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MITIGATION AGAINST WEIGHT AND COMPACTION STRENGTH LOSSES DURING CARBONATION OF OIL WELL CEMENT

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Abstract

Cementing in the oil sector covers a wide range of temperature. In this research, the effect of the formation temperature on hardened cement contaminated with CO_2 was studied. Studied also was the effect of additive in the cement slurry during preparation as inhibitor against future carbonation. It was discovered that rice husk ash additive minimized hardened cement carbonization to only 2.34% loss in cement core dry weight. It was also discovered that preparing cement with brine reduces possibility of future carbonization. There was 22.2% weight loss for brine mixed cement while the cement mixed with ordinary water had a weight loss of 34.25% due to contamination with CO_2. This result was obtained even when the ordinary Portland cement had a coring period of over four months which was seven folds curing period than that of the cement with the rice-husk ash/brine additives and so is expected to have higher resistance against carbonization than the ones with additives. The ordinary Portland cement had higher compressive strength, 2.39N/mm^2, than others. Portland cement mixed with brine (sea water) had low compressive strength of 0.73N/mm^2 for a curing period of 16 days. Addition of rice husk ash to the offshore cement mixed with sea water improved the compressive strength to 1.62N/ mm^2. This indicated that in the face of carbonization, cement mixed with brine will give weaker strength than those mixed with normal water under the same environmental condition. Hence, addition of rice husk ash to cement will minimize carbonation of the cement and give the cemented well a good well structural integrity on exposure to CO_2 gas during CO_2 flooding/storage or during CO_2 leakage from adjacent reservoir.

***Keywords**: carbonization; cement curing; cement compressive strength; cement additive; rice husk ash; brine; oil well cement.*

1. Introduction

Carbonation results when carbonate ions from dissolved carbon dioxide react with the Ca^{2+} ions of the cement paste and precipitate calcium carbonate [1-2]. The deeper the depth of cement placement, the higher the temperature of the formation rock and fluid that is in contact with the cement. In the presence of CO_2 contamination, the hardened cement is liable to breakdown due to possible carbonization effect. This is because CO_2 is acidic gas and has ability to react with the cement. Since calcium carbonates dissolve at high temperatures, there is possible dissolution of oil-well cements under high temperature. CO_2 gas can react with rocks and altered its properties [3] and is believed to also have similar alteration effects on properties of hardened cement.

When hardened, cement can be exposed to environmental factor that will alter its properties and structures, especially exposure to CO_2. Carbonation is a natural aging process for cement but it varies with hydration time and atmospheric conditions [2].

2. Methodology

The following steps were followed in this research:

- Sample of Portland cement mixture was prepared cured and preserved for 4 months.
- Other samples of Portland cement slurry were prepared with rice husk ash as additive, brine as additive and mixture of rice husk and brine as additives.
- The various cement samples were allowed to harden through natural curing process of 16days.

- Cement cores were obtained from the samples using Delta 17-750L core drill machine.
- The core samples, soaked in water, were placed in core holder and then injected with CO_2 for about 5 minutes daily for a month and the change in core weight was measured as indication of carbonization effect due to reaction with injected aqueous CO_2. The cores were soaked in water during the CO_2 injection because oil well cement will definitely be in contact with water in the subsurface.
- Also measured were the compressive strengths of the cores to check the integrity of the cement during CO_2 contamination.
- The cores were oven dry to measure the final dry weight and then percentage weight loss was calculated as stated in Table 1.

3. Results and Discussion

The initial weight and final weight of the cores used is presented in Table 1 while the compressive strength after carbonation is as stated in Table 2.

Table 1 Dry core sample weight loss

Core Sample	Before experiment (g)	After experiment (g)	Weight Loss (g)	Percentage weight loss (%)
Ordinary Portland Cement	14.6	9.6	5.0	34.25
Cement with rice husk ash	12.8	12.5	0.3	2.34
Cement with brine	18	14	4	22.22
Cement with Rice husk ash and mixed with brine	12.1	11.7	0.4	3.31

Table 2 Samples compressive strengths after carbonation

Sample	Diameter (mm)	Height (mm)	Area (mm^2)	Failure load (N)	Compressive strength (N/mm^2)
Ordinary Portland Cement	23.50	18.50	2233.28	5340	2.39
Cement with rice husk ash	24.50	22.00	2636.19	3000	1.14
Cement with brine	24.50	26.90	3013.34	2190	0.73
Cement with Rice husk ash and brine	24.50	20.00	2482.25	4010	1.62

The result of contamination with CO_2 when the hardened cement is located in water zone is as shown in figures 1 to 4. The weight for each core sample was discovered to be relatively constant initially and then decrease gradually until a minimum weight was obtained.

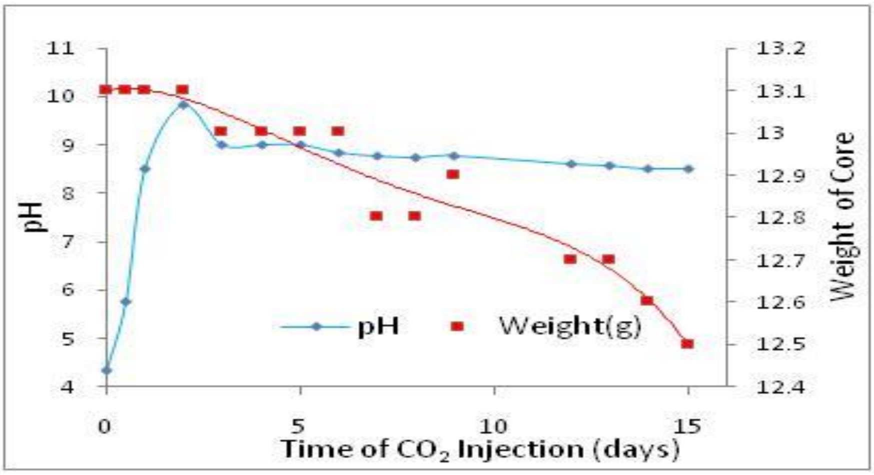

Figure 1 pH and wet weight of portland cement core

The pH reached the maximum at the day 2. After this, there was a drop in the pH which then remained almost constant till the end of the 15th day. At the point of maximum pH, there was weight loss of 0.1g between the 2nd day and the 3rd day. The weight remained constant for another 4 days after which there was a weight loss again and this tends to continued until the 15th day. The weight remained constant after this day.

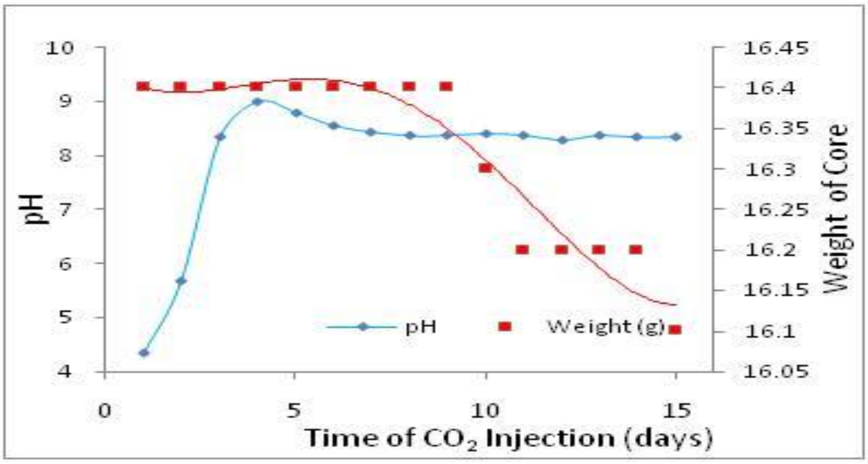

Figure 2 pH and wet weight of portland cement with rice husk ash

For the sample 2, there was also a change in the pH which reached the maximum on the 4th day. After this, there was a slight drop in the pH which then remains almost constant at the 7th day. The weight of the sample remained constant until the 9th day, followed by rapid weight loss for the next 2 days. The weight remained constant for the next 3 days and then dropped on the 15th day. For this sample, the maximum pH does not correspond with beginning of weight loss.

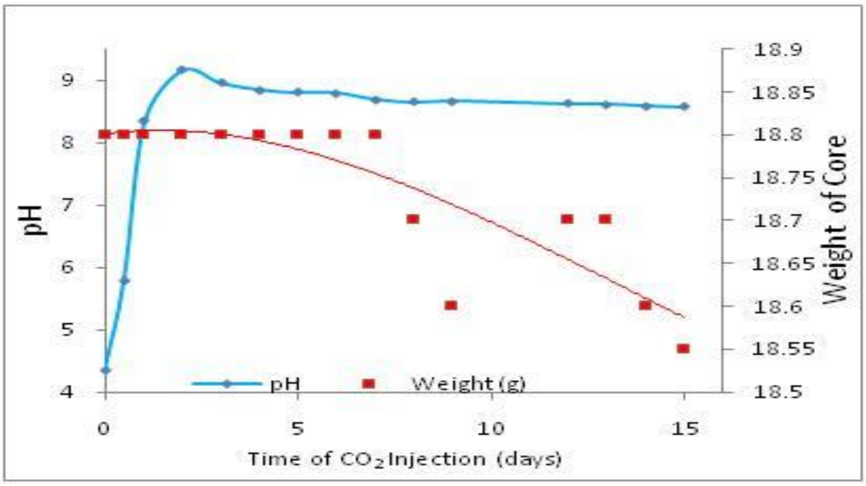

Figure 3 pH and wet weight of portland cement with brine core

The pH variation for sample 3 is similar to that of sample 2 and the weight remained constant for the first 7 days after which there was a sharp weight loss. For this sample also, there was a time lag between the maximum pH value and the starting of weight loss signifying beginning of reaction between sample and the carbonized water.

The pH variation for this sample is similar to that of sample 2 and 3. The pH reached the maximum in the 1st day and then dropped slightly for the rest of period of investigation. The sample weight remained constant for the first 5 days after which there was a sharp weight loss. For this sample also, there was a time lag between the maximum pH value and the starting of weight loss signifying beginning of reaction between sample and the carbonized water

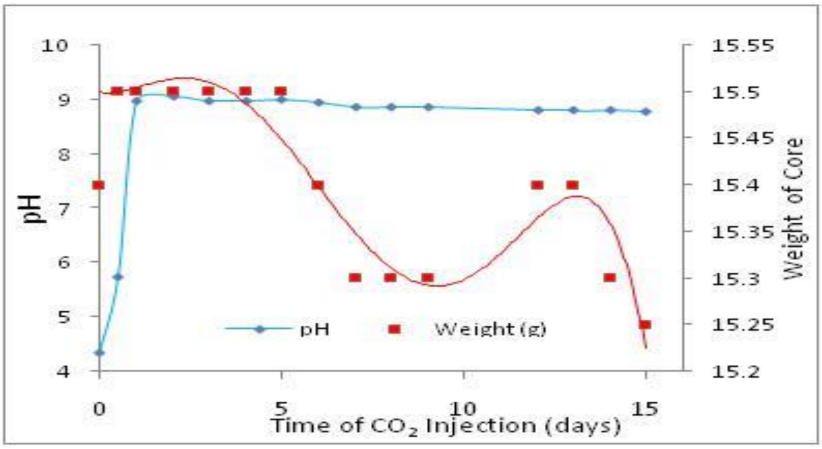

Figure 4 pH and Wet Weight of Portland Cement With RIce Husk ash and Brine Core

4. Conclusion

From table 1, it was discovered that the ordinary Portland sample lost 34.25% of its weight throughout the experiment while the ordinary Portland mixed with brine lost 22.22% of its weight. The cement with rice husk ash and brine lost 3.31% of its weight during the experiment while the rice husk ash cement lost 2.34% of its weight during the experiment.

From this it can be concluded that the ordinary Portland cement sample undergone more carbonization than others due to its highest loss of core weight. This was followed by the cement core with brine while the core with rice husk ash undergone the least carbonization during the experiment. Hence, rice husk ash additive is a good mitigating material against oil-well cement damaged due to contamination with CO_2. Moreover, the use of the rice husk ash additive is recommended for wells specifically drilled for CO_2 underground injection or storage.

In table 2, the various compressive strengths of the samples after carbonation reaction is reported. Ordinary Portland sample gave the highest compressive strength after carbonization. The core sample with both rice husk ash and brine additives gave a better compressive strength than the core sample with only rice husk ash additive while the compressive strength for the cement core with only brine additive was the least. It can then be concluded that mixing the cement with rice husk ash additive as carbonization inhibitor will make the cement to have higher strength.

The peak pH value determines the highest concentration of calcium carbonates, i.e. the highest carbonization, formed in a sample during the reaction for a given period of time. This is because calcium carbonate is basic. It is therefore assumed that the increase in the pH value of a cement sample in solution during a reaction can represented the extent of carbonation. It is also an indication of the magnitude of carbonation that occurred in the sample. For the Cement with brine, higher pH was expected since brine itself caused an increase in the pH of the core in solution. This can be seen right from the second day when the pH of the cement cores with brine was the highest already though with minimal weight change. Since cement core sample with the rice husk ash additive gave the lowest variation in pH, it is assumed that it undergone the lowest carbonization and this was confirmed with its lowest weight loss among all the core samples.

Since the carbonization of the cores with rice husk ash additive and that of rice husk ash and brine additives have very low carbonization effect on contamination with CO_2, it is recommended that both rice husk ash and brine be combined as carbonization inhibitor additives in oil well cement in order to gain higher cement strength.

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