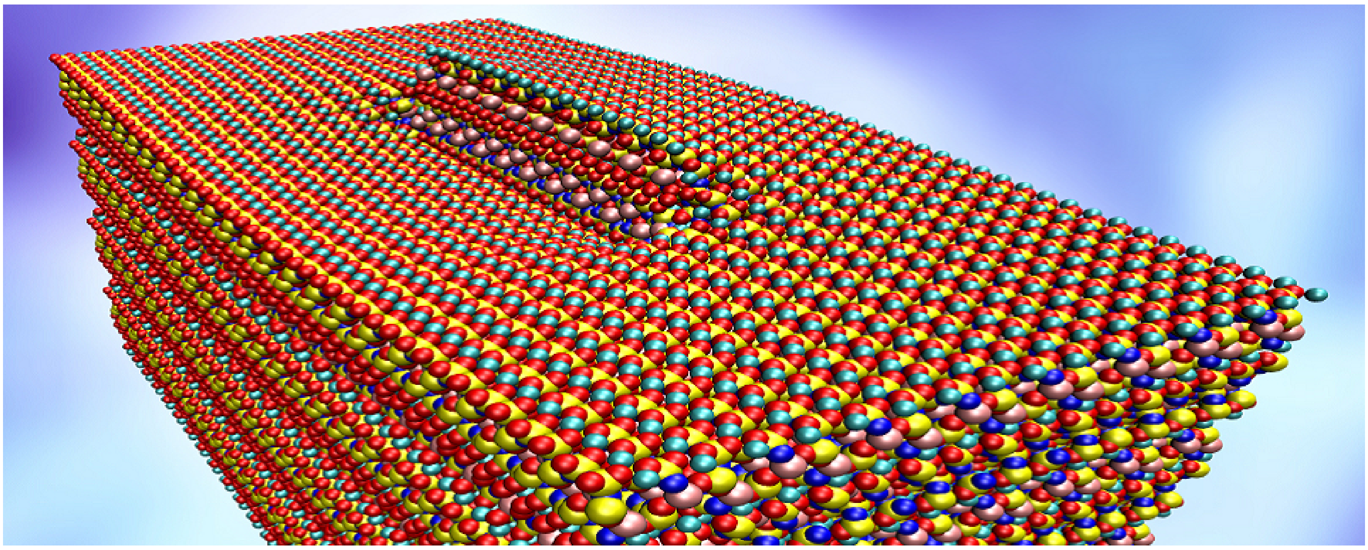
Concrete is a highly regarded building material in large part due to its inherent strength and durability – something that was first recognized by the Ancient Romans thousands of years ago. What stands the Ancient Roman concrete apart from today's concrete though, is the fact that we rely heavily on reinforcements to protect structural integrity over time and require regular maintenance due to cracking and corrosion. Roman concrete on the other hand is unreinforced and yet we still see these structures standing today. For instance, the dome on the Pantheon (built 2000 years ago) remains the oldest unreinforced concrete structure still standing.

What is it that made Roman concrete so tough?

The secret lies in the molecular structure of tobermorite. Tobermorite is a naturally occurring chrystalline material similar to the calcium-silicate-hydrate (C-S-H). They both have properties that enable them to act as the glue that keeps concrete ingredients together. The former is a key ingredient in the concrete that the Romans used and following in-depth molecular computer analysis, helps explain the unmatched durability of this ancient material.

Through this analysis, researchers were able to determine that tobermorite forms in layers (think of paper stacks) that solidify into particles. These particles often have what is known as shear defects which help relieve stress by allowing the layers to slide past one another. The layers are only able to slip a little bit at a time, however, due to the presence of jagged screw 'defects' that lock them back into place.



A screw dislocation disrupts the regular rows of atoms in tobermorite. (Credit: Multiscale

Materials Laboratory/Rice University)

The study demonstrated that defect-free tobermorite was susceptible to deformation due to water molecules trapped between the layers facilitating uninterrupted sliding. In particles that did contain screw defects on the other hand, the layers could only glide so far before the tooth-like dislocations lock them back into place. This effectively passes the buck to the neighboring layer which too glides for a short distance before being locked in and so on. This continuous cycle in turn relieves stress without causing cracking. As stated by Rouzbeh Shahsavari, an assistant professor of civil and environmental engineering and materials science and nanoengineering at Rice University, this defect-induced gliding and locking pattern around the tobermorite particle's core makes it more ductile and able to adjust to stress.

"The insight we get from this study is that unlike the common intuition that defects are detrimental for materials, when it comes to complex layered crystalline systems such as tobermorite, this is not the case," says Shahsavari. "Rather, the defects can lead to dislocation jogs in certain orientations, which act as a bottleneck for gliding, thus increasing the yield stress and toughness. These latter properties are key to designing concrete materials, which are concurrently strong and tough, two engineering features that are highly desired in several applications."

Shahsavari concludes that this study provides the first report on how to leverage seemingly negative characteristics found in the composition of concrete and turn them into highly desired properties.

Source: http://www.futurity.org/tobermorite-concrete-defects-1329032-2/