The Maurice A. Biot Lecture

Department of Civil Engineering & Engineering Mechanics, Columbia University
Engineering Mechanics Committee, ASCE Metropolitan Section
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Relating Permeability to Thermal Strain of Saturated Materials

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November 12, 2019 (2:40 - 3:40 pm)
214 Pupin Laboratories

Abstract: When a saturated porous body is subjected to heating or cooling, the thermal strain is strongly affected by the expansion of the pore liquid, which is typically an order of magnitude larger than that of the solid matrix. The pore pressure depends on the competition between the rate of volumetric expansion of the liquid and its flux toward the free surface; by measuring the strain during a heating/cooling cycle, the permeability of the matrix can be determined. An analytical solution to this problem has been used to measure the permeability of materials ranging from gels to cements.

In temperate climates, concrete is protected from frost damage by introducing air-filled voids that are tens of microns in diameter and a few hundred microns apart (whereas the pores in the cement paste are tens of nm in diameter). One function of the voids is to prevent high water pressure, as ice crystals propagate through the pores, by providing nearby sinks into which the displaced water can flow. Microscopy indicates that the voids are surrounded by a mineral shell that is much denser than the surrounding cement paste, but is still permeable. A new analysis allows the permeability of the shell to be found by measuring the thermal strain of air-entrained paste. Preliminary experimental results indicate that the shell has a permeability about an order of magnitude smaller than that of the paste. The small pore size implied by this low permeability explains why ice crystals growing inside the voids cannot propagate into the surrounding paste (viz., because the small radius of curvature required for the ice to pass through the shell is forbidden by the Gibbs-Thomson equation).

Biosketch: George W. Scherer received his BS and MS degrees in 1972 and his PhD in materials science in 1974, all from MIT, where his thesis work was on crystal growth in glass. From 1974 to 1985, he was at Corning Glass Works, where his research included optical fiber fabrication, viscous sintering, and viscoelastic stress analysis. The latter work was the subject of his first book, Relaxation in Glass and Composites (Wiley, 1986). From 1985 through 1995, he was a member of the Central Research Department of the DuPont Company, where his work dealt principally with sol-gel processing, and especially with drying. In collaboration with Jeff Brinker of Sandia National Labs, he wrote a book entitled Sol-Gel Science (Academic Press, 1990). He is a fellow of the American Ceramic Society and a member of the Materials Research Society. In 1997 he was elected to the National Academy of Engineering. In February, 1996, he became a full professor in the Department of Civil & Environmental Engineering at Princeton University, and a member of the Princeton Materials Institute (now, PRISM). His research involves mechanisms of deterioration of concrete and stone, particularly by crystallization of ice and salts in the pores. He retired in the spring term of 2017, becoming an Emeritus Professor in June, 2017.

The Maurice A. Biot Lecture was established at Columbia University in 2004 in remembrance of the late Professor Maurice Anthony Biot and his renowned achievements as an engineer, physicist, and applied mathematician. Biot was a professor of mechanics at Columbia University in the period 1937-1945.