IN SITU HEATING TEST IN CALLOVO-OXFORDIAN CLAYSTONE: MEASUREMENT AND INTERPRETATION

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To study the thermo -hydro-mechanical effects of the early thermal phase on the clay host rock of a deep repository, Andra has performed a new in-situ heating test called TED experiment. This experiment is the second one being carried out in the Meuse/Haute-Marne Underground Research Laboratory The aim of the TED experiment is to measure the evolution of the temperature; deformation and pore pressure fields around several heaters and to backanalyse the thermo-hydro-mechanical properties of the rock. The TED experiment was also designed to estimate the overpressure generated by heat in the zero flux plan between several heaters and to study the evolution of the damaged zone due to heat. Analysis of the experimental results will help in calibrating numerical models which will be applied to the disposal cell cases.

The test set-up consists of three boreholes containing the heaters and twenty one instrumented observation boreholes. Each heater is 4 m long and may generate a power of 1500 W. The distance between each heater is about 2.6 m, which is close to the ratio of the disposal cell geometry concept. The surrounding boreholes were strategically located to follow the anisotropic THM behavior of the claystone. There are twelve pore pressure measurement boreholes (a total of eighteen piezometers), nine temperature measurement boreholes (108 temperature sensors) and 2 strain measurement boreholes. In order to optimize the inverse problem analysis, special attention has been paid to the reduction of uncertainties regarding the sensors location in the boreholes. Possible sensors location errors were indeed found to be a problematic issue for analysis and parameter determination in the previous thermal experiment ([1]).

The central heater was activated on January 25, 2010 starting with a relatively low heating power of 150 W, then the heating power was increased to 300W and finally to 600 W. Each step was about four months long. After one year the two surrounding heaters were activated and the same heating load was applied. Before each heating step, permeability tests were performed in all pressure measurement boreholes in order to investigate the impact of heat on the rock permeability.

After two years of heating, the measurements of the temperature field provide clear evidence of thermal anisotropy. The pore pressures measured (Figure 1) also confirm the anisotropy of permeability and stiffness. The in situ permeability measurements do not show any changes as a function of temperature. The correlation between the measured temperature and pore pressure and the results obtained by modeling is very good ([2], [3], [4], [5]).

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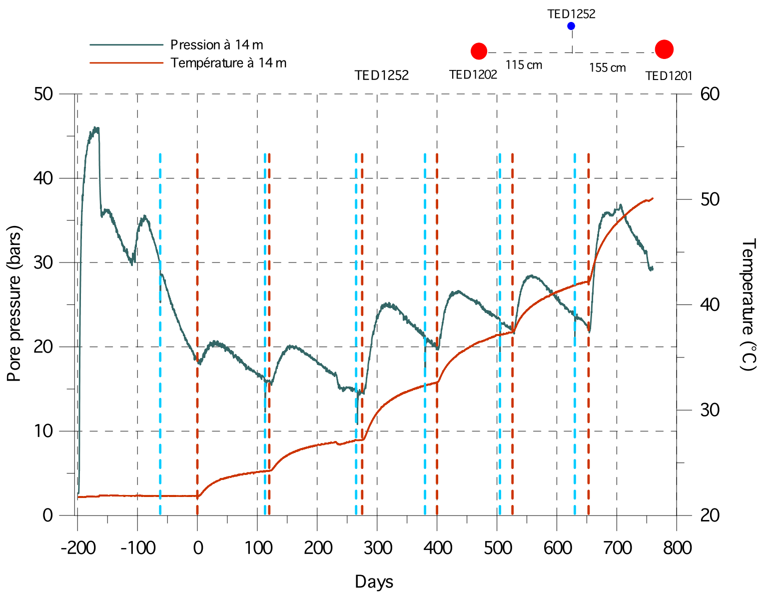

Figure 1 Pore pressure and temperature measurements in TED experiment. Dates of permeability tests are represented in blue dashed lines and dates of heating step in red dashed lines

Thermal conductivity and heat capacity values were determined on the basis of the back-analysis of the in situ measurements ([2], [3], [4]). They are very similar to the values taking from samples which then increase the viability of those parameters. The successful reproduction of the temporary instantaneous pore pressure decrease after increasing power by numerical modeling, confirms the mechanical anisotropy in Callovo-oxfordian claystone [3].

TED experiment results show the capability of current models to satisfactorily predict the evolution of temperature and pore pressure in the far-field of disposal cells.

The THM behavior will also be analyzed during the cooling phase. Cooling will start once the excess pore water pressure generated by heating will be drained in most of the installed piezometers.

References

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THERMO-HYDRO-MECHANICAL BEHAVIOR NEAR A HIGH LEVEL WASTE DISPOSAL CELL

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Thermo-Hydro-Mechanical (THM) evolution near a high-level-waste (HLW) disposal cell has an important influence on the damaged zone evolution and the carbon steel liner loading. The prediction of the behavior of the interaction between the steel liner and the rock mass is made difficult because of coupling and phenomena complexity, and because of difficulties in implementing experimental devices and numerical simulation tools.

Based on interpretation of experimental results and simulation of the phenomena that have influence on the THM behaviour around a HLW cell, this study aims to provide answers and describe qualitatively and quantitatively the following points:

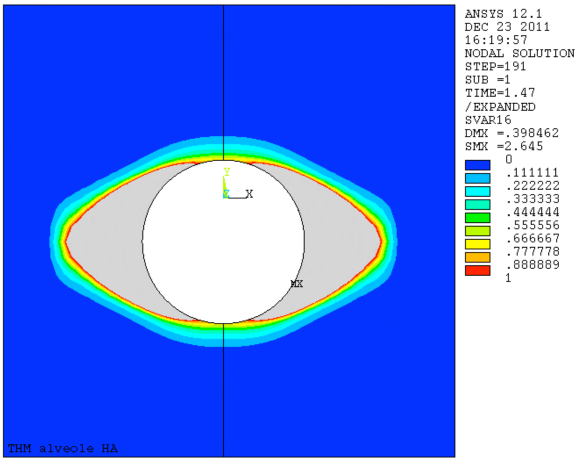
- Evolution of the space between the liner and the surrounding clay.
- Modalities of the liner loading until its failure.
- Evolution and extension of the damaged zone.
- Uncertainties and their impact on elements cited above.

ALC1603 drillig, 1 :1 scale, 1 year after excavation

Numerical simulations were performed to quantify as accurately as possible these phenomena. Elastoplastic law with creep consideration was developed and used in the numerical model. Within this law, a new variable, incorporating the damage state, was integrated which allows modifying mechanical properties of the claystone due to its degree of damage.

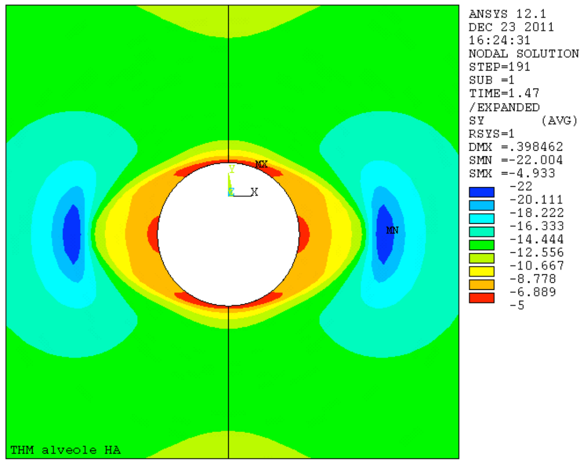
The first step was the definition of this law and its setting in relation to the different observations of the underground laboratory. This law can reproduce the convergence anisotropy and the damaged zone shape. The results provide new insights in the behavior of the damaged clay around the drill hole.

The second phase consisted in simulating several cases. Simulations were chosen by analyzing the principal uncertainties and their expected effect on the THM behavior of the near cell zone and the liner loading. Examples of these variable parameters are: the space between liner and clay drainage, liner water tightness, rate of clay convergence, package type, cell direction and the state of the cell wall.



Computed damaged zone shape

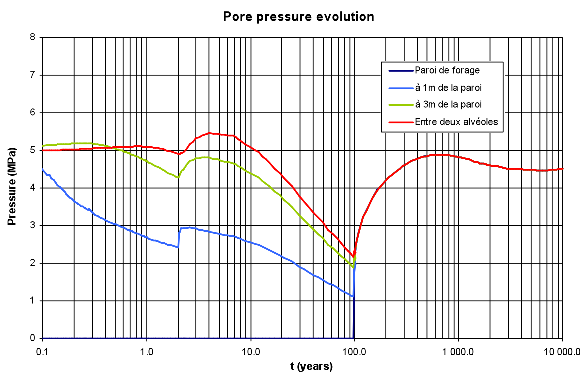
(time = 1.5 years)



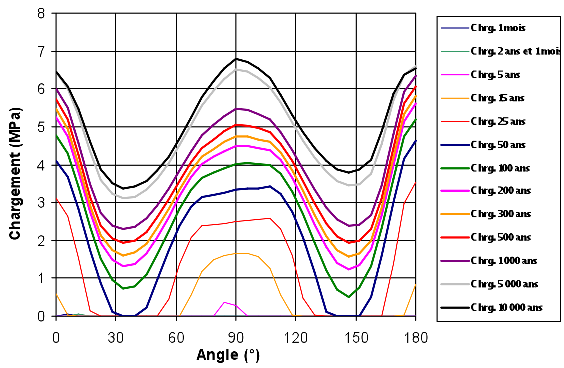
Ortho-radial stress around the HLW disposal cell

(time = 1.5 years)

This study allowed understanding the THM behavior near the HLW disposal cell and defining the loading modalities of the liner under several possible cases. The effect of various uncertainties has been estimated.



Evolution of the water pressure within the space and the claystone



Mechanical loading of the liner induced by the clay thrust