



Influence of chemical degradation on mechanical behavior of a petroleum cement paste

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ABSTRACT

Cement paste used in the Oil Industry is generally subjected to chemical degradation due to flow of acid fluids in various situations. The present study focuses on the evolution of thermo-hydro-mechanical (THM) behavior with chemical degradation of petroleum cement paste. Triaxial compression tests with different confining pressures (0, 3, 10 and 20 MPa) are carried out on a standard oil cement paste in sound state and completely degraded state by ammonium nitrate solution under a temperature of 90 °C. The results obtained show that the material in its initial state exhibits a small elastic phase and a strong capacity of compaction. The mechanical behavior depends on the load induced pore water pressure. Because of the increase in porosity caused by chemical degradation, the mechanical strength (cohesion and friction angle) and Young's modulus decrease. The dependence of mechanical strength and Young's modulus on confining pressure is smaller in the chemically degraded cement paste than in the sound one. In fine, the mechanical behavior of the whole material becomes more ductile. As a result, such effects of chemical degradation should be taken into account when modeling such cement paste materials exposed to such chemical degradations.

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1. Introduction

The study of thermo-hydro-chemo-mechanical behavior of cement-based materials is of great interest in various applications, particularly for radioactive waste storage, oil wells exposed to acid gasses sequestration in geological formation like carbon capture and storage. Here we are interested in this topic for possible applications in the Oil Industry. When building a well, cement pastes are largely used in various situations, like cementing casings or plugging a wellbore. They could be also used as barrier for sealing geological sequestration of acid gasses such as CO₂ and H₂S in depleted reservoirs. In such situations, the cement pastes are subjected to mechanical loading, temperature variation, interstitial pore pressure changes and chemical attacks. Therefore, the understanding of different coupling phenomena and appropriate modeling are fundamental to design such structures.

Many works have been devoted to chemical degradation of cement pastes. Among various scenarios, a basic one is the degradation of cement paste by de-ionized or slightly ionized water. The chemical degradation, which is a non uniform evolution process [1–13], mainly comes from the calcium leaching of portlandite (Ca(OH)₂) and calcium silicate hydrates (C–S–H): the first dissolves completely while the second decalcifies itself gradually by reduction of C/S ratio in solid phase

[1,2]. The portlandite dissolution appears suddenly from a threshold of a calcium concentration in pore water of approximately 21 mmol/l, while the C–S–H dissolution phase begins from a concentration about 19 mmol/l [14]. Here one should notice that the leaching process is also influenced by material composition [12,15]. Such chemical leaching leads to an increase in porosity and thus modifies mechanical and transport properties of the material. Poromechanical behavior, for instance Biot's coefficient, is therefore affected. For instance, there is a decrease in mechanical strength [3,7–9,12] and elastic modulus [3,4,6,12], there is also a transition from brittle behavior to ductile one [3,12], and an amplification of material sensitivity with respect to pore water pressure by the increase in Skempton coefficient [7–9].

Most studies so far were performed at ambient temperature only and under uniaxial compression. The purpose of the present study is to investigate chemical degradation effects on thermo-hydro-mechanical (THM) behavior of an oil cement paste, which means under temperature and under triaxial stress. It is carried out by comparing THM behavior at sound state with that at chemically completely degraded state. This paper will emphasize the study of cement paste mechanical properties. Moreover, the degradation kinetics with real chemical solutions (water for example) is generally low. In order to reduce testing time in the present work, the degradation is obtained by an artificial acceleration procedure using an ammonium nitrate solution NH₄NO₃ with a concentration of 6 mol/l. Such acceleration procedure is based on the assumption that the final consequence of chemical degradation on microstructure modification is the same for

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