Comparison of Optical Fiber Sensing Technique and Strain Gauge in a Measurement of Rock Deformation Caused by Chemical Osmosis

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Mass transport and water flow in subsurface are generally considered to be much smaller than those on surface environment. Stability of subsurface environment is useful to isolate specific substances (e.g. CO_2 or high-level radioactive wastes) from human societies for a long time. For these purposes, argillaceous formations perform as effective seal layer because of its low permeability and smaller diffusion coefficient.

It is known that some argillaceous rocks show semipermeable membrane behavior, i.e., the process called chemical osmosis. Chemical osmosis causes water flow across semipermeable membrane driven by the gradient of osmotic pressure between two solutions (Marine and Fritz, 1981). Previous research showed that the pressure change caused by chemical osmosis can reach to about 20 MPa (Neuzil, 2000). Osmosis-induced pore pressure change can cause deformation of porous medium (Greenberg et al., 1973: Noy et al., 2004), however, the detailed discussion on the osmosis-induced deformation behavior of argillaceous rocks is still premature because of the difficulty for measuring multiple strain in the sample.

Generally, normal strain gauges by measuring the changes of the electrical resistance are used for laboratory-scale rock deformation experiments. Experiments for measuring deformation caused by chemical osmosis take a long time and drifts caused by water intrusion and/or delayed heat dissipation is considered to be the issue for the accurate measurements. Distributed optical fiber sensing (DOFS) is a technique for possibly avoiding the measurement drift. In DOFS measurement, the backscattering light is used to measure strains along the fiber, and DOFS can use entire optical fiber as a sensor, thus, strain behavior at multiple points along the optical fiber can be obtained.

The purpose of this study is to investigate the applicability of both strain gauges and DOFS to the laboratory-scale chemical osmosis experiments through the comparison of both results, and to discuss the strain behavior of argillaceous rocks by chemical osmosis. In this experiment, core samples with the height of about 30mm and diameter of about 50mm made from mudstones collected from the Wakkanai Formation in Hokkaido prefecture and the Oganocho Formation in the Chichibu Basin, Saitama prefecture, were used. Strain gauges were attached to the sample, and axial and circumstantial strains near the both edges were measured. Optical fiber was attached helically to the sample, and the strains along the direction of the fiber were measured. The lateral and top surfaces of the specimen were sealed by silicon rubber to prevent water flow through these surfaces. In the experiment, the bottom surface of the sample was contacted to NaCl solution with 10g/L higher concentration than that of pore water, and osmotic flow was induced by the concentration gradient. The strains of the specimen caused by osmotic flow were measured by both DOFS and strain gauges. Temperature was kept almost constant throughout 240 hours by putting the apparatus into a box made with heat insulating material and the experimental room was controlled by air conditioner.

In the initial phase of the experiments, the strain behaviors measured by both strain gauges and DOFS showed a good agreement. Initial strain behavior characteristic to the poroelastic effect was found only in the measurement by strain gauges because of the much shorter sampling interval compared with that in

DOFS. On the other hand, after 20 hours, strains measured by the strain gauges near the bottom of the sample, i.e., high-concentration side, started to increase while those measured by DOFS not. It is considered to be caused by the unstable behavior of strain gauges.

Keywords: Chemical osmosis, optical fiber sensing technique, argillaceous formation, poroelasticity