SUCCESSFUL TOP OF CEMENT ACHIEVED IN TROUBLE WELLS WITH A CONFORMANCE PRODUCT

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ABSTRACT

When dealing with cementing operations with problematic formation issues, achieving satisfactory top of cement (TOC) is essential. A central Texas operator encountered zonal isolation challenges that resulted in inadequate TOCs. One of those challenges was achieving a density both above the pore pressure and below the fracture gradient. In some wells, this density window was as narrow as 0.02 to 0.04 psi/ft. Karsts and tectonic-fractured formations exist in this field, which often result in uncovered zones and TOCs at unacceptable levels. Formations such as these, with heavy erosion and cave-related brecciation, can have huge voids at volumes that are nearly impossible to measure. To meet regulatory requirements and achieve successful zonal isolation, competent cement sheaths are necessary. Initially, expensive cement-squeeze applications evolved as the zonal isolation effort was initiated in these trouble wells. However, it was decided to use a conformance product to allow the cement column to exist at a high enough level to be deemed a successful solution without the aid of the squeeze application. This paper presents a case history of several central Texas wells in which satisfactory TOC was difficult to achieve. The challenge was to get cement high enough to meet regulatory requirements, without having to perform a squeeze job. The wells discussed exist in an environment with washed out formations occurring in a narrow window of design density. The design criteria involved overcoming these washed out regions that consume cement volume. The service company provided a solution of using a conformance product to achieve adequate TOC without the aid of a squeeze application. This paper compares several wells before and after using this water super-absorbent polymer procedure, demonstrating an improved percentage of adequate TOCs and significant cost savings to the operator.

INTRODUCTION

Cement placement was desired where cement filled the volume without breaking down the formation, squeeze work was not required to lift the TOC to cover the zone, and economic goals were achieved. The operator was experiencing difficulty meeting these criteria when cementing in this area. The main issues were primarily related to the formation, which, as previously mentioned, was one of karst and brecciated cave-ins. As volumes of cement were pumped, the operator still required cement-squeeze work to achieve an adequate cement top. An expensive problem was becoming even more so. Basic engineering solutions were sought to address the costly issue. The service company was asked to provide a solution based on experience with both the geographical area and conformance materials. A successful solution was presented.

BACKGROUND

Many central Texas wells with formation issues experienced trouble achieving adequate TOC. The wells were observed before and after the water super-absorbent polymer conformance solution was initiated. Before the conformance solution was executed, TOCs were inadequate and a squeeze job was necessary. If cement was not brought up to an acceptable level, squeeze holes would have to be shot and the cement top lifted to satisfy requirements. Of the wells that were cemented before the process was applied, none circulated cement, and almost all wells required the aid of a cement squeeze. Out of the wells squeezed, only 50% were successful after only one squeeze. Of the 102 wells cemented using the water super-absorbent polymer process, only one required a squeeze job and many of the wells circulated cement.

In addition to the success using the water super-absorbent polymer procedure, this paper discusses possible solutions considered by the operator to address the trend of unsatisfactory TOC in these wells with formation problems. Possible choices considered were use of a whipstock plug, cement squeeze, plug to abandon, conventional plug, and a lost-circulation plug. Stage tools and cement baskets were also attempted in the design phase, but were unsuccessful because of a crossflow in the formation.

POSSIBLE CAUSE OF PROBLEM—FIELD ACTIVITY

Well production or injection, activity, and/or natural erosion can modify reservoir properties as a result of degradation of the rock. Injectivity of pressure support or long and extremely large volumes of flooding systems can cause vast variances in permeability compared to the original exposed formations, having been changed because of the erosional effects and dissolution of the formation rock (Creel et al. 2005).

Also subject to variances in permeability are wells that have been producing or injecting for long periods, thus experiencing numerous geological events.

GEOLOGY—KARST ENVIRONMENT

Certain geological sequences of events have created interesting challenges to cementing programs. The area in Crockett and Sutton counties comprises a cave network. Historically, karsted reservoirs have been poorly understood. A carbonate depositional environment that experiences a relative fall in sea level shortly after deposition of the system, tectonic uplift, and/or an emergence of the depositional system to permit the operation of surficial processes should theoretically experience karstification. In those areas in which the water table has fluctuated over time and the carbonates remain shallowly buried or exposed, significant karst dissolution can be generated. This appears particularly important when extrinsic factors, such as climate, sea level, and the presence of vegetation, interact with favorable intrinsic factors, such as lithology, structure, and statigraphy. Only those carbonate systems that are buried rapidly and experience rapid diagenesis and are never brought up to the surface or the shallow near-surface will avoid karst effects (Mazzullo and Chilingarian 1996).

Breakdown of a breccia zone is delineated on the floor of the karst system. This breccia was largely sourced for the overlying roof and adjacent cavern sides during collapse. It overlies or is deposited on what appears to be an intact (unbrecciated) rock mass. So, the karst cavern is filled with breccia sourced from the roof and walls, along with other sediment material transported to the system along channels. The roof of the system is then delineated by incipient breccia or “crackle breccia.” The “crackle breccia” forms as stress is redistributed above the original karst cave. **Figure 1** illustrates the cave-related breccation process.

In support of the factors necessary to create a karst environment, a report by the US Geological Council noted the following: “The surface stream water indicates a carbonate subsurface environment with erosion to the bedrock taking place. The major cations in streamwater were calcium and magnesium, and bicarbonate as the predominant anion. The predominance of these solutes in stream water is attributed to the weathering of carbonate minerals in the underling limestone and dolomite bedrock (Mast et al. 1999).

POTENTIAL SOLUTIONS

Diverters

While most diverters are typically associated with matrix acidizing, diversion can also be used in other treatments, such as cementing wells. These also include conformance, scale squeezes, sand consolidation, and hydraulic fracturing (Reyes et al. 2010).

Possible diverters to consider are conformance products and any bridging agent, such as lost-circulation materials (LCMs). Diverters can be both mechanical and chemical.

TOPPING-OUT CEMENT

Top-out jobs can be performed on wells in which regulation requires the well to circulate cement. If cement is not initially lifted high enough, then regulatory agencies recommend performing a top-out cement job. Here, the cementing company will rig up 1- to 2-in. pipe to the annulus open-ended and pump cement, letting it gravity fall to move cement to the surface. Generally, Class C neat cement is used with the possible addition of an accelerator. Although being able to perform a top-out cement job would be considered a success, the cement top still must be at a high enough level for permission to top out to be granted.

LIGHTWEIGHT CEMENT SLURRY

By not “breaking down” the formation, it is difficult to achieve a higher TOC, especially for a well with lower fracture gradient. Therefore, cement density reduction can be used to reduce the hydrostatic pressure of the cement column. Current industry technology allows density reduction by means of three different mechanisms: addition of extra water, foaming the cement slurry, and bulk blending microspheres into the dry cement powder (Kulakofsky et al. 2003). Each of these methods is discussed in more detail next.

Water-Extended Slurry

The most simple and least expensive method to reduce slurry density is to add water. The major benefit to this method is the lower cost because water is relatively inexpensive. While this is probably the most widely used practice in the industry, there are some downsides, such as free water, lower compressive-strength development, and slurry-stability problems (Reyes et al. 2008).

Foamed-Cement Slurry

Another option for lowering the cement-slurry density is to inject gas, most often nitrogen, into the cement slurry, resulting in a foamed slurry. The benefits include increased elasticity of the “cured” cement (McCulloch et al. 2003), increased compressibility of the liquid slurry, and provision of operator ability to easily change design density as well/job conditions change. Increased elasticity helps the cement maintain its seal in the presence of outside stresses (Tahmourpour et al. 2004).

Low-Specific-Gravity Additive Cement Slurry

A third option for achieving lightweight cementing for oil and gas wells is by adding a low-specific-gravity additive, or hollow beads. These beads are microspheres, which are batch mixed with the dry cement. They are available as solid plastic beads of approximately 1.0 specific gravity, hollow pozzlanic spheres of approximately 0.7 specific gravity, and hollow glass bubbles of a 0.32 to 0.61 specific gravity. This method is explained with more detail in Reyes et al. (2008).

CONFORMANCE MATERIAL—WATER SUPER-ABSORBENT POLYMER

The water super-absorbent polymer was designed to alleviate injected fluids in flood situations from flowing into fractured or highly vugular, karsted, or eroded zones where the flood injection fluids could eventually communicate directly with the producer.

. The use of water super-absorbent polymer is a patented process and uses a water-swellable synthetic polymer capable of absorbing 30 to 400 times its weight in water **(Figure 2).** Benefits of this conformance material include

- Helps improve sweep efficiency of injection systems
- Helps increase production from mature fields
- Is effective within hours
- Can be added on-the-fly with standard pumping equipment
- Water absorption is controllable
- Resistant to CO_2 contamination, acid contamination, and H_2S environments
- Withstands water influx and prevents the dilution of cement
- Nontoxic and environmentally acceptable, as it contains no heavy metal crosslinker
- Can be removed with an oxidizer or bleach compound

The swelling rate is controlled by the carrier fluid (salinity) and temperature **(Figure 3).** Depending on the well situation and swell time desired, the carrier fluid can be NaCl brine, KCl brine, CaCl brine, produced water, seawater, or fresh water. The service company also used porosity-filling conformance materials that helped broaden the ability to be creative with solutions and provide options to address well issues.

This conformance material was also used on the karsted wells discussed in the following case histories to help provide the cement-slurry a material to bridge against while lifting cement higher in the annulus to the desired TOC.

CASE HISTORY

These wells are located in Sutton and Crockett counties in the northern area of the field. Before the water super-absorbent polymer application, the typical well string was drilled to an undisclosed depth using 8 5/8-in. casing and a 12 1/4-in. drill bit.

In March of 2008, the drilling program moved south, where the first lost-circulation problem was encountered. A lost-circulation plug was set at this depth and shut down for 18 hours to wait on cement (WOC). Then, drilling resumed and casing was set two days later. Using 300 sacks of cement with 2% calcium carbonate and a 3-lbm/sack of LCM, most of the problems were alleviated. During May to April of 2008, a LCM was set using 350 to 400 sacks of cement, 3% calcium carbonate, and a 4-lbm sack of LCM. Then, after WOC, the well was drilled through and the casing set. Starting in May of 2008, the operator observed the TOC at a lower depth than desired after setting the lost-circulation plug and drilling to total depth and setting the casing. Typically, squeeze holes were shot with the packer run-in-hole and a squeeze cement procedure with 400 sacks of cement, 3% calcium carbonate, and 4-lbm sack of LCM. Usually, the first squeeze was unsuccessful and another squeeze was required. Cement tops continued to remain low.

SOLUTION

On Well A1, the first attempt to use the conformance material was to achieve a higher TOC. A total of 220 lbm of water super-absorbent polymer was set in 20 bbl of fresh water. Shutdown occurred after running the water super-absorbent polymer in place for 30 minutes. During this time, the water super-absorbent polymer started to swell. Then, 135 sacks of cement with 3% calcium carbonate with 10% accelerator followed by 200 sacks of cement with 2% calcium carbonate were pumped. A temperature survey was run and indicated TOC at a satisfactory depth with adequate zonal isolation. With TOC at this level, a top-out job could now be run instead of a cement squeeze operation. This was a success. Moving forward, the plan was to continue running the conformance-material product on all wells in front of the cement. It was known that all wells would not be problematic, but treating every well helped ensure that the trouble wells were addressed without having to perform squeeze work. The price for running the conformance material on all the wells was cost-effective compared to not running and performing squeeze work on the wells that encountered TOC issues.

ECONOMICS

The incremental cost per well for performing the polymer treatment was approximately 25% of the cost that would have been estimated for squeeze applications, considering the success rate on previous wells. **Table 1** shows a 56% success rate of squeeze applications on these previous wells, indicating that multiple squeeze applications were required in many cases in this area.

After observing 102 wells since the polymer program began, only one well to date has required a cement squeeze job. This amounts to a success rate of 99% using the polymer system. Many of the wells now circulate cement. Before the conformance-material program was implemented, there were no wells that circulated. For the 102 wells in which the program has been implemented so far, it has saved the customer significant time and money. The cost to perform this process is 25% of the potential cost associated with not doing it. This equated to cost saving to operator of 75%. The success of this program has also saved rig time and improved overall time to production for these wells.

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TABLE 1—SNAPSHOT OF WELL SUCCESS PERCENTAGE BEFORE CONFORMANCE MATERIAL							
No. of Jobs	No. of Sqz	No. of Wells	Success, Y/N	Squeeze Success, %	Well No.	Job Type	Job Date
1					F-001	Whipstock	19-Mar
2	1	1	Y	100%	303	SQZ	9-Apr
3					202	Whipstock	25-Apr
4					203	Whipstock	28-Apr
5					202	Whipstock	28-Apr
6					A-202	Whipstock	29-Apr
7					A-202	Plug Back	2-May
8	2	2	N	50%	A-202	SQZ	7-May
9	3	2	N	33%	A-202	SQZ	9-May
10					A-204	Whipstock	10-May
11	4	2	Y	50%	A-202	SQZ	11-May
12					A-202	PTA	13-May
13					A-205	PTA	3-Jun
14					304	PTA	18-Jun
15					301	Plug	11-Jul
16					101	Plug	26-Jul
17					A-205-X	Lost Circ	10-Aug
18	5	3	Y	60%	A-205-X	SQZ	16-Aug
19					A-202 X	Lost Circ	26-Aug
20					A-202-X	Whipstock	28-Aug
21					201	Whipstock	9-Oct
22					302	Whipstock	20-Oct
23					A-206	Whipstock	22-Oct
24	6	4	N	50%	A-206	SQZ	28-Oct
25	7	4	N	43%	A-206	SQZ	30-Oct
26	8	4	Y	50%	A-206	SQZ	31-Oct
27					202	Lost Circ Plug	5-Nov
28					306	Circ Plug	16-Nov
29					102	Whipstock	18-Nov
30					45-21-5	Whipstock	3-Mar
31					B 101	NoSvc Misc Pta	11-Oct
32					B 201	Lost Circ Plug	18-Oct
33					303	Lost Circ Plug	31-Oct
34					1	Lost Circ Plug	31-Oct
35					5-2-1	Lost Circ Plug	1-Nov
36					5-2-1	Lost Circ Plug	2-Nov
37					B 102	Lost Circ Plug	10-Nov
38					5-2-1	PTA	3-Nov
39					B 102	Lost Circ Plug	10-Nov
40	9	5	Y	56%	5-2-1X	SQZ	19-Dec

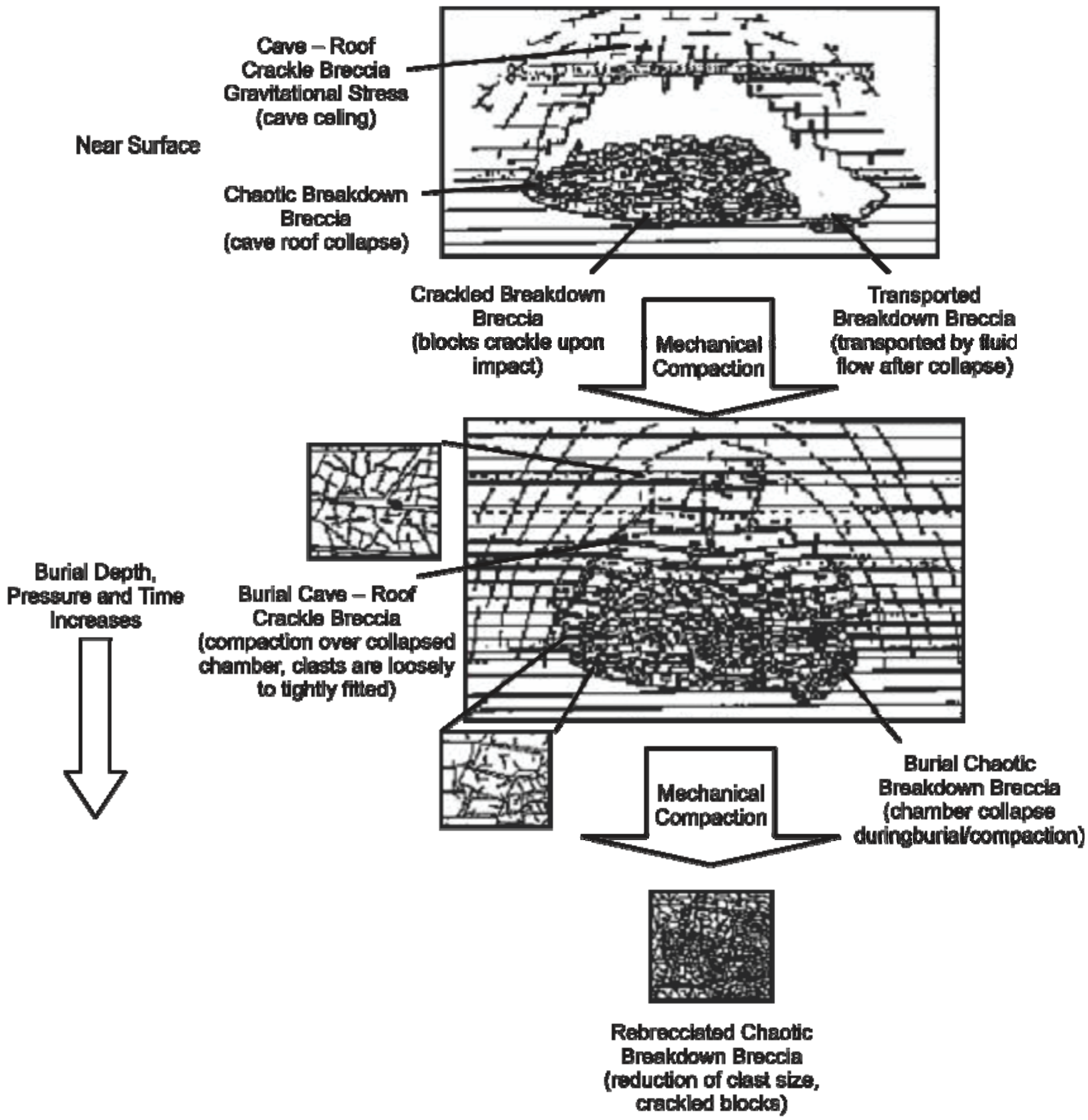

Figure 1—Schematic diagram illustrating effect of burial on karst-related dissolution and brecciation process. Above the horizontal line is Near-surface; below is burial as depth increases (Hoak et al. 2011).

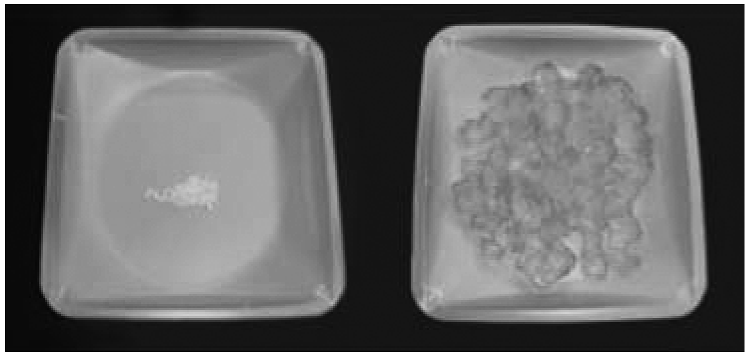

Figure 2—Equal amounts of material before and after swelling. Time elapsed was three hours using dyed water to make material more visible.

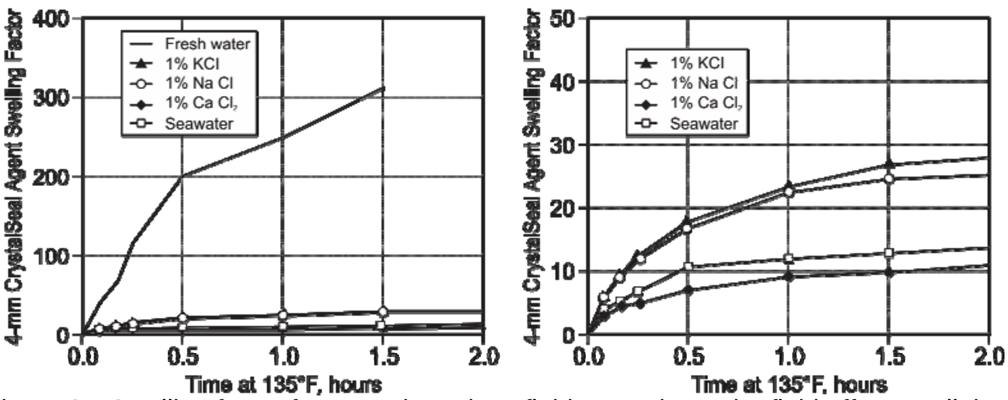

Figure 3—Swelling factor for agent in various fluids. Ions in carrier fluid affect swell time.