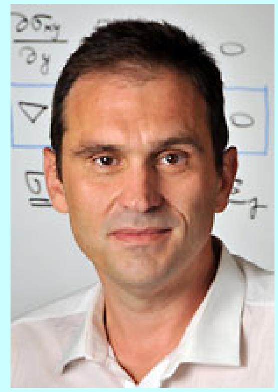
The Maurice A. Biot Lecture

Department of Civil Engineering and Engineering Mechanics
Columbia University

Poromechanics: From Atoms to Concrete Structures

Dedicated to Olivier Coussy (1953–2010)



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October 5, 2010 (2:30-3:30 pm)
Inter-school Lab, CEPSR

Abstract: More concrete is produced than any other synthetic material on Earth. The current worldwide cement production stands at 2.3 billion tons, enough to produce more than 20 billion tons or one cubic meter of concrete per capita per year. There is no other material that can replace concrete in the foreseeable future to meet our societies' legitimate needs for housing, shelter, infrastructure, and so on. But concrete faces an uncertain future, due to a non-negligible ecological footprint that amounts to 5-10% of the worldwide CO2 emissions. It now appears that poromechanics can be the discipline that enables the development of a sustainable green concrete future.

We here adopt the perspective originating from Galileo's Strength of Materials Theory, that weight, and thus CO2-emission, increases with the volume of the produced material, while strength of structural members increases with the section. Hence, as one increases the strength of a material by a factor of x, one reduces the environmental footprint by 1/x for pure compressive members such as columns and perfect arches and shells, $1/x^{2/3}$ for beams in bending, and $1/x^{1/2}$ for slabs. Similarly, if one adopted a Linear Elastic Fracture model, an increase of the fracture toughness KIc = y K_{Ic0}, would entail a reduction of the environmental footprint by 1/y for columns and $1/y^{4/5}$ for (notched) beams in bending or in torsion. Thus far, all this hints towards a critical role of Mechanics, and in particular Strength of Materials and Poromechanics of concrete, in redesigning concrete materials and structures for the coming of age of global warming. In contrast to the classical top-down empirical approaches, we have chosen a bottom-up approach that starts at the electron and atomic scale to nanoengineer the fundamental building block of concrete; to assess the properties of the porous microstructure by nanoindentation; and upscale strength, fracture, creep and stiffness properties from nanoscales to macroscales of day-to-day concrete engineering applications. The key to all this is poromechanics at the interface of physics and engineering.

Biosketch: Franz-Josef Ulm is the George Macomber Professor of Civil & Environmental Engineering at the Massachusetts Institute of Technology. He received his Civil Engineering degree from the Technical University Munich, a PhD from the Ecole Nationale des Ponts et Chaussees, and the Habilitation Degree from the Ecole Normale Superieure de Chachan in France. Prior to joining MIT, he was research engineer at the Laboratoire Central des Ponts et Chaussees, Paris, France, last as head of the concrete research group. Trained by Dr. Olivier Coussy in poromechanics, Dr. Ulm joined MIT in January 1999, where he is responsible for Materials and Structures. He is the Director of the Concrete Sustainability Hub (CSHub@MIT), an industry sponsored research center dedicated to the reduction of the environmental footprint of cement and concrete production.

The Maurice A. Biot Lecture was established at Columbia University in remembrance of the late Prof. 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.

http://www.civil.columbia.edu/biot

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