Detection of crack repairing actions of bacterial concrete

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CTR2, Improved Cement Material Meeting

The current research aims to show the self-healing properties of bacterial concrete for healing/sealing of microstructural cracks. This is shown for concrete using three different types of cement (i.e., white Portland cement, ordinary Portland cement and oil-well cement) in a sulphate environment. Herein, we have used alkaliphilic *Bacillus alkalinitrilicus* bacterial spores along with its nutrient (calcium lactate) encapsulated in a light weight aggregate (LWA) and introduced in the concrete as a part of the aggregate. Furthermore, another setup was made by direct infusion of this bacterial spores and nutrients into cement. Different hydration periods have been investigated as a part of the study to probe possible hydration effects on the crack-healing activity of bacterial concrete. The ultrasonic pulse velocity technique has been used to detect the crack-repairing phenomenon of the bacterial concrete after continuous sulphate attack over a year. The water absorption, apparent volume of permeable voids, porosity measurements are addressed for the durability aspects. The primary aim is to investigate the healing/sealing of cracks on a scale from a few µm and below before its expansion starts to harm structural integrity. Additionally, we have applied thermodynamic modelling to estimate the crack-healing capacity as a function of crack volume, portlandite content, healing agent and cement volume.
Self-healing cement for oil well applications

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The Self-healing cement project aims to apply a microbially-engineered system for calcium carbonate precipitation in deep sub-seafloor environments to fix cracks formed in cement structures around oil wells and boreholes. At these locations microorganisms must withstand high pH (>10), hydrostatic pressure (up to 30 MPa) and temperature (up to 75°C) - conditions that are only permissive for growth and activity of polyextremophilic microorganisms. We will present results showing the feasibility and kinetics of using bacteria embedded in super absorbent polymers for catalyzing calcium carbonate precipitation. Such polymers can be mixed into cement for obtaining self-healing properties, and bacterial activities can be monitored in situ in the polymer and cement using isothermal microcalorimetry. We will also present results showing how bacterial physiology respond to oil-well conditions including high temperature, hydrostatic pressure and pH. A key finding here being that such multiple extremes can have synergistic effects promoting microbial activities. This is important when evaluating bacterial isolates for use in self-healing cement applications and it furthermore emphasizes the importance of systematically simulating in situ conditions for oil-well microbiology studies.
Optical sensing of pH in oil well cement

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Abstract text

The Self-healing cement project aims to apply a microbially-engineered system for calcium carbonate precipitation in deep sub-seafloor environments to fix cracks formed in cement structures around oil wells and boreholes. The cement matrix however imposes a harsh alkaline environment for bacterial activity to facilitate the precipitation needed for crack healing. An important parameter determining the biocompatibility of concretes and cements is therefore the pH environment. We have implemented the use of a planar optode system that enables high spatial resolution measurements of pH around and in side submillimeter cracks in hydrated oil well cements. Specifically, the optode can image pH with a spatial distribution of 50 μm per pixel and a gradient of 1.4 pH units per 1 mm. The effect of fly ash substitution and hydration time on the pH of the cement surface was evaluated by this approach. The results showed that pH is significantly reduced from pH > 11 to below 10 with increasing fly ash content as well as hydration time. Hereby the cement becomes compatible with microbial activity, which we experimentally validated by embedding bacteria into the cement and monitoring their metabolic activity. In conclusion, our results demonstrate that the pH of class G cements can reliably be measured and modified to sustain microbial activity.
Mechanical testing of oil & gas well cement sheath

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The formation of cracks and interfacial damage at the primary cement sheath compromises the overall structural stability, imperviousness and durability of the system. These cracks also provide a flow path for fluids through the cement sheath. Therefore, it is necessary to investigate the possible flow paths due to crack formation in both interface between casing and cement and in radial direction of the cement sheath. New measurement systems have been implemented to identify and quantify the crack formation. The detection and development of the cracks has been measured using digital image correlation (DIC) and continuous fiber optics measurements.