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Topic: Numerical and experimental investigation of induced convective flow by high-temperature heat storage in water saturated sediments

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ANGUS II

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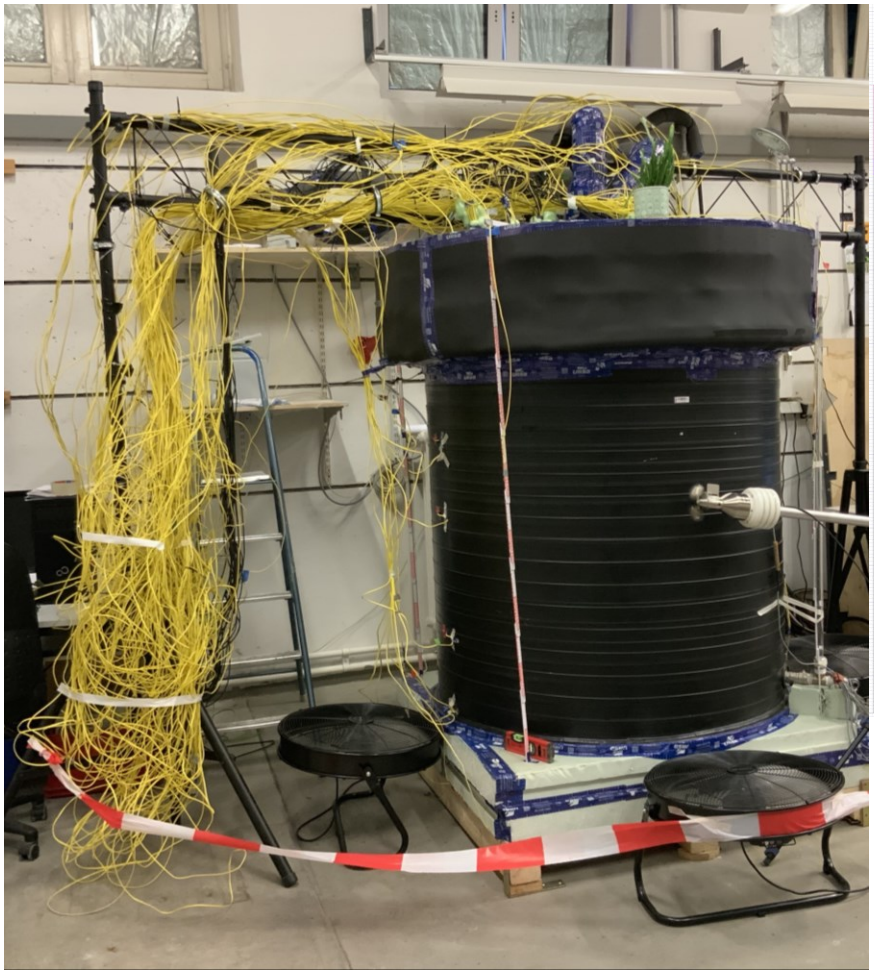
Motivation of this study

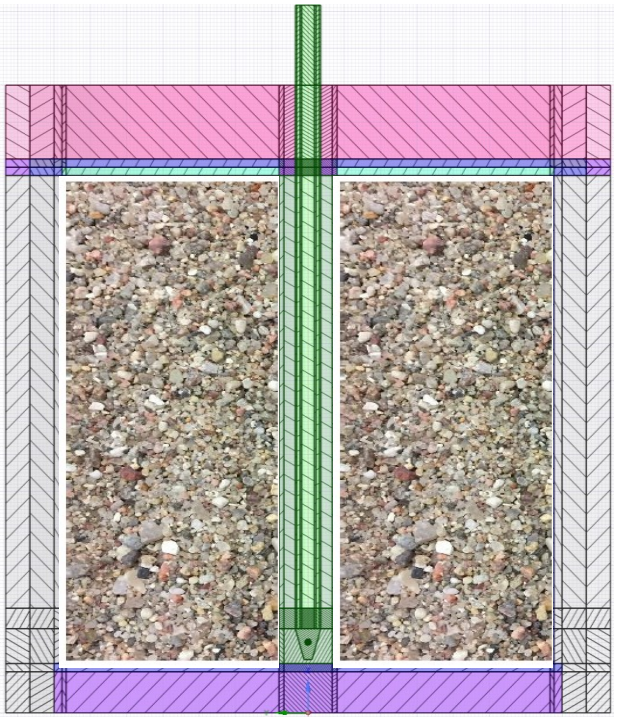
- BTES for high temperature heat storage in order to balance disparities between heat demand and supply from renewable heat soures
- Storage preferably in low permeability formations
- Negative impacts on storage performance by high permeability and highly heat conductive interlayers due to groundwater flow and/or convection

Aim of this study

- Experimental and numerical investigation of impacts of convection on performance of BTES
  - ➢ Storage experiments on a Lab-Scale analogue of a BHE in a saturated high permeability sediment
  - ➢ Model development and validation for numerical sensitivity analysis and scenario simulations.

Laboratory scale experiment



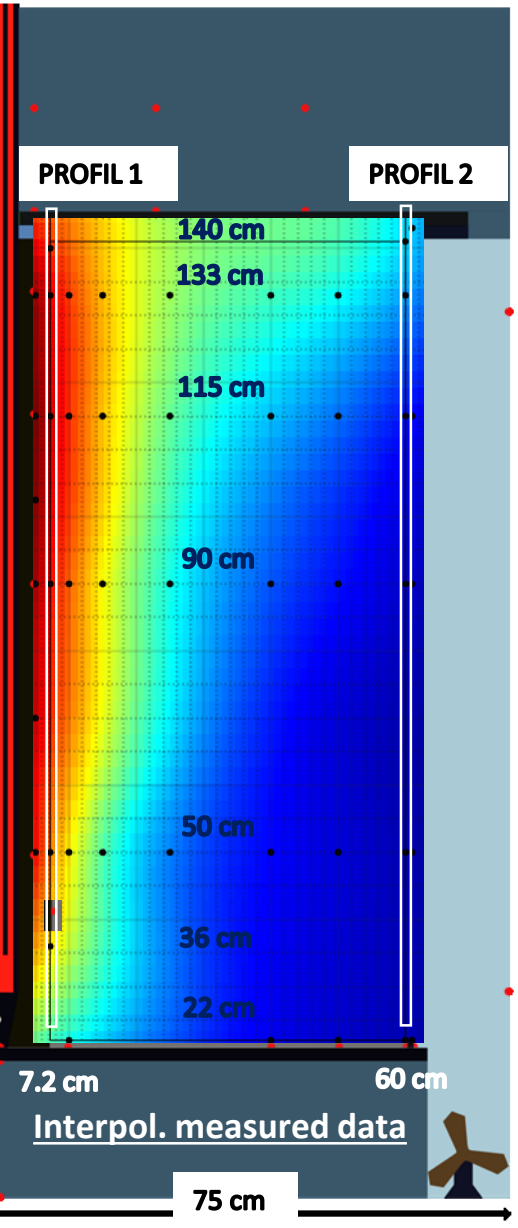


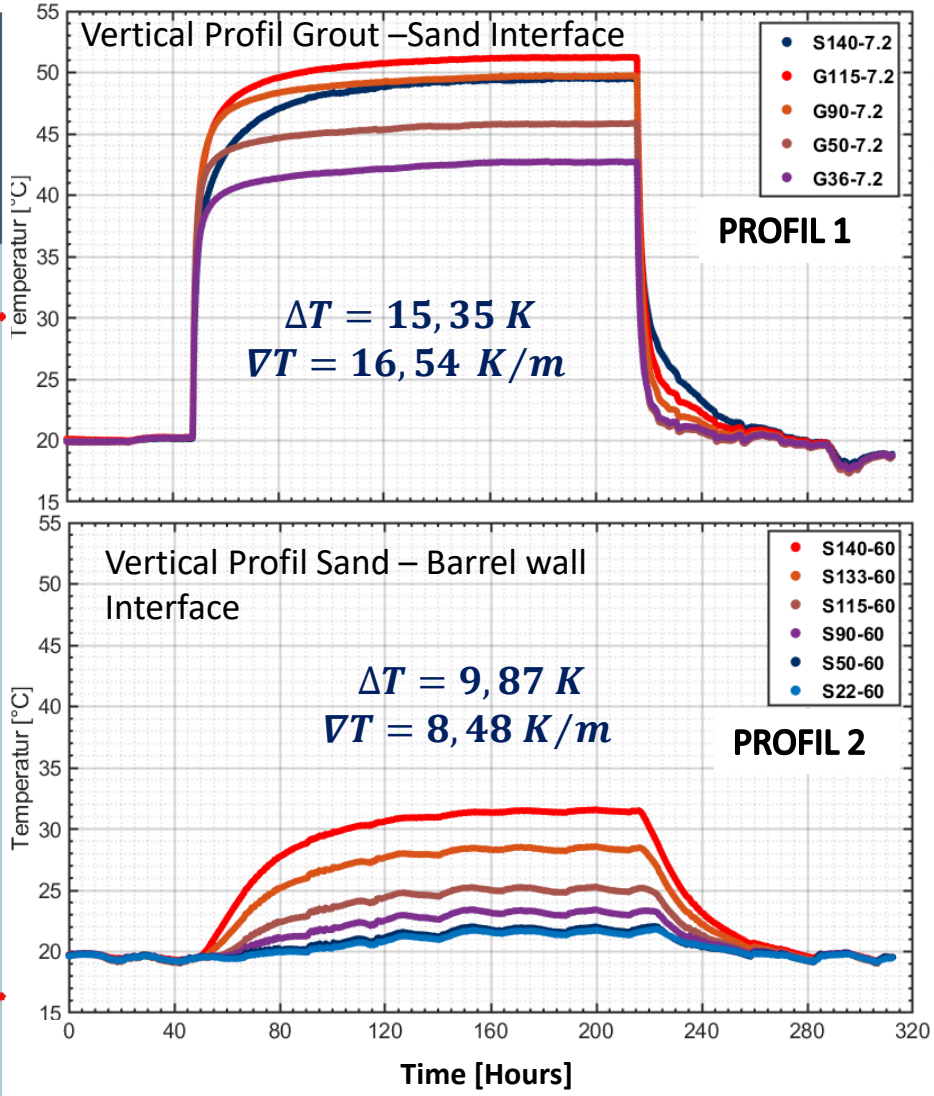
PE barrel ~ 1.346 m³ as storage Container:

- Streusand (0 – 4 mm) and water as heat storage medium
- Coaxial BHE with 1.65 m length and 5.14E-3 m³ volume
- Thermally enhanced cement 3 – 4 W/m/K for the grout
- Insulation (top and bottom) and forced convective air layer (mantle)

- Charging process: circulation of hot water (30, 50, **70**, 80, 90°C) from heating bath with ~ 4.5 l/min flow rate
- Discharging process: circulation of “cold” (15 – 17 °C) tap water with ~ 0.4 l/min flow rate

Experimental results (70°C charging test)





- Temperature curves on the vertical profil as well as the existence of a vertical temperature gradient indicate a vertical thermal stratification of storage medium.

- At the barrel wall, there is no temperature difference between 50 – 22 cm

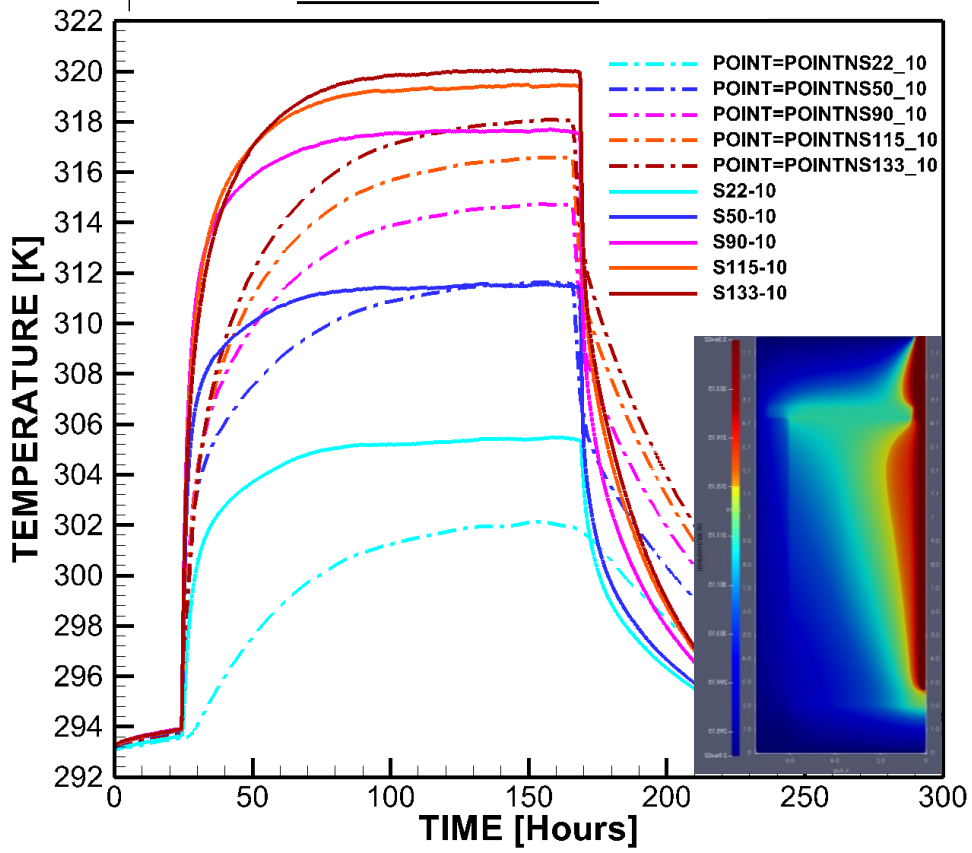
- The vertical temperature gradient decreases from the grout surface to the barrel wall with a rate of -0.153 K/m.

→ Heat transport is dominated by density driven convective flow.

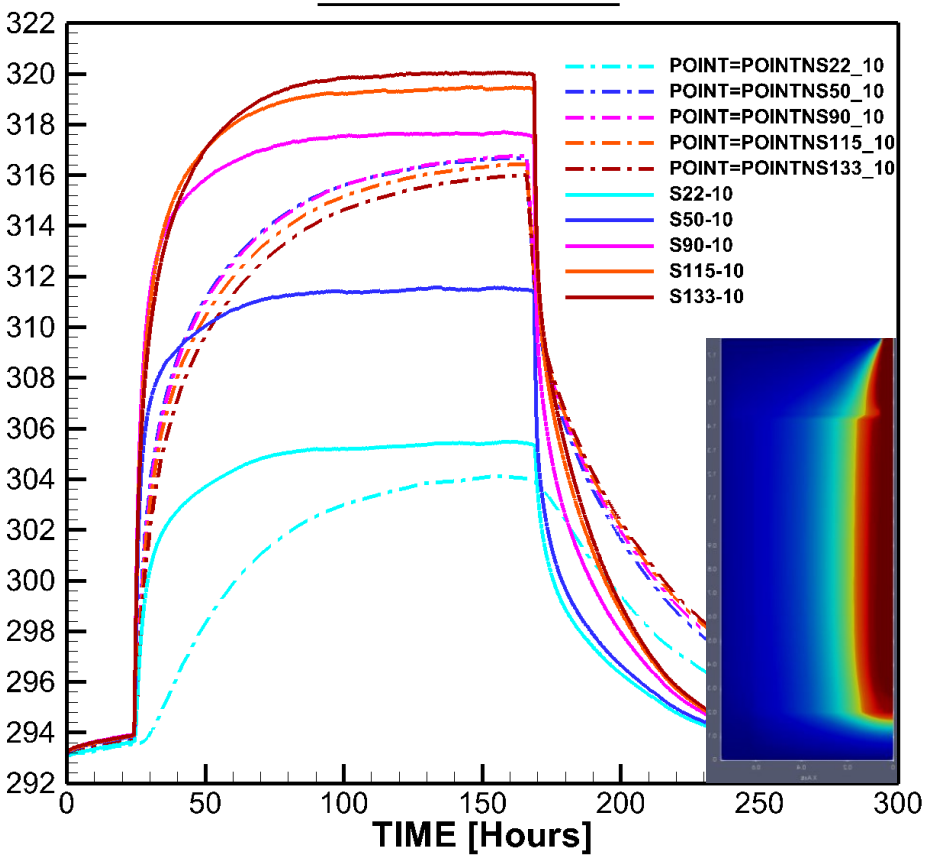
Radial temperature profiles and temperature gradients indicate an inclined thermal front. This is obvious in the ratio of thermal gradient (**0.61 < 1**) between lower part and upper part of sand medium. The Rayleigh-Number for the experiment is **44.15.**

Comparison of experiment and modeling

THERMO-HYDRAULIC PROCESS VS LABORATORY



PURE THERMAL CONDUCTION PROCESS VS LABORATORY



- TH-coupled simulation reproduces the tilted thermal front
- TH-coupled simulation qualitatively reproduces the temperature stratification

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Conclusions:

- Qualitative agreement between temperature fields from lab experiment and TH-coupled (convective) simulation
- Confirmation of convective circulation of pore fluid and dominance of convective heat transport

Next steps:

- Parameter estimation and model fitting to laboratory data.
- Investigation of the influence of cyclic heat injection on the onset of convection and its magnitude.
- Investigation of effects of thermal preloading before (cyclic) heat storage on the transition from conductive to convective heat transport