IMPROVED BONDING AND CONTROL OF ANNULAR FLOW ACHIEVED WITH EXPANSIVE CEMENT

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ABSTRACT

Poor bond logs and high water production have plagued a certain development field. Introduction of a unique expansive admix has brought a dramatic switch from failure to success in this trouble area. This has resulted in good bond logs, reduced water production, and is expected to decrease future problems with casing corrosion. All components necessary for chemical expansion are included in the admix to make it more versatile than standard chemical expansion additives.

Field results will be used to document the positive results achieved in this development field. Case histories will be given for a number of these wells as well as a discussion of cementing techniques used.

INTRODUCTION

A developmental field in west Texas was plagued by poor cement bonding obtained from primary cement jobs across production intervals. Consequences of this problem included interzonal communication resulting in high water production and shortened well life due to corrosion.

To solve this problem various different "expanding" cement systems were tried. These cements, however, provided little improvement to bond logs and production profiles.

A new cement admixture was incorporated into the cementing program which, when tested in the laboratory under given well conditions, consistently had good expansive properties. The additive itself utilizes similar chemical reactions that standard expansion additives rely upon, but is not cement dependent for its effectiveness. The end results of using this new admix were (1) substantial improvement in bonding, and (2) reductions in water production.

A discussion of this admixture will be given, followed by field results of its use, to demonstrate its effectiveness in eliminating microchannels and improving cement bonding and well production.

THEORY

There are two types of expansive additives being used today. One is a chemical admixture which utilizes crystalline growth to cause the cement to expand.[1] The other expands by in-situ gas generation while the cement is still in a plastic or unset state.[2]

The crystalline reaction depends on tricalcium aluminate (C_3A), which is found in varying quantities in most Portland cements. The maximum expansion is limited by the amount of C_3A in the cement being used. Maximum allowable C_3A content for API Classes C, G, and H cements is 8% for moderate sulfate resistant cement specifications, and not all of this is chemically active or usable. Class C cement used in this area of Texas contains essentially zero percent C_3A, which makes significant expansion nearly impossible to obtain using traditional expansion additives.

To overcome problems of low C_3A content, an expansive admixture has been formulated which supplies the necessary components to provide cement expansion. This eliminates any dependence upon the base cement's chemical composition and makes it effective with any type or class of Portland cement.

An interesting aspect of this admixture is the relationship between compressive strength development and linear expansion that exists when it is incorporated into the cement blend. One would expect that cement blends with a high C_3A content would yield greater linear expansion; however, this did not prove to be the case. Laboratory tests have shown that this admixture provides greater expansion when added to a lower strength 50:50 pozzolan:Class C cement blend which contains zero percent C_3A, than with a 100% Portland Class A cement system.[2] This phenomenon is thought to be due to the lower and slower compressive strength development of the pozzolan and cement mixture. Apparently, lower restrictive forces are exerted upon the crystalline growth, allowing for greater expansion before the cement attains a "final" set.

Past studies have repeatedly shown that the expansion yield of single component, and some composite expansive additives, will decrease rapidly with temperature. Typically, maximum expansion occurs at low temperatures (80 to 110°F) but is reduced by as much as over 80% as temperatures approach 170°F. However, this new expansive admix can still provide worthwhile expansion at temperatures up to 170°F.

CEMENTING PRACTICES

It must be kept in mind that when chemical expansion admixtures are used in a cement system, optimum results will only be obtained when good slurry design and job procedures are followed. Effective displacement techniques[3] must be considered to help ensure that the cement displaces the mud and forms a uniform sheath around the pipe. If there is no cement behind the pipe to start with, it obviously cannot be expected to provide a good bond. Cement design must also consider the following slurry properties:

1) Free Water: High free water separation can leave void spaces in the cemented annulus, exposing the pipe to corrosion and allowing fluid flow.

2) Thickening Time: Excessively long thickening times have been found to reduce linear expansion.[2]

3) Fluid Loss: Fluid loss control is beneficial in any cement slurry that is used to prevent microchannelling by annular fluid migration. Volume loss resulting from filtrate loss from the cement slurry is the driving force that permits pressure to drop in an annulus and allows fluid invasion.

FIELD APPLICATION

A particular oil field in west Texas, dating back to the 1920's, had been troubled with high water production from a zone near the production interval charged by water injection. Communication of water was most likely due to channelling in the cemented annulus, which often appeared on bond logs. The corrosiveness of the water also posed a threat to the longevity of the wells in this field.

Various changes were made in the cementing program over the years to cope with these problems. Cement systems containing conventional cement expansion additives were used to obtain expansion to close the microchannel. However, due to the probable lack of one or both of the reactants for the chemical reaction, it is doubtful that much useful expansion was realized. Lost circulation material was also used, but neither it nor any of the other systems were successful in stopping the water flow.

The new expansion admix was incorporated into the cementing program in a 50:50 pozzolan:Class C cement blend with fluid loss control. The use of a pozzolanic cement blend allowed for more expansion than higher compressive strength cement systems. Even though this cement had zero percent C_3A, laboratory tests indicated that it had 0.66% linear expansion in 28 days (Table I), which is significantly higher than the 0.3% that would be expected with a Class A cement (high C_3A) plus a traditional expansion additive. Test results also demonstrate that this blend had 360 psi compressive strength in 12 hours and nearly 2000 psi in 4 days (Table I).

Field results demonstrate significant improvements being obtained with the new expansive admix. Bond logs from 18 production casing cement jobs showed only one well to positively exhibit some microchannelling. CBL's from two other wells indicated the presence of very slight microchannels. Prior to introduction of the expansive admix in this field, approximately 35 to 40% of the wells exhibited severe microchannelling. Studies conducted on several wells demonstrated that water and gas were communicating through microchannels into the oil producing zone. Wells cemented with the expansive admix have exhibited higher than average oil production, with less gas and water than previous average field production.

A final benefit that will not be realized for some time is the increased lifetime of the wells. Past experience has shown that wells with poor bond logs in this area have been deteriorated by corrosive water rusting out casing, while wells that show good bond logs last longer.

Case History No. 1:

The case history of a specific well in this field indicates the type of problems commonly encountered before this expansive admix was employed. In this example, lost circulation material and accelerators as well as a reactive preflush were incorporated in the cementing program for this well. Despite the success achieved with similar cementing programs in other fields, poor bonding and indications of microchannelling were observed in the productive interval following the primary cement job. Following a squeeze job the interval was perforated and acidized, yielding 29 BOPD and 2266 BWPD. To further reduce water production additional squeeze jobs were performed, five in all, before a squeeze pressure of 1700 psi was finally achieved. After acidizing the perforations, production stabilized at 558 BOPD and 114 BWPD.

Case History No. 2:

A 7 in. casing was set at 1360 ft. in a 9 in. hole. Last casing was an 8 5/8 in. at 950 ft. Lead and tail slurries were used to cement the well. They consisted of:

Lead Slurry: Class C cement + 5 lb gilsonite/sk + 0.75% fluid loss + 7.01 gal water/sk; 14.1 lb/gal, 1.49 cu ft/sk

Tail Slurry: 50:50 Class C cement:pozzolan + 2% bentonite + 5 lb gilsonite/sk + 14% expansive admixture + 0.5% fluid loss; 5.69 gal water/sk, 14.3 lb/gal, 1.40 cu ft/sk

Results: Laboratory test data indicate that the tail cement blend had 0.342% linear expansion in only three days, and 0.656% in 28 days. During the job, cement was circulated to surface. Afterwards a CBL was run, showing a slight microchannel. Production stabilized at 187 BOPD with 12 BWPD.

Case History No. 3:

Again a 7 in. casing was set in a 9 in. hole at 1544 ft. The last casing was an 8 5/8 in. at 959 ft. Lead and tail slurries consisted of:

Lead Slurry: Class C cement + 5 lb gilsonite/sk + 0.75% fluid loss additive + 1/4 lb cellophane flakes/sk + 7.01 gal/sk water, 14.1 lb/gal, 1.49 cu ft/sk

Tail Slurry: 50:50 Class C cement:pozzolan + 2% bentonite + 14% expansive admixture + 0.5% fluid loss + 5.6 gal/sk water, 14.3 lbs/gal, 1.40 cu ft/sk

Results: Cement was circulated to surface during the job. The CBL showed slight-to-no microchannel. This well produced 172 BOPD and 3 BWPD.

CONCLUSIONS

1) An expansive admixture is now available which does not depend on chemicals (C_3A) in the basic cement to obtain good expansion.

2) Economical pozzolan cement blends provide better expansion than higher compressive strength cement slurries like Class A cement.

3) Microchannel problems may be solved with a new expansive admixture.

4) Water production can be greatly reduced when this new expansive admixture is incorporated into the cement slurry.

5) The longevity of a well can likely be increased with this expansive admixture. Elimination of microchannel and decreasing water production can decrease the exposure of casing to corrosive water, and increase the service life of the tubular goods.

REFERENCES

1) ACI Manual of Concrete Practices, Part I, 1973.

2) Sutton, D.L., Prather, D.A.: "New Expansion Additive Gives Good Results with Low C_3A Cements," Proceedings, 1986 Southwest Petroleum Short Course, Lubbock, Texas, p. 39-48.

3. Haut, R.C., and Crook, R.J.: "Primary Cementing:The Mud Displacement Process," SPE 8253, 54th Annual Fall Technical Conference and Exhibition of SPE of AIME, Las Vegas, NV, September 23-26, 1979.

4. Sutton, D.L., Sabins, F.L., and Faul, R.R.: "Preventing Annular Gas Flow," (Two Parts), Oil & Gas Journal, Dec. 10-17, 1984.

Table 1
Expansive Cement Performance Data @ 85°F

Slurry: 50:50 Class C cement:pozzolan + 2% bentonite + 5 lb gilsonite/sk + 14% expansive admix + 0.5% fluid loss additive + 5.69 gal/sk water, 14.3 lb/gal, 1.40 cu ft/sk

Thickening Time:	4 hours, 20 minutes
Fluid Loss:	331 cc/30 minutes
Rheology:	Plastic Viscosity - 103 cps Yield Point - 75 lb/100 ft^2 n' - 0.66 K' - 0.013 lb.sec/ft^2
Compressive Strengths:	12 hour - 360 psi 24 hour - 705 psi 48 hour - 1190 psi 72 hour - 1590 psi 96 hour - 1940 psi
Linear Expansion:	1 day - 0.162% 3 days - 0.342% 6 days - 0.639% 28 days - 0.656%