the ENERGY lab

R&D FACTS

RESEARCH & INNOVATION CENTER

Materials Engineering & Manufacturing

Evaluation of Foamed Wellbore Cement Stability Under Deep-Water Conditions

Background

Foamed cement is a gas-liquid dispersion that is produced when an inert gas, typically nitrogen, is injected into a conventional cement slurry to form microscopic bubbles. Foamed cements are ultralow-density systems typically employed in formations that are unable to support the annular hydrostatic pressure exerted by conventional cement slurries. More recently, the use of foamed cement has expanded into regions with high-stress environments, for example isolating problem formations typical in the Gulf of Mexico. In addition to its lightweight application, foamed cement has a unique resistance to temperature- and pressure-induced stresses. Foamed cement exhibits superior fluid displacement, gas-migration control, and long-term sealing through resistance to cement-sheath stress cracking. As a result, it is often the system of choice for shallow flow conditions and the prevention of compaction damage in deepwater production in offshore environments.

The increased use of foamed cement systems in high-stress environments makes understanding their stability in the wellbore vital. Current testing methods are limited to atmospheric conditions, and there is a significant knowledge gap regarding the stability and properties of foamed cement as it is placed in the well and post-placement. Foamed cement stability depends on time evolution of the gas bubble-size distribution and varies as it is pumped and placed in the well. Unstable foams can result in uncemented sections or channels and failure to achieve zonal isolation. A stable foam provides the desired zonal isolation and casing support when installed properly in the wellbore.

Primary Project Goal

The overall goal of this work is to develop a sufficient scientific base to be able to apply quantitative risk assessment formalism to evaluate the exploration and production of deepwater and ultra-deepwater resources. Adequate definition of materials performance and properties is critical to this effort. The outcome of this project is to develop a dataset comprised of laboratory and field observations to develop an understanding of the stability and properties of foamed cement as it is placed in the well and post placement.

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Objectives

- Address current lack of knowledge and understanding of the stability of foamed cements as they are placed in the well
- Evaluate foam stability, bubble size, and channeling (bubble coalescence) as they are affected by pressure, shear, and cement design
- Correlate atmospheric, laboratory pressure, and field-generated foamed cements

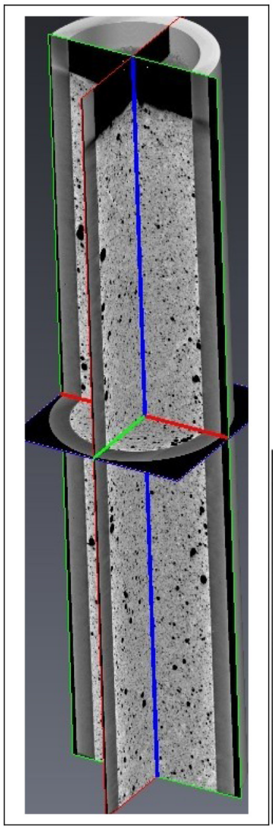
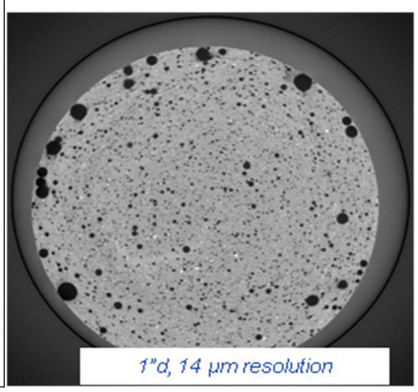


Figure 1. 3D CT scans of a 1-inch cement core.



Project Description

NETL recently completed an assessment report to identify research needs in the cementing of offshore wells, *An Assessment of Research Needs Related to Improving Primary Cement Isolation in Deep Offshore Wells*. The information developed for this report was drawn from a literature search, contacts at various industry professional organizations, and interviews with industry experts associated with the cementing of offshore wells. NETL technical reports can be accessed at the following site: http://netl.doe.gov/onsite_research

NETL is partnering with various industry partners to investigate the properties of foamed cements at various pressures, shear rates, and foam qualities. This study is utilizing NETL's geomechanical testing laboratory and industrial computer tomography (CT) scanner to correlate 3D image datasets of bubble size distribution of foamed cement with materials properties. Sample datasets include (1) atmospheric foamed cement generated using the current API RP 104-B test method across a range of foam qualities, (2) laboratory generated foamed cement under a range of pressures across a similar range of foam qualities, and (3) field-generated foamed cements from three major service companies. A unique methodology was developed and implemented to capture the cement under representative field pressure conditions. Foamed cement was collected into sampling vessels utilizing the same full-scale industrial equipment used to execute wellbore cementing field operations.

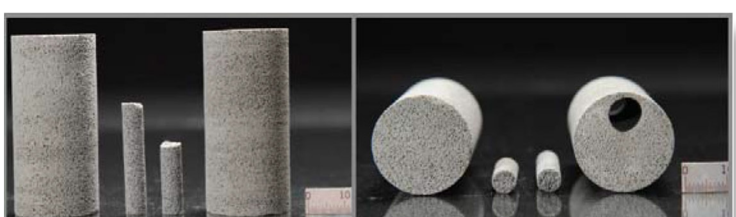


Figure 2. Lab-generated atmospheric 40 percent quality foamed-cement samples.

Figure 3. Field-generated, 2-inch diameter foamed cement sample collected at 500 psi with an overall quality of 20 percent. Outer portion of core shows heterogeneity from emplacement processes.

The increased use of foamed cement systems in high-stress environments makes understanding their stability in the wellbore vital. If the foamed cement is unstable, gas can coalesce, and bubbles will increase in size, causing gas pockets to form and rise in the cement column. Unstable foams can result in failure to achieve zonal isolation. A stable foam will be able to provide the desired zonal isolation when installed properly in the wellbore. This research will help bridge the disconnect that is prevalent between cement as tested in the laboratory and cement as mixed and pumped in the field. Ultimately, this research will provide industry with the knowledge needed to ensure the safe operation of deep and ultra-deep offshore wells in which foamed cement systems are used.

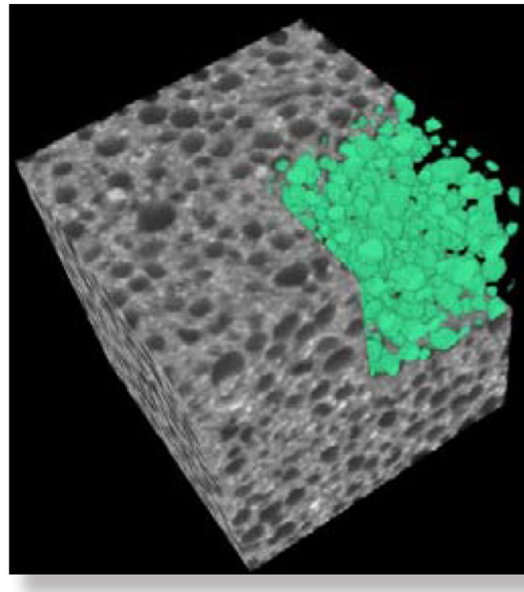


Figure 4. Segmented portion of 30 percent quality atmospherically generated foamed cement scanned with NETL's high-resolution industrial CT scanner. Cement displays fairly homogeneous distribution of voids.

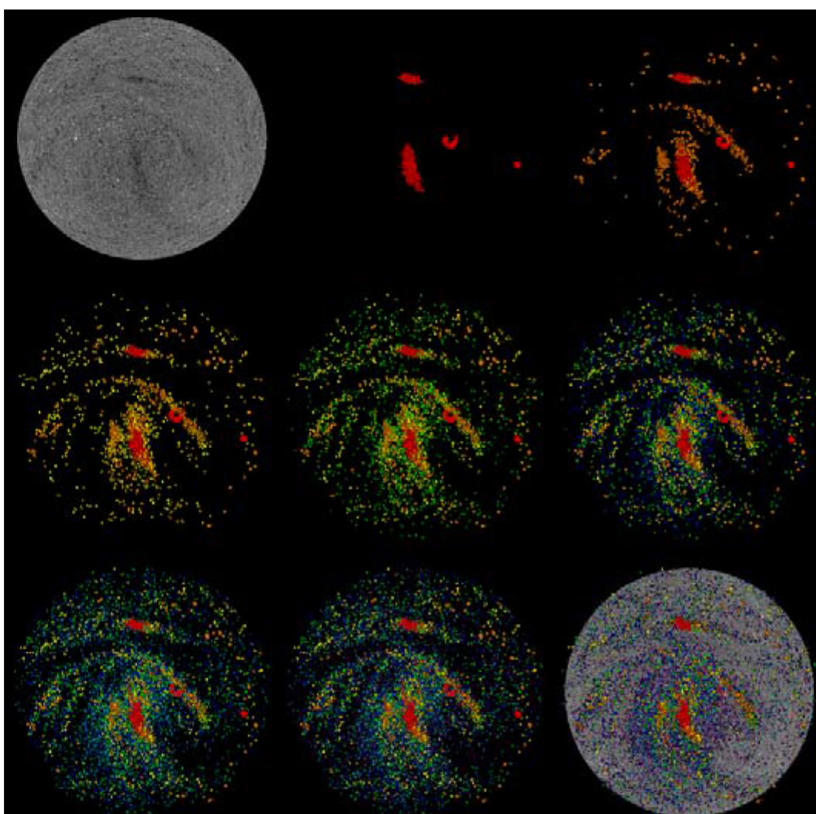


Figure 5. Segmented portion of field-generated foamed cement scanned with NETL's high-resolution industrial CT scanner highlighting the largest (red) to the smallest (violet) voids within the cement.

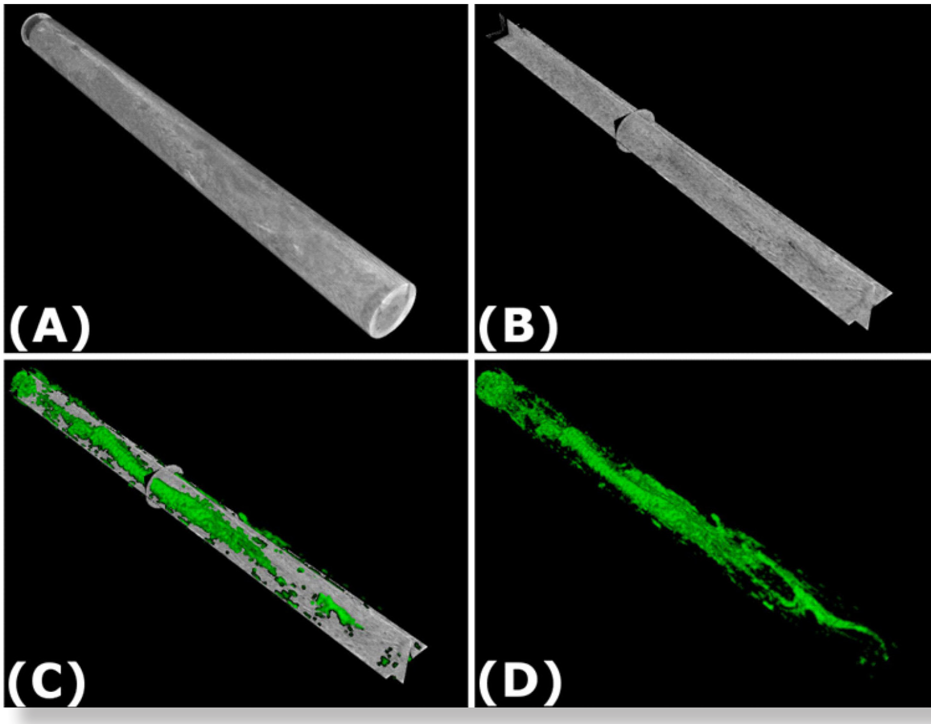


Figure 6. Three-dimensional reconstructions of CT scans of pressurized field-foamed cement in a 3-foot-long vessel. The injection port is in the bottom-right of each image; the retracting piston is in the top-left of each image. The top-left image is a reconstruction of the entire cement sample. The top-right image is an orthoslice along the primary directions of the vessel. The bottom-left image is an othroslice and a 3D rendering of isolated low-density zones. The bottom-right image is a 3D rendering of just the low-density zones.

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