A multi-scale model to study gas transport processes in clay materials

Gilles Corman [1,*] and Frédéric Collin [1]

[1]University of Liège - ArGEnCo Department, Liège, Belgium; gilles.corman@uliege.be

In the field of radioactive waste confinement, the question of gas transfers in clay formations is a crucial issue. A certain amount of gas, such as Hydrogen may be generated during the exploitation phase in the nearfield by the deterioration of the metal components of the system. As the host medium is characterised by a very low permeability, various gas transport processes could occur as a function of gas accumulation and pressurization [1], including the development of preferential gas pathways through the sound rock mass, which could lead to undesirable changes in the favourable containment properties of the host rock.

There is a growing body of experimental evidences [2, 3] that natural heterogeneities and pre-sxisting fractures in clay-rich materials represent preferred weaknesses for the process of opening discrete gas-filled pathways. Capturing the related transport mechanisms therefore requires to go from macroscopic to microscopic scale. Hence, a multi-scale modelling approach that models the micro-scale effects explicitely on their specific length scale and couples their homogenized effects to the macro-scale is proposed in the present work. Based on a periodicity assumption of the microstructure, a relevant Representative Element Volume (REV) is defined based on experimental data, which makes it possible to idealise the flow behaviour of the material microstructure with different families of discontinuities, and an assembly of tubes substituting the porous matrix blocks. This complete hydraulic constitutive model is solved at the scale of the microstructural constituents, and is directly affected by the mechanical effects tackled at the macroscopic scale, which makes the whole model hydro-mechanically coupled.

This model has been subsequently applied to simulate a gas injection test parallel and perpendicular to the bedding of initially saturated samples of Boom Clay [3]. This analysis provides a rather good agreement with the experimental results in terms of pressure response, outflow volume and average axial strain. In addition, it allows to simulated the creation of a preferential flow pathway along the sample axis (Figure 1b, top), which serves as basis to numerically reproduce the development of random pathways through the sample in plane strain state (Figure 1b, bottom), and aims to improve the mechanistic understanding of the gas transport processes at play in clayey barriers.

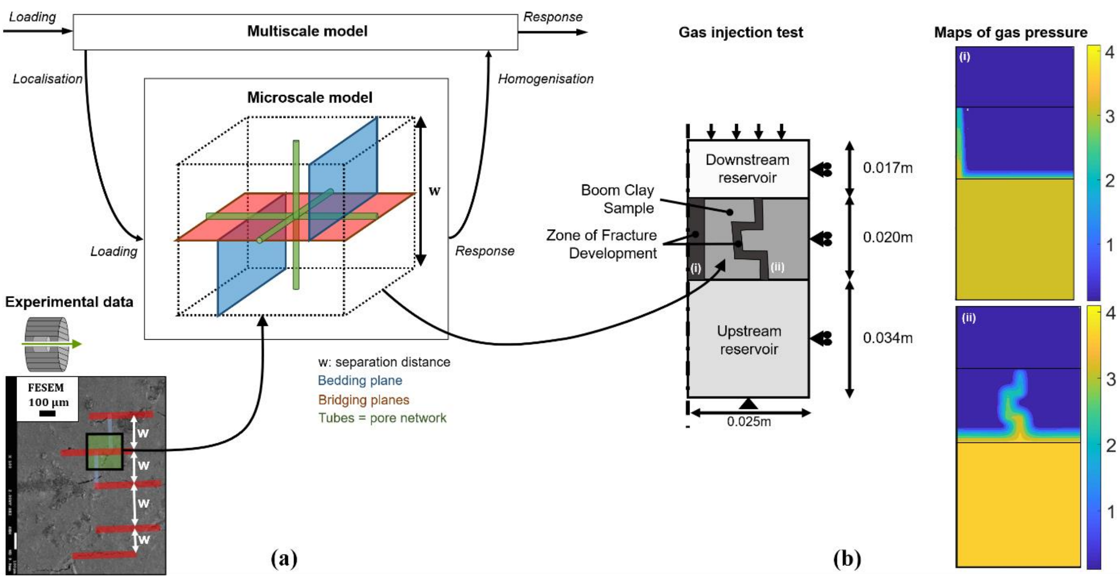

Figure 1: (a) Multi-scale approach. (b) Modelling of a gas injection experiment.

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