New Process for Plugging Abandoned Wells

EPA Grant Number: R827015-01-0
Title: New Process for Plugging Abandoned Wells
Investigators: Subhash Shah
Institutions: University of Oklahoma
EPA Project Officer: Tom Veirs/ Bala Krishnan
Project Period: November 13, 2000 to November 12, 2001 (N/C Ext. to December 31, 2001)
Project Amount: $89,359
Research Category:

Description:

Quarterly Report: February 14 – May 13, 2001

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1. Introduction and Project Goals

Cement grout is the present material used in plugging the abandoned wells. Fly ash is known to have properties very similar to cement and can be produced with strength similar to cement grout. Blends of fly ash (especially the less cementitious Class F fly ash) and cement have been used in the oil industry since 1950. Presently, only about half of the fly ash produced by the various coal-burning power plants in the state of Oklahoma is used in cementing applications. The remainder must be treated as a waste product and disposed of in landfills.

Much of this fly ash is the higher lime content, more cementitious, Class C fly ash. The objective of this research is to show that Class C fly ash can be retarded like cement when slurried and, further, that it can be pumped and placed like cement with coiled tubing instead of employing a rig. This will prove the concept of utilizing this kind of setup for wells where it will apply. On wells where there is a means of handling pipe, mixing and pumping, only the plugging material will be required. The optimum formulation developed will be suitable for both the coiled tubing and jointed pipe applications.

The specific objectives of this project are to obtain the cementitious properties of Class C fly ash from five coal-fired power plants in Oklahoma and, utilizing these properties, to produce a fly ash grout similar to cement grout. Furthermore, the ability to pump this slurry through coiled tubing to place a plug of fly ash grout will be proven. The end result is to utilize a fly ash grout for plugging of abandoned oil, gas, and water wells rather than a cement grout. The research is divided into two phases: (1) laboratory analysis of samples of the fly ash from selected power plants and development of optimum grout formulations, (2) the pumpability of these formulations through coiled tubing and straight pipe will be proven and the frictional properties investigated.

2. Work in progress

Planned	**Progress**	Task completion date
Method of development for fly ash formulation	Developing the optimum formulation of fly ash • Compressive strength tests with API Spec 10 and Spec 10A	March – June 2001

3. Development of Methodology for Fly Ash Formulation

The tests with various formulations with two replication samples are under progress. This will provide the optimum formulation of fly ash, which can produce pumpable and high compressive strength fly ash plug.

3.1 Test Procedure

The procedures defined in Section 7 of API Spec. 1 (1990) and Section 8 of API Spec. 10A (1995) have been applied to this test. Two samples have been cured in water curing bath maintained at different temperatures (80, 100, and 120 ^{o}F). Figure 1 shows the constant temperature water curing device used in this test. The detailed test matrix is developed based on the pre-test results. These results show that the "Red Rock" sample has the highest strength, and "Oologah" sample has the lowest strength. The pretest results are shown in Fig. 2.

Two fly ash sourses were then selected from the pre-test: "Oologah" and "Muskogee". "Oologah" showed the lowest compressive strength and Muskogee showed the second highest compressive strength. The reasons for these selections are that 1) if the test results of "Muskogee" are acceptable, then the "Red Rock" sample, which showed the highest compressive strength, can be considered as acceptable, 2) if the test results of "Oologah" are acceptable, all fly ash sources can then be acceptable for this project. Table 1 represents the detailed test matrix.

Fig 1 – Constant water temperature curing device

Table 1 – Compressive strength test matrix

Level of source			Curing Temperature		
			80 °F	100 °F	120 °F
Source	Oologah	0.5% D and 0.5% R	X	X	X
		0.5 % D	X	X	X
		0.5 % R	X	X	X
	Muskogee	0.5% D and 0.5% R	X	X	X
		0.5 % D	X	X	X
		0.5 % R	X	X	X

Note)
0.5 % D : 0.5 % weight percent dispersant
0.5 % R : 0.5 % weight percent retarder

The samples are tested by the hydraulic testing machine (Carve lab press), of which hydraulic capacity is 0 – 20,000 lb_f. In order to obtain higher accuracy, low force reading gauge was added (Fig. 3).

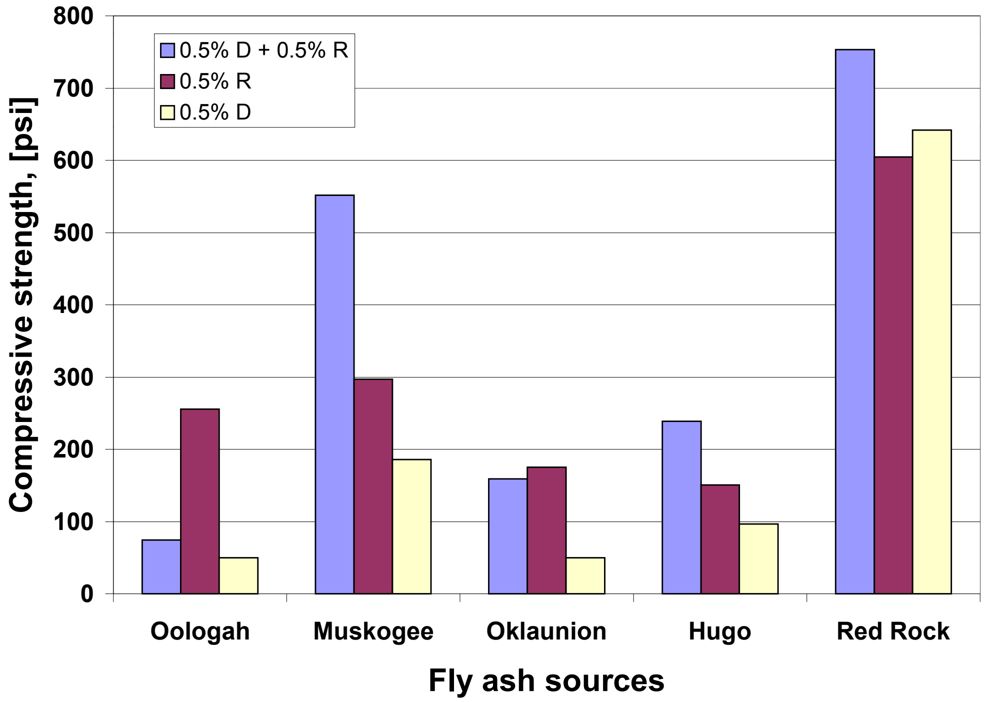

Fig. 2 - Compressive strength test with 24 hours water curing at 120 °F

Fig. 3 – Compressive strength tests with Carver laboratory hydraulic unit

3.2 Sample Preparation

Plastic coated 2-in. diameter paper mold was used to make samples for compressive strength tests. Grease is thinly applied on the interior face of the mold and the contact surface of the stainless plate. The contact surface of the halves of each mold was also coated with grease to make the joint water tight when assembled. Excess grease was removed from the interior surface of the assembled molds. The molds were placed on a thinly greased stainless plate. Grease was also applied to the exterior contact line of the mold and the base plate.

3.3 Slurry Preparation

Eight hundred grams of fly ash sample was weighed by using the electronic scale having 0.01 gram accuracy. Water was weighed by graduated glass cylinder according to Section 5.3 of API Spec. 10. Retarder and/or dispersant were added in water while agitating in the mixer.

3.4 Test Results

Presently, the compressive strength tests with various formulations are under way. The brief test results are shown in Figs. 4 and 5. Figure 4 illustrates the effects of 0.5% dispersant on compressive strength. An increase in water curing time on both samples increases the compressive strength. The compressive strengths of samples are over 500 psi after one week of curing time, regardless of water bath temperature. This compressive strength (500 psi) is generally accepted as a minimum strength for both production and abandonment plug by the oil and gas industry. The compressive strengths of the samples cured at 80^{o}F show the highest strength. Figure 5 represents the effects of 0.5% retarder on compressive strength. The compressive strengths with 0.5 percent of retarder are also over 500 psi after one week of curing time, regardless of water bath temperature. The details of test results and their analysis will be included in the Annual Report.

4. Next Quarter Plans

4.1 Development of methodology for the fly ash formulation

Through the compressive strength tests with various formulations, the optimum formulation of the fly ash will be determined. The compressive strength tests will be performed under different curing times: 24 hrs, 48 hrs, and 1 week. The compressive strength will be calculated by dividing the maximum load in lb_f by cross-sectional area in square inches. The dimensions of the test faces will be measured to ± 1/16-in. (1.6 mm) for calculation of the cross-sectional area. The rate of load increase will be 400 psi per minute for specimens expected to have greater than 500 psi strength. For specimens expected to have less than 500 psi strength, 100 psi increment per minute will be applied. The compressive strength will be recorded and averaged to the nearest 10 psi. The weight percent of dispersant and retarder will be adjusted by the results of thickening time test.

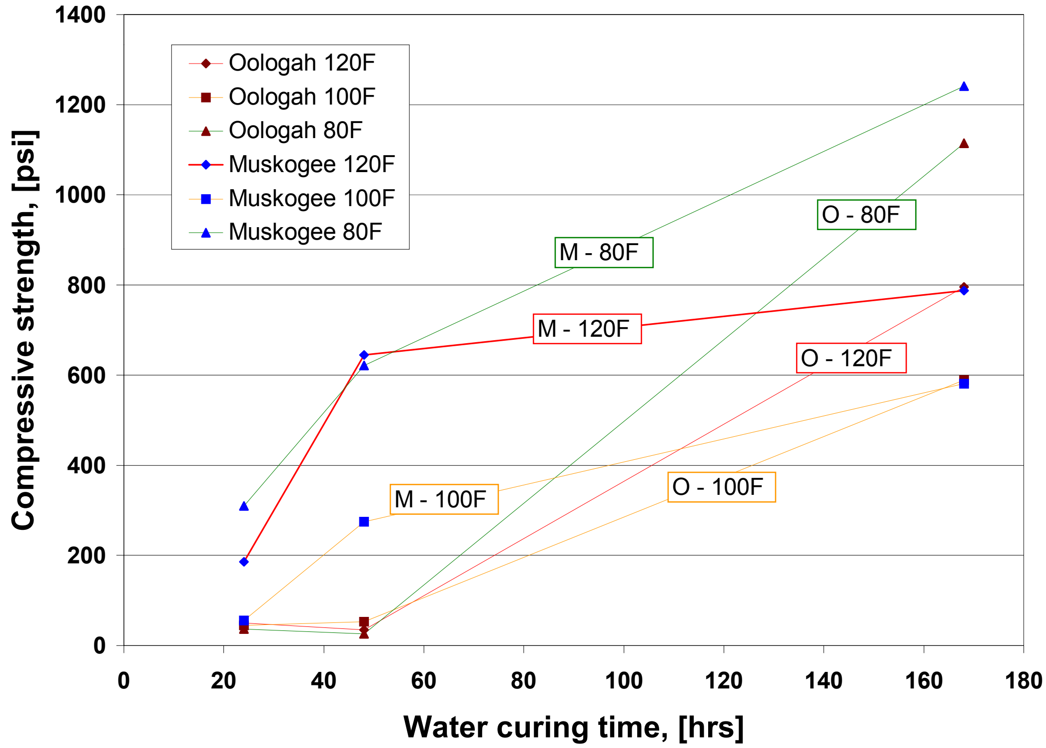

Fig. 4 – Effects of 0.5% dispersant on compressive strength

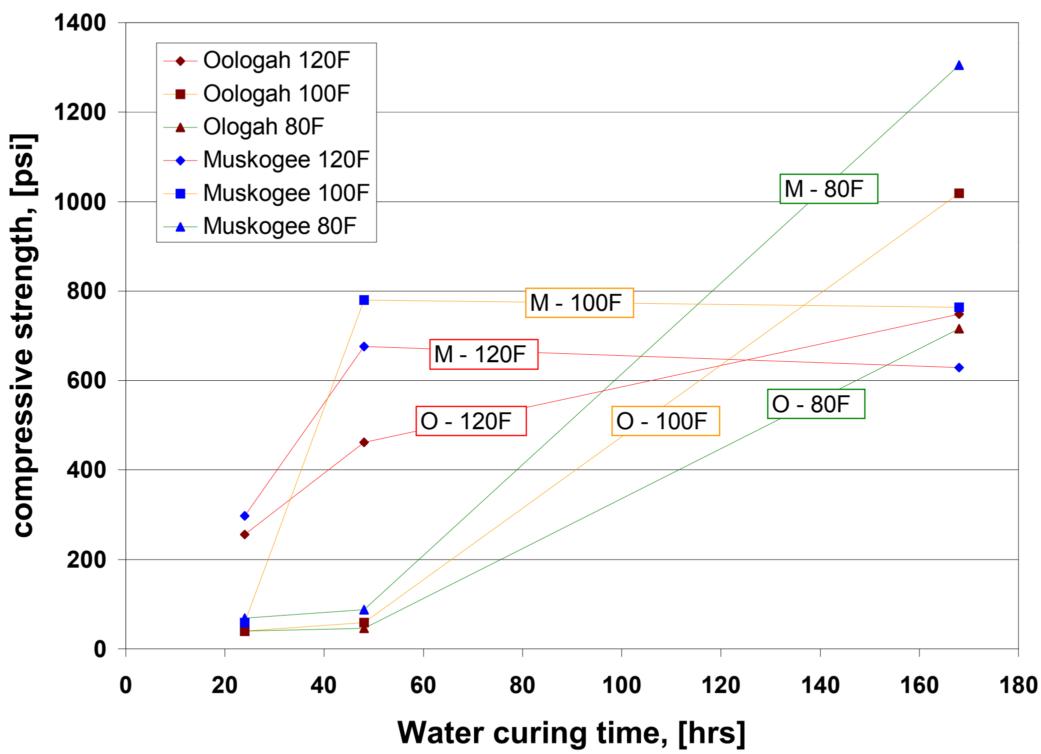

Fig. 5 – Effects of 0.5% retarder on compressive strength

4.2 Thickening time tests

The elapsed time between the initial application of pressure and temperature of the apparatus and the occurrence of a consistency of 100 B_c will be reported as the thickening time for the test. The maximum consistency during the 15-30 minutes stirring period will be reported. The acceptance requirements for the maximum consistency during the 15-30 minutes stirring period will be 30 B_c for fly ash cement formulations in accordance with API RP 10A.

4.3 Product durability tests

The test cores will be made from three different fly ash sources and Portland cement. The core samples will be cured for one week at 120^{o}F water bath temperature. The weight of core samples will be measured before they are immersed simultaneously into the solutions (brine and acidified water) This procedure will be performed separately for brine and acidified water (pH $\cong$ 5.0). The test standard ASTM C 216 – 97: "Standard Specification for Facing Brick" will be applied on this product durability test. An increase in gravitational weight of each sample will be measured and calculated for maximum saturation coefficient.