TIME TABLE

TIME	Monday	Tuesday	Wednesday	Thursday	Friday
	May 18	**May 19**	**May 20**	**May 21**	**May 22**
9.00 - 9.45	Registration	Carol	Desmorat	Huespe	Moës
9.45 - 10.30	Jirásek	Carol	Desmorat	Huespe	Moës
11.00 - 11.45	Jirásek	Carol	Desmorat	Desmorat	Moës
11.45 - 12.30	Jirásek	Carol	Meschke	Desmorat	Moës
14.30 - 15.15	Jirásek	Huespe	Meschke	Moës	
15.15 - 16.00	Jirásek	Huespe	Meschke	Moës	
16.30 - 17.15	Hofstetter	Huespe	Hofstetter	Meschke	
17.15 - 18.00	Hofstetter	Huespe	Hofstetter	Meschke	

ADMISSION AND ACCOMMODATION

Applicants must apply at least one month before the beginning of the course. Application forms can be sent by post or on-line through our web site: http://www.cism.it. A letter of confirmation will be sent to accepted participants.

The registration fee is 600,00 €.

A limited number of participants from universities and research centres who are not supported by their own institutions can be offered board and/or lodging in a reasonably priced hotel. Requests should be sent to CISM Secretariat by **March 18, 2009** together with the applicant's curriculum and a letter of recommendation by the head of the department or supervisor confirming that the institute cannot provide funding. Preference will be given to applicants from countries which sponsor CISM.

The Deutsche Forschungsgemeinschaft offers scholarships to German students (please contact Dr-Ing. Marcel Urban, DFG, Kennedyallee 40, 53175 Bonn, Germany, tel. +49 (228) 885 2655, e-mail: Marcel.Urban@dfg.de - web site: http://www.dfg.de).

Information about travel and accommodation are available at http://www.cism.it/cism/travel_reach.htm, or can be mailed upon request.

For further information please contact:

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ACADEMIC YEAR 2009

The Broglio Session

Centre International des Sciences Mécaniques
International Centre for Mechanical Sciences

NUMERICAL MODELING OF CONCRETE CRACKING

Advanced School
coordinated by

Günter Hofstetter
University of Innsbruck
Austria

Günther Meschke
Ruhr University Bochum
Germany

Udine, *May 18 - 22,* 2009

NUMERICAL MODELING OF CONCRETE CRACKING

The reliable numerical simulation of the initiation and propagation of cracks plays an important role for the integrity assessment of concrete structures. To this end a large number of material models for concrete cracking based on different theories (e.g., damage mechanics, fracture mechanics, plasticity theory and combinations of the mentioned theories) as well as advanced finite element methods suitable for the representation of cracks (e.g. the Extended Finite Element Method and Embedded Crack Models) have been developed in recent years.
Classical models for concrete cracking are based either on the so-called smeared crack approach or the discrete crack approach. Smeared crack models are based on the theory of continuum mechanics and are characterized by spreading the dissipated energy along the width of the localization band. The class of discrete crack models is characterized by incorporating the discontinuity of the displacement field due to cracking directly into the finite element formulation in order to capture the strong discontinuity kinematics of a discrete crack. To this end, a discontinuity interface is introduced. Its behaviour is described by a discrete traction-separation law. In contrast to crack faces introduced along element boundaries, the strong discontinuity kinematics can be introduced within the domain of a finite element. Hence, a macroscopic crack path may cross a given spatial discretization in an arbitrary way. In this context one can distinguish between enriching elements with additional degrees of freedom, representing the displacement jump across the crack, and enriching nodes with additional degrees of freedom. The former method is denoted as elements with embedded discontinuities, whereas the latter is known as the Extended Finite Element Method.
The aim of this CISM Course is to impart basic knowledge of the different approaches for modelling damage and cracking of concrete and to provide a critical survey of the state-of-the-art in this field of computational mechanics. The lectures cover a relatively broad spectrum of topics related to crack modelling, including continuum-based and discrete crack models, induced anisotropy, advanced crack models based on the concept of finite elements with embedded discontinuities and on the extended finite element method, models of crack propagation in concrete subjected to cyclic and dynamic loading and meso-scale models for cracked concrete. Also, extensions to coupled problems such as hygro-mechanical problems will be addressed. Special emphasis will be put on the potentials of the different approaches for practical applications in Civil Engineering.
The course is addressed to doctoral students, young researchers and practicing engineers.

PRELIMINARY SUGGESTED READINGS

M. Jirásek, Nonlocal damage mechanics, Revue Européenne de Genie Civil, 11 (2007), 993-1021.

G. Meschke, S. Grasberger, Numerical modelling of coupled hygro-mechanical degradation of cementitious materials. Jour. of Engineering Mechanics (ASCE), 129(4):383–392, 2003.

J. Oliver, A.E. Huespe, MD. Pulido, E. Chaves, From Continuum Mechanics to Fracture Mechanics: the Strong Discontinuity Approach, Engineering Fracture Mechanics. 69 (2002), 113-136.

J. Lemaitre, R. Desmorat, Engineering Damage Mechanics: Ductile, Creep, Fatigue and Brittle Failures, Springer, 2005.

C. Feist, G. Hofstetter, An Embedded Strong Discontinuity Model for Cracking of Plain Concrete, Computer Methods in Applied Mechanics and Engineering, 195 (2006), 7115-7138.

N. Moës, J. Dolbow and T. Belytschko, A finite element method for crack growth without remeshing, International Journal for Numerical Methods in Engineering, 46 (1999), 131-150.

I. Carol, A. Idiart, C.M. Lopez, A. Caballero, Multiaxial behavior of concrete, a meso-mechanical approach, Revue Européenne de Genie Civil, Vol. 11, pages. 907-926 (2007).

LECTURES

All lectures will be given in English. Lecture notes can be downloaded from CISM web site, instructions will be sent to accepted participants.

INVITED LECTURERS

Ignacio Carol - Technical University of Catalonia, Barcelona, Spain
4 lectures on: discrete crack models using zero-thickness interface elements and meso-scale applications: cracking and fracture of concrete using discrete-crack approach via zero-thickness interface elements along mesh lines; application to meso-mechanics of concrete and to diffusion-driven and coupled durability phenomena in concrete.

Rodrigue Desmorat - École Normal Supérieure de Cachan, France
5 lectures on: damage models for cyclic and dynamic loading: Isotropic versus anisotropic damage; thermodynamics of damage; standard and non standard damage models; dissymmetric tension/compression damage models for concrete; micro-cracks closure effect and quasi-unilateral conditions; cyclic & hysteretic damage models; permanent strains; strain rate effect by visco- and delay-damage (application to impact).

Günter Hofstetter - University of Innsbruck, Austria
4 lectures on: plasticity based crack models & applications: smeared crack models; crack model with embedded discontinuities; applications of concrete models to numerical simulations of concrete structures: (i) pre-cast tunnel lining, (ii) pre-stressed RC shell, (iii) pre-stressed concrete reactor containment model, (iv) RC tunnel structure subjected to fire (v) anchor pull out test.

Alfredo E. Huespe - Univ. Nacional del Litoral, Santa Fe, Argentina
6 lectures on: crack models with embedded discontinuities: typical constitutive models with strain softening; kinematics of strong discontinuities; regulari-zation of strain softening models with strong discontinuities; the continuum-strong discontinuity approach; finite elements for capturing strong discontinuities; local and global discontinuity tracking algorithms.

Milan Jirásek - Czech Technical University, Prague, Czech Republic
5 lectures on: smeared crack models: isotropic and anisotropic damage models; principles of strain and energy equivalence; smeared representation of oriented cracks; concepts of fixed and rotating cracks; objective modelling of strain localization; cohesive crack approach; crack band approach; nonlocal damage models.

Günther Meschke - Ruhr University Bochum, Germany
5 lectures on: X-FEM based crack models in the context of poro-mechanics and finite element methods for multiphase problems: continuum-based damage models in the context of hygro-mechanical problems; chemical dissolution problems and chemically expansive processes in concrete structures; consideration of reinforcement; X-FEM models (3D implementation aspects and extension to hygro-mechanical formulation).

Nicolas Moës - Ecole Centrale de Nantes, France
6 lectures on: X-FEM based crack models: X-FEM basics; crack modeling in 2D and 3D; enrichment strategies and technical issues; configurational forces and extraction of stress intensity factors; advanced issues (cracks in incompress-ible media; cracks under contact; cracks with cohesive zone); size effect and changes in crack topology.

NUMERICAL MODELING OF CONCRETE CRACKING

Udine, May 18 - 22, 2009
Application Form
(Please print or type)

Surname _____

Name _____

*Affiliation*_____

*Address*_____

_____

*E-mail*_____

*Phone*_____*Fax*_____

Method of payment upon receipt of confirmation (Please check the box)

The fee of Euro 600,00 includes IVA/VAT tax and excludes bank charges

❑ *I shall send a check of Euro* _____

❑ *Payment will be made to CISM - Bank Account N° 094570210900, VENETO BANCA - Udine (CAB 12300 - ABI 05418 - SWIFT AMBPIT2M - IBAN CODE IT83Z 05418 12300 09457 0210900).*
Copy of the receipt should be sent to the secretariat

❑ *I shall pay at the registration counter with check, cash or VISA Credit Card (Mastercard/Eurocard, Visa, CartaSi)*

IMPORTANT: CISM is obliged to present an invoice for the above sum. Please indicate to whom the invoice should be addressed.

Name_____

Address_____

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C.F.*_____

VAT/IVA* No_____

(*) Only for EU residents or foreigners with a permanent business activity in Italy.

Only for Italian Public Companies
❑ *I ask for IVA exemption (ex law n. 537/1993 - art. 14 comma 10).*

Privacy policy: I understand that data received via this form will be used only to provide information about CISM and its activities, within the limits set by the Italian legislative decree no. 196/2003 and subsequent amendments.
Complete information on CISM's privacy policy is available at www.cism.it.

I have read the "Admission and Accommodation" terms and conditions and agree.

Date _____ Signature _____