The Biot-Bažant Conference

on Engineering Mechanics and Physics of Porous Materials

A One-Time Fusion of Concreep and the Biot Conference on Poromechanics

June 1-3, 2021

Massachusetts Institute of Technology

Georgia Tech

Northwestern University

Schedule At-A-Glance

TIME IN US CDT		6/1/2021 - TUE DAY 1	6/2/2021 - TUE DAY 2	6/3/2021 - TUE DAY 3
7:45 AM	8:00 AM	Welcome	Plenary Debate #2	Plenary Debate #4
8:00 AM	9:00 AM	Bažant's Opening Lecture		
9:00 AM	9:15 AM	Break	Break	Break
9:15 AM	10:30 AM	Parallel Sessions	Parallel Sessions	Plenary Debate #5
10:30 AM	10:45 AM			Break
10:45 AM	11:15 AM			Van Damme's Closing Lecture
11:15 AM	11:30 AM	Break	Break	
11:30 AM	11:45 PM	Plenary Debate #1	Plenary Debate #3	
11:45 PM	12:45 PM			
12:45 PM	1:00 PM	Break	Break	
1:00 PM	3:00 PM	Parallel Sessions	Parallel Sessions	
3:00 PM	3:15 PM	Break	Break	
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Bažant's Opening Lecture

Day 1 (6/1/21) 8:00 - 9:00 am CDT

Unsaturated Nano-Poro-Mechanics of Century-Scale Creep and Hygrothermal Deformations of Concrete

Although the poromechanics of saturated materials and of unsaturated materials with capillary porosity has already been developed, a comprehensive model for unstaturated nano-poromechanics has been unavailable. Here we aim at formulating such a model based on Gibbs free energy of the solid-fluid system and on the recently derived and verified Nguyen-Rahimi-Bažant (NRB) isotherm, which corrects the BET isotherm for the effect of hindered adsorbed water in filled nanopores and extends through the capillary range up to saturation. The model is further incorporated into the recent extended micro-prestress theory and hydration model to characterize and predict a wide range of published experimental data, including 1) a complete sorption isotherm of hydrated cement paste (including the capillary range), 2) pore size distribution, 3) autogenous shrinkage, 4) drying shrinkage, swelling and creep 5) water loss or humidity change due to heating, 6) thermal expansion at various humidities, and 7) water loss of specimens caused by compression. The present model is expected to help gain insights into the deleterious moisture effects on long-time deformations, cracking damage, and fracture in concrete infrastructure and thereby indirectly lengthen their service time. Adaptations to shale and coal beds are possible with proper modification, depending on their pore size features.

Zdeněk P. Bažant

Born and educated in Prague (Ph.D. 1963), Bažant joined Northwestern in 1969, where he has been W.P. Murphy Professor since 1990 and simultaneously McCormick Institute Professor since 2002, and Director of Center for Concrete Geomaterials (1981-87). He was inducted to NAS, NAE, Am. Acad. of Arts & Sci., Royal Soc. London, the academies of Austria, Japan, Italy, Spain, Czech Rep., Greece, India and Lombardy, and Academia Europaea. Honorary Member of: ASCE, ASME, ACI, RILEM. Received Austrian Cross of Honor for Science and Art I. Class; 7 honorary doctorates (Prague, Karlsruhe, Colorado, Milan, Lyon, Vienna, Ohio State); ASME Medal, ASME Timoshenko, Nadai and Warner Medals; ASCE von Karman, Freudenthal, Newmark, Biot, Mindlin and Croes Medals, and Lifetime Achievement Award; SES Prager Medal; Outstanding Res. Award from Am. Soc. for Composites; RILEM Gold Medal; Exner Medal (Austria); Torroja Medal (Madrid); etc. He authored eight books: Scaling of Struct. Strength, Creep in Concrete Str., Inelastic Analysis, Fracture and Size Effect, Stability of Structures, Concrete at High Temp., Creep & Hygrothermal Effects, Probab. Mech. of Quasibrittle Str. He is one of the original top 100 ISI Highly Cited Scientists in Engrg. (www.ISIhighlycited.com). H-index: 137, citations: 81,000, i10 index: 658 (Google, incl. self-cit.). In 2019 Stanford U. weighted citation survey (see PLoS), he was ranked no.1 in CE and no.2 in Engrg. worldwide. In 2015, ASCE established ZP Bažant Medal for Failure and Damage Prevention. His 1959 mass-produced patent of safety ski binding is exhibited in New England Ski Museum, Franconia, NH. http://cee.northwestern.edu/people/bazant/

Van Damme's Closing Lecture

Day 3 (6/3/21) 10:45 - 11:45 am CDT

Materials, Processes, and (infra)Structures for the Ecological Transition: an opportunity for poro-science and engineering

The future is bright for high surface area and/or porous solids with controlled structure and properties, be it for the energy transition (energy efficiency, preference for renewables or net zero-emission fossil fuels), for the industrial transition (local production of recyclable goods in a circular economy perspective), or for the agri-food transition (replacement of a chemical input-demanding and soil-degrading agriculture by an organic and soil-preserving one). In chemical and process engineering, including energy devices like batteries and fuel cells, the classical paradigm of unit operations that are capable of carrying out specific transformations (mixing, heating, reaction,separation, etc.) in distinct pieces of equipment, will tend to be replaced by the so-called process intensification, focusing on development of multi-functional and miniaturized modules able to combine several classical unit operations into a single processing step. Materials and devices allowing for the controlled encounter, exchange and reaction of heat, momentum, molecules – often in the fluid or confined state – and electrons in a minimal volume will be much needed. A similar trend may develop in civil engineering, under the pressure of – mainly urban – excessive land occupation and resource utilization. Buildings and infrastructures and their constitutive materials will be asked to be increasingly multifunctional, while still being fully recyclable. This evolution will affect the way we discover, model, design, and manufacture materials and devices. Typical and, hopefully, convincing examples will be discussed.

Henri Van Damme

Henri Van Damme is a physical chemist and material scientist. Born in Belgium, he received his graduate degree in bio- and chemical engineering and his PhD degree in materials science, both from the University of Leuven. He then moved to the CNRS (French National Center for Scientific Research) in Orléans, France, where he was appointed to a research scientist position. From 1976 through 1985, including a sabbatical year at the University of Wisconsin, Milwaukee, he worked on heterogeneous catalysis and photocatalysis and on the photochemical conversion of solar energy. From 1985 through 1999, he established and was director of the CNRS Research Center on Dispersed Matter and his interest shifted to granular, porous and dispersed materials. In 1999 he joined the Ecole de Physique et Chimie Industrielles de Paris (ESPCI-Paris) where he has been professor of thermodynamics and materials science from 1999 to 2009. In 2009 he joined the Laboratoire Central des Ponts et Chaussées (LCPC, now IFSTTAR), the main civil engineering lab in France, as scientific director. From 2014 to 2016 he was visiting professor in the Civil & Environmental Engineering Department (CEE) of the Massachusetts Institute of Technology (MIT) and member of the MIT-CNRS joint research unit on multiscale materials for energy and the environment.

Henri Van Damme has devoted most of his carreer to the physical chemistry and physics of geomaterials like glass, clays, cement, or source rocks, and their interactions with the molecular world, with applications in the field of catalysis, energy (solar and fossil), construction and process engineering. He has been president of the Condensed Matter Physics division of the National Committee for Scientific Research (France). He is currently member of the Advisory Board of the newly established Université Gustave Eiffel (Paris) and member of the Advisory Board of the Civil Engineering and Geomatics department of ETH Zurich.

Plenary Debate #1

Day 1 (6/1/21) 11:30 am - 12:45 am CDT

Fluids and solids are not fully coupled in porous media.

For: Gilles Pijaudier-Cabot

Gilles Pijaudier-Cabot graduated from Ecole Normale Supérieure de Cachan in 1985 and obtained a Ph.D. from Northwestern University in 1987. His research activities dealt first with damage and fracture in quasi-brittle materials, with physical aspects of fracture and later on durability mechanics, combining damage mechanics with chemistry of cement. Starting in 2004, he focused interest on the permeation properties of concrete and rocks undergoing mechanical loads, with applications to waste storage, safety of nuclear vessels, and hydraulic fracture for unconventional hydrocarbon production. At Université de Pau et des Pays de l'Adour, he created in 2008 a group dedicated to hydro-mechanics of porous materials, including lattice approaches for failure, analytical models for estimating multi-phase fluid flow properties in rocks and coupled adsorption and swelling phenomena in micro-porous materials. Today Gilles Pijaudier-Cabot is directing the hub "New frontiers in porous materials", a joint venture between Université de Pau et des Pays de l'Adour and SEGIM at Northwestern University.
Gilles Pijaudier-Cabot received the bronze medal from CNRS in 1991 and the Jean Mandel prize of the French association of mechanics in 1992. He is member of Institut Universitaire de France (IUF) since 2012. In 2019, he received the Dolomieu award from the French Academy of Sciences. He has been recently elected chair of the French national committee evaluating research on radioactive materials and wastes.

Against: Roland Pellenq

Roland Pellenq is Director of Research at CNRS, the French Government Agency for Scientific Research at the EPiDaPo George Washington / CNRS joint laboratory and a Visiting Professor in the department of Physics at Georgetown University in Washington DC. Roland Pellenq is a computational materials scientist with a strong interest in the physics and mechanics of micro- and nanoporous materials and confined fluids. After a Master in Plasma Physics from Aix-Marseille University (France), He obtained a PhD in Chemical Physics from Imperial College London (UK) in 1994 and received his Habilitation degree in Physics from the University of Orléans (France) in 2000. Roland Pellenq's research is dedicated to the development of bottom-up simulation approaches (starting at an atomistic level of description) for a large variety of critical problems in energy and environment, ranging from hydrogen and CH4 storage, CO2 sequestration, shale gas to fundamentals of cement and concrete research and more recently on Urban Physics. R. Pellenq is the author or co-author of 230+ papers published in major peer reviewed scientific journals. He was the founder and head of the MIT-CNRS joint laboratory "Multi-Scale Material Science for Energy and Environment" located on the MIT campus (2012-2020) together with Prof. F. Ulm (MIT. Cambridge, US). He now leads a research effort in France, in Europe and in the US on Urban Physics linking city texture as seen through the prism of Statistical Physics and applied to environmental, public health and climate challenges named COMPLEX-Cities that is associated to the international CNRS Research network USERS (Urban Sciences and Engineering for Resilience and Sustainability) also led by R. Pellenq together with Prof. E. Del Gado (Georgetown U., Washington US). Since Nov. 2020, R. Pellenq serves as Associate Vice-President for International relations in charge of US and Canada for Paris-Sciences&lettres University (Paris, France).

Plenary Debate #2

Day 2 (6/2/21) 7:45 - 9:00 am CDT

Darcy's law is meaningless for flow within individual pores.

For: Catherine O'Sullivan

Catherine O'Sullivan is a Professor in Particulate Soil Mechanics at Imperial College London. Originally from Ireland, she obtained her PhD from the University of California at Berkeley in 2002. Since arriving at Imperial College in 2004 she has continued to develop research that examines soil behaviour focussing on the particulate scale.

Catherine has authored a textbook on the use of discrete element modelling in geomechanics and has authored/co-authored over 80 contributions to international journals. In 2015 she delivered the Géotechnique lecture. Funding for her post-graduate studies and research has been provided by the Fulbright Programme, the O'Reilly Foundation, the IRCSET, the EPSRC, the ICE, the Leverhulme Trust, NERC and ARUP. Catherine was a member of the Géotechnique Advisory Panel 2010-2012 and is currently a member of the editorial boards of Computers and Geotechnics, Granular Matter and an Editor of the ASCE Journal of Geotechnical and Geoenvironmental Engineering.

Against: Benoît Coasne

Benoit Coasne obtained his PhD in Physics on capillary condensation in nanoporous materials (Paris, 2003). Then, he worked from 2003 to 2005 as a postdoc with Prof. Keith Gubbins on freezing of nanoconfined systems (Raleigh, NC, USA). Benoit Coasne was then appointed CNRS researcher in Montpellier (2005) and promoted CNRS Research Director (2015). During a 3 year visiting stay, he was leading fundamental research on multiscale modeling of adsorption and transport in the CNRS/MIT lab at MIT in Boston (2012/15). He is currently affiliated CNRS Research Director in the Interdisciplinary Physics Lab in Grenoble, France. He is also currently appointed Senior Scientist Councelor for Veolia Water Technologies. Benoit Coasne was Co-founder and first President of the French Adsorption Society.

Benoit Coasne's research consists of studying by means of statistical mechanics and molecular simulation tools the thermodynamics and dynamics of fluids, electrolytes and solids confined in porous media. This activity is relevant to physics and chemistry of condensed matter but also materials science with emphasis on multiscale and hierarchical solids. Dr. Benoit Coasne's research on adsorption, confinement, and phase transitions in porous materials cover a broad range of confined systems from atoms, molecular fluids, elec-trolytes/ionic liquids, and solids. He has published 170 papers including 2 Nature Materials, 5 Nature Comm., 2 Chem. Soc. Rev, 3 Phys. Rev. Lett., 3 J. Phys. Chem. Lett. His work has also resulted in 36 invited lectures.

Plenary Debate #3

Day 2 (6/2/21) 11:30 am - 12:45 am CDT

Cementitious composites at fresh state are visco-plastic solids.

For: Erik Schlangen

Dr. Erik Schlangen is Professor in the chair of "Experimental Micromechanics" and head of the Material & Environment section at the faculty of Civil Engineering and Geosciences at Delft University of Technology in the Netherlands. He is also the director of the Microlab for micromechanical and material research which is part of the same University. He is specialized in fracture mechanics of quasi-brittle materials like concrete, durability mechanics, finite element modelling, design of experimental techniques and self-healing of concrete and asphalt. He is the inventor of the Delft lattice model for simulation of fracture. He owns a patent on healable concrete. He initiated the self-healing bacterial concrete and is the inventor of the self-healing asphalt with steel-wool and induction heating that is applied in several applications.
He is editor of several state of the art reports and conference proceedings and has (co)authored more than 400 technical papers in Journals and conference proceedings and has given many key-note and invited lectures at conferences. He is editor of Construction & Building Materials and he is Editor in Chief of the journal Advances in Concrete Construction.

Against: Emanuela Del Gado

Emanuela del Gado is Provost's Distinguished Associate Professor at Georgetown University, Washington, USA. She received her undergraduate degree (Laurea in Physics, cum laude) at the University of Naples "Federico II" in Italy, where she also obtained a PhD in Physics in 2001. She was a Marie Curie Fellow at the University of Montpellier II in France and a post-doctoral researcher at ETH Zurich in Switzerland, and held visiting positions at ESPCI (France) and MIT. Before joining Georgetown University as Associate Professor with tenure in 2014, Emanuela was a Swiss National Science Foundation (SNSF) Assistant Professor in the Department of Civil, Environmental and Geomatic Engineering at ETH Zurich.
Emanuela Del Gado is a theoretical physicist working on engineering motivated problems. She uses statistical mechanics and computational physics to investigate materials with structural and dynamical complexity, from model amorphous solids, gels and glasses, to new green formulations of cement; nanoscale structure and mechanics of cement gels; self-assembly of nanoparticles and fibrils at liquid interfaces; biomimetic coatings and mechanics of tissues; mechanics and rheology of gel networks.

Plenary Debate #4

Day 3 (6/3/21) 7:45 - 9:00 am CDT

Multiscale models are not quantitative.

For: Roberto Ballarini

Roberto Ballarini obtained his Ph.D. in Civil Engineering from Northwestern University (1985). He is currently Thomas and Laura Hsu Professor and Chair of Civil and Environmental Engineering at University of Houston. Ballarini previously served as James L. Record Professor and Head of the Department of Civil Engineering at University of Minnesota, and Leonard Case Professor of Engineering at Case Western Reserve University.

Professor Ballarini's research focuses on the development and application of theoretical, computational and experimental methods to characterize the response of materials to mechanical, thermal, and environmental loads. He is particularly interested in fracture and fatigue of materials and structures. His multidisciplinary research has been applied to problems arising in civil engineering, mechanical and aerospace engineering, materials science, microelectromechanical systems, and biological materials. He published more than 120 papers in high-impact journals including Science and Nature, and has been a visiting professor at numerous universities around the globe. Several of Ballarini's research results have been featured in the popular press, including the New York Times Science Times, American Scientist, Pour la Science, Business Week, Financial Times, and Geo. He served as President of the ASCE Engineering Mechanics Institute, and is currently Editor of Journal of Engineering Mechanics. Ballarini is the recipient of the 2019 Raymond D. Mindlin Medal.

Against: Christian Hellmich

Dr. Christian Hellmich, Fellow of EMI-ASCE and corresponding member of the Austrian Academy of Sciences, is Full Professor at the Department of Civil Engineering and director of the Institute for Mechanics of Materials and Structures of the Vienna University of Technology (TU Wien). There he obtained all his academic degrees, having spent the years 2000 to 2002 as postdoctoral fellow at M.I.T. He is well known for well-validated material and (micro)structural models, in terms of theoretical foundations and applications to concrete, soil, rock, wood, bone, and biomedical implants, up the structural level (tunnels, pipelines, bridges, biological organs such as the skeleton) - with complementary experimental activities if necessary.

Plenary Debate #5

Day 3 (6/3/21) 9:15 - 10:45 am CDT

Reactive tailings: All you need is strength.

For: Andrew Whittle

Andrew J. Whittle is the Edmund K. Turner Professor of Civil and Environmental Engineering at MIT. His research deals with the development of constitutive models for soil behavior and their application in predicting the performance of foundations and underground construction projects. He has also carried out extensive research on wireless sensor networks for monitoring underground infrastructure notably in the detection and localization of leaks in water pipe networks. He serves as Chief Scientific Advisor for a start-up company, Visenti Pte. He has served on review panels for hurricane protection systems in New Orleans (NRC), and the 'stem-to-stern' safety of the Big Dig tunnels in Boston, and was a Director for the Massachusetts Department of Transportation (2009-2015).

Dr. Whittle is a Co-Editor of the International Journal of Numerical and Analytical Methods in Geomechanics (since 1999). He has published more than 200 papers in refereed journals and conferences, and received several awards for his work from the American Society of Civil Engineers, including the Casagrande Award (1994), the Croes Medal (1994), Middlebrooks Prize (1997, 2002, and 2005) and Huber Research Award (1998). He is a licensed professional engineer in New York State. In 2010 he was elected to the National Academy of Engineering.

Against: Susan Burns

Susan E. Burns, Ph.D., P.E., F.ASCE is Professor and Associate Chair for Administration and Finance in the School of Civil and Environmental Engineering at the Georgia Institute of Technology. Dr. Burns earned a Bachelor Degree in Civil Engineering B.C.E. (1990), M.S. Civil Engineering (geotechnical) (1996), M.S. Environmental Engineering (1996), and Ph.D. in Civil Engineering (1997), all from Georgia Tech.

Dr. Burns' research focuses on applications in geoenvironmental engineering, with particular emphasis on the beneficial use of waste materials including dredged sediments, fly ash, and biomass fly ash; treatment of highway stormwater runoff using engineered materials; erosion control of soils on highway rights-of-way; and interfacial behavior of organic- and inorganic-coated soils.

She is a recipient of the National Science Foundation CAREER Award, a Fellow of the American Society of Civil Engineers, and was named the 2020 Engineer of the Year by the Georgia Society of Professional Engineers.

Session Program

DAY 1

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AM	Session 1.1	Session 2.1	Session 3.1	Session 4.1	Session 5.1	Session 6.1	Session 7.1
PM 1	Session 1.2	Session 2.2	Session 3.2	Session 4.2	Session 5.2	Session 6.2	Session 7.2
PM 2	Session 1.3	Session 2.3	Session 3.3	Session 4.3	Session 5.3	Session 6.3	Session 7.3

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	1	*2*	*3*	*4*	*5*	*6*
AM	Session 1.4	Session 2.4	Session 3.4	Session 4.4	Session 5.4	Session 6.4
PM 1	Session 1.5	Session 2.5	Session 3.5	Session 4.5	Session 5.5	Session 6.5
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Track 1

1.1 Special Session Celebrating 70th Birthday of Prof. Rudnicki, Part 1

Chair Dmitry Garagash
Day 1 9:15 - 11:15 am

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My nearly career-long collaborations with John Rudnicki
James Rice, Harvard University

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Effect of pore pressure oscillations on slip on a fault governed by rate and state friction
John Rudnicki, Northwestern University

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Hydraulic fracture in weak rock
Emmanuel Detournay, University of Minnesota

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Fracture mechanics of faults with rate-and-state friction
Dmitry Garagash, Dalhousie University

418
Impact of layering and mineral-fabric orientation on fracture surface roughness
Laura Pyrak-Nolte, Purdue University

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Following in the footsteps of John Rudnicki: Simulation of sequence of induced earthquakes and aseismic slip due to injection into a hydrologically isolated rate and state fault
Ahmed Elbanna, University of Illinois Urbana-Champaign

1.2 Special Session Celebrating 70th Birthday of Prof. Rudnicki, Part 2

Chair Steve WaiChing Sun
Day 1 1:00 - 3:00 pm CDT

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Yonggang Huang, Northwestern University

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Are configurational forces real forces
Roberto Ballarini, University of Houston

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Simulation of compaction localization in porous rock at laboratory and field scale
Giuseppe Buscarnera, Northwestern University

314
Special session honoring the 70th birthday of John Rudnicki: Micro-CT-based porosity analysis of biomass particles
Qiushi Chen, Clemson University

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Special session honoring the 70th birthday of John Rudnicki: Plasticity theories as evolving level sets
WaiChing Sun, Columbia University

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Microscale modeling of the mechanical behavior of black shale
Gianluca Cusatis, Northwestern University

1.3 Modeling and Characterization of Nonlinear Beahavior of Geomaterials

Chair Jose Andrade
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Julia Leuthold, Karlsruhe Institute of Technology

320
Micromechanical investigation of particle size effect of granular materials in biaxial test with DEM
Pei Wang, The Hong Kong Polytechnic University

353
Study of the gas impact on clayrock integrity with a second gradient model
Gilles Corman, University of Liege

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Role of soil viscosity on diffusive instability and flowslide runout
Yanni Chen, Northwestern University

373
Modeling penetration of self-burrowing impactor probes into granular regolith using the cavity expansion theory
Mahdi Alaei Varnosfaderani, University of Manitoba

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Numerical procedure to obtain the effective dynamic permeability of heterogeneous poroelastic media
Nicolas Daniel Barbosa, University of Lausanne

1.4 Computational Modeling of Localization Instability

Chair Jia-Liang Le
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Flaw size sensitivity of amorphous silica nanostructures
Kedar Kirane, Stony Brook University

282
Mechanism-based energy regularization in numerical modeling of quasibrittle failure
Anna Gorgogianni, University of Minnesota-Twin Cities

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Mechanical and fracture characteristics of multi-size carbon fibers reinforced concrete
Mohammed Abdellatef, University of New Mexico

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Waves as a trigger for multiscale, multi-physics instabilities
Klaus Regenauer-Lieb, The University of New South Wales

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Chair Giovanni Di Luzio
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Bo-Ye Fu, Chinese Academy of Sciences
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Cracking and fracture of cement exposed to calcium leaching
Patience Raby, University of New Mexico
389
Fracture in a swelling medium
Jacques M. Huyghe, University of Limerick

Track 2

2.1 Interplay Between Creep, Relaxation, and Shrinkage

Chair Mija Hubler
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Andreas Brugger, University of Innsbruck
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Zhenming Li, Delft University of Technology
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Matthew D'Ambrosia, MJ2 Consulting
292
Shrinkage and swelling of hardened cement paste containing high amounts of limestone powder during water ad- and desorption
Christian Herget, Technische Universität Darmstadt

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Sannidhya Ghosh, University of Colorado Boulder
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Rihards Gailitis, Riga Technical University
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Raul Marrero Rosa, Northwestern University

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Chair Mija Hubler
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Abudushalamu Aili, Nagoya University
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Petr Havlasek, Czech Technical University Prague

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Chair Madura Pathirage
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Modeling rate sensitivity in soils with multiple viscous mechanisms
Zhenhao Shi, Tongji University
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Ange Akono, Northwestern University
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Chair Franz-Joseph Ulm
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Thomas A. Bier, Technische Universität Bergakademie Freiberg

Track 3

3.1 Shrinkage and Sustained Load Behavior

Chair Roman Wan-Wendner
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Christopher Schmidt, Rheinisch-Westfälische Technische Hochschule Aachen
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Ismail Aldellaa. University of Glasgow

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Chair Jia-Liang Le
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Marek Krzaczek, Gdansk University of Technology
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