IJST EXPLORE International Journal of Science and Technology
CENTRE OF PROFESSIONAL RESEARCH PUBLICATIONS
ISSN 2049-7318

International Journal of Science and Technology Volume 2 No. 10, October, 2013

The Effects of Increasing Temperature and Pressure on Cement Slurries Treated with Ughelli Sands

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ABSTRACT

In a series of experiments carried out at the material laboratories in the Mechanical Engineering Laboratory of the University of Benin, Edo state, Nigeria, Ughelli sands were progressively used to substitute the imported silica flour and the effect on compressive strength analysed and noted. Results showed that the Ughelli sands can be a substitute for the more expensive silica flour commonly used by the drilling companies in Nigeria to combat the effect of the cement retrogression in High Pressure High Temperature (HP HT) terrain in the country, especially in the Niger Delta Basin. . These sands contain approximately 93 % silica and at over 60 % substitution can be used for HP HT operations in the Niger Delta.

Keywords: *Ughelli Sands, Silica Flour, Cement Retrogression, Niger Delta*

1. INTRODUCTION

This paper documents an investigation into the use of indigenous sands from Ughelli (Delta state, Nigeria) to control cement retrogression. Cement retrogression has been observed to be dependent on temperature and pressure. Traditionally silica flour has been used to prevent retrogression.

In a set of experiments carried out at the material laboratories in the University of Benin, Edo state, Nigeria, Ughelli sands were progressively used to substitute the imported silica flour and the effect on compressive strength of the cement –sands slurry noted.

2. EXPERIMENT

The loss of compressive strength is one of the indications of a weakening of the cement structure at elevated pressure temperature conditions (HP HT). This condition is known as cement retrogression. It is desirous to use this experiment to understand the role Ughelli sands can play in the prevention or reduction of cement retrogression in HP HT environments of the Niger Delta basin of Nigeria. To this end several cement- sand slurries (slurry composition A to F) were prepared. The composition of these slurries is shown below in table 1.

2.1 The Constituents of the Cement Slurries Tested

1. Ughelli sands
2. Silica flour
3. API Grade G cement
4. water (water density 1.004gm/ml, temperature 71.6 deg F)

Cement slurries A to F were prepared with these constituents in different ratios as shown in table 1 and subjected to different pressure temperature conditions.

Table 1: The ratios of Silica flour and Ughelli sands used in each slurry composition

S/N	Cement slurries	Silica flour	Ughelli sands
1	A	0.107	0.333
2	B	0.107	0.333
3	C	0.250	0.208
4	D	0.250	0.208
5	E	0.355	0.071
6	F	0.355	0.071

Where: Ratio = a/b

a = weight of additive e.g. silica flour or Ughelli sand, in gram

b = weight of API grade G cement, in gram

The temperatures range investigated in this experiment were from 200 deg F to 350 deg F as follows:

1. 200 deg F,
2. 250 deg F,
3. 300 deg F
4. And 350 deg F.

And the pressures were from 5,000psi to 10,000 psi.

Each of the slurries cement was cured for 30 minutes. The study aimed at an investigation of the development of early age compressive strength. (Early-age compressive strength: This is the compressive strength of cement at initial times after the preparation and placement of cement grout into the wellbore.) The development of high early-age compressive strength oil well cement is an important task in the oil well cement design. Achievement of suitable early-age compressive strength of oil well cement ensures both the structural support for the casing and hydraulic/mechanical isolation of borehole intervals.

3. THE METHODOLOGY

The experiment involves mixing the above listed constituents in various percentages to produce cement slurry. The volume of water used was kept constant at 1500 ml for each of the slurries mixture. The slurries obtained were subjected to the same 30-minutes curing times, and varying high pressure, and high temperature conditions. Under these HP HT conditions the cement slurries were subject to increasing load. The maximum loads before failures were determined. The compressive strength was calculated.

4. RESULT

The experimental result is as shown on the tables (1) – (3). The average temperature in the laboratory during the experiments was 75.5 deg F. Each table below represents analysis of slurries of constant composition at a constant temperature. The pressure the specimens were subjected to increase by a power of 100.

5. DISCUSSION

A plot of the data showed the effect of increasing temperature and pressure for constant composition figure (1) to (3). Each figure represents a constant composition and highlights the effect of increasing temperature and pressure. The correlation was found to be multiple linear regressions; direct but not perfect. A discernable trend was observed.

A regression analysis was done and the standard deviation was used to compare the characteristics of each of the individual values in each compositional and temperature group. It was observed that the effect of small changes in pressure is not pronounced (on the compressive strength) at constant composition and temperature. Values for the variance ranged in value from 0.0 to 0.1 while the standard deviation was from 0.1 to 0.3, the Ughelli sand was considered to be mature and well sorted sand.

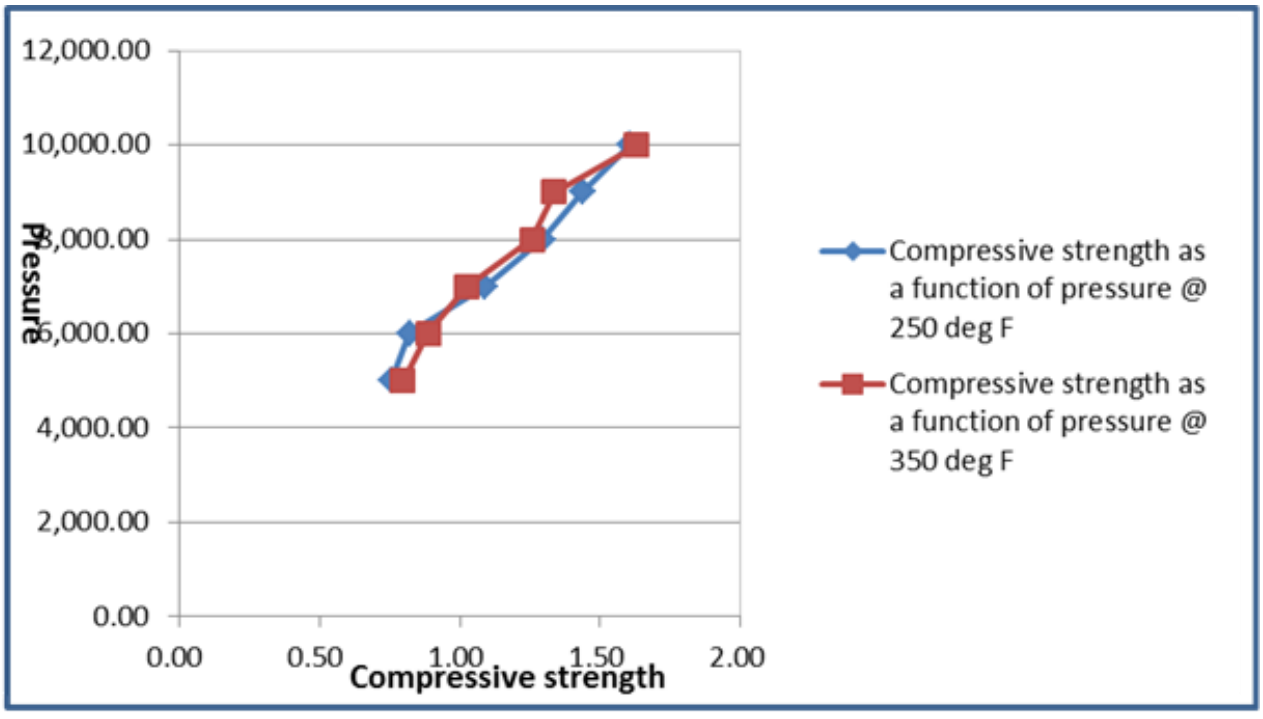

Figure 1: Compressive strength at 250 deg F and 350 deg F

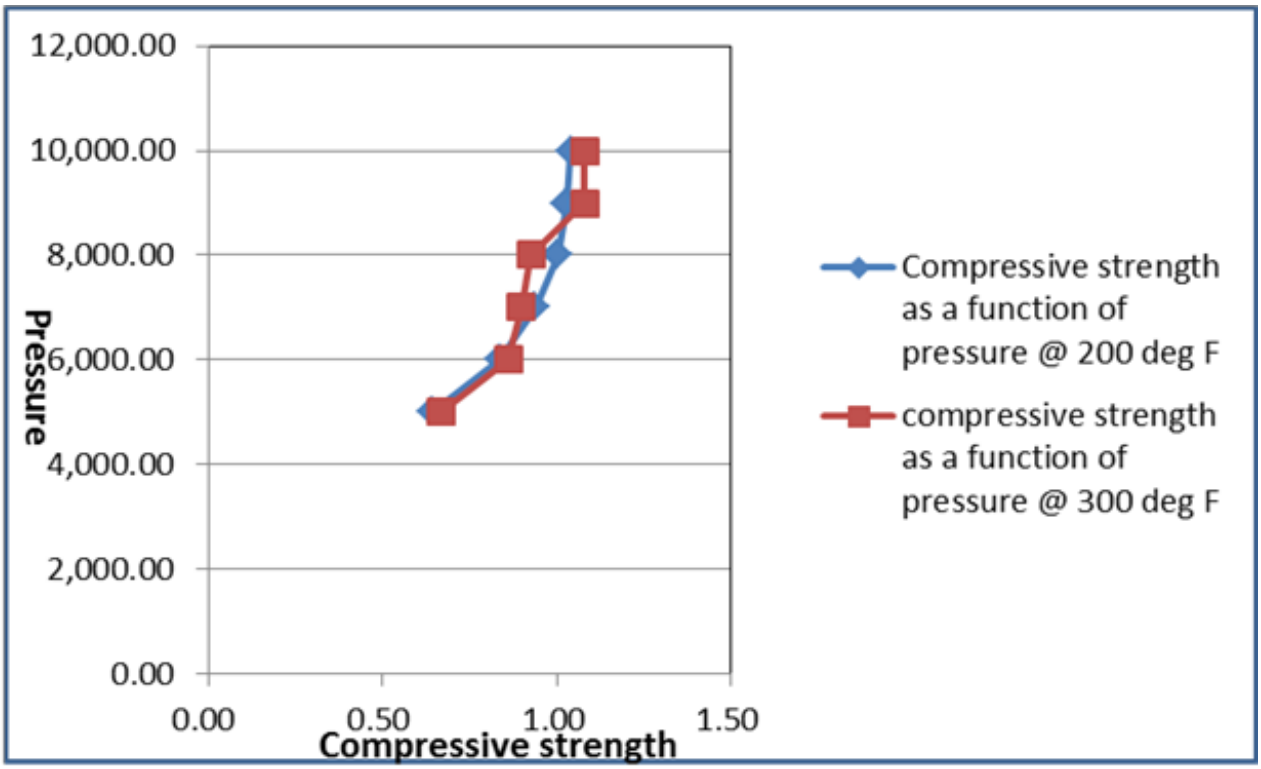

Figure 2: Compressive strength at 200 deg F and 300 deg F

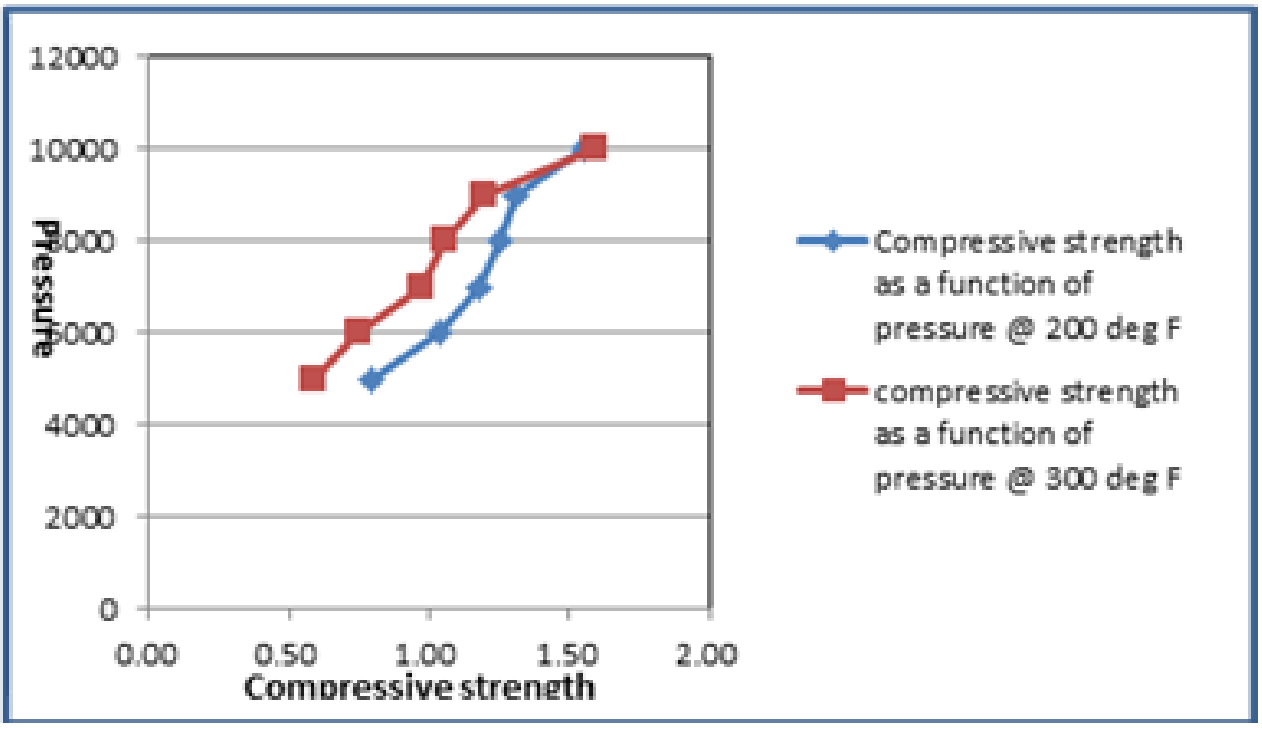

Figure 6: Compressive strength at 200 deg F and 300 deg F

6. CONCLUSION

The compressive strength of cement slurry used in cementation is dependent on a host of variables which

includes the physical properties of the cement, physical properties of the formation water, composition of the cement, composition of the formation water, temperature, and pressure.

However in this paper we examined a limited number of these, namely temperature, pressure and the composition of the slurry (i.e. the percentage of silica flour and Ughelli sand in each slurry)

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Table 2: Experimental data for slurry composition A and B

S/N	Dry weight of Silica flour (gram)	Dry weight of Ughelli sands (gram)	Dry weight of API grade G cement(gram)	Temp. deg F	Pressure, Psi	Max. Load ,KN	Compress. Strength, Psi
1	2,080.00	6,500.00	19,500.00	200	5,000.00	6.2	0.7958
2	2,080.00	6,500.00	19,500.00	200	6,000.00	8.1	1.0397
3	2,080.00	6,500.00	19,500.00	200	7,000.00	9.2	1.1809
4	2,080.00	6,500.00	19,500.00	200	8,000.00	9.8	1.2579
5	2,080.00	6,500.00	19,500.00	200	9,000.00	10.2	1.3093
6	2,080.00	6,500.00	19,500.00	200	10,000.00	12.1	1.5532
7	2,080.00	6,500.00	19,500.00	300	5,000.00	4.6	0.5905
8	2,080.00	6,500.00	19,500.00	300	6,000.00	5.8	0.7445
9	2,080.00	6,500.00	19,500.00	300	7,000.00	7.6	0.9755
10	2,080.00	6,500.00	19,500.00	300	8,000.00	8.2	1.0526
11	2,080.00	6,500.00	19,500.00	300	9,000.00	9.3	1.1937
12	2,080.00	6,500.00	19,500.00	300	10,000.00	12.4	1.5917

Table 3 : Experimental data for slurry composition C and D

S/N	Dry weight of Silica flour (gram)	Dry weight of Ughelli sands (gram)	Dry weight of API grade G cement(gram)	Temp. deg F	Pressure, Psi	Max. Load ,KN	Compress. Strength, Psi
13	4,680.00	3,900.00	18,720.00	250	5,000.00	5.9	0.7573
14	4,680.00	3,900.00	18,720.00	250	6,000.00	6.4	0.8215
15	4,680.00	3,900.00	18,720.00	250	7,000.00	8.5	1.0911
16	4,680.00	3,900.00	18,720.00	250	8,000.00	10.1	1.2964
17	4,680.00	3,900.00	18,720.00	250	9,000.00	11.2	1.4376
18	4,680.00	3,900.00	18,720.00	250	10,000.00	12.5	1.6045
19	4,680.00	3,900.00	18,720.00	350	5,000.00	6.2	0.7958
20	4,680.00	3,900.00	18,720.00	350	6,000.00	6.9	0.8857
21	4,680.00	3,900.00	18,720.00	350	7,000.00	8	1.0269
22	4,680.00	3,900.00	18,720.00	350	8,000.00	9.8	1.2579
23	4,680.00	3,900.00	18,720.00	350	9,000.00	10.4	1.3349
24	4,680.00	3,900.00	18,720.00	350	10,000.00	12.7	1.6302

Table 4: Experimental data for slurry composition E and F

S/N	Dry weight of Silica flour (gram)	Dry weight of Ughelli sands (gram)	Dry weight of API grade G cement(gram)	Temp. deg F	Pressure, Psi	Max. Load ,KN	Compress. Strength, Psi
25	6,500.00	1,300.00	18,200.00	200	5,000.00	5	0.6418
26	6,500.00	1,300.00	18,200.00	200	6,000.00	6.5	0.8343
27	6,500.00	1,300.00	18,200.00	200	7,000.00	7.3	0.9370
28	6,500.00	1,300.00	18,200.00	200	8,000.00	7.8	1.0012
29	6,500.00	1,300.00	18,200.00	200	9,000.00	8.0	1.0269
30	6,500.00	1,300.00	18,200.00	200	10,000.00	8.1	1.0397
31	6,500.00	1,300.00	18,200.00	300	5,000.00	5.2	0.6675
32	6,500.00	1,300.00	18,200.00	300	6,000.00	6.7	0.8600
33	6,500.00	1,300.00	18,200.00	300	7,000.00	7.0	0.8985
34	6,500.00	1,300.00	18,200.00	300	8,000.00	7.2	0.9242
35	6,500.00	1,300.00	18,200.00	300	9,000.00	8.4	1.0782
36	6,500.00	1,300.00	18,200.00	300	10,000.00	8.4	1.0782