SEMINAR (blended mode)

Discrete Modeling of Fracture in Quasi-Brittle Materials: Twenty-Five Years of Accomplishments and Future Outlook

In this presentation a computational framework developed in the last 25 years for the simulation of fracture in quasi-brittle materials. The overall framework is centered on the so-called Lattice Discrete Particle Model (LDPM). LDPM is a discrete mesoscale model of concrete that can accurately describe the macroscopic behavior of concrete during elastic, fracturing, softening, and hardening regimes.

LDPM has been calibrated and validated extensively through the analysis of a large variety of experimental tests. LDPM can reproduce with great accuracy the response of concrete under uniaxial and multiaxial stress states in both compression and tension and under both quasi-static and dynamic loading conditions. The LDPM technology has been proven to supersede by far most of other available computational techniques for the simulation of concrete, especially for applications where the description of material internal structure and the link among different length scales is important.

The LDPM formulation is obtained by modeling the interaction among coarse meso-scale aggregate pieces as the interaction among polyhedral cells (each containing one aggregate particle) whose external surfaces are defined by sets of triangular facets. At each facet strain and stress, vectors are used to formulate the constitutive law describing physical mechanisms such as tensile fracture, cohesion, friction, etc. In a similar discrete fashion, the effect of fiber reinforcement can also be taken into account.

The presentation will give an overview of recent successes of the LDPM technology and the development of multiscale/multiphysics frameworks that use LDPM as the main fundamental component. The use of these novel approaches is demonstrated in relation to a variety of applications spanning several different themes relevant to fracture of quasi-brittle materials.

The presentation will also provide an overview of current work that combines discrete modeling and machine learning and an outlook of what the next 25 years of research in this field might look like.

Biosketch of Gianluca Cusatis

I am a faculty member of the Civil and Environmental Engineering Department at Northwestern University that I joined in August 2011. Prior to joining Northwestern, I worked at Rensselaer Polytechnic Institute for 6 years. I obtained my ''Laurea'' degree and my PhD degree in structural engineering from Politecnico Di Milano (Italy). I teach 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. My 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 my current research focuses on formulating and validating multiscale and multiphysics computational frameworks for the simulation of 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. I am a member of ASCE and ACI and active in several technical committees. I held leadership positions in ASCE EMI, ACI 446, ACI 209, IA-ConCreep, and IA-FRAMCOS. In 2018 I was awarded the prestigious EMI Fellow membership grade. From September 2021 to February 2024, I was on leave from my teaching and service responsibilities at Northwestern University to serve as Program Director for the CMMI ECI program at the National Science Foundation.

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