

# Fluidic functional verification for closing structures and fluid-based sealing of the contact zone STROEFUN III

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**US/GERMAN WORKSHOP**

Salt Repository Research,  
Design, & Operation

# Agenda

Topic 1: First application of MgO-mortar in salt mines

Topic 2: Asse Mine Prototype Testing

Topic 3: Comparison of Pressure Build-up

Topic 4: Asse Mine – Construction on Industrial Scale

Topic 4: R&D Project MgO-SEAL: Solubility Equilibria

Topic 5: Idea

Topic 6: Concept

Topic 7: Dam construction

Topic 8: Permeability measurement

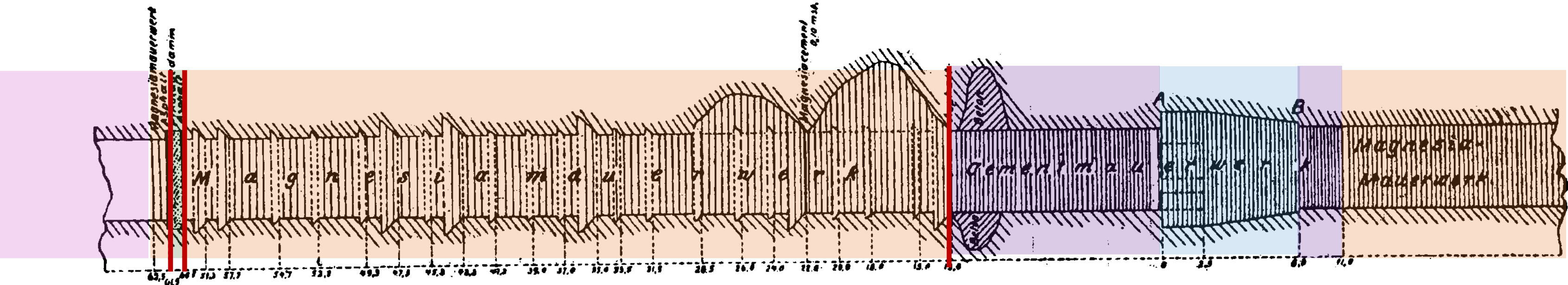
Topic 9: Injection

Topic 10: Samples

Topic 11: Breakout session

# First application of MgO -mortar in salt mines

In 1898 the 161,5 m long drift seal in the Leopoldshall salt mine – cross-cut between Leopoldshall I/II and Leopoldshall III was built

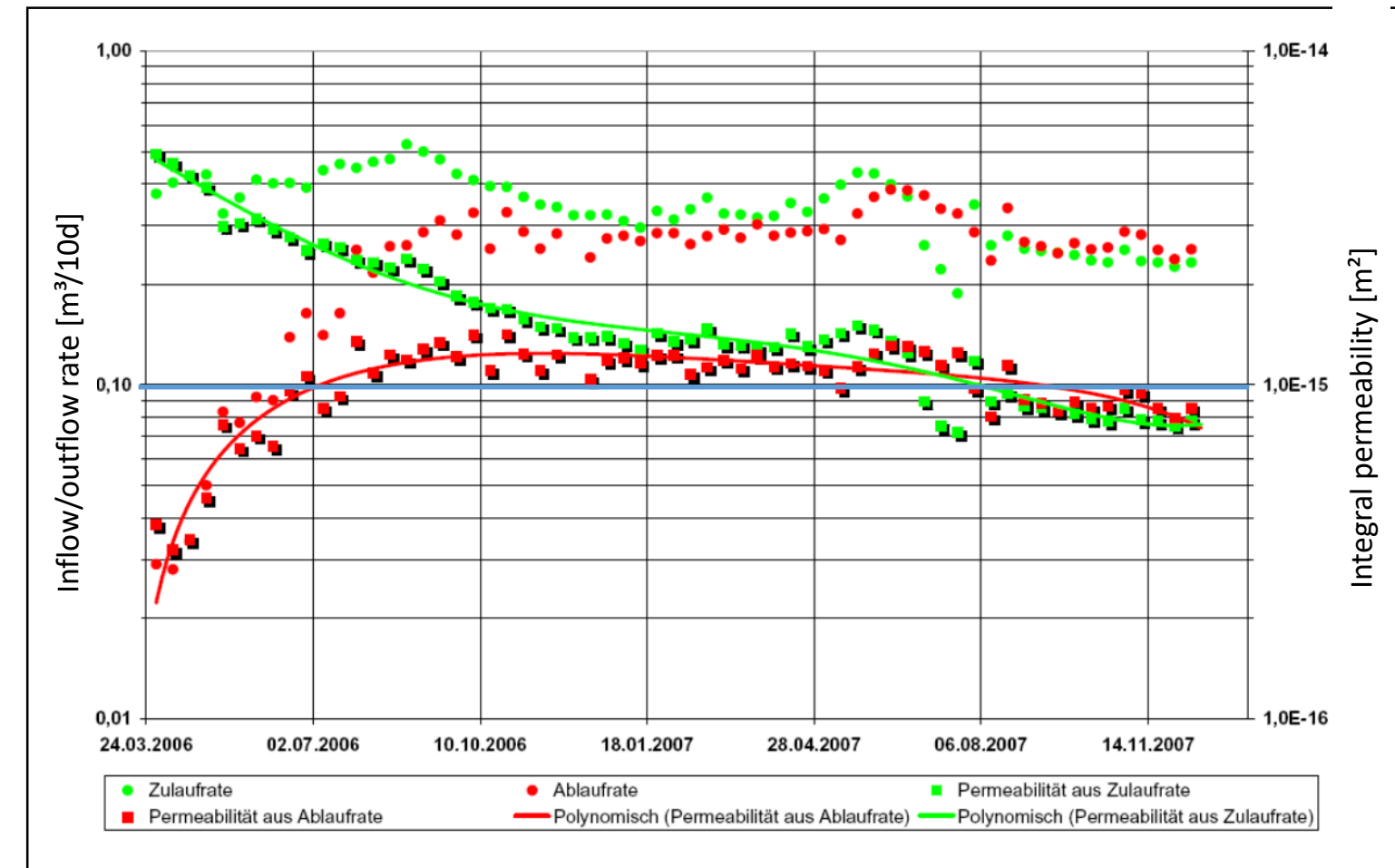


- Brick masonry with cementitious mortar (existing part)
- Brick masonry with cementitious mortar (new part)
- Brick masonry with MgO-mortar separated by
- Asphalt gaps
- Pikotage dam
- Saturation chamber (crushed carnallite)

Before the sealing body was erected the drift contour was removed up to 1 m and subsequently washed with  $MgCl_2$ -rich brine ... the miners worked on an empirical basis ... but the seal became effective

# Asse Mine Prototype Testing – Pilot Seal A2

About 100 years later ... in order to demonstrate proper functionality prototype testing was required by mining authority constituting a prerequisite to close the Asse Mine ...



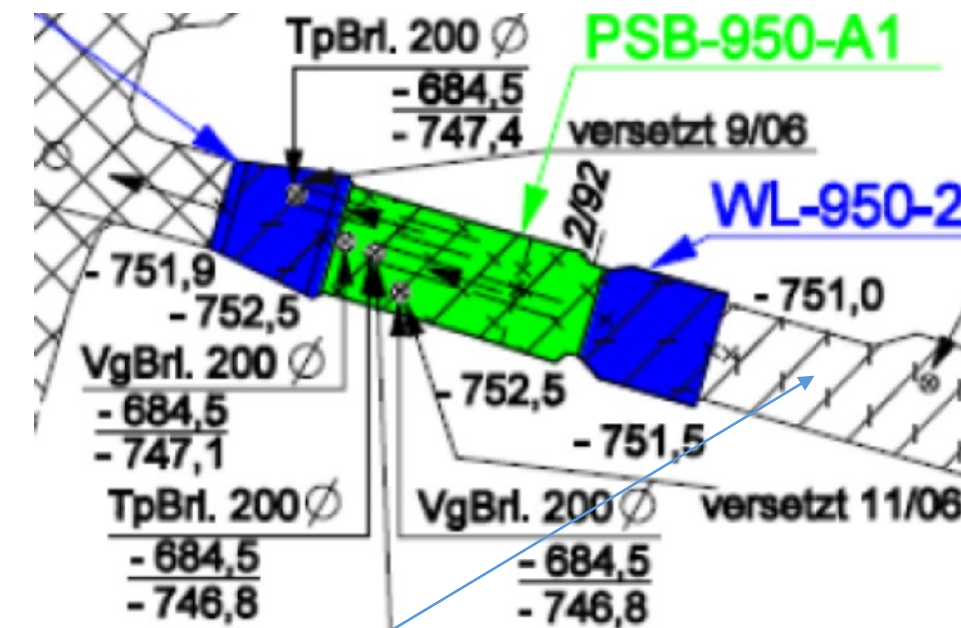
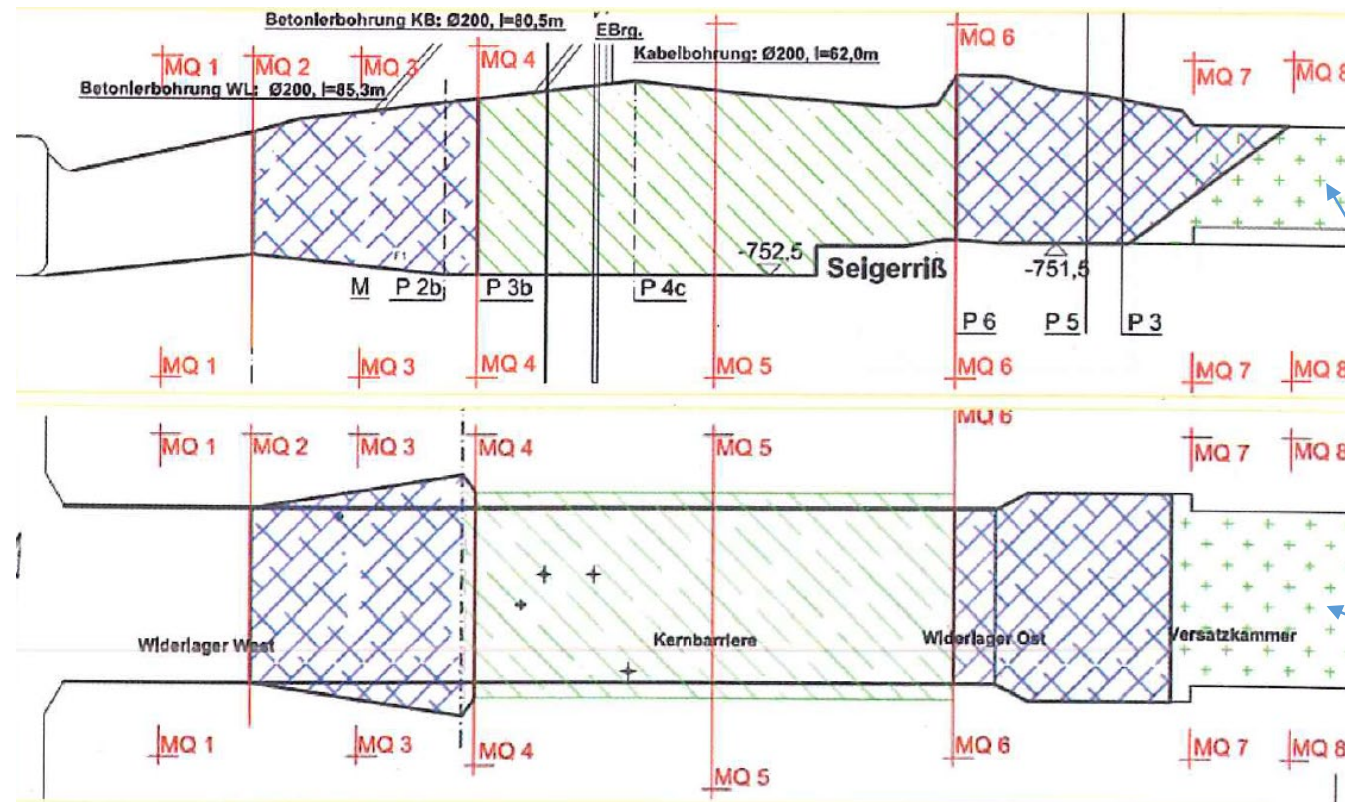
## Lessons learnt from Pilot Seal A2 (PSB A2)

- Removal of EDZ according to mining experience was not sufficient
  - Selection of a low permeable but „soft“ building material was not favorable
- EDZ acted as a preferential pathway

Requirement for licensing

Source: GSF, HMGU & DBETEC

# Asse Mine Prototype Testing – Pilot Seal A1



## Improved construction features of Pilot Seal A1

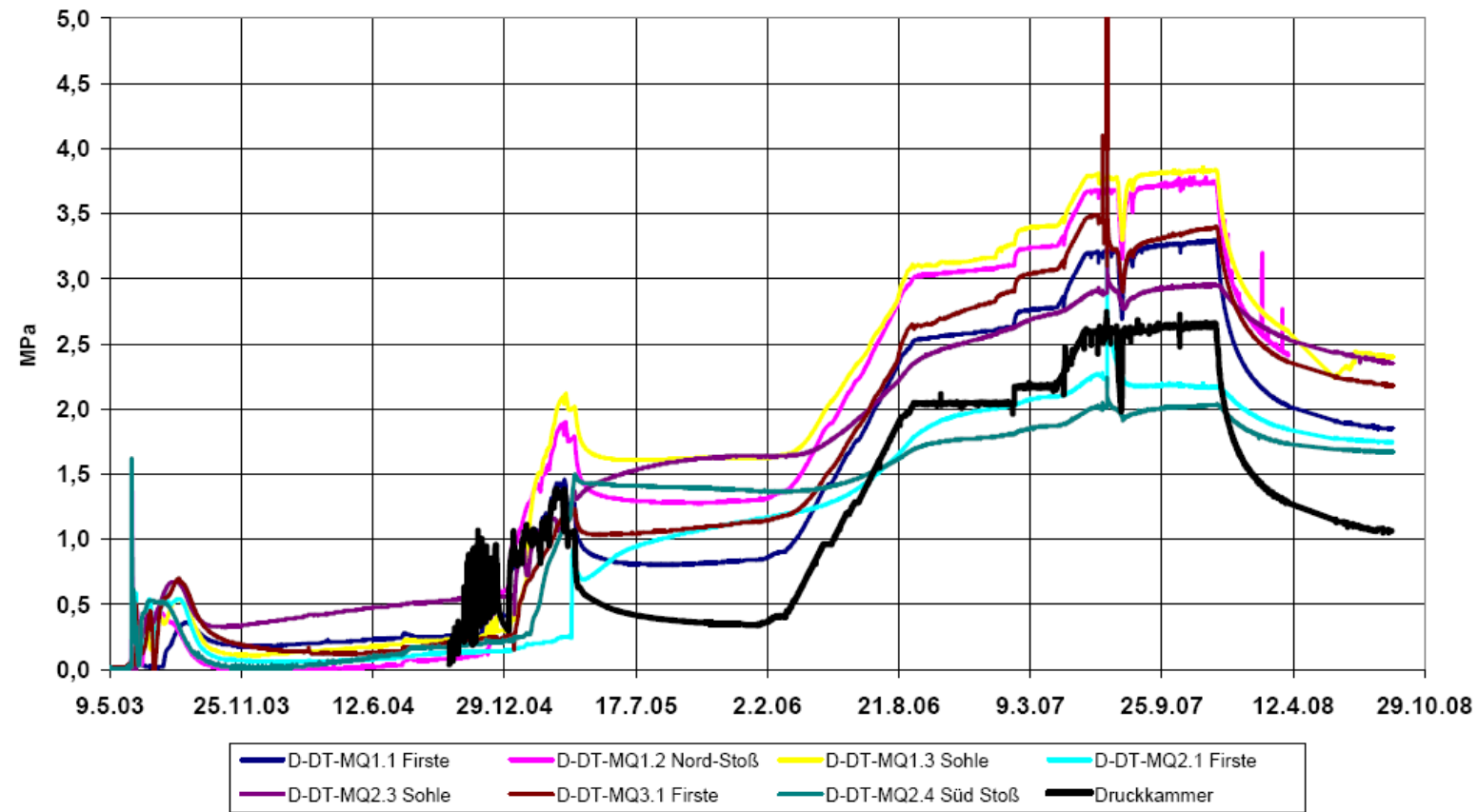
- Removal of EDZ based on measured values
- Selection of a „stiff“ building material for the sealing body

And to gain deeper insight extended installation of measuring devices – temperature, total pressure, pore pressure

Source Asse GmbH,  
DBETEC

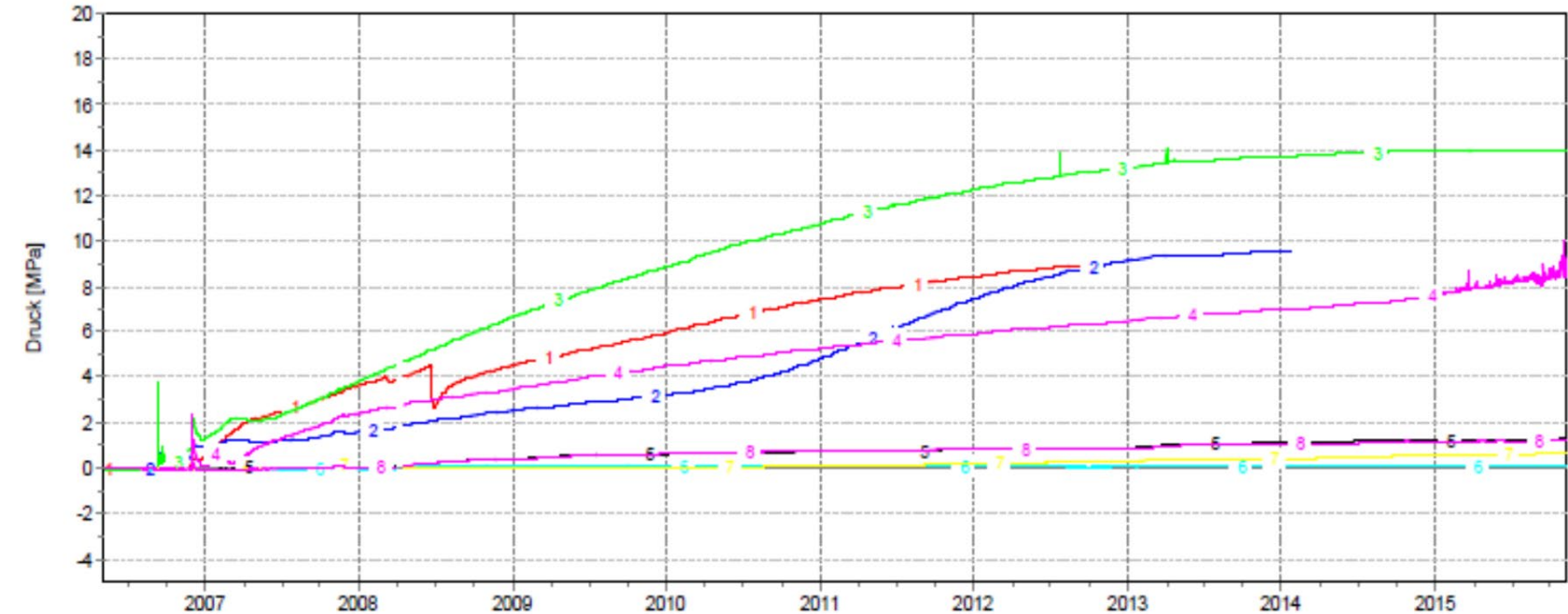
# Comparison of Pressure Build-up

Pilot Seal A2 – if the pump stopped pressure decreased immediately



Source: HMGU, DBETEC

Pilot Seal A1 – if the pump stopped no pressure decrease was detected



Kurve	Messstelle	Messart	MQ	Lage X	Lage Y	Höhe	Zeltraum
1	MQ5 S2 Sohle radial	Betonspannung	5	Sohle	Mitte	-751,57 mNN	04.05.06 00:02:44 - 08.11.15 22:02:01
2	MQ5 S3 Nordstoß radial	Betonspannung	5	Nordstoß	Mitte	-749,20 mNN	04.05.06 00:02:53 - 08.11.15 22:02:12
3	MQ5 S4 Südstoß radial	Betonspannung	5	Mitte, Südstoß	Mitte, Südstoß	-749,29 mNN	04.05.06 00:03:02 - 08.11.15 22:02:19
4	MQ5 S5 Firste radial	Betonspannung	5	Firste	Mitte	-746,82 mNN	04.05.06 00:03:11 - 08.11.15 22:02:51
5	MQ5 D5 Sohle	Porenwasserdruck	5	Sohle	Mitte	-751,56 mNN	04.05.06 00:03:20 - 08.11.15 22:02:58
6	MQ5 D6 Nordstoß	Porenwasserdruck	5	Mitte	Nordstoß	-749,17 mNN	04.05.06 00:03:29 - 08.11.15 22:03:05
7	MQ5 D7 Südstoß	Porenwasserdruck	5	Mitte	Südstoß, Mitte	-749,22 mNN	04.05.06 00:03:38 - 08.11.15 22:03:12
8	MQ5 D8 Firste	Porenwasserdruck	5	Mitte	Firste	-746,78 mNN	04.05.06 00:03:47 - 08.11.15 22:03:20

Source: Asse GmbH, DBETEC

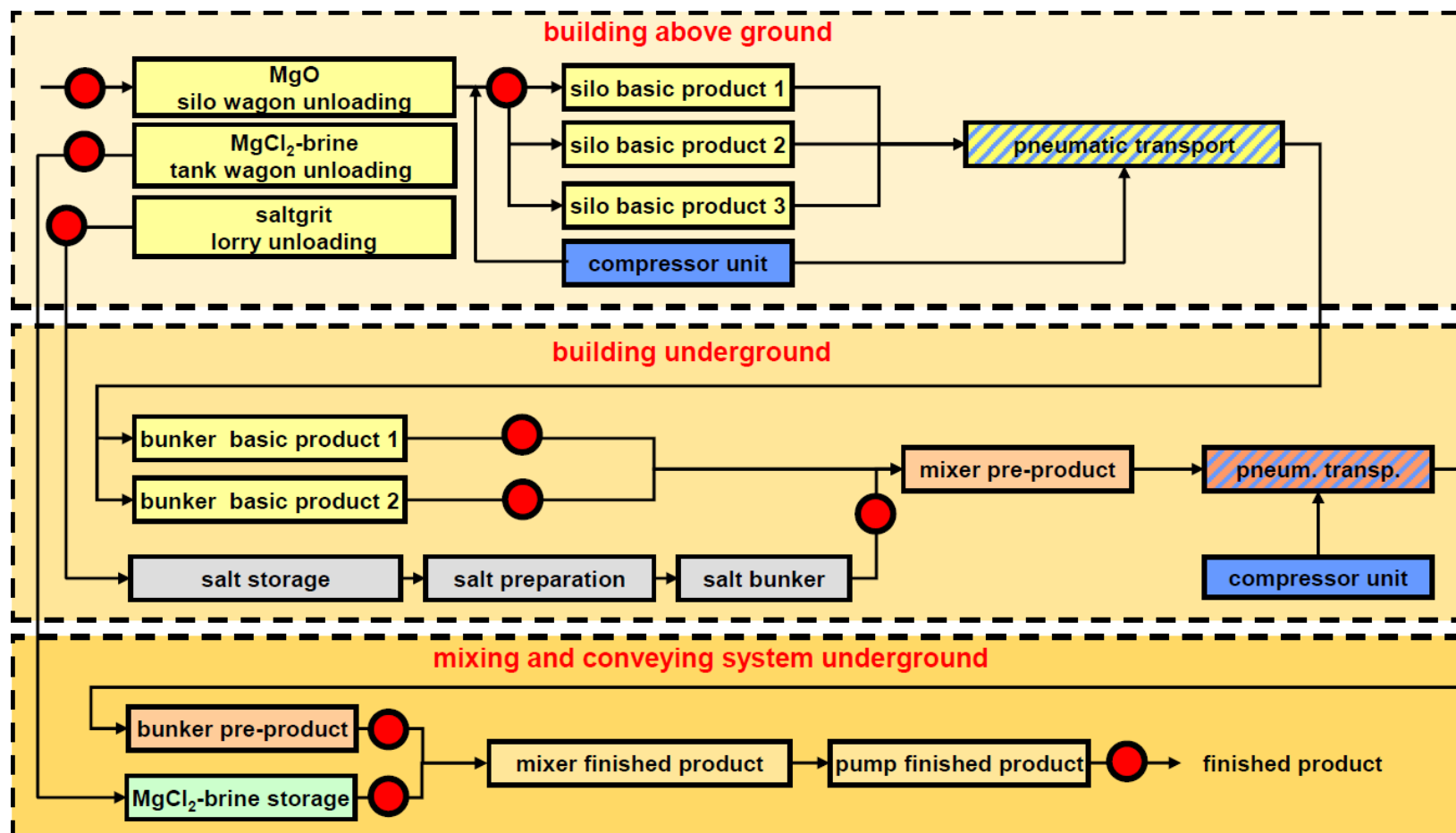
Pilot Seal A1 showed improved tightness → PSB A1 design was selected for routine application

# Asse Mine – Construction on Industrial Scale

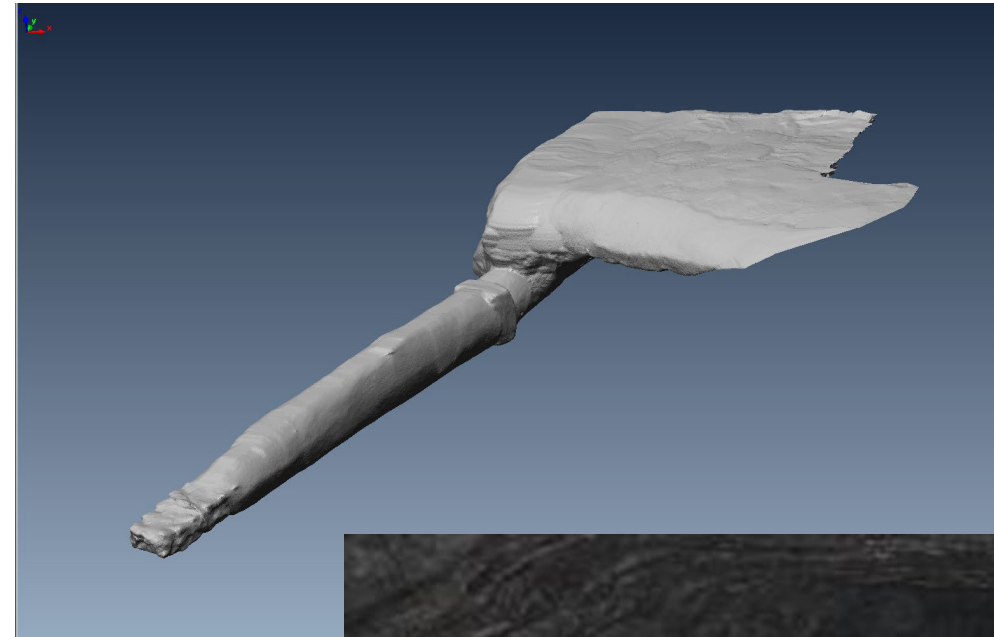
## Application of standardized workflows

- Planning (hydraulic resistance requirement)
- Preparation of flow barrier's location
- Construction
- Upon completion final check of quality assurance data against quality criteria, additional tests/checks in the case of deviations (up to now need for additional in situ tests/compatibility checks 1 in 21)

Example: Production and quality assurance of A1 suspension



● Sampling for quality assurance of building material



3D-laserscan of a re-ripped drift seal location



Casting of sealing body

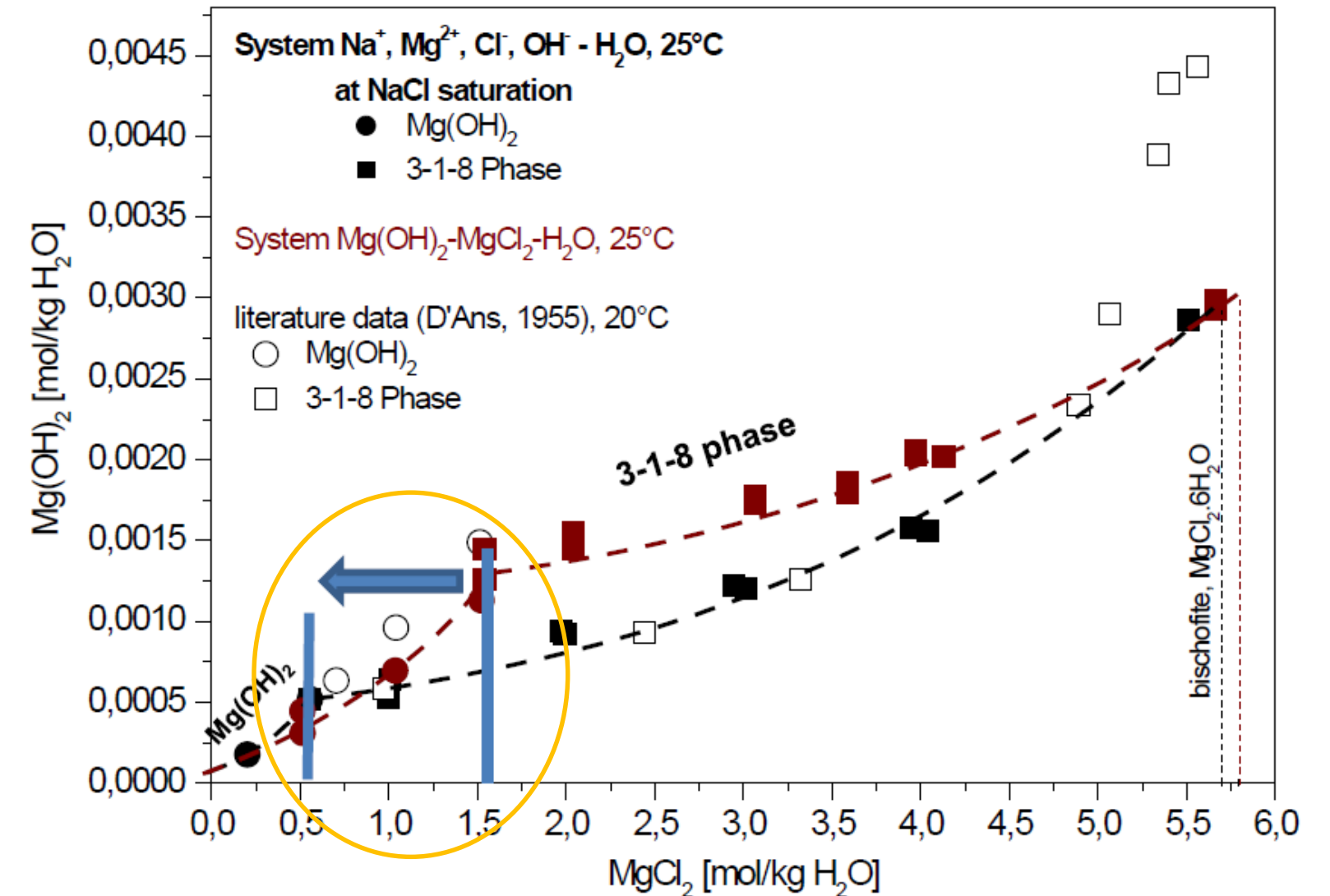
Source: BGE & BGETEC, US-German WS 2018, 2019

# R&D Project MgO-SEAL Solubility Equilibria

System  $\text{Mg}(\text{OH})_2 - \text{MgCl}_2 - \text{H}_2\text{O}$ ,  $25^\circ\text{C} - 120^\circ\text{C}$

- 3-1-8 phase – thermodynamically stable up to  $80^\circ\text{C}$
- At higher temperatures 9-1-4 phase
- 5-1-8 phase metastable – no stability field exists
  
- At NaCl saturation the stability field of the 3-1-8 phase is extended to  $0.5 \text{ mol Mg}^{2+}/\text{kg H}_2\text{O}$

... System  $\text{Na}^+, \text{Mg}^{2+}, \text{Cl}^-, \text{OH}^- - \text{H}_2\text{O}$  at  $25^\circ\text{C}$



Source: TU BAF & IfG, US-German WS 2019



# Idea

- What is STROEFUN III about?
  - Fluidic functional verification for closing structures
  - Proving the hydraulic properties of a closure structure without damaging the construction
  - Fluid supported sealing of the contact area
- Project from Jan. 2019 up to July 2022
  - 5 different partners and 2 service providers



Supported by:

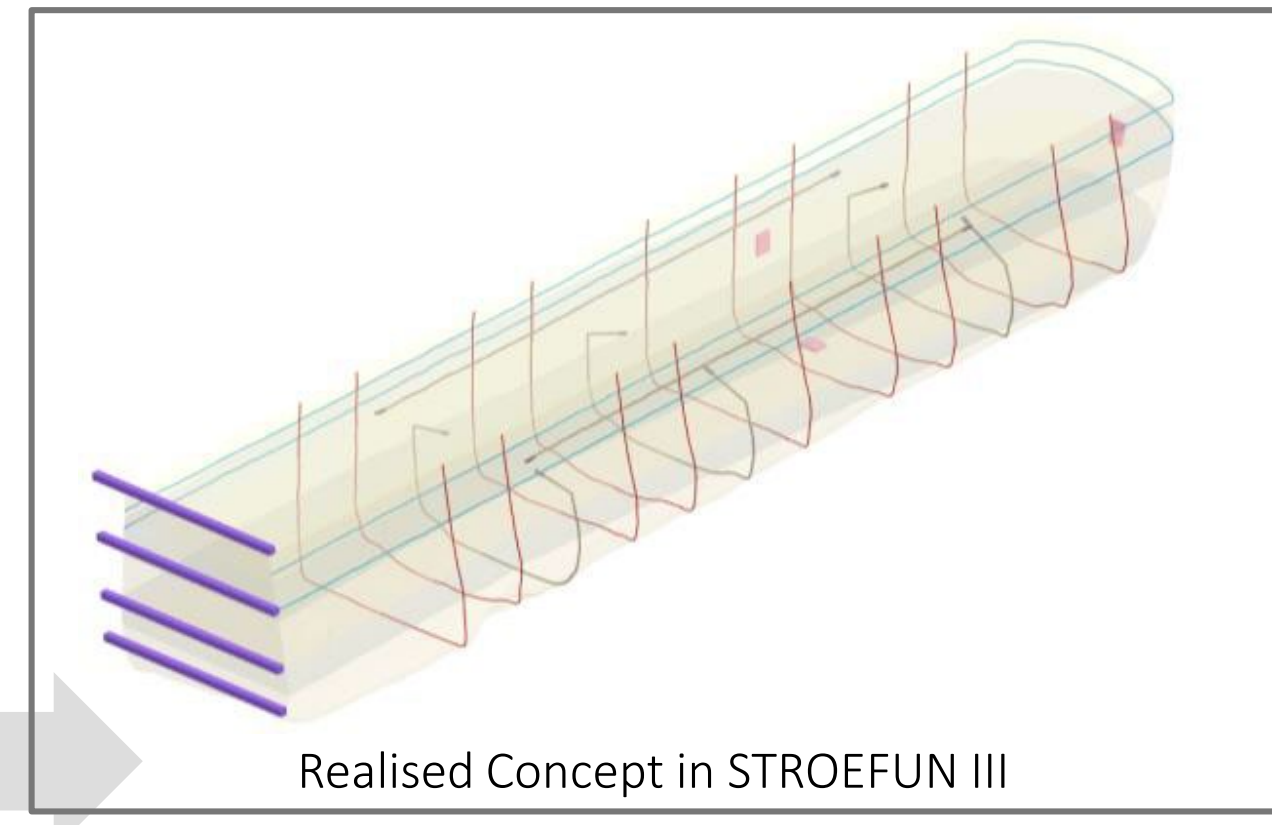
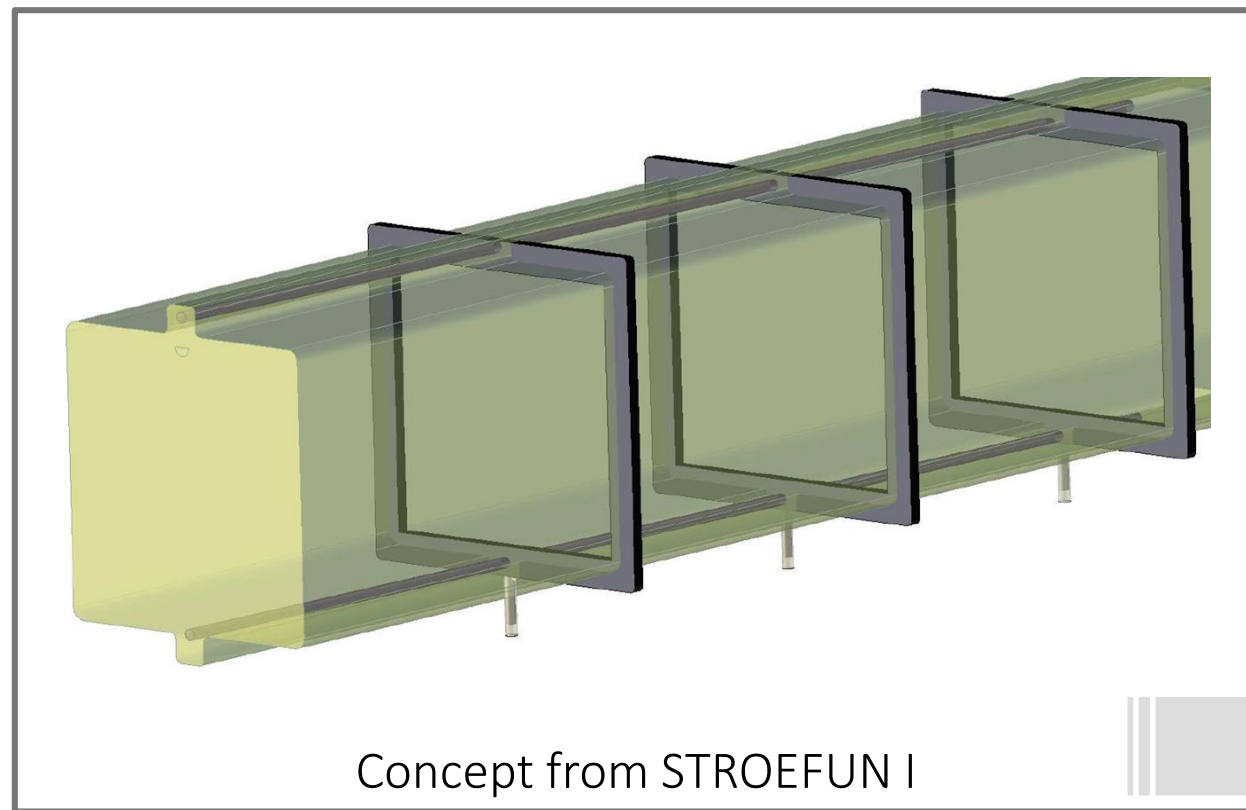


on the basis of a decision  
by the German Bundestag

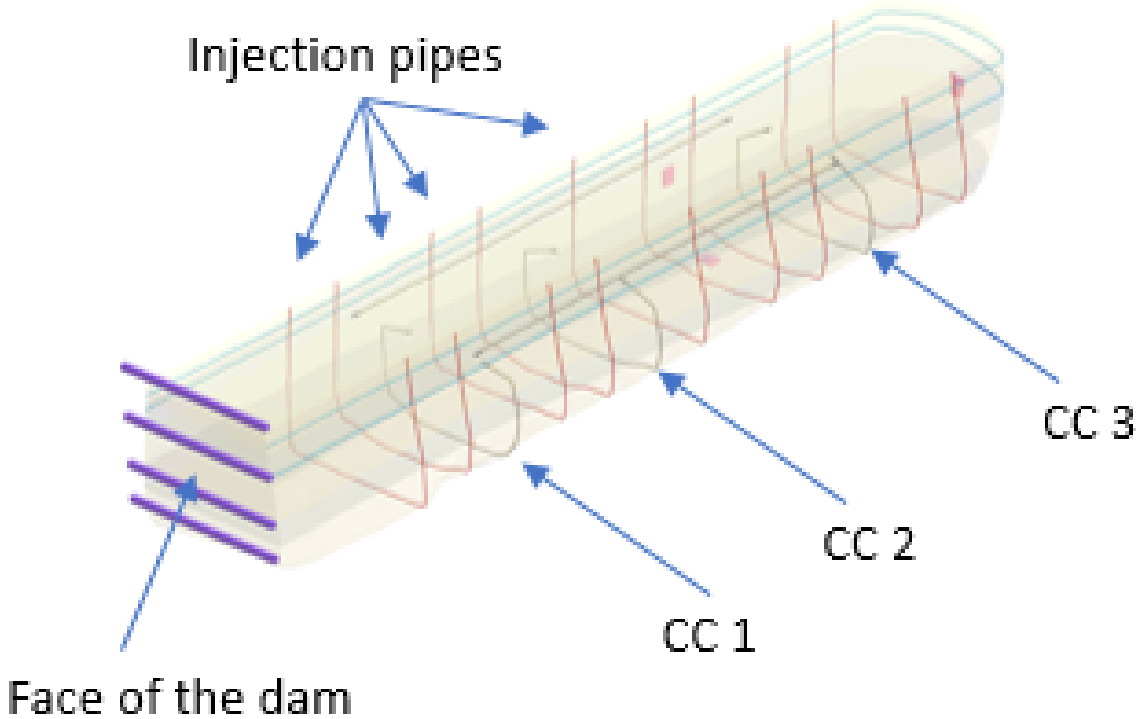


# Concept

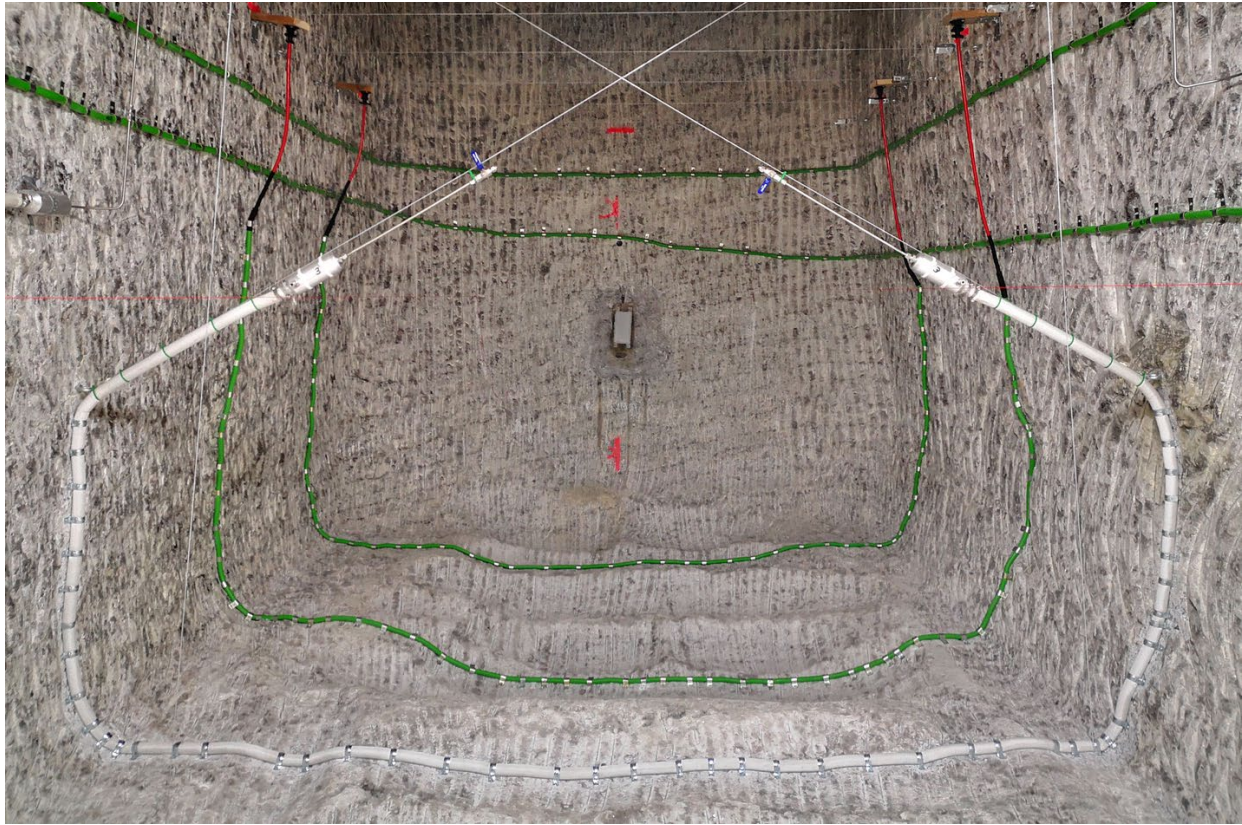
- Control chambers which can estimate the integral permeability between each other
  - Air pressure wave is applied to the contact zone
  - Monitored by the chamber system along the rock contour



# Concept



Overview of the installed measurement, test and injection infrastructure



Pre-installed CC3 (without connecting pipes)

# Dam Construction

- The concrete is based on the A1-recipe from the BGE Tec
  - Anhydrate as an additive

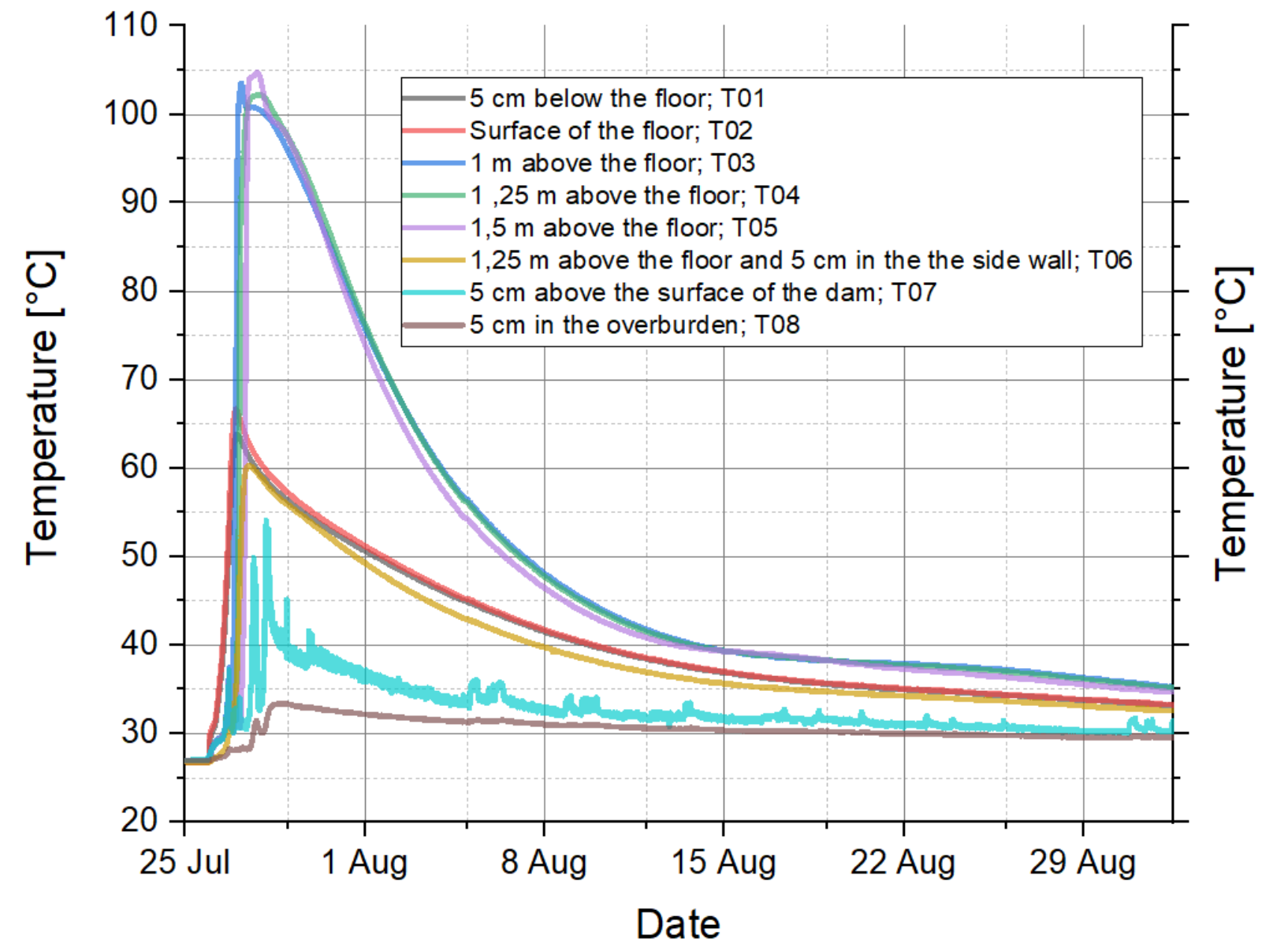
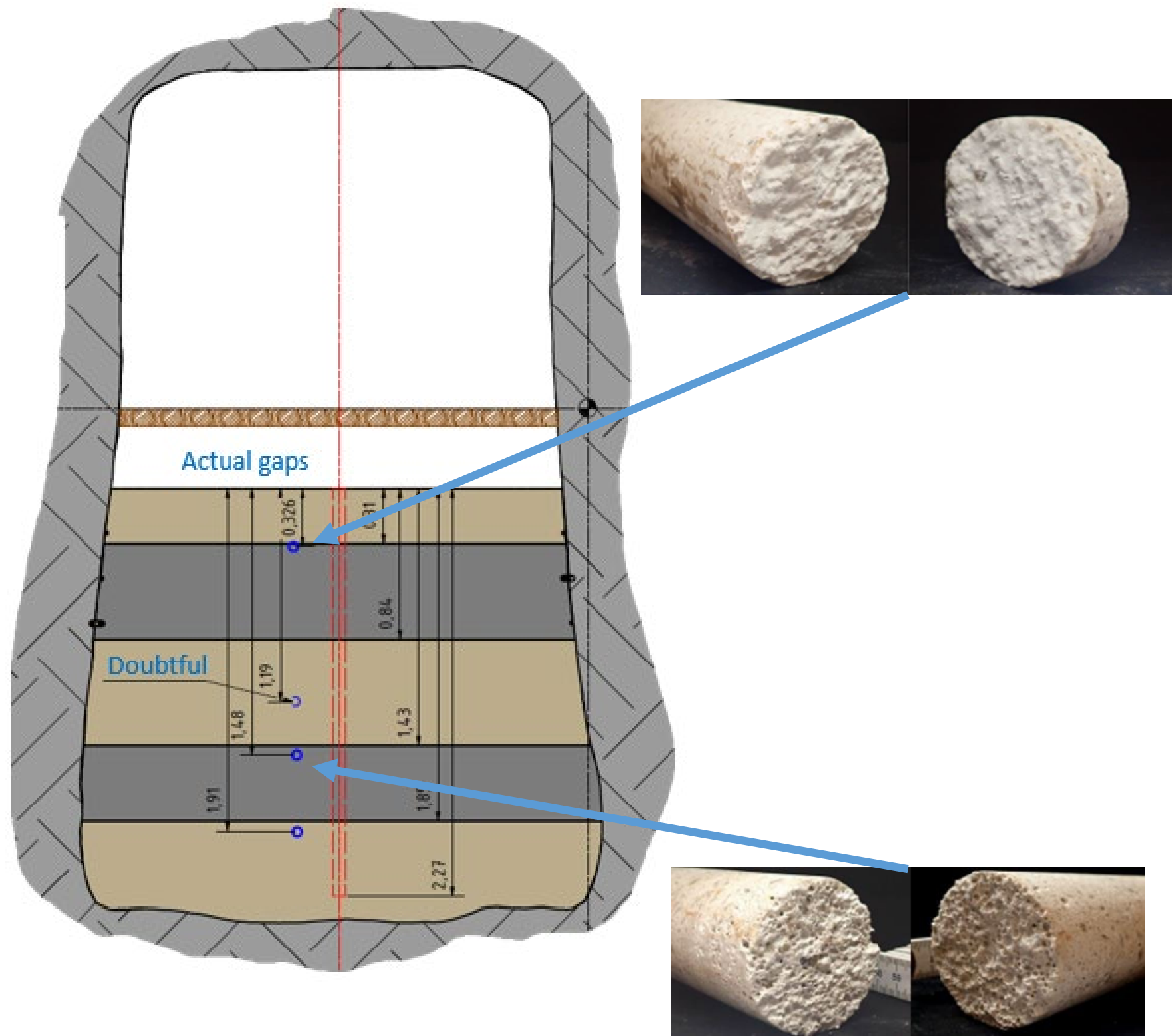


# Dam Construction

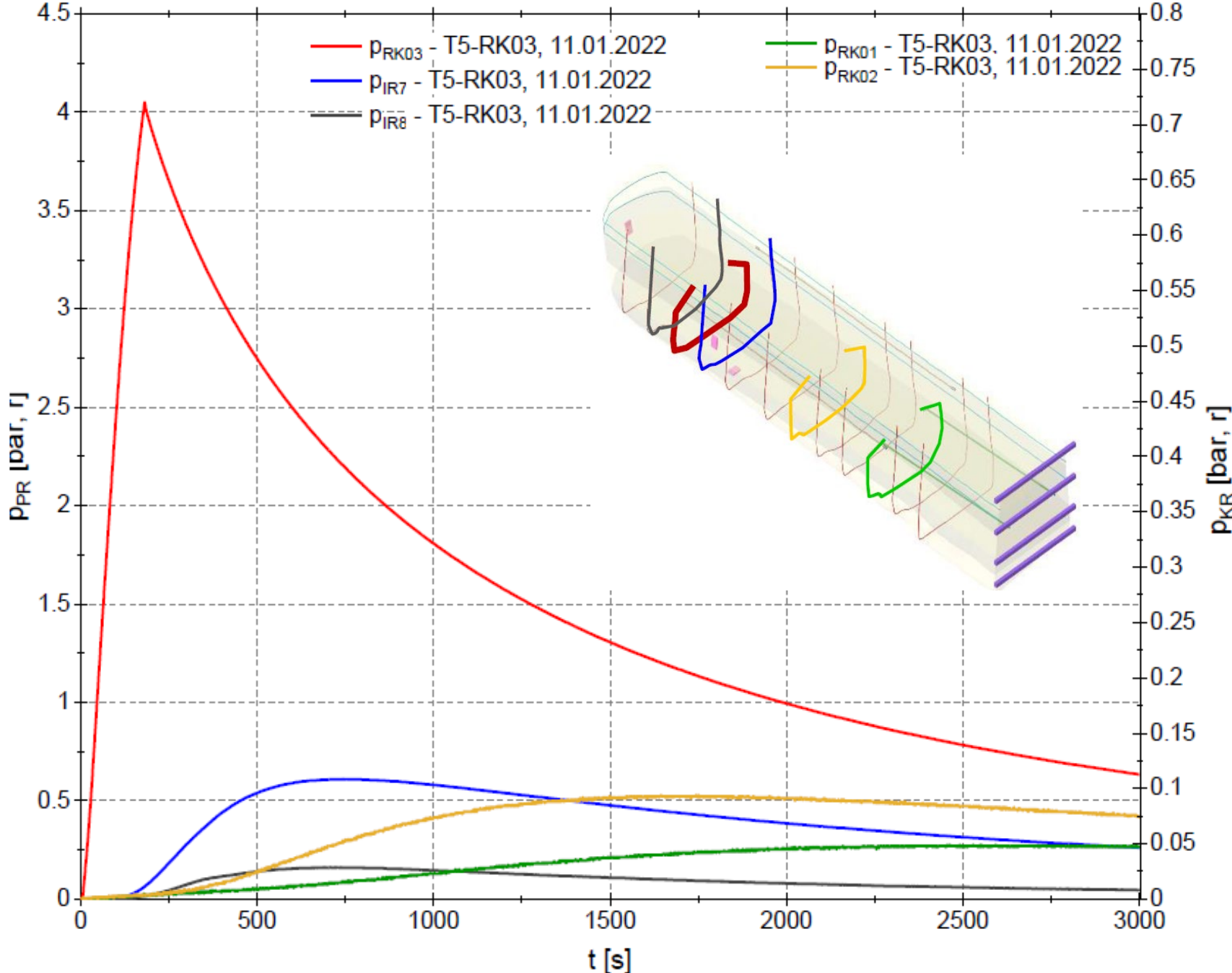


Crack formation after a 2 hours break; July 27<sup>th</sup> 2021- 16:36



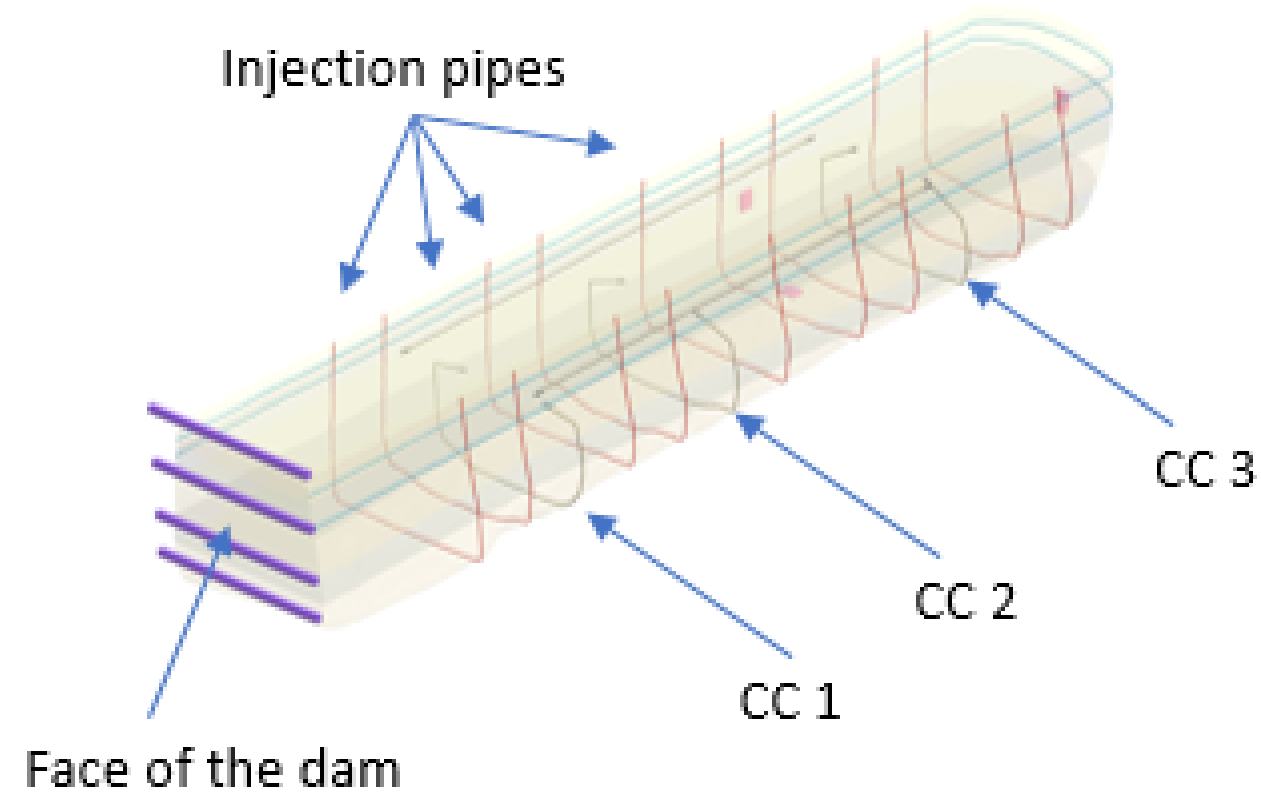


# Permeability Measurement



Measured date	Tested control chamber	Permeability between CC 1 und CC 2 [m <sup>2</sup> ]	Permeability between CC 2 und CC 3 [m <sup>2</sup> ]
01/21/2022	01	$8,0 \times 10^{-15}$	$3,0 \times 10^{-15}$
06/13/2022	01	$7,0 \times 10^{-15}$	$9,0 \times 10^{-16}$

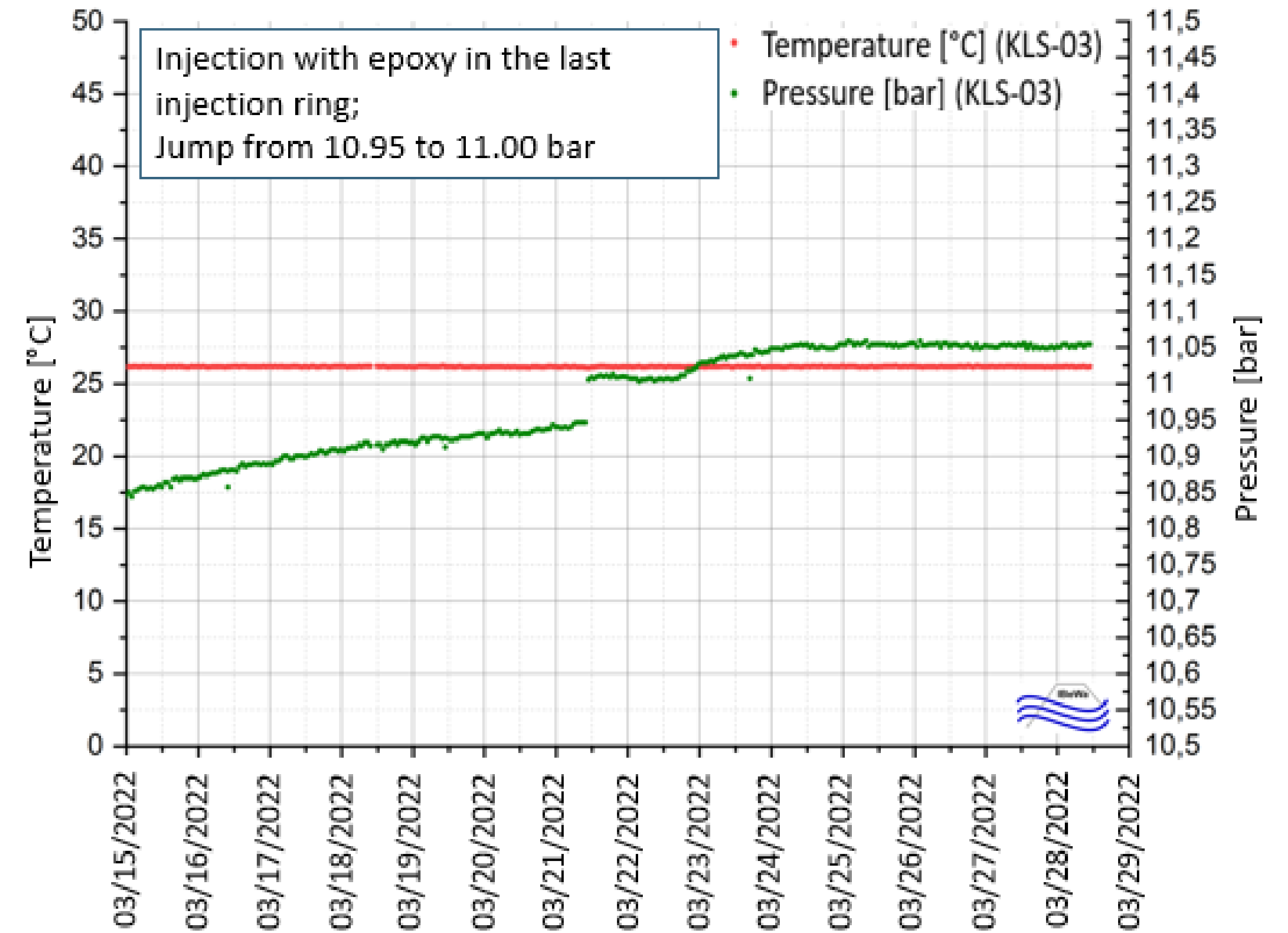
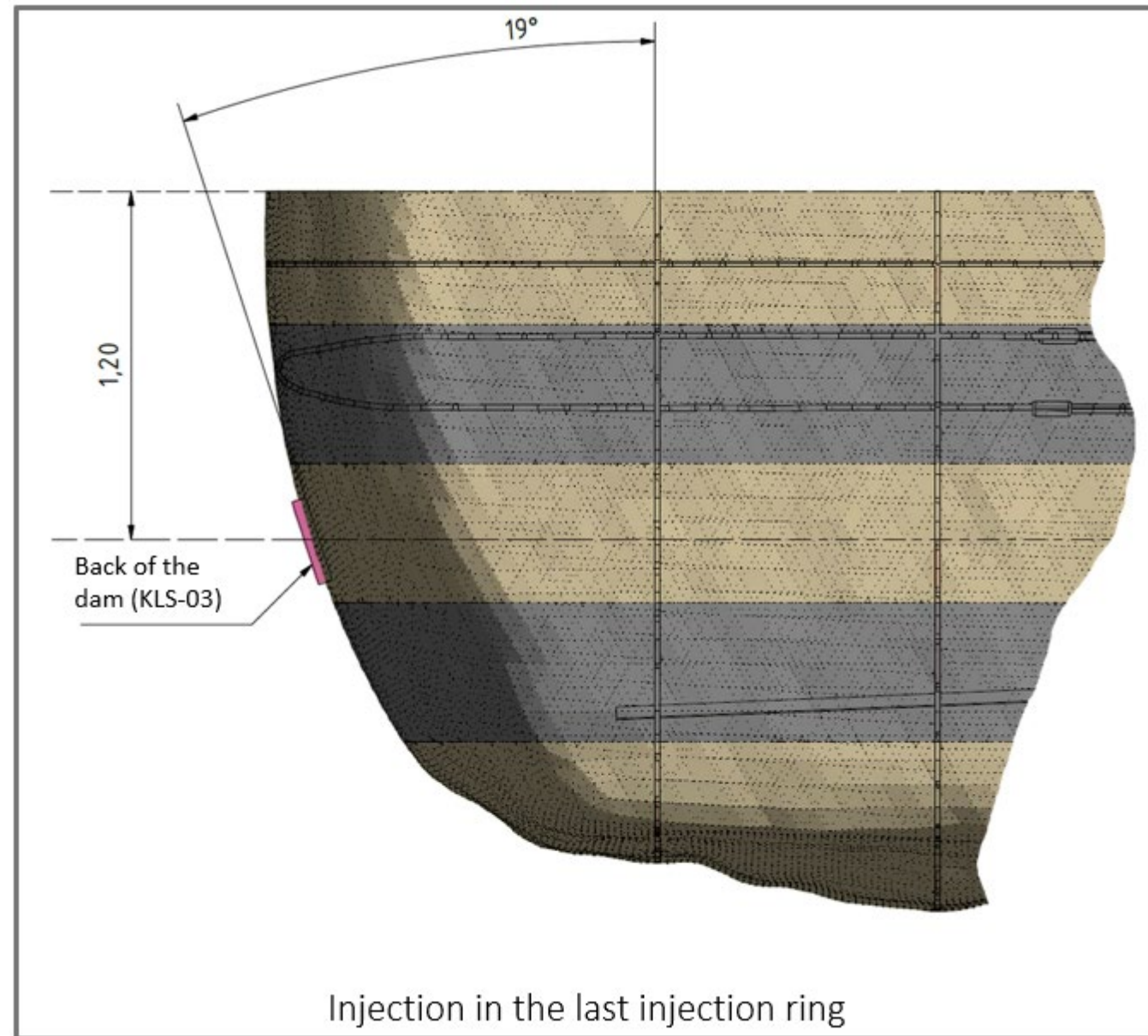
# Injection



- Injection of 1,8 L of injection grout have been injected at the last injection pipe at a pressure of 18 bar
- Afterwards 7,0 Liter of Epoxy was injected in the same injection pipe (40 bar)
- Injection in the first two injection pipes failed (70 bar) using an injection grout
- While cleaning, an attempt was made to injection the cleaning liquid, a particle free  $MgCl_2$ -solution. 0,075 Liter have been injected (65 bar)

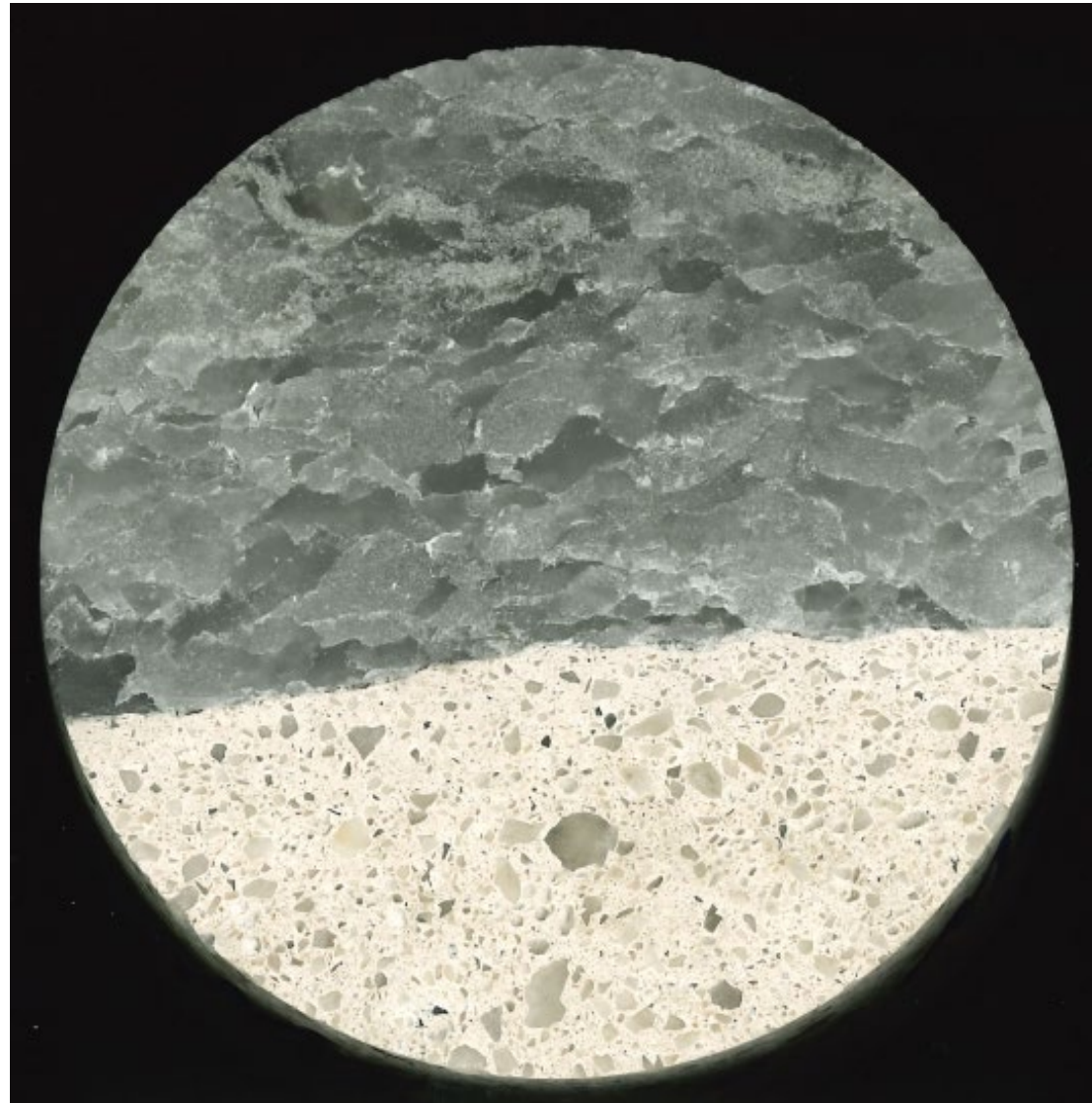


# Injection

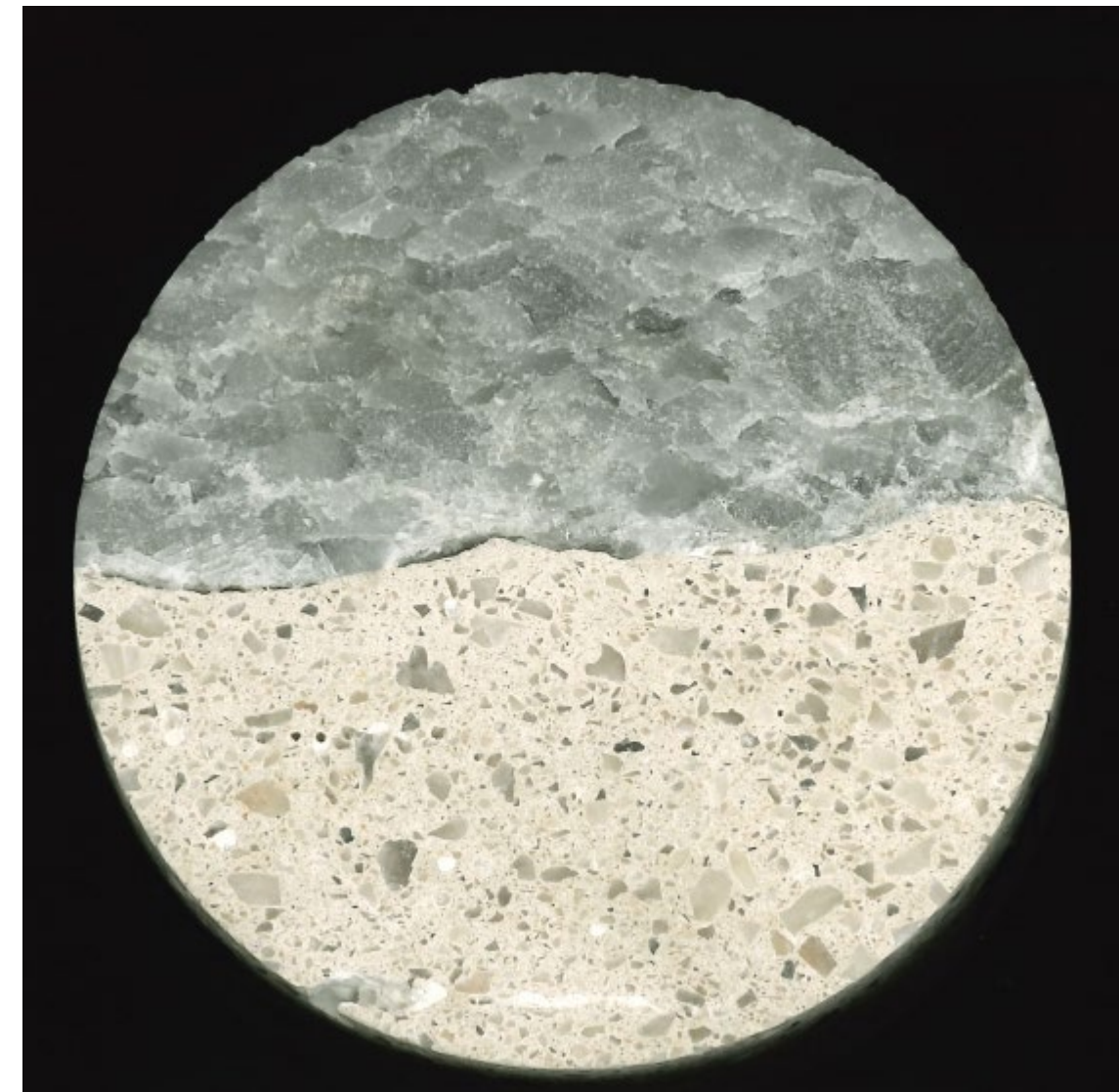


# Samples

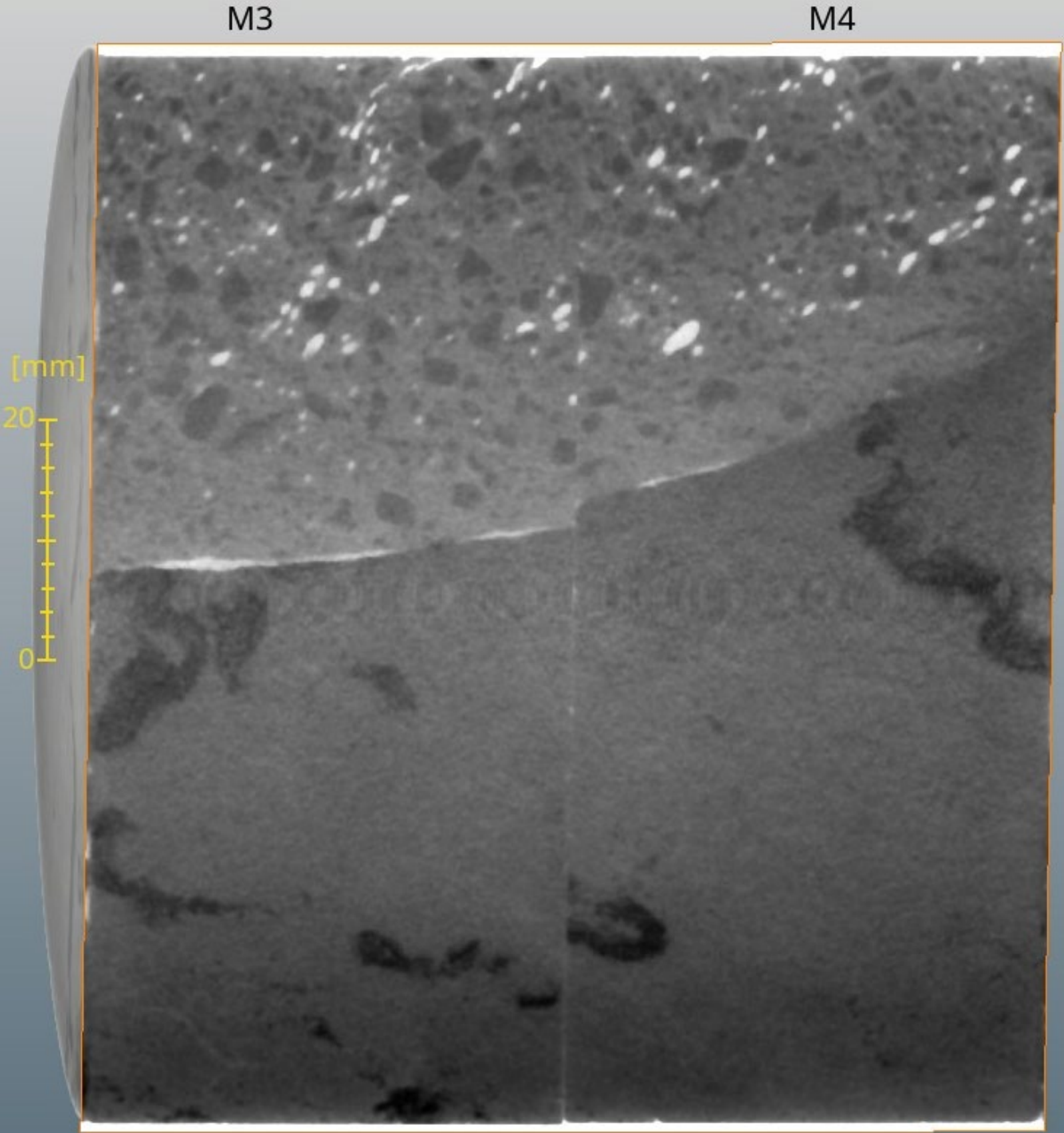
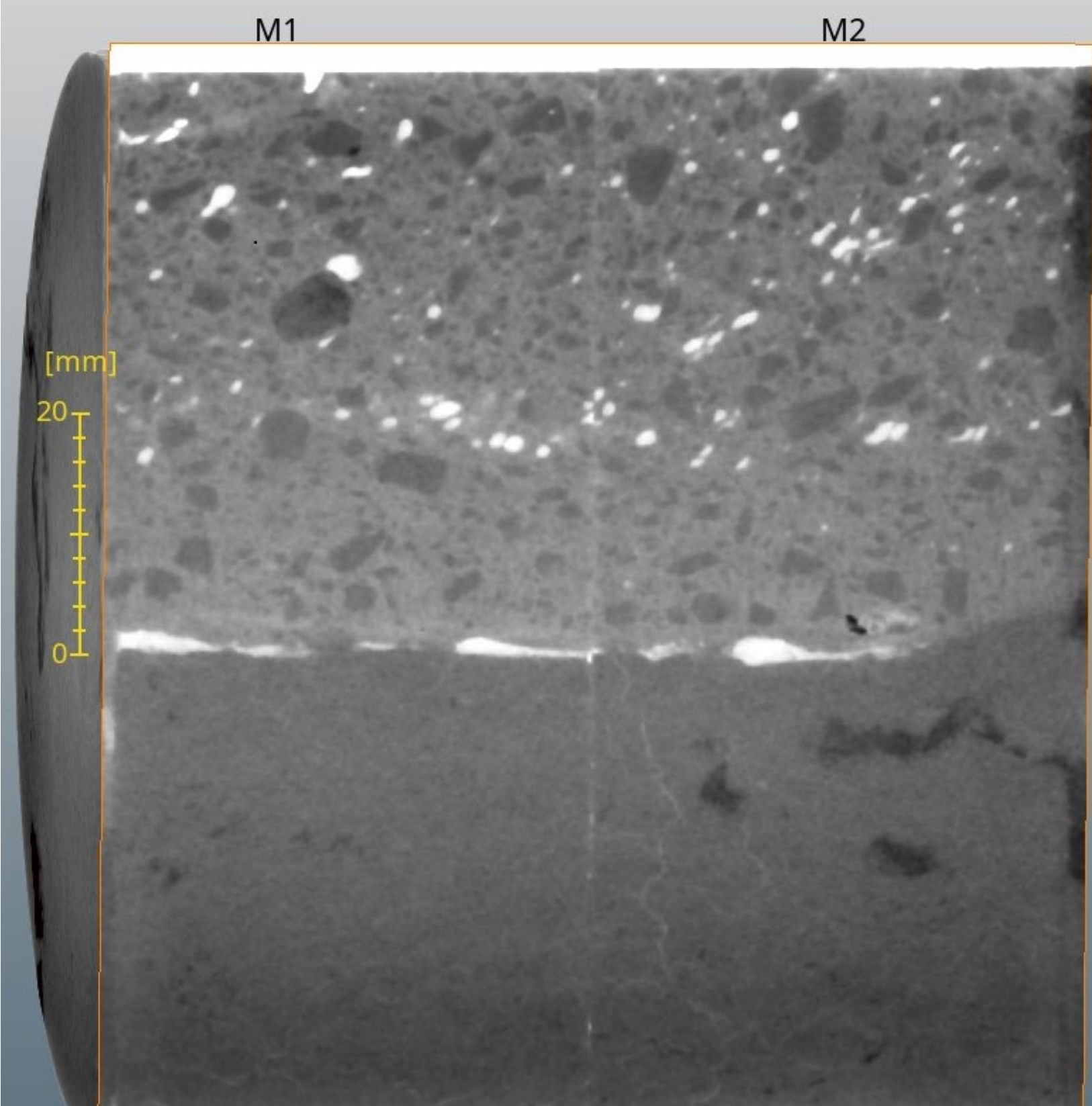
- M4



- M1



# Samples



# Actual Status

- Evaluation
- Report
- Project application → Focus on the uncertainties
  - Foam development
  - Contact zone between host rock and concrete
  - Contact zone between concrete and concrete
  - Injection
  - Permeability development



# •Questions?

