Researcher uses nanosilica to strengthen concrete (w/ video)

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Every day, concrete structures crack and erode prematurely due to Alkali Silica Reactivity (ASR), a chemical reaction that causes fissures in the material as it sets. Jon Belkowitz, a doctoral student at Stevens Institute of Technology, plans to put an end to this problem through his study of chemical reactions within concrete at the nanoscale. Taking advantage of Stevens nanostructure characterization tools and materials, his research into the optimal use of nano silica will create a new concrete mixture that will result in longer-lasting buildings, roadways, sidewalks, stairs, sewers, and dams.

"With the advent of nanotechnology, the material properties of concrete, including ASR mitigation, allows engineers and architects the ability to use concrete in applications that were once impossible," John says.

Optimizing Concrete

On the most basic level, concrete is a mixture of finely-powdered cement, rock aggregate, and water. A reaction between the cement and water yields calcium silicate hydrate, which gives concrete its strength, as well as ASR gel. The ASR gel forms at the interface of the alkaline cement and the non-crystalline silica found in the aggregate. As the concrete hardens, the ASR gel expands, causing residual stresses that weaken the concrete and cause it to deteriorate. As pressure builds at the interface, the concrete starts to crack and crumble from within, over a period spanning days to years.

"Using nanostructure characterization tools, we are now able to understand the many mysteries of concrete, for example, that there are three types of water in hydrated concrete, and those three different types of water have three different types of molecular movements, which means three different forces," John says. The more you know about concrete, he notes, the more complex it becomes. He hopes his research will uncover new methods of increasing the mechanical properties of concrete.

Jon's research takes a three-tiered approach: "I'm using this new nanotechnology to not only stop ASR from being produced, but I'm also using nano silica to strengthen the hydrated cement matrix of concrete to resist the expansive nature of the ASR gel," Jon explains. "I'm also trying to change the properties of the excess water within the concrete so that it can't react with soluble alkalines in silica to cause ASR gel."

Despite the material's ubiquity, the reactions within concrete as it dries and strengthens are difficult to control. "This is an ongoing problem in the concrete industry," Jon says. "In the past we really had no way to understand the development of the crystallgraphic grains of the concrete matrix. We could set up models, or use other minerals to compare to Calcium Silica Hydrate. We don't create the same structure every single time. Through the use of nanostructure characterization tools, we now have the ability to gain a better understanding of the hydrated cement matrix that makes up concrete."

Jon's research is being conducted in the Nanomechanics and Nanomaterials Laboratory under the guidance of Dr. Frank Fisher, Associate Professor of Mechanical Engineering and Co-Director of the Nanotechnology Graduate Program. Though Jon hopes to apply his research in civil engineering applications, his work is multidisciplinary, combining solid-state physics, mechanical engineering, polymer synthesis, and chemical engineering.

Jon's research is funded by New Jersey Alliance for Engineering Education (NJAEE), through the National Science Foundation (NSF) Graduate Teaching Fellows in K-12 (GK-12) Program. He works in a local high school in Bayonne, New Jersey ten hours a week as part of the program, and says he enjoys the opportunity to share his passion with students. "It's exciting to open up their minds to new possibilities," Jon says. "They eat it up."

A "Concrete Geek"

Jon comes to Stevens with 15 years of concrete experience: 10 years in the United States Air Force placing concrete on civil engineering projects around the world, and 5 years at concrete manufacturing giant LaFarge, where he designed new types of concrete in a lab and translated these into products with real-world applications. Jon graduated with distinction from Colorado School of Mines with a Bachelor of Science degree in Civil Engineering and the University of Denver with a Master of Science degree in Materials Science. Currently he owns Intelligent Concrete, LLC, which is dedicated to concrete research, development, and education.

This wide-ranging experience allows him to converse equally well with scientists, business, and laypeople. It also gives him a realistic approach. "One of the hardest things to do in the concrete industry - or in any industry - is to take lab data and translate it into commercial industry," Jon says. "In the lab you have nearly perfect conditions. In the real world, it's messy." His concrete knowledge has already yielded results. In 2008, his Chronolia Road Patch Design received the "Innovation of the Year Award" from the American Concrete Institute - Rocky Mountain Chapter.

Jon has made a life for himself out of concrete, but would not have it any other way. "I'm a concrete geek at heart," he says. In fact, it is something of a "family business," Jon quips. Jon's father works in marketing for a concrete company, and his wife is pursuing her undergraduate degree in Engineering at Stevens, looking to specialize in concrete.

As he looks to the future, Jon is confident that his work at Stevens studying the smallest reactions within concrete will yield big rewards in the future.

Provided by Stevens Institute of Technology

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