The impacts of a chemical reaction known to cause structural problems in concrete dams

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Researchers from the MIT Concrete Sustainability Hub, the University of New Brunswick, and Oregon State University visited the Mactaquac Dam in New Brunswick, Canada, in August. Credit: Jeremy Gregory/MIT Concrete Sustainability Hub

When the Mactaquac Dam opened in New Brunswick, Canada, in 1968, it was expected to have a service life of 100 years, but a chemical reaction occurring within the concrete used to build the dam has drastically shortened that timeline.

"Concrete is a mix of cement, crushed rock, sand, and water. Alkali-silica reaction, the cause of the major issues in New Brunswick, occurs when alkalis in the cement pore solution encounter reactive forms of silica in the rock used to make the concrete," explains Jeremy Gregory, executive director of the MIT Concrete Sustainability Hub (CSHub). "The reaction produces a gel which expands as it absorbs water and exerts pressure that can cause cracking and result in structural problems in concrete infrastructure."

Researchers from the CSHub, the University of New Brunswick (UNB) and Oregon State University (OSU) have teamed up on a project to address several concrete durability issues, including alkali-silica reaction (ASR). Researchers at UNB are conducting ASR experiments, while OSU researchers are leading work on another durability issue known as freeze-thaw. Most of the project's computational work is done at MIT, along with some experimental measurements.

"Our research collaboration looks at understanding ASR from fundamental building blocks," explains Thomas Petersen, a grad student in the MIT Department of Civil and Environmental Engineering and research assistant with the CSHub. "Starting from an atomistic description, we wish to understand the mechanisms leading to the expansion of the bulk concrete composite. Is the gel expanding? Is the CSH [calcium-silicate-hydrate] expanding? We are looking to answer these questions by understanding the molecular configurations of the materials."

As part of a larger concrete durability project, researchers from the MIT Concrete Sustainability Hub, the University of New Brunswick, and Oregon State University are studying a chemical reaction known as alkali-silica reaction, which can cause cracking and result in structural problems in concrete infrastructure. Credit: Jeremy Gregory/MIT Concrete Sustainability Hub

The team visited Mactaquac during a meeting in August. Petersen says the visit offered a great opportunity to learn about the potential impact of the team's research on infrastructure systems. CSHub postdoc Laurent Béland agrees, noting that observing the "crazy expansion" at Mactaquac in person rather than in pictures, made the sometimes-abstract ideas he explores, more, well … concrete.

"Seeing the impacts of ASR on a structure that large, in person, makes you realize how big this problem is; not only is this major dam supplying electricity, it's making sure a pretty big city won't be flooded," says Béland. "As an atomistic simulation expert, I'm coming at this from one perspective. Working with people to be able to absorb what this is all about, you see the research impact scaled up."

The Mactaquac Dam has swelled some 9 to 12 inches in height since it was constructed 50 years ago. Cracking is visible throughout the structure, but the issues extend well beyond the concrete.

"There are gates that no longer close—there's a seven- or eight-inch gap," says Béland. "There are also places where engineers have had to cut through the dam to relieve pressure and, for obvious reasons, you'd prefer that dams not have to be cut into."

Edmond Zhou (right), a researcher with the MIT Concrete Sustainability Hub and MIT grad student in physics, takes a picture of at a test site set up by research collaborators from the University of New Brunswick near the Mactaquac Dam. Credit: Jeremy Gregory/MIT Concrete Sustainability Hub

Additionally, the dam's turbines, which are used to generate hydroelectric power, need to periodic adjustments to prevent contact with the blades, and the steel beams and columns that help house the turbines and shafts must also be occasionally readjusted to maintain stability. Engineers are working to keep the dam in operation through the end of its intended service life, roughly the year 2068. These efforts are costly. Petersen notes, "A full-time engineering unit and $8 million per year are needed to maintain the dam and ensure its health into the future."

The civil engineers and cities planners who built the Mactaquac Dam did test the aggregate for susceptibility to the alkali-silica reaction, however they did not test under conditions that well represented the conditions of the dam. The industry is still seeking fast, reliable testing methods for ASR that take such factors into account, something the CSHub-UNB-OSU durability project hopes to achieve.

"The benefit of working on applied topics is that the consequences of diligent and informed engineering practices is vividly portrayed in our everyday life," says Petersen. "By advancing our modeling techniques and testing procedures, mistakes in the design of the Mactaquac dam can be avoided in the future."

More information: Research Brief: Atomistic Modeling of ASR Gel: cshub.mit.edu/news/research-br … tic-modeling-asr-gel

Research Brief: Mechanical properties of Alkali Silica gels: cshub.mit.edu/news/research-br … s-alkali-silica-gels

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