SURFACE PIPE CEMENT GIVES HIGH - EARLY STRENGTH WITH NEW CEMENT ADDITIVE

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ABSTRACT

A newly developed cement additive provides excellent compressive strengths for lightweight, filler-type cement compositions used for cementing surface pipe. Cement compositions incorporating the new additive will meet Texas Railroad Commission strength requirements for surface pipe and critical zone applications.

Cement compositions mixed at densities of 11.6 to 12.2 lb/gal developed in excess of the required 250 psi compressive strength in 24 hours for a surface pipe and a composition mixed at 12.4 lb/gal developed 1200 psi in less than 72 hours for critical zone applications.

Slurries containing this additive have also shown good fluid loss properties, accelerated setting times, and high temperature stability.

Laboratory test results as well as field results from cement compositions typically used in surface pipe, critical zone, filler cement, and high temperature applications are presented.

INTRODUCTION

A recent survey of oilfield service company engineers responsible for cementing operations in Texas revealed two areas of concern regarding cementing of surface pipe and cementing across critical zones.

1. An economical cement was needed to cement surface pipe. These slurries are required by the Texas Railroad Commission (TRC) to reach 250 psi compressive strength at 80°F (at atmospheric pressure) after 24 hours waiting on cement (WOC) time.[1]

2. A slurry was needed to meet the provisions above and to also reach 1200 psi compressive strength after 72 hours to comply with TRC requirements for cementing zones of critical cement.

Although the original emphasis of the research was to meet TRC criteria for surface pipe and zones of critical cement, the lightweight slurries developed have provided many other benefits which are also discussed in this paper.

DISCUSSION

Slurries tested were laboratory prepared designs using cement from the same batches in each cement class tested. Test results might be different for different cement batches, but values, whether higher or lower, would be expected to follow similar trends. Table 1 lists pertinent data from 13 of the slurries tested in attempts to develop one or more that would economically meet the commission criteria. Several of these were adequate for surface pipe, and others were found suitable for cementing surface pipe as well as for cementing across critical zones. Slurries 9 through 13 contain a finely divided, highly silaceous material (HSM) that provides lightweight fill without sacrifice of strength. This additive imparts an early pozzolanic type reaction during hydration of well cements and results in rapid compressive strength development down to 40°F in slurries of 11 lb/gal and lower density.

Extensive surface area (15,000 m^2/kg) of this unique material provides for a wide range of water extension at a fixed concentration while maintaining little or no free water. HSM generally is more efficient in slurries of high water-to-cement ratio. In slurries of normal density, compensation for viscosity increases caused by addition of HSM can be made by adding dispersants or extra water.

HSM helps control filtrate loss in both lightweight and normal weight slurries without expensive cellulose additives or synthetic polymers. Even at low slurry densities with low dynamic consistencies, and without complexing agents, HSM provides a high degree of thixotropy.

Compressive strength tests were conducted in accordance with API Specification 10,[2] "Specification for Materials and Testing for Well Cements" to determine whether strength retrogression would occur in an HSM slurry at 400°F. Base slurry formulation contained pozzolan additive, HSM, and cement, yielding an 84 lb sack. Expansion test data was collected using unrestricted expansion molds under temperature and pressure.

APPLICATIONS

1. Surface Pipe. To comply with the commission compressive requirements for cementing surface pipe, many operators have continued to use premium cements, since normal filler slurries would not meet the requirements. HSM compositions meet the requirements at lower densities than other commonly used systems (Table 1).

2. Filler Cements. Filler compositions featuring HSM provide good early strength at densities as low as 10 lb/gal, whereas bentonite slurries lighter than 11 lb/gal provide poor early strength development. Properties of HSM allow for use of a high percentage of water in the slurry, and economy is gained from use of high water content since it is the cheapest commodity available on location (Table 2).

3. Fluid Loss Control. Improved fluid loss control, a characteristic that many studies have found desirable,[3,4,5] has been realized with compositions containing HSM. Control of fluid loss reduces the risk of bridging due to uncontrolled filter cake buildup, reduces slurry volume losses during transition time, enhances bonding, increases effective cement expansion, and reduces the probability of fluid migration through the cement.

Most conventional fluid loss control additives are polymers and dispersants and probably control fluid loss by making initial filter cake less permeable to filtrate water. HSM probably alters the particle size distribution of the slurry, making a more dense filter cake. HSM compositions give reasonably good fluid loss control with the addition of smaller amounts of fluid loss additive (Table 3).

4. High Temperature Stability. Table 4 illustrates the high temperature strength of slurries containing HSM.

CONCLUSIONS

The purpose of this investigation was to determine if an economical cement system, that met the Texas Railroad Commission compressive strength guidelines, could be developed. As a result of this investigation a cement system was developed that met the TRC strength requirement guidelines for surface pipe and critical zone applications. It was also determined that the highly silaceous material aids in controlling free water and fluid loss as well as providing for acceleration. Aside from surface pipe and filler cement applications the HSM cement system proved to be thermally stable at elevated temperatures.

This system has been successfully used in various field applications. To date approximately 25 jobs have been conducted. Field results are as follows.

Case History 1

The HSM cement system was used to cement steam injection wells along the Gulf Coast. The average depth of the wells was 1500 ft. The bottomhole static temperature varied from 120°F to 400°F depending on location in the pattern. The wells were drilled with a 9.5 lb/gal water base mud. Seven inch casing was set at TD with the HSM cement system used as both the lead and tail. The slurry properties and conditions are as follows:

Lead: (Class H cement + Pozzolan additive + HSM)
84 lb sack + 25 lb/sk silica flour + 2% bentonite + 17.45 gal water/sk mixed at 11.5 lb/gal with 2.97 ft^3/sk yield.

Thickening time: 4:00 + @ BHCT of 115°F
Free Water: 0%
Compressive Strength: 300 psi in 24 hours
@ 300°F

Tail: (Class H cement + Pozzolan additive + HSM)
84 lb sack + 25 lb/sk silica flour + 0.8% fluid loss additive + 11.96 gal water/sk mixed at 12.5 lb/gal with 2.23 ft^3/sk yield.

Thickening time: 4:00 + @ BHCT of 115°F
Free water: 0%
Compressive Strength: 1000 psi in 24 hour
@ 300°F 1300 psi in 48 hour

All of the jobs were successful with bond logs showing good bond.

Case History 2

The HSM cement system was used as a lead composition to cement a 5½" liner at a depth of 11900 ft. An 8" hole was drilled from 5800 to 11900 ft with the top of the 5½" liner set at 5460 ft. Neat Class H cement was used as the tail and was placed from 10000 ft to T.D. The HSM lead was placed from 10000 back to 5450 ft. Well conditions and HSM slurry properties were:

Lead: (Class H cement + Pozzolan Additive + HSM) 84 lb sack + 0.7% Fluid loss additive + 10.9 gal water/sk mixed at 12.0 lb/gal with a 1.94 ft^3/sk yield.

Thickening time: 5:04 @ BHCT of 126°F
Fluid Loss: 183 cc/30 min @ 126°F
Free Water: 0% @ 80°F
Compressive Strength: 910 psi in 12 hours
@ 183°F 1030 psi in 24 hours

Evaluation of the bond logs indicated the quality of the job was very good.

Case History 3

In eastern New Mexico the HSM cement system was used as a filler on a 5½" liner set at 8850 ft. A 7 7/8" hole was drilled from 5000 ft to TP with the top of the liner set at 4230 ft. Neat Class C cement was used as the tail and was placed in the bottom 900 ft of the liner. The HSM filler was placed from 7950 back to 4200 ft. Well conditions and HSM slurry properties were:

Lead: (Class C cement + Pozzolan Additive + HSM) 84 lb sack + 10.9 gal water/sk mixed at 12 lb/gal with a 1.94 ft^3/sk yield.

Thickening time: 4:00 @ BHCT of 105°F
Fluid Loss: 392 cc/30 min @ 80°F
Free Water: 0% @ 80°F
Compressive Strength: 740 psi in 12 hours
@ 150°F BHST 920 psi in 24 hours

The job was a success and interpretation of the bond logs indicated that the overall quality of the job was good.

REFERENCES

1. Casing, Cementing, Drilling, and Completion Requirements Rule 13. Railroad Commission of Texas, Oil and Gas Division 051.02.02.013.

2. Specification for Materials and Testing for Well Cements API Specification 10 (SPEC 10) Third Edition, July 1, 1986.

3. Shell, F. J. and Wynne, R. A.: "Application of Low-Water-Loss Cement Slurries," paper 875-12-1 presented at Spring meeting of the Rocky Mountain District API, Denver, Co., April 21-23, 1950.

4. Beach, H. J., O'Brien, T.B., Goins, W. C. Jr.: "Formation Cement Squeezes by Using Low-Water-Loss Cements," Oil and Gas Journal (May 29 and June 12, 1961).

5. Harris, F. N. and Carter, L. G.: "Use a Chemical Wash and a Low Fluid Loss Cement," Drilling (January 1964).

Table 1
Cement Slurries for Surface Casing

Slurry No.	Composition	Water (gal/sk)	Density (lb/gal)	Yield (ft^3/sk)	Compressive Strength 80°F (psi) 24 Hr	72 Hr
1	Class C Cement + 10% bentonite + 5% salt	12.02	12.85	2.17	515	1080
2	Class A Cement 10% bentonite + 5% salt	12.02	12.85	2.17	255	620
3	Class A Cement 10% bentonite + 3% salt	11.8	12.8	2.14	295	690
4	Halliburton Light Cement (HLC) + 6% bentonite + 3% salt	9.5	12.0	1.79	160	---
5	Class A Cement + 3% extender + 3% salt	17.5	11.4	2.82	170	---
6	HLC (60 lb/ft^3 Pozzolan Additive) + 6% bentonite + 3% salt	9.9	12.45	1.85	185	---
7	85% (by volume) Class A Cement + 15% (by volume) Pozzolan Additive (60 lb/ft^3 Pozzolan) + 8% bentonite + 3% salt	11.0	12.7	2.01	305	560
8	Class A Cement + 8% bentonite + 3% salt	10.4	13.2	1.93	415	990
9*	Class A Cement + Pozzolan Additive + HSM + 0.5% $CaCl_2$	10.9	12.0	1.95	305	---
10*	Class A Cement + Pozzolan Additive + HSM + 0.5% $CaCl_2$	9.48	12.4	1.76	325	1265
11*	Class C Cement + Pozzolan Additive + HSM + 1.0% $CaCl_2$	10.2	12.2	1.85	340	1205
12*	Class A Cement + Pozzolan Additive + HSM + 0.5% $CaCl_2$	10.2	12.2	1.85	300	---
13*	Class A Cement + Pozzolan Additive + HSM + 1% $CaCl_2$	11.25	12.2	1.98	250	---

NOTE: Except for numbers 11 and 13, slurries were pre-pumped 20 minutes on Atmospheric Consistometer at 80°F. Slurries 11 and 13 were pre-pumped 1 hour on atmospheric consistometer.

*84 lb sack weight

Table 2
Compressive Strengths
(Cement: Pozzolan Additive: HSM—84 lb sack)

Slurry Density (lb/gal)	Water Requirement (gal/sk)	Slurry Volume (ft^3/sk)	Additives (Percent by Weight)	Compressive Strength (PSI) 8 Hr	12 Hr	24 Hr	72 Hr
			60°F (Atmospheric)				
10.0	29.48	4.45	4% gel, 4% $CaCl_2$	NS[1]	NS	NS	5
11.0	16.70	2.73	2% gel, 4% $CaCl_2$	NS	SNMS[2]	15	45
11.89	11.37	2.01	4% $CaCl_2$	10	25	60	130
12.44	9.36	1.74	0.5% Friction Reducer, 4% $CaCl_2$	15	45	115	300
13.66	6.38	1.34	0.75% Friction Reducer, 4% $CaCl_2$	70	190	430	965
			80°F (Atmospheric)				
11.0	16.70	2.73	None	---	---	30	95
11.5	13.22	2.26	None	---	---	80	195
			85°F (Atmospheric)				
12.44	9.36	1.74	None	50	---	135	---
			100°F (Atmospheric)				
10.0	29.48	4.45	4% gel, 2% $CaCl_2$	NS	SNMS	10	95
11.0	16.70	2.73	2% gel, 2% $CaCl_2$	20	30	95	495
11.0	16.37	2.68	None	---	---	60	330
11.89	11.37	2.01	2% $CaCl_2$	75	115	355	1,170
12.0	10.92	1.94	None	---	---	135	925
12.44	9.36	1.74	0.5% Friction Reducer, 2% $CaCl_2$	130	200	575	2,125
13.66	6.38	1.34	0.75% Friction Reducer, 2% $CaCl_2$	415	675	1,835	4,615
			140°F (Atmospheric)				
10.0	29.48	4.45	4% gel	20	65	160	200
11.0	16.70	2.73	2% gel	530	830	1,115	1,440
11.89	11.37	2.01	None	435	935	1,290	1,455
12.44	9.36	1.74	0.5% Friction Reducer	625	1,405	1,825	2,335
13.66	6.38	1.34	0.75% Friction Reducer	1,980	3,100	3,940	5,000
			150°F (Atmospheric)				
10.0	28.38	4.28	None	---	---	---	240
11.4	13.22	2.26	None	400	480	580	675
12.0	10.92	1.94	None	640	700	900	1,010
			230°F (3000 psi)				
10.0	29.48	4.45	4% gel	190	395	425	338
11.0	16.70	2.73	2% gel	575	1,125	1,215	1,190
11.89	11.37	2.01	None	1,775	2,555	2,378	1,958
12.44	9.37	1.74	0.5% Friction Reducer	2,415	3,090	2,750	2,825
13.66	6.38	1.34	0.75% Friction Reducer	4,390	4,300	5,265	5,600

1. NS = Not Set

Table 3
Fluid Loss Properties in Fresh Water

Composition	Slurry Density (lb/gal)	Water Requirement (gal/sk)	Slurry Volume (ft^3/sk)	Atmospheric Consistometer (Bc) Initial	Atmospheric Consistometer (Bc) 20 min	Fluid Loss 1000 psi 325 m.s. (cc/30 min)
		125°F				
Class A Cement (neat)	15.6	5.2	1.18	18	18	1,500
Class A Cement + 6% HSM + 0.7% Friction Reducer	15.7	5.2	1.21	3	8	480
Class A Cement + 9% HSM + 1.0% Friction Reducer	15.8	5.2	1.23	4	8	257
		150°F				
Halliburton Light Cement + 10% HSM + 0.5% Friction Reducer	13.8	7.7	1.60	4	7	275
Class A Cement + 10% HSM	14.9	6.5	1.41	13	22	355
Class A Cement + 10% HSM + 1.4% Friction Reducer	15.8	5.2	1.24	3	5	165

Table 4
Physical Properties at 400° BHST
(Class H Cement: Pozzolan Additive: HSM — 84 lb sack)

Slurry No.	Water (gal/sk)	Slurry Weight (lb/gal)	Slurry Volume (ft^3/sk)	Silica Flour (lb/sk)	$CaCl_2$ (%)	Gel (%)	Non-Retarding Fluid Loss Additive (%)	Expansive Additive (%)	Compressive Strength (psi) 400°F BHST
									4 Days
1	14.0	12.0	2.51	25	2.0	---	1.0	---	2265
2	14.61	12.0	2.63	30	2.0	---	1.0	---	2000
3	14.39	12.0	2.64	25	---	---	1.0	10.0	1415
									7 Days*
4	16.97	11.5	2.91	25	---	2.0	0.5	---	860
5	16.97	11.5	2.91	25	---	2.0	0.6	---	540
6	11.75	12.5	2.21	25	---	---	0.5	0.3	1825
7	11.75	12.5	2.21	25	---	---	0.6	0.3	1740

* Heat-up rate: 80°F-300°F in 24 Hours
300°F-400°F in 24 Hours