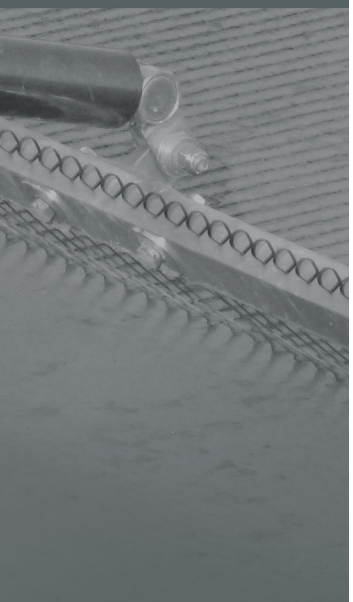
Exploring Cement Hydration Kinetics

International Summit on Cement Hydration Kinetics and Modeling



THE QUEST TO identify the underlying mechanisms that control cement hydration continues to be a challenge for modern materials science but has the potential to alter the fabric of constructed infrastructure for the global benefit of all. In 2009, a workshop supported by the Federal Highway Administration (FHWA), the National Science Foundation and other participating partners*, the International Summit on Cement Hydration Kinetics and Modeling, examined various aspects of cement hydration. The Summit was followed by an August 2010 Web conference to report on progress since the summit, and the drafting of an industry hydration roadmap.

Cement Hydration

Proportioning and placing portland cement concrete is performed thousands of times each day as the most-used building material on Earth. This process is unique in that the final product, a complex composite made from aggregate, water, other additives, and portland cement, is formulated on demand and batched and delivered in a plastic and unhardened state at the point of use. However, there are many common problems that can develop in the field, most associated with hydration, the chemical reaction that transforms the anhydrous cement into a hydrated binder that provides strength and durability to concrete.

Shrinkage and related cracking is one issue, resulting from autogenous volume change due to hydration and later-age drying after the curing period. Serious expansion and cracking can also take place in concrete when a secondary process causes an alkali silica reaction and expansive gel formation. Other problems can include adverse interactions between components, which can have unexpected effects on hydration and associated workability, setting time, and strength gain.

Industry Knowledge

A lack of knowledge about hydration processes makes improving, predicting, and controlling the performance of portland cement concrete a difficult task, accomplished today by trial-and-error experimentation combined with the experience of engineers, technologists, contractors, and producers. Developed under a program sponsored by FHWA, High Performance Concrete Paving (HIPERPAV) software is now used to analyze the early age behavior of concrete. However, with the exception of the efforts of the Virtual Cement and Concrete Testing Laboratory consortium, managed by National Institute of Standards and Technology, there has been a general lack of resource organization and dissemination of tools for modeling cement hydration in the United States. Although a number of isolated studies have looked at various aspects of hydration, until the 2009 International Summit there had been no industry-wide focal point and support for large-scale discussion.

Improving Capabilities

"We aim to facilitate interest in hydration modeling and discussion about the next steps in advanced cementitious systems research," says Richard Meininger at FHWA. "The recent Web conference was a valuable opportunity to continue discussions from the Summit. We were able to examine why ongoing research is important, how hydration modeling can be effective in improving cement and concrete products, and its performance in sustaining the transportation system through improved industrial, construction, and repair processes."

U.S. Department of Transportation
Federal Highway Administration

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Sponsors

The National Science Foundation • FHWA • W.R. Grace • BASF • Mapei • Canadian Research Center on Concrete Infrastructure • Natural Science and Engineering Research Council of Canada

Co-organizers

Joseph J. Biernacki (Tennessee Technological University Center for Manufacturing Research) • Will Hansen (University of Michigan) • Jeffrey Bullard (National Institute of Standards and Technology) • Jacques Marchand (Laval University, Canada)

The online event involved participants from the international Summit, the FHWA's Offices of Infrastructure R&D, Infrastructure programs, and the Exploratory Advanced Research (EAR) Program. It provided the cementitious hydration community with an update on the efforts underway and the proceedings papers being developed following the Summit. These papers will provide the cornerstones on which future research and sustainable technology will be built.

Developing a Roadmap

The draft report that emerged from the 2009 Summit and was discussed during the Web conference is titled Paving the Way for a More Sustainable Concrete Infrastructure—A Roadmap for the Development of a Comprehensive Description of Cement Hydration Dynamics. Joseph Biernacki from the Tennessee Technological University, who organized the Summit and took the lead in producing the report, was online to discuss the roadmap:

"The roadmap is a vision for research over the next 10 years, though some of the short-term goals should be achievable in 3 to 5 years," explains Biernacki. "Among the most pressing issues at hand are those that will impact the design of cementitious materials and systems that lead to smaller carbon footprints and hence improved life cycle performance. It is not intended to provide answers but to identify questions and suggest directions in which to move."

The roadmap is intended to bring together various industry visions and efforts and has been designed to be reconciled with Roadmap 2030, the concrete industry's plan for achieving a more sustainable, cost effective, and improved concrete for the 21st century. Roadmap 2030 includes many challenges and goals where a better understanding and modeling of hydration is paramount.

Future Efforts

Activities such as this aim to encourage researchers and users of concrete to consider developing and using models to examine the effects of changes in proportions and materials. It enhances collaboration with the VCCTL activities and products at NIST, and the basic science approach now beginning at the cement and concrete industry supported MIT Concrete Sustainability Hub.

What Is the Exploratory Advanced Research Program?

FHWA's Exploratory Advanced Research (EAR) Program focuses on long-term, high-risk research with a high payoff potential. The program addresses underlying gaps faced by applied highway research programs, anticipates emerging issues with national implications, and reflects broad transportation industry goals and objectives.

To learn more about the EAR Program, visit the Exploratory Advanced Research Web site at www.fhwa.dot.gov/advancedresearch. The site features information on research solicitations, updates on ongoing research, links to published materials, summaries of past EAR Program events, and details on upcoming events. For additional information, contact David Kuehn at FHWA, 202-493-3414 (email: david.kuehn@fhwa.dot.gov), or Terry Halkyard at FHWA, 202-493-3467 (email: terry.halkyard@fhwa.dot.gov).

"The EAR Program continues to encourage collaboration between FHWA Program Offices, TFHRC researchers, and the external research community," says Meininger. "Continued exposure to advanced research in this way will ultimately enhance understanding of hydration modeling resources and the way that advanced techniques can improve research capabilities and tools."

Learn More

To view topics from the 2009 Summit visit http://blogs.cae.tntech.edu/hydration-kinetics. For more information or to discuss cement hydration kinetics, contact Richard Meininger at FHWA, at 202-493-3191 (email: richard.meininger@dot.gov).

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