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Analysis of biopolymer modified oil cement under supercritical CO_2

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Field Code Changed

Storing CO_2 in deep underground reservoirs is key to reducing emissions to the atmosphere and standing against climate change. However, the risk of CO_2 leakage from geological reservoirs to other rock formations requires a careful long-term analysis of the system. Mostly, oil well cement used for the operation must withstand the carbonation process that changes its poromechanical behavior over time, possibly affecting the system's integrity.The use of nanoadditives for cement, such as bacterial nanocellulose (BNC), has been increasing in recent years. This biopolymer has particular properties that can improve cement performance, like high mechanical properties and thermal resistance. For this reason, and in light of the problems that carbonation may pose in the long term in the context of geological storage of CO_2 studies were carried out under supercritical CO_2 conditions analyzing the behavior of cement with nanocellulose additions.Rheological, mechanical, thermal, and microstructural tests were performed on samples with different percentages of BNC [1]. Subsequently, cylindrical specimens were subjected to supercritical CO_2 conditions (20 MPa and 90 °C) with different percentages of nanocellulose using two curing methods, one long-term curing at low temperature [2] and one short-term curing at high temperature [3].These results showed that BNC produces an increase in slurry viscosity but retains a greater amount of water which aids in its subsequent hydration. This could be observed in its microstructure, where a greater amount of hydration products, a higher degree of hydration, and a decrease in porosity were observed. It is likely that this increase in hydration was the reason that cements with nanocellulose had a uniaxial compressive strength up to 20% higher than neat cement. It was also observed that higher BNC contents improve the thermo-mechanical behavior under oscillating bending stress. After carbonation, the microstructure shows that the capillary porosity decreases steadily to values of 5%, which reduces the penetration of carbonic acid into the sample. All cements showed a reduction in mechanical strength, but cements with BNC had a lower degree of carbonation and better mechanical behavior, because of the lower capillary porosity prior to carbonation (Figure 1). However, these effects were not observed when the cement was subjected to a curing process under unfavorable conditions at high temperatures. In this case, the large increase in porosity dulls the short-term hydration effects and the strength of cements with nanocellulose is lower prior to the carbonation process. After carbonation, a relative increase in the strength of the samples with BNC is higher, however, it is still below the strength of neat cement [4]. These experimental studies were simulated using a coupled chemo-hydro-mechanical model. The model simulates the carbonation front advance in cement subjected to supercritical CO_2 and the changes generated by the chemical reactions using the classic balance equations of continuum mechanics relative to mass, momentum, entropy, and energy. Simultaneous dissolution of portlandite and C-S-H, dissolution of calcite, and a damage model were considered. The carbonation progress of the samples was represented and an extrapolation was made to an oil well based on the parameters obtained from the experiments and simulations.

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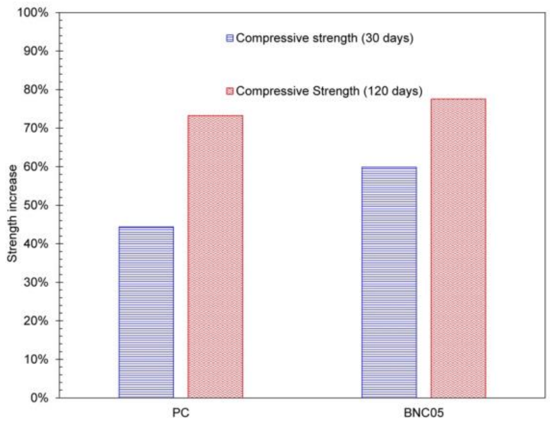

Figure 1: ***Compressive strength after carbonation of Portland Cement (PC) and Bacterial Nanocellulose (BNC05) samples for 30 and 120 days of carbonation.***

Contributor statement

Diego Manzanal: Conceptualization, Methodology, Writing - review & editing, Supervision, Project administration, Funding acquisition.

Jean-Michel Pereira: Conceptualization, Methodology, Writing – review & editing, Supervision, Funding acquisition.

Juan Cruz Barria: Investigation, Software, Validation, Formal analysis, Data curation, Visualization,

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