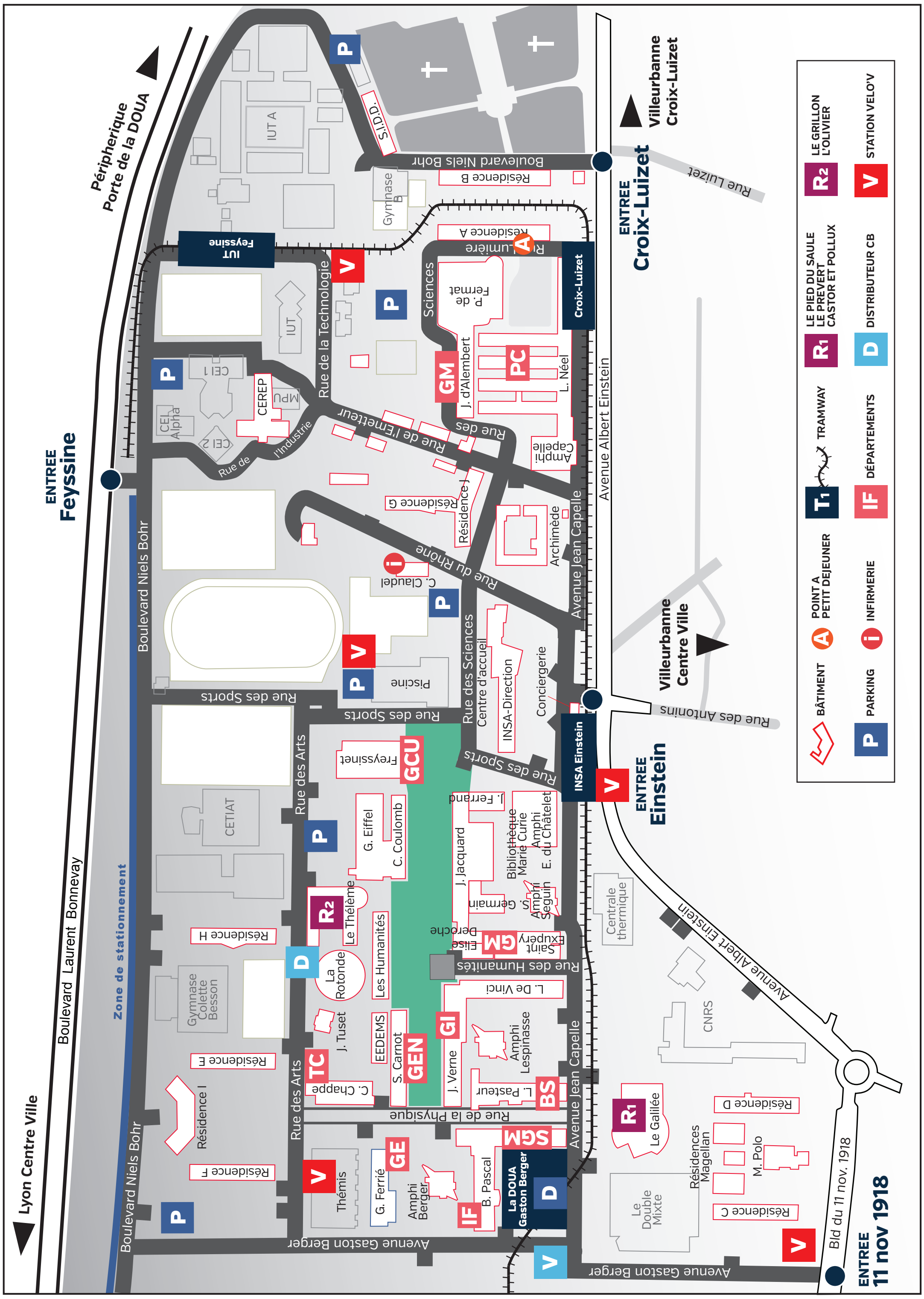
2019 EMI International Conference

Engineering Mechanics Institute

Conference Program

GEOMAS

JULY 3 – 5, 2019 LYON, FRANCE



Map of the Campus

Welcome!

On behalf of the Steering Committee, the Local Organizing Committee and the International Scientific Committee, I would like to welcome you on La Doua Campus at INSA Lyon – France.

We are proud to host the fifth EMI International Conference following the 2015 Conference hosted by the Hong Kong Polytechnic University, 2016 Conference hosted by University of Lorraine France, EMI2017 International Conference in Rio de Janeiro, Brazil, 2018 Conference hosted by Tongji University that the Engineering Mechanics Institute (EMI) of the American Society of Civil Engineers (ASCE) organized outside the United States. This important event will be taking place for the second time in Europe.

2019 EMI International Conference feature about 200 oral presentations in the 27 Mini-Symposia organized in parallel sessions. The participants come from the six continents, with high participation of young researchers and PhD students who will have a great opportunity to exchange on an international platform.

The Plenary lectures will be given by five highly distinguished leading researchers covering a large scope of hot topics in Civil, Mechanical and Material Engineering. Several keynote lectures are given within the mini-symposia by leading researchers in their research field so all together a large number of topics will be covered during the conference.

A mini-Symposium “Mechanics of Granular and Clay Materials” is organized in honor of Professor Pierre-Yves Hicher, Emeritus Professor et Ecole Centrale de Nantes, France.

A joint workshop on Horizon 2020 calls for “materials, processes, nano and energy efficient building” is organized by the National contact point and the European Commission (Anne de Baas, Project Officer).

We would like to take this opportunity to express our sincere gratitude to all colleagues and friends who helped in the organization of the Conference, the EMI Board of Governors, Prof. George Deodatis - EMI President, Dr. Amar Chaker - EMI Director, and Ms Verna Jameson – EMI Senior Manager for the assistance they provided and of course to INSA Lyon for the support and for hosting this Conference.

A special thanks to the Plenary Speakers, Mini-Symposia Organizers, Sessions Chairs and all the participants of the conference.

We wish you a very fruitful Conference and a pleasant stay in Lyon!

Marie-Christine Baïetto, Salim Belouettar, Ali Daouadji, Zhenyu Yin

Committees

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Said	TAIBI	Université de Normandie	France
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François	TROCHU	Ecole Polytechnique de Montréal	Canada
Matthieu	VANDAMME	Université Paris-Est	France
Vera	VEN BEEK	Delft University of Technology	Netherlands
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Richard	WAN	University of Calgary	Canada
Henry	WONG	Ecole Nationale des Travaux Publics de l'Etat	France
Zhenyu	YIN	The Hong Kong Polytechnic University	Hong Kong
Daniil	YURCHENKO	Herriot-Watt University	United Kingdom
Rachid	ZENTAR	Ecole des Mines de Douai	France
Zidong	ZHAO	Hong Kong University of Science & Technology	Hong Kong

Program

Program at a glance

Tuesday, July 2, 2019
16:30 - 19:00, Registration
17:00 - 19:00, Ice Breaker at INSA Lyon

Wednesday, July 3, 2019
08:00 - 16:30, Registration
08:00 - 08:30, Welcome session
08:30 - 09:30, Plenary lecture 1: Prof. Cherbal FARHAT
09:30 - 10:30, Plenary lecture 2: Prof. Patrick SELVADURAI
10:30 - 11:00, Coffee break
11:00 - 12:30, Parallel sessions
12:30 - 14:00, Lunch
14:00 - 15:30, Parallel sessions
15:30 - 16:00, Coffee break
16:00 - 17:30, Parallel sessions
19:00 - 21:00, Welcome Reception at on campus (Hotel de Ville – cancelled)

Thursday, July 4, 2019
08:00 - 12:30, Registration
08:30 - 09:30, Plenary lecture 1: Dr Anne de BAAS
09:30 - 10:30, Plenary lecture 2: Prof. Fernandino AURICCHIO
10:30 - 11:00, Coffee break
11:00 - 12:30, Parallel sessions
12:30 - 14:00, Lunch
14:00 - 15:30, Parallel sessions
15:30 - 16:00, Coffee break
16:00 - 17:30, Parallel sessions
18:30 - 19:30, Social Hour at *Salle de la Corbeille – Palais de la Bourse (Lyon)**
19:30 - 22:30, Banquet at *Salle de la Corbeille – Palais de la Bourse (Lyon)**

Friday, July 5, 2019
09:00 - 10:00, Plenary lecture 1: Prof. François TROCHU
10:00 - 10:30, Coffee break
10:30 - 12:00, Parallel sessions
12:00 - 12:30, Closure
12:30 - 14:00, Lunch

**Palais de la Bourse* is located close to exit Metro Cordeliers (Metro Line A – Red line)

8:00-8:30	8:30-10:30	10:30-11:00	11:00-12:30	12:30-14:00	14:00-15:30	15:30-16:00	16:00-17:30		18:30-20:00	19:30-22:00
Tuesday (July 2, 2019) *Registration (14:00-19:00)*										
									Ice Breaker (17:00-19:00)	
Wednesday (July 3, 2019) *Registration (8:00-16:00)*										
Opening session	Plenary Lecture 1 Lecture 2	Coffee break	Parallel Sessions	Lunch	Parallel Sessions	Coffee break	Parallel Sessions		*Welcome Reception*	
Thursday (July 4, 2019) *Registration (8:00-16:00)*										
	Plenary Lecture 1 Lecture 2	Coffee break	Parallel Sessions	Lunch	Parallel Sessions	Coffee break	Parallel Sessions			*Banquet Dinner*
Friday (July 5, 2019) *Registration (8:00-16:00)*										
	Plenary Lecture 1 Lecture 2	Coffee break	Parallel Sessions	Lunch						

List of Mini-symposia

MS1 : From capillary bonds to immersed granular flow
(Chairs: Jean-Yves Delenne, Farhang Radjai, Anthony Wachs)

MS2 : Suffusion Process and Mechanical Behavior
(Chair: Zhenyu YIN)

MS3 : Induced Seismicity
(Chairs: Nathalie CASAS, Guilhem Mollon)

MS4 : Mini-Symposium(*) in Honour of Professor Pierre-Yves HICHER
(Chairs: Daouadji Ali, Zhenyu YIN)

MS5 : Recent Advances in the Behavior of Granular Materials
(Chairs: Christophe Dano, Pierre-Yves Hicher)

MS6 : Computational and Analytical Methods in Geomechanics
(Chairs: Siegfried Maiolino, Frederic Pellet)

MS7 : Resilient Behavior Modelling of Granular Based Materials
(Chair: Cyrille Chazallon)

MS8: Poromechanical Couplings in Geomaterials and Geostructures
(Chairs: Antonin Fabbri, Jean-Michel Pereira, Henry Wong)

MS9 : Enriched Continuum Mechanics and Bridging Different Scales
(Chairs: Angela Madeo, Patrizio Neff)

MS10 : Biomechanical Modeling of the Human
(Chairs : Yoann LAFON, Karine Bruyère, bertrand Frechede, Raphaël Dumas, Sonia Duprey, Laure-Lise Gras, Laura Dubuis, Mélanie Ottenio, aline Bel Brunon)

MS11 : Innovative Materials for Sustainable Construction
(Chairs : Elodie Prud'homme, Geneviève Foray, Martin Cyr, Hubert Rahier, Aveline Darquennes)

MS12 : High Temperature Effects on the Dynamic Strength of Concrete
(Chairs: LEVON AVETISYAN, Ashot Tamrazyan)

MS14 : Thin Textile (and Fiber) Reinforced Cement Composites and Ferrocement
(Chairs: AMIR SILARBI, Tine Tysmans, CORINA PAPANICOLAOU)

MS18 : Machine Learning and Informatics for Materials Discovery and
(Chairs: Mathieu Bauchy, N M Anoop Krishnan)

MS19 : Stability and failure of structures and materials
(Chairs: Noël Challamel, Wadee Ahmer)

MS20 : Towards the Next Generation of Smart Structures
(Chair: Mariantonieta Gutierrez Soto)

MS22 : Robustness of Infrastructures
(Chairs: Simos Gerasimidis, George Deodatis)

MS23 : Shell Buckling
(Chairs: Simos Gerasimidis, Pedro Reis)

MS24 : Vibration Control of Structures Under Multiple Hazards
(Chairs: Said Elias Rahimi, Aly-Masoud Aly, Vasant Matsagar, Rajesh Rupakhety)

MS25 : Current Challenges in Multiscale Mechanics - From Materials to Structures
(Chairs: Christian Hellmich, Stefan Scheiner, Bernhard Pichler)

MS26 : Linear and Nonlinear Vibrations of Complex Structures
(Chairs: El Mostafa Daya, Hakim Boudaoud, Guillaume Robin)

MS27 : Effects of Manufacturing on the Mechanical Performance of Composites
(Chair: de Luca Patrick)

MS28 : Dynamic behaviour of Geomaterials
(Chairs: BRARA Ahmed)

MS29 : COMPOSELECTOR H2020 Project
(Chairs: BELOUETTAR Salim, KAVKA Carlos , PATZAK Borek , KOELMAN Hein)

MS30 : High Performance Structural Polymer-based Composites and Their Related Applications
(Chairs: DAVID RUCH, Henri PERRIN, BELOUETTAR Salim)

MS34 : Multiscale and multiphysics approaches for durability of construction materials and structures
(Chairs : Ariane Abou Chakra, Laurie Lacarrière)

MS35 : Other EMI' interest papers
(Chairs: DAOUADJI Ali, BELOUETTAR Salim)

			03-Jul			04-Jul			05-Jul	
		Chairs	Wednesday m (11:00-12:3	Wednesday aft (14:00-15:3	Wednesday aft (16:00-17:3	Thursday morn 12:30)	Thursday after (14:00-15:3	Thursday afte (16:00-17:3	Friday morning 12:30)	Room
Track 1	MS1+MS2	Jean-Yves Delenne, Farhang Radjai, Anthony Wachs								321-04-03
Track 2	MS3	Nathalie Casas, Guilhem Mollon								321-04-02
Track 3	MS4	Ali Daouadji, Zhenyu Yin								Auditorium Emilie du Châtelet
Track 4	MS5+7	Christophe Dano, Cyrille Chazallon, Pierre-Yves Hicher								321-04-06
Track 5	MS6+8	Siegfried Maiolino, Frederic Pellet, Antonin Fa Henry Wong								321-04-01
Track 6	MS9	Angela Madeo, Patrizio Neff								321-04-08
Track 7	MS11	Elodie Prud'homme, Geneviève Foray, Martin Aveline Darquennes								321-04-02
Track 8	MS12+28	LEVON AVETISYAN, Ashot Tamrazyan, Ahmed Brara								321-04-01
Track 9	MS14	Amir SILARBI, Tine Tysmans, CORINA PAPANICOLAOU								321-04-02
Track 10	MS18	Mathieu Bauchy, N M Anoop Krishnan								321-04-06
Track 11	MS19	Noël Challamel, Wadee Ahmer								321-04-03
Track 12	MS22+MS23	Simos Gerasimidis, George Deodatis, Pedro Reis								321-04-01
Track 13	MS24	Said Elias Rahimi, Aly-Masoud Aly, Vasant Matsagar, Rajesh Rupakhety								321-04-05
Track 14	MS25	Christian Hellmich, Stefan Scheiner, Bernhard Pichler								321-04-05
Track 15	MS26+MS2	Daya, Gutierrez Soto, Robin, Boudaoud								321-04-08
Track 16	MS29	BELOUETTAR Salim, KAVKA Carlos , PATZAK Borek , KOELMAN Hein								321-04-03
Track 17	MS30	DAVID RUCH, Henri PERRIN, BELOUETTAR Salim								321-04-06
Track 18	MS34	Ariane Abou Chakra, Laurie Lacarrière								321-04-05
Track 19	MS35	Ali Daouadji, Zhenyu Yin								321-04-06

Plenary Speakers

Prof. Charbel FARHAT, Stanford University, USA

Charbel FARHAT is the Vivian Church Hoff Professor of Aircraft Structures, Chairman of the Department of Aeronautics and Astronautics, and Director of the Stanford-KACST Center of Excellence for Aeronautics and Astronautics at Stanford University. His research interests are in computational engineering sciences for the design and analysis of complex systems in aerospace, mechanical, and naval engineering. He is a Member of the National Academy of Engineering, a Member of the Royal Academy of Engineering (UK), a Member of the Lebanese Academy of Sciences, a Doctor Honoris Causa from Ecole Centrale de Nantes, a Doctor Honoris Causa from Ecole Normale Supérieure Paris-Saclay, a designated ISI Highly Cited Author, and a Fellow of AIAA, ASME, IACM, SIAM, USACM, and WIF. He has trained more than 90 PhD and post-doctoral students. For his research on aeroelasticity, aeroacoustic scattering, CFD, dynamic data-driven systems, fluid-structure interaction, high performance computing, and model reduction, he has received many professional and academic distinctions including: the Ashley Award for Aeroelasticity and the Structures, Structural Dynamics and Materials Award from AIAA; the Lifetime Achievement Award and the Spirit of St Louis Medal from ASME; the Gordon Bell Prize and the Sidney Fernbach Award from IEEE; the Gauss-Newton Medal from IACM; the Grand Prize from the Japan Society for Computational Engineering Science; and the John von Neumann Medal from USACM. He was knighted in France in the Order of Academic Palms, and awarded the Medal of Chevalier dans l'Ordre des Palmes Académiques.

Prof. Patrick SELVADURAI, Mc Gill University, Canada

Dr. A.P.S. SELVADURAI is currently William Scott Professor and Distinguished James McGill Professor in the Department of Civil Engineering and Applied Mechanics. He obtained his Ph.D. degree in Theoretical Mechanics from the University of Nottingham, under the tutelage of the eminent continuum mechanicist the late Professor A.J.M. Spencer FRS, for research in the area of "Non-linear Elasticity" and in 1986 the D.Sc. in Theoretical Mechanics for research into "*Mathematical Modelling of Problems in Geomechanics and Elastomechanics*". He joined the Department of Civil Engineering at Carleton University, Ottawa, Canada in 1975 as Assistant Professor, became Professor in 1981 and Head of the Department from 1982 to 1991. In 1993, he was invited by McGill University to become Chair of the Department of Civil Engineering and Applied Mechanics, a position he held until 1997.

In 1991, Dr. Selvadurai received the *Inaugural Horst Leipholz Medal* of the Canadian Society of Civil Engineering and in 1993 the *Engineering Medal for Research and Development* of The Professional Engineers of Ontario. In 1998, Dr. Selvadurai received the *Humboldt Forschungspreis* (Humboldt Foundation of Germany), given to internationally acclaimed scientists and engineers. In 2000, he became the first civil engineer to be awarded *the Killam Research Fellowship Canada Council for the Arts*, one of Canada's most distinguished research awards. In 2001 he was awarded the *Inaugural John Booker Medal* of the International Association for Computer Methods and Advances in Geomechanics-IACMAG. In 2003 he received the prestigious *Max Planck Forschungspreis in the Engineering Sciences*. In 2007, he was awarded the *Killam Prize in Engineering* from the Canada Council for the Arts and the *Gold Medal of the Canadian Congresses of Applied Mechanics*. In 2008 he received the *IACMAG Medal for Outstanding Accomplishments in Geomechanics*. In 2010, he was awarded the *ALERT Research Medal*, by the Alliance of Laboratories in Europe for Research and Technology. In 2013, he was awarded the *Eric Reissner Medal* of the ICCES and the *Maurice A. Biot Medal* of the ASCE. In 2017 he was awarded the *C.S. Desai Medal* of the IACMAG for outstanding contributions to computational geomechanics.

Dr Anne de BAAS, Programme Officer EC RTD LEIT NMBP, European Commission

Anne Francisca de BAAS, Dutch from origin received a physics education in Eindhoven, Utrecht and Delft in the Netherlands and a MBA in Brussels, Belgium. She has been working at the European Commission since 1992 in DG CNECT and DG RTD.
Most recently, she works on ontologies and ontology-base market places for both materials modelling and materials and manufacturing data. These market places target to share and re-use knowledge generated in EU projects and elsewhere.
Her former responsibilities have included the organisation of best practice activities and technology transfer programs and responsibility for benchmarking of industrial software applications. Economic and technical business analyses of 2800 European industries, ensuring return of investment in research and development resulting in the selection of 600 projects. The best practice extracted is documented in a booklet called 'management of economic issues' and accompanied by a booklet on how to manage outsourcing of research called 'dealing with subcontractors' (www.fuse-network.com). She wrote a brochure on Road-Mapping, the work with Network of Excellences and on metamaterials all available on http://ec.europa.eu/research/industrial_technologies/index_en.html

Prof. Fernandino AURICCHIO, University Pavia, Italy

After a Bachelor degreein Civil Engineering at the University of Napoli, Italy (1989), a Master of Science (1991) and a Ph.D. (1995) at the University of California at Berkeley, USA, since 2001 Ferdinando AURICCHIO is professor of Solids and Structural Mechanics at the University of Pavia, Italy, where he started to develop strong collaborations with the Department of Mathematics (being also a Research Associateat IMATI-CNR Pavia) and with several medical institutions.
He received the Euler Medal by ECCOMAS (European Community of Computational Methods in Applied Sciences) in 2016 and he became Fellow Award by IACM (International Association for Computational Mechanics) since 2012.Since 2013 he is Vice-President of ECCOMAS.
In 2018 he was appointed as a member of the Italian National Academy of Science, known also as Accademia dei XL.
Major research interests are the development of numerical schemes (in particular, finite element methods, both for solids and fluids, with a particular attention to innovative materials), the development of simulation tools to support medical decision (in particular, for cardiovascular applications), and more recently everything that is related to additive manufacturing. In fact, he has organized a 3D-printing lab, exploring new materials, new printing technologies, new uses of 3D printing, ranging from civil engineering 3D printed concrete beams to bio-manufacturing.

Prof. François TROCHU, Ecole Polytechnique Montreal, Canada

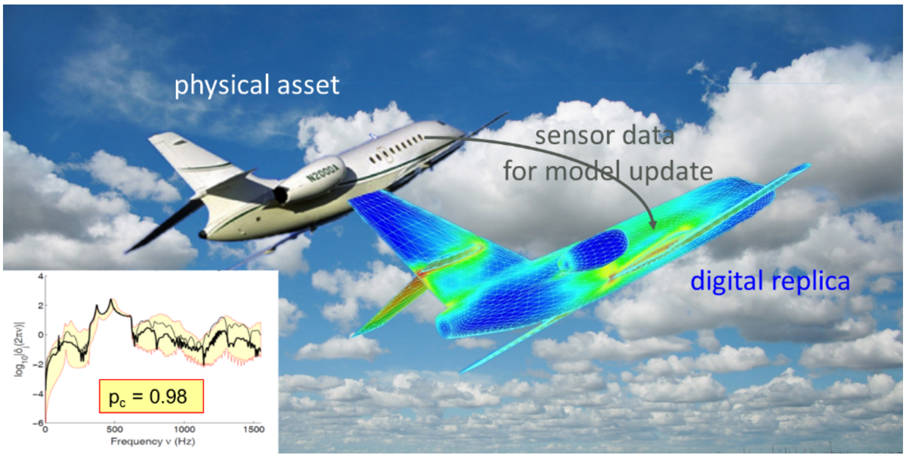
Dr. François TROCHU is professor of Mechanical Engineering at École Polytechnique de Montréal. After graduation in 1974 from École Polytechnique in Paris, he obtained his Master's degree under the supervision of Dr. J. T. Oden in Aerospace Engineering at the University of Texas at Austin in 1975. In 1990, he received his Ph.D. from École Polytechnique, Montreal, on the development of random finite elements and the application of kriging to groundwater flows in porous media. Since 1990, F.
Trochu is Professor in the Mechanical Engineering Department of École Polytechnique de Montréal and has published over 100 papers on composite manufacturing in scientific journals. Actively involved for nearly 30 years in applied research in Liquid Composite Molding (LCM), Professor Trochu is the creator of the commercial software PAM-RTM developed to simulate the Resin Transfer Molding (RTM) process with over 100 users worldwide. Professor Trochu held from 2003 to 2017 a Tier I Canada Research Chair on High Performance Composites and between 2005 and 2015 two successive Industrial Research Chairs on composite manufacturing by resin injection with General Motors (GM) and Safran.

Plenary Lectures

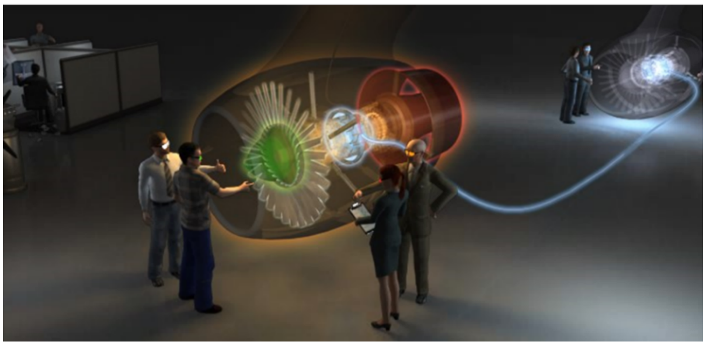
Plenary Lecture: Wednesday July 3, 8:30 – 9:30 AM
Amphitheater SEGUIN

Feasible Data-Driven Probabilistic Modeling/Learning for Digital Twins

Charbel Farhat
Department of Aeronautics and Astronautics
Department of Mechanical Engineering
Institute for Computational and Mathematical Engineering
Stanford University, Stanford, CA 94305, USA



A digital twin refers to a digital replica of an asset – whether a physical platform or a process – that can be used, for example, to optimize in near real-time the operation and/or life cycle management of this asset, or more generally, to drive the Intelligent Enterprise by linking engineering and operations such as maintenance. The advocated enabler of such a computational capability is the integration of artificial intelligence, machine learning, and software analytics with data to create living digital simulation models that update and change as their physical counterparts change. Specifically, early forms of digital twins appear to be based on the integration of data analytics with model-based prediction of a few, scalar, quantities of interest (QoIs). In this lecture however, the issue of whether a system can be represented reliably by a few QoIs will be raised. Then, a more robust approach for realizing a digital twin based on adaptable, stochastic, low-order but high-fidelity computational models will be presented. This approach integrates physics-informed machine learning techniques, probabilistic reasoning, and data-driven thinking with projection-based model order reduction to construct stochastic, hyperreduced, computational models that can operate in real time and self-adapt using data extracted from physical sensors. Two sample digital twins constructed using this proposed approach – one for a small-scale replica of an X-56 type aircraft and one for a three-dimensional MEMS device – will be presented, and their real-time performance will be illustrated and analyzed.



Plenary Lecture: Wednesday July 3, 9:30 – 10:30 AM
Amphitheater SEGUIN

Poro-Hyperelasticity: The Mechanics of Fluid-Saturated Soft Tissues

A.P.S. Selvadurai
William Scott Professor and *Distinguished James McGill Professor*
Department of Civil Engineering and Applied Mechanics
McGill University
Montréal, QC, Canada H3A 0C3

Abstract
The lecture presents the formulation of the mechanics of a fluid-saturated porous medium where the porous skeleton can undergo hyper-elastic deformations. The modelling has potential applications in the study of highly deformable biological tissues including brain matter, synthetic materials impregnated with fluids and highly deformable porous solids used as tactile sensors, where the fluid can be the air present in the void space. Conventional treatments of soft biological materials assume the applicability of classical hyperelasticity. The presence of the saturating fluid, however, completely changes the character of the modelling approach, in that the partitioning of stresses between the fluid and the porous skeleton needs to be addressed. The flow of the saturating fluid, induced by hydraulic gradients, is an added consideration. The presentation summarizes recent analytical results for canonical problems involving one-dimensional strains, pure shear and expansion of annuli. The role of these developments in the validation of computational schemes that can ultimately be used in the solution of problems with complex geometries is also discussed. The material presented in the plenary lecture is a summary of recent articles [1-4] on the topic.

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[2] Suvorov, A.P. and Selvadurai, A.P.S. (2016) On poro-hyperelastic shear, *Journal of the Mechanics and Physics of Solids*, 96: 445-459.
[3] Selvadurai, A.P.S. and Suvorov, A.P. (2017) On the inflation of poro-hyperelastic annuli, *Journal of the Mechanics and Physics of Solids*, 107: 229-252
[4] Selvadurai, A.P.S. and Suvorov, A.P. (2018) On the development of instabilities in an annulus and a shell composed of a poro-hyperelastic material, *Proceedings of the Royal Society, Mathematical and Physical Sciences Series A*, https://dx.doi.org/10.6084/m9.figshare.c.4271114.

Plenary Lecture: Thursday July 4, 8:30 – 9:30 AM
Amphitheater SEGUIN

Constituency building and standardisation in the NMBP programme: physics-based modelling and data sharing

Dr Anne de BAAS
Programme Officer EC RTD LEIT NMBP
European Commission

Abstract

Horizon Europe, the next frame work programme, will deal with Big Data and Artificial Intelligence. In order to prepare that the NMBP Programme will prepare Industry Commons. In the WP2020 there will be two Calls (to be launched in July 2019) on data sharing. One call will deal with ontologies in materials and manufacturing. The other will create a market place for NMBP-related data.
The state of the art in data documentation in the modelling area (MODA) and characterisation area (CHADA) will be presented. The modelling market place, a forerunner of the Industry Commons market place, will be presented. The European Materials Modelling Council will be shown as a good example of constituency building with its successful scope of joint activities.

Plenary Lecture: Thursday July 4, 9:30 – 10:30 AM
Amphitheater SEGUIN

Additive Manufacturing: modeling and computational challenges!!

Ferdinando Auricchio

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Additive Manufacturing (AM) – also known as 3D printing – is taking off in many industrial processes. In particular, powder bed fusion for metal manufacturing has definitively changed the way of prototyping metal parts but also plastic 3D printing is changing many approaches in modern engineering.
However, AM is a complex physical process, involving different phenomena, e.g., heat conduction, phase change, surface change, and residual stress rising; accordingly, it is a complex coupled thermo-mechanical problem and simulation is fundamental to predict temperature distribution and stresses during and after the printing process.
After a general introduction to the technology and to possible applications, the presentation will focus on some new approaches to describe the complex physics occurring during the manufacturing process as well as on optimization problems associated to the freedom which is possible thanks to additive manufacturing. The presentation will try to highlight unresolved issues and open possible research directions.

Plenary Lecture: Friday July 5, 9:00 – 10:00 AM
Amphitheater SEGUIN

Fabrication of High Performance Parts by Liquid Composite Molding and Application to Polymer Based Composites

François Trochu, Professor

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Liquid Composite Molding (**LCM**) regroups a family of manufacturing processes to fabricate high performance composites based on injecting a liquid phase through a solid porous material. When the liquid cools down, evaporates or chemically reacts, a composite part is created by the combination of two phases. An increasing number of industrial applications are now in production or currently developed to fabricate polymeric, metallic or ceramic composites. The theoretical background to model these processes is based on two basic laws governing liquid flows and consolidation in porous materials pioneered in Civil Engineering by Darcy and Terzahgi. Permeability turns out to be a key parameter to model liquid injection processes through fibrous reinforcements. This presentation aims to show how the scientific background developed initially in Civil Engineering was successfully applied to composite manufacturing.

The concept of permeability can be extended from the classical saturated permeability of Darcy's law to model different polymer based injection processes such as *Resin Transfer Molding* (RTM), *Vacuum Assisted Resin Infusion* (VARI) or *Liquid Resin Infusion* (LRI), namely resin infusion with distribution media. Several examples of application to polymer composites will be presented to illustrate how the unsaturated, equivalent, flexible and apparent permeability have been used successfully or are being considered to simulate reactive resin flows through porous materials and fabricate high performance aircraft, automotive, marine or wind energy composites.

Current challenges encountered in *Liquid Injection Molding* will also be discussed. In particular, the use of granular materials appears promising to create adaptive molds and reduce tooling costs. This is especially necessary to make parts of large dimension such as ship hulls or wind blades. It is the case also for many infrastructure applications. Granular materials have been investigated for a long time in Soil Mechanics. It turns out that they can provide a unique material for composite tooling because they can deform, and at the same time, if needed, provide rigidity under vacuum. Examples of adaptive injection technology will be presented.

Mini-Symposium Honoring Pierre-Yves Hicher

Thursday July 4th 2019, 14h00 - 17h30
Amphitheater Emilie du Châtelet
Library Marie Curie (BMC)

Mechanics of Granular and Clay Materials
A mini-symposium honoring Professor Pierre-Yves Hicher

Dr. Pierre-Yves Hicher

Emeritus Professor since 2015
EMI Fellow

Former Director of the Research Institute in Civil and Mechanical Engineering at the Ecole Centrale de Nantes

Pierre-Yves Hicher is a distinguished research scholar and teacher in engineering mechanics and geomechanics whose outstanding contributions to these fields are recognized world-wide.
His work has improved understanding and enriched the body of knowledge about the mechanical behavior of soils and granular materials mainly through having developed methodologies for connecting macroscopic properties to the microstructure of complex heterogeneous materials.
Among his major contributions can be cited the original experimental procedures and parameter identification methods under inverse analysis techniques, the homogenization techniques for modeling the mechanical behavior of disordered granular materials, and more recently, the practical criteria and models for addressing internal erosion in geomaterials with specific attention to landslides and the stability of hydraulic works.
After starting his professional career as a consultant in offshore oil structures and nuclear waster disposal in deep clay clayers, Dr.Hicher turned his attention to research projects which resulted in the publication of nearly 100 articles in peer-reviewed journals with over 4000 citations, 8 books and over 80 conference articles and presentations. He has supervised the work of 38 PhD students in the fields of soil mechanics, foundation engineering, granular materials, constitutive modeling and numerical modeling, and he is a reviewer for many international journals.
These facts and figures, impressive as they seem, do not fully reflect the breadth and spirit of Pierre-Yves's total contribution to academia and engineering. The missing information concerns above all his extraordinary humaneness as a scientist and a mentor to numerous students and colleagues.

It must also be noted that Pierre-Yves Hicher 's fundamental contributions to granular micro-mechanics and constitutive modeling have brought resolutions to practical and complex problems in geomechanics often considered “dirty”.
These problems, which were largely ignored by the engineering mechanics researchers in the heyday of his career, include micro-mechanical analysis of clays; characterizing the effects of particle breakage; developing rational methods for analyzing particle suffusion; analyzing clay swelling, partially saturated soils, and grouted and naturally cemented sands; developing micro-mechanical analyses of in situ testing and of the cyclic hardening of soils.
Each of these problems has now become a subject of engineering interest and scientific scrutiny, thanks in no small part to Dr. Hicher’s devoted efforts to the soil mechanics community.

(written by Ali Daouadji, Matthew Kuhn, Angelika Lee)

List of confirmed speakers

Félix	DARVE
Bernard	CAMBOU
Edouardo	ALONSO
Patrick	SALVADURAI
David	MUIR WOOD
Richard	WAN
Antoinette	TORDESILLAS
Jianfu	SHAO
Wei	Wu
Farhang	RADJAI
François	NICOT
Farid	LAOUAFA
Olivier	MILLET
Cyrille	CHAZALLON
Christophe	DANO
Chaofa	ZHAO
Xianfeng	LIU
Dongmei	Zhang
Zhenyu	YIN
Ali	DAOUADJI

List of mini-Symposia

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List of accepted abstracts

MS1: From capillary bonds to immersed granular flow

COUPLED DEM-LBM METHOD FOR SUBMERGED COHESIVE GRANULAR FLOW THROUGH AN ORIFICE

Li-Hua Luu * [1], Jianhua Fan [2], Noury Gildas [2], Philippe Pierre [1]

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[2] Bureau de Recherches Géologiques et Minières (BRGM) (BRGM) – Bureau de Recherches Géologiques et Minières (BRGM) – 3 avenue Claude-Guillemin BP 36009 45060 Orléans Cedex 2, France

The flow of granular materials through an orifice, notably involved in hopper and hourglass, has been addressed by a considerable number of studies. For dry non-cohesive grains, the mass discharge rate is predicted by the well-known Beverloo law (1961). We propose to extend this classical problem to submerged and cohesive cases, motivated by geophysical applications to cover-collapse sinkhole phenomenon. Using a parallelized (GPU) 2D numerical modeling, which describes the solid phase by the discrete element method (DEM), including a cohesion model with damage, and the fluid phase by the Lattice-Boltzmann method (LBM), we investigate the solid flow rate when varying the size of the orifice. In the submerged and cohesion-less case, we first study the adapted Beverloo equation proposed by the experimental work of Wilson et al. (2014), based on the terminal fall velocity of isolated grains and using a larger analogous cutoff than in the Beverloo equation for dry grains. Then, once added particle cohesion, we show that this prediction remains valid provided that the previous cutoff increases with cohesion. Finally, we study a second empirical law for granular discharge rate involving the pressure difference around the orifice that we directly acquire from our numerical simulations. These latter results are favorably compared to a recent experimental study (Guo et al., 2017).

Beverloo, W. A., Leniger, H. A., & Van de Velde, J. (1961). The flow of granular solids through orifices. *Chemical engineering science*, *15*(3-4), 260-269.

Wilson, T. J., Pfeifer, C. R., Mesyngier, N., & Durian, D. J. (2014). Granular discharge rate for submerged hoppers. *arXiv preprint arXiv:1307.2812*.

Guo, S., Yu, T., & Zhang, Y. (2017). Water-submerged granular flow through a long efflux tube. *Granular Matter*, *19*(3), 45.

Keywords: Cohesive granular matter, Beverloo law, Erosion, Submerged hopper

*Speaker

DEM-LBM METHOD FOR THE STUDY OF LOCAL EROSION LAW FOR COHESIVE GRANULAR SOILS

Pierre Philippe *† [1], Zeyd Benseghier [2], Li-Hua Luu [3], Pablo Cuéllar [4], Stéphane Bonelli [2]

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Soil erosion by a surface fluid flow is an old but still topical issue with many practical applications, both in built or natural environments: fluvial morphological changes, pollution spreading by sediment transport, bridge pier scour, erosion of earthen hydraulic structures, etc. This physical process remains poorly understood and requires investigation. The present contribution describes a systematic analysis of erosion rate versus interfacial fluid flow based on a GPU-parallelized 2D numerical modeling. Specifically, the soil's particles are described by the discrete element method (DEM) while the interstitial liquid is modeled by the Lattice-Boltzmann method (LBM) (Cuéllar, 2015). The mechanical description of the solid particles includes a cohesion model via a contact law with a parabolic yield envelope including critical values in traction, shear and rolling (Delenne, 2004). In addition, the previous cohesion model has been extended with a time-dependent damage model (Silvani, 2007, 2009). Here, we propose a simple and consistent empirical erosion law, seeking to relate the intrinsic erodibility parameters, viewed as material properties, to the microscopic quantities underlying our modeling. To this end, a study case with a constant fluid shear-stress configuration was analyzed for different combinations of particle size and cohesion strength, leading to the systematic estimation of the erodibility parameters, especially the critical threshold for erosion occurrence and the kinetic modulus that specifies the rate of soil's mass entrainment.
Cuéllar, P., Philippe, P., Bonelli, S., Benahmed, N., Brunier-Coulin, F., Ngoma, J., Delenne, J.-Y., Radjai, F. (2015). Micromechanical analysis of the surface erosion of a cohesive soil by means of a coupled LBM-DEM model. *Proc. 4th Int. Conf. on Particle-based Methods, PARTICLES 2015.*

Delenne, J.-Y., El Youssoufi, M.S., Cherblanc, F.,Bénet, J.-C. (2004). Mechanical behaviour

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and failure of cohesive granular materials. *Int. J. Numer. Anal. Meth. Geomech.*, 28, 1577–1594.
Silvani C., Bonelli S., Desoyer T., (2007) Fracture of rigid solids: a discrete approach based on a damaging interface modelling, Comptes Rendus de Mécanique, n∘335, pp. 455-460.

Keywords: DEM, LBM, erosion, granular media, cohesion

Pendular capillary bridges between unequal-sized spherical particles: Rupture distances and capillary forces

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This study focuses on axisymmetric capillary bridges between unequal-sized spherical particles in the pendular regime. An analytical theory as well as closed-form expressions have been developed for the rupture distance and the capillary force. These expressions have been validated with a very large dataset of numerical solutions of the governing Young-Laplace equation, generated through a high-resolution integration method.

For small capillary bridge volumes and contact angles smaller than 20 degrees, it has been shown that the meridional profile of the capillary bridge between unequal-sized particles can be accurately described by part of ellipses and that the contact radii for the large and the small particle are approximately equal. Contrary to the widely used toroidal approximation, the developed analytical theory takes into account the governing Young-Laplace equation, according to which the capillary force is constant along the capillary bridge. The analytical theory rigorously shows that expressions developed for cases with equal-sized particles can be directly employed in cases with unequal-sized particles by the use of the Derjaguin radius when the capillary bridge volume is small. Expressions for the rupture distance and the capillary force have also been derived analytically.

For large capillary bridge volumes, the use of the Derjaguin radius is not sufficient to accurately describe the properties of capillary bridges between particles with unequal sizes. By curve-fitting to the large dataset of numerical solutions of the Young-Laplace equation, a closed-form expression for the rupture distance has been developed, that accounts for the influence of the particle size ratio and that is accurate over a wide range of capillary bridge volumes. Expressions in the literature for the capillary force between unequal-sized spherical particles have been rigorously evaluated. With the new expression for the rupture distance, an improved closed-form expression for the capillary force has been formulated that is accurate for a wide range of small and large capillary bridge volumes (more specifically, when the ratio of the capillary bridge volume to the cubic root of the Derjaguin radius is smaller than 0.5) and separation distances, for contact angles smaller than 40 degrees.

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Keywords: Capillary bridge, Unequal sized particles, Young Laplace equation, Ellipse approximation, Derjaguin radius, Granular materials

Coupling LBM and DEM to simulate the motion of wet granular assemblies

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We first describe the coupling of Discrete Element Method (DEM) and Lattice Boltzmann Method (LBM) to simulate partially saturated granular materials in motion. Our implementation combines the Rothman-Keller multiphase Lattice Boltzmann model [1] with the treatment of wetting angle proposed by Akai et al [2].
Our method is validated by comparisons with semi-analytical results in two and three dimensions involving the dynamics and rupture of one liquid bridge between two solid objects.

As simple model illustrating the basic features of wet granular rheology, we study the motion of one mobile grain sliding over fixed granular bed. In this simple analogue of Couette flow under controlled normal stress, the mobile grain has a constant velocity parallel to the substrate while being pressed against it by a controlled force. The influence of control parameters on the system behavior and the possible occurrence of different flow regimes are discussed.

Huang, H., Sukop, M., & Lu, X. (2015). Multiphase lattice Boltzmann methods: Theory and application. John Wiley & Sons.

Takashi Akai, Branko Bijeljic, Martin J. Blunt,Wetting boundary condition for the color-gradient lattice Boltzmann method: Validation with analytical and experimental data, Advances in Water Resources, Volume 116,2018,Pages 56-66.

Keywords: Lattice Boltzmann Method, Discrete Element Modeling, wet granular materials

*Speaker

Shear flow of wet granular materials in the pendular regime: from the quasistatic to inertial and viscous regimes. Experiments and DEM simulations.

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The rheology of wet granular materials in steady shear flow under controlled normal stress is characterized by the internal friction coefficient and the solid fraction. Those quantities are measured in a laboratory rheometer, for a model system that lends itself to discrete (DEM) numerical simulations. In addition to the inertial number (a dimensionless form of the imposed shear rate), the state and the behavior of the system depend on dimensionless reduced stress P*, comparing the applied normal stress to the tensile strength of intergranular contacts in the presence of a wetting liquid bridge. Experimental and DEM results are shown to agree quantitatively once the appropriate value of the intergranular friction coefficient is identified from the quasistatic flow behavior of dry grains. DEM simulations enable the exploration of wider parameter ranges and reveal how the structure of contact and liquid bridge networks in shear flow determines rheological properties. The 'effective stress' idea, or the assumption that capillary forces act like increments of externally applied stresses on granular contact networks, lead to surprisingly good, albeit not exact, quantitative predictions of resistance to shear and Coulomb cohesion in the quasistatic limit for not too small P* (> 1). Cohesion-dominated systems under low P* (of order 0.1) are prone to strong shear strain localization in thin bands. Increasing the wetting liquid viscosity induces similar large effects on the internal friction coefficient and the solid fraction of the flowing material in simulations and in experiments.

Keywords: wet granular materials, shear flow, DEM, cohesion

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Plastic irreversible compression of wet granular materials assembled in loose states

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Capillary cohesion in wet granular assemblies in the pendular regime may stabilize quite loose, open structures spanned by tenuous contact networks. Well equilibrated packs of mono-sized spherical grains are thus observed with low solid fractions (e.g., 0.25). The behavior of such systems under growing stress levels in isotropic or oedometric compression, depending on their initial structure, is studied by DEM simulations. The irreversible density increase is controlled by P*, a reduced pressure defined as the ratio of the controlled confining stress to the tensile contact strength (capillary adhesion) of intergranular contacts, non-dimensionalized by the diameter squared.
A limited number of laboratory experiments on wet beads assembled by pluviation in very loose states, subjected to oedometric compression, leads to compression curves very similar to the simulated ones. Those curves, in the P* range corresponding to the larger irreversible compaction rates, take the classical form of a linear variation of void index e with log(P*).
DEM computations are carried out resorting to a somewhat idealized initial ballistic aggregation assembling process. Compression behavior is potentially strongly influenced by a small resistance to rolling in the contacts, and evinces a sensitivity to the initial structure, which varies, for the same solid fraction, in coordination number and in the distribution of the size of large pores.

Keywords: wet granular materials, plasticity, DEM, aggregation

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Micromechanical Description of Stresses in Fine-grained Wet Media: Adsorption and Capillary Forces

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Micromechanical analysis of force transport and description of stress within triphasic granular media in the pendular regime considering the capillary effect of discrete liquid bridges has been previously investigated. However, experimental and theoretical evidence showed that in wet porous media, liquid-filled corners and pendular spaces are further connected through liquid films coating exposed solid surfaces. Indeed, liquid is retained by capillarity and adsorption within the pore structure of the geomaterials, while both effects are included in matric potential that represents saturation-dependent component of the chemical potential of liquid. Compared to capillarity in the form of discrete liquid bridges, the adsorption component is usually ignored in the analysis of granular materials. In particular for fine-grained wet materials, interfacial forces become considerable and adsorption in the form of liquid film strongly influences the material's behavior. This study presents an analytical model that incorporates the critical effect of adsorption on the interaction between wet fine particles in a more realistic configuration of the liquid system presented by both adsorbed water film and capillary bridge. The focus is on an in-depth understanding of how the liquid-gas mixture in the pore spaces changes the mechanical properties of porous media; especially in the assembly of micro to sub-micro particles where adsorption plays an important role and changes the pore liquid configuration, introducing new interparticle forces. To this end, surface forces of different kinds in sub-micro to nano-scales, affecting interfacial regions between different phases, thermodynamics of liquid films and their mechanical equilibrium are investigated. Furthermore, stress description for fine-grained (e.g. clays) wet porous media will be presented using homogenization approach to upscale such a microscale analysis to the macroscopic level, accounting for the combined effect of adsorption and capillarity. The upshot of this work is that we propose a micromechanical relation which reduces to the so-called effective stress expression in geotechnical engineering that accounts for attractive and repulsive forces arising from physico-chemical interactions.

Keywords: Partially saturated porous media, Fine grained materials, Adsorption, capillarity, Adsorbed water film, Interfacial surface forces, Micromechanical analysis, Stress description, Homogenization approach.

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Lattice Boltzmann simulations of the wetting of granular materials

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In nature and industry, granular media often occur as triphasic materials composed of solid particles, liquid and air. For instance, concrete, particle-embedded composites or even food pastes are obtained by mixing viscous liquids with gains. Hydro-mechanical features play a crucial role on the rheology and on the yield strength properties of such mixtures. Among other illustrations, soil succion is a major factor in slope stability and weathering; in wetting process, aggregates growth depends on fluid-particles interactions; the vadoze zone, above the phreatic zone where water is retained by capillary action, is essential for agriculture and pollution transport...

In this study, we use capillary condensation simulated by a multiphase Lattice Boltzmann model as a means to generate distributions of liquid. Liquid droplets condense from the vapour phase between and on the grains, and they transform into capillary bonds and liquid clusters as thermodynamic equilibrium is approached. The liquid-gas and fluid-solid interactions are derived using a nonlocal potentials in the framework of Multiphase Lattice Boltzmann method. A floodfill algorithm is employed to identify the liquid clusters and to determine their volume and connectivity with the surrounding grains. The internal pressures of each cluster and of the entire liquid phase are analysed as a function of the saturation degree. The global liquid-retention curve can thus be assessed as well as the capillary-induced forces acting on the grains. We investigate the evolution of the capillary negative pressure with the amount of liquid. Different states reflecting the connectivity of the liquid phase and local particle environments are evidenced. An intriguing finding is that the liquid phase undergoes a percolation transition for a liquid content well below full saturation. Interestingly, the tensile stress carried by the grains increases as a function of the amount of liquid up to a peak in the funicular state beyond which the stress falls off as a result of pressure drop inside the merging clusters.

*Speaker

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Delenne, J.Y., Richefeu, V. and Radjai, F., 2015. Liquid clustering and capillary pressure in granular media. Journal of Fluid Mechanics, 762.

Keywords: Lattice Boltzmann Method, unsaturated granular materials, liquid clustering, liquid, retention curve

MS2 : Suffusion Process and Mechanical Behavior

Modelling the elasto-plastic behaviour of suffusive soils

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Granular soils subjected to seepage flow may suffer from internal erosion. When this process is selective (i.e. it concerns the finest fraction of the granular skeleton) and volumetric, it is commonly refered as suffusion. Suffusion affects the hydromechanical behaviour ofthe corresponding soil. Within a earth-structure, suffusion may bring the hydromechanical state of the soil close to the one that triggers failure. From the mechanical point of view, experimental[1][2] and numerical studies[3][4] (based on Discrete Element Methods) has shown that suffusion may involve volumetric strains, which are possibily of dilation or compaction, depending on the stress state from which suffusion occurs. As the fine content decreases during suffusion, the density of the soil is modified: a soil initially dense becomes loose. Moreover, the soil strength decreases while suffusion develops. The present work focus modelling the mechanical behaviour of soil subjected to suffusion. We extend an existing elasto-plastic model[5] by introducing the suffusion induced porosity as a hardening variable and a parametrization of the characteristic state. The modified hardening law models the changes in density state due to suffusion. The porosity driven characteristic state models the residual strength reduction and specifies the nature of the volumetric plastic strain (dilative or contractive) during suffusion. To illustrate the model abilities, numerical integrations of the elasto-plastic model are carried out under monotonic loadings. Under drained triaxial conditions, the strength reduction, the change in the density state, and the nature of the volumetric strain are reproduced. Under oedometric conditions, the model predicts two phenomenons: the stress state evolves as suffusion progresses and the typology of the post-suffusion response differs from that of the intact soil. Further works will be devoted to the model calibration and implementation within an existing finite element code.

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Keywords: Suffusion, Mechanical Behaviour, Elastoplastic Model

MS3 : Induced Seismicity

The exploring of the induced seismicity caused by the explosions in the north of morocco.

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For the geophysical community, an earthquake isn't just a natural disaster; it's also a source of information about the earth. The signal processing is a way to find earth parameters to have a better lecture about earth behavior. The information extracted from the signal of the events is used for security purpose such as seismic hazard and risk mitigation, for mining, for petroleum exploration and several fields. In the last years Morocco had a lot of earthquakes all over the country, especially in the north. In this work we are interested to treat the local and the regional earthquakes by SEISAN software in morocco's network. We present in this work the picking of wave phases, polarity, the compute of the localization of an earthquake, the frequency specter, the different magnitude types, the signal time duration, azimuth, auto-picking, the focal mechanism, the green function and moment tensor inversion of waveforms.

Keywords: Induced Seismicity, earthquakes, explosions, signal processing.

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Study of induced seismicity in Morocco

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The issue of induced seismicity is relatively new in the Moroccan scientific landscape and remains marginal in the geophysical studies. After the earthquake in the region of Al-Hocima, this subject appears implicitly in some new studies with a lot of assumptions, concerning the two months of continuous seismic activity induced, and the study of the main causes of this phenomenon. Otherwise, the mining exploring can have dangerous effects on the soil and the crust over large areas, which increases the possibility of having induced seismicity in the regions. Especially, in Atlas Meseta region in Morocco, which are characterized by relative and moderate seismic activity and mining activity or mine blasting on a daily basis this mining explosion are used to extract the phosphate, because the largest reserve of phosphate in the world is located in this region. In this research work, we will study the characterization and the effects of explosions on the crust, caused by the phosphate extraction in the Atlas Meseta area. On the other hand, we focused also on understanding the mechanics of the deformation in the Alboran Mediterranean region that provoked the induced seismicity for this long duration. We wish to understand at best the influence of the internal structure, particularly the role of faults in the production of these seismic jolts in this area.

Keywords: Earthquakes, Explosions, Induced seismicity, crust.

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SLIP IN GRANULAR FAULT GOUGES

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Discrete Element Method (DEM) is one of the most relevant approaches to simulate granular materials, in particular in soil and rock mechanics in the context of Enhanced Geothermal Systems. To study the slip mechanism occurring within granular fault gouge, discs (2D) or spheres (3D) are used to reproduce particles, due to the simplicity of generation and contacts detection. However, over-simplifications of particle shape do not represent the complexity of the assembly, as grains have angular shape which should be introduced.A 2D model is proposed with two rough surfaces representing the rock walls of the fault containing a granular media obtained by the wear associated to previous slips. We used the DEM with realistic non-circular grain shapes, imposing a constant normal stress and a shear velocity on the upper rock wall to simulate slip triggering. This model is implemented using multibody dynamic for the granular part within the code MELODY [1]. The simulation used realistic angular grains based on grain shapes obtained from the literature and generated with the code Packing2D [2].
We first confirmed with our model that the shape of particles have an influence on friction, based on comparisons with previous results [3] and [4]. The influence of grain size distribution within the gouge has been emphased. Several types of distribution have been selected, such as fractal distributions, distributions with granular gradient, Gaussian distribution, etc. The mechanical contribution of small particles in the media and their influences on the slip behaviors have also been studied. Meaningful results on shear band localizations and slip behaviors into the granular gouge are also presented.

Keywords: Friction, Physic of induced seismicity, Modelling in tribology, Granular fault gouge

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Management of Industrial Risk in Urban Area, Case Study of the City of Bejaia (Algeria)

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During these last years, Algeria was frequently touched by major risks among which we can talk about the industrial risk, they put in danger life of persons and causes inestimable damages, such a situation must be taken very carefully and the use of prevention is the best way of escaping to it. Any industrial activity is in very narrow relation with the concept of the risk, it is due on one hand to the typology of these activities and the nature of substances and used raw materials, on the other hand to the type of the danger that every activity can provoke. This problem requires a methodology which bases itself at once on a theoretical approach and the investigation survey on ground.

The main interest of this article concerns the management of industrial risks and their impacts on the urban environment, in activity of the space " in full urban area " by treating the industrialization to Bejaia with the inventory of fixtures of its fabric, its setting-up, its activities and their typology, as well as the risks and industrial dangers that the population can provoke these industrial activities on the city, the environment in which they live.

From the data, we managed to make a well detailed analysis and a synthetic diagnosis on the inventory of fixtures, while going out at the end with an accumulation of problems and of various technological risks from which the city of Bejaia suffers.

Keywords: risk industrialist, raw material, Bejaia, risk management, impact, data and mapping

*Speaker

MS4 : Mini-Symposium in Honour of Professor Pierre-Yves HICHER

Environmental risk assessment and protection measures due to dewatering during construction of Wangfuzhuang Metro Station, Jinan, China

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Jinan is famous due to its spring group with rich groundwater resources. The groundwater system should be protected during construction of the metro system. This paper presents a case study of the environmental risk assessment due to dewatering and recharge during construction of Wangfuzhuang Metro Station, Jinan, China. The Fuzzy Analytic Hierarchy Process (F-AHP) is employed to evaluate the impact on the environment. Moreover, groundwater inflow was calculated for a submersible full well and groundwater level line equation under the coupling action of a submersible full dewatering-recharge well group. Based on these analytical results, the dewatering and recharge schemes of the deep foundation pit excavation are designed. Both results from numerical simulation and field measurements show that dewatering and recharging at the Jinan R1 line site were effective in environmental protection.

Keywords: Foundation Pit, Dewatering and Recharging, Fuzzy hierarchy analysis, Numerical analysis

*Speaker

Definition of meso-domains in granular matters

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Several works [1-2] have recently shown the interest of analyzing 2D granular materials at a meso-scale to get a better insight into the evolution of their internal texture when submitted to mechanical loadings. For these 2D analyzes, meso-loops are easily defined by closed polygons made of contacting particles. The geometry of these meso-loops is characterized by two variables derived from a loop tensor defined in [1]: the elongation degree, characterized by two classes: W (weakly elongated class) and S (strongly elongated class) and the elongation direction defined by the orientation of the considered meso-loop (loop tensor major principal direction).
The concept of meso-loops considered in 2D cannot be directly adapted to 3D materials. However, the weighted Delaunay triangulation can help to define corresponding 3D meso-domains by partionning a 3D granular material into tetrahedra whose vertices correspond to the centers of particles. Nevertheless, this partition tends to over-subdivide the void space into too many local voids and consequently into too many 3D meso-domains. To remove this bias, a merging of adjacent tetrahedra is required. Three different merging criteria are considered in this work. The first one is based on the overlapping inscribed void spheres approach [3,4]. The second one considers the porosity of the common face shared by two adjacent tetrahedra, while the third one considers the ratio of the face porosity to the porosity of the adjacent tetrahedron.

Our study is based on 2D and 3D DEM simulations and led to the following conclusions:

The 2D analyses put in evidence a very significant evolution of the meso-texture of a granular sample submitted to a mechanical loading. This phenomenon clearly explains the internal anisotropy evolution and the mechanical hardening (or softening) of granular materials.

For 3D media, the merging criterion based on an absolute value of the facial porosity is not able to retrieve the results given by the overlapping inscribed void sphere criterion contrary to the criterion considering the relative facial porosity with respect to the porosities of the adjacent

*Speaker

tetrahedra.

The first and third merging criteria seem to be of great interest to clarify the definition of local void and local 3D meso-domains. Therefore, they can be used to study filtration processes in granular materials or to characterize their mechanical behavior by an upscaling approach based on a meso-scale.

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Seblany F., Homberg U., Vincens E., Winkler P., Witt K.J., *Merging criteria for defining pores and constrictions in numerical packing of spheres* , Granular matter, 20(37) (2018)

Keywords: granular material, DEM, meso domain, merging criteria, void space, filtration, upscaling approach

Definition of meso-domains in granular matters

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Our study is based on 2D and 3D DEM simulations and led to the following conclusions:

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The 2D analyses put in evidence a very signicant evolution of the meso-texture of a granular sample submitted to a mechanical loading. This phenomenon clearly explains the internal anisotropy evolution and the mechanical hardening (or softening) of granular materials.

For 3D media, the merging criterion based on an absolute value of the facial porosity is not able to retrieve the results given by the overlapping inscribed void sphere criterion contrary to the criterion considering the relative facial porosity with respect to the porosities of the adjacent tetrahedra.

The first and third merging criteria seem to be of great interest to clarify the definition of local void and local 3D meso-domains. Therefore, they can be used to study filtration processes in granular materials or to characterize their mechanical behavior by an upscaling approach based on a meso-scale.

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Keywords: Granular material, DEM, meso domain, merging criteria, void space, filtration, upscaling approach

From bonded geomaterials to asphalt concrete mixes

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I will present in this communication the evolution of my research topics, starting from my Ph. D. entitled Modelling of the mechanical behaviour of bonded geomaterials to current researches which are based on granular materials, mainly used in pavement structures, from unsaturated unbound granular materials and asphalt concrete mixes, to balast used in high speed railway tracks. My researches have started with analytical and numerical modelling based on FEM, it was about 20 years ago, and, 15 Ph. D. students after, it continues with other modelling tools like DEM and SG-BEM.

Keywords: granular materials, aspahalt concrete

*Speaker

Rapid flows of saturated soils

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The quasi-static behavior of saturated soils has been a subject of constitutive and micromechanical models in the quasi-static regime and mostly in application to liquefaction, slope stability and soil erosion. The post-failure deformation of saturated soils, rapid debris flows and submarine avalanche flows have been addressed to a much less extent despite their crucial role for risk assessment. Immersed granular flows have been investigated and modelled recently as dense suspensions by accounting for fluid viscosity. In this talk, I present a recent work [1] on extensive simulations of saturated granular materials subjected to long simple shear deformations with the scope of identifying the effects of fluid viscosity, grain inertial and confining pressure on the flow behavior. The simulations are based on a coupled DEM-LBM approach. We show that the dependence of the effective friction coefficient and packing fraction with respect to the material parameters can be reduced to a well-defined scaling behavior combining viscous, inertial and static stresses to which the immersed grains are subjected during their flow. The simulation data can also be analyzed in terms of normal and shear effective viscosities under undrained conditions. Our results are in good agreement with the available experimental data. [1] L. Amarsid, J.-Y. Delenne, P. Mutabaruka, Y. Monerie, F. Perales, and F. Radjai, " Viscoinertial regime of immersed granular flows ", Phys. Rev. E 96, 012901 (2017).

Keywords: granular materials, saturated soils, dense suspensions, inertial effect, viscosity

*Speaker

Solutions of Young-Laplace Equation – Validation in Microgravity Conditions

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We revisit from an inverse problem method the exact resolution of Young-Laplace equation for capillary doublets without gravity. The missing information on the pressure deficiency p (which is often an unknown of the problem) will be restored without experimental device of suction control. Only the use of a digital camera with macrozoom allows to measure the suction $s = -p$ according to the observed value of the gorge radius, then compared to critical bounds. The sought value s results immediately via a set of available explicit formulas.
We establish a simple criterion based on the observation of the contact points, of the wetting angles and the gorge radius, to classify in an exhaustive way the nature of the surface of revolution: portion of nodoid, of unduloid, both with concave or convex meridian, of catenoid, of cylinder or of circular profiles (toroid). In every case, we propose an exact parametric representation of the meridian based on the observed geometry of the boundary conditions and on a first integral of Young-Laplace equation that traduces a conservation energy principle.

Moreover, we prove that the inter-particle force may be evaluated on any section of the capillary bridge and constitutes a kind of specific invariant for surfaces of revolution. The proposed method leads to very convenient analytical expressions easy to use and avoids to have recourse to the simple toroidal approximation or to spline functions that do not respect (except in an exceptional theoretical case) the Young-Laplace equation.

The pertinence of the addressed approach has been already put in a prominent position on several experimental results obtained on various geometries of capillary bridges in microgravity, in order to get off the gravity that distort the capillary bridge as soon as the volume of liquid or the sphere diameter are not "very small". Moreover, the stability of solutions of Young-Laplace equations is analyzed, based on the second variation criterion of the associated potential (minimization problem under constraints), revisited through Vogel's stability criteria. A high-speed camera has been added to the experimental device to capture the rupture of capillary bridges.

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Keywords: Capillary bridge, Young, Laplace equation, Microgavity

Exploiting synergies in granular micromechanics, network science and artificial intelligence towards near real-time forecasting of landslides

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Land, rubbish and mud slides, avalanches, rockfalls, as well as slips in mines are unfortunately common place. The impact is often devastating and costly. Much earlier warning of events could allow safer practices, including evacuation or remedial actions. Granular masses (i.e., rock, soil and snow), at the heart of these failure events, manifest complex patterns of motions that give clues to the likely location and time of impending failure. Here we combine the techniques of complex networks and AI, along with fundamental knowledge of precursory dynamics of granular failure, to develop a method that can extract relevant patterns and deliver near real-time forecasting of a landslide from data on the surface motion of the monitored site. We demonstrate this capability for a rockfall in an open pit mine using data from ground-based radar.

Keywords: landslide forecasting, ground, based radar, artificial intelligence, complex networks, granular micromechanics

*Speaker

A three-scale model for plastic deformation and damage evolution of shale rocks

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The micro-structure of a typical shale rock is first identified through microscopic observations at different scales. It is found that in view of determining the macroscopic mechanical behavior, three representative scales should be taken into account. At the mesoscopic scale, the shale rock is composed of a mixed clay matrix and mineral inclusions (quartz, calcite, pyrite and kerogen). At the microscopic scale, fine inclusions (fine calcite and kerogen) are embedded in a clay matrix. Then at the sub-nanoscale, the clay matrix is a porous medium constituted of solid clay particles and inter-particle pores. It is assume that then solid clay particles constitute a continuum matrix which exhibits an elastic plastic behavior described by a Drucker-Prager type criterion. Based on this micro-structure description, we have proposed a three-step nonlinear homogenization procedure. An analytical plastic criterion is established to describe the effective plastic behavior of the porous clay matrix, explicitly depending on the inter-particle porosity. At the second step, the effect of fine inclusions is taken into account by using an incremental method. Then at the third step, the macroscopic elastic-plastic behavior of shale rock is determined by considering the effect of large inclusions by again using a second incremental method. Further, the shale damage due to the debonding of interfaces between the mineral inclusions and the matrix phases is also taken into account. The proposed micro-mechanics based model is bale to explicitly take into account the influences of porosity and mineral compositions on the macroscopic response of shale rocks. Applied to some typical shale rocks, it is found that the proposed model is able to capture the main features of mechanical behavior of shale rocks.

Keywords: Upscaling, Homogenization, Numerical modelling, shale rocks

*Speaker

Transition from slow to fast landslide motion

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The presentation describes the conditions explaining a change in the regime of landslide motion when a slowly moving unstable mass accelerates and becomes a fast event. Slow creeping motions are explained by strain rate effects on friction. Residual friction increases with the logarithm of shearing strain rate. In parallel, plastic work on shearing bands result in thermal pressurization of pore water pressure and a reduction in available shear strength. The interaction between the two mechanisms is first explored in simple sliding mechanisms (planar and compound slides). Problem solution requires the formulation of energy and mass balance equations in the sliding surface and its vicinity as well as the dynamic equilibrium. The Material Point Method is then used to generalize the formulation to arbitrary geometries. However, scale effects associated with the shear band dependence on the element size of the computational mesh should be addressed. The final part describes the application of the method developed to a real case.

Keywords: xxx

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Integrating a micromechanical model for multiscale modelling of granular materials

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The Chang-Hicher micromechanical model based on a static hypothesis has proved its efficiency in predicting soil behaviour. For solving boundary value problems, the model has now integrated stress-strain relationships by considering both the micro and macro levels. The first step was to solve the linearized mixed control constraints by the introduction of a predictor–corrector scheme and then to implement the micro–macro relationships through an iterative procedure. Two return mapping schemes, consisting of the closest-point projection method and the cutting plane algorithm, were subsequently integrated into the interparticle force-displacement relations. Both algorithms have proved to be efficient in studies devoted to elementary tests and boundary value problems. Closest-point projection method compared with cutting plane algorithm, however, has the advantage of being more intensive cost efficient and just as accurate in the computational task of integrating the local laws into the micromechanical model. The results obtained demonstrate that the proposed linearized method is capable of performing loadings under stress and strain control. Finally, by applying a finite element analysis with a biaxial test and a square footing, it can be recognized that the Chang-Hicher micromechanical model performs efficiently in multiscale modelling of granular materials.

Keywords: Granular material, micromechanical model, finite element method, multiscale modelling

*Speaker

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A hypoplastic constitutive model for overconsolidated clay

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Hypoplastic models were originally developed for cohesionless soils. In this paper, we present a simple hypoplastic model for overconsolidated clay. We make use of the equivalent pre-consolidation pressure by Hvorslev, which is treated as a stress-like internal state variable. From our previous study we know that the nonlinear term gives rise to a translation of the response envelope with reference to the stress. This translation dictates the effective stress path in undrained triaxial tests. The stress-like internal state variable is introduced in the nonlinear term, which renders an elegant formation for the model with few parameters. The model performance is compared with test results from literature. The effective stress paths of different OCRs in undrained triaxial tests can be well captured by the model. Moreover, we show that the Hvorslev failure envelope can be obtained as a natural outcome of the model. The use of the equivalent pre-consolidation pressure offers many possible model extensions for different material behavior, e.g. induced anisotropy and thermal-mechanical coupling.

Keywords: Hypoplastic constitutive model, over, consolidation, clay

*Speaker

On the origin of failure in granular materials from a microscale point of view

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Roughly speaking, granular media exhibit three basic scales: the specimen scale, the contact scale, and an intermediate scale made up of a set of adjoining particles. In this lecture, we will discuss this latter scale, in a two dimensional context. More specifically, the granular assembly can be regarded as a two phases medium. Grain column like patterns (force chains) develop within the medium, participating actively to its mechanical strength. These columns are surrounded by grain loops, made up of 3, 4, 5, or 6 grains (larger grain loops are much less frequent). According to the number of constituting grains, the mechanical properties of grain loops are very different [1]. In particular, 6 grains loops are prone to deform, contributing locally to a change in the void ratio. On the contrary, 3 grains loops deform just a little, but resist quite well to a deviatoric stress. According to the initial porosity of the assembly, and depending upon the loading path considered, the nature of grain loops surrounding force chains is versatile, with continuous transition mainly from 3 grains loops to 6 grains loops (or vice versa). This is a new route to investigate from a microstructural point of view why a granular assembly may be destabilized, leading to a localized or diffuse failure pattern [2-5]. In addition, these ingredients are shown to give rise to a microstructural interpretation of the so-called critical state, according to the failure mode taking place.

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Keywords: XXX

Elasticity-Fabric-Failure Relation for Anisotropic Rocks

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The present work links the directional elasticity properties of rocks to the manifestation of anisotropy in the conditions of failure, and hence strength. By depicting rocks as assemblies of elastic-bonded particles, micromechanical formulation of elasticity and force distribution in conjunction with a local strength criterion eventually lead to macroscopic strength properties with fabric tensor as a mutual microstructural descriptor. As such, knowing the elastic properties of rock, the proposed analytical procedure computes the associated fabric anisotropy of contacts, which is in turn used to estimate rock strength anisotropy, thus avoiding tedious experimental determination. The accuracy of the procedure is verified by comparing predicted strength anisotropy characteristics of sandstone and slate samples with available experimental results. The findings indicate that rock strength anisotropy can be captured realistically only, when in addition to contact normal-based fabric, microscopic strength parameters are also directional in character to reflect the preferential bonding process of grains during rock formation.

Keywords: Rock Strength Anisotropy, Micro, Mechanics, Bonded Granular Materials, Elastic Anisotropy, Fabric

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Pierre-Yves ‘s contribution to the experimental characterization of soil behaviour

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Pierre-Yves is internationally recognized for his theoretical developments in constitutive modelling of geomaterials. But he is also at the origin of the developments of many experimental geotechnical set-ups. This presentation will show some of these innovative tools. It will also depict Pierre-Yves's human qualities in his professional life (as a Professor, Lab Director and colleague) but also outside the lab.

Keywords: Hicher experimental

*Speaker

Degradation in granular media : coupling grain breakage and diffuse instability.

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In this presentation, we will discuss two phenomena originated from the microscopic scale:
- Grain breakage which occurs for "weak" grains such as calcareous sands or "hard" grains such as granitic grains when subjected to high stresses,

- Diffuse (global) instability which occurs for all granular media whatever their density if the relevant loading paths and control variable are applied.

We will show that these two phenomena affect the macroscopic behavior of granular media and can be well captured with a constitutive model and experimentally highlighted. Moreover, these two phenomena can be combined even if very few experimental data are available. In this situation, we will show that the model we proposed is able to give a relevant predictive macroscopic behavior of granular media.
These works have been done in collaboration with Pierre-Yves Hicher.

Keywords: Grain breakage, diffuse instability, constitutive modeling, experimental testing.

*Speaker

MS5 : Recent Advances in the Behavior of Granular Materials

VALORISATION Du SCHISTE ET DU LAITIER CRISTALLISE DANS LES CORPS DE CHAUSSEES

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Le développement de l'industrie génère des quantités indénombrables de produits et de co-produits tels que le laitier du haut fourneau. Malheureusement ce type de matériaux est souvent jeté dans la nature ou abandonnés dans des décharges inappropriées.
Ces derniers temps, beaucoup de matériaux, font l'objet du recyclage qui présente plusieurs avantages, environnementaux et économiques, (se débarrasser des quantités importantes de déchets, libérer les espaces occupés par ces matériaux, compenser le manque en granulats dont souffrent certaines régions).

La présente étude s'inscrit dans le cadre du recyclage et de la valorisation des matériaux locaux et recyclés. Elle fait partie d'un projet de recherche entamé sur le recyclage des déchets. Elle a pour objectif, la reconstitution d'un matériau composite de schiste et de laitier (matériaux très abondant en Algérie) pour une utilisation en couches inférieures de chaussées (couche de forme, de fondations et éventuellement en couches de base).

Pour réaliser cette étude, sont récupérés des granulats de schiste et de déchets du haut fourneau (laitier cristallisé). Les deux matériaux sont concassés et tamisés séparément ensuite, mélangés à différentes proportions (30, 50 et 70%) pour reconstituer des échantillons sous la classe granulaire souhaitée.

Dans le but d'étudier leur comportement sous différents types de sollicitations mécaniques et climatiques auxquels ils seront soumis ultérieurement dans la nature, les échantillons sont d'abord identifiés (essais d'identification), ensuite soumis à plusieurs séries d'essais mécaniques, à savoir, le compactage Proctor et de portance CBR, le cisaillement direct à la boite de Casagrande, la résistance aux chocs et à l'usure, la dégradabilité et la fragmentabilité.

Les résultats obtenus à l'issue des différentes expériences réalisées, permettent de tirer les conclusions suivantes :

- Les mélanges étudiés développent des densités sèches légèrement réduites comparativement à celles développées par le schiste seul, toutefois, elles restent assez importantes (supérieures à 2) et satisfaisantes comparativement aux seuils fixés par les normes dans le cas d'un matériau routier.

*Speaker

- L'ajout de laitier cristallisé améliore sensiblement la portance des mélanges même en présence d'eau. Ces résultats sont très intéressants et dépassent les qualités espérées pour ce type de matériaux.

- Les mélanges étudiés présentent des résistances très intéressantes au cisaillement, traduisant particulièrement des angles de frottement interne très importants.

- En ce qui concerne les essais aux chocs, les résultats obtenus pour les échantillons étudiés présentent des résistances faibles à moyennes comparativement aux matériaux modèles de référence, par contre, leur résistance à l'usure s'améliore au fur et à mesure que la teneur en laitier augmente. Par ailleurs, les essais de dégradabilité et de fragmentabilité révèlent notamment que le laitier est peu dégradables sous sollicitations hydriques et peu fragmentable sous sollicitations mécaniques.

Les mélanges étudiés (schiste + laitier) présentent des comportements et des propriétés mécaniques très intéressantes, notamment pour des teneurs en laitier supérieures à 50 %.
Il convient alors, d'engager des efforts substantiels et des actions concertées des acteurs économiques, des administrations, du pouvoir et des chercheurs pour encourager et développer l'utilisation des matériaux présentés et d'autres matériaux de recyclage dans plusieurs domaines de construction

Keywords: Matériaux locaux, comportement, valorisation, chaussées, environnement

Large-scale test on geosynthetic reinforced unpaved roads on soft subgrade.

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The geosynthetics were used in the reinforcement of unpaved road since the seventies. The efficiency of geosynthetics reinforcement in unpaved road over soft subgrade was highlighted. Geosynthetics can improve the performance of weak subgrades under temporary unpaved roads by the following mechanisms: lateral restraint and reinforcement of base course aggregates, tension membrane effect in rutted areas, and reduction of mixing between subgrade and base soils. The road structure becomes even more heterogeneous and the mechanisms more complex with the addition of geosynthetics. It is important to identify and clarify these mechanisms in order to propose an efficient design method for this structure. A large-scale laboratory test was designed to characterize the geosynthetics effects and reinforcement mechanisms in unpaved roads. It is composed of a large geotechnical box with 5 m of length, 1,9 m of large and 1,4 m of height, were the unpaved road layers are placed, and a large-scale apparatus (SAT: Simulator Accelerator of Traffic) to simulate a cyclic traffic load circulation on the top of a reinforced platform. A detailed experimental Protocol was established regarding the soil preparation, the installation and the compaction procedure to reproduce the site conditions and analyze the geosynthetics installation damage. During each test, the ruts, the vertical stress distribution in the loose subgrade and the geosynthetics deformation were monitored. In this paper, the apparatus and the protocol procedure are described. Moreover, experiments results are presented in terms of ruts evolution over cycles, stress distribution in the loose subgrade and its evolution over cycles. Based on these results, the geosynthetics effects regarding the ruts development and the stress diffusion on the loose subgrade are discussed and compared. Moreover, a numerical simulation was developed and calibrated based on the results of these experiments.

Keywords: geosynthetics, unpaved roads, reinforcement, large, scale test

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Geotechnical instrumentation of piles anchored in molasse.

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The complexity of some structures like dams, bridges or high-rise buildings requires a good knowledge of the soil, the structure itself and the interface. The major causes of geotechnical problems in such structures are high loads and urban congested areas, especially if the soil characteristics were not well defined during the design. In Lyon-France, the soil layers are the Rhône's alluviums and the molasse. While the alluviums consist of sand, gravels and sandy gravels of good compactness, the molasse is a particular and challenging sandy soil which properties are not well understood. FONDASILEX is a research project funded by the AURA region, to study the foundations of Silex2, a high-rise building under construction in Lyon. The structure is founded on twenty reinforced concrete piles, 1.2 meter in diameter and 17 meters in length, that are anchored inside the molasses. They were specifically monitored. The stress was measured directly on piles head with total pressure cells and indirectly along the piles with vibrating wire extensometers, optical fibers and strain gauges. In addition, the displacement of the soil is measured using a fiberglass rod extensometer with six anchors at various depths. Additional geotechnical parameters were defined using experimental tests (e.g., sieve analysis, triaxial, oedometer). The results of the instrumentation will allow calibrating a numerical model done on FLAC3D, using a non-linear anisotropic constitutive model to prove the shortcomings of conventional methods.

Keywords: instrumentation, piles, alluviums, molasse, deformation, stress, displacement, optic fiber

*Speaker

Physical modelling of Monopile Foundation under Combined Cyclic Loading

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Monopiles are the most common foundation systems for offshore wind turbine structures, statistically about 80% (Wind Europe, 2018). A monopile can be characterized as flexible or rigid predominantly depending on the embedded length to diameter ratio (L/D) and relative pile and soil stiffness. The present design codes are mainly for flexible piles whereas the current practice tends to rigid ones. More, the magnitude of lateral loading is dominant in offshore monopile foundation coming from wind and waves. In usual practice, standard API design procedure, established for the flexible piles, comprising uncoupled non-linear p-y interaction curves along embedment depth is used to investigate the lateral loading behavior of a monopile foundation. This approach is recognized as highly conservative (e.g. Byrne et al., 2017) for a rigid pile. The soil-structure interaction for rigid monopile foundation has been observed to be coupled vertically and laterally. Upon lateral loading, ideally a rigid pile foundation is expected to rotate about a pivot point along pile embedment and hence the pile base additionally contributes to the lateral loading response.
Here, the experimental study carried out to understand the coupled form of interaction under combined VHM (vertical, horizontal and moment) monotonic and cyclic loading conditions is presented. The pile dimensions and loading magnitudes are estimated from an extensive similitude analysis between calibration chamber model pile and a prototype pile (Gupta et al., 2019). The loading magnitudes for the prototype pile are taken from typical values for a 2MW offshore wind turbine (LeBlanc et al., 2010) established on a monopile foundation. The experimental campaign was investigated with 3D finite element modelling prior to the lab experiments to optimize and validate the estimated parameters.

Multiple tests are performed in the calibration chamber with different vertical and lateral stresses keeping the same initial soil stress state (Ko = 0.5) and with similar loading magnitudes. This allows making a comparison of the model pile-soil-resistance behavior at different simulated depths along prototype pile embedment. This enables to study the local soil-pile interaction for embedded monopile in sand incorporating lateral and vertical loadings. More, the evolution of stress in the sand mass is captured through miniature soil stress transducers strategically placed in the soil volume.
A constant mass placed on the pile top representing the dead weight of the wind turbine structure is taken as the vertical load. The point load is laterally applied to the pile with an eccentricity producing an additional moment at the mudline level. This, collectively with vertical load,

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results in the combined loading input. Also, a constant amplitude sine wave with one-way and two-way profiles is used to apply cyclic lateral point loading. The pile is instrumented with strain gauges to capture the bending moment profile to further estimate the lateral soil resistance profile along the embedded depth. The results of the experiments are compared with the corresponding outcomes from the 3D finite element model. The obtained results demonstrate the key differences from the conventional p-y interaction approach and highlight the significance of vertical-lateral coupled interaction.

Keywords: monopile, calibration chamber, cyclic loading, similitude, soil stress transducers

Controlled desiccation behaviour of a clayey material: shrinkage's characterization and cracking mechanisms identification by image correlation

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The objective of this research was to analyze the shrinkage, initiation and propagation of cracks related to controlled desiccation in clays. Cracks have an important influence on soil parameters and may affect its stability and integrity. For a better understanding of the shrinkage phenomenon and the cracking mechanisms, an experimental investigation system based on vapor equilibrium technique proposed by Tang and Cui (2005), and digital image correlation (DIC) method, was developed.
The experimental approach consists first, to carry out a series of different controlled desiccation tests under three suction levels; 361MPa, 110MPa and 38MPa on saturated remoulded clayey specimen with dimensions of 190×130×4 mm3 (Ighil Ameur, 2016). During the tests, both temperature and water content are measured while relative humidity was controlled and measured. Images of the sample surface were captured using an HD camera by a controlled time interval, and automatically saved in the computer.

The obtained results showed that the shrinkage kinetics depends on the imposed suction. More the suction is higher more the kinetics is faster. Compared with the drying kinetics, the results show that shrinkage develops more quickly than drying, and when the shrinkage is finished, sample continues drying process.
The total local strains obtained are composed of two parts: (a) the shrinkage strains which are only negatives and (b) the 'mechanical' strains acting on the cracking and can be negatives or positives. When the 'mechanical' strain increases and exceeds a critical value, cracks initiate and propagate. Only cracks in opening mode (mode I) were observed through all the tests.

Keywords: clay, vapor equilibrium technique, digital image correlation, desiccation, shrinkage, mechanical strain, suction, crack initiation.

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Influence of elastic anisotropy on the mechanical behavior of soil

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The behavior of granular materials can be modeled using a non-linear elastic part showing an incremental response depending on current stress state, while the plastic part can be described appropriately by a smoothed Mohr Coulomb-based plastic criterion. In order to reproduce this behavior of soil under prescribed loading, a new constitutive model is proposed as a combination of a hyperelastic formulation and a plastic criterion within the elastoplasticity framework. In this new model, both inherent and induced anisotropies are taking into account in the elastic part by mean of a pressure exponent parameter. The tangent stiffness matrix of the elastoplastic model varies as a function of current state of stress which is in accordance with experimental observations of granular materials and leads to define only one set of parameters for the different initial mean stresses. It is found that the stress-strain responses including hardening tendencies are affected by different values of the pressure exponent which accords to different levels of anisotropy, and the level of influence of anisotropy is related with density of soil.

Keywords: hyperelasticity, induced anisotropy, pressure dependency, Houlsby model, Plasol algorithm, pressure exponent

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Hydro-mechanical modeling of granular soils considering internal erosion

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Internal erosion occurs when fine particles are plucked off by hydraulic forces and transported through the coarse matrix. The known causes are either a concentration of leak erosion, backward erosion, soil contact erosion, or suffusion (USACE, 2015). This study attempts to formulate a coupled numerical model within the framework of continuum mechanics to investigate the phenomenon of internal erosion and its consequences on the behavior of granular soils. The saturated porous medium is considered as a material system composed of 4 constituents in 2 phases: the stable fabric of the solid skeleton, the erodible fines, the fluidized particles and the pure fluid. The fines can behave either as a fluid-like (described as fluidized particles) or as a solid-like (described as erodible fines) material. Thus, a liquid-solid phase transition process is considered by a mass production term in the corresponding mass balances. The mechanical behaviours of the solid skeleton are reproduced by a non-linear incremental constitutive model including the critical state concept has been adopted (Yin et al. 2018). The model was enhanced by formulating the influence of the fines content on the critical state line in the *e-p'* plane based on experimental results in order to take into account the impact of the loss of fine particles on soil deformability and strength. The predictive ability of the approach has been examined by simulating the laboratory tests. A series of hydraulic-gradient controlled downward erosion tests on gap-graded HK-CDG mixtures, performed by Chang and Zhang (2011) with a newly developed stress-controlled erosion apparatus, were selected for simulations to investigate the initiation and the development of internal erosion in soils subjected to multi-step fluid flow under complex stress states, as well as the stress-strain behavior of soils subjected to internal erosion. The proposed model was able to reproduce the general trend of the cumulative weights of the eroded soil under different stress states. It is also able to reproduce the mechanical behaviors before, during and after erosion. Furthermore, the simulation results confirmed that the deformation is linked to the stress ratio under which the erosion process is active. Interestingly, besides the stress ratio, the amount of loss of fines, which indicates the yielding from a stable to an unstable mechanical response, appeared to be related to the initial density as well as to the initial fines content of the soil mixture.

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Keywords: granular soils, internal erosion, hydro, mechanical coupling, critical state, fines content

A coupled hydro-mechanical modeling of internal erosion around shield tunnel

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Tunnel leakage is one of the most important factors affecting the ground movement (Zhang et al. 2017). However, the effect of loss of fines has not been deeply discussed in previous studies. The leakage of underground water through the cracks and joints of lining commonly carries fines in the form of silt and clay from the surrounding ground, i.e. internal erosion (Bonelli and Marot 2011). The change of porosity due to loss of fines affects the mechanical behaviour of the surrounding soil (Yin et al. 2014; Yin et al. 2016). Conversely, the change of porosity influences the permeability of the sand and, therefore, its hydraulic conductivity. In this study, the effect of leakage on the tunnel in a sand layer was investigated numerically through a coupled hydro-mechanical continuum approach by considering the internal erosion phenomenon induced by the local flows of underground water.

The saturated porous medium is modelled as a system of 4 constituents: the solid skeleton, the erodible fines, the fluidized particles and the fluid. The fines can either behave as a fluid-like (described as fluidized particles) or a solid-like (described as erodible fines) material. Thus, a liquid-solid phase transition process is considered by a mass production term in the corresponding mass balances. Furthermore, the flow in the porous medium is governed by Darcy's law, in which the permeability of the medium depends on the porosity. The mechanical behaviours of the solid skeleton are reproduced by a critical state based constitutive model (Jin et al. 2016; Yin et al. 2013, 2016), which is able to take into account the influence of the change of porosity on the mechanical behaviours of the soil during the process of internal erosion.

The suggested numerical model was applied to analyse the hydro-mechanical response of an existing tunnel installed in sand layer and experiencing a local internal erosion due to the leakage of underground water from the damaged joints or cracks. The results showed the development of the eroded zone and indicated that with the development of ground water leakage and internal erosion, there was an obvious increase in the maximum bending moment in the tunnel lining and in the ground surface settlement.

Keywords: granular soils, internal erosion, hydro, mechanical coupling, tunnel leakage

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Spherical-harmonics-based generation of shape-controlled realistic grains for DEM study on particle-scale behavior of clean and degraded ballasts

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Modeling ballast shape changes due to particle degradation in a quantitative and controllable manner has attracted many researchers' concerns. In this study, based on 3D laser scanning of clean and degraded ballast particles, the spherical harmonic (SH) anlalysis is conducted to derive the frequency domain SH descriptors for capturing the degradation-related surface changes at multi-scale morphological levels. Based on the statistics of the SH descriptors for ballasts at different stages of degradation, this study proposed a simple method to reconstruct clean and degraded ballast particles with identical morphological features to the laser-scanned samples. To validate this method, two virtual assemblies, e.g., clean and degraded ballasts, were generated using the proposed algorithms. The shape features of the generated paticles are quantitatively analyzed based on the conventional shape indexes, and statistically compared with those of the real samples. Furthermore, DEM simulations are conducted to simulate repose angle tests of the generated ballast samples. The irregular particle shapes are approximated by a cluster of spheres fitting well to the particle corners and surface. The numerical phenomenon indicated that the reconstruted shape features, e.g., corner sharpness and surface concavities of the clean ballasts show remarkable enhancement of the interlocking and anti-rotation effect than those of the degraded ballasts. The results proved that the proposed method is robust and efficient in reconstruction of realistic ballast particles and can be further applied to future DEM simulation of various ballast experiments under different degradation-related shape changes from both macroscopic and microscopic point of view.

Keywords: Particle reconstruction, ballst degradation, particle shape, spherical harmonic, DEM simulation

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Discrete element modeling of non-cohesive granular soil and chip-like Tire-Derived aggregates mixture

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Due to the increment of waste tire and the unique properties of tire rubber in many engineering applications, the mixture of Non-cohesive granular soil and Tire-Derived aggregates (TDA) becomes a popular composites as environment-friendly materials. The present work aims to demonstrate the microscopic mechanisms on the mixtures of non-cohesive granular soil and chip-like tire derived aggregates (CTDA). A series of numerical triaxial tests are conducted on the mixtures with different chip contents based on discrete element method. The mechanical behaviors of mixtures with different chip content are discussed from microscopic to macroscopic. It demonstrates that the increased CTDA are able to limit the rolling of granular soil, showing an increasing percentage of sliding contacts among soil and CTDA, thereby enhance the mixture strength. In addition, the increased CTDA provide extra tangential force to soil, the importance of tangential force increases with increasing mobilized tensile force and CTDA content.

Keywords: DEM, granular soil, Soft chips, Triaxial compression, TDA.

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Keynote Lecture - Numerical modeling of salt and gypsum rocks dissolution : from micro-scale to industrial scale

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This presentation deals with the dissolution of soluble rocks such as salt and gypsum for instance,
and the geomechanical consequences like subsidence, sinkholes, underground collapses.
The dissolution approach is based upon the assumption of a pseudo-component dissolving with a thermodynamic equilibrium boundary condition. A local non-equilibrium diffuse interface model is presented for describing solid–liquid dissolution problems.
The control equations are generated by the upscaling of the micro-scale balance equations for a solid–liquid
dissolution using a volume averaging theory. This results into a macro-scale diffuse interface model (DIM) that
does not require an explicit treatment of the dissolving interface, e.g., the use of arbitrary Lagrangian–Eulerian (ALE) methods,
for instance. Test cases were performed to study the features and influences of the effective coefficients inside
the DIM. In particular, an optimum expression for the solid–liquid exchange coefficient is obtained from
a comparison with the referenced solution by ALE. Although the developed method can be used for any soluble rock,
the potential of the proposed methodology is illustrated on meso-scale configurations corresponding to salt/gypsum cavity dissolution. Comparison between
in-situ experiment data and numerical modeling shows the method is a good prediction tool.A final boundary value problem is also studied in which salt is replaced by gypsum to show the applicability of the proposed methodology to analyze rocks with different solubilities.

Keywords: rocks, dissolution, numerical modeling, geomechanics, micro scale, salt, gypsum

*Speaker

Wave Dispersion Analysis of Discrete Granular Chains: Discrete versus Non-Local Approach

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The current study focuses on the wave dispersion analysis of a discrete granular system. With regard to wave propagation, granular elements create a structured wave-guide network through which mechanical energy is transferred. In the presence of length scales, the elastic wave propagation problem involves an interplay between wave dispersion and structural features. The granular model composed of uniform grains elastically connected with both shear and rotational springs by considering Winkler elastic foundations. This structural system can be considered as a lattice elastic model or a Cosserat chain model with shear interaction. The length scale (grain diameter) at which the system is probed is an important issue bringing together multi-scale behavior and heterogeneity. First, from the vibration equation governing the model, the natural frequencies are exactly calculated for the simply supports boundary conditions. Then it is shown that the discrete equations of this granular system, for an infinite number of grains, converge to the differential equations of the Bresse-Timoshenko beam resting on Winkler foundation. The difference equations of the system are continualized by a rational expansion based on a Padé approximation which could give an acceptable homogenized solution compared to a polynomial expansion (Taylor series). Scale effects and wave dispersion characteristics of the granular chain are clearly captured by the continuous gradient elasticity model.

Keywords: Granular medium, Discrete Cosserat, Wave propagation, Dispersion analysis

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MS6 : Computational and Analytical Methods in Geomechanics

An advanced Hoek & Brown model with strain-softening: constitutive performance and numerical analyses

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To describe the influence of joints, fractures and discontinuities on the mechanical behaviour of a rock mass, the approach proposed by Hoek & Brown (HB) has been successfully employed over the past decades in common engineering applications, thus enabling to characterize the complexities of the rock mass within a continuum framework. The goal of this presentation is to show a HB formulation used to simulate rock degradation processes resulting from brittle failure modes characterized by intense shearing and dilation. For this purpose, the material properties have been decreased by introducing a softening rule in which an equivalent plastic strain has been employed to govern the material destructuration. To accurately describe nonlinear dilation during the failure process, a softening mechanism has been enforced also in the formulation of the plastic potential, thus guaranteeing an augmented flexibility to calibrate the real behaviour of rocks. The implemented Hoek & Brown with softening (HBS) has been tested through parametric analyses at the material point level as well as by solving initial boundary problems with the finite element code PLAXIS 2D, thus emphasizing the effectiveness and the numerical performance of the selected model.

Keywords: Hoek & Brown yielding, strain softening, nonlinear dilation

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Investigation of load transfer mechanisms in reinforced cohesive soil embankments using DEM

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Soil cavity formations by soil dissolution or underground collapses are at the origin of large surface subsidence that constitutes a risk of damage or failure for infrastructures. Soil reinforcement with shallow geosynthetics is an economical and functional solution to reduce the induced surface settlements. Previous research has mainly focused on the load transfer mechanism and the arching effect in cohesionless backfill when the cavity opens. Experimental and numerical studies dealing with cohesive soils are very rare, although this situation is commonly found in practice. To overcome this lack of knowledge, a numerical study based on Discrete Element Modelling is carried out to better understand the load transfer mechanisms that happened in cohesive embankments prone to underground cavity opening. The results are compared with experimental data obtained on a small-scale laboratory model. The comparison focusses on the collapse mechanisms of the cohesive embankment, the values of the efficacy of the load transfer mechanisms, the shape of the vertical load distributions acting on the geosynthetic layer, the vertical displacements, the strain and the tensile forces within the geosynthetic sheet.

Keywords: Geosynthetics, Numerical modelling, Subsidence

*Speaker

Multi-scale description of elasto-plasticity in partially saturated swelling clays

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The current work aims at a micromechanical description of swelling in partially saturated clays. This is achieved via a two-stage upscaling procedure based on the average-field theory applied to three-dimensional REV of clay. At the nano-scale, the REV of clay includes parallel clay platelets and oblate spheroidal pores in between them which are saturated with an electrolyte solution. Swelling forces at all spacing ranges, including the osmotic and crystalline regimes, are considered. At the microscopic level, the REV is comprised of flocculated clay aggregates and partially saturated inter-aggregate micro-pore space. At issue, is reconstructing the complex couplings of mechanical, capillary and swelling forces at the macroscopic level and their effect on the overall plastic behavior of clay.

The inter-play between mechanical, capillary and swelling forces across the two-scales lead to the clay aggregates gliding upon each other. The behavior of the interface between adjacent clay aggregates which describes their sliding, plays a prominent role in the macroscopic behavior of clays. It shows itself in the form of induced plasticity which is upscaled here using principles of micromechanics developed for eigen-stressed/strained composite media. This work reconstructs all the complex couplings to finally arrive at a poro-plasticity model at the macroscopic scale. The macroscopic plastic strain is directly related to sliding action between clay aggregates at the micro-scale, described here using a simple failure law for aggregate interfaces. Recent developments in the micromechanics of eigen-stressed/strained composite media are crucial in enabling us to achieve such a micromechanical description of plasticity in clays. In this regard, concentration and influence tensors are utilized to track the microstructural changes in the form of change in micro-porosity and clay platelet spacing, as well as plastic strains at the microscopic scale. The nonlinearity of the stress-strain description is shown to originate from the dependency of the particles' elasticity on spacing with electrochemical origins.

Capillary and swelling stresses also emerge in the developed macroscopic model. Capillary stress emerges from the interaction of fluid phases at different scales, and takes into account surface tension effects. The swelling part on the other hand, correlates with the net disjoining hydration and electrochemical forces at the nano-scale. As a result, the stress description of clays is embedded with microstructural information. In the end, it is shown how the developments in this work lead to a successful capture of the observations in experimental tests of swelling in clays.

Keywords: Multiscale, Homogenization, Poroplasticity, Unsaturated, Swelling

*Speaker

Comparaison of unsupported tunnel convergence using Drucker Prager and Hoek-Brown criteria

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The convergence-confinement method and the self-similarity principle from Corbetta are usual tunneling design method. We propose here to use the steady-state algorithm with 3 dimensions models and dierent criteria to expand the results from Corbetta in new situations.
In the steady-state algorithm, the referential of the observer is in movement with respect to the applied load and we suppose the steady-state (so the advancement rate of the face has to be constant and the section far enough from the entrance), so plastic strains are transported from a Gauss point to the next. With this method, the computational time is reduced compared to step-by-step algorithm.
Here, we use this numerical methods to obtain plastic strain for different criteria.
The Mohr-Coulomb criterion and its circular version: the Drucker-Prager criterion are often used to determine the behavior of the ground under excavation. However, the parabolic Hoek-Brown criterion seems to be more realistic whithin rock masses.
The steady-state algorithm is developed here for the Drucker-Prager criterion and a smooth version of the 3D Hoek-Brown criterion. Plastic strain are obtained using projection algorithm in principal stress space. The stress space is described using Haigh-Westergaard decomposition, and plastic strain are obtained with closest point projection for associated behavior, or using the direction given by the dilatancy angle for non-associated behaviour.
Results from the Drucker-Prager criterion with an angle of friction nul, which is then the Von Mises criterion, are use as a first reference. Then, we use our code to determine convergence and plastic zone for Drucker-Prager and Hoek-Brown materials, with associated behavior, or with non-associated behavior using constant or varying dilatancy angle.
The results obtained are compared with those from Corbetta for the Drucker-Prager criterion, and with the use of varying dilatancy angle and the Hoek-Brown criterion we can determine convergence and plastic zone for new types of ground behavior.

*Speaker

Keywords: Tunnel excavation, computational method, steady, state algorithm, Hoek, Brown, Drucker, Prager

On the Suitability of Elastic Foundation Models

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Elastic foundation models are extensively used to idealize the track substructure beneath the rail beam. These models, at the cost of certain simplifications, offer the advantage of being computationally inexpensive and are thus more likely to be used in engineering practice. This paper investigates the suitability of the elastic foundation models for predicting the deflection response of the rail track systems subjected to motion induced dynamic loading.
A generalized track model which incorporates the effects of all essential structural and sub-structural track components-sleepers, rail-pads, ballast, and sub-ballast-is considered. Two different approaches are followed to model the subgrade. In the first approach, the subgrade layer is modeled using a viscoelastic element whose stiffness is derived from the properties of the underlying soil medium. A time domain deflection analysis of this so-called elastic foundation model is subsequently carried out to evaluate the rail beam deflections under the moving train loads. In the second approach, the soil medium beneath the track model is modeled as a semi-infinite elastic media. For this case, the deflection results are obtained in the time domain using a numerically stable, wavenumber based analytical approach. The rail beam deflections for both the models are evaluated for different train velocities using the track parameters associated with the high-speed railway line along two different sites for which data is available in the open literature: (a) a soft soil site in Sweden and (b) a stiff soil site in Portugal.

The results show the comparisons of rail beam deflections obtained from the considered track models with the experimental data recorded at these sites. It is found that at lower train velocities (70-120 kmph) both models adequately capture the gross rail-track behavior at both sites. Further, at higher train velocities (180-220 kmph), the elastic foundation model shows reasonable agreement with the measured deflection values for stiff soil site, however, underestimates the deflections observed at the soft soil site. On the other hand, deflection results of the model comprising the semi-infinite elastic media are seen similar to the experimentally observed profile for both the sites.
The underestimation in the deflection magnitudes in case of elastic foundation model may be attributed to the inability of the constituent viscoelastic element to consider the inertia- and wave-propagation related effects associated with the soil medium. The semi-infinite elastic media, on the other hand, is capable of incorporating those effects of the soil medium and thus,

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captures the deflection behavior even at higher train velocities. It is additionally shown that in general the magnitude of the experimental value of the critical velocity in the case of the soft soil site is appreciably lower (due to the associated lower wave propagation velocity) than that predicted by the elastic foundation model. However, at the 'rock-type' sites, these pair of velocities may be of comparable magnitude, and thus, the elastic foundation model may prove suitable in these circumstances.

Keywords: Railway track, Elastic foundation models, Dynamic load, Analytical model

Numerical Modeling of Liquefaction-induced Lateral Spreading: A Validation Study

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Liquefaction-induced lateral spreading and its consequences have been the subject of intense and extensive research efforts in recent years. Currently available design methodologies usually rely on empirical methods that provide a wide range of highly variable predictions for a specific design scenario. An alternative approach is to apply modern geomechanics tools that are based on rational modeling of soil constitutive behavior and a numerical simulation platform that considers the coupling of the different phases of a liquefiable soil. In this paper, the results of an extensive set of centrifuge experiments conducted over the course of an international research project (Liquefaction Experiments and Analysis Project, LEAP) are used the evaluate the validity of a numerical modeling platform that uses a critical state model of granular soils within a fully-coupled finite element simulation. Various aspects and stages of the soil response during different seismic events are evaluated and discussed. It is demonstrated that with a carefully calibrated constitutive model, it is possible to reproduce the trends observed in the experiments with reasonably good accuracy.

Keywords: Constitutive Modeling, Earthquake, Finite Element, Granular Materials, Lateral Spreading, Liquefaction

*Speaker

Analytical methods for computing the contribution of rock bolts to reinforce joints. Validation and consequences for rock slope engineering

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Fully grouted rock bolts are commonly used for rock masses reinforcement to ensure the stability of rock slopes and underground cavities. For this purpose, the determination of rock bolt contribution to reinforced joint shear strength is of the utmost importance.
Numerical or analytical methods are required to predict the efficiency of the rock reinforcement system. Numerical modelling is an option which is still cumbersome. For this purpose, several experimental studies have been performed during the last decades, mostly on small scale rock joint and bolt specimens. However, to accurately assess the rock bolt contribution, scale effect has to be accounted for. For this reason full scale lab tests are required as an alternative to in situ tests for which boundary conditions are more difficult to control.

A large scale shear testing machine was developed in Cerema-Lyon. It aims to study full scale bolted rock joint behavior. The dimensions of the machine allows one to test a joint specimen made up with two concrete blocks having 150 cm in length, 100 cm in width and 62.5 cm in thickness.

Experimental results were satisfactorily compared with an analytical model which is able to compute the contribution of the rock bolt to the shear strength of the joint as well the associated displacement of the joint. These conclusions allows us to establish some guidelines to help the designer of reinforced rock slopes, to precise the optimum installation of rock bolts. We also focus on the necessity for engineers to ensure that bolt will remain in the elastic domain.

Keywords: Rock mass reinforcement, rock slope stability, fully grouted rock bolt, analytical method, rock engineering

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MS7 : Resilient Behavior Modelling of Granular Based Materials

Cold recycling of asphalt aggregates without binder addition

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Reclaimed asphalts (RA) come from the demolition of wearing courses and are incorporated in hot or cold mix. The ORRAP (Optimal Recycling of Reclaimed Asphalts in low-traffic Pavements) project studies the cold recycling of 100% RA without binder addition, in base and subbase layers of low-traffic roads. For environmental reasons, the purpose is to increase the reuse of RA having high PAH (Polycyclic Aromatic Hydrocarbons) content. Indeed, the French law prohibited the hot recycling beyond 50 mg/kg of PAH. Consequently, the cold strategy is largely encouraged between 50 and 500 mg/kg, the allowable limits. This required knowledge of performances of RA. From an experimental point of view, a series of triaxial tests was performed. Monotonic triaxial tests were carried out to determine failure resistance at several temperatures: 20◦C, 50◦C and 20◦C with a prior preheating at 50◦C. Then, the resilient and permanent strains of RA were analysed thanks to Repeated Load Triaxial (RLT) tests at several water contents and frequencies. The experiments revealed that increasing temperature causes a drop of failure resistance while cohesion is increased. Regarding the RLT tests, higher water content and lower frequency imply higher strains. The resilient strains from the laboratory tests allowed to calibrate an analytical model: the non-linear elastic Boyce model. Finally, numerical simulations by discrete element approach with the LMGC90 software were used to model laboratory results.

Keywords: reclaimed asphalt aggregates, cold recycling, thermo hydro mechanical behaviour, monotonic triaxial test, repeated load triaxial test, Boyce model, discrete element method

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†Speaker

Modeling of 2PB complex modulus test of HMA based on Non-Smooth Contact Dynamics method

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By means of 3D Non-Smooth Contact Dynamic (NSCD) simulations, the 2PB complex modulus test is reproduced numerically for a Hot Mixed Asphalt (HMA). A viscoelastic fluid phase surrounding the solid particles is simulated by a contact model acting between them. This contact law is based on the Burger's model and was implemented in the LMGC90 software. To validate the proposed contact model, a campaign of experimental and numerical Two-Point Bending (2PB) complex modulus tests was performed on trapezoidal samples. The results show a good agreement between experimental and numerical data regarding the norm of the complex modulus —E*— and the associate phase angle Phi. The proposed model could be used to simulate the mechanical behavior of multilayer road structures and to assess road deformation, cracking and particles pull-out induced by traffic loading.

Keywords: Complex modulus test, NSCD method, Burger's model, viscoelastic granular material

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A Micromechanical Model for Biopolymer-bound Soil Composites

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Extraterrestrial construction presents many interesting and new challenges. Unlike Earth, there are limited natural resources, other than extraterrestrial soils, that are readily available on the moon or Mars. Transporting large amounts of construction materials from Earth is cost prohibitive. Thus, to take advantage of limited in situ extraterrestrial resources, this work focuses on a novel class of biopolymer-bound soil composite materials. These quasi-brittle composites are produced by desiccating a mixture of soil, water, and a biopolymer binder to create a versatile material with uniaxial compressive strength comparable to concrete. This presentation will discuss ongoing work on modeling the microstructure of this material with the purpose of informing the design of future BSC Composites. It will touch upon creating Statistically Equivalent Periodic Unit Cells (SEPUC) based on machine segmented MicroCT images to then test virtually using finite element analysis. The final goal of the project is to have a robust computational simulations at the micro and mesoscales fed by experimental data in order to predict the material's mechanical properties and aid in the structural design of conceptual structures on the Moon, Mars or other celestial bodies.

Keywords: Biopolymer, soil, periodic unit cells, SEPUC, image segmentation, MicroCT, microstructure modeling

*Speaker

Interdependent evolution of robustness, force transmission and damage in a heterogeneous quasi-brittle granular material: from suppressed to cascading failure

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Despite extensive studies on quasi-brittle failure, there still lacks a unified framework that can quantify the interdependent evolution of robustness, damage and force transmission. Here we develop a framework to do so. Using data derived from DEM simulations of concrete specimens under uniaxial tension, we uncover evidence of an optimized force transmission, characterized by two novel transmission patterns which predict and explain damage propagation from the microstructural to the macroscopic level. The first comprises the optimized flow routes: these reliably predict the tensile force chains that emerge in the system. The second are the force bottlenecks which provide an early prediction of the ultimate location of macrocracks. We found bottlenecks take turns in accommodating damage to curtail the failure of tensile force chains in the region. This cooperative behavior, while serving to minimize the impact of damage (i.e., reduction in the load-carrying capacity of the sample), progressively heightens interdependency among bottleneck contacts. In turn, this predisposes the dominant bottleneck to cascading failure which then triggers catastrophic failure of the system.

Keywords: resilience, robustness, force transmission, damage evolution, heterogeneous quasi, brittle granular material

*Speaker

Acoustic emission on the Hole Erosion Test

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Dikes and levees are prone to failure through internal erosion, induced by concentrated seepage that takes off and transports soil particles through the embankment and its foundation [1]. One means to monitor these concentrated leaks is passive Acoustic Emission (AE) monitoring. This monitoring involves acoustic transducers to passively listen for acoustic energy released from internal sources. Here, we study the potential of this approach at the laboratory, on the Hole Erosion Test [1, 2]. Turbulent pipe flow in the hole generates acoustic waves that propagate in the soil sample. Acoustic sensors (accelerometers) installed on the equipment allow to measure these signals. The analysis sheds light on acoustic frequencies characteristic of the internal flow, between 0-30 kHz. We can see two vibratory responses on the acoustic signals, one corresponding to the pipe flow and a second corresponding to the experimentation bench response. The correlation of both frequency and intensity with flow velocity and hole diameter is studied.

Keywords: Acoustic emission, internal flow, vibratory response

*Speaker

MS8: Poromechanical Couplings in Geomaterials and Geostructures

Effects of internal erosion on the stability of slopes composed of loose deposits

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Under rainfall infiltration, internal erosion process usually takes place within slopes composed of loose deposits, and it is considered as one of the main mechanisms leading to failures of such soil slopes. In this paper, a set of mathematical formulation capable of capturing the main features of the coupled unsaturated seepage and internal erosion process is proposed. Within the formulation, an unsaturated erodible soil is treated as a three-phase multi-species porous medium based on the mixture theory. The governing equations, including the mass conservation equations and the fines migration laws, are implemented into a FEM code. By simulating the internal erosion process within unsaturated soil columns under rainfall infiltration, the influences of both the fines detachment and deposition on the stability of slopes are demonstrated numerically.

Keywords: Internal erosion, Fines migration, Rainfall infiltration, Slope stability, Unsaturated soils

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The effect of depositional layering tendency of inclusions on shale elastic anisotropy

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Under the single polarization observation, the shale can be simplified as a composite of clay matrix and inclusions. After image processing, the spatial distribution of inclusion is calculated, which shows that the distributions along the lamination plane and the sedimentation direction respect an normal distribution. A significant greater standard deviation in the sedimentation direction confirms a depositional layering-tendency of inclusion. A two-step homogenization approach is employed to study the effect of the depositional layering tendency on shale elastic anisotropy. The results implies that the depositional layering tendency of the Longmaxi shale has limited effect of shale elastic anisotropy.

Keywords: single polarization, image processing, up, scale homogenization, elastic anisotropy ratio, depositional layering tendency

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An exploration of the optimum state based on dynamic compaction (Proctor test) and double static compaction

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Proctor test is commonly used in the laboratory to determine the optimum state for earthen materials. This is because both Proctor test and in-situ rammed construction belong to the same family of dynamic compaction. However, this method is possibly not suitable for other kinds of earth construction (e.g. compacted earth blocks (CEB)) which are generally produced by compaction of soil under a quasi-static pressure. To invetigate the optimum state, Proctor test were firstly conducted on two kinds of earth: STR and CRA with an external compaction energy (2435 kJ/m3); in the second part, a series of static compaction was carried out in a strain-controlled compression testing machine, and the corresonding static compaction energy is calculated from a family of force-displacement curves. The experimental results indicate that: similar iso-energy curves are found for both dynamic compaction and static compaction; with increasing of energy, the iso-energy curve shifts leftwards and upwards, leading to a reduction of optimum moisture content and an increase of maximum dry density; besides, it is worth noting that all the optimum points approximately lie on a line of constant saturation degree.

Keywords: Optimum state, Proctor test, double static compaction, iso, energy curves

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Towards a physical splitting of the void space into pores and constrictions

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In recent years, the mechanical behaviour of porous media has attracted extensive attentions in many engineering fields including the petroleum industry, the nuclear waste disposal and the erosion control in earth structures. A physically representative network structure of the porous medium is then essential to better understand the transport processes occurring within its void space. In this work, the Discrete Element Method (DEM) has been used to simulate the behaviour of granular spherical materials. Then, individual voids and constrictions have been identified by constructing a weighted Delaunay tessellation. However, this partitioning method leads to an over-segmentation of the void space into many local pores, and thus, it must be corrected by introducing an appropriate pore merging criterion. Different merging criteria were investigated. In a second part, dry numerical filtration tests have been performed to question the validity of different pore structures obtained by different merging criteria. The results have shown, for one of the investigated merging criteria, a very close correlation between the modal value of the constriction size distribution (CSD) and the ability of a successful transit of fine particles through the filter. It means that for a given merging criterion, the poral structure holds a physical meaning in terms of filtration property which is not the case in general. We advise to use this specific merging criterion when the weighted Delaunay tessellation is used to partition the space of a granular material made of spheres.

Keywords: DEM, sphere, Delaunay tessellation, filtration

*Speaker

Micromechanical origins of soil thermal collapse

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Understanding the mechanical response of soils under non-isothermal conditions is paramount for the analysis and design of geostructures, such as shallow and deep geothermal systems or nuclear waste repositories, whose safety and serviceability are governed by thermo-mechanical couplings. Geomaterials, and soils in particular, have a complex thermo-mechanical behavior that originates from their multiphasic microstructure and the physical and/or chemical interactions between their constituents. Temperature variations can induce volumetric deformation: soils subjected to heating thermal loading under drained conditions have been observed to undergo either a reversible (i.e., thermo-elastic) and/or an irreversible (i.e., thermo-plastic) deformation depending on the stress state and stress history characterizing the material structure. Although the soil constituents individually expand proportionally to their thermal expansion coefficient and the applied temperature increase, soil matrices can shrink upon heating. This phenomenon is often termed thermal collapse and involves an apparent negative thermal expansion coefficient of the material.

Prior to this study, various constitutive models at the continuum scale have been made available to describe the thermal collapse phenomenon for soils. Qualitative interpretations have been proposed to explain the microscopic origins of the soil thermal collapse, mostly for fine-grained materials such as silt and clay. Indeed, such a phenomenon is uncommon for most materials, even for other amorphous materials like glass that can only undergo volumetric expansion upon heating. Rubber can exhibit a behavior comparable to that of soils where thermal shrinkage stems from entropic changes in the configurations of the polymer chains. Despite the available knowledge, a sound theoretical understanding and quantification of the fundamental physical variables and processes that govern the thermal collapse of soils appears unavailable.

Looking at the previous challenge, the present work investigates the micromechanics of the thermal collapse of soils by unraveling the origins of such a phenomenon through space-resolved numerical simulations at the particle length scale, which is considered responsible for the addressed phenomenon, with a focus on coarse-grained soils. The considered approach provides microscopic explanations on the mechanisms leading to topological reorganization and instability of the material structure during thermal shrinkage. The effect of the confining pressure relative to the solid grain stiffness is investigated and provides insight into the experimentally observed stress-dependence of the thermal collapse of coarse-grained soils. Further understanding of the thermal collapse phenomenon contributes to the advancement of novel engineering applications, such as the natural stabilization and consolidation of soil masses or the performance improvement of geoenergy systems.

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Keywords: soil, thermal collapse, nonisothermal, micromechanics

MS9 : Enriched Continuum Mechanics and Bridging Different Scales

A new two-dimensionnal metastructure with acoustic frequency band gaps

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A architectured material inhibiting wave propagation at audible frequency range, called "frequency band gap" is proposed. Dispersion diagrams were obtained using the Bloch-Floquet method analysis – which is presented here – with some FEM calculations are given. Temporal simulations, allowing further experimental validation, are also introduced, showing the interest in using such metamaterials in bidimensional structures.

Keywords: Metamaterials, band gap, Bloch Floquet, wave propagation, dispersion

*Speaker

Towards the engineering design of metamaterials' structures through micromorphic enriched continuum modeling

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Engineering metamaterials showing unorthodox behaviors with respect to wave propagation are recently attracting attention for their innumerable astonishing applications. We are particularly interested in those metamaterials that can inhibit wave propagation in particular frequency ranges which are known as "frequency band-gaps".
A wealth of modeling efforts are currently made trying to account for the observed band-gaps in a reliable manner. The most common models are intrinsically microscopic and are based on the use of Bloch's theorem for periodic microstructures or on numerical homogeneization techniques. Nevertheless, to the authors' knowledge, a systematic treatment of band-gap modeling based on the spirit of Enriched Continuum Mechanics is still lacking and deserves attention. The idea of using enriched continuum theories to describe microstructured materials needs to be fully developed in order to achieve a simplified modeling and more effective conception of large-scale engineering "metastructures" made up of metamaterials as building blocks. This would allow for the design of real, large-scale engineering structures which are able to resist to vibrations and shocks in a large range of frequencies.
In this presentation, we will show how enriched continuum models of the micromorphic type can be effectively used to model the dynamic behavior of anisotropic band-gap metamaterials, including boundary effects. The essential properties of metamaterials' behavior will be addressed including dispersion, band-gaps and scatteriang at metamaterials' boundaries. The obtained results will be shown to open the way to new applications in the realsm of (meta-)structural design.

Keywords: enriched continuum modeling, metamaterials, band, gaps

*Speaker

Well-posedness of nonstandard relaxed models including novel micro-inertia terms

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The aim of this talk is to present some results regarding the existence of solutions of some problems arising from the modelling of elastic materials using generalized theories of continua. We give some existence results concerning the already introduced relaxed micromorphic continuum model and we point out that these results are also valid for energies which are not positive definite in term of the usual used constitutive tensor in classical micromorphic theory. In view of some evidence from physics of meta-materials we focus our effort on two recent nonstandard relaxed micromorphic models including novel micro-inertia terms. These novel micro-inertia terms are needed to better capture the band-gap response.

Keywords: nonstandard relaxed models, well, posedness, micro, inertia terms

*Speaker

Remodelling and fibre re-orientation in fibre-reinforced living tissues

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In this work, we address the mechanical behaviour of a certain class of living tissues, modelled as soft, fibre-reinforced porous media, filled with an interstitial fluid [1,2]
In particular, we are interested in studying how the mechanical properties of a biological tissue are influenced when structural rearrangement occurs, as response of external or internal stimuli. For this purpose, we provide a constitutive framework in which we account for the coupling among the deformation, the evolution of the fluid flow and two kind of non-reversible phenomena, whose occurrence is responsible for the structural adaptation of the tissues under study. One of such processes relies on the onset and production of irreversible strains, while the other one is related to the evolution of the fibre pattern [3]. To keep track of them, two suitable kinematic variables are added to the classical ones, and the dynamical equations are derived from a balance of generalised forces [3,4].

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Keywords: biological tissues, remodelling, anelastic distortions, fibre reorientation, enriched kinematics

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A Phase field approach of damage evolution in partially saturated porous media

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Phase field models have been successfully applied to damage evolution and fracture propagation in brittle materials. The primary advantage of phase field modeling lies in the alleviation of pathological mesh dependencies by facilitating regularizations on the evolution of the phase field parameter. The effectiveness of this approach in the context of damage-gradient modeling of fracture has been demonstrated by [1]. This approach has been drawn into the framework of mechanics of porous media by several authors [2], [3], [4]. However, to the best of our knowledge only recently has this approach been extended to the case of partially saturated media [5]. In the current study, assuming that the porous media is composed of a wetting fluid(liquid water), a non-wetting fluid(wet air) and a deformable porous skeleton, the variational approach to damage proposed by [6] and implemented as damage-gradient models for brittle fracture by [1] within the finite element code based on FEniCS Library [7] is extended to the analysis of partially saturated continua. The variational forms of the governing equations are derived and appropriate boundary conditions are imposed in the context of a one-dimensional test. Further developments of this work will be devoted to the extension of this approach to the phase field theory of partially saturated porous media proposed by [8]. In this case, in addition to the damage variable, the saturation degree will be considered as another phase field parameter.

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Keywords: Phase field, Damage gradient, Partial saturation, Poromechanics

Microstructure-related Stoneley waves and wavefront manipulation at a 2D Cauchy/relaxed micromorphic interface

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We present the reflective properties of a 2D interface separating a homogeneoussolid from a band-gap metamaterial by modeling it as an interface between a classical Cauchy continuum and a relaxed micromorphic medium. We show that the proposed model is able topredict the onset of Stoneley interface waves at the considered interface both at low and high-frequency regimes. More precisely, critical angles for the incident wave can be identified, beyond which classical Stoneley waves, as well as microstructure-related Stoneley waves appear. We show that this onset of Stoneley waves, both at low and high frequencies, strongly depends onthe relative mechanical properties of the two media. We suggest that a suitable tailoring of therelative stiffnesses of the two media can be used to conceive "smart interfaces" giving rise to widefrequency bounds where total reflection or total transmission may occur.

Keywords: enriched continua, metamaterials, band, gaps, wave propagation, interface, relaxed micromorphic model

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Phase Field Topology Optimization with Cosserat Continuum Theory

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We present a Phase Field Model for the evolution of load-bearing solid structures on basis of the Cosserat continuum theory. The process is ruled by an Allen-Cahn equation and optimizes the homogeneity of different stress criteria. The phases, namely material and void, separate from a homogeneous initial state. Thus, the model nucleates holes to obtain the desired material proportion within the design space. The variational approach drops conservation of mass but considers several thresholds of stress to formulate its sensitivity function. We observe that couple stress, which is an indicator for inhomogeneous deformation, yields smooth transitions between different topologies. With regard to this we consider Isogeometric Analysis for our numerical formulation. It allows for higher continuity between elements and shows good performance for the

reproduction of the phase transition. With help of an analytical example we discuss this issue. Additionally, some numerical examples demonstrate that Isogeometric Analysis avoids mesh-pinning. Finally, we use the evolving topologies of that model to generate beam structures automatically. These structures can be optimized in a second step concerning shape and size. The idea and performance of such a two step optimization is shown in several examples.

Keywords: topology evolution, phase field modeling, isogeometric analysis, two step optimization

*Speaker

Indentation in Planar Layered Elastic Media

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Indentation in elastic, possibly heterogeneous media, is a classical and important engineering problem. Such processes are often modeled through the familiar linear elasticity equations, which are partial differential equations (PDEs). These PDEs contain within them material coefficients, originating from the material's constitutive behavior. In heterogeneous media, these material coefficients are not constants, but vary with space. This makes the solution of the associated boundary value problem complex.
Progress may be made for finely mixed heterogeneous media by modeling the material coefficients as rapidly oscillating periodic functions in space. This then allows the use of periodic homogenization techniques. Homogenization converts the heterogeneous material into a 'homogenized' material, which is easier to analyze mathematically and computationally. This work deals with the application of homogenization to a problem of indentation in a planar heterogeneous medium, specifically a half-space consisting of two different isotropic elastic layers arranged periodically atop each other. We explicitly calculate the elastic coefficients of the homogenized material in terms of the material coefficients of the constituent materials. It is shown, by defining an appropriate error estimate, that the pressure profile under the indenter in case of the layered medium converges to that of the homogenized material, as the layer thickness is reduced, or if the force on the indenter is increased. It is also shown that the upper bound of the error depends only upon the ratio of the Young's moduli of the two materials constituting the layered medium.

It is well known that the periodic homogenization of a layered medium gives the leading-order term correctly in the two-scale asymptotic expansion of a given field variable in terms of its heterogeneity (i.e. layer thickness). However, the original problem is a singular perturbation problem, which introduces boundary layer terms from the first order onwards. We thus also compute the influence of boundary layers at the first order to help improve the rate of convergence of the relevant field variables, such as the indentation pressure.
The utility of our result lies in the investigation of finely layered media. The numerical investigation of such media is difficult because of the rapid fluctuations of the material coefficients. However, as is shown in this work, the relevant physical quantities can be well approximated by those that are obtained as solutions to the limiting homogenized material.

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Keywords: Indentation, heterogeneous media, layered media, homogenization, linear elasticity

Transparent relaxed micromorphic description of anisotropy in metamaterials

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Metamaterials are attracting today growing attention in the scientific community due to their numerous possible astonishing applications. By their intrinsic nature, metama- terials show strong heterogeneities at the level of the microstructure and, except for few particular cases, their mechanical behavior is definitely anisotropic. This is often the case when dealing with band-gap metamaterials, since it is very likely that the band-gap prop- erties strongly depend on the direction of propagation of the traveling wave. In our work, we propose a transparent framework for the study of anisotropy in metamaterials through the introduction of the anisotropic relaxed micromorphic model. In this model, only fourth order elastic tensors are featured, so remaining in the framework of the class of symmetries of classical continuum mechanics. Notwithstanding this simple formulation, the anisotropic relaxed micromorphic model allows to realistically describe the anisotropic mechanical behavior of a large class of metamaterials, including those exhibiting band-gap behaviors. We support such claims by providing precise examples of the efficacy of such model on actual metamaterials, by showing that the anisotropic relaxed micromorphic model is able to globally reproduce i) the dispersion curves for all direction of propagation ii) the band gap properties as function of the direction of propagation iii) the polar diagrams of the velocity for all modes of interest (also those at higher frequencies).

Keywords: anisotropy, dispersion, planar harmonic waves, relaxed micromorphic model, enriched continua, dynamic problems, micro, elasticity, size effects, wave propagation, band, gaps, parameter identification, effective properties, unit, cell, micro, macro transition

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Dynamic response of metastructures as relaxed micromorphic continua

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In this talk, we show that transient waveforms arising from several localised pulses in a microstructured elastic material can be reproduced by a corresponding generalised continuum of the relaxed micromorphic type. In the low frequency regime, the anisotropic waveforms are captured by an effective Cauchy theory. At higher frequencies, such as in the band-gap or for frequencies corresponding to the optical branches, localised waveforms are well reproduced by the relaxed micromorphic model. The findings are further elucidated in the context of scattering of elastic waves from microstructured domains.

Keywords: Relaxed micromorphic model, elastic metamaterials

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A priori identification of material parameters in the relaxed micromorphic model

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The relaxed micromorphic model is an extended continuum model able to describe band gap phenomena in metamaterials.
In this talk we show how size independent static material parameters in this model can be determined a priori for metamaterials with periodic structures.
To this aim the rational of the relaxed micromorphic model is presented. Classical periodic homogenization predicts the large scale response and is one ingredient of the identification process; another ingredient is the maximal stiffness of representative unit cells under affine Dirichlet conditions and lastly we need to invoke a homogenization formula reminiscent of a series of spring stiffness which is unique to the relaxed micromorphic model. The program is probed in 2D for a tetragonal metamaterials.

Keywords: Enriched continuum mechanics, micromorphic models, band, gap metamaterials, parameters' identification

*Speaker

A phase field approach to fingering and fracturing in partially saturated porous media

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The variational phase-field approach to fracture allows to caracterize nucleation and evolution of cracks in solid continua adopting the minimization of the total energy potential as the criterion of fracture propagation within the framework in a nonlinear damage model. The total energy includes not only the potential energy but also the power dissipated by fracturing which depends on a damage parameter (the phase field) whose localisation is allowed by a gradient contribution.
The goal of the present contribution is to extend this formulation to partially saturated porous media within the framework of the phase field approach to poromechanics. In this case an additional phase field, with respect to damage, say the saturation ratio, allows to describe the mixture of (at least) two immiscible fluids saturating the porous space as a biphasic fluid. Localisation of the fluid flow is allowed because of a kind of Cahn-Hilliard regularisation of fluid energy potential.
This doubly phase field model is expected to be able to describe coupled localisation phenomena in partially saturated media during drainage and imbibition processes. This could be for instance the case of the interface between an aquifer reservoir and a so-called tight rock. Fingering of the fluid, stored in the aquifer rock, can occur through the low permeability caprock, so affecting its local response and possibly inducing strain localisation in it.

Keywords: Phase, field, multi, phase fluids, porous media, higher gradient theory

*Speaker

MS11 : Innovative Materials for Sustainable Construction

NUMERICAL FATIGUE ANALYSIS OF FRP-STRENGTHENED CONCRETE BEAMS

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The aim of this research is to investigate the effect of Carbon Fiber Reinforced Polymer (CFRP) composite fabric on monotonic and fatigue behaviors of reinforced concrete beams. The analyses were conducted to study stresses distributed throughout the critical regions, known as cracked zones, in reinforced concrete (RC) and CFRP-strengthened RC beams. Load–deflection curves, strain responses and propagation of tensile cracks would provide an insight into the performance of the CFRP strengthened beams subjected to different cycles of fatigue loading. The uniaxial constitutive model developed by Chang and Mander [1] is adopted in the present numerical study as the basis of the stress-strain concrete relation. This constitutive model is an advanced, rule-based, generalized, and non-dimensional model that simulates the behavior of confined and unconfined, ordinary and high-strength concrete in both compression and tension. The analysis results show good agreement with test results especially in the maximum capacity of the samples. The maximum bearing capacity and corresponding ultimate displacement are determined as (63400 N, 2.82 mm) and (62803 N, 2.66 mm) in the test and numerical analysis, respectively. To determine the initial load for cyclic analysis load protocol, a static Riks analysis is performed and 40 percent of the RC beam bearing capacity is determined for the initial load. Based on the bearing capacity, the initial load is obtained and cyclic analysis is performed. The numerical model simulates the crack distribution near the interface zone. The analysis results shows that the Concrete Damage Plasticity (CDP) in concrete tensile cracking can be successfully implemented in a typical finite element model to predict the fatigue behavior of RC beams under cyclic loading.

Keywords: Carbon Fiber Reinforced Polymer, Fatigue, Finite element analysis, Retrofitting

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How the moisture of production, temperature and time of curing affect the physico-mechanical performances of stabilized compressed earth block

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This paper presents the effect of production and curing parameters on the physico-mechanical performances of compressed earth blocks (CEBs) stabilized with 0, 10 and 20 wt % CCR (calcium carbide residue), a portlandite-rich industrial by-product. CEBs were produced using kaolinite-rich material (collected from Kamboinse) and quartz-rich material (collected from Pabre) at optimum moisture content (OMC) and OMC+2. They were cured in closed environment (wrapped in polymeric bags) at 20 ◦C, ambient temperature in lab (30±5 ◦C) and 40 ◦C. After curing, the CEBs were dried at 40 ◦C until constant mass before testing the compressive strength. For the earthen material from Kamboinse cured at 30±5 ◦C, increasing the moisture of production from OMC to OMC+2 decreased the compressive strength 0.19 times (from 4.3 to 3.6 MPa) and 0.26 times (from 4.4 to 3.3 MPa) respectively for CEBs stabilized with 10 % and 20 % CCR. For the same material, the compressive strength reached similar value (about 4.2 MPa) with 10 % CCR at 28 and 45 days of curing, while it respectively reached 3.6 and 4.4 MPa with 20 % CCR at 28 and 45 days. The compressive strength of CEBs cured at 40 ◦C increased 3.3 times (1.1 to 4.71 MPa with 0 to 20 % CCR) for Kamboinse and only 2.5 times (2 to 7.1 MPa) for Pabre. For CEBs cured at 20 ◦C, the compressive strength increased only 1.3 times (1.1 to 2.47 MPa) for Kamboinse and barely 0.7 times (2 to 3.43 MPa) for Pabre. This difference in improvement of the compressive strength of stabilized CEBs suggests that kaolinite-rich materials are more susceptible to CCR stabilization than quartz-rich materials. Moreover, the results suggest that the compressive strength of quartz-rich material is more sensitive to the curing temperature than that of kaolinite-rich material.

Keywords: Calcium carbide residue, compressed earth blocks, compressive strength, curing temperature, moisture of production

*Speaker

Contribution to the development of hydraulic eco-cement using pozzolans locally available in Burkina Faso

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The use of mineral additives in cement industry can potentially contribute to the reduction CO2 emissions and high energy consumption from cement production. The objective of this work is to study the feasibility of developing a ternary cement in which the clinker will be partially substituted by two mineral additives among calcined clays, rice husk ash and granite dust. A preliminary study was made on the binary cement in which the CEM I was substituted by 25 % of these additives in order to evaluate their strength activity index on mortar at 28 days (i28). The chemical pozzolanicity of the mineral additives was evaluated through the Frattini test, the modified Chapel test, the electrical conductivity and the amorphicity rate. All the results showed that the calcined clays and rice husk ash have very good reactivity and improve the mechanical strength of the mortar (i28 between 78% and 115%) except the granite dust. The analysis of the results showed that the improvement of the mechanical strength depends on the fineness and the amorphicity of the mineral additives. Overall, a good correlation is observed between the different chemical pozzolanicity tests and the strength activity index. However, the additives in substitution to the CEMI have slightly higher water demands than CEM I alone, except the granite dust. The results on normal consistency have shown that the water demand of the rice husk ash is the highest. This may be a limit for its use at a high rate of substitution in cement.

Keywords: Clinker, mineral additive, pozzolanicity, strength activity index, ternary cement

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Synthesis of geopolymer binders using clays and sands from Fez region in Morocco and study of mechanical strength

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Fez city in Morocco, is well known with the buildings of the Old Medina, which is its oldest walled part. The clays used to build it were taken nearby the city. Nowadays, these clays are mainly used for building materials, especially the manufacture of bricks, and in traditional pottery. The low mechanical strength and the carbon dioxide emission after firing remain the main inconvenient. To access the improvement of these row materials, it will be necessary to use a new material at room temperature. Consequently, the aim of this study is the development of a performant binder, based on Moroccan raw materials. To achieve this objective, different sands and calcined clays samples were used. At first the reactivity of the raw materials was evaluated by identifying the physicochemical and structural data using thermal analysis, X ray diffraction (XRD) and infrared spectroscopy (FTIR). Then the calcination temperature was determined, and the formulation was investigated. The calcined clays were mixed to a potassium alkaline silicate solution to obtain a reactive mixture. Consolidated materials were successfully synthetized and their nature were evaluated by in situ infrared spectroscopy (FTIR), and then tested by mechanical compressive tests. The results show a resistance range between 13 and 49 MPa, depending on the used clay.

Keywords: geopolymer aluminosilicate silicate solution Morocco

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Study of the interaction between clays and alkali-activated slag's hydrates in stabilized poured earth concrete

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The main benefit of earth construction is its ability to narrow and regulate heat and humidity flow with the outside environment, especially thanks to its capacity to exchange water in both liquid and gaseous states. Nonetheless, clays are a weak and unstable binder, thus it's needful to stabilize them with a stronger one, such as cement, but this kind of reinforcement leads to a decrease of thermal capabilities. Stabilization by alkali-activation could be an alternative to cement, improving mechanical strength, stability to water and maintaining thermal capabilities and ecological benefit of poured earth concrete.

In this study, blast furnace slag and sodium hydroxide solutions are used as raw materials for alkali-binder formation and added to three natural earth samples for stabilization. Cation-exchange capacity and electrical charge density of clays play a role in both hydration and stabilization process. The aim of the study is to characterize and evaluate the interaction between clays particles of natural earth and hydrates produced during slag's hydration. First of all, sodium and calcium adsorption on clays particles surface are evaluated by direct measurement with specific ionic sensors during quenching test in four different sodium hydroxide solution in presence of slag or not. Hydrates produced in presence of clays are then characterized by thermal analysis (DTA-TGA), X-ray diffraction (XRD) and *in situ* infrared spectroscopy (FTIR) analysis to evaluate the impact of clays on slag's hydration process.

The three different earth samples tested show different sodium adsorption amounts and kinetics depending on the type and amount of clay particles present in raw earth. Hydration speed and hydrates formed are thus both impacted by clays activity in different ways depending on the mineralogical composition of natural earth. Scanning electron microscopy (SEM) observation also show that hydrates morphologies are different from those obtain with slag alone.

Finally, clays and hydrates interface is investigated mechanically with a pull-off test. This test allows to investigate if stabilization is reached by hydrates percolation or by adhesion between clays and hydrates particles. Comparison with portland cement hydrates would allow to partially understand stabilization mechanisms and why thermal behavior could be different between these two types of stabilization.

Stabilization with alkali-activated slag, by improving mechanical strength and stability to water improves the potential use of raw earth materials for sustainable construction in any kind of environment.

*Speaker

Keywords: Earth concrete, slag, clays stabilization, in, situ FTIR

Hybrid cements made of engineered CaO-Al2O3-FeOx-SiO2 slags

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Synthetic slags with a compositional window relevant to the non-ferrous metallurgical industry, i.e. FeO = 40-65 wt.%, SiO2 = 22-40 wt%, CaO = 4-20 wt%, Al2O3 = 5-12 wt%, were investigated for their reactivity in alkali-activated blended cement, also known as hybrid cements. Slags were made by melting analytical grade oxides and metals at 100 ∘C above the liquidus temperature, followed by water quenching. Hybrid cement pastes were subsequently synthesized by mixing 80 wt% of the above slag, after milling to a Blaine surface of 4000 cm2/g, with 20 wt% ordinary portland cement (OPC), activated with solid Na2SO4 and water. The water over binder mass ratio (W/B) was equal to 0.4 (B = Slag+OPC+Na2SO4) and the Na2SO4 concentration was 0.75 M (1.5 N). The kinetics of cement hydration and reactions of the slag were investigated using isothermal calorimetry operating at 10 and 20 ∘C. From these data, the pre-exponential factor A and the apparent activation energy Ea of the cement hydration and slag reaction for the different slags were calculated. The strength development was monitored by compressive tests on cubes made of those pastes, after 2, 7 and 28 days. The reaction products were identified by XRD. The measured strength was correlated with the heat flow, cumulative heat, A and Ea. By mapping the chemical composition and mineralogy, reactivity and compressive strength, an optimal slag chemistry is proposed for the Na2SO4-activated hybrid cements. This could lead to the upcycling of non-ferrous metallurgy slags and reducing the environmental impact of cementitious materials.

Keywords: Alkali, activation, slag, hybrid cement, non, ferrous metallurgy

*Speaker

Multiphysical model for describing self-healing mortar containing biochar-immobilized bacteria

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This work aims to analytically and numerically describe and predict the ability of bacteria (Bacillus sphaericus) to heal cracks in mortar. The ureolytic bacteria induces microbial calcium carbonate by releasing urease enzyme, which in turn stimulates the degradation of urea into carbonate and ammonium; the carbonate then reacts with the calcium ions (in calcium nitrate) to produce calcite to heal cracks. The bacteria is immobilized in biochar, which is the solid by-product of pyrolysis; the biochar and bacteria are included in mortar mixture, together with special nutrient solution (the spore solution). Published studies found that biochar-immobilized bacteria heals cracks more efficiently.
The modeling approach consists of 4 major steps or sub-models.

Firstly, the Pore Wall Bubbling model describes the protrusion and expansion of pores in biochar. The predicted pore size distribution, hence porosity, was then used to calculate the overall porosity of the biochar-containing mortar using the second sub-model known as the Fractional Porosity Model. Next, an absorption model was used to describe uptake of the spore solution and used to estimate the spore concentration within the biochar. Finally, the rate of healing of a hypothetical cylindrical crack in mortar was estimated from the rate of production of calcite (due to the spore concentration calculated above), which depends on the rate of urea hydrolysis - the latter of which was described using a hydrolysis-diffusion model solved using Galerkin's finite element method.
Theoretical predictions agree very well with experimental results. Several deductions and possible improvements to the model are also suggested.

Keywords: Biochar, self, healing concrete, Bacillus sphaericus, multiphysical

*Speaker

Physical and mechanical properties of Portland cement blended with dehydrated cement

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Cement is one of the most used substances in the world and only its production represents 5% of annual anthropogenic global CO2. Thus, from the global environmental point of view of preservation and effective utilization of natural resources, it is beneficial and necessary to recycle construction waste cementitious material. After thermal treatment, hardened cement can regain its hydration capacity consisting of a complex mixture of dehydrated phases, residual hydration products, and unhydrated cement. This study aims to investigate the effect on the physical and mechanical properties of cement pastes of Portland cement blended with dehydrated cement. To infer the properties, experimental studies on compressive strength development, consistency and setting times were carried out.

Keywords: Portland cement, Dehydrated cement, Physical properties, Mechanical properties

*Speaker

Surface mechanisms occurring during ageing (T, RH) of nanostructured silica, use of TGA/DSC, TGA/μGC-MS and FTIR as complementary tools to deepen the understanding

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Assessing the durability of super-insulation products (more than 90% porosity) is a key step before they can become widespread in the building market. Those innovative materials are most of the time based on silica and have pore and particle size of the same order, a few ten nanometers. Due to their tremendous amount of mesoporosity and surface available, their chemistry and their textural properties will evolve. Unstable silica surfaces in alkaline media has been widely studied with Alkali Silica Reaction (ASR) in the civil engineering field but mechanisms associated to silica surface reactions remain unclear. Understanding how temperature and moisture impair silica surface is compulsory to both optimize the synthesis and widen applications for these high-end systems. Our study includes most commercial silicas (powder and aerogel) which differ by their chemistry (precipitated: hydrophilic SiOH, fumed: rather hydrophobized (SiOSi and SiOH) and intentionally hydrophobized (SiR)) and their structural properties (particles size, pores size, specific surface area...). These samples are aged for various time, then characterized using some physico-chemical techniques. We focus here on Fourrier Transformed Infrared spectroscopy (FTIR), Differential Scanning Calorimetry (DSC) and Thermogravimetric analysis (TGA) coupled with mass spectroscropy (MS) and gaz chromatography (μGS). Our purpose is to get a refine image of processes occurring on material surface, rather than on material bulk. Regarding aerogels, FTIR and TGA/DSC allow to observe changes in the hydrophobicity due to ageing. Mechanisms are discussed and scenario are proposed for each type of silica.

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Keywords: Silica, ageing, surface, TGA, FTIR, aerogel

Mechanical and X-ray tomography characterization of silica aerogel composites

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As new regulations for energy efficiency are becoming tougher in the building sector, the required thickness for insulation with conventional materials (glass wool, polymeric foams...) may become prohibitive. This is a strong driving force for the development of a new class of products, the Super-Insulation at Atmospheric Pressure (SIAP) materials, based on the use of silica aerogel. Silica aerogels offer unprecedented low thermal conductivities thanks to their very high nanoporosity (_˜ 95%), but also exhibit very low mechanical properties.
The materials studied here are composite panels produced using a bimodal distribution of silica aerogel grains and latex as a binder. A good understanding of the mechanisms responsible for the failure of this composite is required in order to properly optimize the material by improving its mechanical properties while keeping its very interesting thermal properties (thermal conductivity is approximately 15 mW/m/K). Mechanical properties of our aerogel composite are influenced by both the intrinsic properties of single silica aerogel grains and the way they are introduced in the composite. Thus, mechanical tests were carried out on both single aerogel grains and composite samples.

Instrumented indentation tests on aerogel composites showed that the material exhibits a broad elastic response in compression that depends on the strain-rate. These observations can be confirmed by compression tests on single grains carried out during x-ray tomography. These in-situ tests allow elastic and failure behavior to be observed in single aerogel grains. Another in-situ x-ray tomography test has been attempted to propagate a stable crack in small samples of aerogel composite to determinate toughness and obtain qualitative information on crack propagation. These tests are supplemented by high-resolution x-ray tomography carried out at ESRF (European Synchrotron Research Facility in Grenoble).

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Keywords: silica aerogel, super insulating materials, instrumented indentation, x ray in situ mechanical tests

Evaluation of the potential of bark and pith fractions of corn and sunflower stalks as bioaggregates for lightweight vegetal concrete design

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The construction industry stands out for innovative materials. Simultaneously, it seeks to reduce the waste production and greenhouse gas emissions. To do so, in the last years, several investigations have been developed involving compounds with raw material of vegetal origin. In the first place, hemp shiv was extensively studied as bio-aggregate for hemp concrete design. Nevertheless, hemp availability is limited in most regions in the world, so the main objective of this research is the development of a lightweight plant concrete based on sunflower or corn stalks, two agricultural by-products largely available.
The first phase of this study consists of the production of the alternative bio-aggregates from the entire stalks of corn and sunflower. It was achieved through a multi-steps procedure combining grinding, separation and sieving phases.

Finally, 3 distinct fractions were obtained for each plant: pith (the inner light and porous part of the stem), bark (the outer and denser part of the stem) and a residual fraction made of a mix of the two phases.

For sunflower, the mass proportions of the different phases were the following: 72.8% of bark aggregates, 4.7% of pith particles, 10.1% of the mix, and a global loss rate of 12.4%. For corn aggregates the respective fractions were 49.6%, 2.7%, and 5.2% with a global loss rate of 42.5% due to the higher adherence between the pith and the bark phases into the corn stem that makes the separation more difficult in comparison with sunflower stalk.

The second phase is the characterization of these bio-aggregates according to the recommendations of the RILEM TC 236-BBM, 2017. Six alternative bio-aggregates and one reference bio-aggregates (hemp shiv) were characterized by determining their bulk density, water absorption kinetics, particle size distribution by image analysis, and thermal conductivity of the bulk

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arrangement.

The measurements evidence very distinct performances, in particular between the bark and the pith fractions of the plant aggregates. Two key parameters were used for composite design: the density of the bulk arrangement of particles and its water absorption capacity after 1 minute of immersion.

Bulk density ranges from 11.8 kg/m3 (sunflower pith) to 124.8 kg/m3 (sunflower bark). Among these values three distinct behaviors can be identified: the bulk density of corn and sunflower bark is similar to the one of the hemp shiv, while pith fractions present densities 4 to 10 times lower. This difference can be mainly related to the distinct intraparticular porosity of the bulk arrangement, i.e. the porous structure of pith and bark particles. As expected, mixes of both fractions present intermediate behavior.

Water absorption after 1 minute is closely linked to the porous structure of the particles and to their size. Bark and hemp shiv particles present water absorption capacities after 1 minute ranging from 137% to 214%, while sunflower pith particles are able to absorb up to 14 times their weight in water.
This study allowed for the production and characterization of six alternative bio-aggregates extracted from corn and sunflower stalks that will then be used for plant lightweight concretes design.

Keywords: bioaggregates, insulation materials, biobased materials, composite materials, plant concrete, corn, sunflower.

Effects of hydroxyl on the mechanical properties of silica nano-structures through atomistic simulations

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Surface hydroxyl groups (water) on silica are well known to influence its surface morphology, and several functional properties. Such groups are involved in many reactions occurring in construction material during elaboration or later on while ageing. Silica aerogels combine the best thermal insulation properties with a tremendous specific surface and might therefor age. Their low thermal conductivity is due to their fractal morphology characterized by a distribution of pore sizes between 2 and 50 nm as well as a very high surface area. Unfortunately, this characteristic structure is also responsible for their brittleness. At the atomic level, the fibrous structure of aerogels is described as a network of interconnected silica nano-spheres also known as primary particles. Up to now, simulation studies were performed but on a simplified set of material: Silica surfaces without hydroxyl nor surfactant. Hence, for a better understanding of the influence of surface-water on the mechanical properties of aerogels we conducted molecular dynamics simulations of silica nano-structures, such as nano-wires and nano-spheres (SNS) under various water concentrations. Using a novel inter-atomic potential (ReaxFF) we can accurately model the water-silica interaction and see how it affects the connectivity and "bulk" properties of the primary particles. Using the information derived from atomistic simulations we are able to draw useful conclusions about the resultant aerogel quality.

Keywords: molecular dynamic, aerogel silica, hydroxyl, mechanical properties

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Repairing capacity of alkali-activated cementitious materials

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Due to ageing, reinforcement concrete buildings and civil engineering structures have to be repaired and/or strengthened. The main objective of these interventions consists in recovering or improving the initial structure properties. It is however important that the systems and repair techniques are carefully chosen to maintain the new performances at short and long term. One of the essential conditions for durable and quality repairs is the compatibility between the repair products and the old concrete. This depends on several factors, such as the repair material, the surface preparation and the placement method. The present research work focuses on the choice of the repair material, particularly on the alkali-activated cementitious materials and their deformational compatibility. Today, the use of this type of materials is advancing in the civil engineering industry in Australia, China and UK. These materials generally present a good resistance to chemical attacks and fire. In this study, three mortar mixtures are tested: two alkali-activated mortars and one reference mortar with Portland cement. The studied activators are sodium sulphate and carbonate, added with a similar sodium content. They present the advantages to be not expensive and widely available on the market. The parameters affecting the early age deformation of the alkali-activated cementitious materials and their durability are determined to evaluate their repairing capacity. The studied parameters are the tensile and compressive strengths, the Young modulus, the autogenous shrinkage and the basic creep. The matrices microstructure (porosity and hydration products) is also characterized.Based on these results, it appears that the mixture activated with sodium sulphate is an interesting solution to limit cracking in the repair material due to the delayed deformations restriction by the support.

Keywords: durability, alkali activation, repair, self, healing, cementitious material

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MS12 : High Temperature Effects on the Dynamic Strength of Concrete

Concrete under Fire and Blast - Combined Modeling at Two Time Scales

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The proposed paper deals with the numerical assessment of normal and high-strength concrete materials in a combined scenario of both fire and explosion. The study is based on and takes account of numerous examples of such load cases from recent years: Explosion and secondary fire in chemical industry, fire in car parks or crashes of airplanes followed by hot burning fuel. The assessment of such combined load cases is not that trivial, neither in terms of experimental investigations nor in terms of predictive numerical simulations.

Explosions are transient processes where material characteristics change in the order of milliseconds. Although fires are counted among transient processes as well, the duration where transformation and degradation occur is orders of magnitudes higher. Most finite element tools and related material models can deal with either one or the other phenomenon. Within the presented study two phenomenon-specific concrete models are used to tackle this problem by utilizing the added value of each of them: On the one hand, a hygro-thermo-mechanical modelling approach for numerical assessment of concrete at elevated temperature was used to capture heat and mass transport phenomena of the multi-phase material. On the other hand the established RHT model for predictive hydrocode simulations of concrete under shock and impact loading was used to capture compaction and strain-rate phenomena.

The paper describes this two-step approach: Analyzing benchmark fire tests as well as standard fires the first model delivered information on propagation of temperature and gas pressure at different depth of a defined concrete body at normal and high-strength level. This was used as reference for the alternation of the hydrostatic and deviatoric description of the second model. Final application of explosion loading within the hydrocode environment delivered reasonable results and highlights the benefits of each material grade for the combined scenario.

Keywords: Concrete, blast, fire, dynamic engineering, numerical analysis

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High temperature effects on the dynamic strength of concrete

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Proper accounting of the material properties and designing of building structures, which could function successfully at high temperatures, is one of the most urgent and difficult tasks. The difficulty is aggravated by the fact that at such temperature levels, the strength properties of materials are decreasing functions of temperature, and significant temperature field gradients cause large thermal stresses, which are often an important factor determining the strength and durability of a structure. Fire impacts accompanied by a dynamic loading on the load-bearing elements of the building structure lead to irreversible consequences . In particular, the fire impact on reinforced concrete structures changes the physical and mechanical properties of concrete and reinforcement . Quantitative assessment of the effects on the dynamic strength and deformative properties of concrete has resulted in a pilot research. Conducted a pilot research and a comparative analysis of the strength results for concrete samples under static and dynamic loading before and after fire impact. Concrete cubes and prisms with dimensions of 10x10x10 cm and prisms of 10x10x40cm have been tested. It has been proved that the value of dynamic hardening coefficient for concrete is reduced to 0.47. In normal conditions, the destruction of samples under static loading takes place within the limits: for cubes - from 347 kN to 352 kN, for prisms - from 270 kN to 274 kN. Dynamic destructive loading at a loading time of 1.0 s. has made up: for cubes - from 416 kN to 422 kN, for prisms - from 320kN to 325kN; at a loading time of 0.4 s.: for cubes - from 425 kN to 429 kN, for prisms - from 322 kN to 327 kN.
The reduction of the cube and prism concrete strength while statically tested reaches 87.94% (at 900 ◦ C). Dynamic tests for cube and prism strength at a loading time t = 1.0 s. have shown that the dynamic strength decreases by 95.23% (at 900 ◦C), and at a loading time t = 0.4 s. by 96.2%.

Conclusion:

1. The dynamic hardening coefficient of concrete at a temperature ranging from 20 ◦C to 254 ◦C is Kbdt =1.28 -1 and from 254 ◦C to 900 ◦C Kbdt =1 - 0.47.

2. Dynamic calculation of a reinforced concrete column under fire impact and after cooling has shown that the stiffness of the element in the elastic stage after cooling is 1.24 times greater than under fire impact. The transition time from the elastic to the elastic-plastic stage under fire impact is 1.32 times lower than after cooling.
3. In normal conditions, the stiffness of the element in the no-crack stage is 1.16 times greater than at the fire temperature 500 C , and 1.45 times greater than the stiffness of the element in

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stage I at 900C.

Keywords: Concrete, dynamic loading, dynamic hardening factor, dynamic strength, fire conditions

MS14 : Thin Textile (and Fiber) Reinforced Cement Composites and Ferrocement

Evaluation of the results' accuracy of embedded optical fibres sensors in Textile Reinforced Cementitious Matrix Composites

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Textile Reinforced Cementitious Matrix Composites, TRCMC, are used on a large scale for the repair and reinforcement of structures and civil engineering works. Their mechanical behaviour, characterised by the appearance of multiple cracks in tension, results from the combination of the behaviour of these two components: cementitious matrix and textile reinforcement. The identification of this behaviour is generally done by surface measurement techniques (gauges, DIC, laser...), and the internal interaction between matrix and reinforcement is deduced by approaches to fracture mechanics and continuum mechanics. To this date, no experimental verification of the internal behaviour of TRCMCs has been done. This study investigates the possibility of integrating optical fibers as strain sensors into the core of TRCMC composites, and evaluates the accuracy of the results obtained as well as the resistance of these optical fibers during crack propagation. In this sense, strain gauges are bonded to the surface of the specimens and optical fibres, based on the Rayleigh backscatter principle, are incorporated into the core of the TRCMC composite, then tested in direct tension and three-point bending. These tests have firstly made it possible to compare the values of the strains obtained by the different measurement techniques as well as the strains deduced by applying the theory of beams in the case of bending, and secondly to follow the evolution of the strains of the matrix and the textile during the evolution of the mechanical test. Finally, an overview of the micro-mechanical parameters that drive the behaviour of the TRCMC and can be quantified by optical fibre is presented, demonstrating that optical fibre measurement is a promising technique that facilitates access to information allowing to understand the mechanical behaviour of TRCMC composites.

Keywords: Cementitious Matrix Composite, Textile Reinforced Concrete, Optical Fibre, Rayleigh Backscatter Technique, Strain Sensor.

*Speaker

Coating effect on the mechanical behaviour of Textile Reinforced Mortars in ambient and increased temperatures

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The mechanical behaviour of textile reinforced cementitious composites (TRC) has been a topic of wide investigation during the past 30 years, mainly due to their potential to create thin and lightweight elements with increased freedom of forming and high structural performance. However, most of the investigation is focused on the behaviour under ambient temperatures while only a few studies about the behaviour under high temperatures have been conducted so far. In the present study, specimens with dry textiles, coated with thermoplastic or impregnated with thermoset materials, are subjected to mechanical testing, with or without having been exposed to fire tests. The well-known positive effect of coating the reinforcing textiles is verified in ambient temperature testing. However, it is shown that in the case of exposure to high temperatures, the coating or impregnation of the textiles has a negative effect in the residual load bearing capacity of the TRC specimens. The load bearing capacity of the specimens in this study is quantified by means of flexural tests. It is observed that the loss of bond between the textiles and the matrix which is caused by the burning off of the the coating, is of outmost importance for the structural properties of the composite and, thus, proper protection should be considered.

Keywords: Textile Reinforced Cements, fire exposure, high temperature, textile coating

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The effect of accelerated aging on polymer impregnated AR and E-glass textile reinforced concrete

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Textile reinforced concrete (TRC) is a relatively new addition to the class of strain hardening cement-based composites. These materials are gaining popularity in the construction industry due to their design flexibility, non-corrosive nature and potential for higher material optimization. Alkali resistant (AR) glass textiles are the most common reinforcement for TRC applications; however, the higher manufacturing cost limits their application in large scale projects. A low-cost alternative is the E-glass textiles with alkali resistant coating. However, the long-term performance of these textiles in the composite is yet to be understood. This paper focuses on the durability of TRC composites reinforced with polymer coated AR and E-glass textiles. After 28 days of curing, the TRC coupon specimens were exposed to hot water at 50C. The time-dependent loss in strength was assessed from the residual flexural capacity at 7, 28, 90, and 160 days of exposure. The AR glass textiles did not show a significant reduction in the flexural capacity, whereas a substantial reduction in strength was observed for E-glass textiles reinforced specimens at 90 days of exposure. The microstructural modifications and the deterioration mechanisms involved are explained with the help of micro-analytical techniques.

Keywords: Textile reinforced concrete, durability, accelerated aging, flexural capacity

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Experimental investigation of transversal connections in 3D Textile Reinforced Cement composites

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Textile Reinforced Cement composites (TRCs) offer a slender and lightweight alternative to traditional steel reinforced construction elements. Their labour intensive and time consuming manufacturing process (when using planar textile reinforcement) is however a major drawback against their potential market uptake. A new iteration in the textile reinforcement are the so-called 3D textiles. These three dimensional entities consist of two textile planes separated over a distance by means of transversal connections and lend themselves to a manufacturing process by pouring, which is similar to contemporary methods used on site. The original purpose of the transversal connections is to achieve a three dimensional integrity, however a correct tuning of the transversal connections can lead to superior post-cracking stiffness of the TRC without increasing the effective in-plane fibre volume fraction. In order to assess the influence provided by the transversal connections, this paper investigates two different aspects of 3D TRCs. Firstly, two different 3D TRC systems (a knitted and a woven alternative) are compared with one reference 2D equivalent system with equal in-plane fibre volume fraction by means of an experimental campaign in tension and bending. In tension no influence of the transversal connections is reported while a clear post-cracking stiffness increase (that depends on the considered 3D system) is witnessed in bending. Secondly, the orientation of the transversal connections with respect to the loading direction (parallel or perpendicular) is compared for the two 3D TRC systems. A clear influence of the orientation is witnessed for the woven 3D TRC system while no influence is witnessed for the knitted alternative.

Keywords: Textile Reinforced Cement Composites (TRCs), 3D Textiles, Transversal connections, Experimental characterization

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TRM to masonry bond strength: The effect of the textile fibre material

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The utilisation of high-performance composite materials for the repair and strengthening of existing masonry structures is nowadays common practice among the engineering community. To this point, textile reinforced mortars (TRM) have been proven to be an efficient technique for the strengthening of the unreinforced masonry. TRMs comprise a textile fibre material impregnated within an inorganic matrix that is externally bonded to the masonry surface. A key parameter that controls the effectiveness of any externally bonded system is the bond between the mortar, the reinforced fibres, and the substrate; this has been often identified as the weak link in TRM strengthening. Hence, a number of experimental campaigns has been conducted to highlight the bonding performance of TRM. However, results are in many cases contradicting due to the inherent complexity of the problem that stem from the uncertainties characterising the constituent material structural properties. Therefore, more experimental results are required to inform the investigation on the TRM to masonry bond mechanics.
In this work, we present preliminary results from an experimental campaign on the masonry to TRM bond by means of single lap shear tests. Four materials are considered in this study, i.e., glass, heavy and light carbon and basalt fibre textiles. A numerical simulation procedure based on the Finite Element Method is also provided with model parameters appropriately calibrated on the experimental results.

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Keywords: textile reinforced mortars (TRM), glass textile, carbon textile, basalt textiles, bond, masonry

*Speaker

Numerical simulation of FRCM bond performance

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The use of externally-bonded composite materials for strengthening and rehabilitation of existing structures is valid alternative to the traditional strengthening techniques. Technologies, such as Fabric Reinforced Cementitious Matrix (FRCM) have been recently developed in order to employ them to strengthen existing reinforced concrete (RC) and masonry structures.
Many authors have studied bond between FRCM-concrete doing single-lap shear tests on FRCM-concrete coupons in order to evaluate the cohesive law between fabric and cementitious matrix as well as matrix to substrate and identify the failure mode. After that, analytical models were developed which discuss the interaction between the fabric and matrix using a fracture mechanics approach. These analytical laws were simplified using a trilinear curve in which a constant branch correlated to the friction.

This study deals with the analysis of FRCM materials using 2D Augmented-Finite Element Method (A-FEM) approach. Constitutive material behaviors were used to implement an A-FEM model, which can predict the failure modes of the composite material. The damage of the matrix was described by a trilinear curve. The fabric was modelled as a continuum layer attached to the matrix with no-thickness cohesive elements. The cohesive law between fabric and mortar matrix was taken from the literature.
The single-lap shear test on the FRCM with one layer of fabric was numerically modeled and compared to the experimental stress-displacement curves. The FRCM composite was comprised of polyparaphenylene benzobisoxazole (PBO) fibers and polymer-modified cement-based mortar. This study indicates that in PBO FRCM–concrete coupons de-bonding mainly occurs at the matrix–fiber interface. Results show that the numerical curves matched the experimental ones. Post peak behavior is characterized by a plateau, different from experimental evidence due to the initial assumption at the basis of the model.

Keywords: FRCM, FEM, Bond, Numerical, Modelling, Composite Materials

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Textile Reinforced Cement Composites - Durability Aspects

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Textile-reinforced concrete (TRC) is an innovative technology. Research findings show that TRC significantly improves the tensile strength, ductility, and energy absorption capacity of the concrete element. Beyond its excellent mechanical properties, TRC offers a potential reduction of self-weight and cost, energy and carbon dioxide (CO2) savings, production of modular and complex shape structures while eliminating the risk of corrosion, providing many possible applications.
The goal of this work was to develop a durable TRC based element. Thin sheets TRC elements were prepared with one layer of textile fabric. The durability of the TRC elements were studied under two different conditions: (1) accelerate aging, and (2) salt exposure conditions such as, continuously exposed to (i) tap water and (ii) NaCl saturated water (NaCl saturated aqueous solution) and (iii) intermittently exposed to NaCl saturated water (Dry/wet cycles). The TRC composites were studied in tension in order to evaluate the environmental exposure influences. Microstructure focused on the interface between textile and matrix was investigated by scanning electron microscopy to learn about the bonding between textile and matrix under the different exposure conditions. The main results of this work will be presented.

Keywords: Textile, durability, cement, composites, tensile behavior

*Speaker

Mechanical investigation on a new sustainable PCM-TRC sandwich panel

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There is a growing interest in the use of phase change materials (PCMs) in the building industry, particularly in cementitious materials.
In the present study, a modified mortar matrix with different amounts of pcm (5wt %, 10wt%, 15wt %) have been prepared. The different pcm-mortar matrixes have been mechanically characterized. It was found that PCM drastically decreases the mechanical performance of mortar.

The 10% PCM-mortar matrix has been reinforced with two layers of AR glass Fabric and has been used as a skin of textile reinforced concrete (TRC) foamed sandwich panel.
The performance of the 10% PCM modified TRC sandwich panel has been compared with a reference TRC sandwich panel (without PCM) in four points bending .It has been found that the mechanical performance of the PCM modified sandwich panel decreases comparing to the reference, however TRC ductile behaviour is conserved during bending which is very encouraging in view of developing new sustainable PCM-TRC sandwich panels with high mechanical and thermal efficiency

Keywords: phase change materials, textile reinforced concrete, sandwich panels, building enveloppe.

*Speaker

Mechanical characterization of single- & double-layer TRM overlays applied on masonry

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Textile Reinforced Mortar (TRM) is an innovative composite material that has already been used successfully as externally bonded strengthening overlay on existing masonry structures. However, there are not yet official guidelines with international resonance for the mechanical characterization of this composite material. The current study concerns an AR glass dry fiber TRM system which is applied on masonry wallettes in the form of single- or double-layer overlays. For the characterization of the TRM system tensile and shear bond tests were carried out applying the ACI 549 guidelines (acceptance criteria proposed in AC434 ICC-ES) and the double-lap/double-prism set-up, respectively. The combination of the experimental results of these tests is attempted for both cases of TRM overlays. Finally, the appropriateness of each applied test procedure for the determination of the tensile constitutive law and of the TRM-to-substrate interfacial bond law is also discussed.

Keywords: TRM, Masonry, Single, & Double, layer overlays, Tensile Strength, Bond Capacity

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A new phase change material textile reinforced concrete composite

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There is a growing interest in the use of phase change materials (PCMs) in the building industry, particularly in cementitious materials.
In the present study, a modified mortar matrix with different amounts of pcm (5wt %, 10wt%, 15wt %) have been prepared. The different pcm-mortar matrixes have been mechanically characterized. It was found that PCM drastically decreases the mechanical performance of mortar.

The different PCM-mortar matrixes have been reinforced with two layers of alkali resistant glass fabrics. The mechanical performance of the new PCM-TRC composites with the different amounts of PCM has been evaluated in a quasi-static direct tensile test according to the recommendations of the RILEM
It was found during the tests that the mechanical performance of the PCM-TRC composites decreases with PCM content and that for a PCM content $\geq$ 15% a critical mode failure by delamination of the composite occurs. Despite this, TRC ductile behavior and textile/matrix load transmission is conserved (despite the presence of brittle PCM) which is encouraging in the view of developing new sustainable PCM-TRC composites

Keywords: PCM, TRC, mechanical characterization, sustainable composites

*Speaker

Experimental investigation of the influence of pre-cracking on the tensile behaviour of the Textile Reinforced Cementitious Composites, using Digital Image Correlation

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Over the last 30 years, the mechanical performance of **textile reinforced cementitious composites (TRC)** has been extensively studied in the literature. However, the influence of pre-cracking on the tensile behaviour of TRC remains relatively unstudied. This paper focuses on the effect of pre-loading with a varying angle on the tensile properties of TRC. The specimens were pre-cracked by loading, under different angles, beyond the multiple cracking stage. Afterwards, they were tested in tension in the perpendicular direction. Comparison of these pre-cracked specimens with reference non-pre-cracked specimens gave insight into the effect of off-axis pre-loading on the TRC tensile behaviour. The results revealed a significant loss in the specimens' initial stiffness and residual ultimate capacity.

Keywords: textile reinforced cementitious composites (TRC), tensile tests, digital image correlation (DIC)

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MS18 : Machine Learning and Informatics for Materials Discovery and Design

Predicting the Mechanical Properties of Glasses by Machine Learning

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The development by machine learning of models predicting materials' properties usually requires the use of a large number of consistent data for training. However, quality experimental datasets are not always available or self-consistent. Here, as an alternative route, we combine machine learning with high-throughput molecular dynamics simulations to predict the Young's modulus of silicate glasses. We demonstrate that this combined approach offers excellent predictions over the entire compositional domain. By comparing the performances of select machine learning algorithms, we discuss the nature of the balance between accuracy, simplicity, and interpretability in machine learning.

Keywords: Machine Learning, Stiffness, Molecular Dynamics

*Speaker

Machine learning models to predict the elastic properties of oxide glasses

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Glasses are archetypical disordered materials that can be formed by the fast quenching of a liquid. Due to the disordered structure, glasses can accodomate a wide-range of compositions with almost any element in the periodic table. This makes it extremely challenging to predict the mechanical properties of glasses, as they exhibit highly non-linear behavior with respect to the glass composition. Herein, using machine learning, we develop models that can predict the elastic properties of oxide glasses. To this extent, we use neural networks (NN) and gaussian process regression (GPR). We show that the models developed herein are highly transferable. Further, we show that GPR exhibits a uniqe feature with which we can obtain the reliabilty associated with each predictions. Overall, we show that machine learning can be used to develop rigorous and reliable models to accelerate the design of novel functional glasses.

Keywords: Machine learning, oxide glasses, neural network, gaussian process regression

*Speaker

Predicting Concrete Strength by Machine Learning

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The use of statistical and machine learning approaches to predict the compressive strength of concrete based on mixture proportions, on account of its industrial importance, has received significant attention. However, previous studies have been limited to small, laboratory-produced data sets. This study presents the first analysis of a large data set (> 10,000 observations) of measured compressive strengths from actual (job-site) mixtures and their corresponding actual mixture proportions. Predictive models are applied to examine relationships between the mixture design variables and strength, and to thereby develop an estimate of the (28-day) strength. Furthermore, to illustrate the value of such models beyond simply strength prediction, they are used to design optimal concrete mixtures that minimize cost and embodied CO2 impact while satisfying imposed target strengths.

Keywords: concrete, machine learning, strength

*Speaker

Rapid Damage Evaluation of Bridge Portfolios using Machine Learning Techniques

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The damage state of a bridge has significant implications on the post-earthquake emergency traffic and recovery operations and is critical to identify the post-earthquake damage states without much delay. Currently, the damage states are identified either based on visual inspection or stored fragility curves. Although these methodologies can provide useful information, the timely application of these methodologies for large scale regional damage assessments is often limited due to the manual or computational efforts. This paper proposes a methodology for the rapid damage state assessment (green, yellow, or red) of bridges utilizing the capabilities of machine learning techniques. Contrary to the existing methods, the proposed methodology accounts for bridge-specific attributes in the damage state assessment. The proposed methodology is demonstrated using two-span box-girder bridges in California. The prediction model is established using the training set, and the performance of the model is evaluated using the test set. It is noted that the machine learning algorithm called Random Forest provides better performance for the selected bridges, and its tagging accuracy ranges from 73% to 82% depending on the bridge configuration under consideration. The proposed methodology revealed that input parameters such as span length and reinforcement ratio in addition to the ground motion intensity parameter have a significant influence on the expected damage state.

Keywords: machine learning, Damage Assessment

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Prediction of properties of glasses using Gaussian Process Regression

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In this work, we present a novel and innovative method for the prediction of glass properties using machine learning (ML). We specifically consider the modeling of Young's modulus of the silicate glasses having sparse data. Even though there are methods like neural network (NN) for modeling the hidden data trends in the data sets, these methods rely on large datasets and often exhibit overfitting when used with a sparse dataset. Further, it is also important to quantify the uncertainty in predictions for a new dataset. Herein, by using non-parametric machine learning approach, namely, Gaussian Process Regression (GPR), we successfully overcome such a lacuna. GPR provides quantitative bounds for the reliability of predictions while extrapolating. Overall, GPR presents an advanced ML methodology for accelerating the development of novel functional materials such as glasses.

Keywords: Machine learning, Neural network, Gaussian Process Regression, Glasses

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MS19 : Stability and failure of structures and materials

Fatigue Lifetime Prediction of Steel Bridges based on Fatigue Analysis and Reliability

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Bridges experience high-cycle loading, therefore it is necessary to evaluate their fatigue lifetime to decide on rehabilitation or replacement of them. The purpose of this research is a study on fatigue lifetime of an existing Railway Bridge. The bridge is modeled in SAP2000 and after multi-step analysis under service moving loads, fatigue lifetime was assigned using Miner linear rule and S-N curves. After evaluating the fatigue analysis process used in this research with data obtained from previous loading experiment, in order to investigate and compare the fatigue performance of various steel railway bridges, three truss bridge models with 27, 36 and 45 m spans and two models with 36 m span, which have girders with box sections and plate sections, respectively, were designed and then analyzed using fatigue and reliability analysis (using Monte Carlo Simulation). The study showed the better performance of the bridges with box and plate sections in terms of fatigue. Also, the extension of the span length increased the fatigue life of the longitudinal members of the truss bridges. By comparing the results of fatigue and reliability analysis, the fatigue lifetime from reliability analysis was less than that of fatigue analysis. By performing multi-step analysis, it was found that the velocity of moving loads does not affect the peak values of the strain and the displacement and therefore fatigue life of members. Finally, in tensile members, fatigue lifetime calculations considering mean stress effect, showed less fatigue lifetime in comparison with results of eliminating mean stress effect.

Keywords: Remaining Fatigue life, Fatigue Analysis, Reliability, Structural Health Monitoring, Steel Bridges

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The influence of lateral impact damages on buckling, postbuckling and failure of channel section beam

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Nowadays a different types of composites materials are more and more popular in many branches of industry, e.g. aircraft industry, aerospace engineering, automotive industry or civil engineering and many others. This paper is focused on thin-walled laminate structures i.e. thin-walled beams made of GFRP laminate. In world wise literature the research conducted on structures from different type of laminates (e.g. FRP, FML) manufactured in different way (e.g. autoclaving or pultruded method), different type of sandwich or FGM structures can be found. However, according to the best authors' knowledge there are still not enough paper devoted to behaviour of initially pre-damaged structures.
The influence of lateral low velocity impact damage on thin-walled channel section beams made of GFRP laminates subjected to pure bending in full range of load (till failure) have been investigated.

Similar investigation been performed by Chen et. al. [1]. The influence of lateral impact on the axial bearing capacity of steel thin-walled tubes with rectangular cross-section have been investigate. The different impact energy, loading position and width-thickness ratios have been considered to access their influence on the residual axial bearing capacity the failure mode, initial stiffness and ductility of tested specimens.

The paper presents the experimental tests and numerical simulation results obtained for initially pre-damaged (i.e. lateral to the structure wall impact with low velocity) and intact channel section columns subjected to pure bending. The beams under investigations are made of eight layers GFRP laminate with five different symmetrical layer arrangement. The experiments have been performed in two following steps: (i) each beam has been impacted in different places and (ii) the impacted and intact beams have been subjected to pure bending till failure. The influence of impact position (mid-with of flange or mid-width of web in different position in longitudinal direction) and different layer arrangement on buckling load, postbuckling behaviour and failure load of pre-damaged and intact beams have been analysed. Additionally, the numerical FEM model allowing to analyse postbuckling behaviour and failure have been developed and validated by results from experimental tests. In numerical simulation simplified damaged model have been introduced and progressive damage analysis with Hashin failure criterion [2] have been employed.

In Authors opinion the knowledge of thin-walled laminate beam behaviour in whole range of load are necessary for designers involved in designing the lighter, more durable and safe structures. Above will be possible if more results for structures with impact pre-damages and their

*Speaker

influence on postbuckling and failure is presented.

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Keywords: Postbuckling, Thin Walled Beams, Laminates, Impact Predamage

REINFORCEMENT THE SEISMIC INTERACTION OF SOIL DAMAGED PILES-BRIDGE BY USING MICROPILES

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This paper presents a Three-dimensional numerical modeling of Soil-damaged Piles-Bridge interaction under seismic loading. This study focuses on the effect of developing plastic hinges in piles
foundation on the seismic behavior of the system. Several field investigations of the seismic damages due to the
recent strong earthquakes have confirmed the decisive role of the plastic hinges in the piles on the seismic
behavior of the system. In particular, this study is interested in evaluating the proposed approach for
strengthening the system of soil-damaged piles-bridge. The proposed approach is based on using the micropiles
which significantly promoting the flexibility and the ductility of the system. This study was carried out using a
Three-dimensional finite differences modeling program (FLAC 3D). The results confirmed the considerable
effect of the developing of concrete plasticity in the piles foundation, which reflects in changing the distribution
of internal forces between the piles. They show the efficiency of using the micropiles as reinforcement system.
The detailed analysis of the micropiles parameters shows a slight effect of pile-micropile spacing. While the use
of inclined micropiles leads to attenuation of the internal forces induced in the piles and the micropiles
themselves.

Keywords: Interaction, Piles, concrete, Seismic, Plasticity, Three, dimensional, Micropiles.

*Speaker

Experimental investigations on bond performance of GFRP bars to concrete under aggressive environments

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The experimental investigation on the long-term bonding properties between glass fiber reinforced polymer (GFRP) bar and concrete was presented here. Three types of GFRP bars with nominal diameters of 8 mm, 12 mm and 16 mm were used in this investigation and all of them were manufactured by Nanjing Fenghui Composite Material Co. Ltd. (Jiangsu, China). Total 48 pullout-test specimens were prepared to evaluate the bond performance of GFRP bar with concrete after their exposure to several aggressive environments, including clear water, alkali solution and salt solution. The exposure duration was 270 d. Test results indicated that the typical failure modes of GFRP bar-concrete members were pull-out failure and splitting failure, and their bond strength showed a clear downward trend with the increasing of exposure time. It can be obtained that the pull-out failure mainly happened to the GFRP bars with diameters of8 mm and 12 mm, while the bars in the diameter of 16 mm typical failed in the mode of splitting failure, which was characterized with 3-5 wide cracks. Compared with the three aggressive conditions, it can be found that the salt solution had the greatest influence on the degradation of the bond strength of GFRP bar-concrete specimens with an average decline of 24.01%; and that the effect caused by the alkali solution was lowest with an average decline of 17.37%. After exposure to different solutions, the bonding-slip curve of GFRP bar-concrete members with diameters of 8 mm and 12 mm exhibited a significant oscillating decreasing trend, and the curve of the members with 16 mm GFRP bars showed a linear relationship. Besides, the diameter of GFRP bar has great influence on the failure mode and bond strength of GFRP bar-concrete specimens and the bonding properties will be improved with the increase of bar's diameter.

Keywords: GFRP bar, pull, out test, aggressive environment, bond strength, bonding, slip curve

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Numerical analysis for the crack growth in a glass plate under thermal loading

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The thermal gradients in materials produce the residual stress. This residual stress often leads to the crack initiation and propagation however the prediction of the crack path due to thermal loading is still challenging. In this research, we aim at the development of the numerical analysis method which can reproduce the crack growth in materials under thermal loading.
An experiment firstly performed by Yuse and Sano (1993) show that the well-controlled quasi-static crack propagation under thermal loading. In this experiment, a thin glass plate in a heater was dipped into a water bath at a constant velocity. Then, due to the thermal gradient, the residual stress field was generated in the glass plate. This residual stress filed promotes the crack growth placed on the bottom edge of the glass plate. They observed the transition of the crack morphology (e.g., straight, oscillating, and branching) depending on the dipping speed, the size of the glass plate, and the temperature between the heater and the water bath. In spite of many theoretical and numerical studies, the effective explanation for this reproducible controlled crack growth has not been proposed.

In this research, we show the numerical analysis to reproduce the transition of the crack path concerning of this experiment by using the numerical analysis method developing by the authors. According to the implementation technique of the residual stress field to PDS-FEM (Particle Discretization Scheme Finite Element Method), our method can treat the release and redistribution of the residual stress due to failure precisely.
In the numerical analysis, we varied the dipping speed and the temperature between the heater and the water bath. Our result could reproduce the multiple transition of the crack path such as straight, oscillating, and branching depending on the varied parameters. This indicates that proposed numerical analysis method has the ability to capture the crack growth under thermal loading.

Keywords: fracture, thermal loading, numerical analysis, PDSFEM

*Speaker

Stochastic analysis of lattice beam vibrations: discrete and nonlocal approaches

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In this paper, we study the stochastic behavior of some lattice beams, called Hencky bar-chain model and their non-local continuous beam approximations. Hencky bar-chain model is a beam lattice composed of rigid segments, connected by some homogeneous rotational elastic links. In the present stochastic analysis, the stiffness of theses elastic links is treated as a continuous random variable, with given probability density function. The fundamental eigenfrequency of the linear difference eigenvalue problem is also a random variable in this context. The reliability can be defined as the probability that this fundamental frequency is less than an excitation frequency. This reliability index is exactly calculated for the lattice beam on various boundary conditions. An exponential distribution is considered for the random stiffness of the elastic links. The stochastic lattice model is then compared to a stochastic nonlocal beam model, based on the continualization of the difference equation of the lattice model. The efficiency of the nonlocal beam model to approximate the lattice beam model is shown in presence of rotational elastic link randomness. We also compare such stochastic function with the one of a continuous local Euler-Bernoulli beam, with a special emphasis on scale effect in presence of randomness. Scale effect is captured both in deterministic and non-deterministic frameworks.

Keywords: Lattices, Stochastic analysis, Nonlocal continuous models, Hencky, Bar, Chain model, Scale effect, Reliability function

*Speaker

A nonlocal continuum elastoplastic model built from bilinear hardening-softening lattices

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The static behavior of an elastoplastic axial lattice is studied in this paper through both discrete and nonlocal continuum analyses. The elastoplastic lattice system is composed of piecewise linear hardening-softening elastoplastic springs connected between each other via nodes, loaded by concentrated tension forces. This inelastic lattice evolution problem is ruled by some difference equations, which are shown to be equivalent to the finite difference formulation of a continuous elastoplastic bar problem under distributed tension load. Exact solutions of this inelastic discrete problem are obtained from the resolution of this piecewise linear difference equations system. Localization of plastic strain in the most solicited elastoplastic spring is observed in the softening range. A continuous nonlocal elastoplastic theory is then built from the lattice difference equations using a continualization process, based on a rational asymptotic expansion of the associated pseudo-differential operators. This continualization process, associated with a cohesive elastoplastic model, leads to a distributed nonlocal continuous theory capturing efficiently the scale effects of the reference axial lattice. The hardening-softening localization process of the nonlocal elastoplastic continuous model strongly depends on the lattice spacing which controls the size of the nonlocal length scales.
Analogy with the one-dimensional lattice system in bending is also shown. The microstructured beam consisting in the Hencky bar-chain connected by elastoplastic rotational springs explains how the length scale calibration of the nonlocal model strongly depends on the degree of the difference equations of each lattice model (namely axial or bending lattice). These preliminary results valid for one dimensional systems allow possible future developments of new nonlocal elastoplastic models, including two even three dimensional elastoplastic interactions.

Keywords: Lattice, Elastoplasticity, Axial strain, Nonlocal model, Localization, Difference equations.

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The Characterization of Fiber-Reinforced Polymer (FRP) Blast Retrofit Failure Modes

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It is critical that military engineers are able to retrofit existing structures against extreme dynamic loads such as blast. Many studies show that reinforced concrete (RC) structural elements retrofitted with fiber-reinforced polymer (FRP) laminates result in increased strengths and blast resistances. There have been few studies, however, on how large RC systems retrofitted with FRP and mechanical anchors behave when subjected to blast loadings. Four large RC slabs retrofitted with carbon fiber-reinforced polymer (CFRP) and two different mechanical anchorage systems were subjected to blast and blast-like loads. The data from the experimental program were used to conduct a spall analysis which showed that none of the specimens developed fundamental spall. The experimental data were also used to conduct an analysis of the failure mechanisms of the four specimens. It was found that the failure mode development depends highly on the mechanical anchorage system used. A new failure mode, "strap-induced debonding", was discovered and classified.

Keywords: FRP, Blast, Delamination, Spall, Retrofit

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Modeling FSP Impact on Steel Plates Using Numerical Codes

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The Army has a long history of conducting experiments investigating the response of materials subjected to penetration and perforation from different munitions or weapons casing. When operating in urban environments, space is limited and proximity is a disadvantage, hence the penetration of the weapon casing fragments can compromise the structure. The produced fragments can be represented by a fragment simulating projectile (FSP). This investigation examines the structural response of steel plates when impacted by FSP's with striking velocities in the ordnance regime. The ballistic data produced from these experiments will be compared to different numerical codes: Nonlinear Meshfree Analysis Program (NMAP) and Elastic-Plastic Impact Code (EPIC). The accuracy of each numerical code is assessed and validated against the experimental data and the strengths and weakness of each model will be discussed.

Keywords: Projectile Impact, Steel Plates, Constitutive Modeling, Penetration Modeling

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Modélisation tridimensionnelle d'une poutre sandwich en utilisant la théorie exact de Saint-Venant.

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Dans cette communication, nous avons présenté une modélisation tridimensionnelle du comportement mécanique d'une poutre sandwich sollicitée à la flexion simple, en utilisant la théorie des poutres de Saint-Venant (3D) dans laquelle la section est libre de se déformer dans son plan (effets de Poisson) et hors plan (gauchissement). Cette poutre est composée par une couche d'âme isotrope intercalée entre deux peaux isotropes. Les résultats numériques obtenus sont très satisfaisants et prouvent la performance de la modélisation tridimensionnelle.

Keywords: modélisation, poutre sandwich, théorie de Saint, Venant, comportement mécanique, flexion.

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Experimental Investigation of Rupture Propagation in Cohesionless Backfill against a Rigid Retaining Wall Rotating about Its Base

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The construction of earth retaining structure in order to ensure a safe and economic design demands prior knowledge of earth pressure theories and rupture surface development pattern. Experimental investigations pertaining to the propagation of the rupture surface and its shape are scarce. Visualization of rupture planes through horizontal dyed sand strips is a crude process and fails to render accuracy and precision. In this context, an experimental programme is designed to investigate the failure pattern using Particle image velocimetry in a soil backfill supported by a rigid retaining wall when the yielding is imparted by wall rotation about its base. The test is conducted on a 600 mm high retaining wall backing 700 mm long backfill soil with six soil pressure transducers mounted centrally on the wall to record the earth pressure. An open source MATLAB module, GeoPIV_RG facilitating the derivation of full-field displacement of soil media through a series of images acquired behind a transparent window at a chosen interval during any geotechnical model testing is being used for present digital image analysis. The obtained strain contours reveal that the rupture surface is no longer linear as suggested by classical theories rather it is curvilinear in shape. The failure surface extends up to backfill length of $0.33H$ for the active condition at 50% RD. The rupture plane is found to make 74 with a horizontal plane. The test data shows that the pressure tends to decrease as the wall deflects and eventually achieves a stable value at a critical rotation of 1x10-4 radian. The recorded active earth pressure shows a nonlinear distribution with depth.

Keywords: Retaining wall, Backfill, PIV, Rupture plane

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B-Spline based Polynomial Chaos for Stochastic Galerkin Methods

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Random quantities of stochastic systems can be approximated by the polynomial chaos representation by truncating the series expansion. Ordinarily, the basis of these series are orthogonal Hermite polynomials, which can be extended by the Askey scheme of polynomials. In this work, B-spline basis functions are used in the chaos expansion, which are commonly used in isogeometeric analysis. Weak convergence of the B-spline chaos is proven and substantiated by numerical results. Further, several stochastic differential equations are numerically solved by a stochastic Galerkin type approach. It turns out, that the B-spline chaos is a generalization of the Legendre chaos and more efficient.

Keywords: multi element polynomial chaos, stochastic Galerkin projection, Bspline chaos, random field approximation

*Speaker

Stability Analysis of Beck's Column for different foundation

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This article deals with the study of a Beck's column for different types of foundations. External restraints are often represented as bed of elastic independent springs [1] or of linear viscous elements [2]. In the former case the presence of elastic restraints yields the well-known Hermann-Smith paradox [1]. In the latter case,
the viscous external restraints provides, instead, the Ziegler paradox [3].The problem of the stability of the Beck's column was studied by the present authors [4,5], the dynamic stability was studied in the presence of a fractional-order hereditary foundation. The authors, in this study, will deal with the analysis of the dynamic stability of the Beck's column by applying the modified Routh-Hurwitz criterion. The study will be carried out considering in particular the fractional Kelvin-Voigt foundation, fractional Maxwell, fractional Zener. Authors study the cases in which the order of the fractional derivative is rational. The governing equation of column may be obtained in classical form with the equilibrium of a column element. The onset of stability of the Beck's column for each of resting foundation is analyzed hereinafter in non-dimensional form. Stability of the solution of the governing equation can not be inferred by direct inspection and, in such a case, several strategies on the stability of Fractional Differential Equation (FDE) has been proposed. The critical load of the column under the action of a follower load is studied by means of a novel complex transform that allows to use the Routh-Hurwitz theorem in the complex half-plane for the stability analysis. In particular it has been investigated in the details that can be traced to the paradox of Hermann-Smith and Ziegler, continuing to observe also in these cases the validity of the Hermann-Smith and Ziegler paradox. The results have been compared to the ones of Atanackovic who investigated Beck's problem under a different types of foundation. In this regard, a numerical study of the cases examined was carried out.
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Keywords: Beck’s Column, Follower Force, Dynamic Stability, Fractional differential equations

MS20 : Towards the Next Generation of Smart Structures

Life-cycle structural monitoring via temporal point cloud analytics

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There is increasing interest in the use of remotely sensed point cloud data for the monitoring and evaluation of structural systems, across a broad range of domains. These data, which can be generated either through laser scanning or photogrammetric methods, have already been employed for tasks such as construction site monitoring or BIM integration. In the field of system life-cycle monitoring, it is often long-term degradations and changes, as well as the forecasting of future system condition, that are of critical interest to asset managers. In this work, we illustrate how point cloud data can be used in this context to support long-term monitoring and management. A suite of point cloud analytical techniques, designed to capture a range of changes within a structure, is first presented. Three separate but related techniques for the quantification of deformations, volumetric losses, and colorimetric changes will be discussed. These techniques operate on a point-wise basis, rather than an implicitly defined 3D surface, in order to capture the small-scale behaviors necessary for structural analysis. They have also been designed for integration with conventional numerical modeling tools to provide quantitative capacity assessments. We then present an approach for the stochastic process modeling of point cloud evolution that leverages computational geometry to serve as the foundation for predictive maintenance and asset management. Experimental studies validating these approaches are presented as well. The results indicate that the accuracy of this overall approach to point cloud analytics is dependent on the quality of the data, as expected. However, it is also dependent on an understanding of stochastic life-cycle dynamics, pointing to avenues for future efforts.

Keywords: structural health monitoring, computer vision, remote sensing, lifecycle assessment

*Speaker

Autoadaptive System for Liquefaction Prevention

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Liquefaction is an important cause of damage to civil infrastructure during earthquakes. Examples can be found in the collapse of apartment buildings in Niigata, Japan, in 1964, the large damage caused to quay walls in the port of Kobe during the Hyogoken-Nambu earthquake in 1995, the collapse of buildings in Adapazari during the August 1999 earthquake in Turkey and, most recently, the damage to the built environment during the 2011 Christchurch earthquake. Mitigation of liquefaction damage can decrease the loss of lives and economic loss that occur during earthquakes. The introduction of small quantities of bentonite, 3% to 5% by dry mass of soil, into the sand pore space prevents liquefaction, or at least the number of cycles needed to produce liquefaction is measured in the hundreds. Given the duration of most earthquakes, this means that the sand would not liquefy. Even when liquefaction occurs, the soil does not completely lose its shear strength. A residual strength remains, which is interpreted as the result of the changes in the rheological properties of the pore fluid caused by the bentonite. As excess pore pressures dissipate after the liquefaction event, the soil "heals" itself and shows behavior under cyclic loading similar to the pre-liquefied soil. Results obtained in resonant column tests indicate that the presence of bentonite increases the linear threshold of the treated sand and thus delays to higher strains the development of excess pore pressures produced by repeated loading. Since the amounts of bentonite added are small, the static strength and stiffness of the soil are not much affected. This constitutes an example of an autoadaptive passive system where the soil adapts by changing its behavior when unexpected or extreme events occur, while maintaining its engineering properties during normal working conditions. Because bentonite particles are electrically charged, particle interactions can be modified chemically. The addition of 0.1% to 1%, by clay mass, of sodium pyrophosphate, reduces the viscosity of the bentonite dispersions to values very close to that of water, allowing delivery of the bentonite into the sand matrix through permeation. Over time, the bentonite slurry recovers its thixotropic properties. The method has significant practical applications to mitigate liquefaction effects at earthquake-vulnerable sites with minimal disturbance to the ground, and thus it may be most appropriate at locations with built infrastructure.

Keywords: Autoadaptive, liquefaction, betonite, permeation

*Speaker

Game theory vibration control methodology for resilient civil structures

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The protection of civil structures in the face of natural disasters requires innovative risk mitigation strategies. Seismic events are unpredictable and present a major threat to buildings and bridge structures. To overcome this problem, the latest solution is the development of smart structures. Smart structures have technology installed to mitigate the damage from the excessive vibrations. The goal is to design a new generation of smart structures equipped with sensors and control devices that can react in real-time during an earthquake. Structural control methods have been subject of significant research, yet they still face limitations that this research overcomes by introducing the concepts of decentralized control, agent technology, and replicator dynamics. Recently, three ideas were introduced for vibration control of smart structures: agent technology, evolutionary game theory, and decentralized vibration control. Two control algorithms are presented: 1) a single-agent Centralized Replicator Controller (CRC) and a decentralized Multi-Agent Replicator Controller (MARC) for real-time vibration control of smart structures. The use of agents and a decentralized approach enhances the robustness of the entire vibration control system. The proposed control methodologies are applied to vibration control of a 3-story steel frame and a 20-story steel benchmark structure subjected to two sets of seismic loadings: historic earthquake accelerograms and artificial earthquakes and compared with the corresponding centralized and decentralized conventional control algorithms. The aforementioned control algorithms are integrated with a multi-objective optimization algorithm in order to find Pareto optimal values for replicator dynamics parameters with the goal of achieving maximum structural performance with minimum energy consumption. A patented neural dynamic model is used to solve the multi-objective optimization problem. Vibration control of irregular structures subjected to earthquake excitations is a complex civil engineering problem with associated torsional vibrations. The methodology was further adapted for active/semi-active control of multi-story irregular base-isolated structures. The control algorithm is evaluated using a 3D base-isolated benchmark structure subjected to major historical earthquakes. Additionally, the idea of combining the conventional base isolation with an active or semi-active control system was also investigated to create smart bridge structures. A novel control algorithm based on game theory and replicator dynamics is employed for hybrid vibration control of highway bridge structures equipped with both a passive isolation system and semi-active control devices subjected to earthquake loadings. The efficacy of the model is demonstrated by application to a benchmark example based on interstate 91/5 overcrossing highway bridge in southern California subjected to near-field historical earthquake excitations. Substantial reduction in both mid-span displacement and deck acceleration is achieved compared with the conventional base-isolated bridge.

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Keywords: Smart Structures, Earthquake, Vibration, Bridge.

MS22 : Robustness of Infrastructures

Formal Concept Analysis for Predictive Modeling and Sustainable Infrastructures

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The construction industry has been estimated to account for about 40% of the global energy consumption and also impact the environment adversely making the improvement in the sustainability of geotechnical processes extremely important. Failures in any of the critical infrastructure components can initiate complete or partial loss of functionality of other related structures and systems and can severely impact the social and economic infrastructure of any country. It is impossible to design engineering systems that are foolproof against all possible threats hence it is necessary to ensure that the systems are inherently capable of bouncing back to its functionality irrespective of the nature or magnitude of shock or distress it is subjected to and thus is resilient.
Geosciences research aims to understand the Earth as a system of complex highly interactive natural processes and their interactions with human activities representing data and models as a "system of systems". One of the major shortcomings currently is the disparate data and models across disciplines. Scientists have been collecting data at varied times in varied places and results are part of separate repositories and often making the wide-area analyses extremely difficult. Our predictive modeling for sustainability depends on the ability to understand the Earth system which in turns depends on the integrated geoscience models across time, space, and discipline. Extreme events and long-term shifts in Earth systems challenge further where the data available is intermittent, has significant sources of uncertainty, and is very sparse.

Advances in intelligent systems have led to robust sensing environments, effective information integration, and intelligent interactive environments based on the big-data analytics techniques. The approach needed has to leverage the advances in data-driven research with domain knowledge models and scientific principles that govern the phenomena under study. This paper proposes Formal Concept Analysis (FCA) for scientifically accurate concept mappings across domains and corresponding knowledge graphs. Scientific knowledge comes in many forms and representations: hypotheses, models, theories, equations, assumptions, data characterizations, and others. It should be possible to translate knowledge seamlessly as needed from one representation to another and the system to be adaptive synching with the continuously updated scientific knowledge.

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Current machine learning methods are not very effective for many geoscience problems considering unavailability of the large training dataset(s). FCA incorporates knowledge about geosciences processes and uses a 'Concept Lattice' that is based on a set-theoretical model for concepts and conceptual hierarchies. It can be used effectively for creating the data-driven models as well as process based simulation models to provide reasonable prediction results.
Machine learning evaluation methodology relies heavily on well-defined standards and benchmark datasets with ground truth labels which are difficult to get in geosciences. FCA may lead to a knowledge-rich and context-aware recommender system. The vast majority of geosciences research products is geospatially localized and with temporal references. Geospatial information can be easily attributed using concept lattices which otherwise requires specialized interfaces and data management approaches.

Keywords: Predictive Modeling, Sustainability, Formal Concept Analysis

Development of analytical framework for objective resilience of corroded steel bridges

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An essential component of community resilience management is the evaluation of its infrastructure. In the framework of resilience estimation, the physical deterioration of the assets should be carefully considered, since American infrastructure is classified in poor to fair condition, with many of its elements approaching the end of their service life (ASCE 2017). The existing damage and deteriorating conditions act as a source of uncertainty and may promote an overly optimistic pre-hazardous resilience network estimation. This work provides an effective tool for functionality assessment of deteriorated steel bridges under normal loading conditions. The proposed methodology emerges from real corrosion data. Initially the current deterioration condition of steel bridges was explicitly studied through MassDOT inspection reports of structures that had experienced beam end corrosion. The analytical model was validated using experimental data obtained from full scale loading tests on beams with natural corrosion. The use of the proposed methodology eliminates the practitioners need for detailed finite element analyses and introduces a useful tool for objective resilience. This tool can assist in improving both failure prognosis and decision making on rehabilitation and upgrades to steel bridges, thus preventing larger consequences for the transportation network.

Keywords: progressive collapse, resilience, stability

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Stochastic Prediction of the Corrosion Propagation Rate in Reinforced Concrete Structures Using Experimental Data

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This study presents a probabilistic framework for accurate prediction of the corrosion propagation rate in reinforced concrete (RC) structures. The presented framework uses the Ensemble Kalman Filter (EnKF) coupled with easily acquired measurements of corrosive crack widths and mid-span deflection increases for identifying and calibrating corrosion propagation models. The calibrated models are consequently used to forecast the extent of corrosion propagation in RC structures. To assess the efficacy of the presented framework, data corresponding to the long-term chloride-induced corrosion experiments initiated in 1984 at "Laboratoire des Materiaux et Durabilite des Constructions" (L.M.D.C.) in Toulouse, south-west France are used. The results accentuate the robustness of the presented EnKF approach by being able to identify and calibrate candidate corrosion propagation models capable of predicting, with reasonable accuracy, the experimental measurements of corrosive crack width and mid-span deflection in RC members.

Keywords: Corrosion propagation rate, Reinforced concrete, Ensemble Kalman Filter, Data assimilation, Uncertainty quantification.

*Speaker

Research on corrosion for the inside of concrete sewer pipelines

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As a part of essential urban infrastructure, sewer pipelines are also powerful guarantee and backing for the healthy development of urban economy. At present, concrete sewer pipeline is widely used owing to its good corrosion resistance, high bearing capacity and being suitable for large diameter. However, with the increase of the service life, hydrogen sulfide induced by microorganisms in sewage can be absorbed by the pipe wall above the sewage liquid level, and further oxidized into sulfuric acid by sulphide oxidizing bacteria. Sulfuric acid can react with concrete. Therefore, corrosion is produced and further affects the usability and safety of the pipelines. In this paper, the corrosion mechanism and corrosion model of concrete sewer pipelines were studied. Different corrosion models were used to predict the actual corrosion depth of concrete pipe. A universal prediction model was selected by comparing the predicted results with the measured results. COMSOL MULTIPHYSICS software was used to simulate the corrosion of pipeline. The simulation results can predict the corrosion depth of concrete pipe wall. The mechanical behavior of the pipeline was analyzed by taking into account the corrosion depth of concrete. The predicted model of the service life of the concrete sewer pipeline was established.

Keywords: corrosion, concrete sewer pipeline, predicted model, service life

*Speaker

Model for Structural Robustness

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The possibility of a local structural failure to propagate into a global collapse of the structural system has fueled the continued development of improved computational methods to model building behavior. In spite of these efforts, recent events are bringing the issue of collapse mitigation to the forefront and highlighting the shortcomings of existing design practices. The catastrophic nature of structural collapse dictates the need for more reliable methodologies to quantify the likelihood of structural failures and strategies to minimize potential consequences. Focusing largely on the correlation between building configuration and robustness, this paper investigates the extent to which a given structural system results in volumetric changes in internal member forces resulting from initial system perturbations based on stochastic approach. The conclusions of this investigation highlight structural "goodness" in geometric terms and rate system robustness and the extent to which desired robustness can be achieved. To demonstrate the proposed approach, we study four different moment-frame structural configurations to determine the relative quality of each system's configuration. Finally, recommendations are made as to how to quantify the quality of geometry and structural robustness in terms of uncertainty in the initial conditions defining the collapse event.

Keywords: Structral Robustness, Progressive Collapse, Infrastructure, Buildings

*Speaker

Impact of early age damage on the seismic vulnerability of reinforced concrete structures

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Reinforced concrete damage over time can cause severe structural problems (e.g. Morandi Bridge in Italy [1]). Many factors contribute to concrete deterioration (Thermal conditions, chemical attacks, shrinkage, creep, carbonatation, corrosion,etc.) [2]. Reinforced concrete deterioration starts at early-age and continues with structure aging. Early-age shrinkage, creep and thermal conditions or initial cracks can have a significant impact on the dynamic behavior of concrete structures. As shown in [3], the natural frequency of a beam subjected to early-age restrained shrinkage is highly affected. In order to quantify the impact of early-age concrete damage on the dynamic behavior of structures, a research project combining both numerical modeling and pseudo-dynamic tests on two groups of reinforced concrete portal frames is undergoing. The first group is a reference group kept in endogenous conditions during its early age period in a way to limit drying effects leading to cracks while the second group is kept in non-endogenous conditions similar to construction site conditions, which induces damage. The present talk focuses on the enhanced multifiber beam model developed for the portal frames and that allows describing their behavior when subjected to a seismic loading while taking into account their initial damage due to early age effects. In this numerical model, concrete shrinkage and thermal deformation are calculated independently using a THC 3D model [4] , while creep is described by a series of three Kelving-Voigt models [5] and calculated using strain superposition in series with concrete μ Damage model [3]. Then values are implemented into a multifiber finite element model. Damage evolution of the RC structures over time is followed using the numerical model during 28 days and then their dynamic response when subjected to a seismic event is simulated numerically.

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Keywords: Early age, pseudo, dynamic, damage, concrete, vulnerabiliy, earthquake

Deep Learning for Fast Seismic Reliability Analysis of Bridge Networks

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In order to optimize mitigation, response, and recovery procedures for bridge networks exposed to major seismic hazards, it is essential to use accurate and efficient means to evaluate system reliability against a variety of possibilities. The predominant approach to quantify the impact of a probabilistic seismic event on a bridge network remains to be the Monte Carlo approach, which significantly suffer from high computational cost, especially when applied to large systems. We will present a deep learning framework for accelerating seismic reliability analysis on a transportation network case study. Two distinct deep neural network surrogates are constructed and studied: (1) A classifier surrogate which speeds up the connectivity determination of networks, and (2) An end-to-end surrogate that replaces modules such as roadway status realization, connectivity determination, and connectivity averaging. Numerical results from k-terminal connectivity analysis of a California transportation network subject to a probabilistic earthquake event demonstrate the effectiveness of the proposed approach.

Keywords: Deep learning, bridge networks, reliability analysis, seismic events

*Speaker

Experimental Quantification of the Robustness of Suspension Bridge Cables using Neutron Diffraction

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We present results and subsequent modeling work from a number of experiments performed at the Los Alamos and Oak Ridge National Lab neutron beam sources aimed to investigate the robustness of suspension bridge cables to individual wire fracture, as commonly caused by pitting corrosion, embrittlement, local material flaws, and fretting. We experimentally quantify the redistribution of service stresses in the case of wire fracture within a cable under tension load by considering both the distribution of confinement forces – a consequence of wire wrapping, compaction straps, and cable clamps – and the friction transfer mechanisms between various wires in the strand. Our results show that the internal mechanics of parallel wire cables are highly heterogeneous and not easily defined by prescribed smooth distributions. The forces within each wire depend heavily on the micro-scale dimensional variations and the resulting local contact mechanics within the packing regime. We aim to use these experimental data to generate and tune rigorous companion finite-element models and quantify stochastically the internal mechanics of parallel wire bridge cables and assess the resulting collapse risk of a damaged cable.

Keywords: Internal mechanics, parallelized systems, friction, contact, neutron diffraction, robustness, progressive collapse

*Speaker

Effects of Geometrical Properties and Galvanizing Practices on High-Mast Illumination Pole Demands During Galvanizing Process

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Cracks that develop during galvanizing at the pole-to-base plate connection of High Mast Illumination Poles (HMIPs) are a major source of concern to fabricators and highway officials in the United States. Due to life-safety concerns, substantial resources are spent performing detailed inspections of welded connections, and financial losses are incurred every time a damaged connection is found. One of the most important causes of connection damage are thermally-induced deformations during the galvanizing process. A study was performed to evaluate the effects of HMIP geometric configuration and galvanizing practice on the critical stress and strain demands during galvanizing. HMIP configurations evaluated in the study had pole shapes, dimensions, and pole-to-base plate connection detailing used in the state of Texas. The main geometric parameters of the study were base plate thickness, pole shaft wall thickness, and number of pole sides. Galvanizing practice variables encompassed dwell time, speed and angle of dipping, and cross-section orientation. Finite element models of pole-base plate assemblies were subjected to a temperature field representative of the galvanizing process and analyzed using coupled thermo-mechanical analysis. Deformations were computed while varying the position of the pole-base plate assemblies through a fixed-location temperature field, following a path that simulated four stages of the hot-dip galvanizing procedure: dipping, dwelling, extraction, and cooling. Results from the analyses showed that HMIP configuration had a significant effect on strain and stress demands during the simulated galvanizing process. Stress and strain demands were highest at locations near the pole-to-base plate connection. In models with the same pole thickness, smaller ratios of pole-to-base plate thickness corresponded to lower stress and strain demands at critical locations. In models with the same base plate thickness, stress and strain demands were inversely proportional to pole thickness, with stresses for 7.9 mm (5/16 in.) thick poles being higher than stresses for 12.7 mm (1/2 in.) thick poles. Stress and strain demands were found to be lower for poles having a circular shape than for multi-sided poles. Increase of bend radius led to reductions in localized strain demands. Dwell time was found to have

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an insignificant effect on stress and strain demands, while increased dipping angle and dipping speed resulted in decreased stress and strain demands during galvanizing.

Keywords: Thermal stress and strain, cracking, hot, dip galvanizing, steel structures, finite element analysis, highway structures

MS23 : Shell Buckling

Imperfection-insensitive thin wavy cylindrical shells under bending: Effect of local radius of curvature on buckling and imperfection-sensitivity

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The imperfection-sensitivity of thin cylindrical shells has long been an obstacle for their optimal applications. To nullify this behavior, a conservative knock-down factor method is utilized for the design of thin cylindrical shells. Alternatively, stiffeners are also used to increase their capacity and to reduce the imperfection-sensitivity. We explore wavy cross-sectional thin cylindrical shells under bending to investigate the impact of imperfections on their load carrying capacity. We found that thin wavy cylindrical shells are insensitive to imperfections under bending in contrast to thin circular cylinders. This insensitivity is achieved by reducing the local radius of curvature and consequently, the effective radius of the cylindrical shell is reduced. This way cylindrical shells become less sensitive to imperfections and increase their load carrying capacity.

Keywords: Stability

*Speaker

On Establishing Buckling Knockdowns for Imperfection-Sensitive Shell Structures

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This presentation contributes to recent efforts aiming to revise long-standing knock-down factors for elastic shell buckling, which are widely regarded as overly conservative for well-constructed shells. The presented work focuses on cylindrical shells under axial compression with emphasis on the role of local geometric dimple imperfections and the use of lateral force probes as surrogate imperfections. Two buckling thresholds are identified (local and global buckling) and related for the two kinds of imperfections. Four sets of relevant boundary conditions are accounted revealing a strong dependence of the global buckling load on overall end-rotation constraint when local buckling precedes global buckling. A reasonably complete picture emerges, which should be useful for informing decisions on establishing knockdown factors.

Keywords: Stability

*Speaker

A nomogram for 2nd order tensor principal values and invariants space

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The second order tensors, such as, stress, strain, moment of inertia tensors are fundamental tensors of engineering mechanics .and plays important role in design and analysis of engineering structures. They can be geometrically represented in 3-D Euclidean space via its 3 invariants . The reduced order second order tensors for plane problems can also be represented on 2-D by their first and second and invariants. Real solutions of the principal values of these tensors can be checked by the discriminant of the characteristic equation of the first and second order tensors. Not all, but certain combinations of the invariants satisfy real roots of the characteristic equation. The regional space of invariants satisfying the real roots can be visualized and shown by 3-D surface and contour plots. Normalized discriminant of the characteristic equation reduce the independent normalized coordinates into two and simplifies the geometry of the space. The principal values of the tensor can be found graphically by using the contour graph of the principal values. This graph can be used as a monograph to help finding the principal values of the any second order tensors by engineering students and engineers. The failure theories of materials can also be expressed in terms of invariants concept. This study is further mathematical investigation of principal values and their geometrical interpretation by means of graphical visualization

Keywords: Tensors, principal values, tensor invariants, nomogram

*Speaker

MS24 : Vibration Control of Structures Under Multiple Hazards

The Performance of the Passive Tuned Mass Dampers for Response Control of Tall Buildings while Subjected Multi-Hazard Loads

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This study presents performace of passive tuned mass dampers (TMDs) to reduce dynamic response of tall buildings under multiple excitations such as wind and earthquake ground motion. A model of a typical tall building is prepared with rotational degrees of freedom reduced by static condensation. The governing equations of motion are formulated and solved using numerical methods. The uncontrolled building (NC) and the controlled building are subjected to a number of artificial earthquake ground motions and random wind forces. The effectiveness of using multiple TMDs as opposed to a single TMD (STMD) is investigated. It is observed that STMD is more effective for wind response mitigation than seismic response mitigation of tall buildings. Multiple TMDs are, however, found to be effective for controlling both wind and earthquake induced vibrations. The robustness of the multiple TMDs are significantly higher than the the STMD, by considering the uncertainty in the paramter of the tall building. The mulitple TMDs designed to control the response of the buildings under the seismic loading may not be that much effective for wind response control of buildings, but not vica versa.

Keywords: vibration control, wind, seismic hazards

*Speaker

Behavior of a Moveable Barrier with a Triangular Shape for Securing Safe Port City Under Wave Overtopping

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With the development of a port city, citizens are likely to enjoy various activities around waterfront, which requires facilities to safeguard people against occurrence of coastal disasters. In the case of Busan Port in Korea, which is being reborn as a world-class brand in maritime tourism, and also performs a role as a mega hub of shipping logistics in Northeast Asia by handling 21.5 million TEU in 2018, Abnormal tidal rise or wave overtopping by storm surge can cause huge damage or casualties at largely-developed port hinterlands or residential amenities. Hence, it is urgent to establish countermeasures to those regions. Particularly, a resilience strategy based on the waterfront space where is most vulnerable to climate change, is required to cope with the abnormal climate beyond the conventional planning. Various barrier design concepts have been suggested to protect property and human life from disasters, they have not been widely applied though. Because they do not satisfy the recent trends that emphasize the surrounding scenery. In this study, we proposed a conceptual design of a moveable barrier with a triangular shape that is installed on a revetment considering technological and social meaning against wave overtopping. That is, it has two main functions, sightseeing and protecting. In case of normal times, it can utilize the barrier plate as an observatory flat deck for sightseeing and secure the right to a view to the sea in normal state. Meanwhile, at the time of the occurrence of wave overtopping or the forecasting, an operation work for standing up starts and that means an abnormal state. It can stand up in a triangular shape to prevent wave overtopping by abnormal storm surge using a winch cable mechanically. Then, when the abnormal state that may cause the wave overtopping is terminated, rotation of the winch reduces the cable tension so that the movable barrier system slowly returns to its original shape due to its own weight. This system mainly consists of front and rear plates, guided rails to maintain the shape of the barrier according to the movement of roller, a fixed pier for the seaside part. Numerical analysis and physical experiment were carried out to understand the fundamental structural and hydraulic performance of the barrier and to calculate the wave pressure acting on the front plate. This pressure time series derived from these tests were applied to the completed standing-up barrier to analyze the structural performance. The stress distribution of the barrier model during the standing-up operation and the behavior of the barrier at the wave-overtopping operation after standing-up were conducted through structural analysis that it exerts excellent performance. However, there remains a need to consider that a proper design method for supporting the hinge and the roller frame in the future. Further research will be pursued to develop the moveable barrier system based on more sophisticated working mechanism.

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Keywords: Moveable Barrier, Wave Overtopping, Disaster, Storm surge

ISOLATED FLOORS FOR NEAR DAMAGE-FREE PERFORMANCE OF BUILDINGS UNDER MULTIPLE HAZARDS

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Performance requirements of structures subjected to multiple hazards, acting simultaneously or spatially over time, may significantly increase the potential for substantial damage, collapse, and economic and life losses. In addition, performance-based engineering has recently evolved from its basic concept of defining performance objectives to prevent structural collapse, with acceptable high level of damage, to minimizing structural loss without compromising on performance. Therefore, it is necessary to create new structural systems that satisfy higher performance goals for multiple hazards and can be easily repaired, with minimal cost, after major events. This requires the utilization of new structural systems and the development of effective optimization methods that can address multiple hazards. In this study, two new floor isolation systems will be introduced. Acting as tune mass dampers, the isolated floors in a given building are utilized to mitigate the building's own response. The response mitigation is realized through the utilization of a new combinatorial optimization approach to simultaneously optimize key design variables of isolated floors to obtain a family of optimal solutions that can accommodate varying level of participation of earthquake and wind hazard. In doing so, a set of alternatives is provided to the designer to accommodate wide variations and combinations in hazards intensities. The results of the study highlight the effectiveness of tuning the selected floors to meet the wind and seismic performance objectives.

Keywords: Floor isolation, Replaceable Elements, Damage Free, Multiple Hazards

*Speaker

Optimization and application of Prominent Tuned Mass Damper

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Since the development of Tuned Mass Damper (TMD), the core of its vibration control has not changed, which means that the effect of vibration reduction is limited by the relative displacement of the primary structure and the subsidiary structure. In order for TMDs to be effective to reduce structural vibration subjected to earthquake excitations, large mass ratios must be used, but this in turn affects the safety of the initial structure. In order to improve this shortcoming, an improved TMD which is inspired by the accelerated oscillator damper (AOD), called Prominent Tuned Mass Damper (Pro-TMD), has been proposed in this paper. An accelerated transmission is installed between the primary structure and the spring of secondary mass to drive the appended spring and mass at larger speed. The optimal solution of Pro-TMD in the case of primary structure without damping is derived. The results show that optimal solution of Pro-TMD structure is similar to traditional TMD. In addition, Pro-TMD is applied to the actual bridge models using different seismic wave loadings. By comparing with TMD, it can be found that the damping effect of TMD is not obvious and may cause reverse effects; while the effect of Pro-TMD is very obvious, it can show certain effects even under adverse earthquakes.

Keywords: Pro, TMD, vibration control, AOD, optimization

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Application of Viscous Fluid Dampers to Rehabilitate Structural Vibrations

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Viscous fluid dampers can be easily applied on model structures. The forced compression of silicon fluid in a piston dampens internal forces and displacements in large quantities. In this study, the location of dampers in terms of quantity and their application on different floors were experimentally investigated in a four-story model structure. The available dampers are initially placed uniformly on the floors, then they are concentrated on certain floors. Undampered, uniformly dampered and other damper designs have been experimentally tested under harmonic loads. The applications of designed damping systems and the experimental results obtained are presented comparatively. Suggestions are made and performance evaluations are carried out based on the results of this study. The most suitable locations of viscous fluid damping systems are determined in the light of the experimental data obtained.

Keywords: Structural vibration, rehabilitation, fluid viscous damper, experimental study

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EFFECTS OF TUNED LIQUID COLUMN DAMPER PROPERTIES ON THE DYNAMIC RESPONSE OF STRUCTURES

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In this study, the effects of liquid heights and viscosity of the liquid contained in tuned liquid column dampers (TLCD) on dynamic behavior of the structural model under harmonic loads were investigated experimentally. In the laboratory experiments, three liquids with different viscosities were used inside the TLCD. Furthermore, the effect of four different liquid heights on dynamic behavior was investigated for each type of liquid. Vibration tests performed only under harmonic load effects were conducted on a reduced 3-story model structure and the frequency of external load effect was adjusted to the fundamental (first) frequency of the building model. In the case of a fixed amplitude harmonic load application, displacements at the floor levels and the change of acceleration values at the top floor level were investigated. It is observed that as the viscosity of the liquids increased, their damping effect decreased. According to the comparisons made between four different liquid heights, as the liquid heights decreased down to a certain value, it was determined that displacements of the structure at the floor levels and the acceleration at the top floor decreased. Experiments have shown that all TLCD models reduced the dynamic behavior of the structure, while the viscosity and height of the liquid used were observed to contribute significantly to better reduction of the dynamic behavior.

Keywords: Tuned Liquid Column Damper, viscosity, liquid height, dynamic response

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Simulation of liquid sloshing in U-shaped containers as dampers in high-rise buildings

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The focus of the present study is on the understanding of efficacy of U-shaped containers to be used as a liquid damper in a high-rise building system. An experimental study was undertaken with a U-shaped container to understand the liquid sloshing effect through a series of free and forced vibration tests. The time history of the free surface motion was recorded using high speed camera and relevant data were captured. As carrying out experiments for different scenario is a difficult proposition, it was felt necessary to develop a numerical simulation model to understand the sloshing behaviour of the liquid, contained in a U-shaped container. As an initial step towards it, three-dimensional (3D) numerical model is developed to observe the liquid sloshing phenomenon and its effects on U-shaped containers. To simulate the 3D incompressible two phase (air and water) flow in a partially filled container, the volume of fluid method (VOF) is implemented in a computational fluid dynamics (CFD) code, solving the Reynolds-Averaged Navier-Stokes (RANS) equations on ANSYS (FLUENT) platform. Two equation turbulence model (k-epsilon) is used specially to investigate the effects of turbulence on the numerical results. The numerical results thus obtained are compared with the experimental ones which show the efficacy of the algorithm.

Keywords: U shaped containers, liquid damper, liquid sloshing, volume of fluid method, computational fluid dynamics, turbulence modelling

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Reliability of a Base-Isolated Building under Earthquake, Wind Excitation and Blast-Induced Ground Motion

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During the service life of a building, it experiences multiple hazards, which include earthquakes, wind excitations and sometimes blast-induced ground motions. Reliability of the passive vibration response control technique, the seismic base isolation of a reinforced concrete (RC) building is assessed here. A numerical model is developed for the base-isolated building and it is independently analysed under earthquake, wind excitation and blast-induced ground motion by conducting nonlinear dynamic time history analysis. The dynamic response quantities such as inter-storey drift, storey shear, floor acceleration and displacement are determined against the multi-hazard scenarios. Limit states for collapse and serviceability are considered under the multiple hazards and reliability of a base-isolated building is evaluated. It is inferred from the obtained results that the vibration response control achieved from the base isolation system employed in the RC building varies significantly with the type of excitation. It calls for a need to optimise the parameters of the base isolation system such that during the service life of the building it provides reliable performance under multi-hazard scenarios.

Keywords: Base, Isolated, Building, Blast, Induced, Earthquake, Ground Motion, Reliability, Wind Excitation

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Extreme Storm Surge Return Period Prediction Using Tidal Gauge Data and Estimation of Damage to Structures from Storm-Induced Wind Speed in South Korea

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Global warming, which is one of the most serious consequence of climate change, can be expected to have different effects on the atmosphere, the ocean, icebergs, etc. Global warming has also brought secondary consequences into nature and human society directly. The most negative effect among the several effects of global warming is the rising sea level related to the large typhoons which can cause flooding on low-level land, coastal invasion, sea water flow into rivers and underground water, rising river level, and fluctuation of sea tides. It is crucial to recognize surge level and its return period more accurately to prevent loss of human life and property damage caused by typhoons.
This study researches two topics. The first purpose of this study is to develop a statistical model to predict the return period of the storm surge water related to typhoon Maemi, 2003 in South Korea. To estimate the return period of the typhoon, Clustered Separated Peaks over Threshold (CSPS) has been used and Weibull distribution is used for the peak storm surge height's fitting. The estimated return period of typhoon Maemi's peak total water level is 389.11 years (95% confidence interval 342.27 - 476.2 years).

The second aim is related to the fragility curves with the loss data caused by typhoons. Although previous studies have developed various methods to mitigate damages from typhoons, the extent of financial loss has not been investigated enough. In this research, an insurance company provides their loss data caused by the wind speed of typhoon Maemi in 2003. The loss data is very important in evaluating the extent of the damages. In this study, the damage ratio in the loss dataset has been used as the main indicator to investigate the extent of the damages. The damage ratio is calculated by dividing the direct loss by the insured amount.
In addition, this study investigates the fragility curves of properties to estimate the damage from typhoon Maemi in 2003. The damage ratios and storm induced wind speeds are used as the main factor for constructing fragility curves to predict the levels of damage of the properties. The Geographical Information System (GIS) has been applied to produce properties' spatial wind speeds from the typhoon. With the damage ratios, wind speeds and GIS spatial data, this study constructs the fragility curves with four different damage states (Level I - Level IV). The findings and results of this study can be basic new references for governments, the engineering industry, and the insurance industry to develop new polices and strategies to cope with climate change.

*Speaker

Keywords: Hurricane, Typhoon, Risk mitigation

An effective controller-observer technique in digital domain for vibration control of structures

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This study presents an effective control algorithm with observer technique for semi-active control of structures with Magneto-rheological (MR) damper. The proposed control strategy is based on servo-mechanism (also known as command-following or tracking system), where measured output of a system tracks the command of reference input. In this case, the feedback to the system in each step is proportional to the sensed error (i.e., difference between output and reference input) such that output response converges to command input as time approaches infinity (i.e., at steady state). Present study formulates this mechanism through a PI controller, where the control force is proportional to the feedback of state (i.e., displacement and velocity) as well as integral state (i.e., integral of error signal) of the system. Optimal gain of the regulator (i.e., both proportional and integrator gain) is calculated by minimizing a desired performance index. Two cases are considered in this study to formulate the quadratic cost function of the performance index, which involves: Case 1 - state and control force, and Case 2 - output and control force. In addition, optimal observer technique through Kalman filter is used to estimate full state vector for feedback from the measured absolute acceleration output. The aforementioned controller-observer system is formulated in discrete time (digital domain) and has many advantages over its analog counterpart. The continuous time signal from the sensor output is converted to step-wise signal by the well-known sample and hold concept. A numerical simulation of the proposed approach is performed on an eight-storey shear building. Optimal damper locations corresponding to the first three modes of the structure (having total mass participation factor $> 95\%$) are obtained from modal controllability method and MR dampers are placed at those locations (first, fourth and sixth floor). The integral of error in the measured displacement of first, fourth and sixth floor is used to define the integral state for the PI controller. For demonstration purpose of the proposed approach, two near field ground motions are considered. In this approach, applied voltage/current to the MR dampers is chosen in such a manner that the damper force for each damper becomes equal to its corresponding optimal control force at each time instant. Finally, the effectiveness of the proposed method is compared with no-damper, passive-off (applied voltage - 0 Volts) and passive-on (applied voltage – maximum capacity) case. These comparisons are performed in terms of reduction in: (a) structural responses (i.e., peak acceleration, displacement and IDR of each floor), (b) optimal control force, (c) sensor noise and process noise covariance of the filter output, and (d) applied voltage (as compared to clipped optimal case). It has been demonstrated in this study that

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the proposed control algorithm provides superior performance and stability in comparison to conventional techniques.

Keywords: Servomechanism, vibration control, PI controller, Multi hazard scenario, Kalman filter

Influence of Adhesive Tape on Damping Behavior of Cantilever CFRP Composite Tubes

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The amplification in vibration is a major cause of concern in many engineering and industrial fields when subjected to dynamic loads such as wind, wave and earthquakes. In order to control such vibrations, various methods have been adopted so far including damping treatments depending on applications. To reduce the undesirable vibration and the noise levels, one such way of the damping treatment (without increasing the overall mass) is the use of adhesive/damping tapes on components, as observed in aircrafts' fuselage and many other applications. However, as per the authors' knowledge, no systematic studies are available in the literature on these important aspects. This study focuses on increasing the damping ratio of the fundamental mode of a cantilever CFRP composite member through the use of adhesive tapes. For this purpose, free vibration and shake table experiments are performed on a woven CFRP composite square tube. The tube is subjected to base excitation with varying displacement amplitudes. Accelerometers are attached at the different locations along the tube length and on the table to record the tube responses and the table motion, respectively. These responses are recorded using the National Instrument Data acquisition system (NI-DAQ) and LabVIEW software. Different types of 3M damping tapes are used during the testing (https://www.3m.com/3M/). To optimize the effective location and optimum length of damping tapes, the tests are performed for two different scenarios: (a) tapes of continuous length are applied on both sides of the tube and (b) tapes are discretized into several small elements and applied at different positions along the tube length. The vibration characteristics of the tube such as natural frequency, mode shape and damping ratio of the fundamental mode are evaluated. To understand the beneficial effect of damping tape, tests are performed on tubes (with and without the damping tapes). It is observed from this study that (i) the damping ratio increases significantly in the constrained tubes (i.e., with damping tape) as compared to the unconstrained tube (i.e., without damping tape) and (ii) there is a nominal effect on the fundamental frequency due to tape. Based on these results, a simplified formula is presented for damping enhancement.

Keywords: CFRP composite, Adhesive tape, Damping behavior, Multi hazard scenario, Base excitation

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MS25 : Current Challenges in Multiscale Mechanics - From Materials to Structures

Analytical and numerical mechanical modelling of composites containing expansive inclusions

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A prediction of the effective mechanical properties of heterogeneous microstructures resulting from nuclear waste cementation processes is presented. These heterogeneous microstructures contain an important volume of low-and-intermediate-level radioactivity and long-lived wastes, such as reactive metal inclusions (uranium, magnesium, and aluminum), and other types of inert inclusions (graphite). However, the presence of free-water in the cement matrix pores may cause corrosion of reactive metal inclusions, and progressive formation of an expansive metal oxide (corrosion product) layer around the metal inclusion accompanied with a significant release of hydrogen gas. The thickness of the developed corrosion product layer can be important with respect to the metal inclusion, which may lead to high stress/strain levels due to a high expansion factor between the oxide and the initial metal. These internal expansions are able to generate microcracking in the cement matrix, and at long term to affect the integrity of the waste containers. Two models are generally used to represent the corrosion product layer when the thickness remains relatively small: (a) Interface model between the metal inclusion and the matrix, (b) Interphase model which describes explicitly the corrosion products as a layer. A predictive model is developed to estimate the effective properties (bulk/shear modulus and interaction coefficient) of the heterogeneous structures including spherical inclusions surrounded by a corrosion product layer embedded in a matrix and subjected to a pure dilatation/shear at infinity. The macroscopic effects of the expansive corrosion products layers are reproduced through the interaction coefficient determined by means of a thermoelasticity analogy. Thereafter, the use of differential scheme allows to extend the developed model to different types of inclusions, both homogeneous and composite, and high volume fraction. At convergence, the developed model shows a good agreement with other analytical models (Generalized-Self-Consistent-method, Mori-Tanaka and interface models). Finally, numerical 3D simulations are performed to determine the effective properties of representative elementary volumes generated numerically for different volume fractions and inclusion shapes, by imposing boundary conditions such as homogeneous strains and homogeneous stresses. A comparison between numerical and analytical results shows a good agreement, which confirms the interest of the model.

Keywords: Differential scheme, composite inclusions, internal expansion, cementitious materials,

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numerical 3D simulation

MULTI-SCALE MODELING OF EVOLVING FIBER CONFIGURATIONS: APPLICATION TO ARTERIES

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Arterial tissues are made of variously organized collagen and elastin networks and exhibit a highly nonlinear anisotropic behavior with the ability to sustain large reversible strains. The latter originates in a load-induced progressive morphological rearrangement of the fibers. The significant role of the microstructure morphology and composition on arterial response [1] motivated us to develop a detailed multiscale model of the arterial wall.

The model accounts for the universal patterns across different scales in the two mechanically significant layers of arteries, namely the adventitia and the media, and introduce the different constituents making up the tissue at these different scales as phases into a representative volume element (RVE). Using the framework of finite strain continuum micromechanics, an incremental approach was used to compute the stress, strain and phase reorientations, at each load increment. In more details, extensions of Eshelby's matrix-inclusion problem allow for deriving analytical expressions for the concentration tensors, that relate the macroscopic strain rate tensor to the strain rate and spin tensors averaged over the phases, to the macroscopically applied strain rate [2,3]. While strain rate provides access to the averaged stress in each phase, the spin tensor allows determining the load-induced fiber rotation. The proposed adventitial model accounts for both the collagen decrimping (in a lower-scale fiber-matrix type RVE) and realignment (in an upper-scale fiber-matrix type RVE). The media is made of a pile of lamellae and interlamellar space, both lamellae and interlamellar space are composed of several RVEs to account for the multiscale nature of this tissue ; the progressive reorientation of all constituents (nalemy collagen and elastin fibers, smooth muscle cells, but also the lamellae themselves) is accounted for.

The model was validated against different experimental datasets (uniaxial, biaxial, tension-inflation tests) on arterial samples from different species (rabbit, porcine, human) [1,4]. The results show the model is able to estimate the contribution of each component into the macroscopic response of the tissue in different test directions and can predict accurately both the macroscopic response and microscopic fiber kinematics.

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We envision that such model would help in predicting the evolution of the tissue mechanical response over time during for instance remodeling or damage.

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Keywords: large strain continuum mechanics, fiber rotation, arterial constitutive model

Data-Driven Multiscale Modeling of Materials Synthesis

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With concentrated efforts from the materials science community to develop new multi-functional materials using unique processing conditions, the need for modeling tools that accurately describe the physical phenomena at each length scale has only further been emphasized. For example, additive manufacturing and shock synthesis lead to unique material morphologies that need to be understood for reliable engineering analysis and product safety assessments. Considering these material complexities, Direct Numerical Modeling (DNM) is accessible only for moderate system sizes. Thus, a multiscale strategy must recognize that just a relatively small part of the material will typically be instantaneously exposed to rapid material transformations. Macroscopic constitutive models obtained from homogenization, of the complex but slowly varying microstructure, may adequately describe the rest of the material. Nonlinear model reduction, pattern recognition and data-mining are a key to future on-the-fly modeling and rapid decision making.
To address these challenges, we present an image-based multiscale framework for modeling the chemo-thermo-mechanical behavior of heterogeneous materials while capturing the large range of spatial and temporal scales [1]. This integrated computational approach for predicting the behavior of complex heterogeneous systems combines macro- and micro-continuum representations with statistical techniques, nonlinear model reduction and high-performance computing. Our approach exploits the instantaneous localization knowledge to decide where more advanced computations are required. Simulations involving this wide range of scales, O(106) from nm to mm, and billions of computational cells are inherently expensive, requiring use of high-performance computing. Therefore, we have developed a hierarchically parallel high-performance computational framework that executes on hundreds of thousands of processing cores with exceptional scaling performance.

Any serious attempt to model a heterogeneous system must also include a strategy for constructing a complex computational domain. This work follows the concept of data-driven (image-based) modeling. We will delineate a procedure based on topology optimization and machine learning to construct a Representative Unit Cell (RUC) with the same statistics (n-point probability functions) to that of the original material. Our imaging sources come from micro-computed-tomography (micro-CT) and focused ion beam (FIB) sectioning. We show that high-performance DNM of these statistically meaningful RUCs coupled on-the-fly to a macroscopic domain is possible. Therefore, well-resolved microstructure-statistics-property (MSP) relationships can be obtained.

*Speaker

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Keywords: Predictive science, Image based multiscale modeling, High performance computing, Model reduction, Big Data, Co designed simulations and experiments

Thermal expansion of cement paste is governed by reversible water uptake/release by hydrates - A multiscale poromechanical analysis

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Quasi-instantaneous thermal expansion of mature cement pastes is governed by the relative humidity within their air-filled porosity and by the decrease/increase of this internal relative humidity resulting from a temperature decrease/increase. The latter is shown to result from quasi-instantaneous water uptake/release by cement hydrates, using multiscale poromechanics and a three-scale representation of mature cement pastes. Partially saturated gel and capillary pores are envisaged to be connected and spherical, with pore size distributions following exponential distributions. Effective pore pressures are quantified based on (i) the pressure of the fluids filling the pores and (ii) the surface tension at the interface between the pore and the surrounding solid matrix. The Mori-Tanaka scheme is used for the scale transition from effective pore pressures to eigenstrains at the cement paste level. In addition, mass conservation of water is explicitly accounted for. Downscaling macroscopic thermal expansion coefficients allows for identifying the molecular water uptake/release characteristics of the hydrates. These characteristics are independent of the initial water-to-cement mass ratio, as shown in the context of predicting the thermal expansion coefficients of different mature cement pastes, with w/c-ratios ranging from 0.50 to 0.70, see also http://doi.org/csgw.

Keywords: multiscale mechanics, poromechanics, thermal expansion, cement paste

*Speaker

Hierarchical Elastoplasticity of Bone: Theory, Algorithm, and experimental Validation

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Bone is characterized by a hierarchically organized microstructure, exhibiting universal" organizational patterns. The volume fractions of the components within those patterns, however, vary between different species, organs, and anatomical locations - resulting in a great variety of mechanical bone properties.

The complex internal structure leads to a need to take into account all the different hierarchical components - some of which behave plastic - in order to explain the overall elastoplastic response of bone. We here propose a multiscale continuum micromechanics model, comprising six homogenization steps, to predict a sample-specific bone strength. The model is based on tissue-independent mechanical properties of bone's three elementary constituents: mineral, collagen and water. The sole source of elastoplasticity lies in mutual sliding between the mineral needles, which are characterized by non-associated Mohr-Coulomb elastoplasticity, while the collagen fails in a brittle manner, according to a Rankine criterion. Upscaling of these processes from the nano to the macroscale was made possible by a novel iterative variant of the so-called return-map algorithm. By considering sample-specific bone compositions in terms of porosity and extracellular

*Speaker

mass density, the model is able to accurately predict sample-specific strength values and thereby explain the great variety in the mechanical properties of bone.

Keywords: multiscale mechanics, elastoplasticity, bone

Utilization of continuum micromechanical up- and down-scaling relations for studying transport processes in porous media

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Continuum micromechanics is a well-established concept which is often used for upscaling elastic, elastoplastic, viscoelastic, or poroelastic material behavior from the microscopic scale, where material properties are know from experiments, to the macroscopic scale. Applications span the whole variety of engineering materials, comprising both classical materials such as concrete, steel, or wood, and materials which have been discovered as to their potential of being considering as engineering material only recently, such as bone or bone replacement materials. Already 15 years ago, Dormieux and Kondo published some remarkable works, emphasizing the similarities between the boundary value problems to be solved in classical homogenization tasks, and the ones occurring in transport processes, such as diffusion or advection, see C R Mecanique, Vol. 332, pp. 135-140, 2004. They concluded that the homogenization laws known from elasticity homogenization can be analogously applied in such transport problems.
In this work, several examples are presented which utilize the aforementioned analogy between microelasticity and a rigorous multiscale view on transport processes. In particular, on the one hand, recent insights will be presented concerning the upscaling of permeabiliy and the downscaling of pressure gradients in bone, leading to remarkable new findings concerning the mechanobiological regulation of bone cell activities. On the other hand, the same approach is demonstrated for studying chloride diffusivity in cementitious materials, allowing for a better understanding of this technologically important process.
In summary, this contribution aims at showcasing the so far mostly unappreciated potential of classical homogenization schemes in the framework of continuum micromechanics, for addressing a selection of highly relevant, but not yet resolved questions of engineering sciences.

Keywords: micromechanics, upscaling, downscaling, diffusion, permeability, bone, concrete

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Role of hydrogel consolidant on hygromechanical behavior of archaeological wood: a molecular dynamics study

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Archaeological wood buried for centuries under sea sediments is highly degraded due to the chemical changes and material loss. Uncontrolled or rapid drying results in drastic distortion and collapse due to high drying stress, therefore consolidation methods and drying processes have been developed to preserve culturally valuable artefacts. Some important cases are the Swedish warship *Vasa* and Henry VIII's warship the *Mary Rose*, both excavated in the 20th century. A consolidation technique using polyethylene glycol (PEG) hydrogel, with different degrees of polymerization, was sprayed for decades at the surface of both shipwrecks to penetrate the wood, replacing the water in larges pores of vessels and lumens and in the nanoporous cell walls. After treatment, the ships have been air dried over years towards equilibrium with 55%RH, as museological conditions Recent studies reveal new challenges arising from PEG molecules breaking down and the formation of harmful acidic compounds, which may lead to further hydrolysis of hemicellulose and crystalline cellulose. In addition, the effect of PEG hydrogel on Wood mechanical properties and stability is unclear. The emerging problems emphasize the need for developing a comprehensive scientific framework for understanding the consolidation at a molecular level. The microscopic level mechanisms governing the hygromechanical behavior of PEG-treated archeological wood are still not fully elucidated. In this study, we use hybrid all-atom molecular dynamics and grand canonical Monte Carlo modeling to provide an insight into the interactions between PEG and wood cell wall polymers. Experimental results from the *Mary Rose* allow validation of simulations. We focus on different components of the S2 layer, crucial in mechanical strength of wood material. These polymeric components are modeled and studied with different PEG mass ratio and moisture contents. The molecular mechanisms by which the interaction between PEG and cell wall polymers alter the mechanical properties and swelling behavior of wood cell wall are investigated through studying porosity change, sorption curves and hydrogen bonding networks. We believe this knowledge not only yields a better understanding of the physics of polymeric mixtures in general, but also helps us in considering novel consolidant materials in the future.

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Keywords: Archaeological wood, PEG consolidation, molecular dynamics simulation, Hygromechanical properties

MS26 : Linear and Nonlinear Vibrations of Complex Structures

Modelling of axisymmetric structures with the wave finite element method

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The axisymmetric element is well-known and integrated in numerous commercial FEM codes for modelling axisymmetric structures. This method permits to transform a three-dimensional problem to a two-dimensional one which reduces widely the calculation time. However, it cannot be used easily for asymmetric loads. In this article, the wave finite element method (WFE) has been developed to adapt this type of loads. Firstly, we consider that the 3D structure is divided into equal parts by axisymmetric plans. Each part can be considered as one period of the structure which is subjected to some loads. Then, by using WFE for one period, we can determine the wave decomposition of the response at the part boundary in function of the loads and the wave base. Secondly, we apply the wave decomposition to all parts until to meet the first part. This technique leads to a relation between the wave amplitudes and the external loads, which can be used finally to compute the structure response without inverse of any stiffness matrix. The numerical results show that when the number of parts is large enough, the calculation time reaches the one of the axisymmetric element. Moreover, this method can be used for complex cylindrical structures.

Keywords: Wave finite element, vibration, axisymmetric structure, dynamic, reduced model

*Speaker

NUMERICAL AND EXPERIMENTAL ANALYSES OF THE FREE AND FORCED VIBRATIONS OF 3D THIN-WALLED BEAMS

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The flexural torsional vibration of 3D thin-walled beams with arbitrary open cross section is investigated in this study. In the model, the effects of rotational inertial kinematic and warping terms are included. Analytical solutions are derived for the mode vibration for simply supported beams in presence of arbitrary conditions, the finite element approach is followed. The 3D behavior of open section beams is predominated by torsion and warping. Due to warping, 3D beams with 7 seven degrees of freedom per node are adopted in the mesh. The basic matrices of motion equations are derived by the help of numerical integration. The model is implemented in Matlab. Free and forced vibrations under harmonic or seismic random loads are possible. In forced vibration, the steady state method is followed and damping is considered by the Rayleigh type. The presence of continuous or discrete viscous and elastic springs is also considered in the model. The model is validated by comparison to benchmark solutions found in literature. Also, commercial codes are used to demonstrate the accuracy of the developed model. Experimental tests were performed on beams with arbitrary cross sections in free and forced vibration context. In the analysis, the vibration modes are researched in the range 1-400 Hz by the help of an instrumented hammer for free vibration tests and an electrodynamic shaker machine for the forced vibration. The vibration frequencies and amplitude of the shaker are controlled. Four accelerometers are positioned along the beam for the dynamic beam response. In presence of arbitrary cross section flexural torsional vibration modes are observed. Test results match well the numerical simulations. Compared to classical models where rotational terms are neglected, more accurate results are then obtained with the present model, especially in presence of higher vibration and coupled modes. Moreover, in the highlight of vibration control of braced structures, presence of 3D elastic springs and viscous dashpots are included in the model. They are included in the numerical model and experiment tests. Their efficiency in vibration control are then proven.

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Keywords: Thin walled beam, Dynamic, Free vibration, Forced vibration, 3D open section, Torsion, Warping, Coupled modes, Finite element method, Experimental test, Intermediate bracings, vibration control.

Natural Frequency Identifications of Spindle-Tool System of Machine Tools during Machining

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For a machine tools, the stability lobe diagram (SLD) which provides the crucial information for a stable machining, such as depth of cut and spindle rotational speed proves to be a very useful tool. The accuracy of SLD strongly depends on the machining dynamics dominated by the spindle tool system. Traditionally the natural frequency and the associated damping of a spindle tool system are determined using the impacting testing, where the spindle is idle. However, during the machining these dynamic characteristics change due to the spindle tool holder rotational effect and the involvement of cutting impedance at the tool tip. To determine the time varying dynamic characteristic of the spindle tool system during the machining, a method using the displacement transmissibility based on the operational modal analysis (TOMA) is proposed. With three accelerometers attached on the spindle of a machine tool during the machining process, the dynamic characteristics corresponding to the spindle-tool system coupled with the cutting impedance can be identified. However, the resulting accuracy is less satisfactory. A technique which improve the accuracy in predicting the natural frequency during the machining from the vibration dada of TOMA is then proposed. Experiments are conducted to assess the performance of this proposed technique.

Keywords: Stability lobe diagram, displacement transmissibility based operational modal analysis, natural frequency, accelerometer

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Relaxed Stationary Power Spectrum Model using Subjective Probabilities

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Modern approaches to solve dynamic problems where random vibration is of significance will in most of cases rely upon the fundamental concept of the power spectrum as a core model for excitation and response process representation. This is partly due to the practicality of spectral models for frequency domain analysis, as well as their ease of use for generating compatible time domain samples. Such samples may be utilised for numerical performance evaluation of structures, those represented by complex non-linear models.
While development of spectral estimation methods that utilise ensemble statistics to produce a single or finite number of deterministic spectral estimate(s), result in a familiar spectral model that can be directly understood and applied in structural analyses, significant information pertaining to the non-ergodic characteristics of the process are still lost.
In this work, an approach for a stochastic load representation framework that captures epistemic model uncertainties by encompassing inherent statistical differences that exist across real data sets is used. Such uncertainties that may be reliably quantified only recently, due to the increase in available data.
The new developed stochastic load representation is utilising subjective probabilities to capture these epistemic uncertainties and represent this information effectively. The discrete power spectrum values are treated as random variables controlled by subjective probabilities, and hence the power spectrum itself as a non-stationary random process. The model will be usable for producing non-ergodic process realizations immediately applicable for Monte Carlo simulation analyses.

Keywords: power spectrum estimation, relaxed power spectra model, subjective probabilities, uncertainty quantification, random vibrations

*Speaker

Symplectic Eigenvalue Analysis Method for Bending, Vibration, and Stability of Beams

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Bending, vibration, and stability of beams are classical problems in structural mechanics. To find a unified and effective method for those problems is a major area of interest in structural mechanics. This study proposes a new symplectic eigenvalue analysis (SEA) method based on the theory of the symplectic dual solution system in applied mechanics. The key idea is to transform these typical problems into the symplectic eigenvalue problem, and then to obtain the solutions by computing the symplectic eigenvalues and eigenvectors. By this, the SEA method unified the solution procedure for bending, vibration, and stability of beams. In addition, this method can obtain the solutions to all variables (deflection, rotation, shear force, and bending moment) simultaneously. This study states that the symplectic eigenvalue problem is correlated with the differential equation, but it is not related to the boundary conditions. Such problem arises naturally in structural mechanics issues which are governed by various differential equations. Meanwhile, this study interprets the physical meanings of the symplectic eigenvalue and eigenvector-the symplectic eigenvalue represents the attenuation rate of the space functions, and the symplectic eigenvector fixes the differentiation relations among variables. The SEA method extends the region of application of the eigenvalue analysis, and it provides valuable insight into the analytical solutions and qualitative analysis for problems of beams. Therefore, it brings new blood into the field of structural mechanics which is an old subject.

Keywords: symplectic eigenvalue problem, equilibrium, singularity analysis, natural mode, axial force, Timoshenko beam

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FREQUENCY ANALYSIS OF FREE AND FORCED VIBRATIONS OF COMPOSITE SANDWICH BEAMS WITH VISCOELASTIC CORE

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In this paper, we present an approach to analysis the free and forced vibrations of composite sandwich beams with viscoelastic core by considering geometrical asymmetry. A theory of high order has been considered taking into account longitudinal and rotational inertia. The formulation of the equation of motion is carried out by Hamilton's principle. A comparative study to validate our numerical approach was performed comparing our results with other references. The results obtained show the effectiveness of the numerical approach. Then a parametric analysis was carried out with different configurations of the sandwich beams in order to analysis the influence of different parameters on the dynamic behaviour. The analysis shows that the viscoelastic loss factor has a significant effect on the vibration behaviour involving the improvement of the damping of the structure. The study of the influence of fiber orientation on vibration behaviour has shown that the damping of the structure can be improved by adopting a better configuration of composite layers. The results obtained from the thickness ratio effect show that the sandwich structure has more dissipative capacity of vibratory energy for the low values of viscoelastic thickness.

Keywords: vibration, sandwich, viscoelastic material, composite, loss factor, finite element.

*Speaker

Quadratic approximations of the Wiener path integral technique for stochastic response determination of diverse engineering dynamical systems

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A Wiener path integral (WPI) based stochastic response determination technique for diverse dynamical systems/structures is developed herein by resorting to functional series expansions in conjunction with quadratic approximations. The technique can be construed as an extension and enhancement in terms of accuracy of the standard (semi-classical) WPI solution approach (e.g., [1]). Specifically, in comparison to the standard approach [1], where only the "most probable path" connecting initial and final states is considered in determining the joint response probability density function (PDF), the herein developed technique accounts also for fluctuations around it; thus, yielding an increased accuracy degree. An additional significant advantage of the proposed enhancement as compared to earlier developments relates to the fact that low probability events (e.g., failure probabilities) can be estimated directly in a computationally efficient manner by determining a few only points of the joint response PDF. In other words, the normalization step in the standard approach [1], which required the evaluation of the joint response PDF over its entire effective domain, is circumvented. The efficiency and accuracy of the technique are assessed in several numerical examples, where analytical results are set vis-à-vis pertinent Monte Carlo simulation data. [1] Psaros A. F., Brudastova O., Malara G., Kougioumtzoglou I. A., "Wiener Path Integral based response determination of nonlinear systems subject to non-white, non-Gaussian, and non-stationary stochastic excitation." Journal of Sound and Vibration 433 (2018): 314-333.

Keywords: path integral, stochastic dynamics, nonlinear system, quadratic approximations

*Speaker

New Rotor Topology Featuring Passive Vibration Compensation Mechanism

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Rotor systems are used in many fields of engineering, from gas turbines in energy generation to reaction wheels for satellite attitude control. Their main limitation in terms of performance often reduces to the vibration level they generate. The two main strategies to reduce this disturbance level is either to apply lateral control forces on the shaft, by means of Active Magnetic Bearings (AMB) for instance, or to act directly on the unbalance, main source of vibrations. However, lateral control forces through AMB become limited at high speed/forces because of flux saturation, whereas rotor balancing can often be done only once in the rotor life before mounting. This project offers an alternative with on-board control force generation, in order to take advantage of the rotating frame high force, low frequency characteristic. A prototype has been designed and constructed to demonstrate how this could be achieved through a combination of passive spring-mass elements in a novel vibration compensation mechanism. A Finite Element Model (FEM) has, in addition, been created to display the effectiveness of such a mechanism in limiting the amplitude of bending modes when integrated in a long rotor supported by AMBs, hence reducing the complexity of the AMBs control. Future work includes the design and realisation of the long rotor version of the system, as well as active setting of the control force.

Keywords: rotordynamic, active control, vibration compensation, magnetic Bearings, finite element modelling

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Wiener path integral variational formulation with free boundaries for efficient stochastic analysis of high-dimensional dynamical systems

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A novel Wiener path integral based variational formulation with free boundaries is developed herein for determining the stochastic response of high-dimensional dynamical systems in a computationally efficient manner. Specifically, although recent work based on sparse representations and compressive sampling [1] has increased drastically the computational efficiency of the WPI technique as compared to its standard implementation, the cost of computing the joint response probability density function (PDF) still unavoidably explodes relatively fast with an increasing number of degrees-of-freedom (DOFs). In this paper, the above limitation is circumvented by marginalizing the joint response PDF in an "a priori" manner based on a variational formulation with free boundaries. In this regard, the associated computational cost becomes independent of the number of DOFs; and thus, high-dimensional systems can be readily treated by the WPI technique. An indicative example pertaining to a stochastically excited 100-degree-of-freedom nonlinear structural system is considered, while comparisons with pertinent Monte Carlo simulation data demonstrate the computational efficiency and accuracy of the developed methodology.
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Keywords: variational formulation, stochastic dynamics, path integral, highly dimensional system

*Speaker

Nonstationary stochastic response determination of nonlinear oscillators with fractional derivative elements

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An approximate analytical technique is developed for determining the non-stationary response amplitude probability density function (PDF) of nonlinear/hysteretic oscillators endowed with fractional derivative elements and subjected to evolutionary stochastic excitation. This is done in conjunction with a stochastic averaging/linearization treatment of the original equation of motion, and with assuming an appropriately chosen time-dependent PDF form of the Rayleigh kind for the response amplitude. The developed technique can be construed as a generalization the results in [1] to account for fractional derivative elements in the oscillator governing equation. The non-stationary response amplitude PDF is approximately determined in closed-form in a computationally efficient manner, while the technique can account for arbitrary excitation evolutionary power spectrum forms, even of the non-separable kind. A hardening Duffing and a bilinear hysteretic nonlinear oscillator with fractional derivative elements are considered in the numerical examples. To assess the accuracy of the developed technique, the analytical results are compared with pertinent Monte Carlo simulation data.

Keywords: Fractional derivative, Nonlinear system, Stochastic dynamics, Non, stationary stochastic process, Evolutionary power spectrum

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Fiber hinge modeling for non-linear seismic analysis

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The main objective of this research is to create a structural reinforced concrete shell finite element model that accounts for non-linear material behavior in seismic analysis. This shell model should be relatively accurate and computationally fit in order to be integrated into finite element analysis softwares. In addition, the whole structural model should be capable of undergoing pushover analysis (non-linear static) and time history analysis (non-linear dynamic).
During the initial stage of this research, we will start with a beam element. The first target is to model beams (frame structures) that account for non-linear material behavior in seismic analysis. This model will be then tested for accuracy and computational fitness in pushover and time history analysis. After passing all the validation requirements, the established concept will be generalized on shell elements.

Modeling the plasticity of an element as a single concentrated node at the middle of the section can give acceptable results for beams since generally the dimensions of a beam's transverse section are relatively small. However, this is not the case for shells, which usually possess a relatively large length. As a result, we can no longer model the entire section's plasticity as one concentrated node at the middle. For this reason we considered the principle of fiber hinges which distributes the plasticity all over the section.

The fiber hinge concept consists in dividing the reinforced concrete section into a set of fibers. Each fiber follows the non-linear uniaxial stress strain curve corresponding to its proper material (unconfined concrete, confined concrete or steel reinforcement). The overall behavior of the section is then obtained from the summation of all the fibers.

A fiber hinge model is implemented in Matlab and the Newton-Raphson method is used to calculate the non-linear deformations in a section corresponding to its internal forces. Then by integrating this procedure all over the length of structural elements, the resulting tangent stiffness matrix and node displacements that consider material non-linearity are obtained.
As a first step of validation, the ultimate loads computed by the proposed Matlab method (for beam elements) are compared to those predicted by classic reinforced concrete calculations. Secondly, the deflections obtained with this Matlab method are compared to the results of an engineering non-linear analysis software.

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Keywords: Finite element model, Material non, linearity, pushover structural analysis, dynamic structural analysis, Fiber hinge

Analytical model for the dynamics of a railway sleeper on a non-homogeneous foundation

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Recently, the analytical model of sleeper has been developed by considering beams on a homogeneous foundation. However, when the ballast is newly tamped, its stiffness is not homogeneous along the sleeper length and this model cannot be applied easily. In this study, we develop a model for such a railway track by considering the sleeper as an Euler-Bernoulli's beam posed on a non-homogeneous foundation. Here, the foundation is separated into three zones along the sleeper length which have different stiffness. We can obtain a dynamic equation of the Euler-Bernoulli's beam for a sleeper subjected to the reaction forces of the two rails. Thereafter, by combining the relation forces and displacements of the periodically supported beam in the frequency domain, the sleeper response can be calculated with the help of the Green's function. The numerical application shows that the more consolidated ballast is, the more flexural strain at the center of the sleeper has. Finally, the sleeper response in different cases of non-homogeneous foundations has been calculated in the parametric study.

Keywords: Railway track, analytical model, instrumented sleeper, non, homogeneous foundation, Green's function

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Impact between reinforced concrete structures subjected to seismic loading

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Civil engineering structures exposed to seismic hazard are equipped with seismic joints, designed to prevent collision between buildings during an earthquake. The design of the seismic joints dimensioning is established by evaluating the displacements of buildings subjected to a reference seismic excitation. In the context of probabilistic safety studies, the consideration of extreme external aggression scenarios, particularly seismic, beyond the regulatory reference frame, leads to questions about the consequences of possible collisions between adjacent buildings. In particular, the nuclear industry wishes to estimate the consequences of an earthquake beyond the reference frame for existing buildings having separation distance that could not prevent a collision for this level of aggression. Mechanical waves from pounding between adjacent buildings are characterized by a high frequency content, which can disrupt the functionality of some nuclear power plant equipment such as electrical cabinets. Therefore, the objective of the research is to best characterize seismic excitation at the anchor point of the equipment by reproducing the impact/contact phenomena between adjacent buildings and the propagation of high frequency waves through the structure.
The numerical simulation of pounding has been studied in the literature for more than 30 years. Nevertheless, the multiplicity of the approaches proposed and the conclusions extracted from them are too divergent to be considered sufficiently predictive in relation to the objective of nuclear equipment operating safety. The pounding problem is characterized by multiple shocks during the earthquake, with material behavior that would remain, for the most part of the seismic duration, in their elastic domain.

The modelling approach aims at predicting the excitation at the anchorages of the equipment in terms of displacement, speed and acceleration over a wide frequency band up to 50 Hz via response spectra. The Finite Element Method (FEM) for spatial discretization is adopted, with an explicit time integration of the equation of motion, which can be parallelized to treat fine meshes by partitioning approaches. In order to reproduce the propagation of high frequency waves in the building, the mesh size must be sufficiently small. It is well known that explicit time integration, based on the centered difference scheme, is better suited to impact/contact problems than implicit schemes (mean acceleration scheme) in the case of numerous impacts

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and wave propagation problems. The price to pay is the size of the time step, which must be sufficiently small in order to respect the condition of stability of the explicit scheme.

For contact/impact processing, we use the explicit time integration scheme proposed by [1], which has proven its efficiency for this type of problem. Two academic examples are discussed in order to verify the properties of the adopted scheme. The third example concerns two-storey reinforced concrete structures that have been tested on the CEA's AZALEE vibrating table.

Fatima-Ezzahra Fekak, Michael Brun, Anthony Gravouil, and Bruno Depale. *A new heterogeneous asynchronous explicit-implicit time integrator for nonsmooth dynamics*. Computational Mechanics, 60(1): 1-21, 2017.

Keywords: Lagrange multipliers, Non, smooth dynamics, Explicit time integration, Waves vibration.

Application of the Wave Finite Element method to multi-span bridges

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The wave finite element (WFE) method is based on wave propagation in periodic structures. Starting from the finite elements (FE) analysis of a single period (sub-structure) this method permits to derive the dynamic behavior of the whole structure. Thanks to a reduction in the degrees of freedom (DOF) of the system, the calculation time is considerably reduced compared to the classic FE method. Numerous structures have been solved with this method but it can not deal easily with boundary conditions. In this study, we develop a technique of WFE to deal with more general cases of structures constrained in an arbitrary manner as a multi-supported bridge. By using the WFE method, the vectors of DOF and nodal loads will be decomposed on the base wave in function of loads and reaction forces of the supports. Then by substituting the boundary condition in this wave decomposition, we obtain a relation between the reaction forces and the loads which permit to calculate the structure response. The numerical applications show that the WFE and FE method agree well and the new method permits to reduce significantly the calculation time.

Keywords: Wave finite element method, periodic structures, wave analysis, boundary conditions, computational time

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MS27 : Effects of Manufacturing on the Mechanical Performance of Composites

Contribution of In-Plane Fibers Bending in Forming Modeling of Composite Reinforcement

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Composite reinforcements are materials with specific mechanical properties given by their fibers. These tensile stressed fibers are very stiff while their bending stiffness is low. Continuous models for the simulation of composite reinforcement forming at the macroscopic scale are currently based on the consideration of several specific deformation modes such as tension in the direction of the fibers or shear between the fiber directions. With these first gradient formulations, the shear gradient between two sheared areas is not considered as it could be observed experimentally.These gradient zones can be associated with the in-plane bending rigidity of the fibers of the fibrous reinforcement. Continuous generalized formulations with a more complex second gradient methods allowed these shear transition zones to be taken into account. A new method to include in-plane fibers bending is presented here. The curvature of the fibers is calculated using neighboring elements. It allows to describe these phenomena by keeping the first gradient formulation with minimal penalty on the calculation time. The bending stiffness of the fibers can be determined experimentally. The consideration of in-plane bending reveals the shear transition zones in a simulated reference test for shear characterization, the bias extension test.

Keywords: composite, in, plane bending, forming, second gradient, simulation

*Speaker

MS28 : Dynamic behaviour of geomaterials

High strain rate behaviour of ice-silicate mixtures

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The dynamic properties of ice are important in many areas, e.g. climatology, glaciology, civil engineering, aerospace applications, and material science. Ice is often not in pure form but, rather, is found as an ice-silicate mixture. A better understanding of the mechanical properties of both ice and ice-silicate mixtures is thus necessary.
In the present study, low-temperature, split-Hopkinson pressure bar facility is used to investigate the mechanical properties at high strain rates of clean ice and ice-silicate mixtures. A comparison of dynamic mechanical strength of clean ice prepared by different fabrication methods is conducted.

Next, ice-silicate mixtures are prepared and effect of volume fraction of silica, particle size of silica particles and their morphology is studied. Ice-silicate mixtures with 4%, 8%, 12% and 20% by weight of silica are tested. Two different particle size range of silica, 90-130μ and 250-350μ are utilized to investigate the effect of particle size. The peak dynamic strength of the ice-silicate mixture initially decreases for lower weight percentage of silica and then shows an increasing trend. The peak stress for 4% by weight is lower than pure ice, but specimens with higher percentage of silica showed an increase in strength with increasing silica content and the peak stress for 20% by weight specimens is found to be considerably higher than pure ice samples. The failure mode is seen to be fragmentation for pure ice samples, and a mixture of crushing and fragmentation for the ice-silicate mixtures. Finally, we have also probed the effect of particle shape by carrying out tests on ice-silicate mixtures prepared by randomly-shaped, natural sand particles obtained from the river basin, and spherical glass silica particles.

Employing the above experimental data, we implement a Johnson-Holmquist II material model as a user subroutine in Abaqus Explicit to computationally model high strain-rate tests. Comparisons between numerical predictions and experimental results in terms of damage shape/extent is then discussed.
In the past, studies on ice-silicate mixtures have been for quasi-static deformations. High strain-rate behaviour has been investigated only for clean ice. The present work provides the first data, and computational material model, for the high-strain rate response of ice-silicate mixtures, and

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will be useful for impact analyses with applications to ice impacts on aero-frames and structures and impact cratering in icy planetary objects.

Keywords: Ice, Ice & silicate mixtures, SHPB, dynamic strength

Determination of dynamic properties of Hostun sand using bender elements under different hygrometric conditions

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Small strain shear modulus Gmax and damping ratio Dmin are two key parameters in the dynamic analysis of soils. They are of prime importance to predict the dynamic behavior of soil, needed to evaluate various types of geotechnical engineering problems such deformations in embankments, foundation stability, foundations of vibrating machines...etc. These parameters, determined in the field of small strains propagating shear waves, are also used to assess the sensitivity of soil to liquefaction and to predict the ground motion effects due, for example, to earthquakes and shocks produced by the detonation of explosives.
In this work, an experimental characterization of granular material by shear wave propagation is presented. The tests are performed using a modified triaxial testing device equipped with a pair of piezoelectric transducers called the bender elements.

The studied material is Hostun sand with subangular small sized particles (0.2 – 0.6 mm) of high siliceous content, tested at different hygrometric states. Cylindrical sand specimens introduced in the triaxial cell are submitted to an incrementally growing mean effective stress and excited by pulses generated and received by the transmitter and the receiver sensor respectively. The transmitted and received signals are later analyzed in order to identify desired characteristics. The tests conducted have clearly highlighted the dependence of the stiffness and damping of the samples on the total or partial presence of interstitial fluid. However, it is found that they evolve independently of the excitation frequency, although this frequency plays an important role in controlling the disturbing near field effect.

Keywords: Bender Elements, Damping ratio, Shear modulus, Shear wave velocity

*Speaker

MS29 : COMPOSELECTOR H2020 Projet mini-symposium

Fibrous composite reinforcements as second gradient materials

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For decades textile composites made of woven fabrics have been successfully employed in aircraft and automobile engineering and they are gaining an ever increased interest due to their excellent mechanical properties. Such materials are constituted by two families of yarns which have very high elongation stiffness, but very low shear stiffness. The strong contrast which they show in their mechanical properties at the mesostructure level is such that classical Cauchy theories are not sufficient for the description of specific deformation patterns usually observed in fibrous composites.

One example is the bias extension test, in which case two experimental evidences are not included in the results obtained from first gradient simulations: the presence of transition layers between two zones with different shear deformation and the more or less pronounced curvature of the free boundaries of the specimen. The first and second gradient solutions are compared showing that the proposed second gradient model is able to describe the onset of both of these phenomena, while the corresponding first gradient solution does not.

Furthermore, a second case realised in the framework of the project H2020 COMPOSELECTOR n 721105, is proposed. The object of the investigation is a thermoplastic fuselage frame made with a high strength carbon fiber system.

Keywords: Textile composites, Second gradient

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Business decisions in the COMPOSELECTOR project

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The COMPOSELECTOR project is developing a Business Decision Support System which integrates materials modelling methodologies and knowledge-based systems with business processes for decision making. Business aspects are implemented in terms of the BPMN and DMN, two well-defined standards used to represent the business processes and their associated business decisions rules. When finished, the system will provide the missing link between business processes, materials science and engineering workflows in the context of composite material modelling, opening a new horizon in engineering industrial applications. In this presentation, details on the use of the BPMN and DMN standards in the context of decision making in material modelling will be presented. The presentation will be complemented with an application case, which describes an example of successful representation of business process from the material modelling domain.

Keywords: business decision support system, BPMN, DMN, material modelling

*Speaker

Decision making under uncertainties

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In our daily life and in business, we often make decisions with uncertain consequences, for instance in the context of investment decisions, in the field of poker, launching a new business product, etc. To successfully cope with these situations, one should be able to estimate and resolve uncertainties at various levels. Decision making under uncertainties is choosing actions related to imperfect observations and unknown outcomes. Designers of automated decision support systems need to consider the various sources of uncertainty. There are different forms of uncertainties and the processing of uncertainty highly depends on the situation. This work includes both review and original research on several aspects related to decision making under uncertainties. The presentation will cover several probabilistic methods for uncertainty quantification; Bayesian inference for parameter estimation and data assimilation; a framework for understanding optimal decision under uncertainty; and model selection based on information theory. A wide range of applications (aeronautics, composite materials, nuclear design) under uncertainties will be covered.

Keywords: Decision making, Uncertainty quantification, Stochastic methods

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business and economic aspects in conceptual design decision making

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During early phase, conceptual development of composites structures, apart from technical aspects and performance, additional key performance indicators needs to be assessed to support decision making. Several of those aspects, like costing, and value will be discussed during this presentation

Keywords: costing, value, composites

*Speaker

MuPIF: Multi-Physics distributed Simulation Platform

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1

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A reliable multiscale and multiphysics numerical modeling requires including all relevant physical phenomena along the process chain and across multiple scales. The complexity of problems requires combination of knowledge from different fields. This brings in also the changeless for software engineering and design. There is a strong need for integration platforms, that enable interoperable integration of existing simulations tools and databases into a complex simulation workflows, providing capability to exchange information and efficiently use available computing resources. The interoperability by definition implies standards. Traditional approaches have been based on syntactic interoperability, based on specific communication protocols and conversion tools. The more attractive are approaches based on semantic interoperability, where data are exchanged together with their meaning, which allows for automated machine interpretation, translation, and verification [1].
The presented contribution introduces multi-physics integration platform MuPIF (www.mupif.org, [2,3]). MuPIF is a distributed, object-oriented framework written in Python. The top level abstract classes are introduced for models (simulation tools) and generic data types. They define abstract interfaces allowing to manipulate and steer derived classes (representing individual models and specific data representations) using the same generic interface. One of the key features of the MuPIF platform is the definition of abstract interfaces for models as well as for high level data types (spatial fields, microstructures, for example). This allows to achieve true plug&play architecture, where individual application cam be plugged into existing workflows and be manipulated using the same interface. As the same concept is applied for high level data, the platform natively support different data formats, storage schemes and even data repositories.

MuPIF supports a distributed workflows, where individual simulations and data can be executed/stored on remote computers, taking advantage of secure communication, public/private key authentication, resource allocation, built on top of python remote object library Pyro4. This allows running MuPIF on various operating systems, arbitrary network setup connections with firewalls while integrating in-house or commercial codes written using different languages. The distributed capabilities can be exploited in many ways, allowing to utilize HPC resources, or offering individual remote applications as a service. Recent simulation chains proved MuPIF capabilities on opto-thermal, CFD, and phase thermodynamic models using Matlab, Comsol, X-stream, Micress. At present, the MuPIF is used in COMPOSELECTOR project [4] to design

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innovative composite materials.

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Composelector: Multi-scale Composite Material Selection Platform with a Seamless Integration of Materials Models and Multidisciplinary Design Framework, EU H2020 project no. 721105, www.composelector.net, 2017

Keywords: Simulation platform, interoperability, distributed simulations, integration, metadata

Use of short fibers as reinforcing fillers for rubber based composites

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To reduce vehicles carbon footprint, tire industry is currently making a lot of efforts in improving tires rolling resistance. This can go through the light weighting of the different materials used in tire fabrication including reinforcing fillers used in rubber matrices. A study of different particles with different shapes have been studied to show the influence of particles morphology on rubber based composites properties

Keywords: rubber based composites, tire technology

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MS30 : High Performance Structural Polymer-based Composites and Their Related Applications

Thermal conductivity of composites with general imperfect interfaces

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This study extends the mechanics of structure genome to heat conduction problem of composites with general imperfect interfaces model. We apply this micromechanics approach to predict

the effective thermal conductivity of composites containing imperfect thermal contact between the matrix

and the reinforcements. The robustness and accuracy of this theory is demonstrated using examples

of spheroidal particles reinforced composites. The proposed micromechanics method is versatile and

applicable for estimating the effective thermal conductivity of nanocomposites.

Keywords: Micromechanics, Structure genome, Imperfect interfaces, Thermal conductivity.

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Functional interfaces and interphases in fiber reinforced polymer composites

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Interfaces play a key role in many areas such as aerospace and automotive sectors. This is particularly the case in polymer composites whose performances are mainly driven by the interface and interphase integrity. In this area, the challenge is to develop new approaches to improve interfacial adhesion between symetric and dyssimetric materials and on the opposite to promote disassembly to fit to recycling issues. Addtionnally, any materials requires additional functionality which can be imparted via surface trearment. In this area, the challenge is to develop new multi functional nanostructured thin films ranging from passive coatings including hydropholic/hydrophobic properties, fireproofing, gas and molecules barrier up to active caotings including stimuli responsive coatings i. e selective membranes and self healing properties. The present work is mainly focused on the design of functional hybrid nanocomposite surfaces.

Keywords: Interfaces, interphases, Fiber reinforced polymer composites

*Speaker

Metallic coating properties analysis depending on composite manufacturing conditions

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General aviation aircraft, large commercial jets and wind turbines are vulnerable to lightning strike. Unlike their metal counterparts, composite structures in these applications do not readily conduct away the extreme electrical currents and electromagnetic forces generated by lightning strikes. Composite materials are either not conductive at all (e.g., fiberglass) or are significantly less conductive than metals (e.g., carbon fiber), so current from a lightning strike seeks the metal paths available. For that reason, lightning strike protection (LSP) has been a significant concern since the first composites were used on aircraft more than 30 years ago.
The CO3 project will thus offer an enabling automated process for the next generation of airplane.

In this work,as part of the CO3 Project, funded by Clean Sky 2 H2020, authors are focussing their attention on cold metallization of thermoset-based composites using Supercritical Nitrogen (SCN) jet as dry and efficient carrier gaz.

CRITT TJFU has developed an innovative method of cold gas spraying deposition assisted SCN jet and demonstrated its high strength adhesion performance on polymeric or metallic substrate compared to the conventional preparation methods. CRITT TJFU established the strong mechanical anchorage of metallic particles in the top surface of polymer constitutes a sub functional metallic thin layer that could be used as resistant and bonding compliant base material for further metallic cold sprayed layer coating completion.

The challenge of this work consist to develop, optimize and validate this coating process approach on carbon fibres reinforced thermoset. In order to generate a strong mechanical anchoring of the metal coating as well as a chemical adhesion with the CFRP substrate.

Due to the intrinsic thermos-mechanical properties of high performance thermoset compare to thermoplastic, the erosion damage at the composite surface could occurs during deposition inducing surface defect as well as composite internal damage. This phenomenon highlights the lack of thermoset-metal adhesion as well as a poor deposition efficiency.

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*Speaker

This study proposes to analyse the relationship between the composite manufacturing conditions, in particular the cure state of the matrix and the resulting metallic coating properties. First thermos-mechanical properties of CRTP depending of the curing conditions are experimentally characterized as well as the initial material health using non-destructive methods such as ultrasonic as well as micro-computed tomography. A metallic powder (copper) are selected as metallization material and is projected on the top of CFRP substrate using an optimized cold gas spraying deposition assisted SCN jet process parameters. Depending on the CFRP manufacturing conditions, measurement, process deposition efficiency as well as coating properties (electrical conductivity, coating morphologies, coating adhesion) are compared together with the reference.
The conclusion of this study highlights the significant role of composite manufacturing process for the optimization of metallization process efficiency and resulting metallic coating properties.

Keywords: automated composite metalization, composite, metal adhesion, lightning strike protection

Specific adhesion test definition for 3D printed composite structures

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In recent years, additive manufacturing methods have attracted increasing interest in both research and industry. They consist in making objects by accumulating successive layers of material. Fused deposition modelling FDM consists of extruding a filament, made from a thermoplastic polymer (TP), through a mobile extrusion head. Currently, it is the most affordable and easiest to implement among additive manufacturing techniques [1,2]. The study of the mechanical properties of 3D printed objects is rare and often concerns measurements on a macroscopic scale [2-3]. The printing parameters [2], the composition of the filaments [4] and the orientation of the construction [3] modify the adhesion between the polymers layers, which limits the mechanical properties of the objects obtained. For a few years more and more composite printed structures are designed, however, no study is reported to date on the specific study of interfacial adhesion. In this paper we design a test to measure the interfacial adhesion between the polymer layers of parts printed by FDM. For this purpose, after a brief review from classical adhesion tests, different models have been evaluated to qualify the adhesion between the different layers from FDM printed objects. As an example an adhesion test was performed on different multi-material printing to evaluate the interface quality.
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Keywords: Thermoplastic, Adhesion test, Composite, FDM

MS34 : Multiscale & Multiphysics coupling of construction materials

Multiscale and multiphysics approaches for durability of construction materials and structures

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The assessment of durability of construction materials and structures subjected to physical and/or chemical evolutions (hydration, ageing, chemical degradations,...) requires multiphysics approaches (chemo-mechanical couplings, heat and mass transport, reactive transport,...) for which evolution laws can be identified by understanding the evolution of material microstructure. It appears important to link microstructure and macroscopic behavior by multiscale investigation of the material performances. The recent developments in terms of microstructural characterization allow a better understanding of the mechanisms at small scales and enhance durability predictions of construction materials and structures at larger scale. The aim of this mini symposium is to address recent studies and developments in multiscale and multiphysics approaches, from an experimental, theoretical or numerical point of view, to understand and predict the behavior of construction materials and structures subjected to chemical, thermal, hydric and/or mechanical loadings.

Keywords: Construction Materials, Durability, Degradation, Multiscale & Multiphysics modelling and experiments

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Composites reinforced flax or carbon fibers under hygrothermal ageing: Follow of durability by Acoustic Emission monitoring and tensile tests

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The present study forms part of the MICRO project, funded by the French National Research Agency (ANR).This project is a large-scale durability study on composites potentially used to strengthen or repair structures. Hand lay-up Fiber Reinforced Polymers (FRP) have proved to be effective in the short term. The objective of the project is to carry out an extensive experimental program to trace the evolution of the composite's behavior under ageing conditions. In this context, this paper presents experimental investigations about the tensile behavior of Carbon FRP and Flax FRP, which have been stored either under ambient conditions or which have been subjected to hygrothermal ageing at 40oC over 16 weeks. The experimental program includes tensile tests with Acoustic Emission (AE) monitoring at four ageing times. The test results show that the properties of composites were hardly affected by hygrothermal ageing whereas failure modes tend to change. Henceforth, AE analysis is useful to help in clarifying the sequencing of the different damage mechanisms and quantifying their contribution to the failure mode. Firstly, a statistical analysis of amplitude distribution (b-value analysis) permits the detection of micro and macro-cracks during tensile tests and the initiation of failure. Secondly, damage modes were clarified distinctly for both composites by multivariable analysis.

Keywords: Hygrothermal ageing, Durability, Carbon fiber reinforced polymer, Flax fiber reinforced polymer, Acoustic Emission, Tensile behavior, Damage clustering

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A Reduced Order Model for computing homogenized properties in Porous Media

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Computation of homogenized properties in porous media, linking microscopical reactions like electrodiffusion governed by Nernst-Planck-Poisson equation, to macroscopical phenomenon, are of huge interest in case of the study of cementarious materials. Indeed, durability of concrete structures is strongly influenced by diffusion of moisture, chloride or CO2.
For example, periodic homogenization is a tool that has been developped to set rigorously macroscopical equations for electrodiffusion, in place of the Nernst-Planck-Poisson system. Such equations can be used for practical purpose. The homogenized diffusion tensor (Dhom), which we derive from a set of hypotheses on asymptotical behaviour of material's microstructure constituting periodic homogenization, is defined as solution of a linear equation depending to the microstructure's geometry. Computation of Dhom is usually achieved using Finite Element Method. However, this method is too slow afford computation of Dhom for a large variability of microstructures. Hence a new approach, using Proper Orthogonal Decomposition (POD), is being developped to improve efficiency of the computation of Dhom.

POD is a method for reducing a data-set's dimension using linear algebra, that has been developped around the 1950s in the works of Karhunen and Loève, and spread to fields of science including fluid mechanics, but also statistics with Principal Component Analysis. In physical issues, the data set contains particular solutions of a space-depending equation, indexed by a parameter which is often time. The method consists of computing an orthogonal basis of the data-space, solution to a minimization problem. POD vectors are computed as eigenvectors of a linear operator, which is Fredholm integral operator if data belong to a functional space. Optimality of the POD's construction ensures that a small number of them can be used to build good approximations of the data. Then the original, physical equation is written in terms of the few selected POD vectors using Galerkin projection : this is called Reduced Order Model (ROM) and can be resolved much faster than the original space-depending equation thanks to the small number of POD vectors.

This study is about resolving the equation which gives Dhom on a serie of microstructures depending on a geometrical parameter, for example radius of a spherical solid micro-inclusion, which is linked to porosity. Equation for Dhom is resolved for a finite, " training " set of microstructures, then POD is performed in a functional space where theese particular solutions,

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called the snapshots, are projected. High speed of ROM eventually allows to compute Dhom for a large number of microstructures belonging to the same serie.
Efficiency of this ROM is influenced by interpolation of the POD vectors, which lie in a theoretical functional space common to all micro-geometries, onto the particular space of functions defined on the fluid domain of the current microstructure. This is an important issue of the method, since each particular solution of the equation giving Dhom lie in a different functional space. ROM has been tested for different resolution of Finite Element Spaces, and several geometries for the microstructure.

Keywords: Electrodiffusion in porous media, periodic homogenization, Proper Orthogonal Decomposition, Karhunen Loève decomposition, PCA.

Investigation on some simplification hypotheses in thermo-hydro-mechanical modeling of cement-based materials for drying applications

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The drying of cement-based materials affects directly their durability, which has a major economical and societal impact. Notably, the variation in saturation of the porous network and the induced drying shrinkage are fundamental processes which drive cracking as well as the penetration of aggressive chemicals.

Given the impact of this inevitable phenomenon, it is important to master the modeling of moisture transport in order to accurately predict its direct impact on durability. However, due to the lack of some experimental insights as well as to the level of complexity of the problem, various simplifications are proposed by different authors concerning:
the number of fluid phases considered in the system, the evolution of the hydric properties in function of temperature and finally, the explicit consideration of the meso-structure of the studied material.

Concerning the first simplification, a comparison between two models responses is performed. The first model is a multi-phase one which explicitly describe all the individual fluid species of interest (liquid water, vapor and dry air), while the second model (simplified model) considers only the description of the liquid water specie under the main assumption of constant gas pressure at environmental conditions. Regarding the second simplification, many drying configurations are tested using the simplified model. The differences between these configurations are the considered behavior laws of hydric properties such as desorption isotherms, intrinsic and relative permeability, which describe the evolution of these quantities in function of temperature.As for the final simplification, 2D hydro-mechanical mesoscopic modeling is considered. The effect of the aggregates on the drying field is studied based on permeability-damage based hydro-mechanical coupling.

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Quantification of these simplifications effects on drying response is performed here by comparing mass loss outputs of the studied configurations. The resulting relative error maps at early, mid and late drying stages are then analyzed for every compared case.

Keywords: Drying of cement based materials, Multiphasic thermo hydric modeling, monophasic thermo hydric modeling, mesoscopic hydro mechanical modeling, hydro mechanical coupling, damage, permeability.

MS35 : Other EMI' interest papers

Development of experimental measurement strategy to analyze the measurement method of location errors of rotary C-axis on five-axis machine tools

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Geometric errors are clearly among the overwhelming error sources in five-axis machine tools. For that reason, the urgent need of any testing cycle on machine contraption is commendable. In addition, the measurement strategy needs to be proficient in an adequate time. Considering this, current study proposes a measurement strategy for geometric errors of a five-axis machine tool. Following our past study, Current work focuses on a blend of various types of test techniques for addressing location errors of a rotary c-axis of five-axis machine tools. This work mainly concentrates on various sorts of examining methodologies that could reduce the total number of measurement plans and time in order to identify location errors, hence enhancing measuring efficiency of five axis machine tools. The experiment results show the capability and enhanced efficiency of the proposed experimental methods that identifies the location errors by using a touch trigger probe and a precise sphere.

Keywords: Location errors, Rotary axis, Five, axis machine tool, Error identification

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Acoustic emission on the Hole Erosion Test

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ABSTRACT Dikes and levees are prone to failure through internal erosion, induced by concentrated seepage that takes off and transports soil particles through the embankment and its foundation [1]. One means to monitor these concentrated leaks is passive Acoustic Emission (AE) monitoring. This monitoring involves acoustic transducers to passively listen for acoustic energy released from internal sources. Here, we study the potential of this approach at the laboratory, on the Hole Erosion Test [1, 2]. Turbulent pipe flow in the hole generates acoustic waves that propagate in the soil sample. Acoustic sensors (accelerometers) installed on the equipment allow to measure these signals. The analysis sheds light on acoustic frequencies characteristic of the internal flow, between 0-30 kHz. We can see two vibratory responses on the acoustic signals, one corresponding to the pipe flow and a second corresponding to the experimentation bench response. The correlation of both frequency and intensity with flow velocity and hole diameter is studied.

Keywords: Acoustic emission, internal flow, vibratory response.

*Speaker

Numerical Simulation of the Bond Behaviour between Bamboo Strips and Normal Strength Concrete

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The bond behavior of reinforcing bamboo strips in concrete is a critical issue in the design of Bamboo Reinforced Concrete (BRC) structures. This study focuses on the bond strength of chemically treated bamboo strips in normal strength concrete. A three-dimensional nonlinear finite element model capable of simulating the pull-out test of bamboo strips from concrete is developed using the commercial finite element software ABAQUS. The results of twenty-four pull-out tests that have different parameters are implemented in the software to study the effect of the presence of node, bar size and the use of stirrups. The interaction properties used in the model provided accurate results in comparison with the experimental bond-slip results, thus the model has successfully simulated the pull-out test. The results of the finite element model are used to better understand and visualize the distribution of stresses in each component of the model, and to study the effect of the various parameters.

Keywords: Bamboo, Bamboo Reinforced Concrete, Bond slip

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The study of biochar's "carbon dioxide exchanger" effect and its impact on carbon sequestration

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The potential of using biochar as a material to sequester atmospheric carbon dioxide was explored in this study. Specifically, the carbon dioxide sorptivity of biochar-coated lime plaster pellets that were placed in a cavity wall was measured in an indoor environment with high carbon dioxide concentration of about 1,000 ppm. A theoretical model was also derived to estimate how the carbon dioxide sorptivity of biochar particles would change when part of these particles is immersed in plaster; this is called embedment enhancement of sorptivity. It is found that if the fraction of the biochar particles that is immersed in the plaster is known, the "carbon dioxide exchanger" effect can be deduced. For example, if 90% of the biochar is immersed, then the measured data suggests that the carbon dioxide sorptivity of biochar increases by about 5.71 times due to the filling of the pore system of the biochar by plaster solution. Overall, this study suggests that a 2.5m-by-2.5m cavity wall containing 300 g of biochar has the potential of removing 63.5 kg of carbon dioxide in one year.

Keywords: Carbon sequestration, biochar, lime pellets

*Speaker

Three-Dimensional Finite Element Analysis of O-ring Metal Seals Considering Manufacturing Tolerances

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Metal seals are widely used in various industrial branches with severe working conditions (e.g. high pressure, high temperature, corrosion, or radioactive radiation). For example, O-ring metal seals are applied in the closure lid system of transport and storage casks for radioactive materials to guarantee an approved specified leak-tightness and the safe enclosure of the radioactive inventory. Within safety assessments of those casks under normal or accident conditions during transport and long-term interim storage for several decades, numerical simulations of the thermo-mechanical behavior of metal seals by using finite element (FE) analyses are suitable and effective.
In general, finite element codes provide the possibility to construct a complex three-dimensional (3D) modelling of metal seals with solid elements, cf. [1], where all components of the metal seals are modeled in detail. This modelling is complex but allows the consideration of underlying physical effects such as elastic-plastic deformation, thermal expansion, creep/relaxation, friction and possible local damage. Therefore, this approach permits the investigation and understanding of the complex behavior of metal seals in detail which can hardly be measured for all seal components.

In a prior work, the complex 3D modelling approach was applied to investigate the influence of each seal component on the global seal force by considering varying material properties and different seal diameters [2]. In the present contribution, the influence of manufacturing tolerances is discussed. At first, the results of prior work are summarized. After that, the manufacturing tolerances of the studied O-ring metal seal types are described and the corresponding FE model with all individual components is introduced. Finally, the influence of varying manufacturing tolerances of each seal component on the global seal force is analyzed and discussed.

Zencker, U., Qiao, L., Völzke, H.: Strategies for Numerical Modelling of Metal Gaskets in Transport and Storage Casks, Proc. of Radioactive Materials Transport and Storage Conference and Exhibition (RAMTRANSPORT 2015, 19-21 May 2015, Oxford, United Kingdom).

Qiao, L., Keller, C., Zencker, U., Völzke, H.: Three-dimensional finite element analysis of O-ring metal seals considering different seal diameters, The Thirteenth International Conference Computational Structures Technology (CSTX 2018, 4-6 September 2018, Sitges, Barcelona, Spain)

*Speaker

Keywords: Finite element method, Metal seals, Material properties, Manufacturing tolerances

Zonage Cartographique Des Aléas Mouvements De Terrains En Milieux Urbains, Cas De M'sila (Algérie)

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Les risques naturels menacent avec plus ou moins d'intensité les activités humaines. L'Algérie a été touchée fréquemment par des catastrophes naturelles, ces dernières mettant en danger la vie des personnes et engendrant des dégâts inestimables. Face à une telle situation l'entreprise de mesures adéquates, capables d'exercer une prévention efficace est incontournable.
L'intérêt principal de cet article est l'étude cartographique sur la base des données géologiques et géotechniques, suivie d'une méthodologie pour éviter de telles catastrophes.

Cette approche cartographique apparaît comme un moyen fiable et économique pour localiser les zones les plus dangereuses par rapport aux mouvements de terrain dans un secteur urbanisé où la densité des points d'information géotechnique est forte.
La connaissance d'un nombre important de paramètres d'identifications des formations géologiques a permis d'expérimenter cette méthode d'évaluation du coefficient du risque.

Keywords: M'Sila, mouvements de terrain, indices de contributions, risque, carte de zonage

*Speaker

Biomechanical Modeling of the Human Body

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The human body is an extraordinary machinery in which all fields of mechanics are involved: from material to structure, from solids to fluids, from small to large scales. Such intricate complexity and the lack of explicit blueprints for this living structure lead to adapting and developing advanced modeling methods and dedicated experiments to better understand and predict the body behavior in healthy and pathological conditions, improve diagnosis, therapeutics and performances. Exploring this living machinery can also inspire new bioinspired designs in other fields of mechanics, as evolution has performed a tremendous optimization work!

The aim of this minisymposium is to gather contributions from the biomechanics community on a large variety of topics, such as...:

• Multiscale approaches

• Structure and material characterization and modeling

• Multibody modeling

• Tribology

• Fluid mechanics and fluid-structure interactions

• Reduced order modeling

• Bioinspiration

• ... Typical illustrations of the biomechanical models will address evaluation of biomedical implants (cardio-vascular, orthopedics), subject-specific simulations based on medical images, assessement of pathological functional abilities.

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Keywords: Multiscale approach, Structural and material characterization and modeling, Multibody modeling, Tribology, Fluid mechanics, Fluid, structure interactions, Reduced order modeling, Bioinspiration

From capillary bonds to immersed granular flow

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Wetted or fully immersed granular materials are ubiquitous in natural flows and technical applications such as sediment transport, erosion processes, submarine avalanches, granulation processes, fluidized beds and flow through particle based materials in heterogeneous catalysis. Recent advances in numerical methods have made it possible to simulate large assemblies of individual grains interacting with one or several fluid phases at scales
ranging from nano to larger scales.
The goal of mini-symposimum is to bring together researchers working on various aspects of numerical modeling and validation of fluid-grains interactions and their applications to industrial or natural processes. It covers but is not limited to the following topics:

- Rheology of inertial and viscous dense suspensions
- Flow through granular porous materials
- Condensation and phase change of water in pores
- Wetting, granulation processes and evolution of granular fabric with capillary interactions
- Erosion processes
- Water in nano-structures such as cement and clays

Keywords: Fluid, grain coupling, Wetting, Erosion processes, Agglomeration, Suspensions

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Induced Seismicity

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One of the principal drags of the geothermal technologies is the slip reactivation in seismic faults or fractures. Stimulation processes used to improve permeability can induce seismic or aseismic slips which can lead to micro-seismic activity. Studying and understanding the triggering mechanisms of slips in faults could make it possible to mitigate micro-seismicity. Both challenging and interesting, induced seismicity remains an important research field for all the geo-energy applications and constructions around the world. In this mini-symposium, we want to focus on the physics of induced seismicity trough the influent factors and triggering mechanisms of micro-macro earthquakes. Lots of methods, models and experiments have been developed to reproduce or prevent seismicity. We invite papers from theoretical, experimental and numerical fields to share findings related to this topic.

Keywords: induced seismicity, seismic and aseismic slip, stimulation processes, rock fracture

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Computational and Analytical Methods in Geomechanics

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This mini symposium focuses on computational and analytical methods in geomechanics and geotechnics. Emphasis will be put on significant advances with potential for applied methods

Keywords: computational methods, geotechnics, geomechanics

*Speaker

Poromechanical Couplings in Geomaterials and Geostructures

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1

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Most of geomaterials being porous (soils, rocks, rammed earth, concrete, etc.), it has long been known that pore fluids interacting with the solid matrix impacts significantly on the mechanical behaviour and that of the structure concerned (tunnels, nuclear or urban waste storage facilities, buildings, geological storage reservoir...). In the last few decades, effects of other phenomena such as heat and physico-chemical interactions have also been investigated and an immense knowledge base have been accumulated. The aim of this mini-symposium is to gather researchers and engineers who are interested by such coupled phenomena or have conducted studies on one or several aspects of such coupled processes, either experimentally or theoretically, to share their experience and insight. The topics of this mini-symposium are composed of but not limited to the following areas: thermal effects, crystallisation, phase change such as freeze-thaw behaviour, chemically-induced swelling-shrinkage, capillarity effects...

Keywords: multiphysic couplings, fluid solid interactions, coupled phenomena, nonlinear behavior

*Speaker

Effects of Manufacturing on the Mechanical Performance of Composites

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This mini-symposium is about accounting for the manufacturing effects in the design of composite structures.
Several physical quantities are affected by the manufacturing process of composite components that subsequently influence its mechanical behavior and performance: fiber orientation, porosity, fiber undulation, local fiber content variations, thickness, degree of cure, fibers tow sections modifications, degree of crystallization, degree of intimate contact, etc.

The state-of-the-art industrial practice to handle the uncertainties associated with these effects is through the use of conservative knock-down factors that can be as large as 50%. This approach leads to oversizing of the composite structural components and results in weight increase and high manufacturing costs. Thus, composite materials cannot be fully exploited to meet the desired benefits. This situation reflects the lack of scientific knowledge, mathematical models, commercial simulation tools and established methodologies in the design of optimally designed composite structures.

In order to rely on numerical simulation to address the effects of manufacturing, it is necessary to have a description of the manufactured parts that includes physical details, to make this information available to the mechanical performance simulation and have material models that can incorporate all the added information in the stress, failure, damage and fatigue simulations.

Manufacturing process simulation, experimental measurements (computer tomography, sensors, etc.) are a source of data to describe the manufactured part. Transfer of information from manufacturing to design calls for geometrical, physical and mathematical model mapping. Generating local material data resulting from the manufacturing is a challenge in itself and eventually the question arises about developing new material models or using raw data in existing material models.

You are encouraged to submit abstracts on these topics.
Contributions to a holistic composite design approach involving machine learning approaches, data analytics technologies and model reduction are welcome.

Keywords: composites manufacturing performance simulation 'process window' multiphysics multiscale ICME

*Speaker

3D Printing with Polymers

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This mini-symposium will provide a forum for presentation and discussion of the state-of-the-art in field of 3D printing with polymers. Emphasis will be on novel polymer material formulations for additive manufacturing (AM), computational methods, and numerical simulations involving material and/or process modelling. Contributions are solicited in, but not restricted to, the following topic areas in 1) Material and process characterization; 2) Recycled and Bio-Based Plastics for Additive Manufacturing; 3) Modelling and Simulation of AM technologies; 4) Topological optimization for architecture material design; 5) Performance analysis of 3D printed structures;

Keywords: additive manufacturing, recycling, optimization, composite, expert system.

*Speaker

Material and Manufacturing Process Modelling for Business Decision Making

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Design and selection of materials and processes for engineering applications is relatively common. Designers have to take into account a large number of material selection or design criteria. The advent of high-quality and efficient computational tools across the whole spectrum of materials, manufacturing process and product development combined with a wide accessibility of High Performance Computing (HPC) at affordable costs, have leveraged the integration of materials modelling in decision process and decision systems.

This mini-symposium will provide a forum for presentation and discussion of the state-of-the-art in field of integration of use of material and process modelling for decision-making. Emphasis will be on Materials and Process Modelling, Materials Databases and Data Integration and Decision Process Making. Contributions are solicited in, but not restricted to, the following topic areas in 1) Multiscale material and process modelling; 2) Interoperability; 3) Multidisciplinary/multi-objective optimization; 4) Methodologies for material and process selection; 5) model selection and model adaptivity.

Keywords: business decision making, Materials and Process Modelling, model selection, optimization

*Speaker

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High Performance Structural Polymer-based Composites and Their Related Applications

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High performance structural polymer-based composites are increasingly used in various key sectors such as aerospace, aeronautics, transport where weight saving and multi functionality are strongly targeted. The objective of this symposium is to gather scientists and engineers from both academia and industry for discussing and exchanging their current RDI activities in the field of High performance structural polymer-based composites. As this is a dynamic field, the scope of this symposium will cover a broad range of mechanical, physical and functional properties of composites. Both theoretical /analytical and experimental works on prediction of the performance of composites components are encouraged as well as challenging industrial applications

Topics include (but not limited):

- Multi functional materials
- Interfaces and Interphases
- Thermal and electrical conductivity, flame properties
- Advanced processing and characterization techniques for High performance structural polymer-based composites
- Assembly and joining
- Micro-mechanics
- Multi-scale modelling
- Fracture mechanics, Failure analysis, Fatigue, Impact
- Structural Health monitoring

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Keywords: functional materials, Interfaces and Interphases, characterization, Multiscale modelling,
• Structural Health monitoring

Thin Textile (Fiber and) Reinforced Cement Composites and Ferrocement

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There are many families of mineral-based composite materials (TRC, TRM, FRCC, FRC, GRC, UHPCC Ferrocement, ... etc) whose acronyms sometimes cover the same reality.
These composite materials cover a very broad spectrum of performance and a variety of applications.

The objective of this session is to take stock of the latest scientific and technical advances related to these materials whose industrial deployment differs according to the type of composite considered

Keywords: Mineral composites, Textile, Fiber, Characterisation, material and structures, design

*Speaker

Innovative Materials for Sustainable Construction

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The environmental context requires the development of sustainable construction with low impact all along its life cycle. Materials are an attractive avenue to meet such challenge, and particularly, emerging materials with low carbon dioxide foot print (rammed or poured earth, geomaterials, by-products valorization, bio-based materials) and energy management through materials (super isolation, energy storage). The difficulty generally stands on antagonism in functional properties required. Understanding phenomena involved at different scales from nano- to macro-scale is a real bottleneck for those materials.

Innovative materials development requires different steps and different strategies. At the beginning, formulation, rheology and shaping are the main concerns. Model materials or simplified systems make it possible to anchor new techniques and methods. Then, functional properties have to be related to the microstructure. Some modelling approaches exist (analytical models, homogenization, molecular dynamics, discrete elements or finite elements) and are often coupled to gain new insights. Finally, constitutive mechanical laws are available, durability and aging mechanisms are studied so as to design a building system. This requires multiscale approaches, durability investigations and properties scale-up. All TRL degrees are expected for this mini-symposium, whether at an academic (TRL 2-5) or industrial (5-8) level.

Materials development, new experimental techniques on simplified or complex systems as well as related computational models, addressing physical phenomena and times scale relevant for these innovative materials are welcome. Innovative and multidisciplinary approaches focused on mechanical behavior and or durability mechanisms as well as predictive model increasing either price/efficiency ratio or safety or sustainability and durability in service are encouraged.

Keywords: Geomatrials, Valorization, Super insulation materials, Mechanical properties, Durability

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High Temperature Effects on the Dynamic Strength of Concrete

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The practice of design and operation of reinforced concrete structures has shown that the load-bearing elements of the building frame in the general life cycle are performing under different combinations of loads. The study of performance of reinforced concrete elements under dynamic loads reveals the most important features of concrete and reinforcement under such effects. Many scientists from around the world have studied the dynamic properties for concrete and reinforcement before and based thereon have developed the methods for calculating reinforced concrete elements. The increase in the number of man-made emergencies poses more and more tasks for designers to study performance of elements under various combinations of loads and often with their high-high values.

The study of knowledge of fire resistance of structures has led to the development of standards for the calculation of the structural elements of a building in each country. But, as practice has shown, the combination of dynamic loads with fire conditions leads to more serious consequences, and the lack of knowledge of the issue does not allow us to develop a general method of calculation and include them in regulations.

This study focuses on the investigation of the properties of concrete under dynamic loadings in fire conditions and the implementation of the results in the calculation of reinforced concrete structures as well.

The pilot research has been conducted to assess the dynamic strength of concrete for high-temperature effects. Concrete cubes (150 mm side) and prisms with dimensions of 100*100*400 mm have been tested in normal and fire conditions under dynamic loadings with loading time of 0.4 and 0.1 seconds. The experiments were carried out in standard temperature conditions up to 9000.

It is known that dynamic hardening factor for concrete, equal to the ratio of dynamic strength to static, in normal conditions is greater than one unit.

Under fire conditions, the value of dynamic concrete hardening, depending on temperature and loading speed, ranges from 0.4 to 0.8. Failure to take this fact into account at the design stage for buildings of a higher level of responsibility, where it is legally required to take into account the particular combination of loads, may lead to irreversible consequences.
The study has shown that the issue of studying performance features for concrete and rein-

*Speaker

forced concrete elements already loaded with a quiescent load during extra dynamic loadings is relevant and one of the most important tasks in the field of construction. Recording a sharp change (decrease) in the dynamic strength of concrete fundamentally changes the generally accepted considerations for the fire resistance of reinforced concrete structures, thus leading to the anticipatory onset of the limit state according to the R criterion – to the bearing capacity.

Keywords: Concrete, dynamic loading, dynamic hardening factor, dynamic strength, fire conditions

Material and Manufacturing Process Modelling and Simulation for Business Decision Making

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Organizers

- Salim Belouettar, Luxembourg institute of Science and Technology (Contact Organizer)
- Carlos Kavka, ESTECO, Italy
- Borek Patzak, Technical University of Prague
- Hein Koelman, Dow

Design and selection of materials and processes for engineering applications is relatively common. Designers have to take into account a large number of material selection or design criteria. The advent of high-quality and efficient computational tools across the whole spectrum of materials, manufacturing process and product development combined with a wide accessibility of High Performance Computing (HPC) at affordable costs, have leveraged the integration of materials modelling in decision process and decision systems.
This mini-symposium will provide a forum for presentation and discussion of the state-of-the-art in field of integration of use of material and process modelling for decision-making. Emphasis will be on Materials and Process Modelling, Materials Databases and Data Integration and Decision Process Making. Contributions are solicited in, but not restricted to, the following topic areas in 1) Multiscale material and process modelling; 2) Interoperability; 3) Multidisciplinary/multi-objective optimization; 4) Methodologies for material and process selection; 5) model selection and model adaptivity.

Keywords: Data Integration, Decision Process Making, Multi, scale material and process modelling, Interoperability, Multidisciplinary optimisation, Business process modelling

*Speaker

Mechanics of Granular and Clay Materials: A mini-symposium honoring Professor Pierre-Yves Hicher

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The mini-symposium is a tribute to Prof. Pierre-Yves HICHER and his tremerous accomplishment.

Dr. Pierre-Yves Hicher

Emeritus Professor since 2015

Former Director of the Research Institute in Civil and Mechanical Engineering at the Ecole Centrale de Nantes

Pierre-Yves Hicher is a distinguished research scholar and teacher in engineering mechanics and geomechanics whose outstanding contributions to these fields are recognized world-wide.

His work has improved understanding and enriched the body of knowledge about the mechanical behavior of soils and granular materials mainly through having developed methodologies for connecting macroscopic properties to the microstructure of complex heterogeneous materials.

Among his major contributions can be cited the original experimental procedures and parameter identification methods under inverse analysis techniques, the homogenization techniques for modeling the mechanical behavior of disordered granular materials, and more recently, the practical criteria and models for addressing internal erosion in geomaterials with specific attention to landslides and the stability of hydraulic works.

After starting his professional career as a consultant in offshore oil structures and nuclear waster disposal in deep clay clayers, Dr.Hicher turned his attention to research projects which resulted in the publication of nearly 100 articles in peer-reviewed journals with over 4000 citations, 8 books and over 80 conference articles and presentations. He has supervised the work of 38 PhD students in the fields of soil mechanics, foundation engineering, granular materials, constitutive modeling and numerical modeling, and he is a reviewer for many international journals.

*Speaker

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These facts and figures, impressive as they seem, do not fully reflect the breadth and spirit of Pierre-Yves's total contribution to academia and engineering. The missing information concerns above all his extraordinary humaneness as a scientist and a mentor to numerous students and colleagues.

It must also be noted that Pierre-Yves Hicher 's fundamental contributions to granular micromechanics and constitutive modeling have brought resolutions to practical and complex problems in geomechanics often considered "dirty".

These problems, which were largely ignored by the engineering mechanics researchers in the heyday of his career, include micro-mechanical analysis of clays; characterizing the effects of particle breakage; developing rational methods for analyzing particle suffusion; analyzing clay swelling, partially saturated soils, and grouted and naturally cemented sands; developing micromechanical analyses of in situ testing and of the cyclic hardening of soils.

Each of these problems has now become a subject of engineering interest and scientific scrutiny, thanks in no small part to Dr. Hicher's devoted efforts to the soil mechanics community.

(written by Ali Daouadji, Matthew Kuhn, Angelika Lee)

List of confirmed speakers

Félix DARVE

Bernard CAMBOU

Edouardo ALONSO

Patrick SALVADURAI

David MUIR WOOD

Richard WAN

Antoinette TORDESILLAS

Wei WU

Jianfu SHAO

Farhang RADJAI

François NICOT

Farid LAOUAFA

Olivier MILLET

Cyrille CHAZALLON

Christophe DANO

Chaofa ZHAO

Xianfeng LIU

Dongmei Zhang

Zhenyu YIN

Ali DAOUADJI

Keywords: Granular materials, Soils, grain breakage, erosion, elastomers, visco, plasticity, multi scale modelling

Suffusion Process and Mechanical Behavior

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Merged with MS1: From capillary bonds to immersed granular flow

Keywords: suffusion, mechanical strength

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Resilient Behavior Modelling of Granular Based Materials

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The objectives of this mini symposium is to bring together scientists who develop models (analytical, DEM, FEM) allowing to reproduce the resilient behaviour of soils, unbound granular materials (crushed rocks, crushed concrete, asphalt aggregates, ...), coarsed aggregates assembly (ballast, ...), asphalt concrete mixes, after conditioning or not, subjected to triaxial loading or bi-axial loadings or uni-axial loading or bending. Multi-scale modelling of multi-phase materials are welcome.

Keywords: resilient behaviour, granular materials, aspahalt concrete mixes, multiscale modelling, multiphase modelling

*Speaker

Current Challenges in Multiscale Mechanics - From Materials to Structures

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Computer simulation-driven characterization and in-silico testing of materials has become a popular strategy in nowadays engineering mechanics and materials science. In many cases, the involved computational methods are of numerical nature. However, if the studied material exhibits some sort of hierarchical organization, with specific organizational patterns discernible on observation scales which are distinctively separated from each other, the aforementioned numerical methods reach (or even exceed) their application limit, due to the then arising enormous computational costs. A well-proven alternative to purely numerical approaches, when dealing with hierarchically organized materials, is multiscale modeling. This technique involves consideration of the physical properties of the constituents of a material on the observation scale where microstructural patterns occur, and establishing physically well-substantiated mechanical rules for scaling the material properties up to an observation scale where the material appears to be quasi-homogeneous (and vice versa). This mini-symposium provides a forum for latest insights and new developments in the diverse field of multiscale modeling, focusing thereby on the mechanical properties of materials. Contributions presenting models ranging from the molecular to the structural scale, and dealing with all kinds of hierarchically organized materials are welcome.

Keywords: Homogenization, Upscaling, Hierarchical Materials, Micromechanics

*Speaker

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Enriched Continuum Mechanics and Bridging Different Scales

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2

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This symposium aims at bringing together current knowledges concerning the bridging of different scales to incorporate the influence of microstructure on the macroscopic behavior of materials. Enriched continua (micromorphic, second gradient) are an example of homogenized media which intrinsically contain information related to the underlying microstructure. Such enriched model can be used to describe interesting microstructure-related phenomena both in the static (exotic material behaviors) and dynamic regime (cloaking, band-gaps, mechanical metamaterials). Contributions related to all other methods used to perform scale-bridging to unveil the statical or dynamical behavior of microstructured materials at scales which are large enough to be relevant for engineering science (e.g. homogenization, computational mechanics, ...) are also welcome.

Keywords: scale bridging, enriched continua, metamaterials, microstructure, homogenization, computational mechanics

*Speaker

Machine Learning and Informatics for Materials Discovery and Design

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The goal of this symposium is to discuss recent advances in machine learning approaches applied to materials and mechanics. Materials of interest include, but are not limited to: cementitious materials, glasses, asphalt, metals, ceramics, hierarchically-designed materials, composite materials, gels, biomaterials, granular materials, etc. Examples of topics of interest include, but are not limited to:
- Machine learning approaches to accelerate the discovery of novel materials.
- Data-driven composition–structure–property models in materials.
- Machine-learning-based geometry optimization and hierarchical design to enhance materials performance.
- Machine learning to predict far-from-equilibrium behavior.
- Informatics approaches for microstructure characterization.
- Combination of machine learning and first-principle simulations.
- Machine learning applied to material imaging/pattern recognition.

Keywords: machine learning, informatics, big data, materials

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Robustness of Infrastructures

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On the forefront of structural engineering mechanics problems today lays the problem of robustness or progressive collapse. The aging of infrastructures and the very high multilevel consequences associated with the phenomenon have raised progressive collapse as one of the most important structural engineering mechanics problems. Progressive collapse can be initiated by numerous sources including construction or design flaws which surpass the common design base of current codes. Triggering events can be extreme events such as earthquakes, hurricanes, floods, abnormal loads not included in the design like gas explosions, vehicle impacts, fire or extreme environmental loads which push the structural system well beyond its strength envelope. In this framework, all infrastructure is vulnerable to progressive collapse at some level. This mini-symposium will bring together the structural engineering industry with academia aiming to provide insights on the actual engineering mechanics of progressive collapse.

Keywords: progressive collapse, resilience, stability

*Speaker

Towards the Next Generation of Smart Structures

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Physical infrastructure subjected to and interacting with the environment requires innovative solutions from *normal* operating conditions, to intermediate stress conditions (i.e. deterioration, severe climate conditions, etc.) and to extreme conditions (e.g. natural and man-made hazards). From sustainable and energy considerations during normal operating conditions to the protection of structures in the face of extreme single or multiple hazard events is a critical and complex issue faced by engineers. To tackle this problem, several innovations are being developed, such as: (1) smart structures, which are designed and instrumented with multifunctional components to integrate sensing, control, and actuation within the structural system, (2) adaptive structures, which can alter their configurations and/or properties to better respond to changes in the environment, and (3) bio-inspired building systems, which mimic natural habitats and/or physiological systems to achieve better performance. However, these advanced types of structures introduce a new series of complexities and require further progress in the fundamental understanding of dynamic response, vibration reduction, life-cycle analysis and risk mitigation of structures subjected to single and multiple hazard events. This minisymposium (MS) provides an opportunity to engineers and researchers to present current findings in dynamic response analysis methods and techniques in risk mitigation of structures subjected to and interacting with the natural environment to meet the needs of humans. This session welcomes studies using conceptual, theoretical, computational, and/or methodological approaches in the analysis of dynamic response, active/passive/hybrid vibration control, and risk assessment/mitigation for advanced structures (as well as ordinary structures equipped with advanced sub-systems) using novel, real-world case studies and/or large-scale applications. While the MS has a predominant focus on civil structures, applications in other engineering fields such as mechanical, electrical, aerospace and materials science and engineering are also welcomed.

Keywords: smart structures, hazards, resilience, vibration control, energy, sustainability

*Speaker

Recent Advances in the Behavior of Granular Materials

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The understanding of the behavior of granular materials has known considerable progress in the last years, due to the use of advanced and more and more sophisticated experimental tools (tomographic techniques, advanced tribology techniques ...), in order to feed constitutive models developed in different frameworks (discrete element models, elasto-plasticity, hypoplasticity, thermodynamics, ...). A general feature consists in crossing the scales, micro or local scale at the grain level to the macro or global at the assembly level and in introducing coupling effects (mechanics, chemistry, temperature, hydraulics, ...). Both experimental tools and numerical modelling aim to better take into account physical mechanisms considered as of a second-order contribution until now, such as time dependency of the behavior of granular media, degradation of particles (breakage, abrasion, attrition, dissolution/precipitation) under complex and usually coupled environmental and mechanical conditions. The goal of this mini-symposium will therefore be to illustrate recent advances in the behavior of granular materials and to highlight the opportunity to gather different approaches (physics, mechanics, experimental/numerical, ...).

Keywords: Granular materials, modelling, experiments

*Speaker

Stability and failure of structures and materials

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This symposium supported by the ASCE EMI Stability Committee is to provide a forum to discuss recent advances and address the future prospects in the area of stability and failure mechanics of structural components, systems and materials. Interested researchers are invited to submit abstracts on topics which include, but are not limited to:

- Instability in columns, beams, plates, shells and sandwich structures.
- Instability of members made from metallic and composite materials.
- Post-buckling analysis including analytical/computational modelling and methods.
- Dynamic stability problems including energy absorption systems or crashworthiness analysis.
- Interactive buckling in thin-walled structures.
- Failure mechanics of materials including cracks, delaminations and micro-buckling.
- Buckling of micro/nano and lattice structures. Wrinkling of thin-films.
- Progressive cellular buckling and snaking.
- Non-local mechanics including instabilities in systems with non-local effects.
- Orthotropic and anisotropic materials and related stability problems.
- Instabilities in layered and granular media including shear and kink band formation.
- Experimental techniques and fixture design for structural and material stability tests.

Keywords: Stability, Buckling, Bifurcation, Structural mechanics, Thin, walled structures

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Shell Buckling

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The arena of shell buckling received great attention after the monumental development of a general theory on elastic buckling and post-buckling behavior by Koiter in 1945. For more than three decades, the literature on shell buckling flourished with investigations on imperfections sensitivity, minimum buckling loads and instability modes. Following this intense progress, the field entered a period of idleness, up until very recently. Today, 74 years after Koiter's presentation, there is a strong resurgence of activity in studying the mechanics of shell buckling which is observed worldwide by numerous research efforts. With the rapid progress in new materials and computational and experimental technology, a breadth of exciting new ideas has revitalized the problem. This mini-symposium will provide a forum for discussing the most recent computational, theoretical and experimental findings in the area of shell buckling, as well as future research directions.

Keywords: Stability

*Speaker

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Linear and Nonlinear Vibrations of Complex Structures

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The objective of this mini-symposium is to constitute a forum for the exchange of knowledge concerning the latest research developments in the field of vibrations. The focus is on new advances in both numerical and experimental methods for linear and non-linear vibrations analysis of complex structures such as thin-walled structures, composites, metamaterials and additive manufactured structures.... Topics of interest include, but are not limited to: experimental methods for passive and active control, reduced models, methods for vibroacoustics problems and new numerical methods to engineering vibration, dynamics, wave propagation problems and others. –

Keywords: Thin walled structures, composites, Passive and active damping, vibroacoustics, vibrations

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Vibration Control of Structures Under Multiple Hazards

Said Elias Rahimi * [1], Aly-Masoud Aly *

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There are significant chances of damages and loss of lives from the aging and vulnerable structures, coupled with wind, wave, and seismic hazards. In general, structures and the infrastructure such the buildings, bridges, offshore may experience catastrophic damages while subjected to forces from multi-hazard. Mostly, in the past, individual hazard studies have been conducted and it was argued that an individual hazard would be more significant. However, due to the rapid growth of the population and the economic developments, exposure to multiple hazards (primary, secondary, etc.) have greatly increased. Unfortunately, even for structures built in the regions where more than one hazards are present, the design codes and hazard mitigation strategies treat such forces completely independent. This fact does not account for the increased risk posed to such structures. Accordingly, the performance of vibration control of structures using different methodologies is necessary for the safety and serviceability of the infrastructure under multi-hazard loads, if single strategy fails in meeting the performance requirements. Therefore, it is very important to assess the response control of structures subjected to multi-hazard loads.

Keywords: vibration control, wind, wave, seismic hazards

*Speaker

Large Scale Flow Simulations

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Flow simulations are at the heart of many everyday life applications such as weather forecasting, indoor climate control and pollutant dispersion across a city, they also have important industrial applications for flight dynamic and wind farms. Due to this large body of applications this area of research has been expanding over the past decades. This mini-symposium will focus on the numerical techniques that underpin large scale flow simulations such as multiscale modeling, mesh generation, solver technology and uncertainty quantification. An emphasis will be made on current difficulties preventing the fast and reliable simulation of large scale flow. The presenters will aim at providing current and new directions of research to mitigate such difficulties.

Keywords: Fluid dynamics, Large scale simulations, HPC, Wind

*Speaker

List of participants

List of participants

- Ahmed Kamal
- Aivaliotis Alexios
- Alfach Mohanad Alfach
- Amarsid Lhassan
- Arab Oussama
- Askouni Paraskevi
- Avetisyan Levon
- Baptista Eduarda
- Behrendt Marco
- Benaimeche Mohamed Amine
- Berger-Vergiat Luc
- Bishara Suzy
- Bobet Antonio
- Bologna Emanuela
- Boudlal Omar
- Brara Ali
- Brügger Adrian
- Cambou Bernard
- Casas Nathalie
- Challamel Noël
- Chaouche Yassine
- Chawla Komal
- Chazallon Cyrille
- Cheikh Sleiman Hani
- Cheng Chih-Chun

- Collet Manuel
- Coulibaly Jibril
- D'agostino Marco Valerio
- Dano Christophe
- Daouadji Ali
- Das Anupam
- Daya El Mostafa
- Defay Angeline
- Delli Carpini Maria
- Di Stefano Salvatore
- Eckert Christoph
- Eghbalian Mahdad
- El Kadi Michael
- El Khomsi Anass
- Essawy Yasmeen
- Fabbri Antonin
- Farahnak Langroudi Mojtaba
- Fieux Gauthier
- Fragkoulis Vasileios
- Gaillard Laura
- Gao Xiangling
- Gerasimidis Simos
- Ghiba Ionel-Dumitrel
- Gupta Ritesh
- Gutierrez Soto Mariantonieta
- Hameed Rashid
- Hamelin Guillaume
- Hirobe Sayako
- Hoang Tien
- Hu Lianxin
- Ighil Ameur Lamine
- Jaafari Chaimaa

- Jeanniot Charline
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- Li Xiaojiao
- Li Gang
- Liang Kun
- Liu Chien-Sheng
- Luu Li-Hua
- Madeo Angela
- Mahmoud Hussam
- Makashev Kuanysh
- Mamaghani Iraj
- Mangalathu Sujith
- Manzari Majid
- Massoumi Sina
- Matous Karel
- Meidani Hadi
- Milane Rosy
- Millet Olivier
- Mondal Bapi

- Mondal Sanchari
- Moreau Antoine
- Morin Claire
- Muench Ingo
- Nasouri Reza
- Neff Patrizio
- Nicot Francois
- Olsson Erik
- Ommi Siddhartha
- Ouchen Ibrahim
- Ozturk Baki
- Panda Jagajyoti
- Pandey Shruti
- Paratore Gabriele
- Patel Smita
- Patrick De Luca
- Paul Sachin
- Peled Alva
- Perrin Henri
- Pezzola Genevieve
- Philbert Nshimiyimana
- Philippe Pierre
- Picandet Vincent
- Pichler Bernhard
- Prud'homme Elodie
- Psaros Apostolos
- Rachdi Sara
- Rahai Ali Reza
- Rahai Mohammad
- Rahimi Said Elias
- Rahmouni Zine El Abidine
- Ramadji Christian

- Reboul Nadège
- Richefeu Vincent
- Robin Guillaume
- Roller Christoph
- Rosa Isamar
- Rousseau Quentin
- Roux Jean-Noël
- Ruch David
- Saad George
- Sachan Deepak
- Sahin Mehmet
- Saidi Mohamed
- Scheiner Stefan
- Seblany Feda
- Seo Jihye
- Shao Jianfu
- Shomali Ali
- Sparks Paul
- Steer Quentin
- Tallarico Domenico
- Tallarico Domenico
- Tan Yonggang
- Tounsi Hafssa
- Van De Sande Jorn
- Vora Tanmay
- Wan Richard
- Wassim Jrad
- Xiaoqin Lei
- Xu Longfei
- Ykhlef Boubakeur
- Zahidi Omaima
- Zalamea Nicolas
- Zhang Yao
- Zhao Chaofa

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