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2010 Engineering Mechanics Institute Conference

TECHNICAL PROGRAM AND BOOK OF ABSTRACTS

EMI 1687 ASCE

ENGINEERING MECHANICS INSTITUTE

USC Viterbi School of Engineering

Wednesday, August 11, 2010

Computational Mechanics of Heterogeneous Materials – I (Haim Waisman, Jacob Fish)
Wednesday, August 11, 10:00am-12:00pm
Cardinal
Chairs: Martin Ruess

- *From Voxel-FEM to p-FEM Based Analyses in Bone Mechanics,* Martin Ruess
- *Micro-Crack Informed Multi-Scale Damage Model: Theory and Computation,* Xiaodan Ren
- *A computational technique for evaluation the effective thermal conductivities of isotropic particulate composites,* Olesya Koroteeva
- *Estimating 3-D Volume using Finite Elements,* Basudeb Mukherji
- *On a Boubary Element Method for the Numerical Solution of Some Problems for Inhomogeneous Anisotropic Materials,* David Clements
- *Numerical Modeling of Deformation of rough-Walled Fractures Due to Normal Stress,* Pasha Ameli

Forward and Inverse Problems of Wave Propagation and Scattering in Heterogeneous Media -II (Dominic Assimaki, Loukas Kallivokas)
Wednesday, August 11, 10:00am-12:00pm
Board Room
Chairs: Dominic Assimaki and Loukas Kallivokas

- *A theory for microtremor H/V spectral ratio: Application for a layered medium,* Francisco J. Sanchez-Sesma
- *The Solution of Green Function to the Problems of Explosive Field with Drainage,* Ding Boyang
- *A Hybrid Formulation for Transient Wave Simulations in Unsplit-Field-PML-Truncated Heterogeneous Media,* Sezgin Kucukcoban
- *A 2.5D displacement-based PML for elastodynamic wave propagation,* Stijn François
- *A Full-Waveform Based Material Profile Inversion in Heterogeneous PML-Truncated Domains With Applications to Lossless and Lossy Media,* Jun Won Kang
- *Seismic Slope Stability Via Maximum Dynamic Shear Stress Estimation Based on 1D Wave Propagation,* Seokho Jeong

Structural Identification and Damage Detection - II (Dynamics Committee)
Wednesday, August 11, 10:00am-12:00pm
Club A
Chairs: Erdal Safak and Lambros Katafygiotis

- *System and Damage Identification of a Three story Infilled Frame Subjected to Seismic Base Excitations,* Babak Moaveni
- *Structural Identification and Damage Detection by Using Interferometric Imaging,* Erdal Safak
- *Impulse Response Analysis of Layered Building Models and Lessons Learned for Structural Health Monitoring,* Maria Todorovska
- *The Effect of Non-Synchronous Sensing on Structural Modal Identification in Wireless Sensor Network: Estimation and Elimination,* Zhouquan Feng
- *Experimental Damage Detection of Shear Structures Using Dynamic Strain Data,* Adrian Brugger
- *A System Identification Based Approach for Estimating Modal Frequencies of Bridges Under Environmental Influence,* Harsh Nandan

Constitutive and Fracturing Behavior of Quasi-Brittle Materials Computation and Experiments: minisymposium in honor of Luigi Cedolin – III (Gianluca Cusatis, Zdenek Bazant)
Wednesday, August 11, 10:00am-12:00pm
Club B
Chairs: Gianluca Cusatis, Zdenek Bazant

- *Mismatch in Periodic Brick and Mortar Construction of Unreinforced Masonry,* Kaspar Willam
- *Sustainability of Structures and Infrastructure,* Paolo Gardoni
- *Cracking in Hybrid-Fiber Reinforced Cement Composites: Simulations of Material Heterogeneity,* John Bolander
- *Simulating Pervasive Fracture Processes in Quasi-Brittle Materials Using Random Polyhedral Finite Elements,* Joseph Bishop
- *A Two-Scale Interface Element for Modelling Fracture Propagation Under Cycling Loading,* Guido Borino
- *On the determination of the cohesive fracture model parameters of concrete,* Luigi Cedolin

Experiments and Modeling for the Mechanics of Soil Erosion (Nadia Saiyouri and Ching Chang)
Wednesday, August 11, 10:00am-12:00pm
Gold
Chairs: Nadia Saiyouri

- *Effects of Soil Parameters on Erosion Behavior of New Orleans Soils,* Wongil Jang
- *Erosion Control by Ground Modification,* James Kidd
- *Prediction of Field Erosion Depth for New Orleans Levee Soils,* Chung Song
- *Experimental and Numerical Investigation of the Seabed Scouring Around a Submarine Pipeline laying on different Types of Seabed,* Matteo Mattioli
- *Monitoring of internal erosion in reinforced granular material: a granulometric approach,* Bogdan Muresan
- *Modelling of internal erosion in reinforced granular material,* Bogdan Muresan

Wednesday, August 11, 2:15pm-4:15pm

Symposium in Memory of Olivier Coussy – III: Poroplasticity/Fracture/Shock Waves (Christian Hellmich, Younane Abousleiman, Franz Ulm, Alex Cheng)
Wednesday, August 11, 2:15pm-4:15pm
Embassy
Chairs: Hoe Ling

- *Thermal Effects in the Poromechanics Responses of Inclined Wellbore Drilling in Naturally Fractured Rock Formations,* Y. Abousleiman
- *Stepwise Propagation of Cracks in Poroelastic Media,* J.M. Huyghes
  Evaluation of an Anisotropic Bounding Surface Model for Pisa Clay, Hoe Ling
- *Predicting Unstable Behavior in Dry and Fluid-Saturated Materials,* J.E. Andrade
- *Implicit Three-Dimensional Finite Strain Biphasic Mixture Dynamic Finite,* Richard Regueiro

fracture in HFRCC are understood in a qualitative sense, quantitative representation of the aforementioned factors is lacking. Such capabilities are needed for material design optimization.
Lattice models have been used to study fracture in a variety of quasi-brittle materials, including concrete [1, 2]. In this research, tensile fracture of HFRCC is simulated using a three-dimensional lattice model based on the rigid-body-spring concept of Kawai. Lattice topology is defined by the Delaunay tessellation of a semi random set of nodal points; the dual Voronoi tessellation defines the element cross-sections and thus their mechanical properties. A distinguishing feature of the model is the explicit representation of randomly dispersed fibers within the computational domain [3, 4]. Debonding along the fiber-matrix interface and pullout of individual fibers that bridge developing cracks are included in the model. The material is resolved at a scale at which small defects, or microcracks, are identifiable within the matrix. The lattice routines are embedded within a program loop that constructs and analyzes multiple, nominally identical models of tensile test specimens. These models differ only in the spatial and orientation distributions of the fibers and defects. Defects are simulated by spatially correlated groups of weak elements and the abilities of macro- and micro-fibers to nullify the effects of these defects are studied. Analyses of a large number of these numerical specimens provides frequency distributions of post-cracking strength and material toughness. It is found that well dispersed micro-fibers effectively pin small defects. Although the same volume fraction of macro-fibers does not provide that desired result, the macro fibers are effective in enhancing material toughness. As expected, combinations of micro- and macro-fibers provide both strength and toughness.

References

[1] E. Schlangen and J.G.M. van Mier, "Experimental and Numerical Analysis of Micromechanics of Fracture of Cement-based Composites," Cement & Concrete Composites, v. 14, p. 105-118, 1992.
[2] G. Cusatis, Z.P. Bažant and L. Cedolin, "Confinement Shear Lattice Model for Concrete Damage in Tension and Compression: I. Theory," J. Engineering Mechanics, ASCE, v. 129, p. 1439-1458, 2003.
[3] J.E. Bolander and S. Saito, "Discrete Modeling of Short-fiber Reinforcement in Cementitious Composites," Advanced Cement Based Materials, v. 6, p. 76-86, 1997.
[4] J.E. Bolander, S. Choi and S.R. Duddukuri, "Fracture of Fiber-reinforced Cement Composites: Effects of Fiber Dispersion," International Journal of Fracture, v. 154, p. 73-86, 2008.

SIMULATING PERVASIVE FRACTURE PROCESSES IN QUASI-BRITTLE MATERIALS USING RANDOM POLYHEDRAL FINITE ELEMENTS

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Structural failures resulting from extreme loading conditions are typically highly nonlinear processes involving complex material constitutive behavior, post-peak material softening, localization, new surface generation, and ubiquitous contact. Examples include penetration, fragmentation, progressive structural collapse due blast loading or seismic events, and hydrofracturing in petroleum engineering. The extent of fracturing is pervasive in the sense that a multitude of cracks are dynamically active, propagating in arbitrary directions, coalescing, and branching.
A pure Lagrangian explicit-dynamics computational methodology is presented that can simulate the pervasive dynamic failure of materials and structures by allowing new fracture surfaces to nucleate only at the interelement faces of a random polyhedral mesh. To minimize mesh induced bias, a randomly close-packed Voronoi tessellation is used. Standard Galerkin methods are used to solve the governing equations. The nodal shape functions of each polyhedral cell are generated using harmonic functions in the original element configuration. The governing equations are regularized by the dynamic insertion of cohesive forces at crack nucleation sites. Engineering 'quantities of interest' include the extent and nature of cracking, fragment- size distributions, and post-failure structural response. The statistical distribution of these engineering 'quantities of interest' due to multiple random realizations of the Voronoi mesh and random material fields is investigated. The convergence behavior of these statistical distributions under refinement can be verified using the Kolmogorov-Smirnov statistic. Figure 1 shows the result of an impact of a rigid sphere onto a concrete column using this methodology.

[a]TWO-SCALE INTERFACE ELEMENT FOR MODELLING FRACTURE PROPAGATION UNDER CYCLING LOADING

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There are several mechanical systems in which structural elements are joined each other by means of internal surface bonds. From a structural design point of view, it appears that those bonding surfaces are the physical location of the most relevant deformation processes. Damage, debonding and fracture propagation typically develop along these surfaces and strongly affect the overall structural response, as well as the final collapse conditions. The accurate mechanical modeling of these surface in terms of kinematics, statics and of nonlinear constitutive relations, is then of a paramount relevance for the overall evaluation of the structural nonlinear response and for the evaluation of the safe structural loading conditions.
Because the joining layers are typically of very small thickness, compared to the structural characteristic size, the assumption of zero thickness interface is often adopted. This assumption produces as a consequence that along the interface the relevant strain measure is the displacement discontinuity, or the vector displacement jump between the two faces of the interface. Displacement discontinuity naturally introduces concepts of fracture mechanics useful for the debonding processes. The second essential point for the interface characterization is the constitutive description of these discontinuity layers. Often, an internal elastic state is implicitly assumed, related to the deformable material inside the layer. Following a modern multiscale approach applied to small layers [1], it is possible to describe the microstructural state evolution inside the interface and reconstruct the interface mechanical response up to failure.
In the present contribution a constitutive interface model is proposed, which is formally developed following the line given in [2] extended in a proper two-scale approach. The model proposed is able to describe the formation and propagation of the fracture for proportional monotonic loading, but overall it has the ability to deal with cyclic loading. As in fact, in case of cyclic loading the closing condition needs to be reproduced, together with the frictional sliding dissipation mechanism.
The interface constitutive relations are developed in a thermodynamic consistent framework and are based on the concept of Interface Damage Mechanics. In the proposed approach, the interface damage variable plays a double role. The first is the traditional strength degradation of the cohesive law, whereas the second is related to the decohesed local fraction, for which, in the case of compressive normal traction component, frictional effects can developed in that fraction. The last aspect allows the

development of a model with a smooth transition from the adhesive state to the frictional one.
Finally, the paper presents some numerical applications regarding debonding tests. The numerical analysis are also extended to tests with assigned cyclic loading. The results are displayed and commented.

References
[1] K. Matous, M. G. Kulkarnib, P. H. Geubelle, Multiscale cohesive failure modeling of heterogeneous adhesive, *J. Mech. Phys. of Solids*, v. 56, p. 1511–1533, 2008.
[2] F. Parrinello, B. Failla, G. Borino, Cohesive-frictional interface constitutive model, *Int. J. Solids Struct.*, v 46, p. 2689–2692, 2009.

ON THE DETERMINATION OF THE COHESIVE FRACTURE MODEL PARAMETERS OF CONCRETE

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Crack propagation in concrete can be modeled only through a realistic representation of the constitutive behavior in the fracture zone, which is characterized by a not negligible extension. Hillerborg's cohesive crack model provides a simple and effective prediction of the type of size effect which is a consequence of the finite dimension of the fracture zone. However, although the calibration of the cohesive crack model parameters through inverse analysis of experimental results is a problem which has been extensively studied, many aspects need further clarification [1]. The approach analyzed in this paper is the one based on the linear representation of the first part of the softening curve, which leads, for each specimen geometry, to an analytical expression of the maximum load as function of the characteristic dimension. Of the various combinations of geometries and sizes which can be utilized for the determination of the fracture parameters, the concurrent use of three-point-bending and Brazilian specimens proposed by Planas and coworkers [2] is investigated here.
A first aspect which is discussed is the range of validity of the previously mentioned analytical expressions, which may affect the convergence of the optimization process used for the identification of the fracture parameters. Limitations in the variability of these parameters are introduced on the basis of physical considerations.
A second aspect is the applicability of the method to the interpretation of experimental results obtained at the Politecnico di Milano in numerous campaigns. A possible explanation of contradictory conclusions is given, and an appropriate methodology for the fabrication of the specimens for this kind of analysis is proposed.
Concludes the paper a discussion of the need for using specimens of different sizes, together with the determination of the allowable minimum and maximum sizes compatible with the actual form of the softening curve.

References
[1] W. Gerstle, B. Mobasher, J. Planas, K. Subramaniam, and G. Cusatis, "Fracture Toughness Testing of Concrete," *Report ACI Committee 446,* 2010.
[2] J. Planas. G.V. Guinea, and M. Elices, "Generalized Size Effect Equation for Quasibrittle Materials," *Fatigue Fract. Eng. Mater. Struct.* , v. 20 (5), p. 671-687, 1997.

Experiments and Modeling for the Mechanics of Soil Erosion
(Nadia Saiyouri and Ching Chang)
Wednesday, August 11, 10:00am-12:00pm
Gold
Chairs: Nadia Saiyouri

EFFECTS OF SOIL PARAMETERS ON EROSION BEHAVIOR OF NEW ORLEANS SOILS

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During Hurricane Katrina, overtopping water caused erosion and subsequent failure of several sections of I-type floodwalls in New Orleans. Damage stemmed from the kinetic energy of water falling from the top of the floodwall was different from that cased by the typical surface erosion caused by shear flow.
This study evaluated the effects of important parameters of levee soils - fines content, degree of compaction, clay mineralogy and water content in relation to the erosion behavior of New Orleans levees subjected to the plunging water. Test results showed that a higher fines content contributed to a higher erosion resistance in general, but not at the very high fines content. Higher degree of compaction did not necessarily contribute to a higher erosion resistance. Underwater soaked soils showed much lower erosion resistance than non-soaked soils. Soils containing expansive clay minerals showed a lower erosion resistance than soils containing non-expansive clay minerals.

EROSION CONTROL BY GROUND MODIFICATION

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