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CASE STUDY

High-Speed Photography: A Geotechnical Gamechanger

Researchers at the University of Queensland use Vision Research high-speed cameras to observe rock tensile strength—and more.

If you walk through the University of Queensland's Geotechnical Engineering Centre (GEC), you might be surprised by what you see playing on the hallway televisions: slow-motion videos of rocks cracking and exploding.

That's because the GEC utilizes high-speed cameras in their Geomechanics Laboratory, which specializes in fundamental and applied research in a range of geotechnical engineering areas, such as soil and rock mechanics and hydrogeology. Academics, postdocs and PhD students have the option to rent out the cameras for research purposes, which include measuring bubble sizes in high-speed flows, monitoring brittle cracking and failure of rocks or rock-like geomaterials, and observing particle breakage in materials under impact and dynamic loadings.

Professor David Williams, director of the GEC, along with Dr. Mehdi Serati, postdoctoral research fellow, are just two of the many department staff members who utilize the two cameras, a Vision Research Phantom v2011 and v2012, which go where previous instrumentation couldn't. "With the cameras, you can chart or test anything that's dynamic," Williams said. "When testing a rock sample under load, for example, cracking happens very quickly. The cameras tell us when and where the crack initiates and how it grows."

These tests enable GEC researchers to assess the tensile strength of natural and composite materials—which has vast implications for applications in civil engineering. For instance, with the data, the researchers and their industry partners can more accurately predict instability in certain construction materials, as well as figure out how to improve pavement and other composite materials to better resist cracking.

CHANGING THE STANDARD

Not only do the cameras enable Williams and his team to more accurately observe and measure material strength; they also enable the researchers to challenge—and ultimately improve—long-established geotechnical laboratory techniques. "Over the years, a lot of these tests have become entrenched," Williams said. "But we need evidence to justify changing them."

For example, the Brazilian test is one of the most established techniques for determining rock tensile strength. It involves compressing a thin, disc-shaped specimen of rock via two diametrically opposite diameter loads until the disc fails along its loaded diameter into roughly two equal halves. "The test has been around for 200 years or so," Mehdi said. "It's popular, easy to execute and is the preferred method for testing a rock's tensile strength among geotechnical researchers."

The problem was, however, that rather than resulting in a single crack at the disc's center, the test often triggered multiple cracks and secondary shear fractures in the vicinity of the contact points. "Cracks that start at the center indicate the tensile strength of a material," Mehdi explained. "But cracks that occur at the loading points do not. "Although the test has evolved over the years to try to eliminate the shear fracturing, each iteration has had its own limitations. That's where the cameras come in.

In an effort to improve the technique, Mehdi and his team conducted a series of Brazilian tests on brittle rocks, including granite, basalt and monzonite. They loaded the specimens under a constant displacement rate until failure occurred, usually within 1 to 2 minutes. They recorded the fracturing process using a Phantom v2011 ultra-high-speed camera system running at 130,000 frames per second (fps) at a resolution of 384 x 288 pixels. As expected, the high-speed footage revealed that additional secondary cracking at the loading points always accompanied tensile failure.

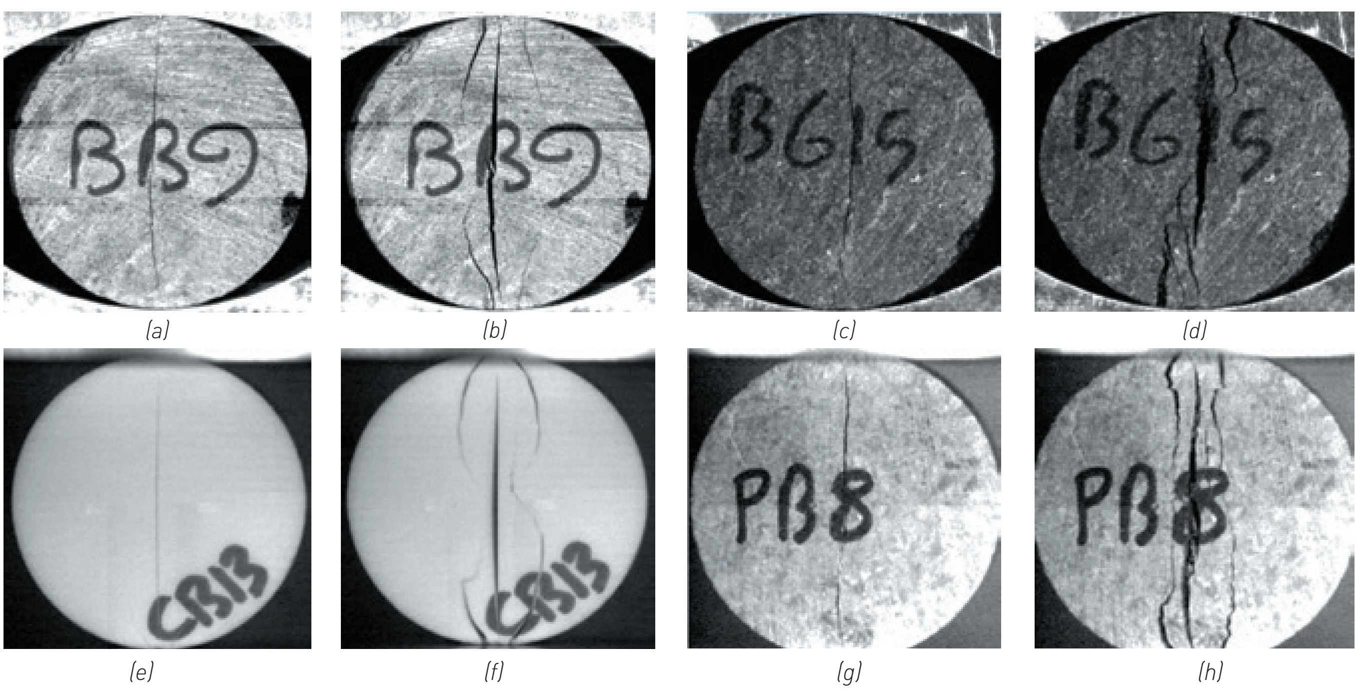
Mehdi and his team hypothesized that using discs that were smaller than the standard testing size would eliminate this problem. Using the same camera setup, they conducted retests using specimen samples that decreased in size for each rock type. The footage revealed a promising outcome: as the size of the discs decreased, less violent fracturing occurred—until, when each rock type hit a certain size, only a single crack formed down the center.

"Although the transition from multiple cracking to single cracking occurs at different sizes in different rock types, the experiment revealed that rock tensile strength is size-dependent," Mehdi said. "Thanks to the cameras, we now have evidence that can improve the Brazilian test. For example, we can develop a size correction model for each rock type that can help us more accurately estimate tensile strength."

"Assumptions aren't always correct," Williams added. "Different materials we test might behave differently because some are more brittle than others. Being able to observe what happens has allowed us to recommend changes to previously entrenched testing methods."

As the high-speed footage revealed, the Brazilian test often triggers multiple cracks and secondary shear fractures in the vicinity of the contact points—rather than initiating a single crack at the disc's center.

"When a rock cracks, we can't predict where the crack will be, which makes trying to measure it with other instruments difficult," Williams said. "But the cameras provide a wide enough view to see the whole picture."



The researchers conducted a series of Brazilian tests on brittle rocks, including granite, basalt and monzonite, and recorded the fracturing process at a speed of 130,000 fps.

FINDING THE RIGHT CAMERA FOR THE JOB

In addition to Mehdi's work on the Brazilian test, several studies have come out of the GEC, as well as the University of Queensland's School of Civil Engineering, thanks to evidence provided by the GEC's in-house Phantom camera setup. "Since we're dealing with a wide range of geometries, we wanted a camera that could run at a minimum of 200,000 to 300,000 fps while providing adequate resolution," Williams said. Both the v2011 and newer v2012 deliver an impressive speed of over 22,000 fps at a full resolution of 1 megapixel. At reduced resolutions, the camera provides frame rates of up to 651,000 fps, or 1 million fps with the export-controlled FAST option.

"When a rock cracks, we can't predict where the crack will be, which makes trying to measure it with other instruments difficult," Williams said. "But the cameras provide a wide enough view to see the whole picture." Having two cameras instead of one also has its benefits. By focusing one camera on the front of a rock and the second camera on the back, the researchers have a better chance of capturing both the origin and propagation of a crack.

But the GEC researchers aren't the only ones who enjoy having the cameras around. That's why the department showcases the slow-motion footage of their findings on television screens around the school. "It's nice to be able to demonstrate these things to laypeople, prospective students, and the general public," Williams concluded. "These are things you can't see with the naked eye. I love seeing the excitement in people's eyes."

University of Queensland researchers routinely use a pair of high-speed cameras, a Phantom v2011 and v2012 (pictured here), to assess the tensile strength of natural and composite materials.

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