Effect of Clay Additives on Curing and Sensing Behavior of Smart Cement

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Abstract: This study presents the results of experiments conducted with smart cement modified with two different types of nano-clays (Bentonite and Laponite). The effect of clay additives on curing was investigated using calorimetry analysis and the effect on compressive behavior was characterized using impedance measurement while loading. The results indicated that the addition of clay reduces the hydration heat (laponite: 22% and bentonite: 23%), increases the one day compressive strength (laponite: 25% and bentonite: 14%) and reduces the piezoresistivity slightly (laponite: 19% and bentonite: 6%).

1. Introduction:

Due to increasing prominence in maintenance and rehabilitation of structures, smart materials capture lot of interest. Various studies have been in progress and reported in the literature, to modify and improve the composition of cement to enhance its curing, mechanical and sensing properties. It is reported that some environmental friendly second nonconductive additives (additional to conductive filler) had positive consequence on piezoresistivity and compressive strength (Chung, 2000). The change was attributed to the improved fiber dispersion. Considerable heat is released during cement hydration. It is reported that the use of secondary additives has reduced the amount of heat released during hydration (Jones and McCarthy, 2006).

2. Objective:

The main objective of this study is to investigate the effect of different nano clay additives on the curing, compressive and sensing behavior of smart cement.

3. Materials and Methods:

Class H oil well cement was modified by adding about 0.04% of the conductive filler with a water to cement ratio of 0.38 to get smart cement. In order to characterize the effect of different nano clay additives, 2”x4” cylindrical specimens were prepared with 0.5% (by weight of cement) of nano clay (Laponite or Bentonite). Monitoring wires were embedded while preparing the specimen.

Electrical resistivity of the slurries was measured using the digital resistivity meter and resistance was measured using a LCR meter. In order to minimize the contact effects, the resistance was measured at 300 kHz using two probe a.c. method. For the compressive property analysis, cylindrical specimens were covered with plastic caps and cured under normal room condition for 24 hours. Then the specimens were demolded and tested using a destructive testing method (compressive loading). In order to compare the sensitivity due to different additives, bulk resistance was taken (real part of impedance at 300 kHz).

Semi-adiabatic calorimeter was used to record the temperature during early hydration (up to five days). The peak temperature and time to reach it were compared for the samples with and without additives. A KD2 Pro thermal property analyzer was used to measure volumetric specific heat capacity, C_v ($J/cm^3/K$) during cement hydration, and heat released during hydration, Q (J) was calculated using $Q = C_v.V.\Delta T$, [V-volume of the specimen (cm^3), ΔT-change in temperature (K)].

4. Results and Analysis:

Addition of 0.5% clay, reduced the C_v of the cement composite and it delayed the time to reach peak temperature. As there is a correlation between time to reach the peak temperature and setting time of the cement, addition of clay could efficiently delay the setting time of cement. Figure 1 shows the resistivity behavior of smart cement and nano-clay modified smart cement from mixing through hardening to curing in the air for 5 hours. Figure 2 shows the variation of stresses and change in specific resistivity during compression loading. As seen in the figures resistivity, change in resistivity at 24 hours, strength gains and sensitivity are also reasonably affected by the addition of clay.

Table 1: Thermal Properties of Class H Oil Well Cement with and without Clay additives

Additives	Peak Temperature (°F)	Volumetric Specific Heat Capacity (J/cm^3/K)	Heat released to reach peak temperature (kJ)	Peak Time (h)
Control Sample	95	2.955	14.001	13.25
0.5% Laponite	92	2.616	10.778	13.75
0.5% Bentonite	95	2.178	10.319	13.35

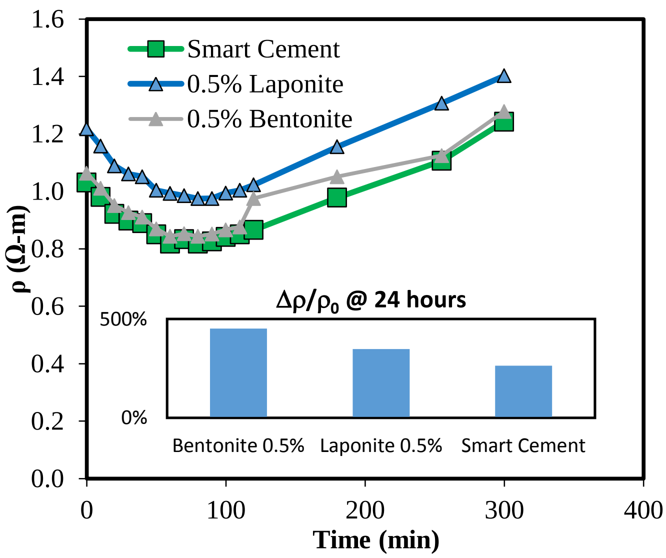

Figure 9: Resistivity change with time for clay added class H oil well cement

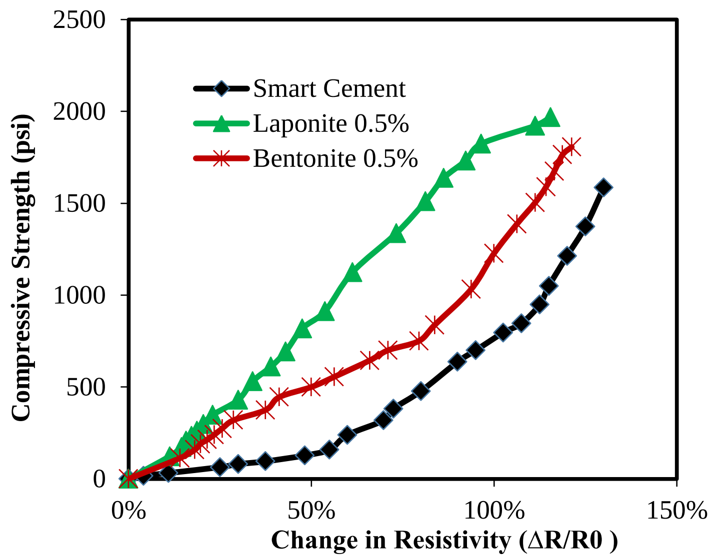

Figure 10: Compressive behavior

5. Conclusion

From the experiment, it can be concluded that addition of 0.5% clay can enhance compressive strength and reduce heat generation of cement composite. In the meantime the sensitivity reduced slightly.

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7. References

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