DIPARTIMENTO DI INGEGNERIA CIVILE E AMBIENTALE

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SEMINAR ANNOUNCEMENT

Beltrami Room, Building 5, ground floor, Leonardo Campus
Department of Civil and Environmental Engineering

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Discrete Modeling of Mesoscale Poromechanics: Formulation and Numerical Examples

Prof. Gianluca Cusatis
Civil and Environmental Engineering Department
Northwestern University

To simulate the hydromechanical behavior of high porosity rocks saturated by a fluid phase, a three-dimensional Lattice Discrete Particle Model is proposed in the following study. For this purpose, the equivalent two-phase porous medium is discretized “a priori” by two networks of lattice elements: the first connects rock grains to mimic the solid phase and the second represents the intergranular fluid network to reproduce fluid flow transport.

The mechanical lattice network generates a meso-structure of material based on its grain size distribution, and simulates the heterogeneous deformation at the grain scale by means of discrete compatibility equations. Grains interact through triangular-shaped planes of contact (facets) where vectorial constitutive laws are imposed at the facets. At the same time, fluid flow along interconnected pores is simulated through a fluid transport network defined by the edges of facets resulting from 3D tessellation of the generated particle system. The flow is assumed to be laminar everywhere, and the fluids are Newtonian and immiscible.

Taking advantage of model’s capability to simulate damage and cracking at the grain scale, one is able to track the evolution of local hydraulic properties with the progressive damage of the material. As fluid transport element is associated with facets, which are also regarded as potential failure planes, the local variation of fluid conductivity due to damaged material is linked to facet crack openings. The fluid flow at the regime of cracked material is assumed to follow Poiseuille's law with the width of flow channel defined by facet crack openings. A diffusion equation of fluid pressure is derived for both the uncracked and cracked material based on fluid mass conservation.

The proposed model is calibrated and verified by considering few fundamental problems of poroelasticity following Biot’s theory. Beyond the elastic regime, the non-linear mechanical behavior of porous rock is also investigated and the results show the effect of heterogenous hydromechanical properties on the overall behavior of the material.

Reference: Prof. Giovanni di Luzio (giovanni.diluzio@polimi.it)

Bio-sketch

Prof. Gianluca Cusatis is a faculty member of the Civil and Environmental Engineering Department at Northwestern University that he joined in August 2011. Prior to Northwestern, Gianluca worked at Rensselaer Polytechnic Institute for 6 years.

He obtained his "Laurea" degree and his PhD in Structural Engineering from Politecnico Di Milano (Italy) in 1998 and 2002, respectively.

He teaches undergraduate and graduate courses of the civil engineering curriculum and performs research in the field of computational and applied mechanics, with emphasis on heterogeneous and quasi-brittle materials. His work on constitutive modeling of concrete through the adoption of the so-called Lattice Discrete Particle Model (LDPM), one of the most accurate and reliable approaches to simulate failure of materials experiencing strain-softening, is known worldwide.

Under the sponsorship of several agencies – including NSF, ERDC, and NRC – his current research focuses on formulating and validating multiscale and multiphysics computational frameworks for the simulation of large scale problems dealing with a variety of different applications including, but not limited to, infrastructure aging and deterioration, structural resiliency, projectile penetration, and design of blast resistance structures.

He is member of FraMCoS, ASCE, and ACI and active in several technical committees. He is the chair of the ACI 209 committee on creep and shrinkage (and former chair of ACI 446 on fracture mechanics), where he leads efforts to develop practical guidelines for the calibration and validation of concrete models. He serves as treasurer for IA-FraMCoS and president for IA-ConCreep.