

# Mechanical properties of Alkali Silica gels

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## PROBLEM

Concrete is composed of aggregates, such as gravel and sand or crushed rock, embedded in cement paste. The cement paste, which acts as a glue between those particles, is porous allowing water and ions to diffuse through concrete at very slow rates. Some of the ions are alkalis released during cement hydration. Certain aggregates containing amorphous silica react with the alkalis in the pore solution forming a silica gel. This reaction is called alkali-silica reaction (ASR). This gel can expand, putting stress on the concrete, and can lead to pronounced volume expansion of the concrete and the growth of micro- as well as macroscopic cracks, potentially contributing to infrastructure failure. In order to understand the mechanisms of this reaction and predict the crack formation, information on the mechanical properties of the concrete and of the gel, are necessary. The research presented here addresses the mechanical properties of the ASR gel.

## APPROACH

CSHub partners at the University of New Brunswick prepared mortar samples with highly reactive aggregates known to lead to the rapid formation of ASR gel. Samples were stored under saturated conditions favoring the formation of ASR gel. The samples were stored for a year before being cut, showing regions with ASR gels of about a hundred microns diameter (See figure, top image). Researchers performed nano-indentation tests, probing the mechanical properties of the gel on the micron level to determine the mechanical properties of these gel pockets. The indentation modulus,  $M$ , and the hardness,  $H$ , (see figure, bottom image) were extracted from the raw curves following the method of Oliver and Pharr.<sup>1</sup> In this method, the projected area of the residual print left by the indenter into the material is computed from the contact depth, taking into account the geometry of the indenter. The contact depth itself is determined by fitting the unloading phase of the mechanical test to a power-law equation. Experiments were conducted at constant relative humidity of about 50%.

## FINDINGS

The mechanical properties of ASR gels show a strong dependence on water content. Water evaporation leads to a significant increase of both  $M$  and  $H$ , whose lowest values measured a few hours after cutting the sample open are respectively 0.4 GPa and 10 MPa. We can anticipate even lower values in the pristine samples for the gel exists at humidity level close from saturation. Therefore, ASR gel likely behaves as a weak viscoelastic material, whose mechanical properties are significantly weaker than the surrounding cement matrix and that of the silica aggregates. Our measurements highlight for the first time the key role of moisture on ASR gel mechanical properties. Future mechanical tests should be performed at various humidity conditions to extrapolate the true in-situ properties of the gels.

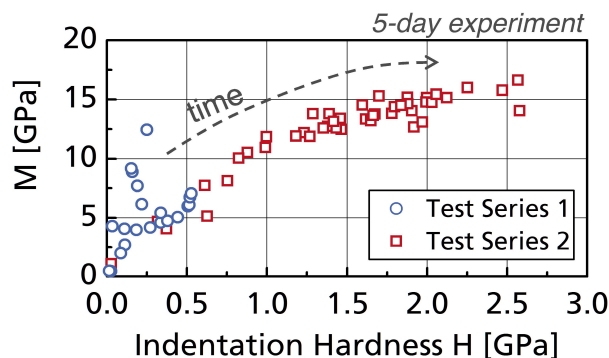
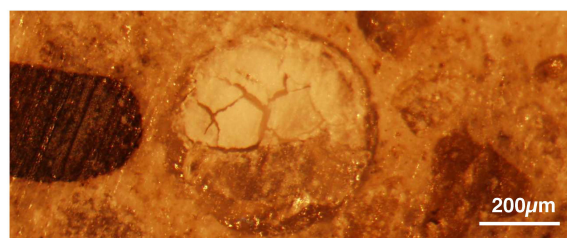


Figure: (Top) Picture of an ASR gel pocket observed in a mortar sample cut in half. (Bottom) Indentation modulus  $M$  vs hardness  $H$  of the ASR gel, determined over a time span of 5 days within the white region visible in the top figure. The gel is drying and both  $M$  and  $H$  are increasing as water evaporates.

## WHY DOES THIS RESEARCH MATTER?

- Alkali-silica reaction (ASR) causes expansion and cracking in concrete, which reduces the service life of infrastructure.
- Knowing the mechanical properties of alkali-silica gels will allow for more precise understanding and prediction of the deterioration process.

<sup>1</sup> \*Oliver WC, Pharr GM (1992) An improved technique for determining hardness and elastic-modulus using load and displacement sensing indentation experiments. J Mater Res 7:1564–1583.