Lummer, Nils (Fangmann Energy)

INNOVATIVE SYSTEME ZUR ZEMENTIERUNG VON GEOTHERMIE-, SOWIE VON H2-SPEICHERBOHRUNGEN

Cementing is one of the most critical steps during the drilling process of geothermal and H2-storage wells. In this context, we employ many techniques and technologies well-known in the oil & gas industry. However, weak formations, CO2-containing formation water, and the necessity of an extreme low ce-ment sheath permeability may entail the use of specially customized recipes.

This paper presents our dream team for geothermal projects in the Netherlands. Here, to counteract losses, the use of lightweight slurries is essential. The HOZlite consists of blast-furnace slag cement and contains hollow spheres providing low slurry densities with a high compressive strength after hardening. The HMR+ Blend, on the other hand, is chemically and physically optimized ensuring durability of the resulting sheath, even in the presence of CO2.

Besides geothermal projects, we also employed the HMR+ Blend for cementing a H2-storage well in Ger-many. As proven by extensive lab experiments, the extreme low permeability of its cement sheath against hydrogen, was the main reason for recommending this innovative solution. HMR+-based slurries already contain 22% NaCl making this system ideal for salt caverns. The evaluation of the corresponding project confirmed the H2-tightness of hardened HMR+ Blend.

Laboratory and field results impressively revealed the premium properties of these new technologies. With our state-of-the art products we delivered excellent cement jobs for ongoing geothermal and H2-storage projects.

Innovative Systems for Cementing Geothermal and H_2-Storage Wells

Dr. Nils Lummer, Moustafa Hassan, Tudor Precup; Fangmann Energy Services

Cementing is one of the most critical steps during the drilling process of geothermal and H_2-storage wells. In this context, we employ many techniques and technologies well-known in the oil & gas industry. However, weak formations, CO_2-containing formation water, and the necessity of an extreme low cement sheath permeability may entail the use of specially customized recipes.

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HOZlite	
Young’s Modulus, GPa	4.77
Poisson’s Ratio	0.22
Density Range, kg/L	1.35 – 1.40
Thermal Conductivity, W/m·K	0.7
Ideal for Cementing GRE-Material	

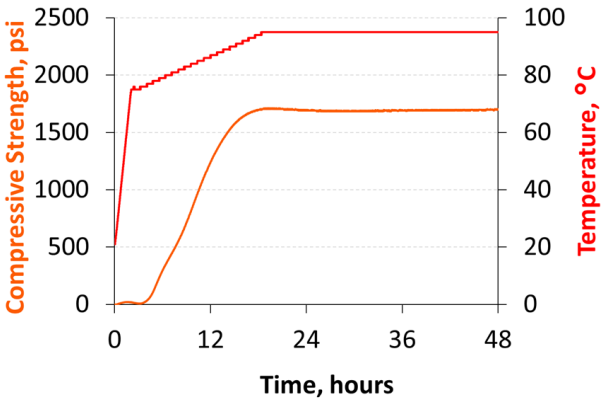

Figure 1: Results of lab testing with HOZlite.

The HMR⁺ Blend, on the other hand, is chemically and physically optimized ensuring durability of the resulting sheath, even in the presence of CO_2. Figure 2 shows corresponding lab results.

HMR⁺ Blend	
Permeability against Brine, mD	$4.4 \cdot 10^{-7}$
Permeability against H_2, mD	$2.2 \cdot 10^{-8}$
Typical Density, kg/L	1.88
CaO / SiO_2-Ratio	0.8
Well-Established for P&A-Applications	

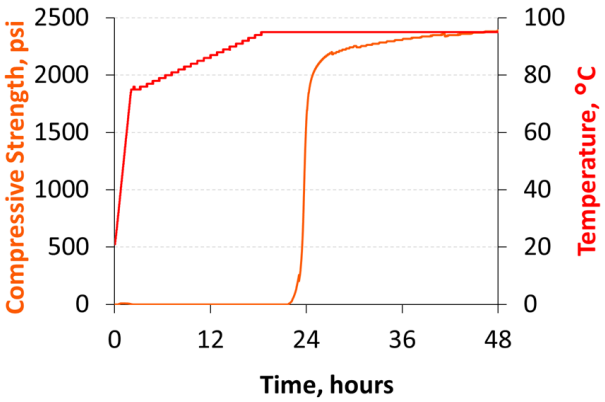

Figure 2: Results of lab testing with HMR⁺ Blend.

Recently, we employed the well-established combination of HOZlite (lead @ 1.35 kg/L) and HMR⁺ Blend (tail @ 1.88 kg/L) in the 20”, as well as in the 16” casing section with great success. Figures 3 and 4 summarize the equipment on site and the corresponding pumping schedule.

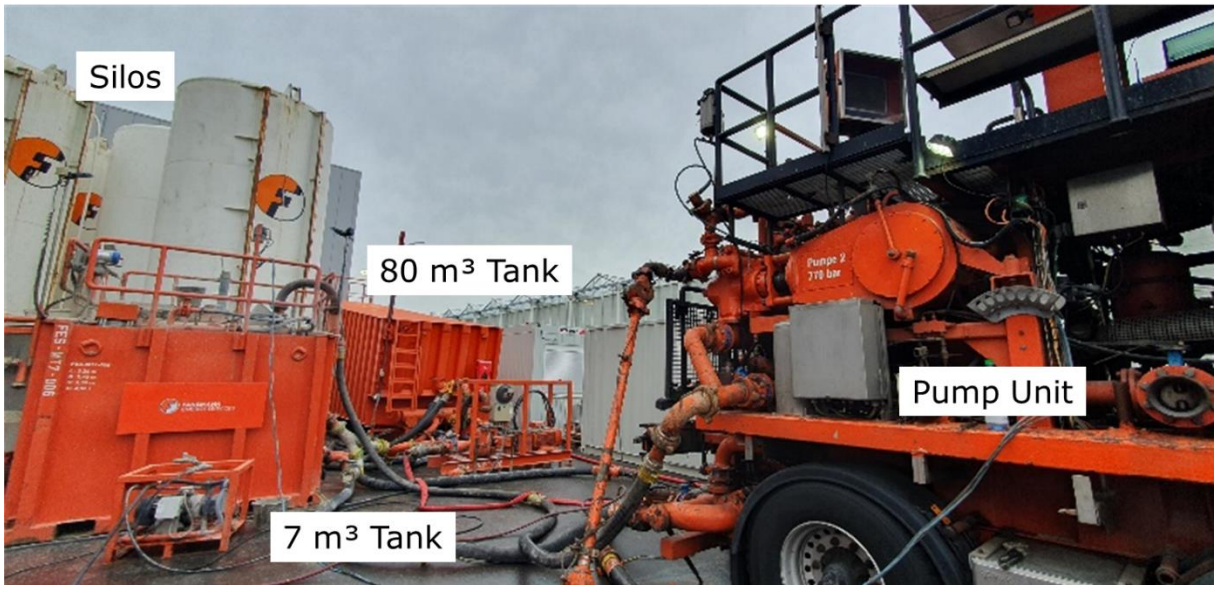

Figure 3: Equipment on site.

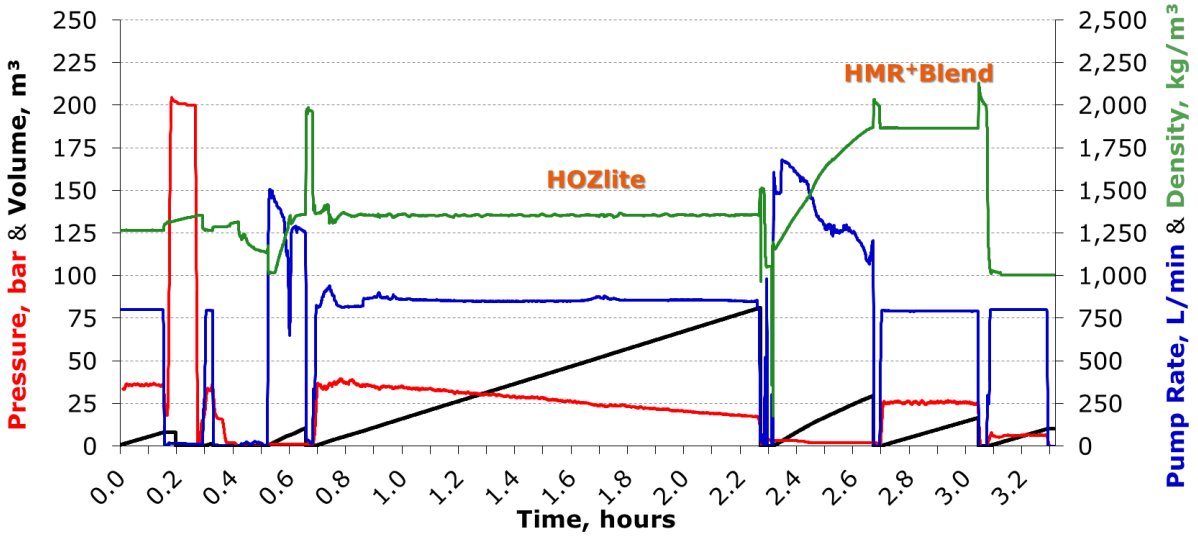

Figure 4: Pumping schedule for cementing the 16” casing section.

Besides geothermal projects, we also employed the HMR⁺ Blend for cementing a H_2-storage well in Germany. As proven by extensive lab experiments, the extreme low permeability of its cement sheath against hydrogen, was the main reason for recommending this innovative solution. HMR⁺-based slurries already contain 22% NaCl making this system ideal for salt caverns. The evaluation of the corresponding project confirmed the H_2-tightness of hardened HMR⁺ Blend.

Laboratory and field results impressively revealed the premium properties of these new technologies. With our state-of-the art products we delivered excellent cement jobs for ongoing geothermal and H_2-storage projects. For a short summary, please see Figure 5.

Figure 5: Summary of paper entitled “*Innovative Systems for Cementing Geothermal and H_2-Storage Wells*”.

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Innovative Systems for Cementing Geothermal and H_2-Storage Wells

Dr. Nils Lummer,
Moustafa Hassan,
Tudor Precup

75. BHT – Freiberger Universitätsforum
Freiberg, June 06, 2024

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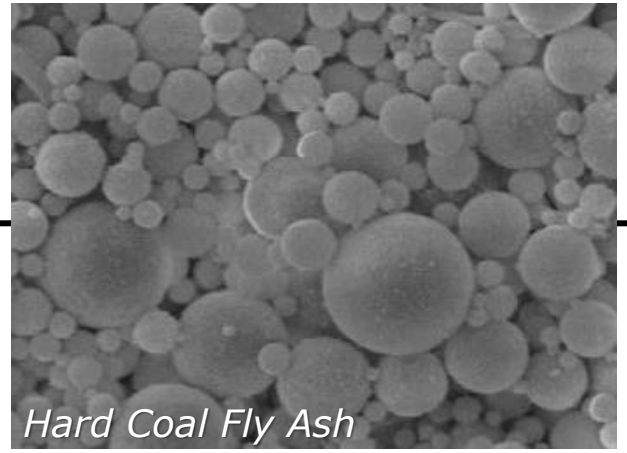
High Multi-Resistant System HMR-Cement

Fly ash enhances the stability of blast furnace slag cement

Portland Cement CEM I →

→ **Blast Furnace Slag Cement CEM III/B**

CEM III/B →



→ ***High Multi-Resistant Cement System***

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High Multi-Resistant System HMR-Cement

Stable against aggressive formation water [EEK (1 / 2016) 16-22]

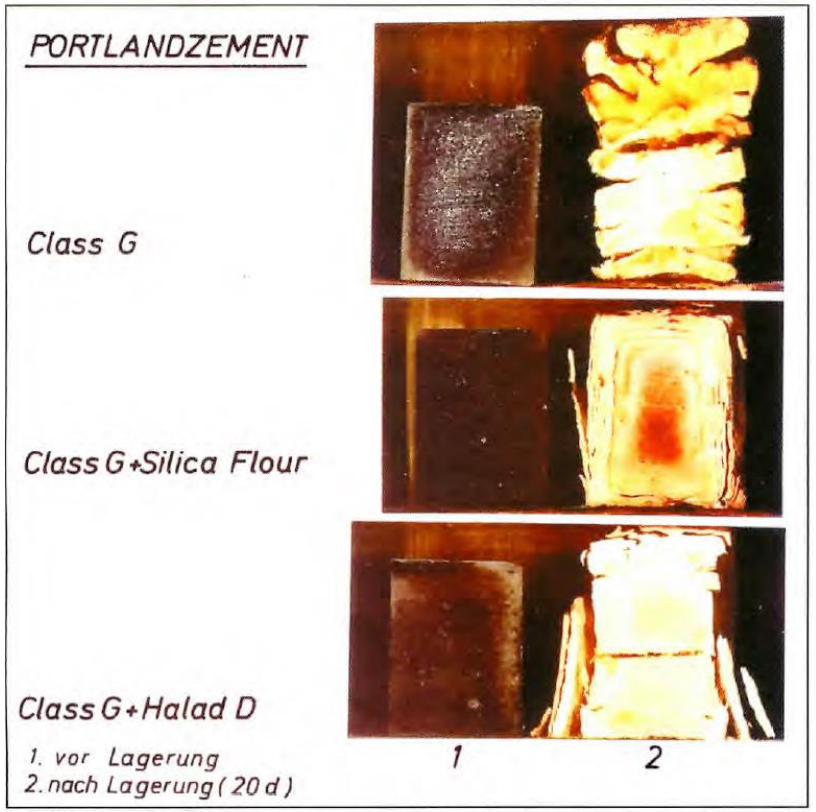

Abb. 4 In Salzwasser erhärteter Zementstein aus Portlandzement Class G mit Additiven, vor und nach Lagerung in Magnesium haltiger Lauge (synthetische Mölln-Lauge, s. Anhang)

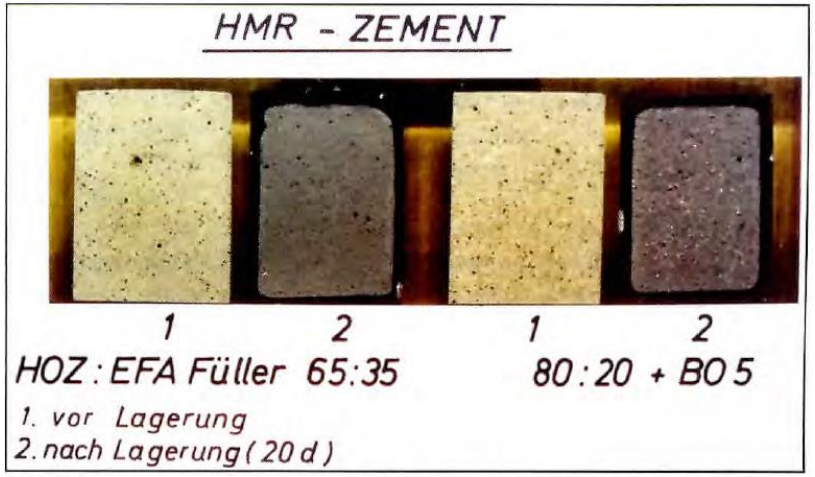

Abb. 5 In Salzwasser erhärteter Zementstein aus Hochofenzement + EFA-Füller, HMR-Zement, vor und nach Lagerung in Magnesium haltiger Lauge (synthetische Mölln-Lauge, s. Anhang)

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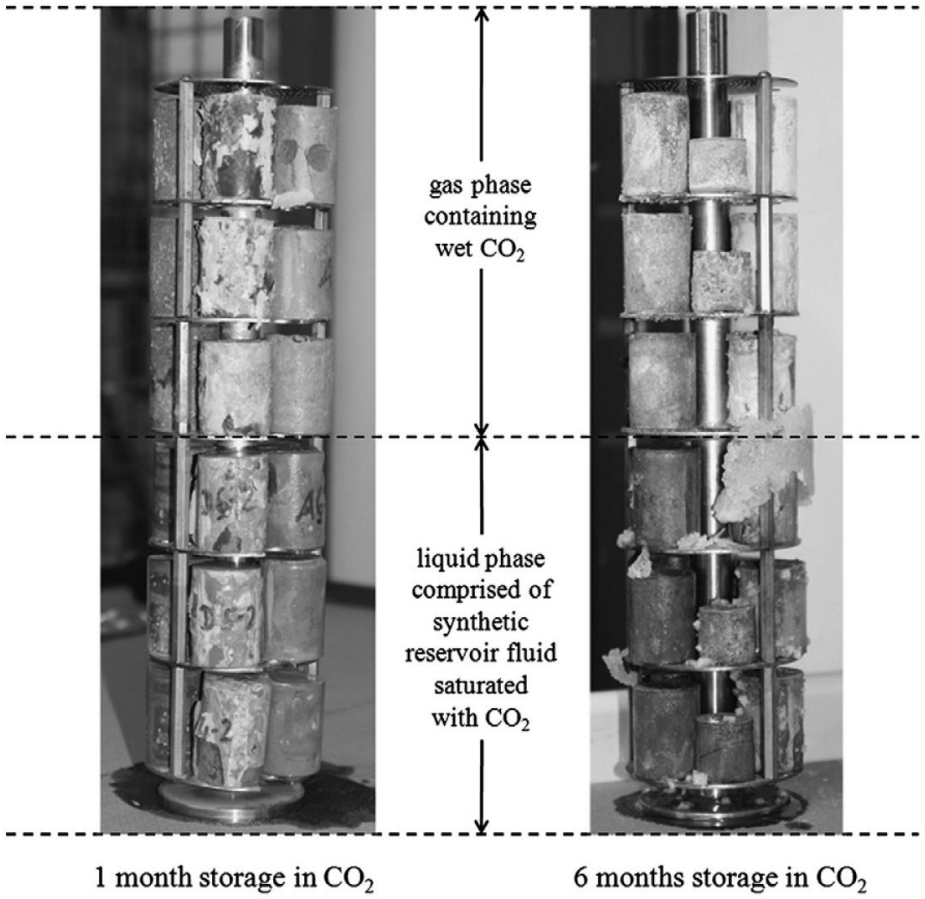
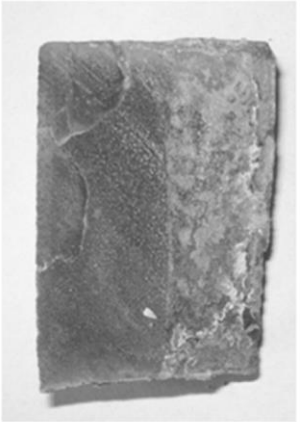
High Multi-Resistant System HMR-Cement

Stable against CO_2 [CCR (45 / 2013) 45-54]

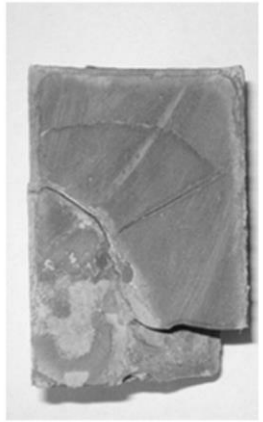


Cementing system	Permeability (mD)				
	Reference sample	1 month CO_2 Liquid phase	1 month CO_2 Gas phase	6 months CO_2 Liquid phase	6 months CO_2 Gas phase
A	<0.0001	0.0083	0.0025	<0.0001	0.089
B	<0.0001	<0.0001	<0.0001	0.0002	0.0016
C	<0.0001	0.0125	0.109	0.288	0.0061
D	<0.0001	<0.0001	0.307	0.554	1.54

Cementing system C, 6 months storage (liquid phase)



Cementing system D, 6 months storage (liquid phase)



Cementing system D, 6 months storage (gas phase)

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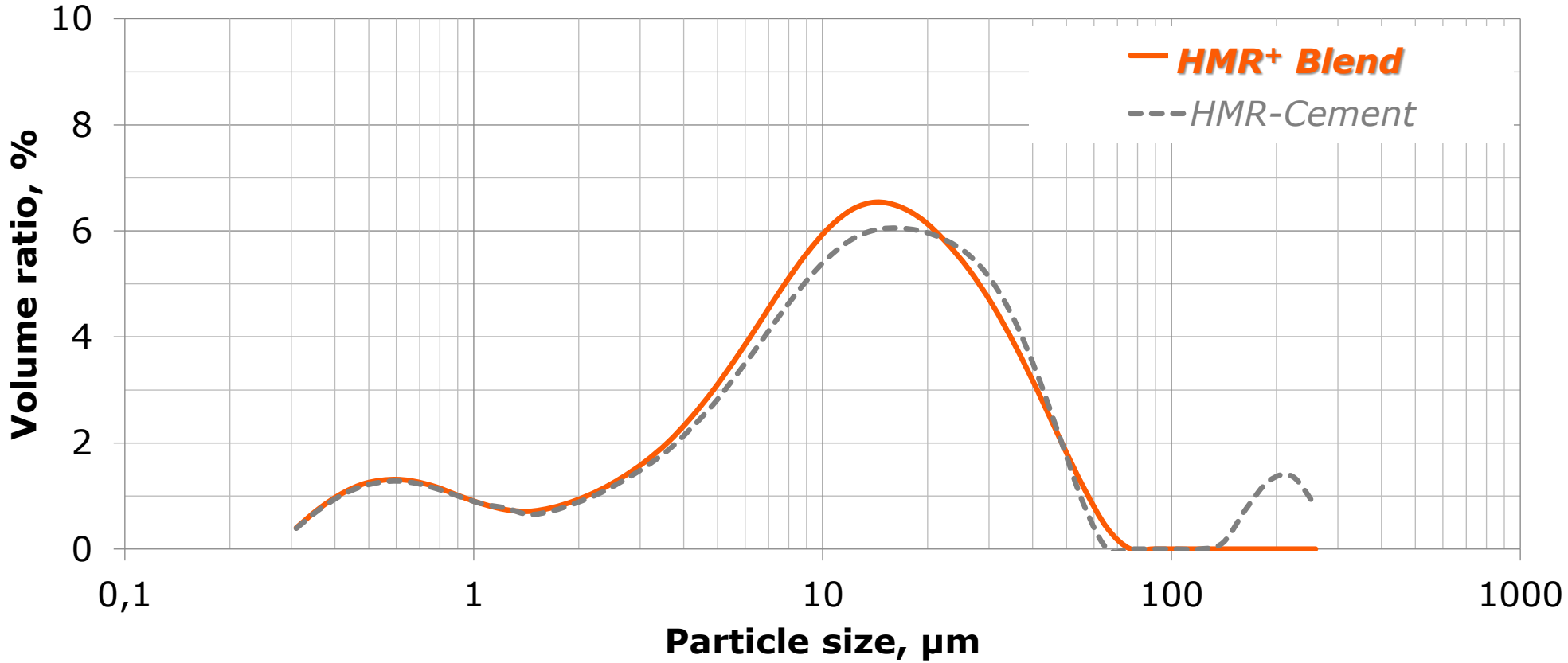
HMR+ Blend: Gas-tight Cement Sheath

Physically optimized particle size distribution



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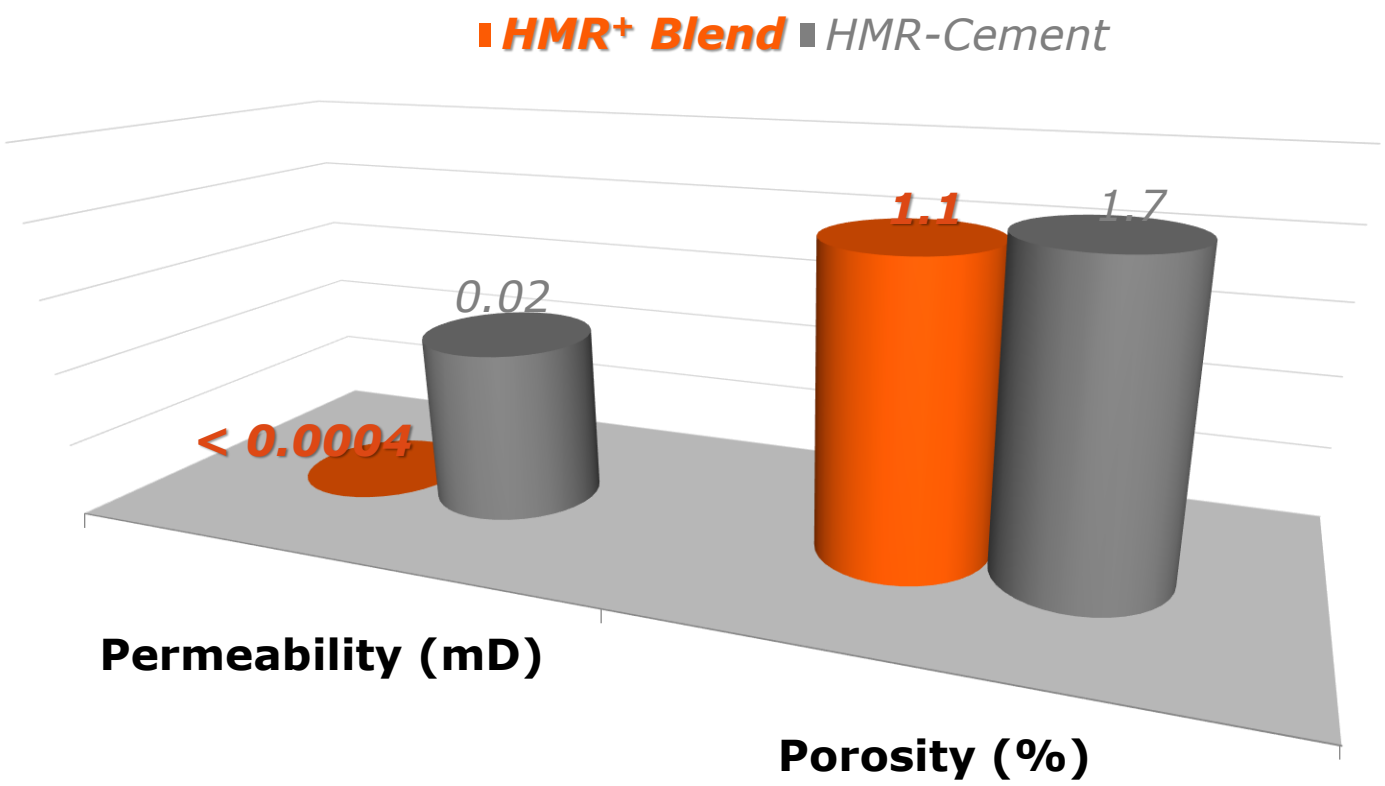
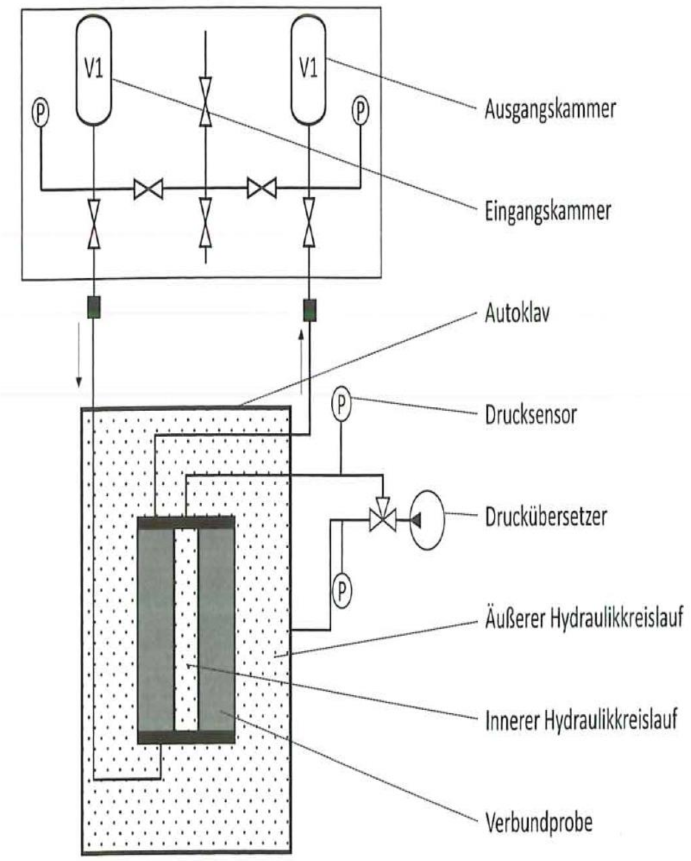
HMR+ Blend: Gas-tight Cement Sheath

Low permeability and porosity results in high multi-resistance



HMR+ Blend: Gas-tight Cement Sheath

Low permeability, even against H_2 [EEK (5 / 2020) 17-21]



Kern	Typ	Teufe [m]	Permeabilität [m²]
HY_S3	Salz	843	$< 10^{-23}$
HY_S7	Salz	1.114	$< 10^{-23}$
HY_S9	Salz	1.006	$< 10^{-23}$
HY_Z3	Zement	-	$2{,}2 \cdot 10^{-23}$
HY_Z4	Zement	-	$< 10^{-23}$

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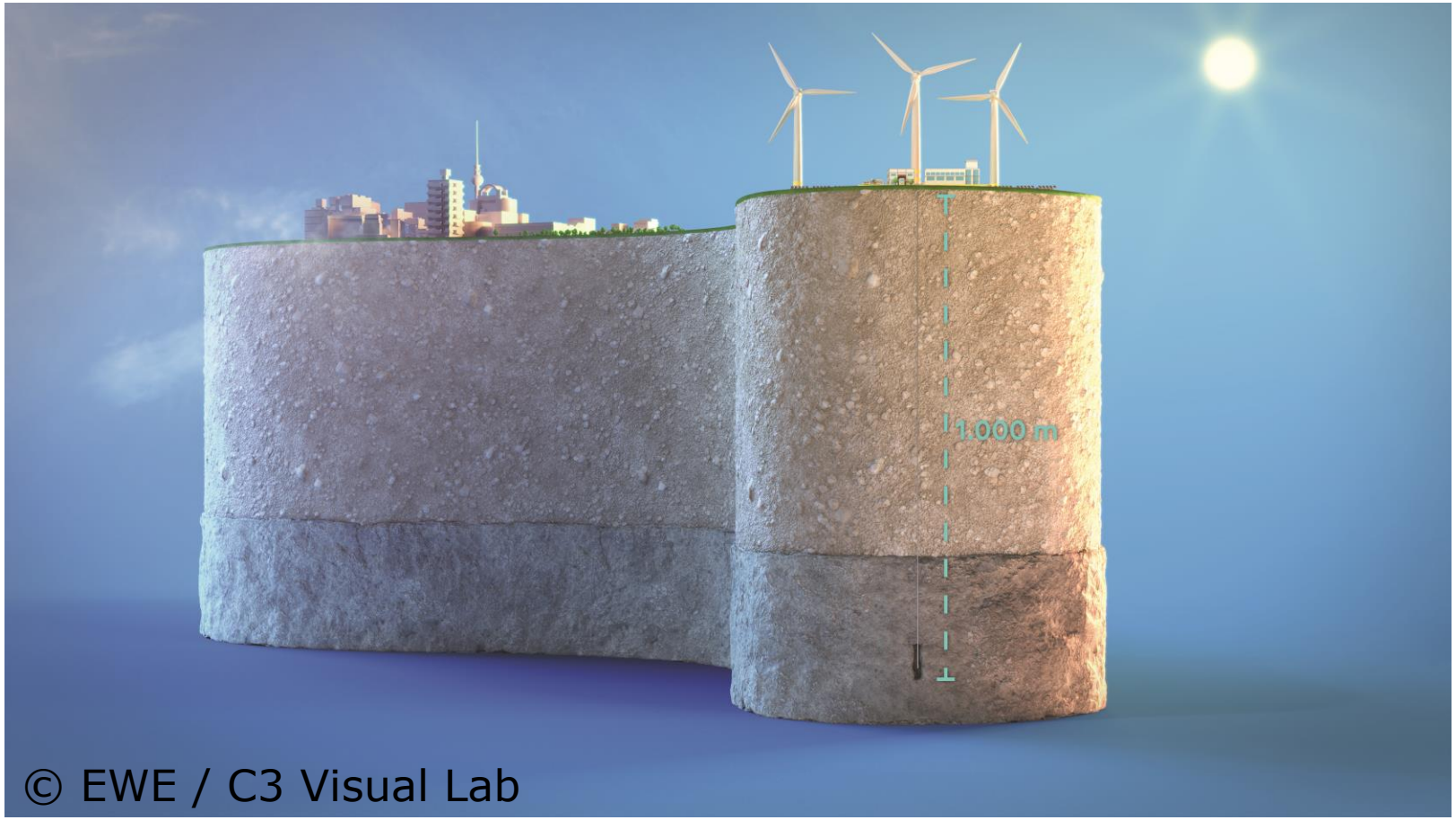
HMR+ Blend: Gas-tight Cement Sheath

EEK: "Erfolgreicher Dichtheitstest in EWE-H_2-Kaverne in Rüdersdorf"



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Cementing Geothermal Wells in NL: HOZlite and HMR+ Blend

Lab results

HMR+ Blend	
Permeability against Brine, mD	$4.4 \cdot 10^{-7}$
Permeability against H_2, mD	$2.2 \cdot 10^{-8}$
Typical Density, kg/L	1.88
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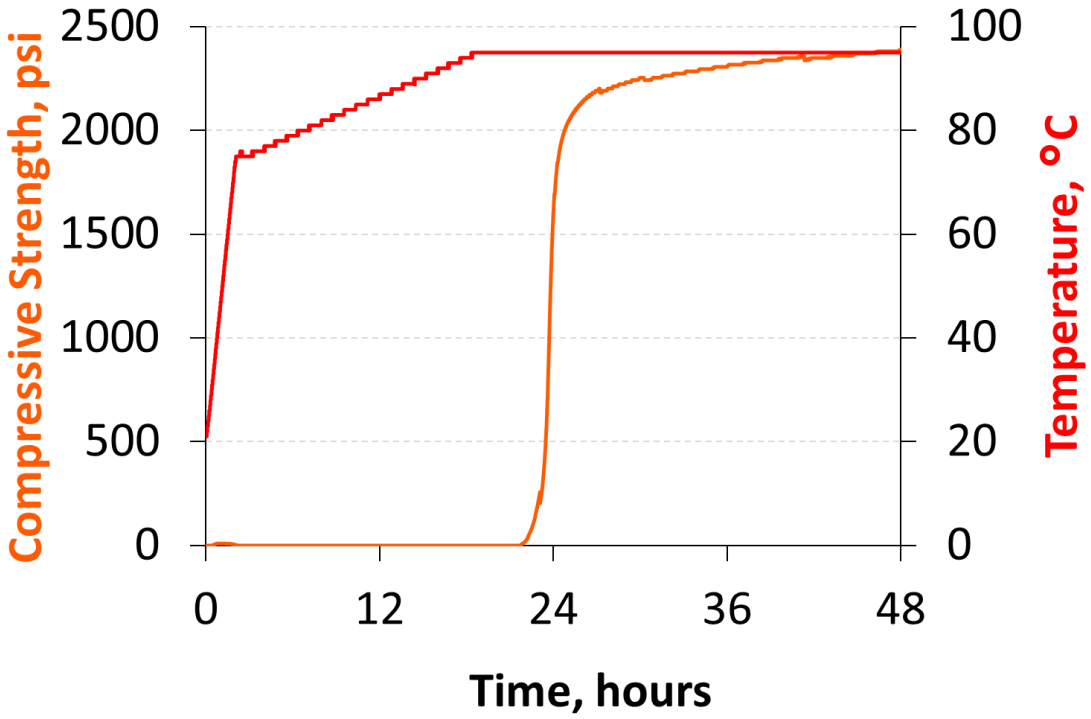

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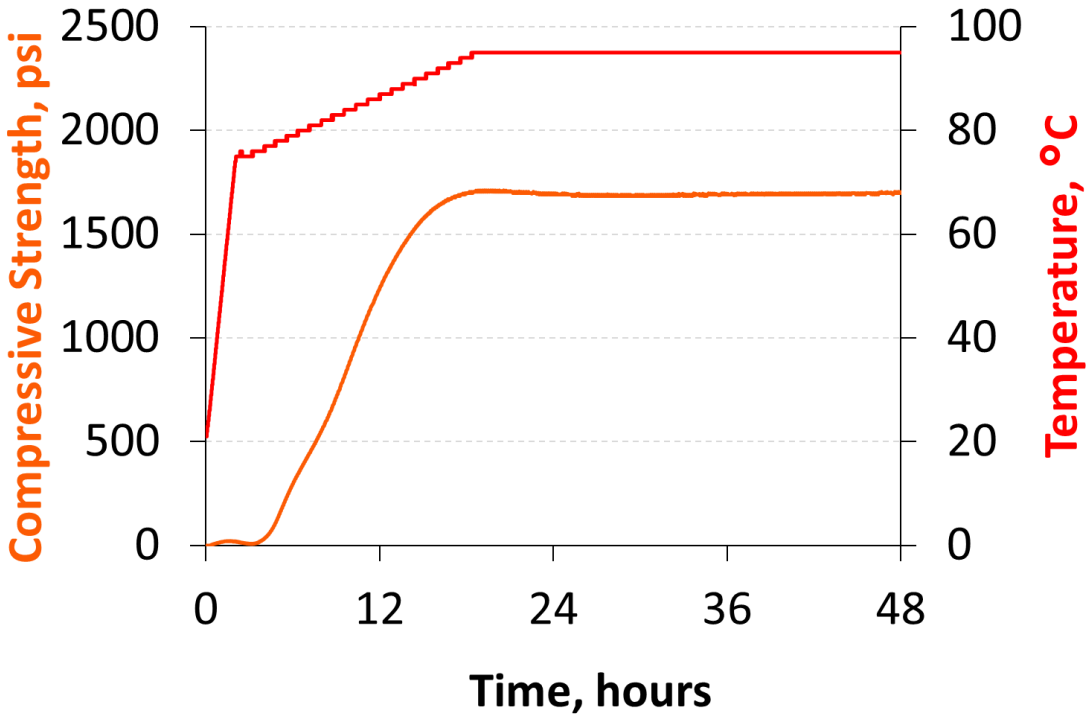

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Cementing Geothermal Wells in NL: HOZlite and HMR+ Blend

Equipment on site

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Cementing Geothermal Wells in NL: HOZlite and HMR+ Blend

Pumping schedule

Step	Volume, m³	Density, kg/L	Pump Rate, L/min
Pressure test			
Pump spacer	1.5	1.25	800
Mix & pump lead slurry	80.0	1.35	800
Mix & pump tail slurry	16.0	1.88	800
Displace with water	10.0	1.00	800

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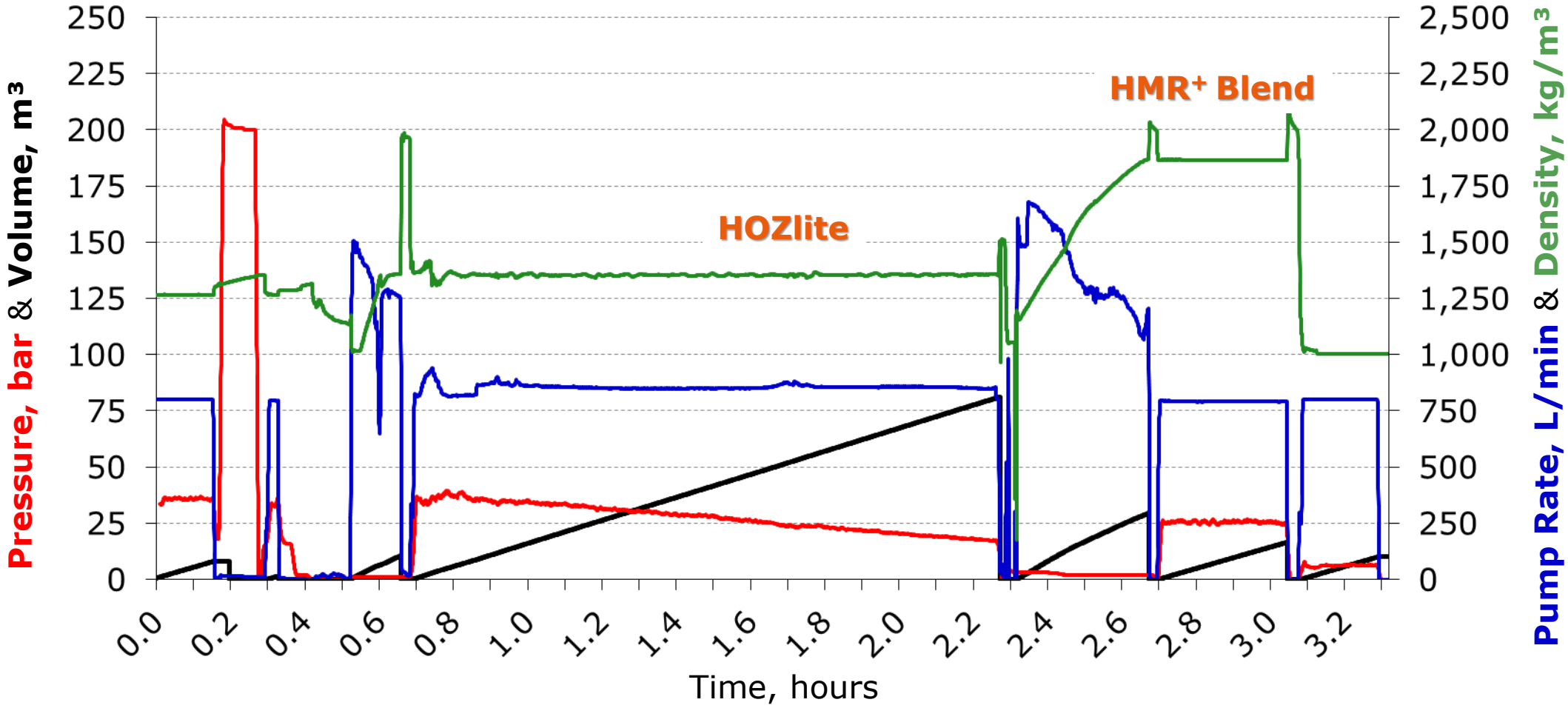
Cementing Geothermal Wells in NL: HOZlite and HMR+ Blend

Pumping schedule



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Cementing Geothermal Wells in Germany: HT Blend and HMR+ Blend

Lab results

1,87 kg/ltr		Zement 1	MF 58,1%			LOT	Comments		R1B1	Rheology	
per mt Cement		*Code*	*Name*	*pro 1,0 m³*						T1 22 °C	T2 80 °C
600,1	lt	FRWA	Fresh water	567,55	lt	CLP Labor			3 rpm	4	14
1,0	lt	CAF_902	Antifoam	0,95	lt				6 rpm	4	19
23,93	kg	CSL_944	Salt	22,63	kg				30 rpm	7,5	43,5
4,00	kg	CRE_120	Retarder	3,78	kg	RT390195-2C			60 rpm	10,5	53,5
									100 rpm	15,5	59,5
									200 rpm	27	70,5
									300 rpm	40	79
									600 rpm	81	98
									10min Gel		
									TT	POD 389 min	70 BC 417 min
									FL		
1350,00	kg	HT Blend	Cement	1,28	ton	CLP Labor			FF		
1057,3	ltr	Yield							CS		

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Cementing Geothermal Wells in Germany: HT Blend and HMR+ Blend

Lab results

1,87 kg/ltr		Zement 2	MF 54,5%			LOT	Comments		R1B1	Rheology	
per mt Cement		*Code*	*Name*	*pro 1,0 m³*						T1 22 °C	T2 85 °C
588,3	lt	FRWA	Fresh water	491,40	lt	CLP Labor			3 rpm	3	18,5
1,0	lt	CAF_902	Antifoam	0,84	lt				6 rpm	4	23
129,04	kg	CSL_944	Salt	107,78	kg				30 rpm	18	50,5
3,00	kg	CDI_290	Dispersant	2,51	kg				60 rpm	39	73,5
4,00	kg	CRE_120	Retarder	3,34	kg	RT390195-2C			100 rpm	70	97
									200 rpm	149	143
									300 rpm	225,5	189,5
									600 rpm		
									10min Gel	14,9 lb/100f2	
									TT	POD 321 min	70 BC 334 min
									FL		
1515,15	kg	HMR+	Cement	1,27	ton	CLP Labor			FF		
1197,2	ltr	Yield							CS		

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Cementing Geothermal Wells in Germany: HT Blend and HMR+ Blend

Pumping schedule

Step	Volume, m³	Density, kg/L	Pump Rate, L/min
Pressure test			
Pump spacer	7.5	1.40	900
Mix & pump lead slurry	27.6	1.87	800
Mix & pump tail slurry	6.7	1.87	800
Displace with mud	44.8	1.22	800

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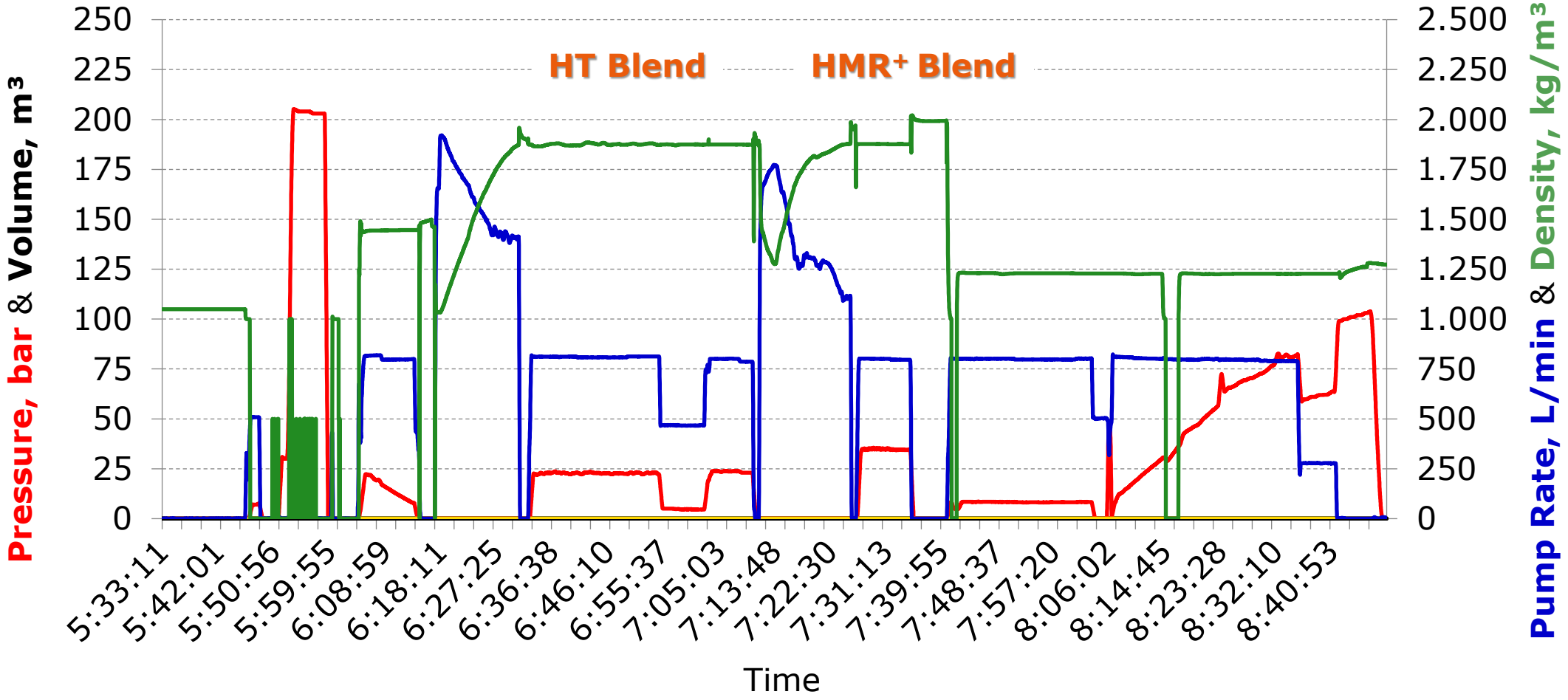
Cementing Geothermal Wells in Germany: HT Blend and HMR+ Blend

Pumping schedule



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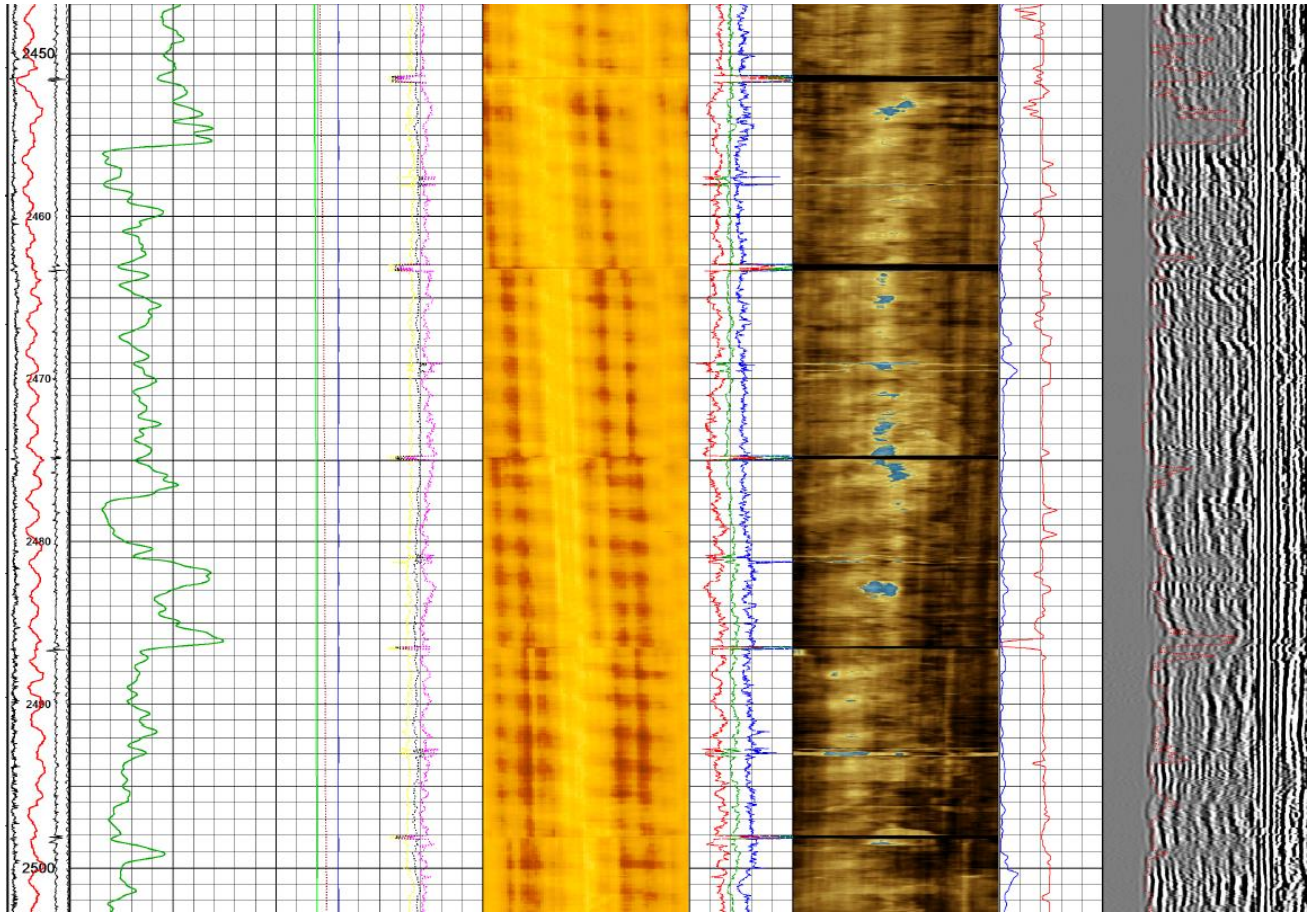
Cementing Geothermal Wells in Germany: HT Blend and HMR+ Blend

Evaluation of hardened HMR+ Blend via logging



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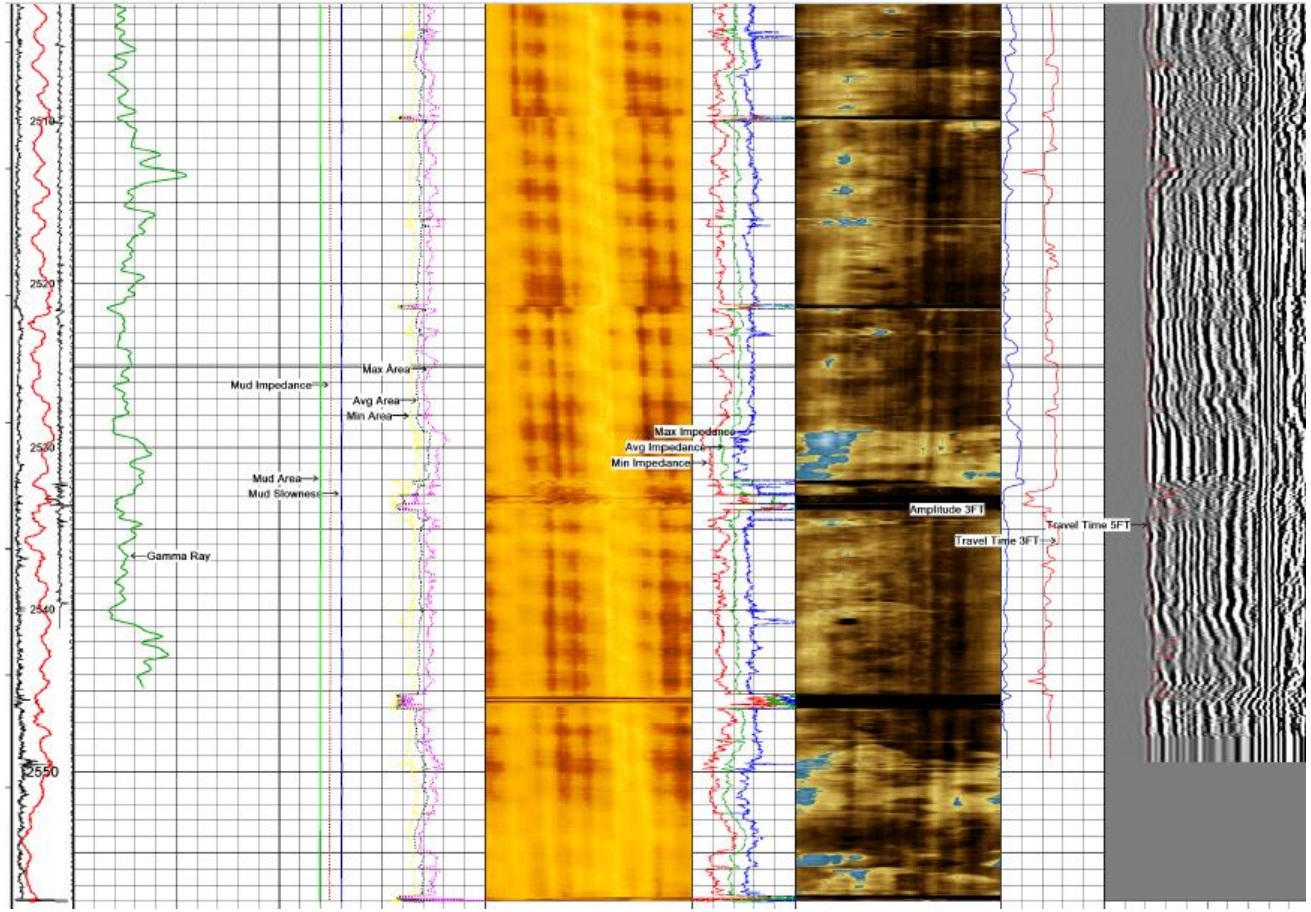

Innovative Systems for Cementing Geothermal and H_2-Storage Wells

Summary

- ✓ **HMR⁺ Blend**
  - Chemically and physically optimized blast furnace slag cement-based system
  - Recommendable for P&A and CCS-projects
- ✓ **HOZlite**
  - Light-weight slurries (1.30 – 1.40 kg/L) for cementing weak formations
  - Optimized heat transfer with a thermal conductivity of 0.7 W/m·K
- ✓ In-house blending and quality control of well-established recipes for premium cement quality

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Ready for Service

For clarification, please contact me directly

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