# Smart Cement Slurry for Real-Time Monitoring: Testing and Modeling

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## Abstract

Smart cement is a highly sensing chemo-thermo-piezoresistive material and has the potential for many applications. From the time of mixing to the entire service life it can be monitored. The monitoring parameter is the electrical resistivity. In this study, smart cement slurry was modified with iron nano particles and foam. The smart cement slurries with and without 1% Nano$Fe_2O_3$ in the high pressure – high temperature cylinder where a two probe method was used with the impedance spectroscopy (IS) to measure the resistivity of the slurry. The shear thinning behavior of the smart cement slurry with and without Nano$Fe_2O_3$ has been quantified using the new Vipulanandan rheological model and compared with the Vocadlo model with three material parameters. The results showed that the hyperbolic rheological model predicated the shear thinning relationship between the shear stress and shear strain rate of the smart cement slurries very well. Based on the Vipulanandan rheological model the maximum shear stresses produced by the smart cement slurries modified with 0%, 0.1%%, 0.5% and 1% were 183 Pa, 199 Pa, 232 Pa and 300 Pa, respectively. Smart cement was also modified with 5% and 20% (by weight) to reduce the density for various applications from oil wells to insulators. The density of the smart cement was 16.3 ppg and with 20% foam it reduced to 9 ppg, a 45% reduction. Addition of 20% foam, reduced the thermal conductivity of the smart cement by 65%. The smart cement slurries with and without foam were piezoresistive. The total fluid loss for the smart cement at 0.7 MPa (100 psi) pressure was reduced from 134 mL to 13 mL with the addition of 20% foam, about a 90% reduction. The electrical resistivity changes of the hydrating cement was influenced by the amount of foam in the cement. Addition of 20% foam increased the initial electrical resistivity of smart cement by 94%. The one day compressive strength of smart cement was reduced to 0.57 MPa (220 psi) from 10.3 MPa (1500 psi) with the addition of 20% foam, a 83% reduction. The solidified smart cement with and without foam were piezoresistive.

The Vipulanandan p-q curing, stress-strain and piezoresistive models predicated the experimental results very well. Also the Vipulanandan Impedance-frequency model predicted both the modified smart cement slurry behaviors.