IMPROVED BULK BLENDING TECHNIQUES FOR ACCURATE AND UNIFORM CEMENT BLENDS

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ABSTRACT

Two of the major factors affecting cement slurry performance are the concentration of additives and their distribution throughout the dry cement blend. Consistometer thickening time tests on one or two batches of the cement are used to monitor the cement blends. Studies conducted have proven that these tests do not necessarily reflect the uniformity or the correct concentration of additives in the blend. To improve the quality of the bulk blending of cement, researchers developed on-site methods to verify the additive concentrations of each batch blended for uniformity and accuracy. They also investigated the effects of the current dry blending procedures, transportation, and air blending on the distribution of such additives as retarders, fluid loss agents, weighting agents, and salts.

INTRODUCTION

Cement slurry design has become more complex over the past few years. The deeper, more hostile conditions in the wells have caused the influx of many new additives. At high temperatures and greater depths, the concentration of potent retarders and fluid loss additives becomes very critical. Small variations in concentrations of additives may cause tremendous changes in thickening time, compressive strength, and mixing viscosities of the cement.

Consistometer thickening time tests are used to establish whether or not a particular field blend will perform as expected downhole. These tests are done using expensive equipment and sometimes an entire working day or more is required to complete one test. The consistometer thickening times are costly because of the equipment involved, the manpower costs associated in running the tests, and the time lost in the field waiting on the test results. Many jobs consist of 10 to 20 blended batches of cement, but only one or two of the batches or a composite of all the batches may actually be tested.

A set of analytical tests was adopted for use in dry cement analysis. Actual concentrations of retarder, accelerator, and fluid loss additive are determined in a sample in less than 1 hour with these tests. These tests along with the chemical thickening time test developed by McElfresh and Cobb[1] are used to determine the accuracy of the blend. These tests are not substitutes for the thickening time test, but they aid in determinating the accuracy of the blend and provide a method of checking several cement batches quickly. These analytical procedures were used in conducting a test to determine the best technique for blending cement and the effects of transportation, sampling, transferring, etc. on cement blends.

SAMPLE VERIFICATION TESTS

The additives in the cement blends are determined by seven analytical tests. The amount of lignosulfonate is determined by a nitrous acid reaction. The borate retarders are determined by reaction with carminic acid. The chloride-containing accelerators are measured by a mercuric thiocyanate and ferric nitrate reaction, whereas the sulfate-containing accelerators are determined turbidimetrically as barium sulfate. The fluid loss additives are quantified with the anthrone test, and the dispersants are measured by complex ion formation with crystal violet.

All of these tests are performed on a portable spectrometer and are accurate to $\pm 1\%$ relative. The remainder of the weighing and extraction equipment is also portable to permit on-site determination of the cement additives.

PNEUMATIC BLENDING EQUIPMENT

Two types of bulk systems were used for this investigation. The first type (Type I) consists of two 400 to 500 cu ft (11.3 to 14.2 m^3) blenders, fitted with two 2-in. (5.1-cm) sample valves located as shown in Figure 1. Both blenders are positions on strain-gauge load cells for all weighing operations.

The second type (Type II) consists of an additional 100 to 150 cu ft (2.8 to 4.2 m^3) admix blender which is valved into a Type I system as shown in Figure 2. In the Type II bulk system, load cells are placed under the smaller admix tank and one of the larger (400 cu ft) blenders.

The placement of the two flow control valves, shown in Figures 1 and 2, are in the line between the neat cement tanks and the blenders for both types of bulk plants and between the two blenders for a Type I plant or between the admix tank and the blenders for a Type II plant. These control valves allow the metering of the flow of cement at a controlled rate to increase weighting accuracy and batch to batch consistency.

Likewise, the sample valves are placed between the blenders to allow sampling of the blend between transfers, and in the line between the blenders and the neat cement tanks to obtain neat cement samples.

TESTS CONDUCTED

Using the verification tests devised and bulk plants equipped as discussed above, different tests were conducted to characterize the blending techniques and analyze the current techniques used to blend cement. These tests include batch transferring and air blending technique (boxing technique), in-line blending technique, sampling techniques, effects of transportation by land and sea, and additive make-up tests.

Boxing Technique vs In-Line Blending Technique

Low-Concentration Additive. Two methods of blending were tested for uniformity of blending. The first method was a boxing technique. For a Type I plant, this method involved mixing the additives with 4000 lbm (1800 kg) of cement in blender B (see Figure 1). This mixture was then sandwiched between two layers of neat cement in blender A. The batch was then percolated with air for 5 to 7 min, then transferred to blender B, and percolated again for 5 to 7 min. Each transfer and percolation was designated as one boxing of the cement. The boxing was repeated 3 to 5 times, and samples were taken during each transfer of the cement.

For a Type II plant, 4000 lbm (1800 kg) of cement was mixed with the additives in the admix blender. This mixture was then sandwiched between two layers of neat cement in blender A. The batch was blended 5 to 7 min and boxed 3 to 5 times to blend the cement.

The second blending method tested was the in-line blending technique. In this technique, the additives were again blended with 4000 lbm (1800 kg) of cement in blender B for a Type I plant. The admixture was then proportioned, with the control valve, into blender A concurrent with the transfer of the neat cement into the blender. Blender B emptied just as blender A attained the full weight of the batch. This in effect proportioned the additives into the neat cement in the fill line to the blender.

A similar method was used for the Type II plant. The additives were mixed with 4000 lbm (1800 kg) of cement in the admix tank. The admixture was then proportioned into blender A along with neat cement. Again the admix tank emptied just as the blender obtained full batch weight.

Samples were taken after in-line blending and after boxing. The fluid loss additive concentration was determined in five samples of blended cement taken from the in-line sample valves after the first and third boxings of the blend. A comparison of the data collected on both blending techniques is shown in Table 1.

After three boxings, the fluid loss additive distribution approached an acceptable level of uniformity. Table 1 gives the retarder distribution after in-line blending and after in-line blending and boxing once. The boxing technique was less consistent and did not provide the same uniformity produced by the in-line method. In-line blending and one boxing provided a blend that had acceptable uniformity (less than 0.04 standard deviation). The boxing technique became more uniform with each transfer, but after three boxings it did not obtain the same degree of uniformity as the in-line technique after one boxing of the batch. The in-line methods proved to provide a better blend with the least amount of time involved.

The boxing technique test also showed the inefficiencies of the pneumatic blenders. These blenders do not provide a highly turbulent environment with large mixing areas. It appears that the blenders have large dead spots that do not mix. Only after several boxings are the dead spots in the blender moved enough to create a near uniform blend.

High-Concentration Additives. When high concentrations of additives such as hematite and silica sand are blended, the admix blender can be overloaded and its blending efficiency decreased. A different technique is used to blend these additives to prevent overloading. The low-concentration additives are in-line blended into the neat cement. This step distributes the retarder and accelerators evenly through the neat cement. The high-concen- tration additives are then added to the blender, and the blend is boxed twice. Table 2 shows the distribution of hematite in a blend using this technique. The high-concentration additives usually affect the thickening time less than the retarders and accelerators. The concentration limits may be broader and the blend still perform to specification. The relative variance of $\pm 5\%$ in the high-concentration additive was accepted as the standard.

Additive Make-Up Tests

Sometimes the thickening time for the blend does not match the pilot thickening time, and additional retarder is required in the blend. These tests were conducted to determine the correct way of adding the extra retarder.

A batch of 100 sacks of cement was blended with retarder after which extra retarder (11 lbm, 5.0 kg) was added to the blender. The batch was then boxed several times. The extra retarder was never detected in the blended cement. A second test was conducted where the retarder concentration was increased from 0.1% to 0.2% by the in-line blending technique. Using this method about 4000 pounds of the 0.1% blend and the added retarder were mixed in the admix blender. The remaining 0.1% retarder blend was in-line blended with the admixture into blender A. The blend was then boxed and sampled. The 0.2% retarder was present in all samples (Table 3). From the data collected, the best method for increasing the amount of additives to the blend was with the in-line method.

Batch Size Test

Because economy dictates that time and effort be optimized, tests were conducted to determine the maximum volume of cement that can be effectively blended in one batch. Batches ranging from 50- to 250-sacks of cement were tested using the in-line blending technique described above, and samples were analyzed to determine their uniformity. A comparison of 150- and 250-sack batches is presented in Table 4. This level of uniformity was not reached after the same number of transfers for every batch size, and some batches had to be transferred and blended again to reach the required uniformity level. The use of 100- to 150-sack batches gave the most consistent results with the fewest number of transfers. The maximum batch size was established from the tests at 40 to 50% of the total tank capacity.

Methods of Sampling

Different methods of sampling were compared to determine the best sampling technique. The methods examined were in-line sampling, core sampling, and automatic sampling.

The in-line sampling technique consisted of momentarily cracking a 2-in. (5.08-cm) valve in the line during the transfer of the cement. Two types of sampling techniques were used with the in-line method: composite and noncomposite sampling. In-line composite sampling consisted of cracking a small valve for a few seconds several times during the transfer of the cement and collecting a single 1 to 2 gallon sample during the complete transfer.

Core sampling techniques consisted of driving a plastic pipe down into the cement in a bulk tank and then retrieving it along with the sample. Two different procedures of core sampling were used: segmented core sampling and composite core sampling. The segmented core was used to determine the distribution or segregation of additives in the bulk tank. The segmented samples were obtained by cutting the pipe into pieces and emptying each piece for analysis. The composite core was used to determine the average concentration in the bulk tank. The samples were collected by emptying the entire pipe contents into one container.

The automatic sampler consisted of a tube that automatically moves into the center of the pipe and collected a small sample about every 15 seconds during the transfer. Only one composite sample was generated during the entire transfer. This type of sample is comparable to the in-line composite sample.

A comparison of the sampling techniques is displayed in Table 5. The in-line samples and in-line composite and automatic samples all gave comparable results, if the cement was well blended. If the batch was not well blended, the in-line noncomposite samples displayed fluctuations in concentration of the additive in the cement. The core, in-line composite, and automatic sampler samples were averaged over the batch and did not indicate whether the cement was well blended. However, these techniques did show that the correct amount of additive was included in the blend. In the cases tested, the core sample was lower in additive concentration than the other methods. In the second test (Table 6), the cement was well blended, and no fluctuation in concentration of additives was seen between each sampling technique.

Effects of Transportation

Tests were conducted to determine how the transportation of the cement blend by land or sea affected the additive distribution. Batches of cement were blended using the in-line blending technique and then transferred to a cement truck pod or boat tank. A core sample was taken before the cement left the plant and after it reached the well site. Core samples were cut into sections and analyzed for concentration differences. These tests were completed for retarder, hematite, and fly ash cenosphere blends. The result of the tests conducted on transportation by land are shown in Tables 6 and 7. The transportation effects appear to be minimal in all cases. The small changes in hematite in Table 7 were not significant, and the trends appeared to be consistent between the samples. If the cement was uniform at the bulk plant, transportation did not affect its uniformity. It was further observed that the hematite-weighted slurries tended to pack immediately, and the movable fluid bed effects disappeared almost as it was placed in the bulk truck.

A set of similar tests were initiated for transportation by sea. Final results and conclusions have not yet been determined. Preliminary results are presented in Table 8. The fluid loss additive appeared to remain nearly uniform, but the calcium chloride ($CaCl_2$) variation was large.

DEVELOPMENT OF BLENDING VERIFICATION PROCEDURE

Other problem areas considered during this study included the effect of human errors and equipment failure during the blending. Of course, these areas cannot be completely controlled or monitored, but a large reduction in the number of problems is possible with small increases in time and effort.

Equipment Failure Problems

The major problem with equipment failure that may affect the blending of cement is blender air problems. In a pneumatic blending system, these problems usually arise from one of the following:

- A slit, tear, rupture, or other degradation of the canvas pads used to distribute the air in the blender.

- Plugging or partial plugging of air lines to the air pads.

- Plugging or partial blocking of the air to the bottom of the blender.

Two human errors commonly encountered are:

- Blend contamination by back flushing of dust collection system, operator error in valve control, or a residual of the previous batch blended.

- Addition of wrong amount of additives.

Normal procedures used may not produce uniform blends when these problems arise. Human errors always occur, but many human errors are detected and eliminated by verifying the concentration of additives in each batch of cement blend.

Blend Verification Procedure

Most problems are eliminated by analyzing for all additives in two to three samples of each batch of cement. This became impractical and time- consuming for most blends. A system of analysis for one additive for each batch however was feasible and served as a good aid in eliminating many of the problems.

Two in-line samples were taken from each batch of cement blended. These samples were analyzed for the most critical additive (usually the retarder). A large difference in additive concentration between the two samples indicated that the batch was not well blended and must therefore be reboxed and resampled. This method also allowed for a quality control check of this critical additive.

Typical results show that in most cases, operator errors and reblending were reduced because of the verification testing. In most cases, the non-uniform blends or low retarder levels were corrected by boxing one extra time. In the extreme cases, the batch was discarded and another batch blended and checked.

The advantage of this system was that each batch was checked for uniformity and concentration of the most critical additive. After verification, the most representitive sample was used for consistometer thickening time tests.

CONCLUSIONS

Tests were conducted to study blending and sampling techniques and to determine the effects of transportation once the cement is blended. The data presented show that the in-line blending technique produces the most uniform samples after one boxing. This method proved to be less time consuming and more effective than other methods investigated. It was also determined that 100- to 150-sack batches were the best size for the blenders used. A general rule of 50 percent of the volume of the blender was set for the maximum batch size.

Several sampling techniques were investigated, and the in-line system proved to provide the most useful information about the uniformity of the blend. The noncomposite samples collected by this method allowed the actual distribution of the additives in the cement to be determined. The studies on the effects of transportation showed that transportation had little or no effect on the blend.

The techniques developed for the analysis of cement blends allow quick easy analysis of most of the common cement additives (lignosulfonate retarders, cellulosic fluid loss additives, salt accelerators, and dispersants). Analysis of the most critical additive in each batch provided a method of checking for uniformity and possible human error. After this check, the most representative sample of the blend is used for thickening time tests, eliminating the necessity of repeating this more time consuming step. Thus, by using the techniques and precautions discussed, the uniformity and overall efficiency of cement blending operations have been markedly improved.

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REFERENCES

[1]McElfresh, Paul M., and Cobb, Jo Ann: "Chemical Thickening Time Test for Cement Blends," SPE 10220, 56th Fall Tech. Conf. of the Society of Petroleum Engineers of AIME (San Antonio, Texas), Oct. 5, 1981.

Table 1
Comparison of Boxing Technique to In-Line Blending Technique

	Boxing technique Fluid loss (%)		In-Line technique Retarder (%)[b]	
	1 Boxing	3 Boxings	0 Boxing	1 Boxing
	0.85	0.93	0.14	0.16
	0.74	0.90	0.20	0.14
	0.77	0.95	0.26	0.15
	0.95	0.98	0.06	0.19
	1.07	1.01		
Mean	0.88	0.95	0.16	0.16
Std dev	0.12	0.04	0.07	0.02

[a]Class H 1:0:0 + 0.9% fluid loss additive.
[b]Class H 1:0:0 + 0.2% retarder.

Table 2
Blending of High Concentration Additives[a]

Sample	Additives by weight of cement, (%)				
	Gel	Hematite	Silica	KCl	Retarder
1	3.7	84	38	1.51	1.62
2	3.8	103	38	1.78	1.63
3	4.3	100	38	1.24	1.61
4	3.1	80	37	1.01	1.52
Mean	3.7	92	38	1.40	1.60
Std dev	0.4	10	0.3	0.29	0.04

[a]Class H 1:0:2 + 35% silica + 88% hematite + 3% KCl + 1.5% retarder + 55.6% water.

Table 3
Comparison of Two Methods of Additive Make-Up Techniques

	Retarder (%)	
	Boxing technique[a]	In-line technique[b]
Before addition	0.34 0.36	0.11 0.12
After addition	0.56 0.33	0.22 0.19

[a]Class H 1:0:0 + 0.4% retarder + 0.2% fluid loss additive.
[b]Class H 1:0:0 + 0.6% fluid loss additive + 0.1–0.2% retarder.

Table 4
Comparison of Different Batch Sizes[a]

Batch No.	Retarder (%)	
	150-sk batches	250-sk batches
1	0.36	0.43
	0.39	0.43
2	0.36	0.34
	0.34	0.36
	0.34	—[b]
3	0.40	0.56
	0.36	0.36
	0.42	—[b]
4	0.36	0.54
	0.37	0.36
Mean	0.37	0.42
Std dev	0.02	0.08

[a]Class H 1:0:0 + 0.2% fluid loss additive + 0.4% retarder.
[b]Only two samples of these batchs were analyzed.

Table 5
Comparison of In-Line Composite, In-Line Non-Composite, Automatic, and Core Sampling Techniques[a]

	Fluid loss additive, (%)			
	In-Line	Automatic	In-line composite	Core composite
Transfer 1	0.93 0.90 0.95 0.98 1.01	1.07	0.90	0.78
Mean Std dev	0.95 0.04	1.07	0.90	0.78
Transfer 2	0.99 0.87 0.91 0.90 0.81		0.92	0.78
Mean Std dev	0.90 0.06		0.92	0.78

[a]Class H 1:0:0 + 0.9% fluid loss additive + 1.0% $CaCl_2$ + 0.6% bentonite.

Table 6
Comparison of In-Line Sampling and Core Sampling Techniques and Effects of Transportation by Land[a]

	Retarder (%)	
	In-line sampling	Core sampling
Before transporting	0.22 0.17 0.20 0.20 0.20	Top 0.20 0.20 0.20 Bottom 0.20
Mean Std dev	0.20 0.015	0.20 0.00
After transporting	0.21 0.20 0.21 0.20 0.20	Top 0.22 0.18 0.20 Bottom 0.20
Mean Std dev	0.20 0.005	0.20 0.014

[a]Class H 1:0:0 + 0.20% retarder.

Table 7
Effects of Transporting Blends by Land on the Additive Distribution[a]

	Before transporting		
	Retarder (%)	Cenosphere (%)	Hematite (%)
Top	0.9	3.0	17.3
	1.0	3.0	18.4
	0.9	2.7	18.5
	1.1	2.7	23.5
Bottom	0.9	2.3	19.0
	After transporting		
	Retarder (%)	Cenosphere (%)	Hematite (%)
Top	0.9	3.0	17.0
	0.8	3.0	18.7
	1.0	3.1	18.8
Bottom	0.9	2.7	20.7

[a]Class H 1:0:0 +3.0% fly ash cenosphere + 2.0% NaCl + 1.0% retarder + 20.6% hematite.

Table 8
Effects of Transportation by Sea on Fluid Loss and Accelerator Distribution[a]

	At dock		At rig	
	Fluid loss additive (%)	$CaCl_2$	Fluid loss additive (%)	$CaCl_2$
Top	0.90	0.46	0.76	1.06
Middle	0.84	0.84	0.81	1.05
Bottom	0.81	0.79	0.69	1.23
Mean	0.85	0.70	0.75	1.11
Std dev	0.04	0.17	0.05	0.08

[a]Class H 1:0:0 + 0.9% fluid loss additive + 1% $CaCl_2$.

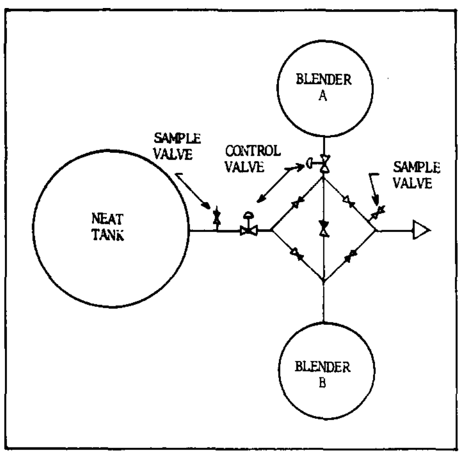

Figure 1 - Standard equipment for Type I bulk system

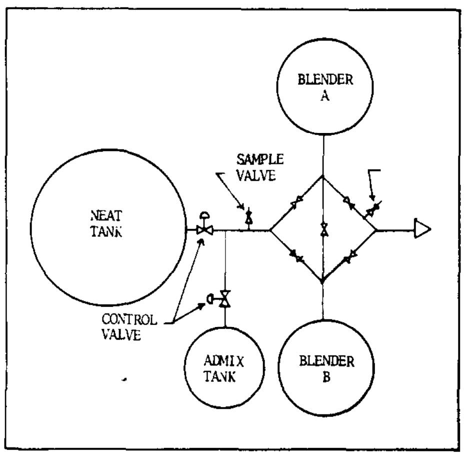

Figure 2 - Standard equipment for Type II bulk system