Model test for Piezoresistivity of the Smart Cement

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Abstract: In this study piezoresistivity of the smart cement sheath was investigated. The various pressure was applied on the harden cement sheath model and the resistance changes were monitored along the depth. The p, q model was used to capture the behavior of the cement sheath under the pressure.

1. Introduction: Several methods have been used to monitor the behavior of cementatious material such as X-ray diffraction, calorimetric analysis, scanning electron microscopy and ultrasonic methods. Electrical resistivity is one of the method can be used to investigate the behavior of the oil well cement (Vipulanandan and Heidari, 2014) due to the accuracy, ease of testing and nondestructive characteristics (Li et al. 2003) of this method.

2. Objective: In this study, the main objective is the investigation of piezoresistivity of the smart cement sheath by indirect loading.

3. Materials and Methods: A small was prepared by cementing a 2" diameter casing in a plexiglass mold. In order to load the cement sheath, the casing was pressurized to 60, 100 and 140 psi and the electrical resistance was measured at Level 1-2, Level 2-3, Level 3-4, Level 4-5 within 26 hours after each loading. Figure 1 shows the lab test cement sheath and casing.

4. Analytical solution: The horizontal principal stresses (radial, tangential stresses) were found as a function of internal pressure. Since no vertical load was applied, the change in the vertical stress σ_z was negligible. The vertical deviatoric stress change ΔS_{zz} will be as follow (Eq. 1).

$$\Delta \boldsymbol{S_{zz}} = \boldsymbol{f}(\boldsymbol{\sigma_{rr}}, \boldsymbol{\sigma_{\theta\theta}}) = \boldsymbol{f}'(\boldsymbol{p_i}) = \boldsymbol{g}\left(\frac{\Delta\rho}{\rho}\right) \quad (1)$$

p, q model by (Vipulanandan et. al. 1990) is used to predict $\Delta\rho/\rho$ variation versus internal pressure (Eq. 2).

$$\boldsymbol{p_i} = \frac{p_{max}\frac{\Delta\rho}{\rho}}{q + (1-q-p)\frac{\Delta\rho}{\rho} + p\left(\frac{\Delta\rho}{\rho}\right)^{\frac{p+q}{p}}} \quad (2)$$

5. Results and Analysis: Figure 2 shows the resistivity changes measurement at 6 inch levels of the speccimen versus pressure. By considering p = 0.92 and q = 0.001 the r-squared is calculated as 0.99.

6. Conclusion: In this study piezoresistivity of the smart cement was investigated. When the pressure was changed from 0 to 140 psi, the resistivity change in the smart cement sheath was about 6%, demonstrating the piezoresistivity of smart cement.

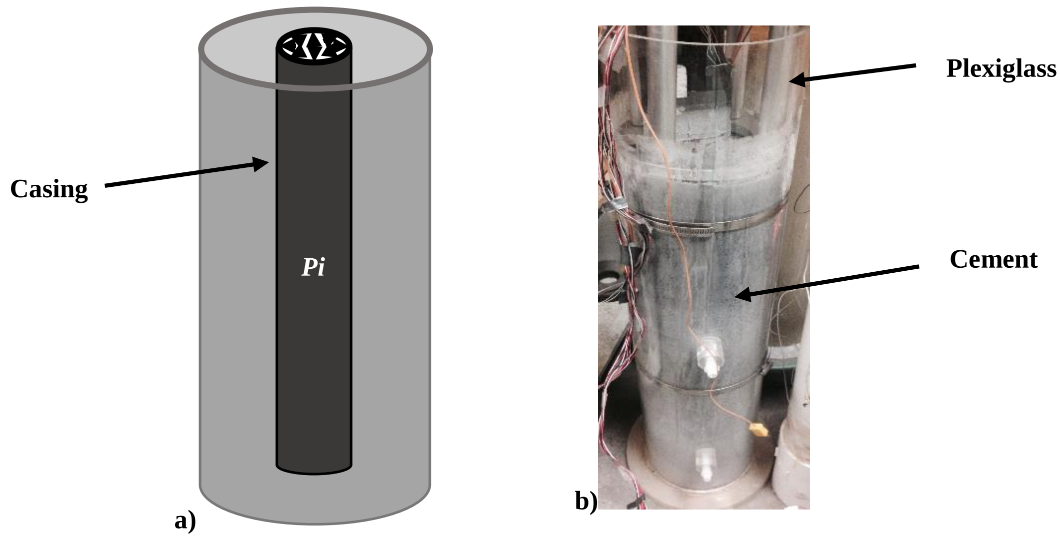

Figure 1. Cement sheath; a) schematic, b) test equipment

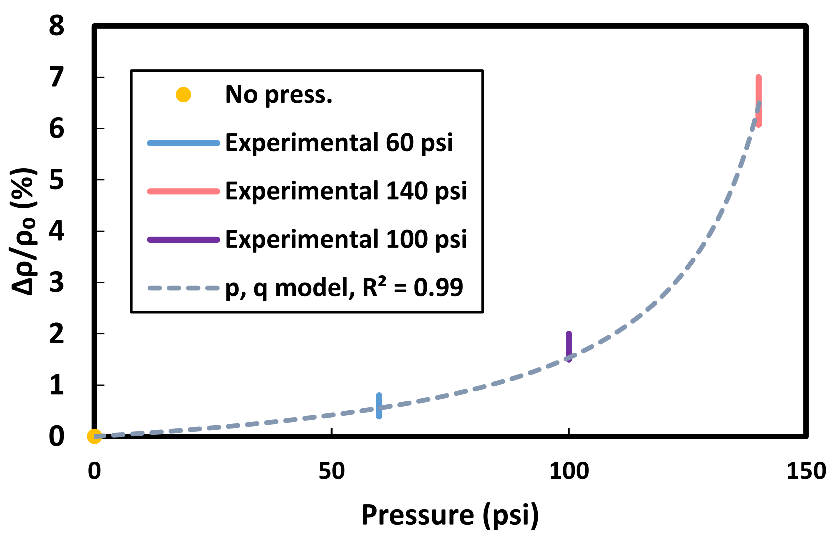

Figure 2. Variation of relative resistivity with pressure for the smart cement sheath

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8. References:

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