ON THE ROLE AND INFLUENCE OF INTERFACES IN UNDERGROUND DISPOSALS FOR NUCLEAR WASTE

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Key words: Interface finite element, THM behaviour, Nuclear waste disposal

Abstract. *Approaches to model the behaviour of underground disposals for nuclear waste have traditionally assumed perfect contacts between the different materials. However interfaces between the materials may affect significantly the hydration process of the bentonite buffer and later act as preferential pathways for the migration of radionuclides. The paper presents an approach to model interfaces using contact finite elements. The influence of interfaces on the hydration kinetics of a bentonite buffer is highlighted.*

1 INTRODUCTION

In recent years, particular attention has been paid to the behaviour of bentonite-based materials in relation to their use as engineered barriers in deep geological repositories for nuclear waste. In this context, the engineered barrier aims at creating a zone of low permeability that is able to delay the water flow from the host rock, hence the release of radionuclides into the environment.

Depending on the country, different concepts of disposal, with different bentonite-based materials, have been envisaged. In most cases, the materials are either pure bentonite or mixtures of bentonite with sand or excavation products. The sealing material may also take different forms, namely compacted blocks or mixture of powder and pellets.

In all concepts of disposal, the engineered barrier will be initially unsaturated and will be subjected to hydration from the surrounding saturated host rock. During this process, it will tend to expand and will develop swelling stresses. Although transient, this stage is very important as it is believed to directly impact the final state and effectiveness of the system. A good understanding of the hydration mechanisms is thus essential to assess the performance of the engineered barriers and the time needed for their full saturation.

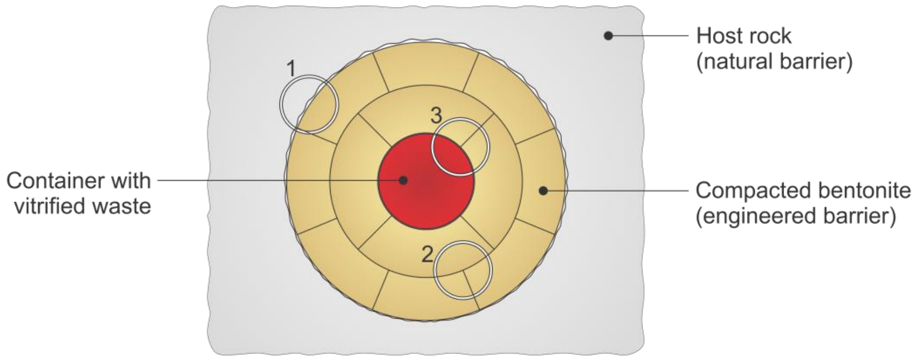

Figure 1: Typical scheme of a deep geological repository for nuclear waste disposal. Interfaces between the different materials are highlighted by the circles 1 to 3.

Traditional approaches for modelling such problems have assumed perfect contacts between the different materials. This strong hypothesis assumes continuity of both mechanical displacements and pore pressures between the materials, which is certainly not true, at least during the first years of the disposal life. Therefore the behaviour of interfaces should be considered for at least two reasons: (1) interfaces significantly affect the transient saturation process of the buffer and (2) they may act as preferential pathways for the migration of radionuclides.

2 FORMULATION OF THE INTERFACE ELEMENT FAIF2

The interface element FAIF2 (Figure 2) is an isoparametric element for two-dimensional analysis. It is implemented in the finite element code Lagamine which has been developed at the University of Liege.

In order to describe the flow not only through the interface, but also within the interface, a three-node formulation is adopted. The finite element FAIF2 uses 2 or 3 nodes on each side of the interface (structure and foundation), as well as 2 or 3 additional nodes inside the interface (interior). The nodes of the structure and the foundation are characterized by 5 degrees of freedom (2 mechanical displacements, water pressure, gas pressure and temperature), while the ones of the interior have only 3 degrees of freedom (water pressure, gas pressure and temperature) and have the same coordinates as the nodes on the structure side of the element (Figure 2).

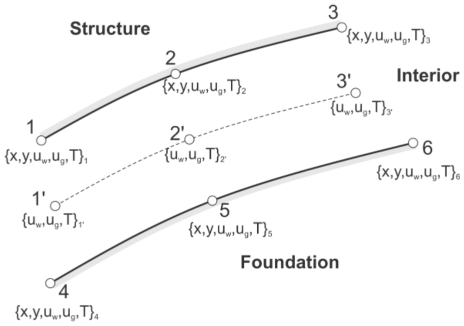

Figure 2: Description of the 2D interface element FAIF2

Different mechanical laws and a multiphase flow law are available to fully describe the THM behaviour of the interface[i,ii].

3 INFLUENCE OF INTERFACES ON THE HYDRATION KINETICS OF BENTONITE PLUGS

The influence of interfaces on the hydration kinetics of bentonite plugs is highlighted through a one-dimensional academic example. Let us consider the contact between two blocks of compacted bentonite (Figure 3). Only block of bentonite is subjected to direct hydration; the second block will progressively saturate in contact with the first block. The contact between both blocks is modelled using the interface element FAIF2. As a first approach, a purely hydraulic modelling of the problem is performed.

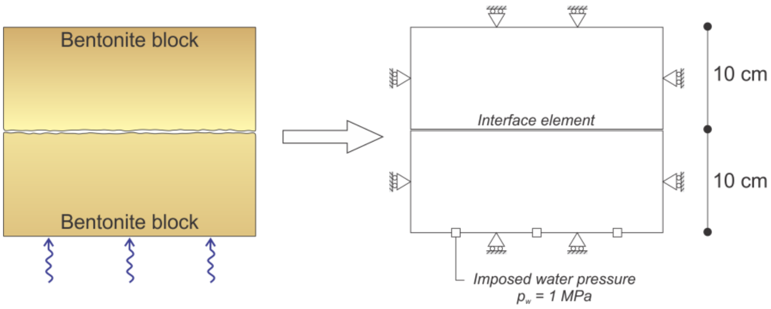

Figure 3: Contact between two blocks of compacted bentonite

In order to describe the transversal flow behaviour of the interface, the concept of transmissivity is used. The transmissivity plays the same role as the permeability is a classical multi-dimensional analysis and relates the transversal flow rate through the interface to the pore pressure gradient in this same direction.

Figure 4 presents the hydrations kinetics of the bentonite blocks in terms of injected volume of water. For sake of comparison, the problem assuming perfect contact between both blocks of bentonite is analysed as well. During the first year of hydration, the hydration kinetics is not influenced by the interface. Indeed it is controlled mainly by the block submitted to direct hydration. Afterwards, the hydration kinetics is not only controlled by the hydraulic state and properties of the material, but also by the one of the interface. Figure 4 shows that this interface can significantly delay the hydration process, which is a key issue in the framework of nuclear waste disposal.

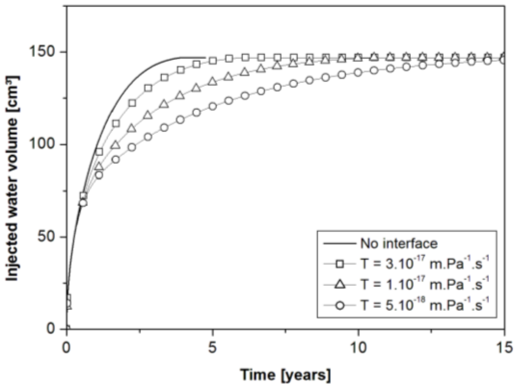

Figure 4: Influence of the interface transmissivity on the hydration kinetics of the bentonite buffer

4 CONCLUSIONS

Interfaces between the different materials of a repository play a critical role regarding the hydration kinetics of the bentonite buffer and the migration of radionuclides. While up to now, most attention has been paid to the THM behaviour of the different materials, the behaviour of interfaces should also be investigated. This characterization requires the development of dedicated laboratory tests, as well as special numerical tools.

ACKNOWLEDGEMENTS

The authors acknowledge the Fédération Wallonie-Bruxelles and the University of Liege for their financial support during the stay of the first Author at the Technical University of Catalonia.

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