Shaft sealing issue in CO_2 storage sites

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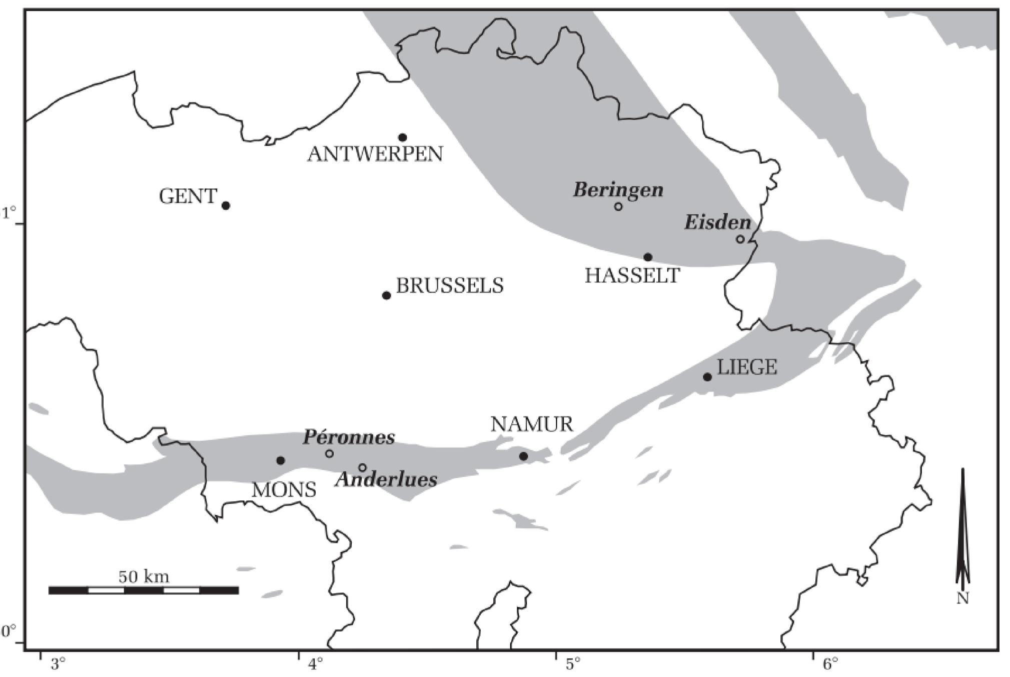
Introduction

Carbon capture and storage is an innovator approach to fight climate changes through the reduction of greenhouse gas emissions. Beyond classical reservoirs, such as depleted oil and gas reservoirs and deep saline aquifers, some abandoned coal mines could be used for the sequestration of carbon dioxide. This solution has been slightly investigated up to now and should receive a special attention in the coming years. In particular, important questions concerning the problem of shaft sealing arise. Indeed this problem appears to be central as far as the economical, ecological and safe stakes of CO_2 storage are concerned. The aim of the work is to study, from a hydromechanical viewpoint, the sealing of shaft within the context of CO_2 sequestration.



Location of Anderlues' coal mined (Piessens & Dusar, 2004)

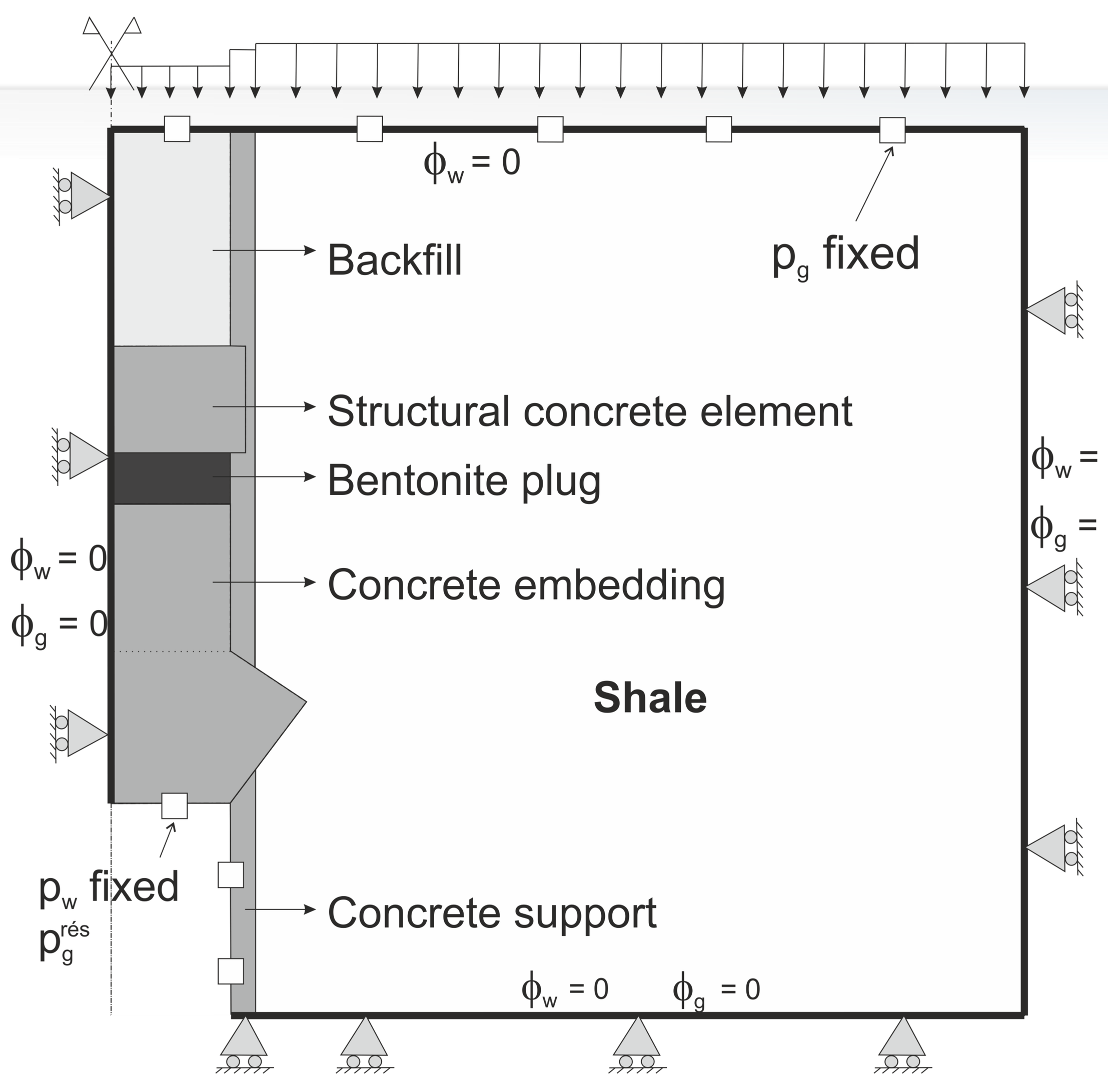
Anderlues' abandoned coal mine

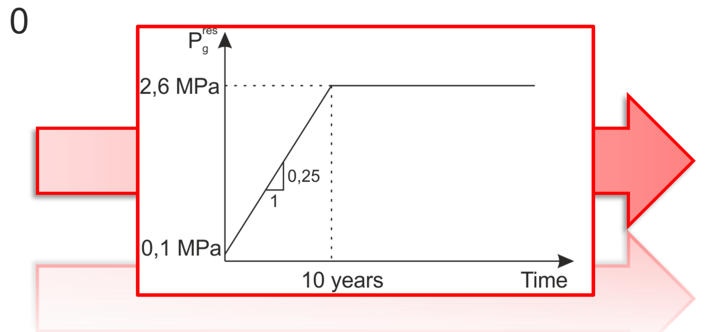
The study is inspired by Anderlues' abandoned coal mine which is located in Hainaut's coal basin (Belgium). After coal mining and firedamp recovery, the mine was exploited between 1978 and 2000 by Fluxys for the seasonal storage of natural gas. Under a pressure of 3,5 bars, the volume of stored gas was about 180 st-Mm³ – among which 90% were stored by adsorption on the residual coal. This important trapping mechanism is considered as one of the strongest and most secure and, therefore, should encourage projects of CO_2 storage in coal mines.

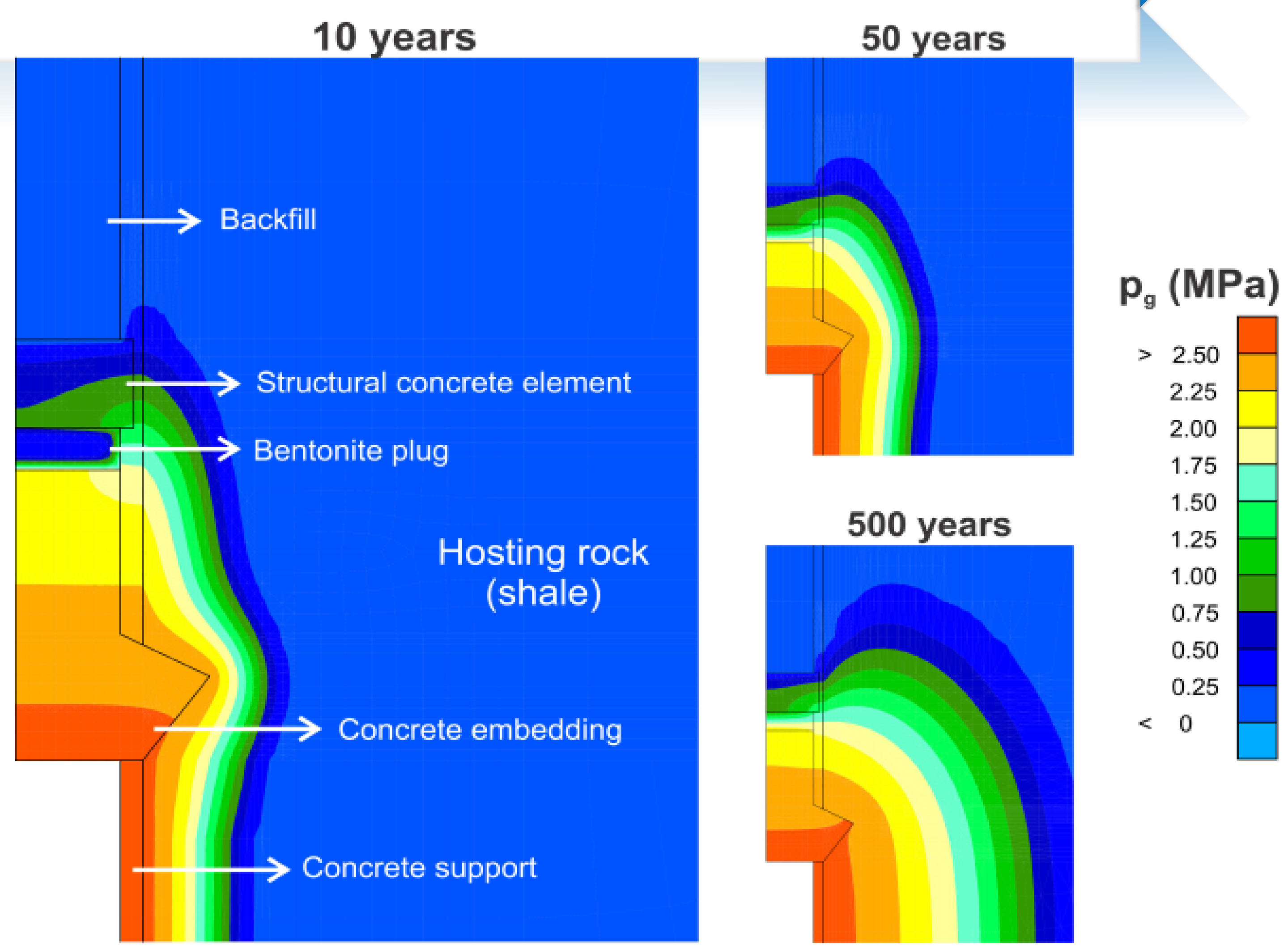
Hydro-mechanical model

A coupled hydro-mechanical model for unsaturated materials was used for the different numerical simulations. The flow model considers the presence of water and CO_2 in each liquid and gas phases. Two transport mechanisms are considered: advection of each phase (Darcy law) and diffusion of water and CO_2 within these phases (Fick laws). Classical elastic and elastoplastic laws are used to model the mechanical behavior of the different materials.

Sinking	Resting (mining)	Sealing	CO_2 injection
50 days …	*…50 years …*	*… 50 days …*	







Conclusions

Four different stages corresponding to the life of a mine shaft were modeled: the shaft sinking, a resting period corresponding to mining, the sealing system placement and the CO_2 injection in the mine.

In the considered scenario, Anderlues' coal mine works are located above the free water table. Therefore the sealing materials are initially partially saturated. Under this hypothesis, the advection of the gas phase appears to be the prevailing transport mechanism of CO_2.

The weak initial saturation of the concrete, as well as its higher intrinsic permeability, give the material a higher gas permeability compared to the shale. The majority of the CO_2 fluxes passes thus trough concrete.
Furthermore we observe that the bentonite plug, in contact with the concrete support, hardy contribute to the limitation of CO_2 discharge into the atmosphere. Indeed, the CO_2 fluxes bypass the plug going through concrete.

Despite these observations, the modeling forecast small volumes of CO_2 rejected to the atmosphere since, within 500 years, less then 4000 tons of CO_2 were rejected into the environment. This optimistic and surprising result can be explained by two limitations of the modeling: (1) the lack of chemo-hydro-mechanical couplings that exist in the different materials (especially in the concrete) and (2) the consideration of an intact host rock (hypothesis that is to demonstrate in an abandoned coal mine!).