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Wellbore Cement Integrity in the Context of CO_2 Geological Storage

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Abstract. CO_2 geological storage is considered as one of the most realist options to reduce greenhouse gas emissions in a significative way so as to mitigate rapidly the global warming issue. Several geomechanical issues have been pointed out and studied in the past decade. In this work, we focus on the integrity of the wellbore cement, which, in presence of CO_2 will be subjected to chemical reactions affecting its thermo-hydro-mechanical behavior. We will also investigate the behavior of the cement-rock interface, which is seen as a possible CO_2 leakage path to the atmosphere.

Keywords. Cement, wellbore, THMC behavior, cement-rock interface, carbonation.

1. Context of the study

In order to mitigate global warming and related issues, CO_2 geological storage is considered as one of the most realist options to reduce in a significative manner the emissions of greenhouse gases. However, the implementation of this technology requires a careful assessment of its safety and of the fate of the CO_2 stored in the geological reservoir. Several geomechanical issues have been pointed out (induced seismicity, reservoir expansion). Possible CO_2 leakage paths have also been identified [2]. Among others, the role played by wellbores crossing the caprock is key.

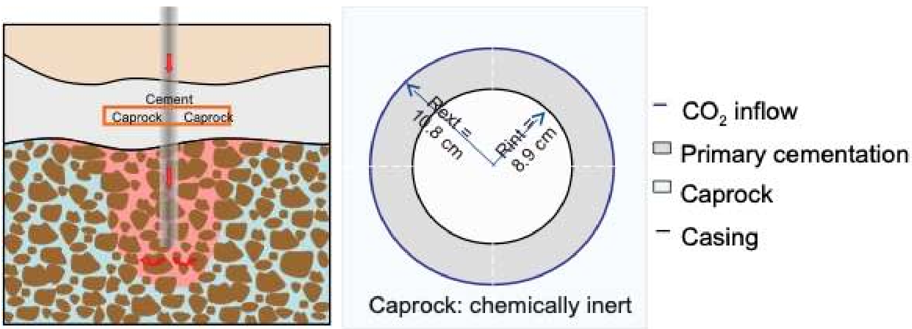

Figure 1. Schematic of an injection well (left) and top view of the considered geometry (from [5]).

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A proper safety assessment of storage site requires refined analyses taking into account the various multi-physical phenomena occurring in the different geological and artificial materials. Reactive transport together geomechanics have to be considered. Poromechanics has proved to constitute a pertinent theoretical framework able to encompass the complex coupled thermo-hydro-chemo-mechanical phenomena observed in theses porous materials (reservoir and cap- rocks, wellbore cement).

In this work, the behavior of the cement sheath constituting the injection well is studied in more detail. The presence of CO_2 in the storage complex will induce chemical reactions within this cement (carbonation reactions). Such a focus arises from the fact that the wells are seen as one of the possible leakage paths within the storage sealing complex, leading to leaks towards the biosphere. Even though CO_2 resistant cements will be used, one can difficultly guaranty that abandoned wells could be encountered by the CO2 plume. A chemo-poromechanical modelling framework of carbonation reactions within the cement sheath is introduced. Its implementation into a numerical code is discussed. A simplified analysis is finally presented, allowing to assess the capabilities of the fully coupled numerical tool developed.

2. Main results

A general framework [1, 3, 4] to model chemo-poromechanical applications is presented and discussed. This framework is applied to the context of CO_2 geological storage, in order to illustrate the proposed methodology.

The simulation of the carbonation of the injection well cement when exposed to the presence of aqueous CO_2 has been presented. It shows that under certain conditions, a relatively large peak of fluid pressure can occur within the cement sheath. This peak could lead to structural damages of the cement. It has also been shown that the occurrence of this pressure peak can be avoided if the cement formulation is appropriate (relatively high permeability for instance).

The proposed framework is relatively general and may easily be extended or transposed to other geomechanical problems involving precipitation / dissolution reactions.

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