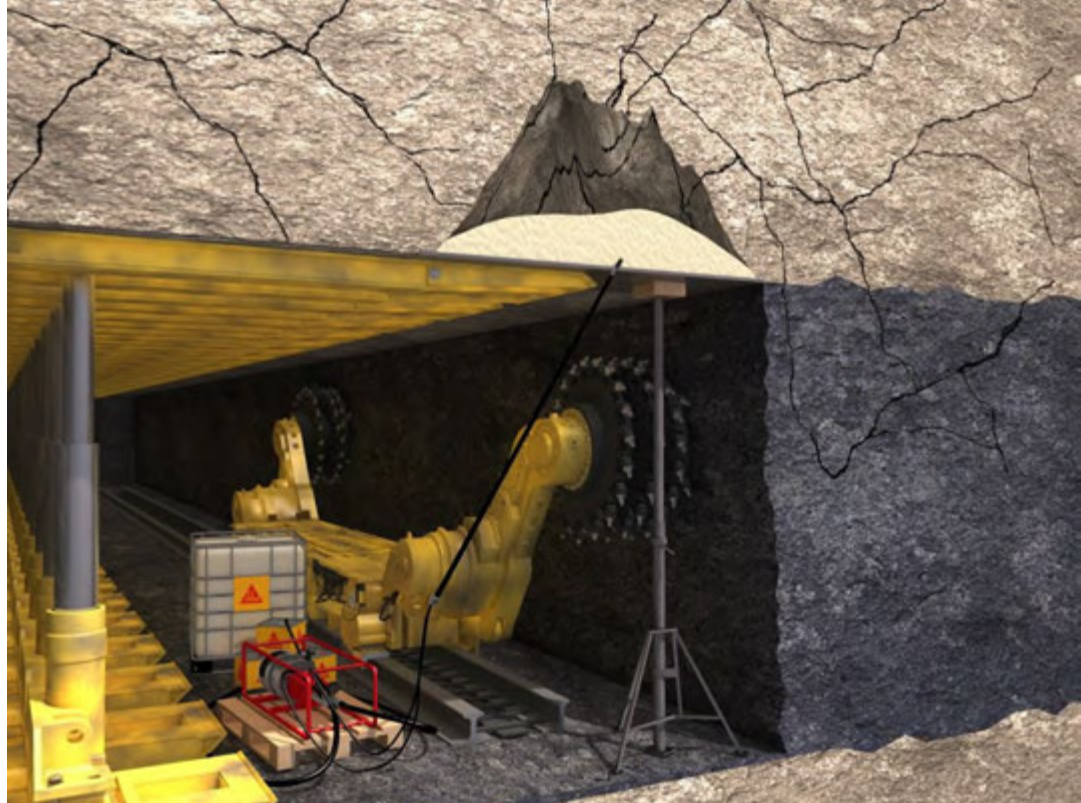


Consolidation, silicate resin coal mining



Consolidation, silicate foam coal mining

- very quick foaming (15 sec) with very high foam factors of up to 35x.
- Silicates generally have much lower reaction temperatures than PU → important in coal mines → approval
- Expansion with or without presence of water



References

References

Project: Tunnel, Iceland

Material: PU Resin, modular

Time: 2015 - 2017

Speciality:

Highly pressurized hot thermic water ingress and cold water ingress



References

Project: Tunel, Colombia

Material: PU Resin, modular

Time: 2016

Speciality:

Confined space – drilling and injection not at the same time possible. Protection of Material and Pump during injections



References

Project: Mine, Peru

Material: PU Resin, modular

Time: 2016

Speciality:

Level over sea: > 4700 m, Oxygen



References

- Project:** High-Speed
Railway tunnel
Spain
- Material:** 2-c Silicate Resin
- Time:** 2015-2016
- Speciality:**
- Supply Chain: Delivery of > 60 tons in
extreme short period (< 1 month)



References

Project: Metro,
Saudi Arabia

Material: PU Resin, modular

Time: 2016-2017

Speciality:
Precast element injections

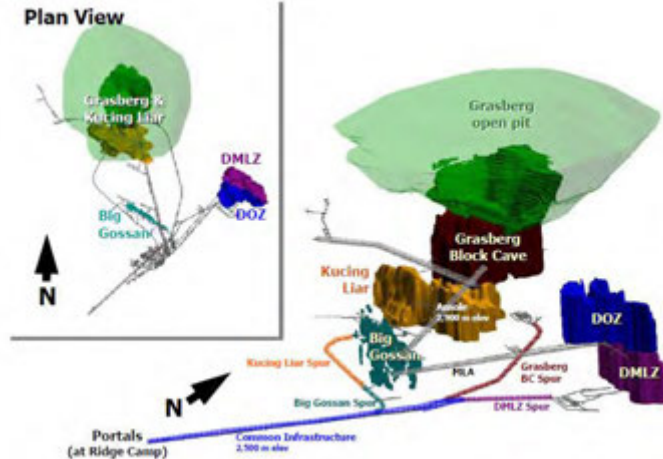


References

Project: MINE INDONESIA

Material: Silicate Foam/Res

Time: 2015-2017



References

Project: Mine, Sweden
Material: PU Foam/Resin
Time: 2017

Speciality:

Injection of shaft at ~1100 m
below ground level



References

Project: Dam, Brazil

Material: PU Foam/Resin

Time: 2012-2014

Speciality:

Supply Chain: Build up Sika-factory and warehouse in Amazonas. Delivery by boat.





THANK YOU FOR YOUR ATTENTION