A concrete advantage for space explorers

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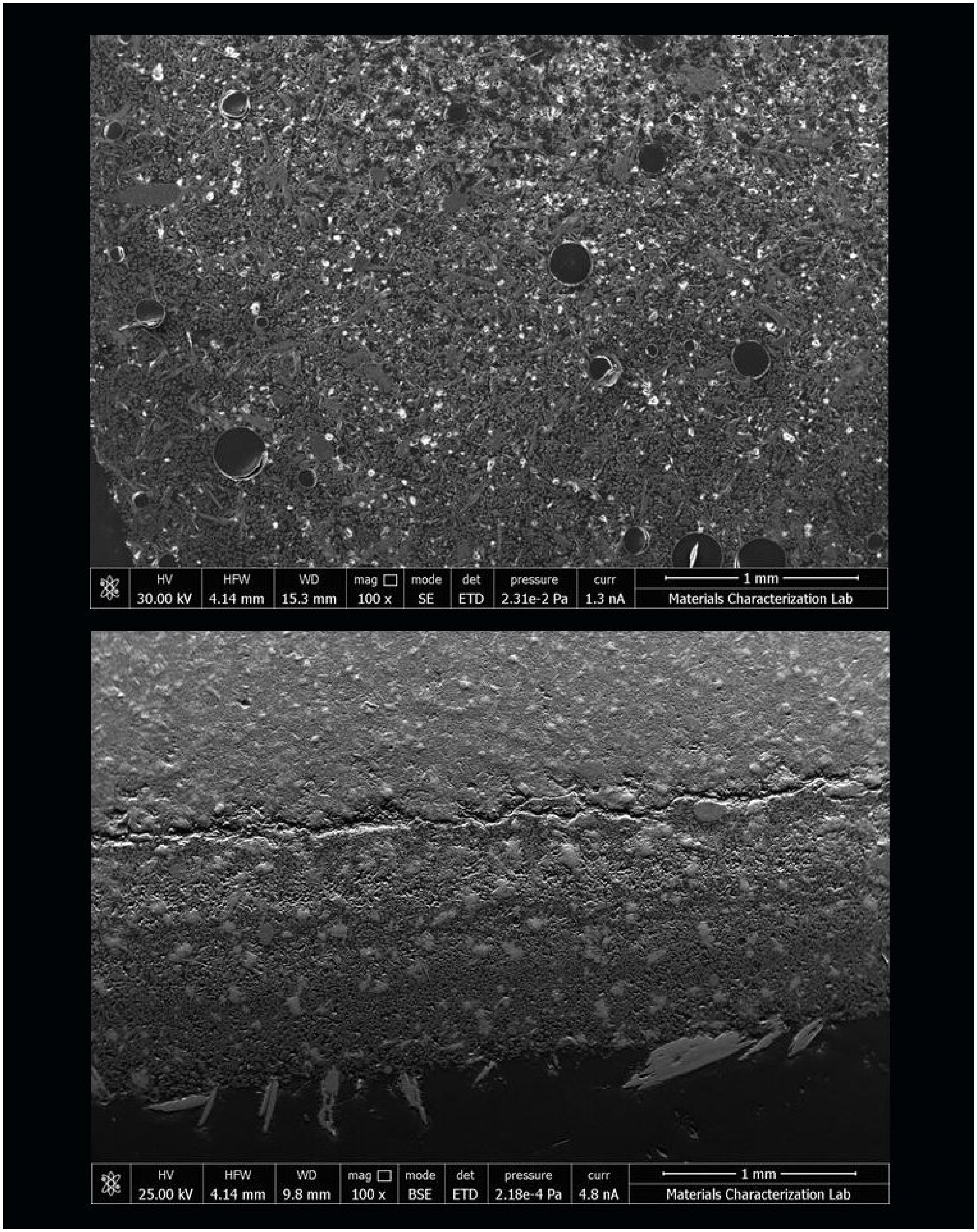
European Space Agency astronaut Alexander Gerst works on the MICS experiment aboard the International Space Station. Observations of how cement reacts in space during the hardening process may help engineers better understand its microstructure and material properties, which could improve cement processing techniques on Earth and lead to the design of safe, lightweight space habitats. Credit: NASA

When humans go to the Moon or Mars to stay, they will need to construct safe places in which to live and work. The most widely used building material on Earth, concrete, may be the answer. It is strong and durable enough to provide protection from cosmic radiation and meteorites and it may be possible to make it using materials available on these celestial bodies.

Concrete is a mixture of sand, gravel and rocks glued together with a paste made of water and cement powder. While that sounds simple, the process is quite complex, and scientists still have questions about the chemistry and microscopic structures involved and how changes in gravity may affect the process.

A recent investigation on the International Space Station examined cement solidification in microgravity to help answer those questions. For the Microgravity Investigation of Cement Solidification (MICS) project, researchers mixed tricalcium silicate (Ca_3SiO_5 or C_3S) and water outside of Earth's gravity for the first time. The main mineral component of most commercially available cement, C_3S controls many of its chemical reactions and properties. MICS explored whether solidifying cement in microgravity would result in unique microstructures and provided a first comparison of cement samples processed on the ground and in microgravity.

The investigators reported their results in a paper published in Frontiers in Materials, "Microgravity Effect on Microstructural Development of Tri-calcium Silicate (C_3S) Paste."



These images compare cement pastes mixed in space (above) and on the ground (below). The sample from space shows more porosity, or open spaces in the material, which affects concrete strength. Crystals in the Earth sample also are more segregated. Credit: Penn State Materials Characterization Lab

"On missions to the Moon and Mars, humans and equipment will need to be protected from extreme temperatures and radiation, and the only way to do that is by building infrastructures on these extraterrestrial environments," said principal investigator Aleksandra Radlinska of Pennsylvania State University. "One idea is building with a concrete-like material in space. Concrete is very sturdy and provides better protection than many materials."

Another significant advantage of concrete is that explorers could theoretically make it with resources available on those extraterrestrial bodies, such as dust on the Moon, also known as lunar regolith. That would eliminate the need to transport construction materials to the Moon or Mars, significantly reducing cost.

Scientists know how concrete behaves and hardens on Earth, but do not yet know whether the process is the same in space. "How will it harden? What will be the microstructure?" said Radlinska. "Those are the questions we're trying to answer."

The researchers created a series of mixtures that varied the type of cement powder, number and type of additives, amount of water, and time allowed for hydration. As the grains of cement powder dissolve in water, their molecular structure changes. Crystals form throughout the mixture and interlock with one another. On first evaluation, the samples processed on the space station show considerable changes in the cement microstructure compared to those processed on Earth. A primary difference was increased porosity, or the presence of more open spaces. "Increased porosity has direct bearing on the strength of the material, but we have yet to measure the strength of the space-formed material," said Radlinska.

"Even though concrete has been used for so long on Earth, we still don't necessarily understand all the aspects of the hydration process. Now we know there are some differences between Earth- and space-based systems and we can examine those differences to see which ones are beneficial and which ones are detrimental to using this material in space," said Radlinska. "Also, the samples were in sealed pouches, so another question is whether they would have additional complexities in an open space environment."

The microgravity environment of the station is critical to these first looks at how cement may hydrate on the Moon and Mars. An on-board centrifuge can simulate gravity levels of those extraterrestrial bodies, something not possible on Earth. Evaluation of cement samples containing simulated lunar particles processed aboard the orbiting laboratory at different levels of gravity is currently ongoing.

Showing that concrete can harden and develop in space represents an important step toward that first structure built on the Moon using materials from the Moon. "We confirmed the hypothesis that this can be done," Radlinska said. "Now we can take next steps to find binders that are specific for space and for variable levels of gravity, from zero g to Mars g and in between."

More information: Juliana Moraes Neves et al. Microgravity Effect on Microstructural Development of Tri-calcium Silicate (C3S) Paste, *Frontiers in Materials* (2019). DOI: 10.3389/fmats.2019.00083

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