Specially Customized Systems for Cementing Geothermal Wells

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1. Introduction

Cementing is one of the most critical steps during the drilling process of geothermal wells. Here, we employ many techniques and technologies well-known in the oil & gas industry. However, HT-conditions, as well as temperature-induced expansion or contraction of metal tubular during the life cycle of geothermal wells pose sever challenges to the long-term durability of hardened system. Additionally, weak formations and CO_2-containing formation water may entail the use of specially customized recipes. Thus, a dedicated design based upon extensive lab research and thorough engineering is crucial.

2. High-temperature stability

The first part of this paper focuses on the development and field trial of an innovative blend for a project in the Upper Rhine Graben. Here, thermal fluid temperature expected to reach up to 180°C. Thus, reactive silica flour addition exceeded the commonly used 35 – 40% for HT-Blends counteracting strength retrogression of the hardened Thermalite system (see Figure 1).

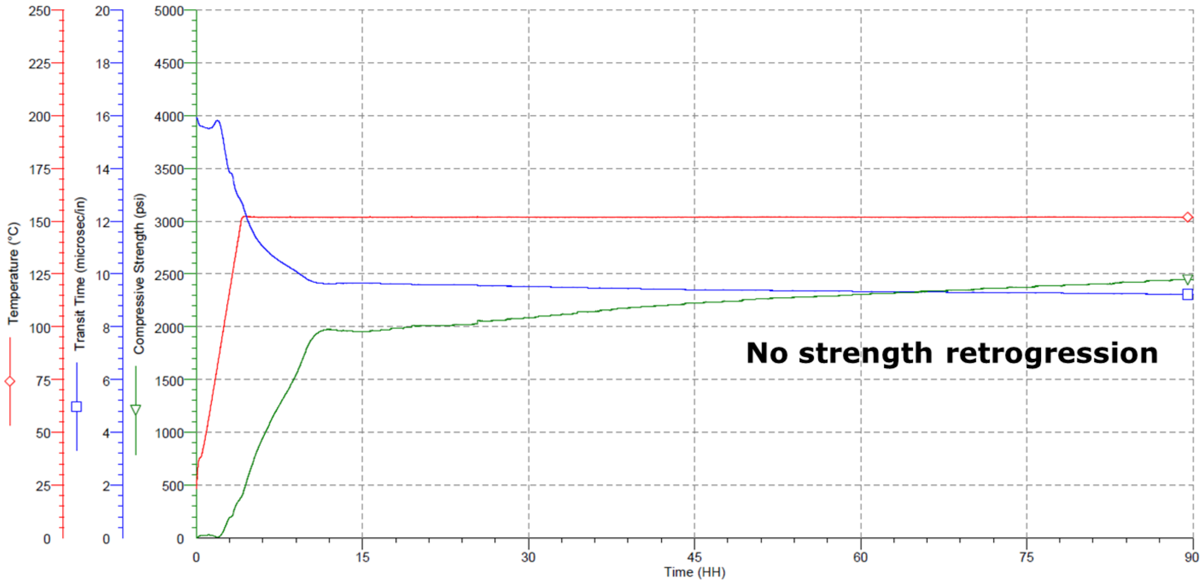


Figure 1: Compressive strength development of Thermalite, as determined employing an ultrasonic cement analyzer.

Furthermore, the mechanical properties (i.e., Young’s modulus and Poisson’s ratio) of the cement sheath were measured via tri-axial compression tests. Based upon computer simulations and ultrasonic measurements, the “flexibility” of the Thermalite was estimated, further optimized, and consequently deemed adequate.

Prior to the actual cementation of the 20″ casing with a lead / tail combination (Thermalite @ 1.6 kg/L / HT-Blend @ 1.9 kg/L), our abrasive spacer effectively removed the silicate-based mud and its filter cake. The corresponding pumping schedule is summarized in Figure 2:

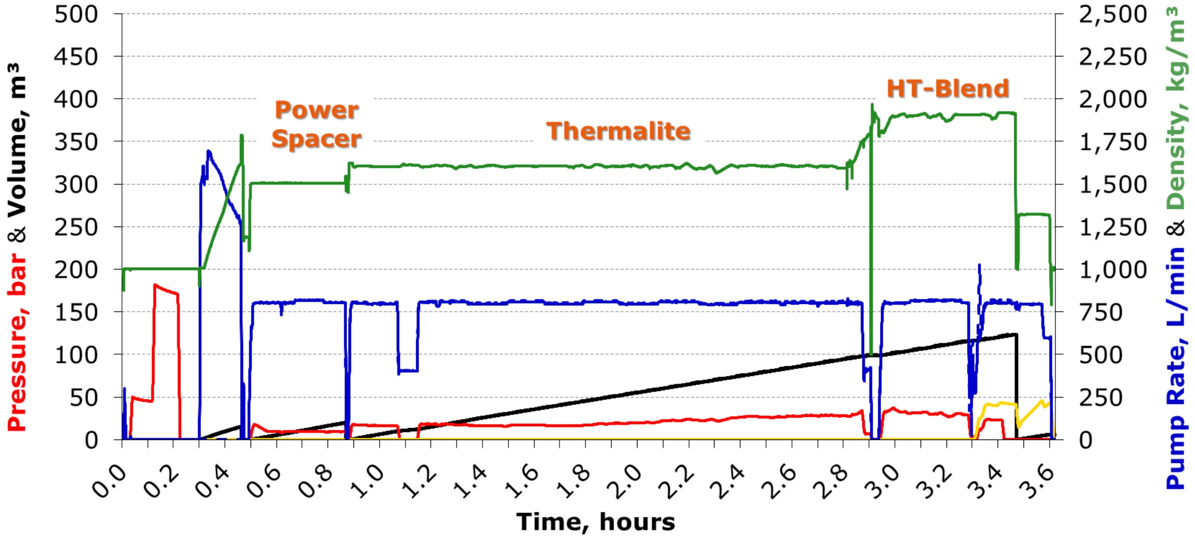


Figure 2: Pumping schedule of the 20″ casing cementation.

The quality of this application was quantified through logging and considered satisfactory to continue with the combination of Power Spacer, Thermalite, and HT-Blend for cementing the 13 ⅜″, as well as the 9 ⅝″ liner section.

3. Light-weight slurry and CO_2-resistant / gas-tight cement sheath

The second part of this paper presents our dream team for geothermal projects in the Netherlands. Here, to counteract losses into weak formations, the use of lightweight slurries is essential. The HOZlite consists of blast-furnace slag cement and contains hollow spheres providing low densities with a high compressive strength after hardening (see Figure 3).

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	0.8
Ideal for Cementing GRE-Material	

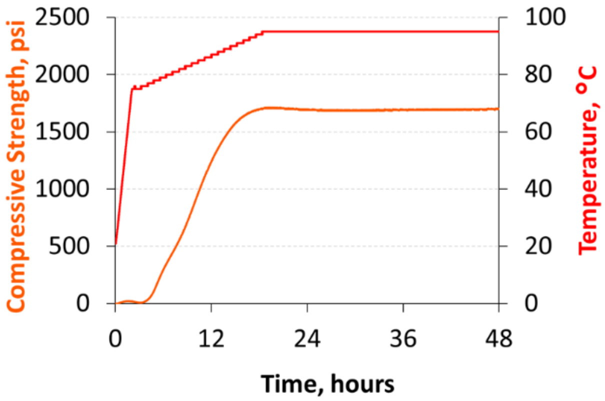


Figure 3: Results of lab testing with HOZlite.

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 4 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	

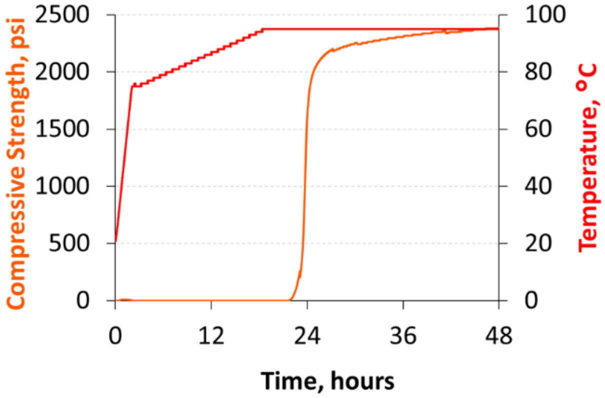


Figure 4: Results of lab testing with HMR+ Blend.

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 5 and 6 summarize the equipment on site and the corresponding pumping schedule.

Figure 5: Equipment on site.

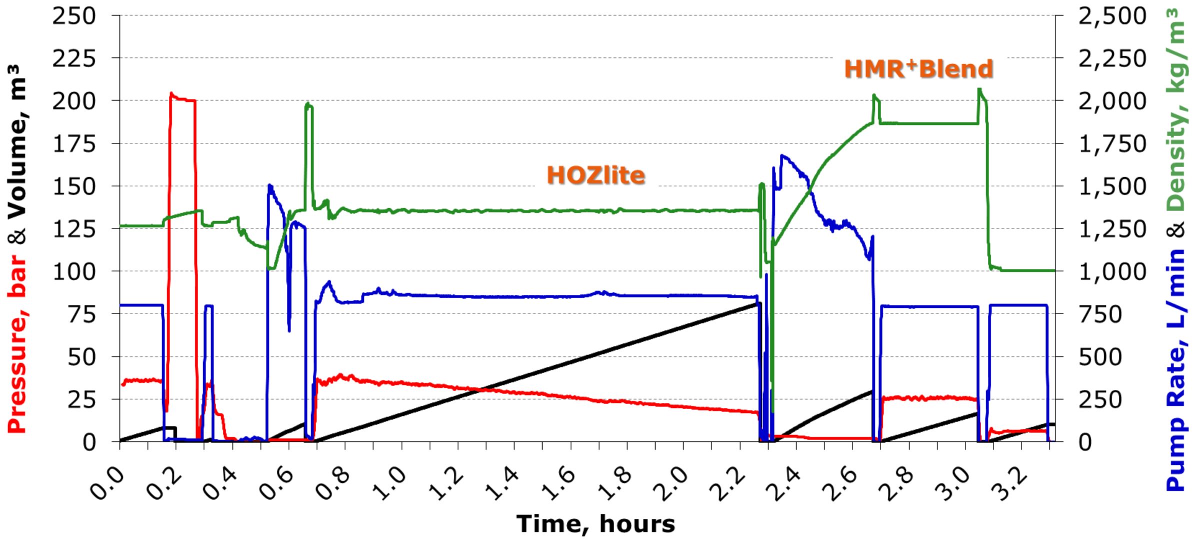
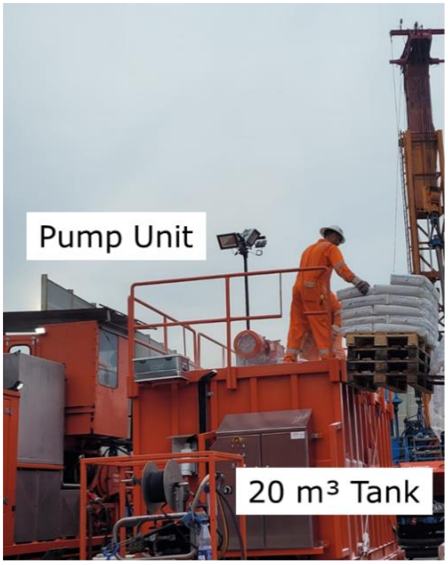


Figure 6: Pumping schedule for cementing the 16″ casing section.

4. Cementing with hydraulic stage tool

For cementing the 7″ casing of a geothermal well in Germany, a hydraulic stage tool was installed. Here, we employed the well-established systems HMR⁺ Blend (stage 1) and API Class G (stage 2), both at a slurry density of 1.6 kg/L. Figure 7 shows equipment used on site, as well as the hydraulic stage tool with its components.



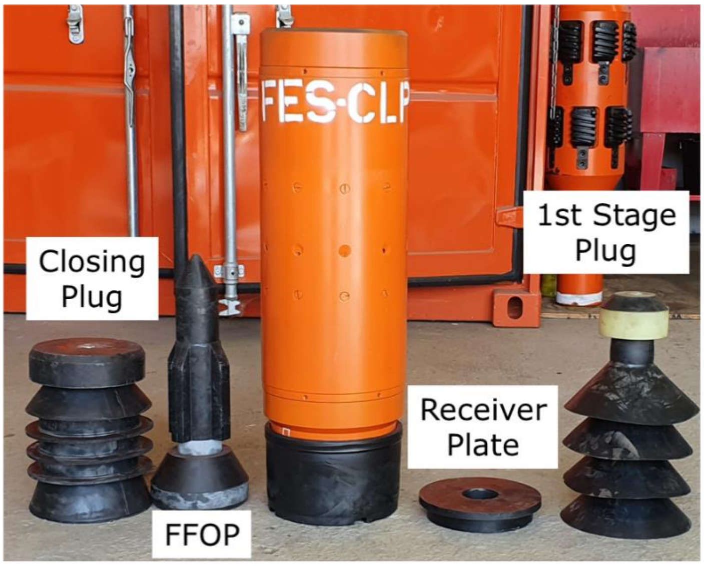


Figure 7: Equipment on site (left) and hydraulic stage tool with its components (right).

Additionally, Figures 8 and 9 summarize the corresponding pumping schedules.

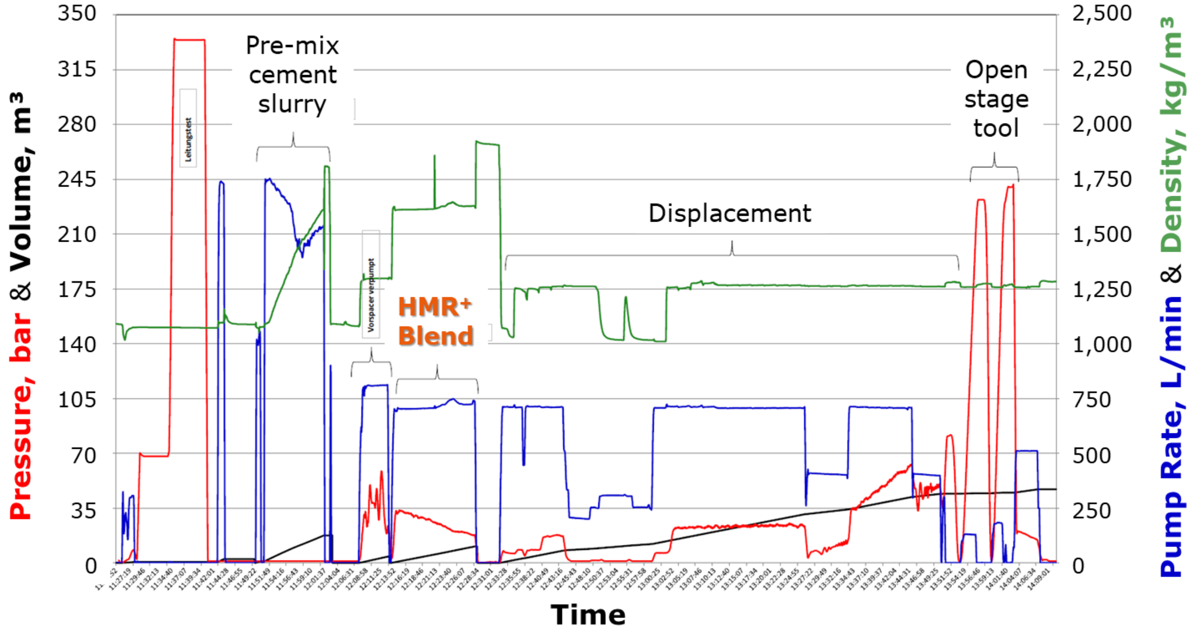


Figure 8: Pumping schedule for cementing stage 1 with HMR⁺ Blend.

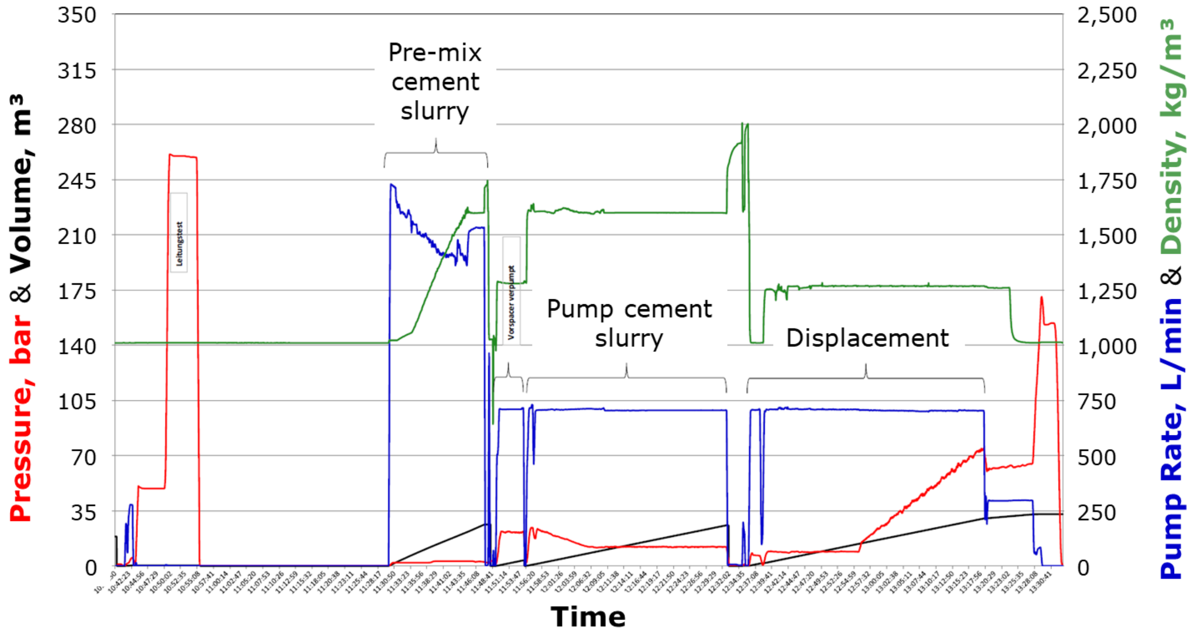


Figure 9: Pumping schedule for cementing stage 2 with API Class G.

5. Summary

Thus, laboratory and field results impressively proved the premium properties of our new technologies for cementing geothermal wells. For a short summary, please see Figure 10.

Figure 10: Summary of paper: Specially Customized Systems for Cementing Geothermal Wells.