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Effect of CO_2-induced reactions on the mechanical behaviour of fractured wellbore cement

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Geomechanical damage, such as fracturing of wellbore cement, can severely impact well integrity in CO_2 storage fields. Chemical reactions between the cement and CO_2-bearing fluids may subsequently alter the cement's mechanical properties, either enhancing or inhibiting damage accumulation during ongoing changes in wellbore temperature and stress-state. To evaluate the potential for such effects, we performed triaxial compression tests on Class G Portland cement, conducted at down-hole temperature (80 °C) and effective confining pressures ranging from 1 to 25 MPa. After deformation, samples displaying failure on localised shear fractures were reacted with CO_2-H_2O, and then subjected to a second triaxial test to assess changes in mechanical properties. Using results from the first phase of deformation, baseline yield and failure criteria were constructed for virgin cement. These delineate stress conditions where unreacted cement is most prone to dilatational (permeability-enhancing) failure. Once shear-fractures formed, later reaction with CO_2 did not produce further geomechanical weakening. Instead, after six weeks of reaction, we observed up to 83% recovery of peak-strength and increased frictional strength (15-40%) in the post-failure regime, due to calcium carbonate precipitation in the fractures. As such, our results suggest more or less complete mechanical healing on timescales of the order of months.