What is the Status of Biot's Dynamic Theory of Wave Propagation in Porous Media?

Robert W. Zimmerman
Department of Earth Science and Engineering
Imperial College, London, UK

Biot's theory of quasi-static poroelasticity, as initially developed in his 1941 paper "General Theory of Three-Dimensional Consolidation" (*J. Appl. Phys*., 1941), is universally accepted as being the correct theory for the small-strain elastic behavior of fluid-saturated porous media. Numerous subsequent researchers have developed theories of linearized poroelasticity, but the results all lead essentially to the same governing equations, aside from differences in notation. In two papers published in 1956, "Theory of Propagation of Elastic Waves in a Fluid-Saturated Porous Solid. I. Low-Frequency Range", and "Theory of Propagation of Elastic Waves in a Fluid-Saturated Porous Solid. II. Higher Frequency Range" (*J. Acoust. Soc. Am*., 1956), Biot developed a theory of *dynamic* poroelasticity, intended to govern wave propagation in porous media. By some measures, Part I of this pair of papers is among the ten most highly-cited papers in mechanics, and this theory is widely assumed to provide the governing equations for wave propagation in rocks, soils, concrete, biological media, and other porous media. Although Biot's development of the dynamic theory started with the equations of his 1941 quasi-static theory, it required the introduction of several assumptions and new parameters. Consequently, it cannot necessarily be said to be the "obvious" or "inevitable" theory of dynamic poroelasticity. In this talk, I will give a critical review of the applicability of Biot's dynamic theory of poroelasticity to real porous media.

Short bio:

Robert Zimmerman obtained a B.S. and M.S. in mechanical engineering from Columbia University, and a Ph.D. from the University of California at Berkeley. He has been a lecturer at UC Berkeley, a staff scientist at the Lawrence Berkeley National Laboratory, and Head of the Division of Engineering Geology and Geophysics at KTH in Stockholm. He is currently Chair in Rock Mechanics at Imperial College London.

He is the author of the monograph *Compressibility of Sandstones*, published by Elsevier in 1991, and the textbook *Fluid Flow in Porous Media*, published by World Scientific in 2018. He is the co-author, with J.C. Jaeger and N.G.W. Cook, of *Fundamentals of Rock Mechanics* (4th ed.), published in 2007 by Wiley-Blackwell, and is the co-author, with Adriana Paluszny, of the new monograph *Fluid Flow in Fractured Rocks*, published by Wiley in 2024.

Prof. Zimmerman served as the Editor-in-Chief of the *International Journal of Rock Mechanics and Mining Sciences* from 2006-2023. In 2010, he was awarded the Maurice A. Biot Medal of the American Society of Civil Engineers, for his "outstanding contributions in applying poroelasticity to rock mechanics and fluid flow in fractured media." He is a Fellow of the American Rock Mechanics Association, and a Fellow of the Royal Academy of Engineering (UK).