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Effects of Lignosulfonate and Temperature on Compressive Strength of Cement

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ABSTRACT

Additive is an important factor that significantly affects the properties of cement. There are many additives used in cement industry. The additives have different functions such as denser, retarder, and viscosifier. In an attempt to obtain appropriate cement, a right additive with an appropriate quantity should be added on the cement.

In this study, we observed the effect of Lignosulfonate on cement. Lignosulfonate has a function as a retarder which is able to extend the compressive strength of the cement concrete. Laboratory experiments were carried out at several temperature conditions. The temperature is varied from 28^{o}C to 80^{o}C. The experiment showed that the compressive strength of the concrete increased as the temperature during the curing time increased within the range studied. The laboratory experiment also indicated that the compressive strength of the concrete increased due to an addition of the Lignosulfonate. It reached a maximum value at the addition of Lignosulfonate as much as 0.2% of the cement weight at various temperatures. An addition of the additive at a higher level resulted in a decrease in the compressive strength of the cement.

1. INTRODUCTION

Cement is usually made to some purposes such as provision of mechanical support of casing string, protection of the casing from corrosion, and support of the well-bore walls to prevent collapse of formations. The basic material of cement can be obtained from calcareous and argillaceous rocks such as limestone, clay, shale and slag. It may also contain sand, iron ore, etc. The basic material of cement selected for the geothermal well is usually API (American Petroleum Institute) Class G cement because the material has high resistance of pressure, temperature and sulfate. Unfortunately, the cement may not be compatible with any complex geothermal well condition. Therefore a special additive is required to improve the properties of the cement.

Retarder is a type of the additive that is able to slow down the cement hydration reactions. It is useful to allow cement slurry pumped in a longer time. Lignin, Calcium-lignosulfonate and Sodium Lignosulfonate are retarders that commonly used in well cementing. They are made from wood or straw. Retarder is normally added into cement slurry with a concentration between 0.1% and 1.0% for every sack of cement.

This paper repots the amount of lignosulfonate that should be added into cement to reach a maximum compressive strength at various temperature conditions. The strength of the cement was investigated for curing time of 8 hours.

2. LITERATURE REVIEW

Cement usually consists of four major components: Tricalcium Silicate (C3S), Dicalcium silicate (C2S), Tricalcium aluminate (C3A), and Tetra alcium aluminoferrite (C4AF) (Rabia, 1985). The silicates, i.e. C3S and C2S are the most important compounds for the strength of hydrated cement paste. Hydration of cement is solidness when water is added to cement powder. The cement hydration is a chemical process which depends on the fineness of cement particles (Mahdavi, 2004). There are two main reactions that release energy which is mainly composed of tricalcium silicate and dicalcium silicate (Dawkrajai, 2006). The reactions can be expressed by:

$$2Ca_3SiO_5 + 7H_2O \rightarrow 3CaO.2SiO_2.4H_2O + 3Ca(OH)_2 + 173.6\ kJ$$

$$2Ca_2SiO_4 + 5H_2O \rightarrow 3CaO.2SiO_2.4H_2O + Ca(OH)_2 + 58.6\ kJ$$

When the cement slurry is placed in an annulus of a wellbore, the cement slurry will be loaded by a various high pressure to the rock formation. Therefore, most of water loses to the formation through dehydration and evaporation process. The actual mechanism of the cement bond process is very complex. It depends on the shape and the type of the formation surface.

Compressive strength is the ability of a material to withstand deformation when a load is applied. Mathematically, the compressive strength (f'_c) is expressed as a ultimate load attained (P) during the test over a cross-sectional area (A) (Báez, 2008) or:

$$f_c^{'} = \frac{P}{A} \tag{1}$$

The compressive strength of a cement concrete depends on type of raw materials including additives used, mixture proportions, concrete structure, method and time of curing, and exposure conditions (Herianto and Fathaddin, 2005; Báez, 2008; Therán, 2008).

3. EXPERIMENT

In this experiment, API Class G type HSR cement was determined as the basic cement. The specific gravity of cement was 3.14 (26.16 ppg). Lignosulfonate with Q Broxin type which was in form of powder was chosen as the retarder. Distillated water which was free from CO2 was used to dissolve the cement and retarder.

Apparatus used in the experiment mainly consisted of compressive strength tester, balance, beakers, graduated cylinders, mixer, cement mold and curing chamber. The compressive strength tester was utilized to determine the compressive strength of the cement, while the others were utilized to prepare the cement specimens for the compressive strength tests.

Table 1 indicates the variation of lignosulfonate, basic cement, and water composition applied in the experiment. The total volume of each cement slurry specimen was 600 ml. The ratio of the water weight to the weight of cement and lignosulfonate was kept constant at 44% in all of the specimens. The weight of cement was also kept constant at 792 grams. The ratio between the lignosulfonate weight to cement weight was varied from 0% to 0.7%.

Table 1: Composition of the cement slurry specimens

% Weight of ligno-sulfonate	Weight of lignosul-fonate (gr)	Weight of cement (gr)	Weight of water (gr)
0.00	0.00	792.00	348.48
0.10	0.79	792.00	348.83
0.20	1.58	792.00	349.18
0.30	2.38	792.00	349.53
0.40	3.17	792.00	349.87
0.50	3.76	792.00	350.22
0.60	4.75	792.00	350.57
0.70	5.54	792.00	350.92

The cement slurry was made as follows. Water was decanted into a mixer which was spun at a low speed (4000 ± 200 rpm). Subsequently, cement and lignosulfonate were poured into the mixer within 15 seconds. After that they were stirred at a higher speed (12000 ± 200 rpm) for 35 seconds.

The cement slurry specimens were placed into several cement molds and compressed to release gas bubbles. They were then immersed in the curing chamber at a constant temperature. The immersion period or curing time of the specimens was 8, 16, and 24 hours. The temperature of the curing chamber was set at 28, 40, 50, 60, 70 and 80^{o}C.

After reaching the curing time, the concrete specimens which had been stiff were compressed using the compressive strength tester. Pressures required making them crack were measured to obtain their compressive strength.

4. RESULTS AND DISCUSSION

Tables 2 to 4 provide the measurement results of the compressive strength for several curing times and operating temperatures. Figures 1 to 3 shows the effect of % weight of lignosulfonate and temperature on the compressive strength of the specimens. The figures show that for curing time of 8, 16, and 24 hours, the maximum compressive strength is reached if 0.2% weight of lignosulfonate added in the cement slurry. These phenomena indicate that there is an optimum composition to result in a maximum compressive strength for the cement concrete. Temperature parameter produces a dehydration of the cement at a certain level. This reaction affects the compressive strength of the cement concrete as well as shown in the figures.

Table 2: Compressive strength at 8-hour curing time

% lingo-sulfonate	Compressive Strength (psi)					
	T = 28^{o}C	T = 40^{o}C	T = 50^{o}C	T = 60^{o}C	T = 70^{o}C	T = 80^{o}C
0.00	–	560	638	1206	1600	2250
0.10	–	900	1283	1753	2150	2600
0.20	–	–	1616	2050	2800	2950
0.30	–	–	616	1216	1783	2216
0.40	–	–	–	700	1000	1750
0.50	–	–	–	–	–	–

Table 3: Compressive strength at 16-hour curing time

% ligno-sulfonate	Compressive Strength (psi)					
	T = 28^{o}C	T = 40^{o}C	T = 50^{o}C	T = 60^{o}C	T = 70^{o}C	T = 80^{o}C
0.00	1183	1708	1916	2500	2900	3250
0.10	1333	2198	2566	3483	3750	4050
0.20	1650	2400	3266	3900	4350	4583
0.30	1466	1716	2400	3000	3900	4216
0.40	1000	1250	1433	1966	2750	3156
0.50	500	700	900	1150	1250	1533
0.60	–	–	–	–	–	–

Table 4: Compressive strength at 24-hour curing time

% ligno-sulfonate	Compressive Strength (psi)					
	T = 28^{o}C	T = 40^{o}C	T = 50^{o}C	T = 60^{o}C	T = 70^{o}C	T = 80^{o}C
0.00	1266	1650	1883	2830	3500	4200
0.10	1833	2300	2816	3633	4250	4700
0.20	2166	2850	3616	4233	4750	4933
0.30	1616	2250	3153	3833	4383	4755
0.40	1333	1753	2266	3033	3750	4200
0.50	1016	1350	1716	2150	2500	3550
0.60	766	950	1000	1216	1250	–
0.70	–	–	–	–	–	–

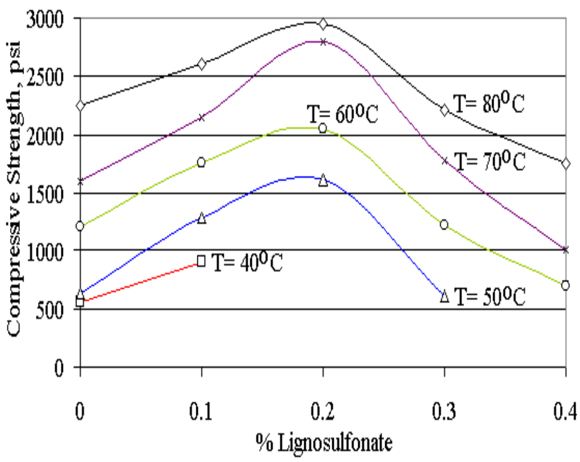

Figure 2: Compressive strength at 8-hour curing time.

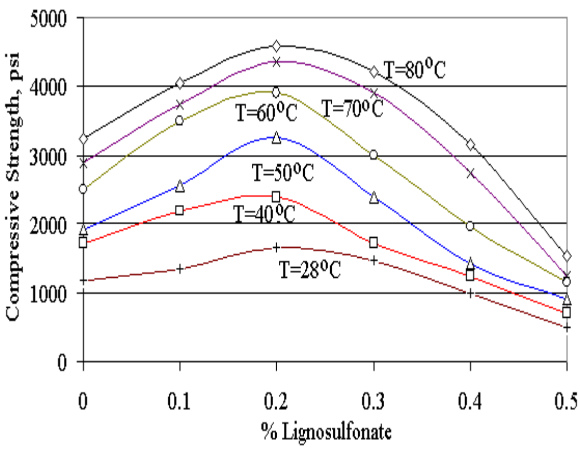

Figure 2: Compressive strength at 16-hour curing time.

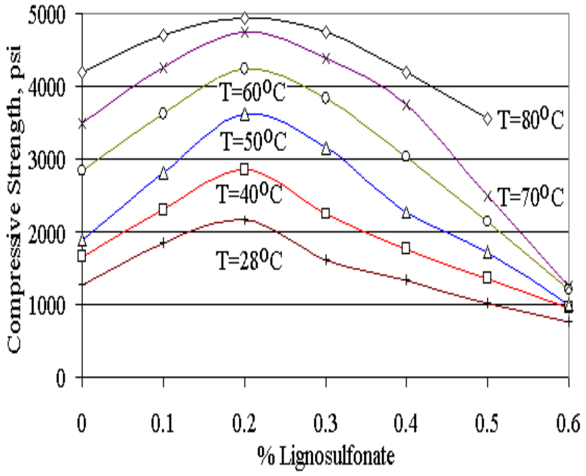

Figure 3: Compressive strength at 24-hour curing time.

Figure 4 shows the change of compressive strength as curing time and temperature. The figure indicates that the compressive strength increases as the curing time increases within the range studied. However the concrete tends to reach a constant the compressive strength as the curve tends to be flat. The figure illustrates that the effect of temperature decreases since the curves become closer as the temperature increases.

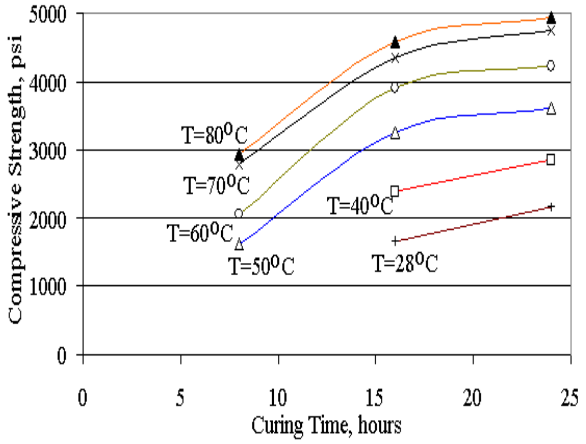

Figure 4: Compressive strength for specimens with 0.2% lignosulfonate.

5. CONCLUSIONS AND RECOMMENDATION

The experiment showed that the compressive strength of cement concrete increased as the temperature increased during a curing time. On the other hand, if the temperature was kept constant, the compressive strength tended to increase as the curing time increased. The compressive strength of the cement concrete was increasing within the range of temperature and curing time studied. The peak of the cement strength could be obtained by extending the range.

The compressive strength of concrete increased due to an addition of the lignosulfonate. It reached a maximum value at the addition of lignosulfonate as much as 0.2% of the cement weight at various temperatures. The addition of the additive at a higher level resulted in a decrease in the compressive strength of the cement.

NOMENCLATURE

A = cross-sectional area, in^2.

f'_c = compressive strength, psi.

P = ultimate load attained, lb.

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