Capillary Pressure Monitoring in Plastic Concrete for Controlling Early Age Shrinkage Cracking

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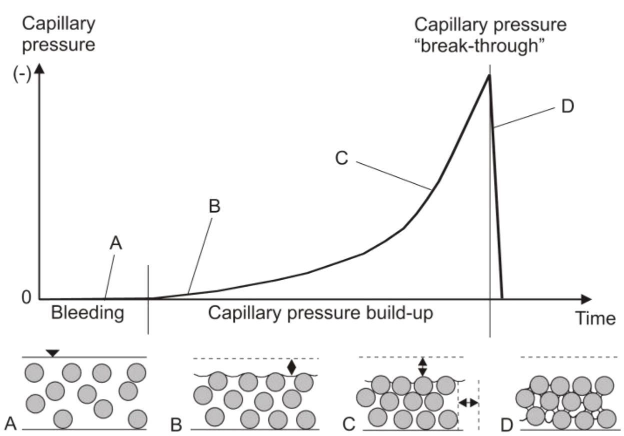
1. Problem

Early age shrinkage cracks in concrete slabs, floors and roads occurring within in the first six hours after casting

Concrete slab on grade with plastic shrinkage cracks (widths up to 1 mm)

Similar cracking phenomena may be observed in inert materials like mud

2. Damage mechanism



Water loss by evaporation causes the build-up of a negative capillary pressure in the pore system (B+C).

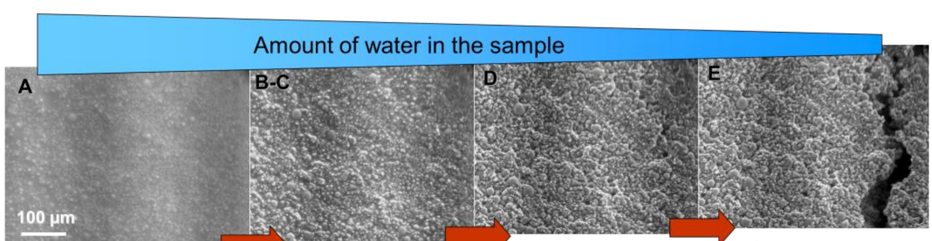
At a certain pressure, air penetrates into the pore system.
→ Capillary pressure "break-through" (D)

The empty pores are weak points and may lead to cracking (E).

Young-Laplace-Equation:

$$p = -\frac{2\gamma}{r} \cdot \cos\beta$$

Visualisation of plastic shrinkage cracking in a water-fly ash suspension by using an Environmental Scanning Electron Microscope (ESEM)



Water film on the surface of the sample

Menisci are formed between the particles

Air penetrates into the pore system

Cracks originate from the empty pores

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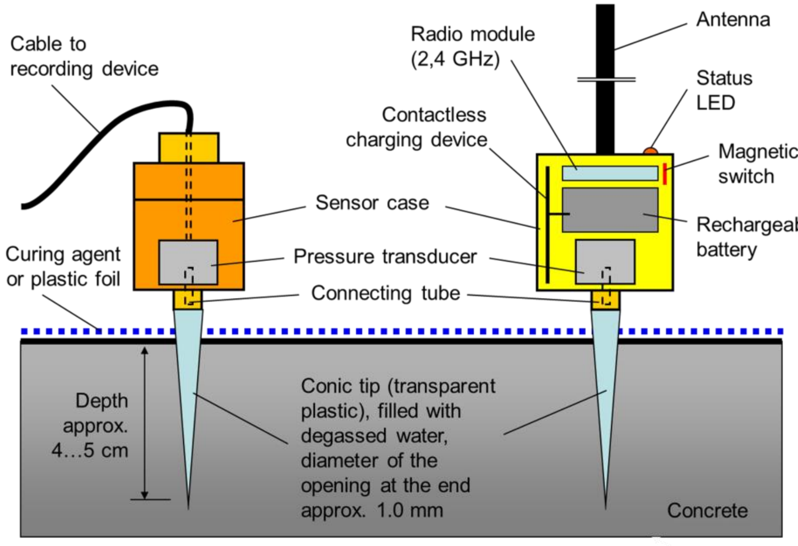
www.capillary-pressure-sensors.com

3. Capillary pressure sensors

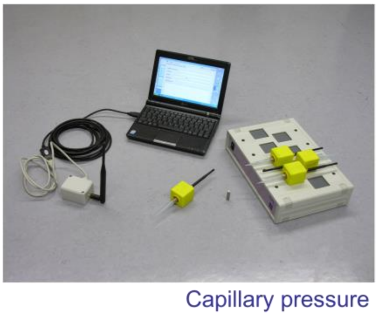


The capillary pressure can be measured with a pressure transducer which is connected to the pore system of the material by a water-filled measurement tip.

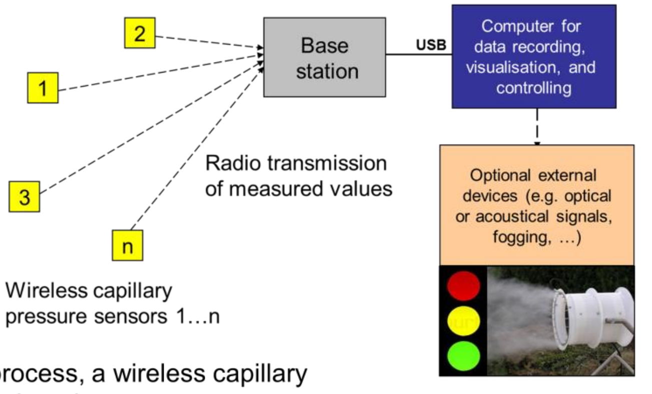
Schematic view of a wired and of a wireless capillary pressure sensor for on-site applications

The measured capillary pressure captures environmental influences on the cracking risk, but also those stemming from the material composition and from the member's geometry.

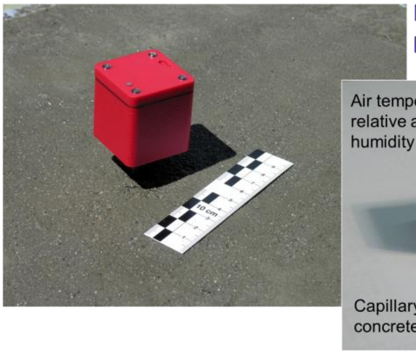
Application of the capillary pressure sensors



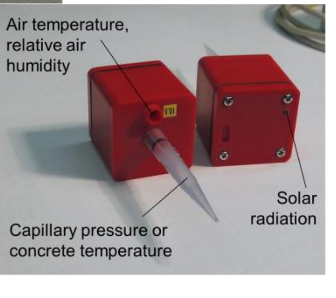
Capillary pressure measurement system



Since cables hinder the construction process, a wireless capillary pressure sensor system has been developed.

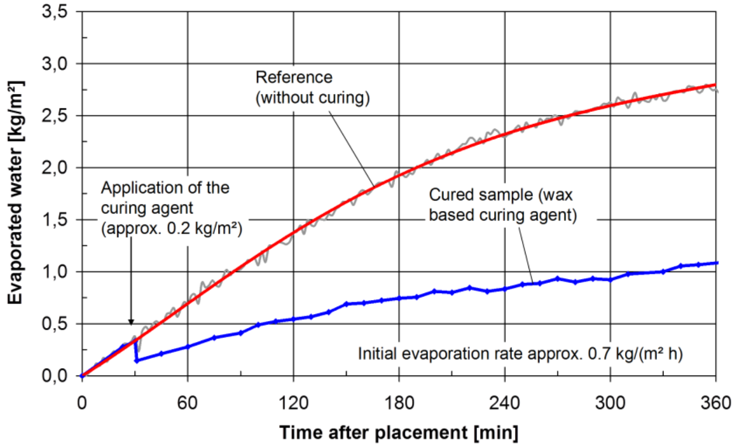


Enhanced capillary pressure sensor



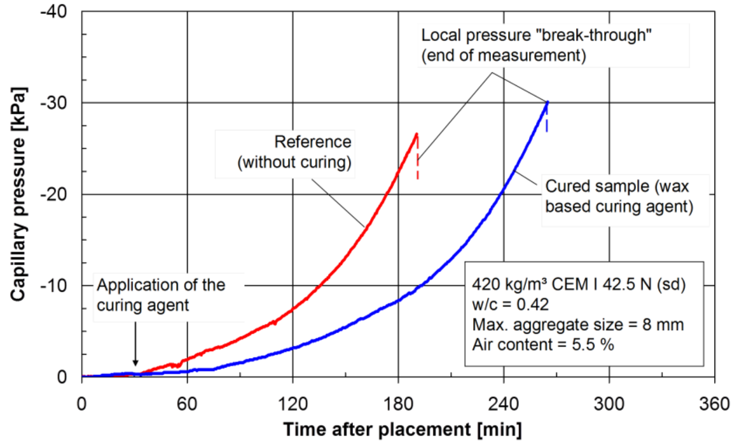
In addition to the capillary pressure, the newest prototypes of the capillary pressure sensors will also allow to monitor environmental conditions (air temperature, relative air humidity, sun radiation) and the concrete temperature.

4. Influence of curing measures



Monitoring of the capillary pressure build-up is useful for the correct timing of curing measures and for the evaluation of their efficiency.

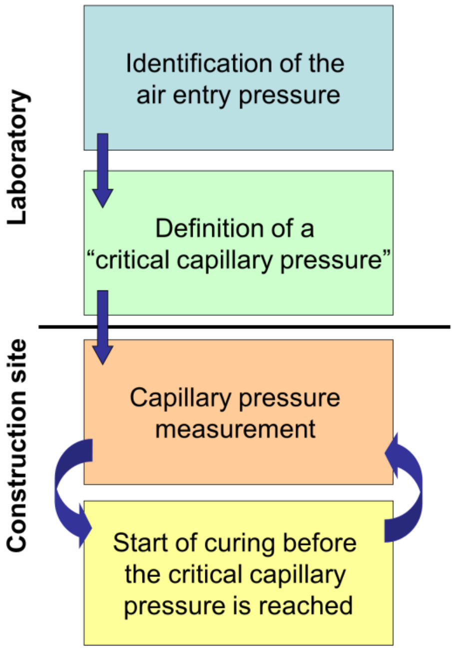
Water loss from a cured and from an uncured concrete sample



The slope of the capillary pressure in the cured sample is not as steep as in the uncured concrete.

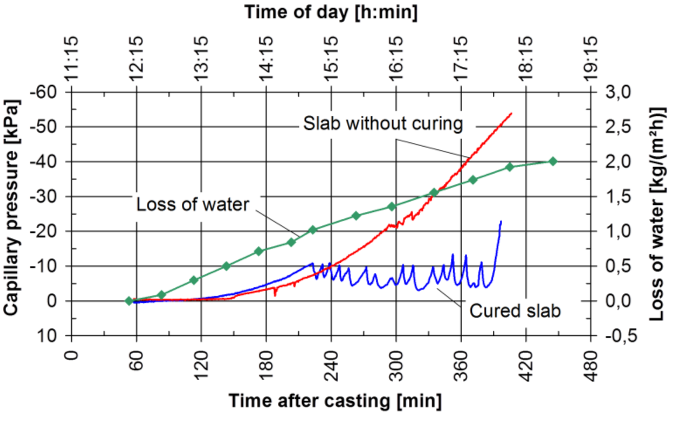
Capillary pressure versus time measured in a cured and in an uncured concrete sample

5. Capillary pressure controlled curing



Fogging device for controlled rewetting

Capillary pressure sensor on a concrete surface

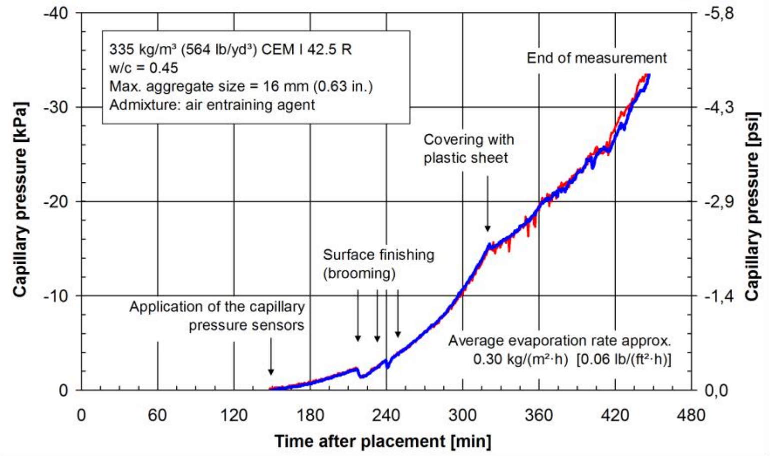


Experimental results of a field test with a capillary pressure based closed loop controlled curing system

6. Practical applications

Example 1: Capillary pressure measurement in bridge construction

The capillary pressure sensors were tested on several construction sites (bridges, parking decks, pavements).

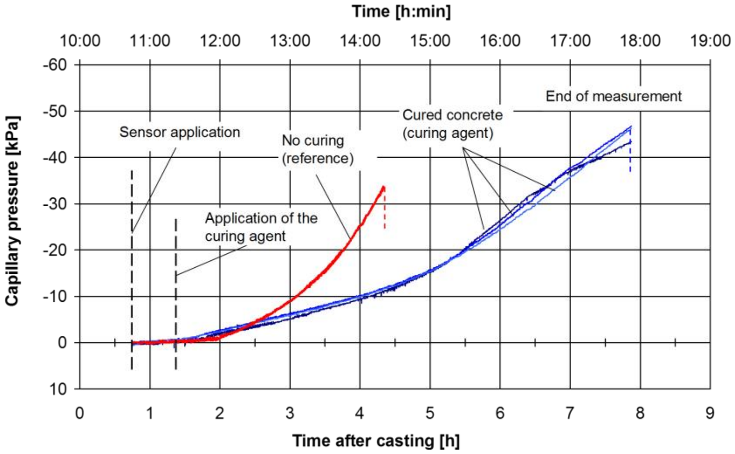


Capillary pressure measured with two sensors in a 0.4 m thick bridge coping

→ With both sensors almost the same pressure was obtained.

→ Effects of surface finishing and curing on the capillary pressure may be seen.

Example 2: Capillary pressure measurement in road construction



Capillary pressure measured in a concrete road and in an uncured reference specimen with the same thickness (25 cm) which was cast simultaneously

→ The curves show the influence of the applied curing method (curing agent) on the capillary pressure development.

Acknowledgements

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