Department of Civil and Environmental Engineering
Case Western Reserve University
Bingham Bldg., Room 237
10900 Euclid Ave
Cleveland, OH 44106

Civil and Environmental Engineering Department Seminar

A Multiscale Lattice Discrete Particle Model for the Prediction of Concrete Properties

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Abstract
For many decades, researchers have tried to formulate continuum constitutive equations for plain concrete; but these attempts, although successful in certain ways, failed to capture to full extent the most important aspect of concrete behavior, cracking and fracture. Fracturing behavior is strongly influenced by its heterogeneous internal structures.

At the meso-scale concrete is considered a two-phase composite in which stiff inclusions, the coarse aggregate particles, are embedded in a softer and weaker mortar matrix. At the mortar scale, concrete can be regarded as a three-phase composite composed of a porous matrix, aggregate particles of all size, and a thin layer of material at the interface between cement paste and aggregate pieces, the Interfacial Transition Zone (ITZ). At the scale of cement paste and ITZ, internal structures feature a complex system of pores with sizes spanning several orders of magnitude.

Furthermore, cement paste is intrinsically a composite structure and, in addition to pores, is composed of several components resulting from the cement hydration process. Modeling the effect of the major material heterogeneities is instrumental to capture the intrinsic material characteristic length associated with fracture, and the consequent reduction of the structural strength as a function of the structural size – the so-called Size Effect.

This presentation will introduce a multiscale extension of the Lattice Discrete Particle Model (LDPM) which aims to predict material behavior across length scales by only utilizing properties of individual constituent materials and mix proportions. Spatial structures are developed via a novel meshing procedure and are based on voxelated data from NIST's Cement Hydration Modeling Software (CEMHYD3D) and Virtual Cement and Concrete Testing Laboratory (VCCTL). Formulation and calibration of the predictive model is demonstrated for an exemplary concrete mix, and elastic properties are validated at both the mortar and concrete scale via uniaxial unconfined compression and triaxial test data. In addition, prediction of cement scale mechanical properties in both elastic and inelastic regime are demonstrated starting from basic single phase mechanical characterization via micro-indentation.

About the speaker:

Cusatis is a faculty member of the Civil and Environmental Engineering Department at Northwestern University that he joined in August 2011. Prior to joining Northwestern, he worked at Rensselaer Polytechnic Institute for 6 years. He obtained his ``Laurea" degree and his PhD in structural engineering from Politecnico Di Milano (Italy). He teaches courses of the civil engineering curriculum and perform research in the field of experimental, computational, and applied mechanics, with emphasis on heterogeneous and quasi-brittle infrastructure 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. In addition, his recent work on waterless concrete for Martian constructions has received widespread attention in the technical community and in the media. Under the sponsorship of several agencies Cusatis's 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, and response of materials and structures to natural and man-made hazards. Cusatis is member of ASCE and ACI and active in several technical committees. He held leadership positions in ASCE EMI, ACI 446, and IA-FRAMCOS. Currently, he serves as chair of ACI 209 and president of IA-ConCreep. Finally, in 2018 he was awarded the prestigious EMI Fellow membership grade.