MULTIPHASE FLOW MODELS OF CONCRETE CELLS OF THE RADIOACTIVE WASTE DISPOSAL FACILITY AT EL CABRIL (SPAIN)

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Abstract. *El Cabril is the low and intermediate level radioactive waste disposal facility for Spain. From the start of the filling (1992) until 2003, no water was collected from the drain situated at the centre of the cell. From 2003 onwards small amounts of water were collected from the drain, indicating flow of water within the cell. This occurred in summer and winter. A hypothesis had been proposed to explain this phenomenon based on multiphase flow and heat transport. We corroborate this hypothesis by means of 2D numerical models, using data measured by sensors in the cells and data from laboratory test. There is a good agreement between the data measured and the ones calculated by the models.*

1 INTRODUCTION

El Cabril is the low and intermediate level radioactive waste disposal facility for Spain, situated in Cordoba (South of Spain). The waste is stored in metal canisters, which are put in concrete containers, which in turn are placed in concrete cells. From the start of the filling (1992) until 2003, no water was collected from the drain situated at the center of the cell. From 2003 onwards small amounts of water were collected from the drain, indicating flow of water within the cell. This occurred during two distinctive periods each year: summer and winter.

This phenomenon could not be explained by infiltrating rainwater. The hypothesis proposed to explain this phenomenon consists of capillary flow through concrete and evaporation and condensation within the cell, produced by temperature gradients caused by seasonal temperature fluctuations outside. A key factor is a 2 cm gap between the wall of the cell and the containers with the radioactive waste.

Several studies have been conducted to explain this phenomenon [i,ii,iii, iv,v] using numerical models. However, these models are hypothetical because they do not use real data of temperature and relative humidity from the cells. Moreover, the hydraulic parameters used by the models are from literature. The objective of this work is to make numerical models of the cells using the data of temperature and relative humidity measured by sensors situated inside and outside the cells. Also we used thermo-hydraulic parameters of the concrete used to build the cells, which have been obtained from experimental test.

2 CONCEPTUAL MODEL

Figure 1 displays the conceptual model that explains the phenomena observed in the storage cells of El Cabril. Each concrete cell is 3 meters buried into the underlying rock and the rest of the cell is exposed to the atmosphere. The temperature inside the concrete cells (containers) is always 20ºC. Outside the temperature oscillates between around 40ºC in summer and around 5ºC in winter. These temperature oscillations outside the cell create a temperature difference between the two sides of an air gap existing between the concrete containers and the wall of the cell. There is a capillary flux through the wall of the cell. Moreover, the underlying rock and the wall of the cell are hydraulically connected. Evaporation is produced at the hot side (wall of the cell in summer and container in winter). The water vapour diffuses from the hotter side to the coldest side and condenses at the coldest side. Consequently, water runs off to the drain. This only occurs in summer and winter because only then the concrete reaches complete saturation.

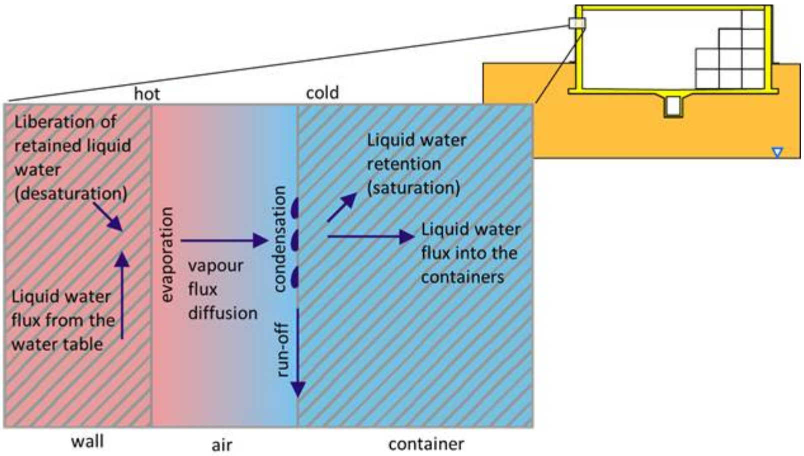

Figure 1: Conceptual model, scenario in summer (i).

In order to simulate these processes 2D numerical models have been built using CODE_BRIGHT (vi). The geometry of the models takes into account the wall of the cell, the containers, the gap between them and the underlying rock. Balance equations of water, gas and energy are solved (vii). A temperature of 19ºC in the entire cell has been considered as initial condition, and the initial liquid pressure decreases gradually from the water table (0.1 MPa) to the base of the cell (-0.9 MPa). A prescribed temperature boundary condition has been used, which also varies with time at the wall and the roof of the cell. We have used the daily average temperature measured by the sensors situated outside the cell. A leakage boundary condition has been applied to the gap of air between the wall and the container allowing water to leave the concrete wall only when liquid pressure exceeds atmospheric pressure. This represents the runoff water to the drain. Finally, at the bottom of the model the water table is simulated by fixing the liquid pressure to 0.1 MPa.

The Porosity and intrinsic permeability used in the numerical models were measured experimentally [viii, ix]. The retention curve, tortuosity, relative permeability and thermal conductivity have been obtained from Massana and Saaltink [ii].

3 RESULTS AND DISCUSSION

Figure 2 displays the results obtained from the numerical model. Sensors have been installed in the gap of air between wall and container in order to measure the temperature of the wall and the container. One of them is at the wall side and another one at the container side. Another sensor is located in the drain measuring the temperature inside the cell. Figure 2*a* shows the evolution of temperature measured by the sensors at 3.5 m from the base of the cell and the one calculated by the model. Two periods every year could be distinguished: summer where the temperature is around 30ºC and winter where the temperature is around 10ºC. The temperature at the wall has larger amplitude than that of the container, which means that the wall is hotter in summer and colder in winter thus causing a temperature difference. There is a good agreement between the model results and measured data by the sensors.

Figure 2*b* displays the saturation of the wall and the container calculated by the model. Similarly with temperature two periods of time every year can be distinguished. In summer, the wall has low saturation (around 0.6) and the container reaches complete saturation. The reverse occurs in winter. This verifies the hypothesis explaining the water can come out of the cell.

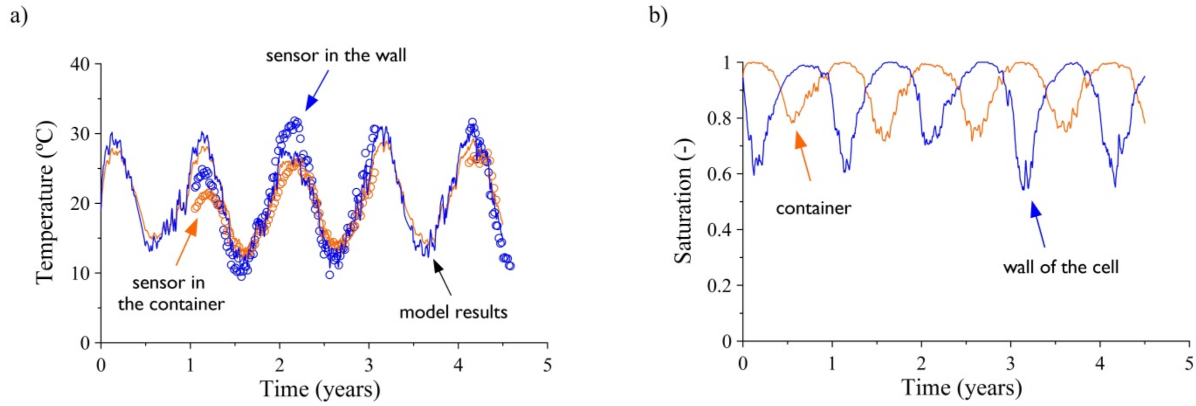

Figure 2: Results of the numerical model: a) temperature of the wall and the container; b) saturation of the wall and the container. Lines are the model results and points are the data measured by the sensors. Colour orange means container and blue means the wall of the cell.

4 CONCLUSIONS

The 2D numerical models can explain the fact that water can come out of the disposal cells due to evaporation and condensation processes inside the concrete and the thermohydraulic behaviour of the system.

- The temperature calculated by the model has a good agreement with the one measured by the sensors inside the cell
- The saturation calculated shows that in summer the wall of the cell is drier (around 0.6) and the wall of the concrete container is saturated (around 1). This corroborates the fact that the evaporation is produced at the hot side (the wall of the cell in summer and the container in winter) and condensation is produced at the cold side.

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