Ultra-Lightweight Cement Slurries Improve Cement Performance

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Cementing systems using ultra- lightweight hollow spheres can improve lightweight cement performance in deepwater operations and provide a viable alternative to conventional lightweight cement slurries.

In today's critical deepwater wells, the use of ultra-lightweight cementing systems could improve well performance by enhancing zone isolation and reducing cementing failures. Many deepwater operations, especially in the Gulf of Mexico (GOM), are characterized by unique conditions that require high-strength, lightweight cements capable of withstanding cycling stresses for extended periods of time.

Results of a recent Department of Energy (DOE) project demonstrate that ultra-lightweight cement slurries using new ultra-lightweight hollow spheres (ULHS) provide higher compressive strengths at lower densities and outperform conventional lightweight cement slurries in long-term durability.

Based on an industry survey conducted by Westport Technology Center in 1997, an average 5 percent of total well costs were spent on cementing (total industry expenditure of $1.8 billion/year), and the average failure rate of cementing jobs was 15 percent. For these cases of failure, cementing costs rise to 17 percent of total well costs. These costs amount to an estimated $470 million/year to repair cementing failures. About one-third to one-half of these failures could be prevented with an effective lightweight cementing system.

In this project, *Cementing Solutions, Inc. (CSI),* sponsored by the DOE's National Energy Technology Laboratory and industry representatives, studied the effects of using ULHS to improve cementing systems, and the ability of ULHS to provide improved cement performance. The objective of the project was to develop cementing systems using ULHS for deepwater and other critical applications, test the physical performance of the cement slurry, and compare test results to the performance of conventional lightweight cements. Results demonstrate that ultra-lightweight cements exhibited high strength, low permeability, easy slurry designs, and durability.

Limitations of Conventional Lightweight Cements

Conventional lightweight cements typically use water as the lightweight agent to decrease density, and include materials that absorb the water and keep the slurry and cement homogenous. These conventional cements, though low in cost, exhibit some severe drawbacks; they achieve very low compressive strengths and have difficulty providing long-term zone isolation under severe stress conditions. In addition, these cements have a minimum density limit of 11.5 lb/gal.

Conventional hollow glass spheres have been used to achieve densities as low as 9.5 lb/gal, however, they are limited in application because of the low crush strength of the beads under pressure. This factor limits the use of these products in many applications.

Foam cements using nitrogen are commonly applied to prevent lost circulation in low-pressure reservoirs, but foam cements have high permeability and low strength, resulting in cementing failures and higher completion costs. In foam cement, nitrogen-filled void spaces can connect to form passageways that allow fluid migration through the cement, leading to cement failures. Additional limitations often seen with foam cements include: higher friction in the well (which can lead to lost circulation), inconsistency in application, difficulty in controlling the cementing job at the surface, lack of quality assurance, and the inability to measure bond strengths with sonic and ultrasonic evaluation tools. Despite these problems, foam cement slurries are currently the industry preference for attaining acceptable densities during critical cement operations.

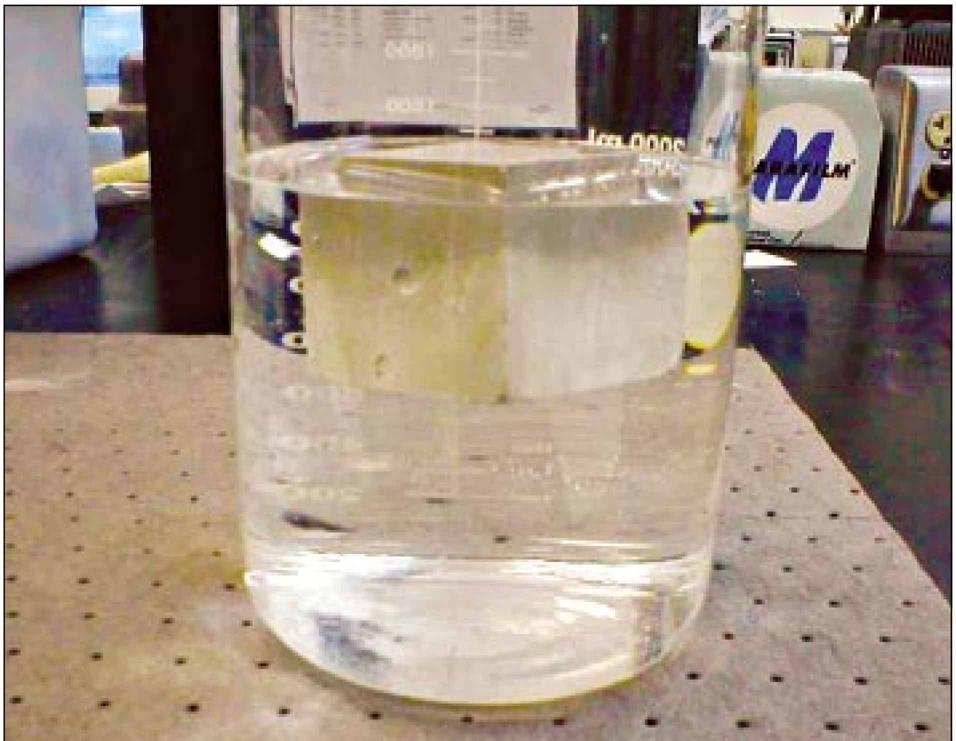

Figure 1: ULHS Slurries Exhibit Densities Less Than Water

Technology Advances in ULHS

Although efforts to improve the quality of zone isolation through the use of lightweight foam slurries have made progress, current data indicates a continuing problem in maintaining a long-term seal with conventional cementing systems. The U.S. Minerals Management Services estimates that 11,000 out of 14,000 producing wells in the GOM have gas pressure on one of the annuli. This figure amounts to more than 70 percent of the producing wells in the GOM. Ultra lightweight cement slurries could significantly increase the success of cement jobs in critical applications.

Although lightweight hollow spheres have been used in the industry for some time, recent technology advances have improved the hollow spheres to be ultra-lightweight, while exhibiting superior crush strengths of 3,000 to 10,000 psi. These ULHS can attain a specific gravity of as low as 0.32 to 0.46 (Figure 1), while resisting wellbore pressures as high as 6,000 psi (Figure 2). While traditional lightweight hollow spheres have achieved low specific gravities (0.67), they fail to withstand high pressures, collapsing in higher-pressure operations. This limits their application to more shallow wells. An added benefit is that ULHS cement slurries are easy to design, mix, and pump.

Project Data and Results

The project team for this effort combines some of the best industry expertise to ensure that the data collected has the widest possible applicability. The project steering committee, comprised of operating companies, service companies, and materials and equipment suppliers, includes representatives from *ExxonMobil, Shell, BJ Services, Halliburton Energy Services, Schlumberger, 3M* (ULHS supplier), *TXI* (cement supplier), and *Chandler Engineering* (laboratory equipment supplier). The $1.13 million, two-year project was funded in part by DOE ($670,000) and in part through industry cost shares ($460,000).

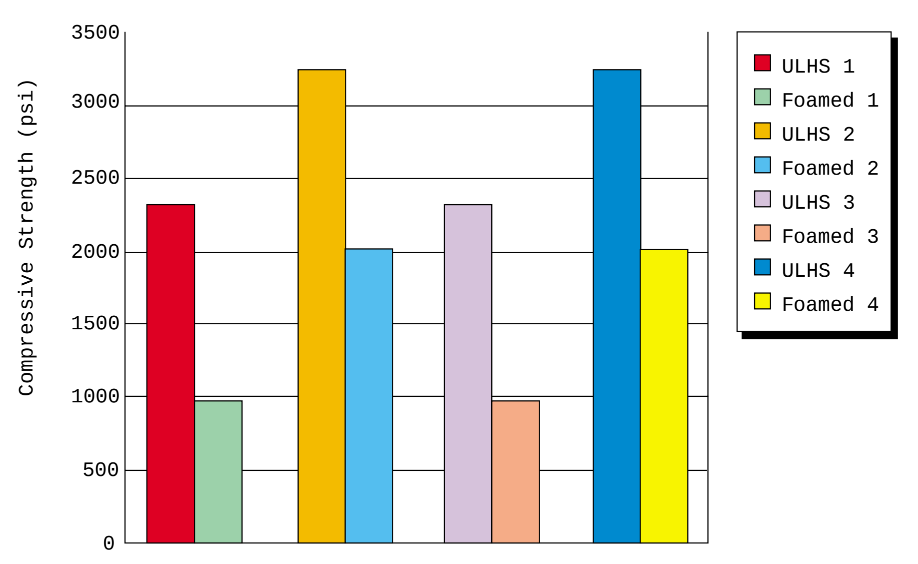

Figure 2: Foam vs. ULHS Compressive Strength Testing at 10.0 lb/gal and 11.5 lb/gal for Four Different Test Conditions

To ensure that the results obtained provide significant value to the industry, the tests were designed and applied to conditions drawn from more than 5,000 data points from field jobs in the U.S. supplied to *CSI* by service companies. *CSI* used these data to determine the conditions under which lightweight cements are most commonly used, as well as to define the type of operations currently being performed in deepwater wells.

In addition to standard testing of cementing slurries containing ULHS, *CSI* performed a unique combination of tests to measure a slurry's ability to withstand formation stresses over long periods of time. Although the mechanical properties of formations are commonly tested, the same mechanical properties tests are not commonly used to test cement. Triaxial load was applied to the samples to simulate wellbore conditions, and the samples were also tested for Young's modulus and tensile strength.

Stress cycling tests were also performed to ensure that the ultra-lightweight cement slurry could withstand the changes in temperature that occur within deepwater wells. Stress cycling within a well can cause the cement-to-pipe bond and ultimately the cement seal to deteriorate. Test results using the ULHS slurry indicated that the slurry could withstand cycling temperature changes of 135°F.

Additionally, special test cells were designed to test the cement's shear bonding capability in both the hard formations typically found on land, as well as in the soft formations common to deepwater wells in the GOM. To prove the value and strength of ULHS, *CSI* had to ensure that ULHS could withstand the stresses found in both types of formations. In both cases, test results indicated that the ULHS slurry could withstand a differential pressure stress of 5,000 psi.

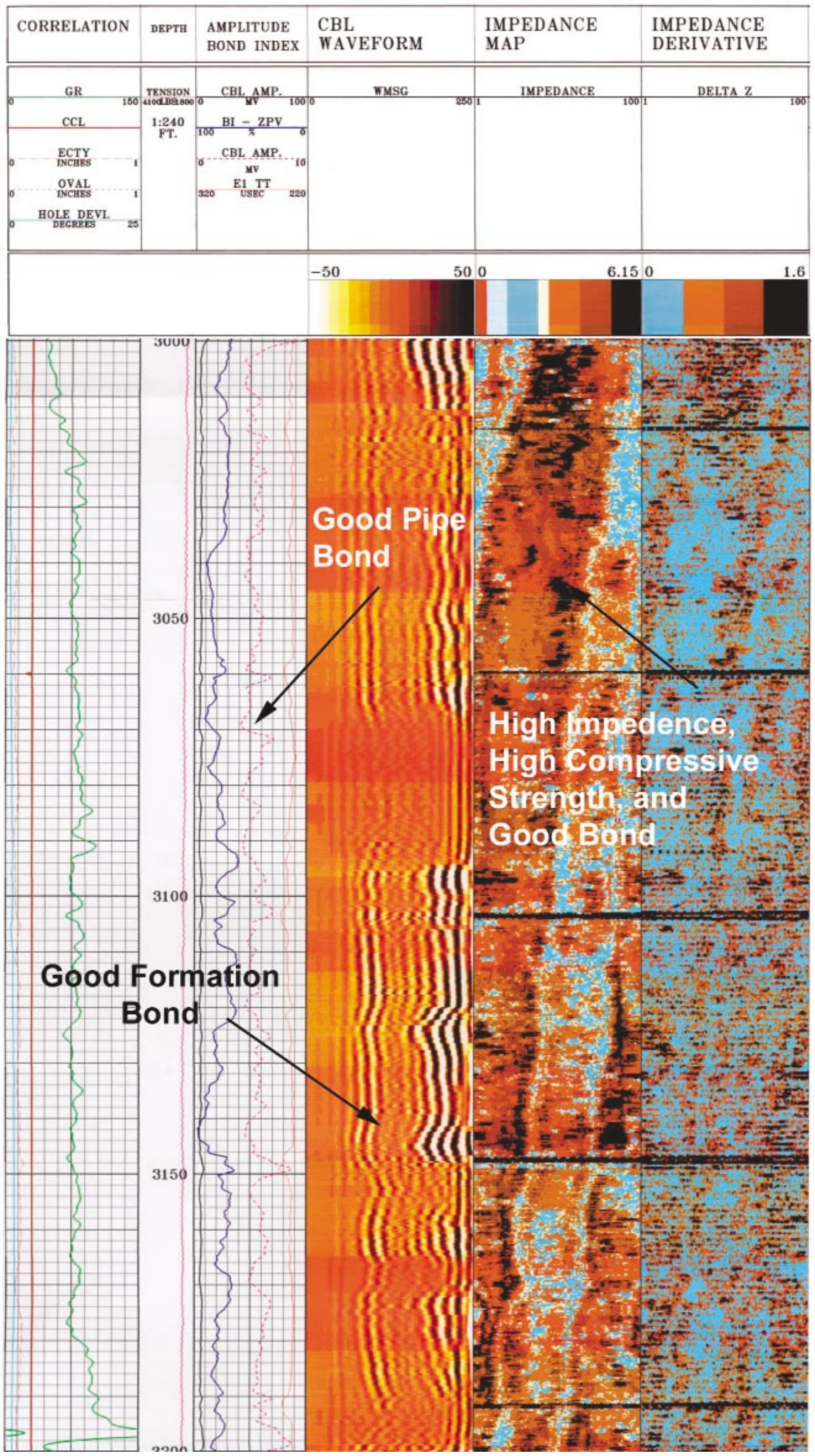

Figure 3: CBL and Ultrasonic Log for 10 lb/gal ULHS Slurry

Field Test Results

Two field tests were designed to test the slurry's performance in actual formations. The first field test was designed to ensure that the slurry could be easily blended, mixed, and pumped on location with little trouble. The second field test was designed to test the slurry's performance in a land-based well that closely resembled deepwater operations. A summary of the field test parameters and results is shown in Table 1.

The first field test was performed on a South Texas well operated by *Conoco*. The slurry was easily blended on location, and was mixed and pumped in the well with no problems. The second field test was performed in the Rocky Mountains in a well operated by the DOE and RMOTC in Wyoming. This well had been previously cemented with foam cement and although there were problems with lost circulation, the well required high-strength cement and good zone isolation. One hundred barrels of the ultra-lightweight cement slurry (using 3M 6K ULHS beads) were mixed and pumped with no problems, and the ULHS beads showed no breakage after one hour of conditioning at the surface. Ultrasonic logs performed on the well after the cement operation showed excellent application of the slurry, good bond properties, and good perforating qualities (Figure 3).

Next Steps

With the field-testing phase of the project complete, the next phase of the project includes transferring this technology to the industry. This phase of the project will be accomplished by leveraging the technology transfer capabilities of the joint industry partners, by publishing information in various publications, through seminars and training, and through technology transfer meetings. This phase of the project is expected to begin in early 2003.

Future applications for this product include: critical operations requiring the use of lightweight cements, wells with formation damage occurring from treatments with conventional cements, and coal seam wells. Because of its high strength, low permeability and low density, this slurry would provide excellent bonding in deepwater offshore wells, or high temperature, high pressure land-based wells. ■

For additional information about the results of this project, or for information on ultra-lightweight cement systems, contact Fred Sabins, Cementing Solutions, Inc., at 713-957-4210 or by email at f.sabins@cementingsolutions.com. For additional information about this project, visit the "What's New" page at CSI's website: www.cementingsolutions.com.