Journal of
Geography & Natural Disasters

Short Communication

Comprehensive review of chemical and mechanical degradation of well cement in CO² environment for Ccs operations

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Abstract:

Statement of the Problem: Carbon capture and storage operations reduce emission of carbon dioxide into the atmosphere which has a large impact on the environment. Long-term storage of carbon dioxide in a reservoir depends on the degradation of Portland cement used to cast these wells due to carbon dioxide. The objective of this research is to provide a comprehensive review of past investigations to help understand the cement???s degradation, the provided solutions to this problem and discuss a potential alternative. Tables were made with information about the types of cement, the curing conditions and the exposure conditions (experimental conditions) used in different studies and their conclusions. Tables comprised of experimental studies conducted on neat Portland cement and cement mix (Portland cement + additives) were included. Field studies were also discussed. Possible migration paths of CO2 and exposure conditions that are likely to happen inside the reservoir were discussed. Quantitative data was extracted from these investigations to understand the structural changes after the exposure. Histograms were made from the data acquired to determine the most used type of cement, exposure condition and additive. The data were constructed to explain different curing and exposure conditions.

Data analysis shows that wide ranges of curing and exposure conditions made the comparison of structural changes impossible between the studies. However, the increase or decrease in porosity, strength, permeability and density of cement cores after CO2 exposure, and alteration depths were compared. Mostly, researchers used class H and class G well cement with CO2 saturated brine/water at static conditions. Flyash is found to be best known pozzolan and can be reliably mixed with cement to provide long term integrity in CO2 storage operations. However, studies suggest that higher amounts of this additive have a negative impact on the cement mix for this environment. Flyash-based geopolymer cement was suggested to be used in CO2 storage operations due to its environmentally friendly nature and higher durability in CO2 environment than Portland cement. The research provided a critical review about the past investigations, which became helpful in understanding the degradation process of Portland cement in a CO2 environment and the behavior of additives. A new flyash-based geopolymer cement was proposed and discussed.

Introduction:

The CO2 stimulation concept was included in the first patent for CO2 EOR technology in 1952. Large scale CO2 EOR projects began in 1972 with the SACROC Unit of the Kelly-Snyder field in West Texas. The SACROC CO2 EOR project is still operating today joined by a growing number of other large-scale commercial projects, including 105 in the USA, 7 in Canada, and 12 in other countries. CO2 EOR projects in the USA currently produce about 245,000 barrels of oil per day. The technology, operational experience and regulatory procedures developed for CO2 EOR has a great record of success commercially, environmentally and in terms of safe operations. This excellent record includes sustained well integrity that seals and structurally supports many thousands of new wells, previously-drilled wells, and well abandonments that, with a few exceptions, have all used Portland-based cement for zonal isolation of CO2 zones. The exceptions (non-Portland cements for CO2 zones) are an estimated 0.15 % of the total of all CO2 EOR wells.

In the United States alone, the Oil & Gas Journal (EOR Survey) reported operations in 15,373 CO2 injection and production wells (94% of global total) and more than 3,500 miles of high-pressure interstate CO2 pipelines—a figure which doesn't include countless miles of flow-lines to and from each well. Sweat man reported that many of these flow-lines and well tubing strings have been lined internally with Portland-based cements to protect the carbon steel pipe from corrosion by CO2 laden aqueous fluids. The CO2 EOR process is defined by the Intergovernmental Panel on Climate Change as subsurface CO2 storage. Projects that properly measure and account for the amount of stored CO2 are eligible for carbon storage accreditation. In this CCS process, permanent CO2 storage is achieved by CO2 displacement of hydrocarbons from reservoir pore spaces and the subsequent trapping or geological sequestration of the CO2 within the reservoir's porosity. A recent report by one of the world's largest CO2 EOR and pipeline operators estimated that 655 million tons of CO2 have been injected and stored in oil reservoirs of all the USA's EOR projects over the past 37 years. This average of 17.7 million tons per year is equivalent to the total emissions from approximately four large coal-fired, electric power generating plants with each one having a capacity of 500 MW (2000 MW total).

Conclusion:

Capturing emitted carbon dioxide from the source of emission and storing it underground is one effective way to reduce the amount of CO2 in the atmosphere and is called carbon capture and storage (CCS). For the successful CCS project, it is necessary to ensure long term storage of injected CO2 inside these selected reservoirs. Portland cement used to cast wells in these reservoirs degrade in CO2 environment and can create migration path for leakage of CO2. The aim of this study was to provide a comprehensive review about the problem, to propose a new geopolymer cement as an alternative to Portland cement, optimize geopolymer slurry for oil well cementing operations and compare the performance of both cement in CO2 environment. The chemical alterations of cement and its effect on the mechanical properties of the cement was analyzed and discussed. Additives used till now with cement to obtain CO2 resistant cement were discussed. Optimization of geopolymer cement slurry using different alkaline activator to flyash ratios, sodium silicate to sodium hydroxide ratios and sodium hydroxide concentrations was performed. The aim of this study was to obtain a formulation of class C flyash-based geopolymer slurry that can be used in oil well cementing purposes. The result concluded that optimized geopolymer slurry has higher strength, lower fluid loss, no free fluid and rheological properties same as Portland cement. Optimized geopolymer cement and Class H Portland cement were then exposed to CO2 environment at two different phases of CO2 for different duration. Variations in the density, strength, and surface of the cement cores were analyzed and compared. Class C flyash-based geopolymer performed better in CO2.