

12TH ADVANCES IN CEMENT-BASED MATERIALS

University of California, Irvine, USA » July 11-13, 2022

ADDRESSING CONCRETE PERFORMANCE IN CARBON EMISSIONS MITIGATION

KEYNOTE

MONDAY, JULY 11 | 8:45 – 9:30 AM



SABBIE MILLER

University of California, Davis

Abstract

Infrastructure materials, especially cement-based materials such as concrete and mortar, are being consumed at a greater rate than population growth as we experience greater affluence and urbanization as well as material deterioration. Thirty billion tons of concrete are produced annually, resulting in 8-9% of anthropogenic CO₂ emissions; a result of both energy resources required and limestone decarbonation during production. There are adjunct effects of 2-3% of energy demand, as well as material and water resource-related stresses, and there is no readily available substitute for these materials. This combination of effects has left the production of cement-based materials among the most critical sectors to tackle in mitigating anthropogenic impacts on the environment. In this talk, I will present some of the risks to people and the environment from the production and use of infrastructure materials, as well as solutions to these challenges that can be found by working at the interface of material science, structural design, and industrial ecology. By bridging material performance and environmental impact assessment, the advancement of cement use in society while addressing challenges including emissions, resources scarcities, and the local, regional, and global implication of environmental impact mitigation strategies will be discussed.

Biography

Sabbie Miller is an Assistant Professor in the Department of Civil and Environmental Engineering at the University of California Davis. Professor Miller's research focuses on lowering the environmental impacts of the built environment, specifically methods to quantify, assess, and mitigate the climate and health burdens from materials demand. She is developing methods for improving materials design procedures to concurrently assess environmental impact and material performance by linking concepts from structural engineering, materials engineering, and life-cycle assessment. Professor Miller serves on several national and international committees pertaining to infrastructure material sustainability, and she is an editorial board member for the Institute of Physics Environmental Research and Infrastructure Sustainability journal. She recently was awarded an NSF CAREER Award to study mechanisms that support carbon capture and utilization in building materials. Professor Miller received her PhD from Stanford University in Civil and Environmental Engineering with a concentration in Structural Engineering and Geomechanics. Prior to joining the faculty at the University of California Davis, she was a postdoctoral scholar at the University of California Berkeley with a concentration in Industrial Ecology.

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FROM NATURAL CEMENTATION TO A GEO-INSPIRED CEMENT: A GEOSCIENCE AND ENGINEERING APPROACH

KEYNOTE

TUESDAY, JULY 12 | 8:30 – 9:15 AM



TIZIANA VANORIO
Stanford University

Abstract

Decarbonizing cement production is an engineering challenge that shares two important features with the geosciences. First, the primary root-cause of the problem requires us to increase reliance on innovative, low-emission raw Earth materials. Secondly, there is also an epistemological link with the geosciences since cement is an essential element of lithification. Traditionally, however, rock physics and mechanics have rarely focused on rock cementation, largely concentrating the attention on the damage aspect of the deformation problem — how rocks deform and fail under stress. But how do sediments naturally heal through cementation? What is the role of the micro- and nano-structure of cementitious phases in controlling stiffness, strength, and mode of failure? These are fundamental questions that go to the heart of the frictional healing of aluminosilicate rocks from the crust seismic cycle, where active faults of the Earth's crust function as large-scale kiln factories — they mechanically pulverize aluminosilicate rocks to the micron or finer scale and internally channel heat that primes the sediment for oxides-fluid chemical reactions, eventually leading to cementation and strength recovery.

In this presentation, I will show that nano does not always equate with manufactured as Earth itself is an excellent nanotechnologist using water for its chemistry and creating reinforced structures at the nanoscale. Specifically, I will share results that reveal the micro- and nano-structure of fibrous cementitious phases in aluminosilicate rocks, highlight the role of hydrothermal water in creating nanostructured fibrous minerals, and show how the presence and spatial orientation of fibrous nanominerals (alignment vs. entanglement) affect strength and are responsible for a transition from brittle to ductile behavior. Such an understanding of the benign workings of Earth down to its nanosized dimensions is foundational to the prospect of transforming natural nano sizes into manufactured technology. We are using a geomimetic approach that harnesses Earth's designs and hydrothermal processes to create cementitious materials with structures that mimic natural micro- and nano-structures. Such an approach and cross-pollination of knowledge between geoscience and engineering plays an important role in innovative processes, leading the way toward the development of durable and low CO₂-cements.

Biography

Tiziana Vanorio is an Associate Professor and Sr. Associate Dean for Educational Affairs in the School of Earth, Energy, and Environmental Sciences at Stanford University. Tiziana leads the Rocks and Geomaterials Lab (RGL) where she integrates laboratory experiments that mimic Earth processes with analytical techniques that characterize the textural, physical, and mechanical properties of rocks and geomaterials. A major emphasis of her work is on studying how the bulk properties of composites are governed by the underlying structure across many length-scales, from the angstrom scale of chemical bonds to the micron scale of the micro-structure. Tiziana's group applies solid-rock interactions and nanoscale phenomena relating to geological systems to engineer new processes and materials. Examples of applications of her research include CO₂ reuse through storage and mineralization and mimicking natural cementation processes and nanostructures of fibrous cementitious phases to address the demand for more sustainable cement. Tiziana is a Marie Skłodowska-Curie Fellow and the recipient of the 2014 SPE Innovative Teaching Award, 2015 Career Award by NSF, and the 2018 Wegener Award by the European Association of Geoscientists and Engineers.

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UPTAKE OF IONS BY C-S-H

DELLA ROY LECTURE

TUESDAY, JULY 12 | 4 - 5 PM



BARBARA LOTHENBACH

1) Laboratory Concrete & Construction Chemistry, Empa, 8600 Dübendorf, Switzerland

2) Department of Structural Engineering, NTNU, 7491 Trondheim, Norway

Abstract

Calcium silicate hydrates (C-S-H) are the main solid phase present in hydrated cements, its composition changes depending on the solution composition. The silica chain length in C-S-H increases with the silicon concentration and the calcium content in the interlayer space with the calcium concentrations. Other earth alkaline and alkaline cations as well as aluminium and iron can be present in different sites in C-S-H depending on the Ca/Si ratio.

At low Ca/Si ratios, silicon in the bridging position can be replaced by four-fold coordinated aluminium. At all Ca/Si ratios approximately 10% of the aluminium is present as penta-coordinated, Al_{IV} , while at Ca/Si > 1 hexa-coordinated aluminium, Al_{VI} , becomes important. Aluminium uptake in C-S-H increases strongly at higher aluminium concentrations in the solution, while higher pH values decrease aluminium uptake. Similarly, also iron(III) and iron(II) uptake depend strongly on the dissolved iron concentrations.

Sodium and potassium are taken up preferentially at low calcium concentrations to compensate the negative surface charge of C-S-H and thus by low Ca/Si C-S-H as present in e.g. in Portland cements blended with fly ash or silica fume. The presence of sodium and potassium does not significantly change the structure of C-S-H but at high concentrations a shortening of the silica chain length has been observed. At constant Ca/Si ratio, more alkalis are bound at higher pH than at lower pH values, as high pH values lower the calcium concentrations and thus the competition with Ca^{2+} .

Biography

Barbara Lothenbach is group leader of the Cement Chemistry and Thermodynamics Group of the Concrete & Asphalt Laboratory at Empa, the Swiss Federal Institute for Materials Science & Technology. She has graduated from ETH Zürich and now is associate professor at University Berne, Switzerland, and adjunct professor at NTNU, Norway. She plays an active role in the promotion of the use of thermodynamic modelling to predict and understand the composition of hydrated cement, fundamental to develop durable and low CO_2 -cements.

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PORTLAND-LIMESTONE CEMENTS IN NORTH AMERICA: Current Status and Research Initiatives

KEYNOTE

WEDNESDAY, JULY 13 | 8:30 – 9 AM



ERIC GIANNINI

Portland Cement Association

Abstract

The Portland Cement Association's Roadmap to Carbon Neutrality identifies the use of portland-limestone cements (PLCs) as a key tool for making immediate improvements in the sustainability of concrete construction. PLCs containing up to 15% limestone are now both widely accepted by most state and provincial DOTs in the United States and Canada, and widely available for use by concrete producers. Their use enables up to a 10% reduction in the embodied carbon of concrete mixtures when used as a direct replacement for portland cement. This presentation will discuss standards for PLCs in ASTM, AASHTO, and CSA, including requirements for special properties, such as high-early strength and sulfate resistance, the influence of codes and specifications on the adoption of PLCs in concrete construction, and supporting research on the performance of concrete containing PLCs. Several ongoing research projects to study PLCs with greater than 15% limestone, similar to what is permitted in European specifications, will also be highlighted.

Biography

Eric Giannini is a Director of Product Standards and Technology for the Portland Cement Association. He earned his M.S. and Ph.D. in Civil Engineering from The University of Texas at Austin. Prior to joining PCA, he worked as a principal investigator for RJ Lee Group and as an assistant professor of civil and construction engineering at The University of Alabama. His research has largely focused on collaborative efforts to understand alkali-silica reactions in concrete, including test method development and the application of NDT and structural health monitoring to transportation and nuclear structures. At PCA, he supports sustain-ability efforts of the cement and concrete industries through standards development activities. He is an active member of ACI and ASTM committees, as well as a past member of several RILEM technical committees on alkali-aggregate reactions.