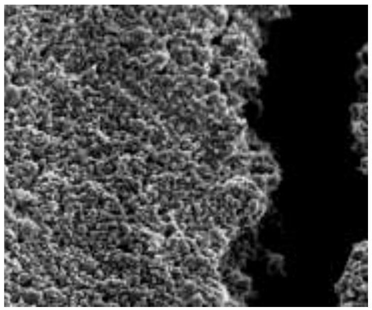
UWS UNIVERSITY OF THE WEST of SCOTLAND

HTWK Leipzig


Capillary Pressure Controlled Concrete Curing in Pavement Construction

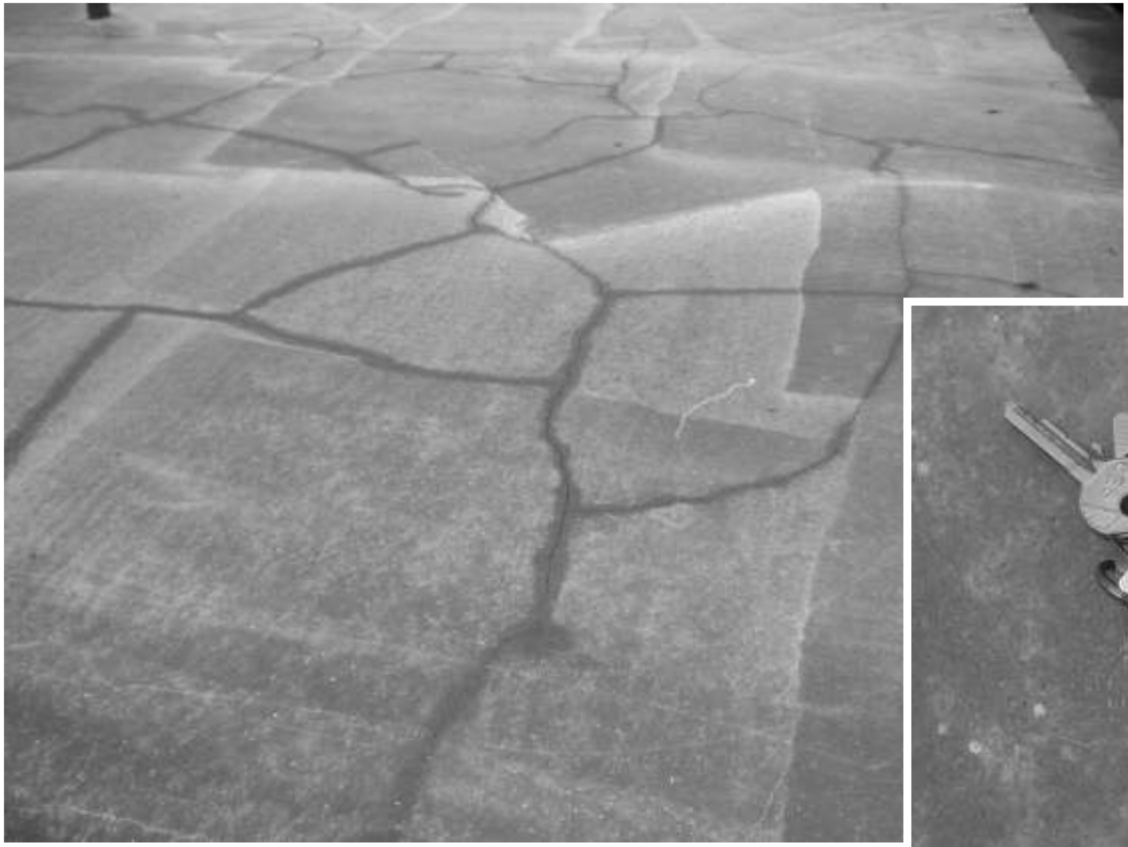
Markus Schmidt [1,2]
mschmid@fbb.htwk-leipzig.de

Volker Slowik [1]
volker.slowik@htwk-leipzig.de

[1] Leipzig University of Applied Sciences, Leipzig, Germany
[2] University of the West of Scotland, Paisley, UK

The Airfield & Highway Pavement Conference
June 9th – 12th, 2013, Los Angeles, USA

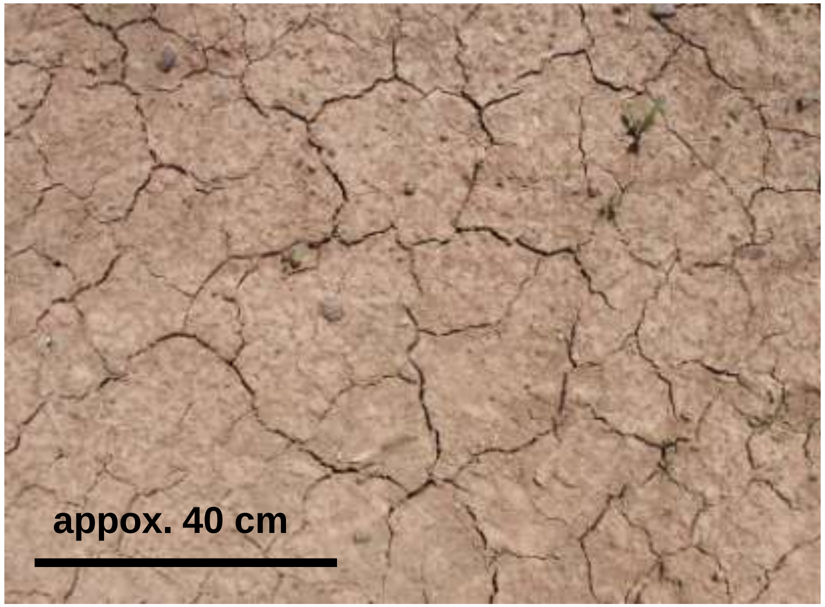
Capillary shrinkage cracking



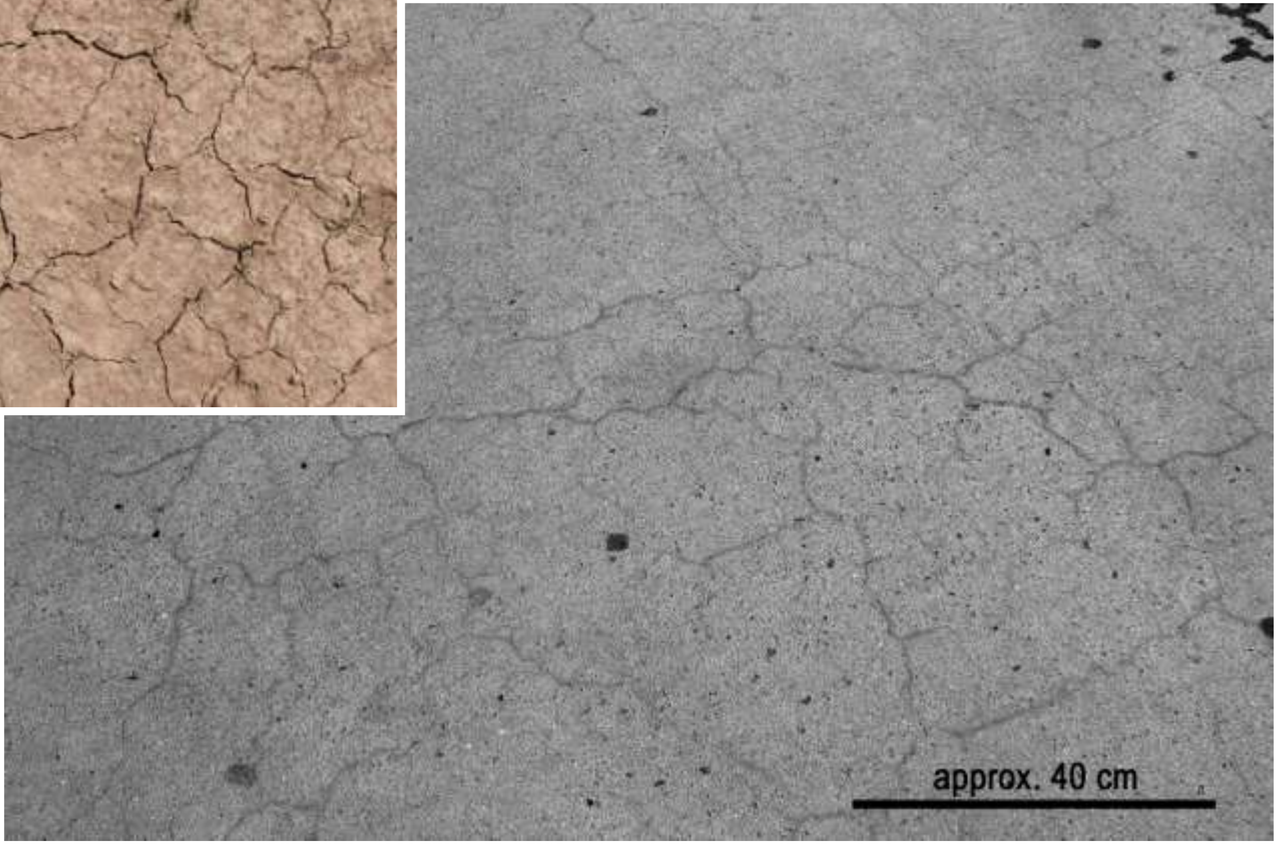
Concrete slab on grade
(Leipzig, 2006)

→ Cracks were formed within the first three hours after casting.

Capillary shrinkage cracking



Shrinkage
cracks in mud



Airport
Berlin-Schönefeld

Capillary shrinkage cracking

Cracked concrete floor (parking structure)

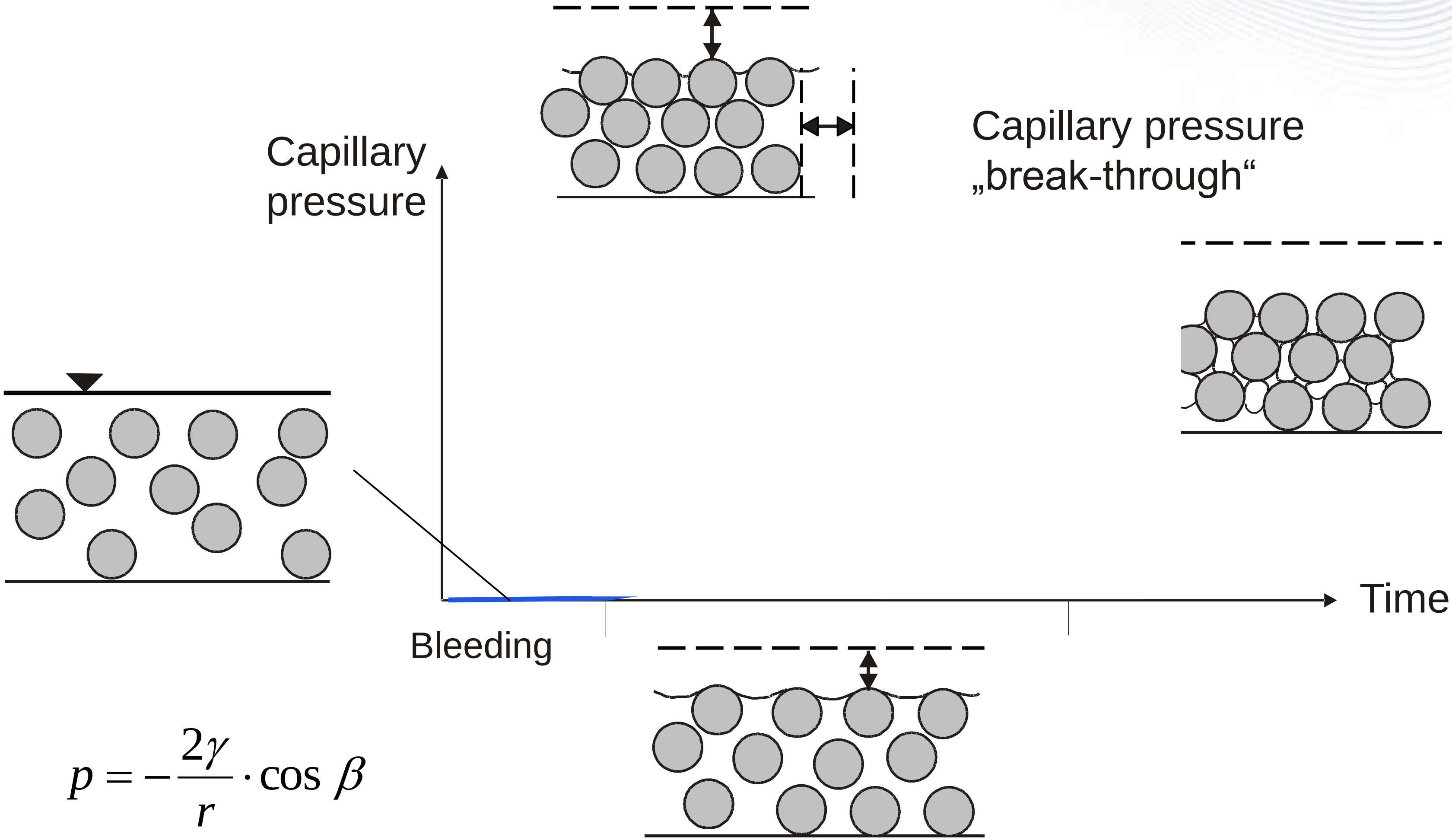
Capillary shrinkage cracking

Power floating (bridge deck)

Preparing an exposed aggregate surface (concrete road)

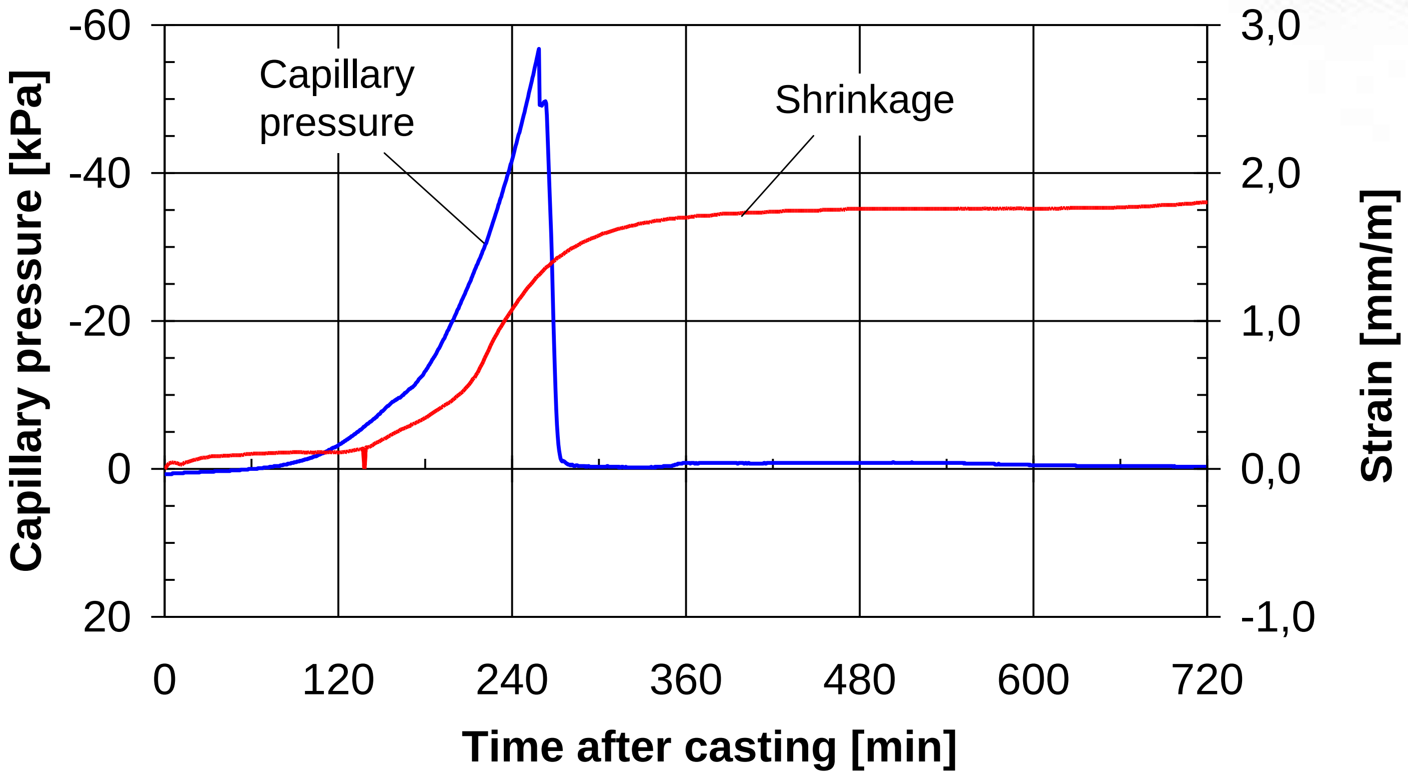
„Repair“ of early age damage during surface finishing?

Capillary pressure build-up



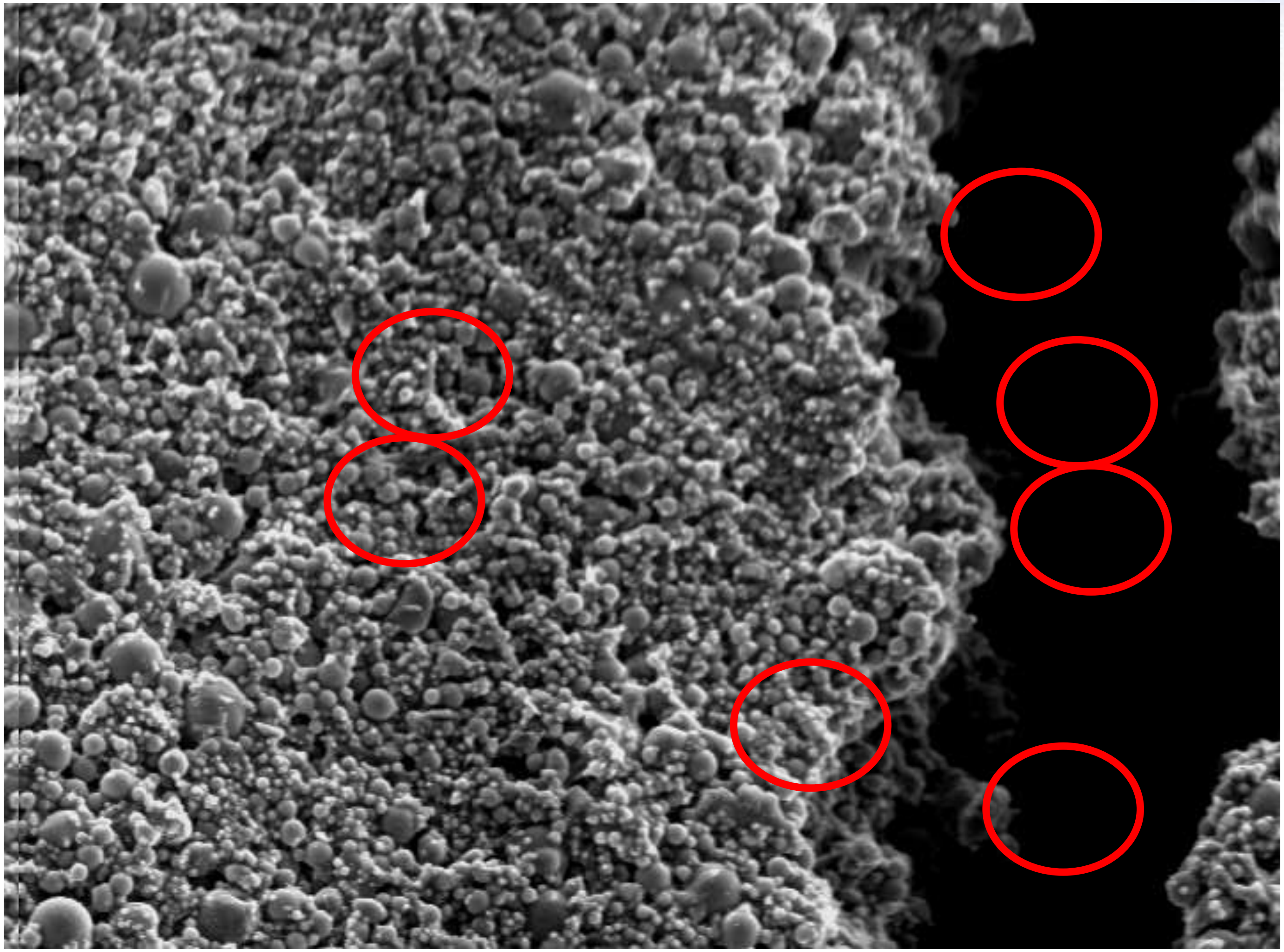
$$p = -\frac{2\gamma}{r} \cdot \cos \beta$$

Capillary pressure build-up

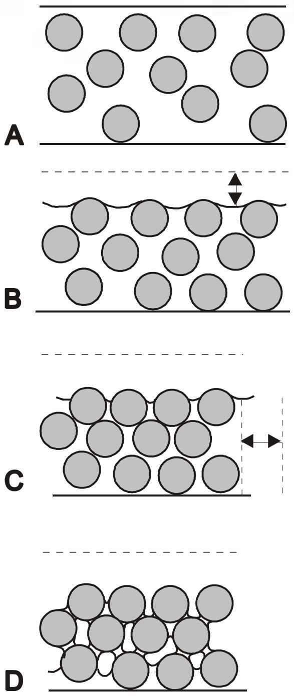


Example of capillary pressure development in cement paste and shrinkage strain versus time

Capillary shrinkage cracking

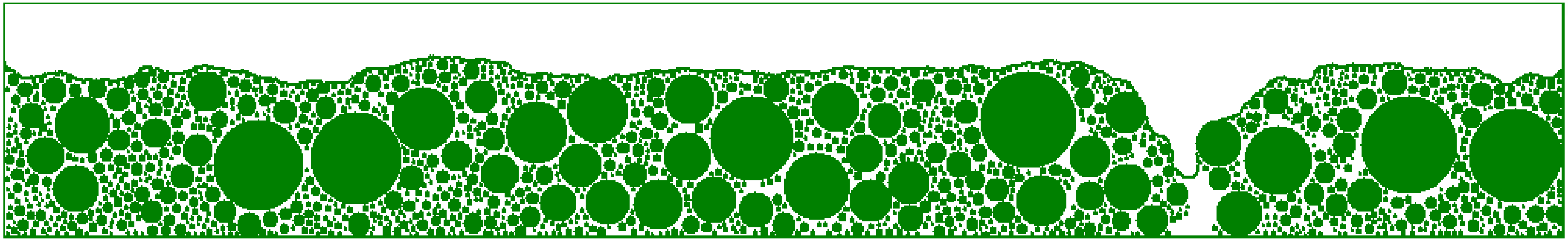


Cross section (schematic)



Fly ash / water suspension observed with an ESEM 100 µm

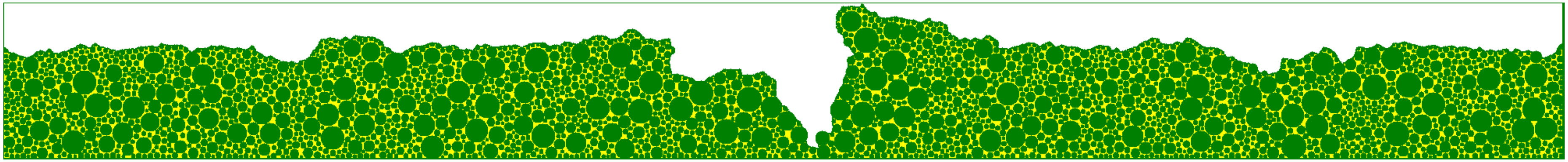
Capillary shrinkage cracking (Simulation)



Drying suspension

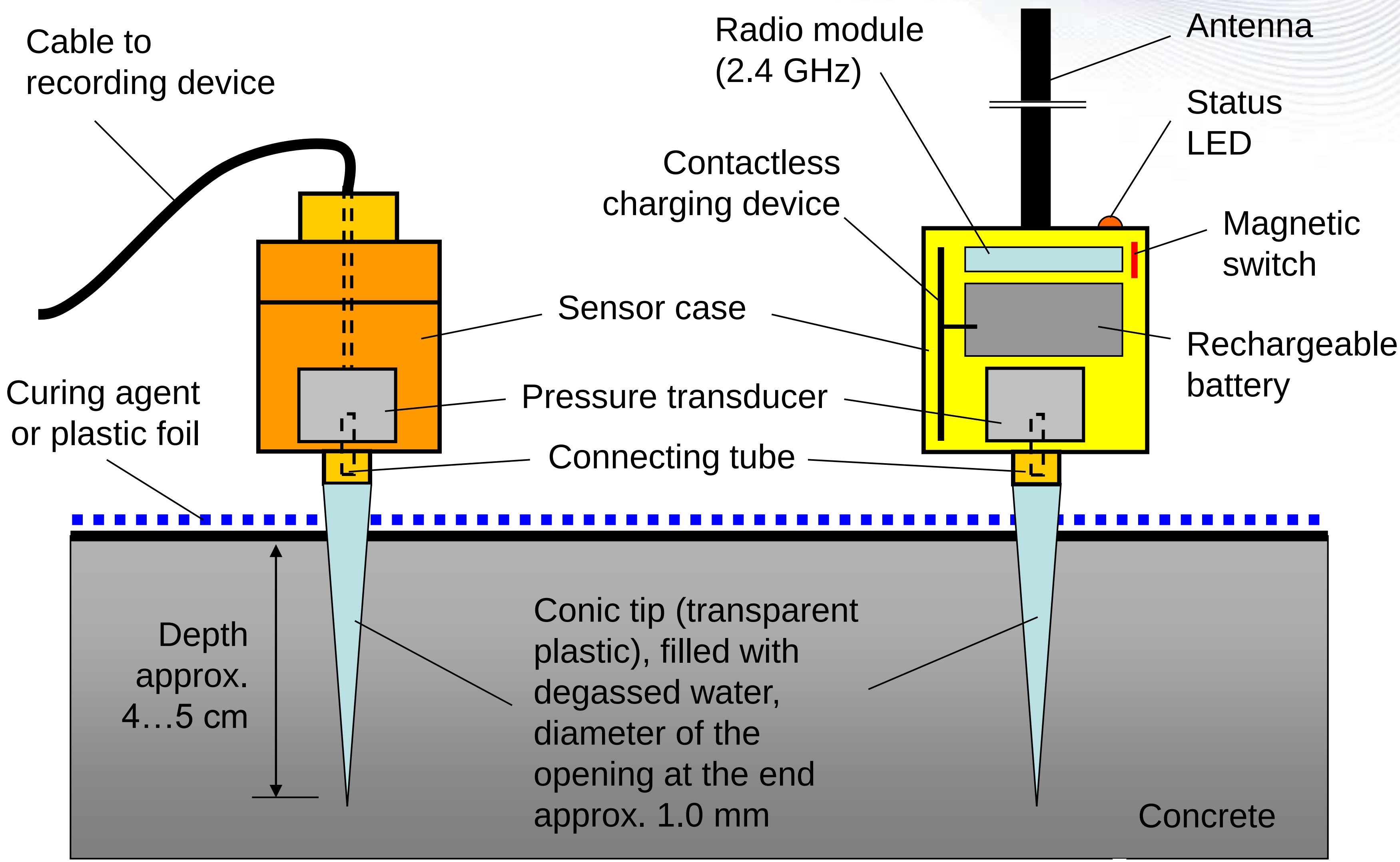
- Water is evaporating.
- Menisci are formed between the particles at the surface.
- Capillary pressure is built up.
- Particles are moving under the action of different forces.
- Strain localization takes place.
- „Cracks“ are formed.

Capillary shrinkage cracking (Simulation)



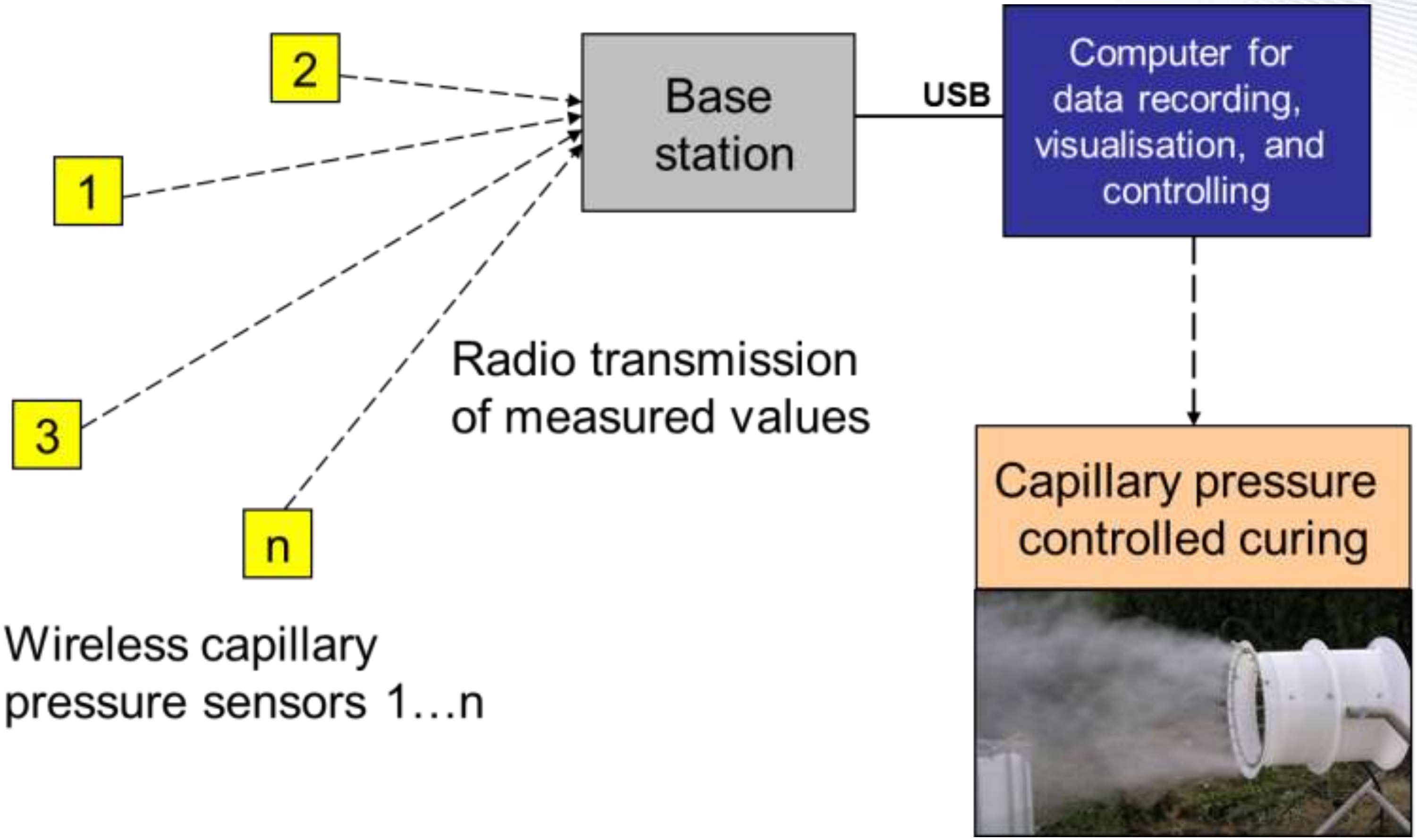
particle sizes ranging from 4 µm to 32 µm

Capillary pressure measurement

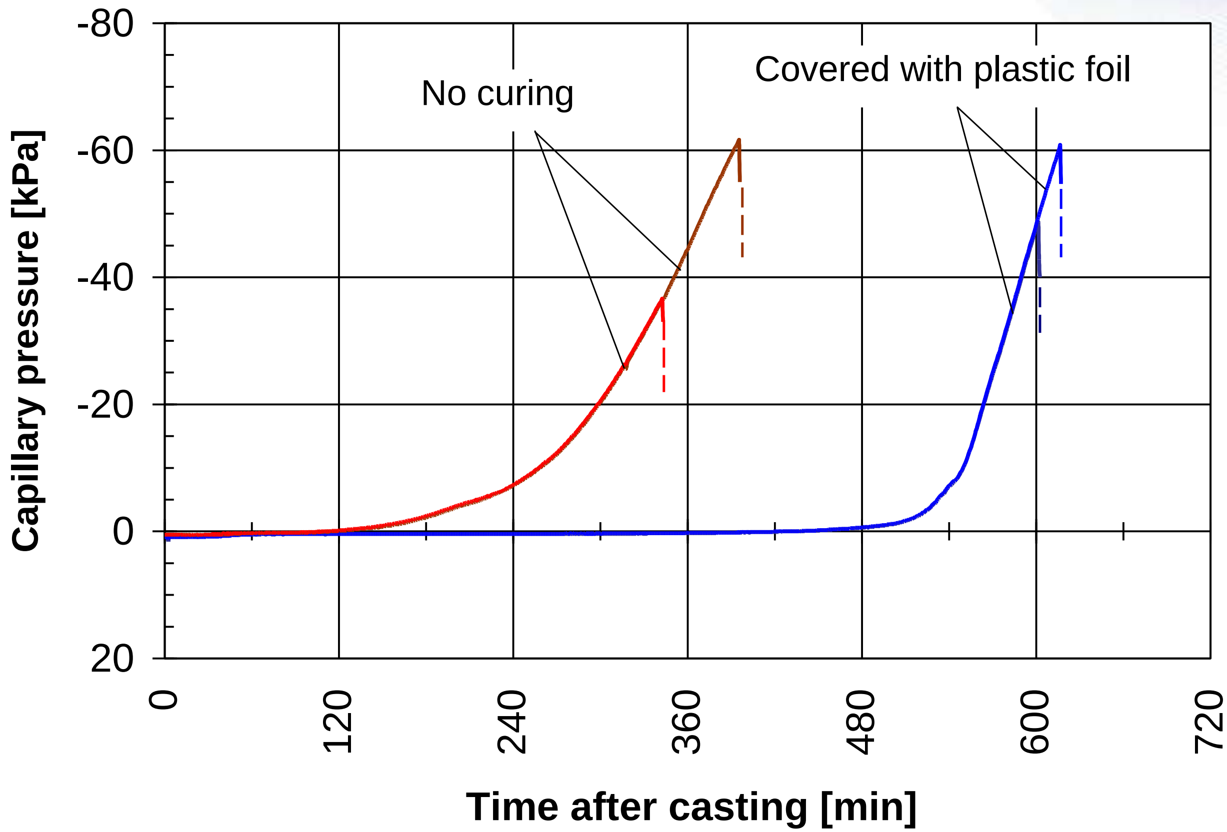


Capillary pressure measurement

Capillary pressure measurement



Influence of curing measures

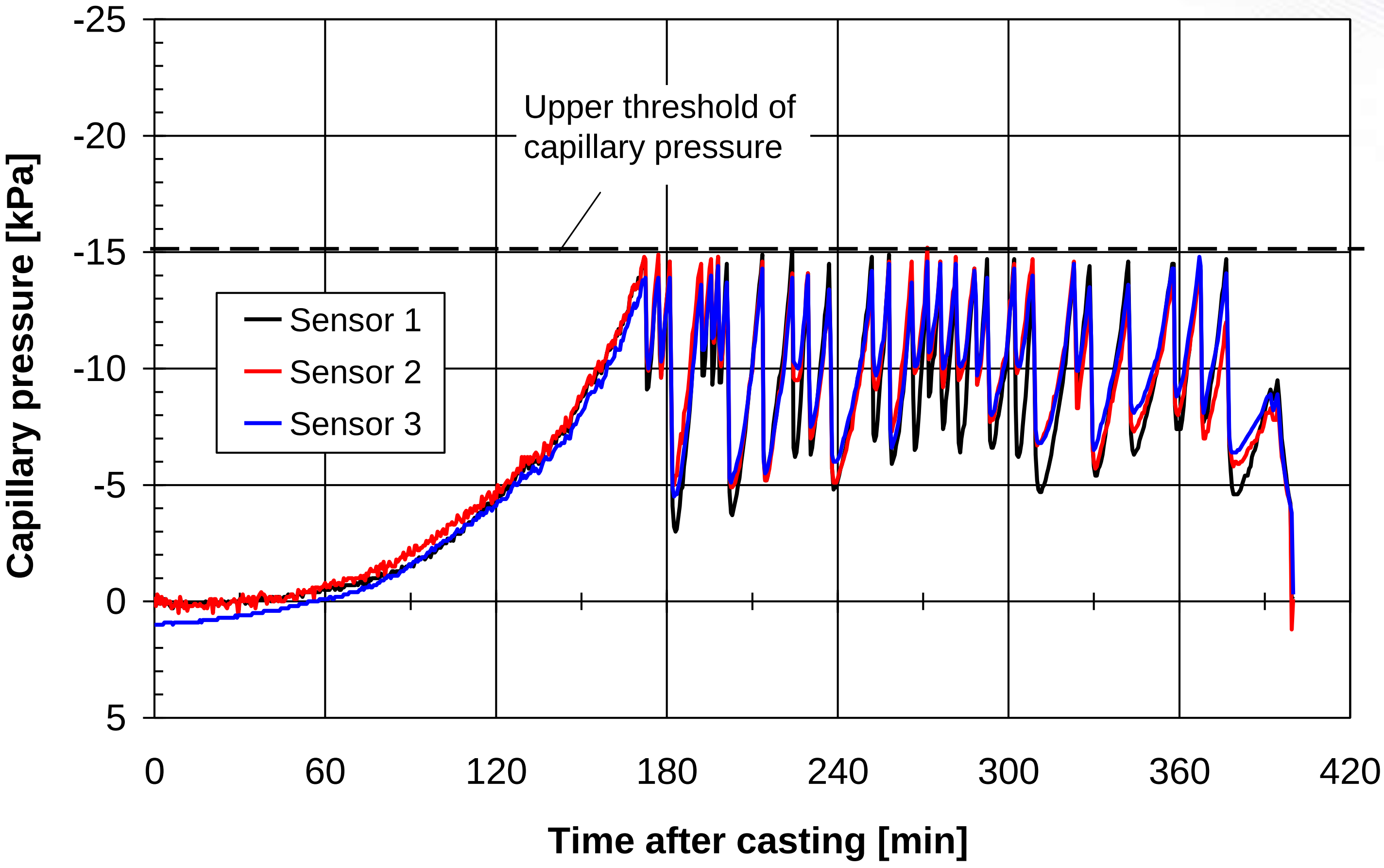


Capillary pressure versus time measured in a cured and in an uncured concrete specimen

Controlled concrete curing

Fogging system

Controlled concrete curing



Capillary pressure dependent surface rewetting

Practical applications

Concrete road construction (highway)

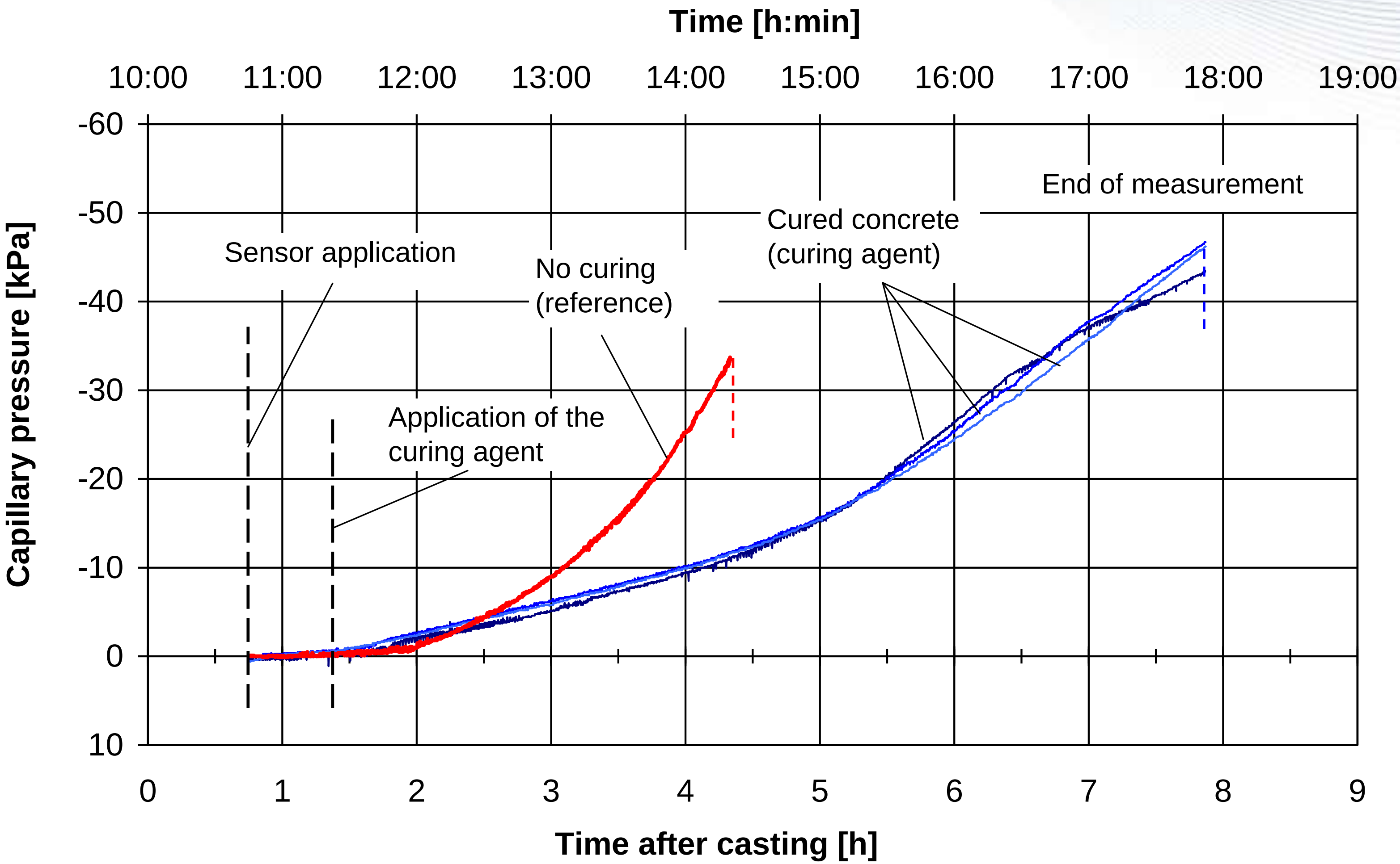
Practical applications

Airfield construction

Practical applications

Exposed aggregate concrete
(highway construction)

Practical applications



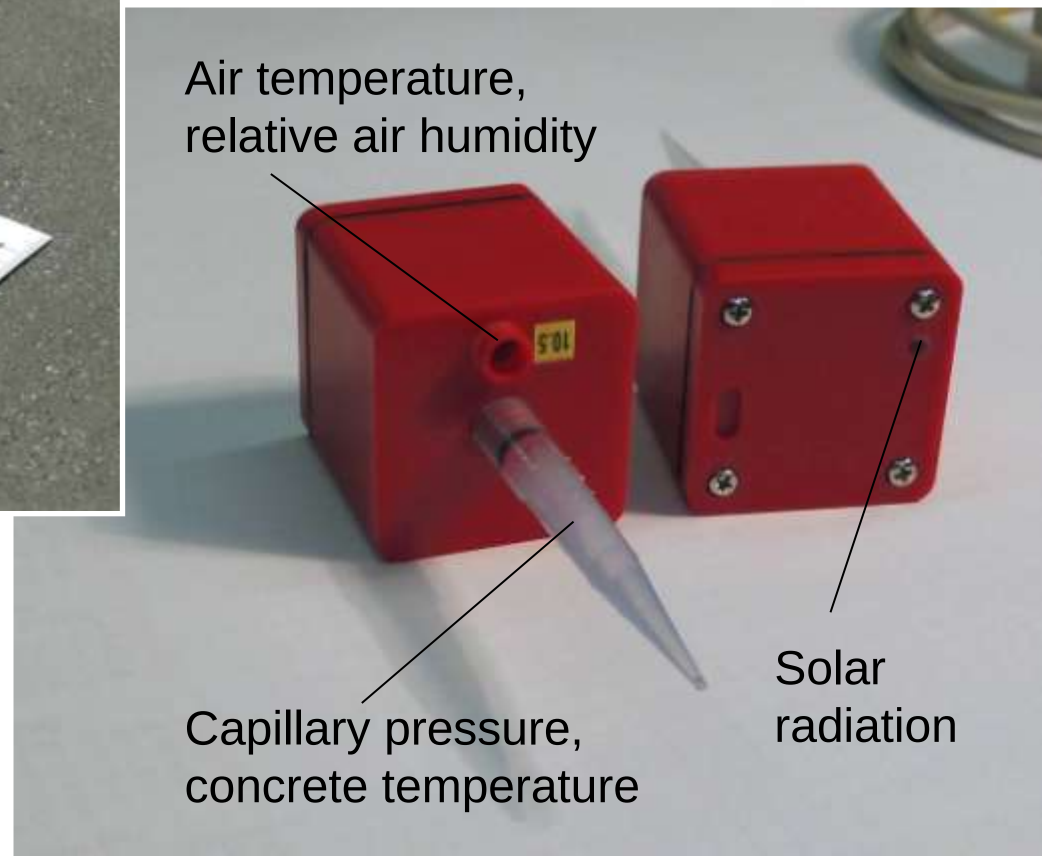
Capillary pressure development in concrete (highway construction)

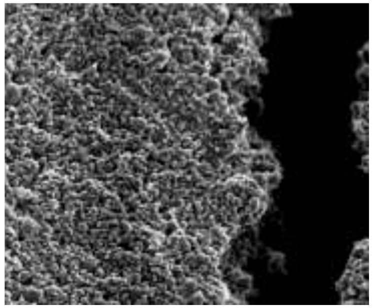
Conclusions

- Plastic shrinkage of concrete is mainly caused by the **build-up of a capillary pressure** in the pore system of the material.
- Early age cracks resulting from plastic shrinkage may have an **unfavorable effect on the durability** of concrete structures.
- The capillary pressure **can be easily measured under site conditions** with special pressure transducers.
- On the basis of the measured capillary pressure, it is possible to make decisions concerning the **timing of curing measures** and to **evaluate the effect** of such measures. This allows to **reduce the early age cracking risk**.
- The measured capillary pressure may serve as a feedback signal for a closed-loop **controlled concrete curing**.

Outlook

Enhanced capillary pressure sensor




Capillary Pressure Controlled Concrete Curing in Pavement Construction

Markus Schmidt [1,2]
mschmid@fbb.htwk-leipzig.de

Volker Slowik [1]
volker.slowik@htwk-leipzig.de

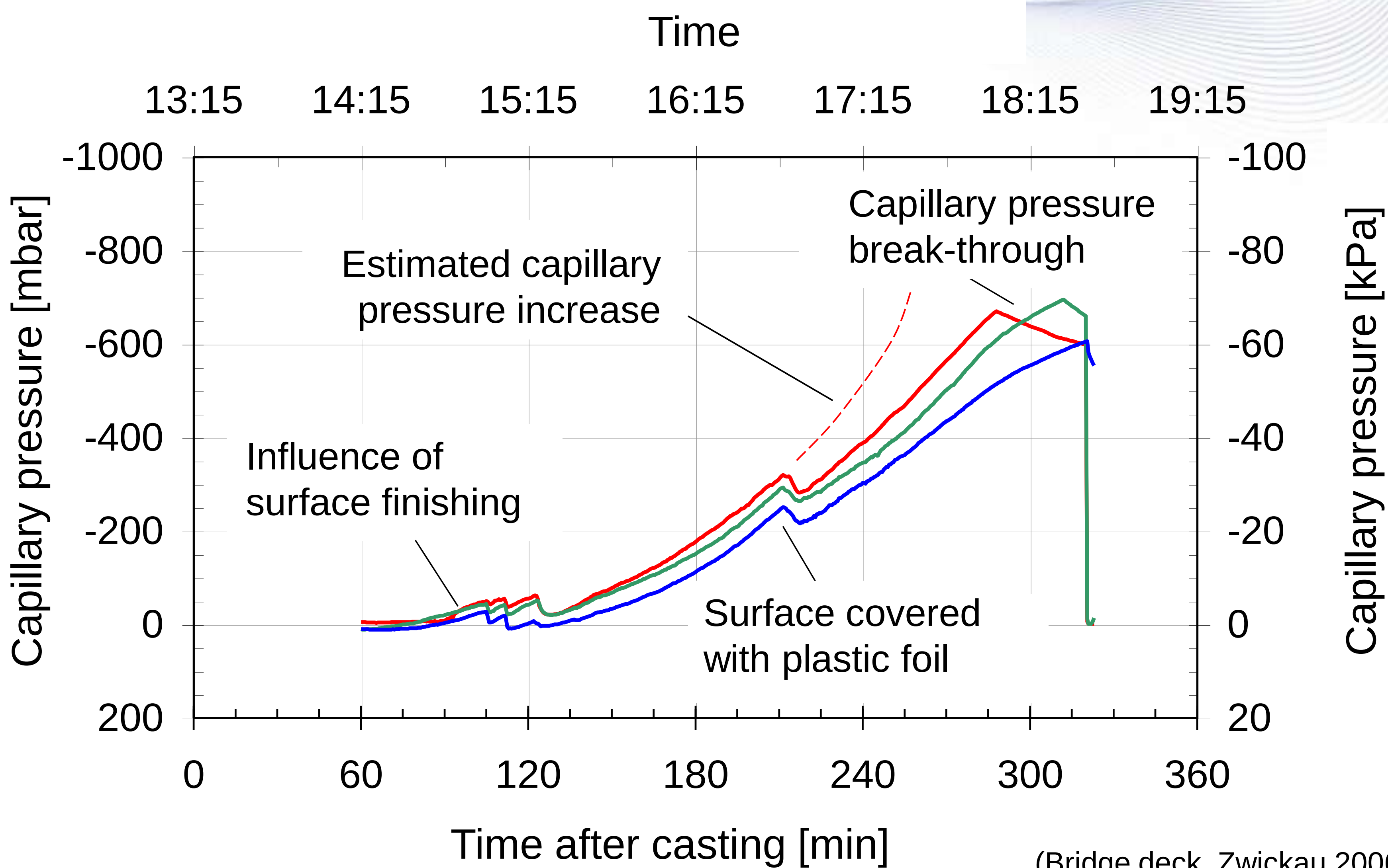
[1] Leipzig University of Applied Sciences, Leipzig, Germany
[2] University of the West of Scotland, Paisley, UK

The Airfield & Highway Pavement Conference
June 9th – 12th, 2013, Los Angeles, USA

On-site capillary pressure measurement

Highway bridge, Zwickau, Germany

On-site capillary pressure measurement



(Bridge deck, Zwickau 2006)

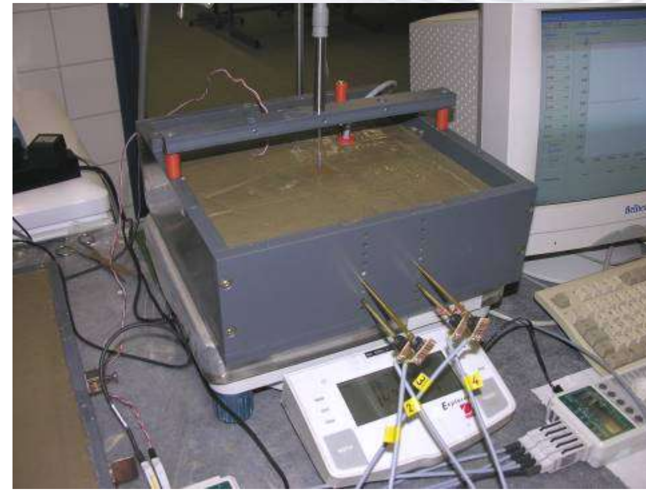
www.capillary-pressure-sensors.com
www.Kapillardrucksensoren.de

Controlled concrete curing

Laboratory

Identify the air entry point and the related capillary pressure (air entry value)

Define a "critical capillary pressure"



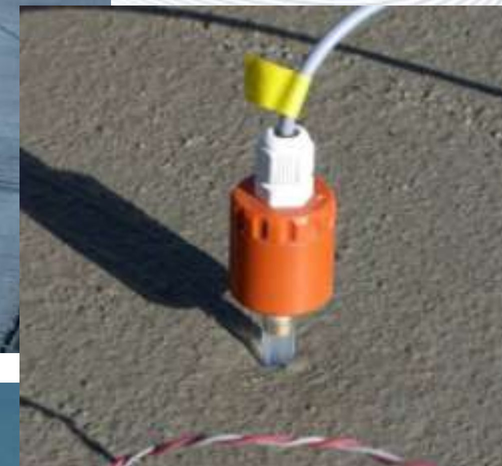
Construction site

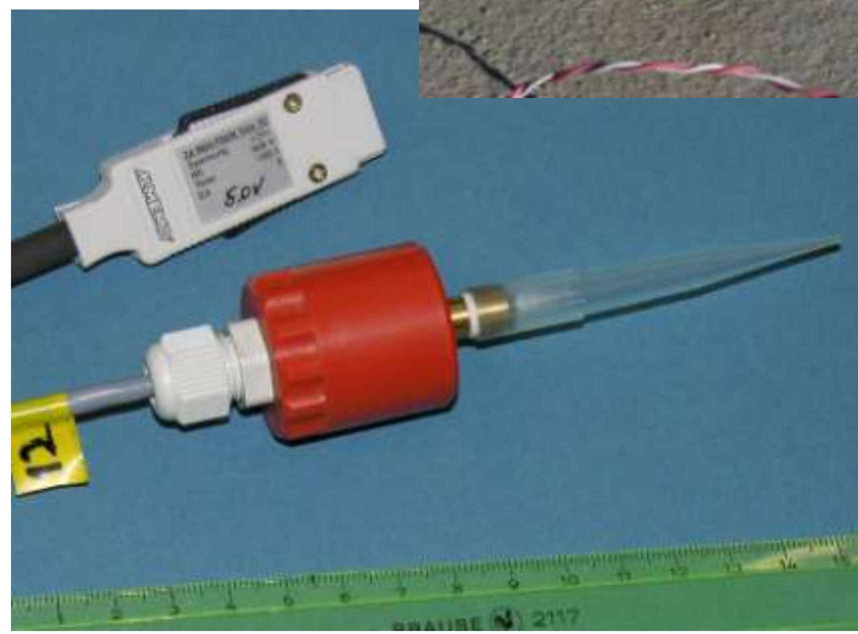
Capillary pressure measurement

Surface rewetting before reaching the critical capillary pressure

Capillary pressure measurement

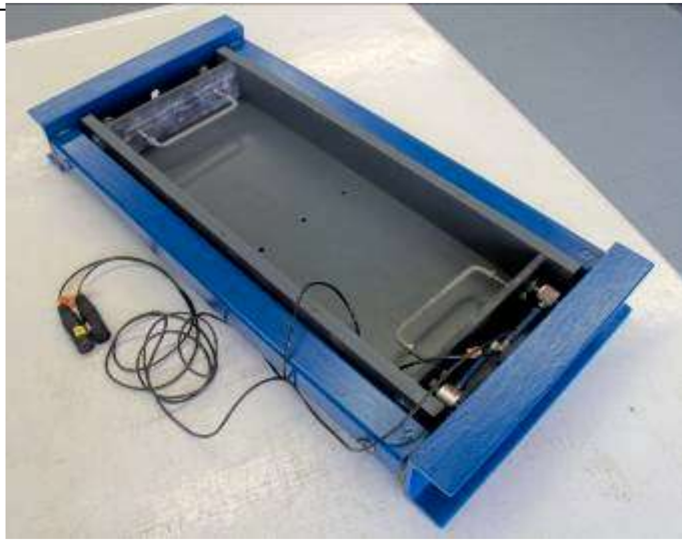
Capillary pressure measurement (laboratory)

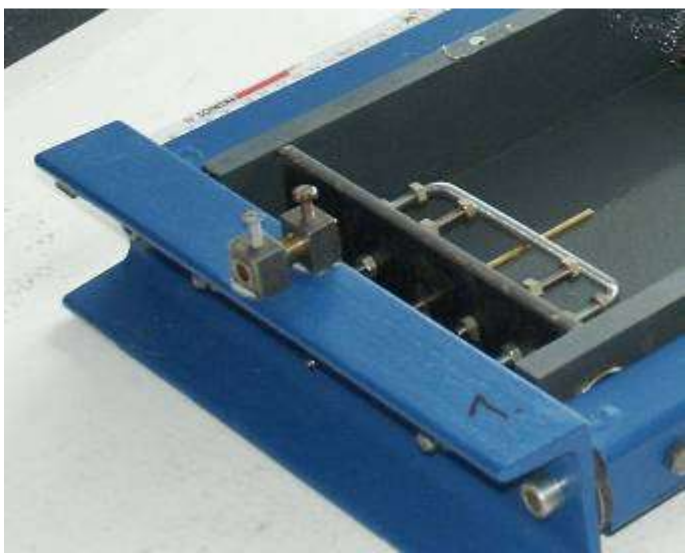


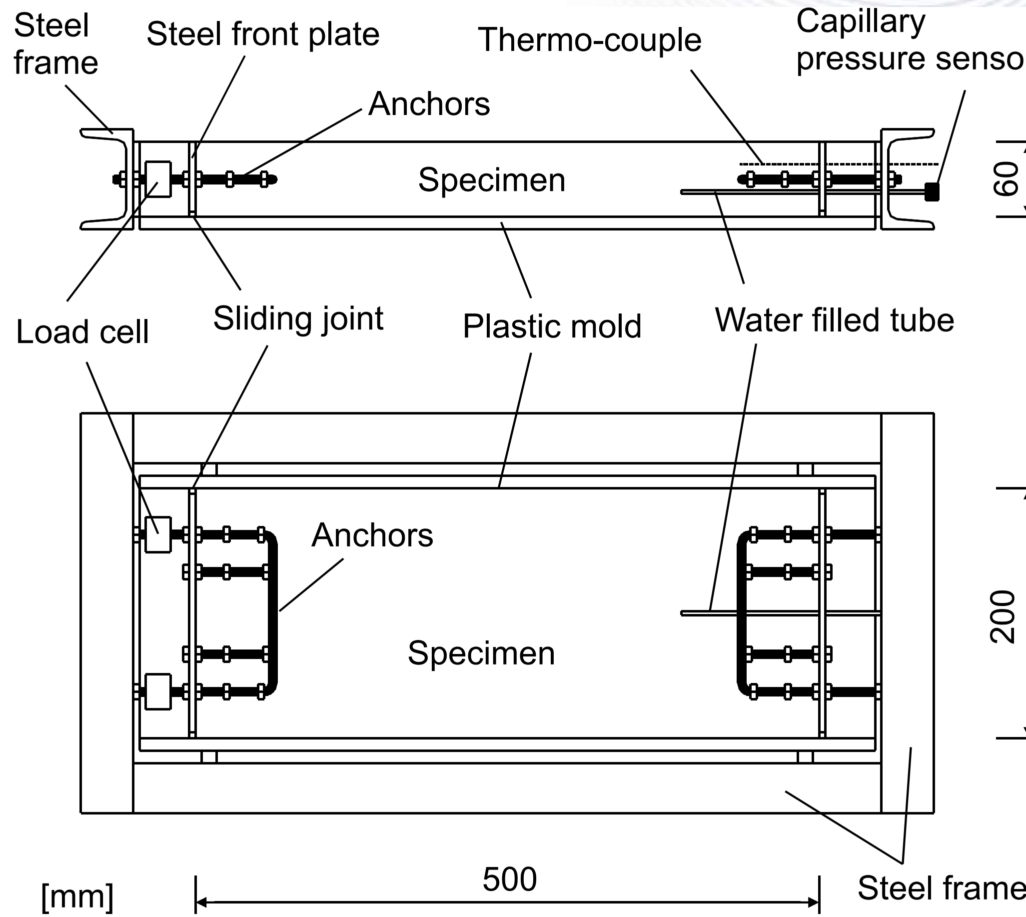


Capillary pressure measurement (construction site)

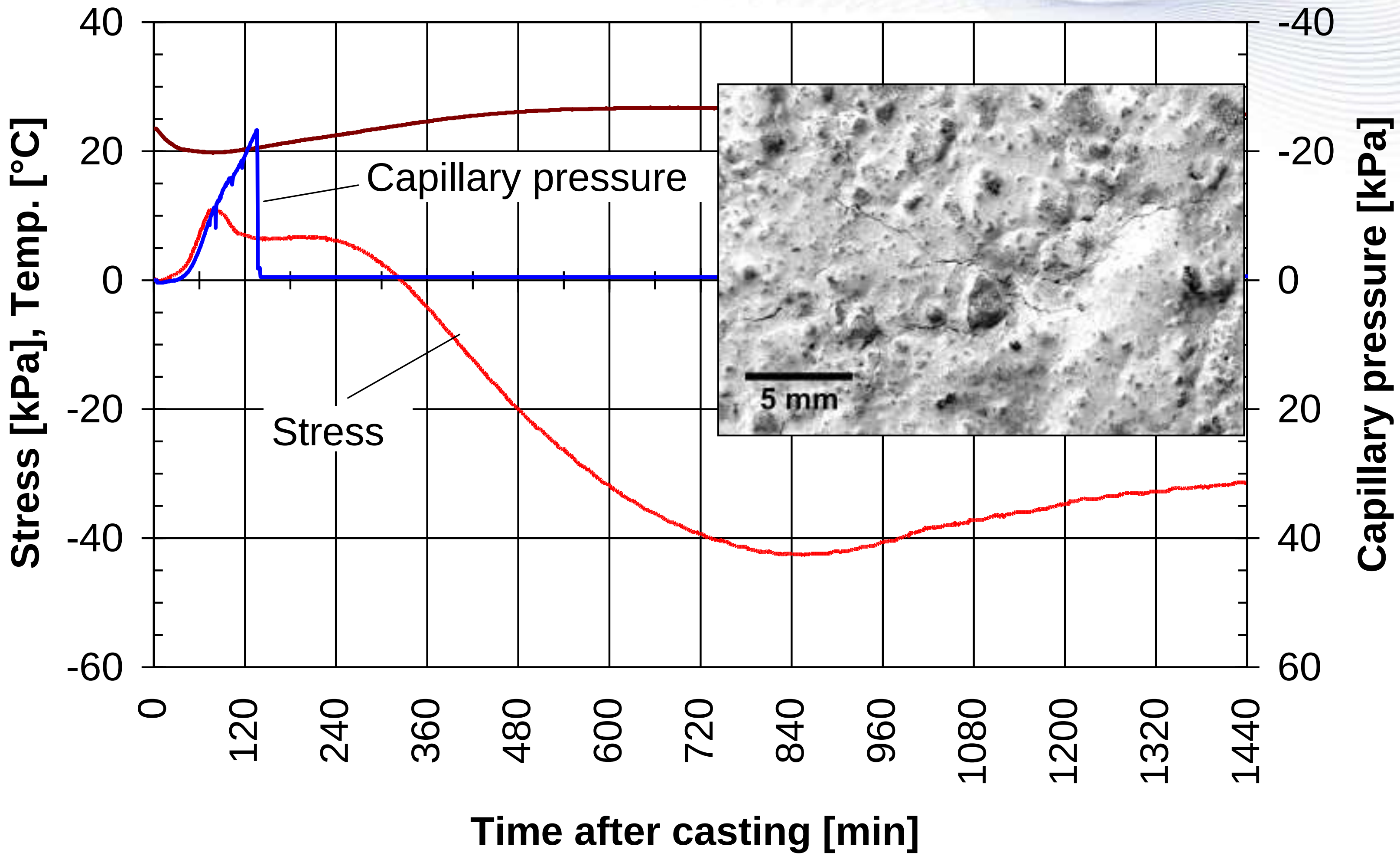
Experimental set-up for constrained shrinkage tests





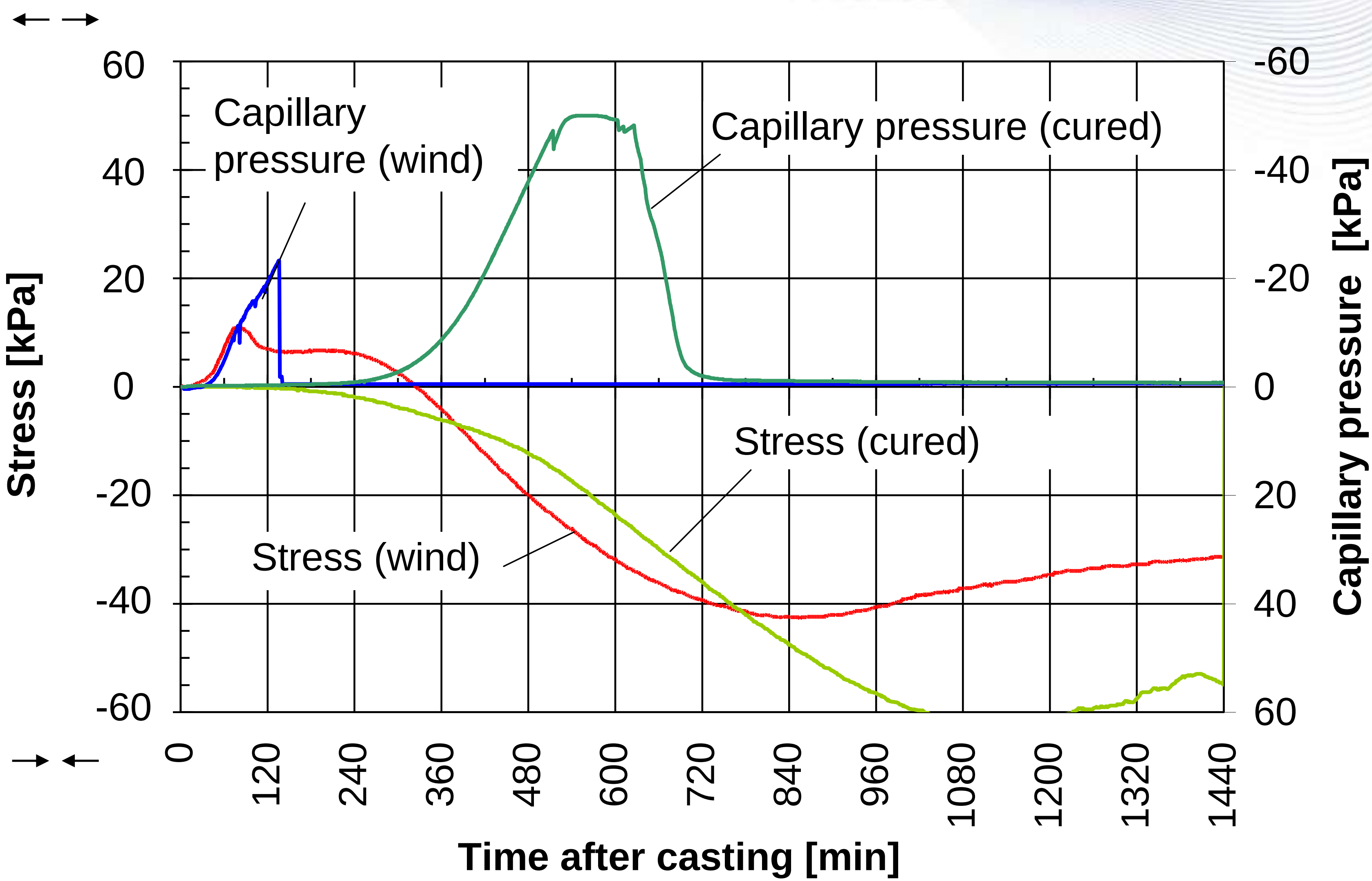


Stress development



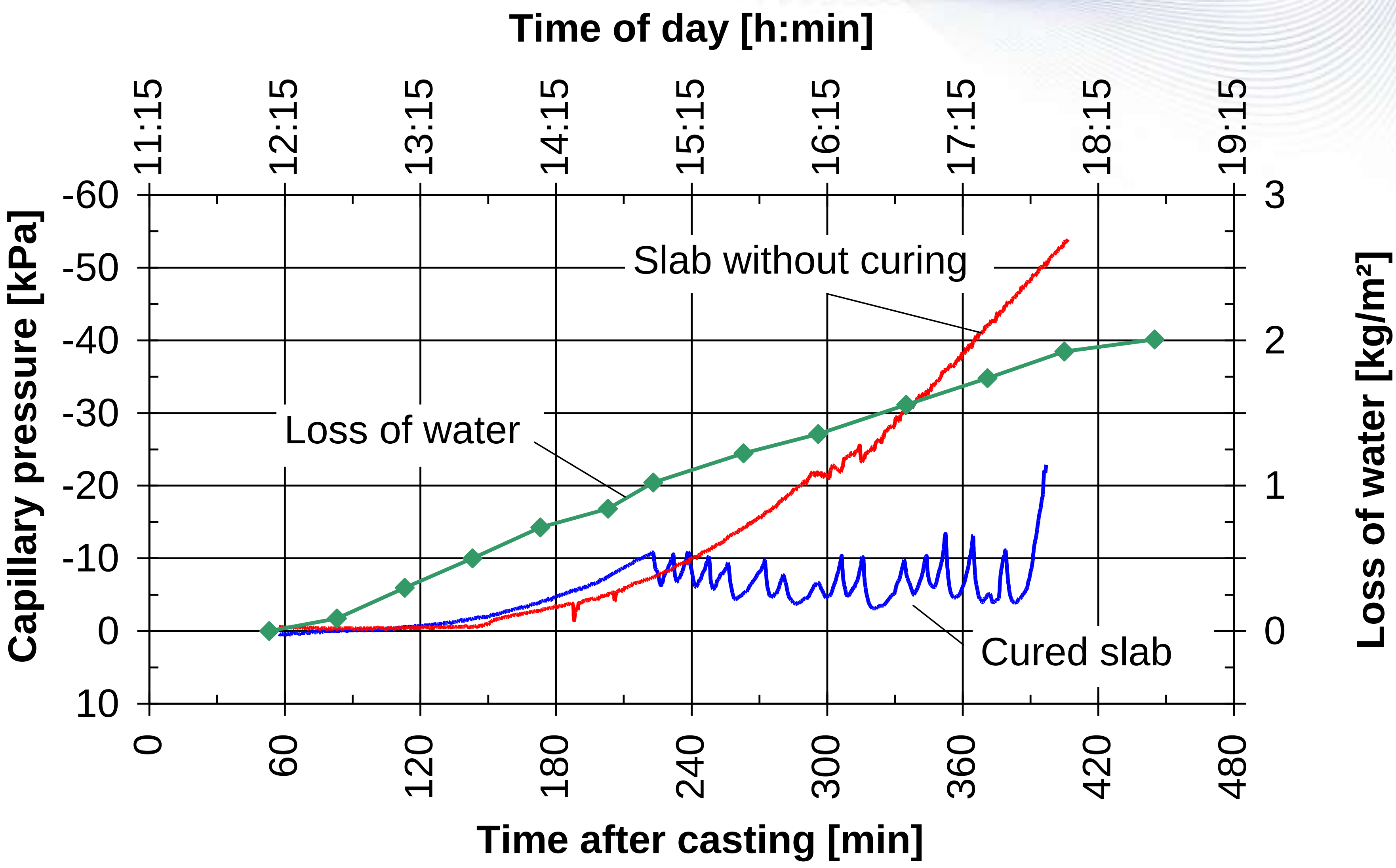
(Concrete, 440 kg/m³ CEM I 32.5 R, w/c=0.41, Temp. 25°C, RH 35%, Wind 5.0 m/s)

Stress development



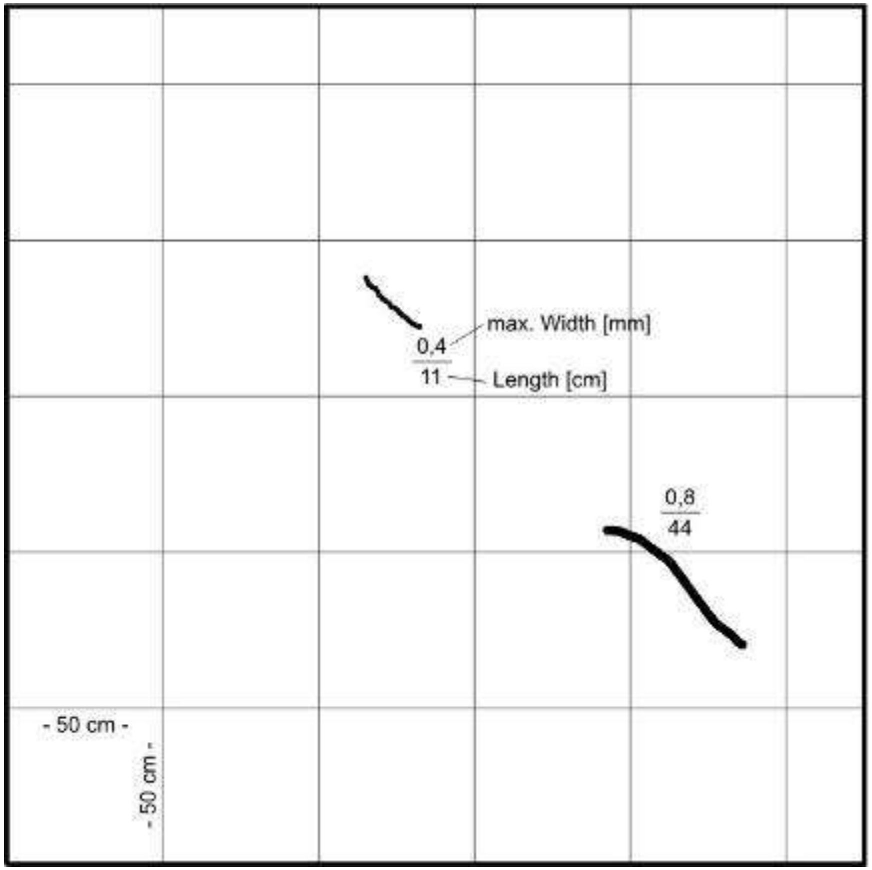
Controlled concrete curing

Controlled concrete curing

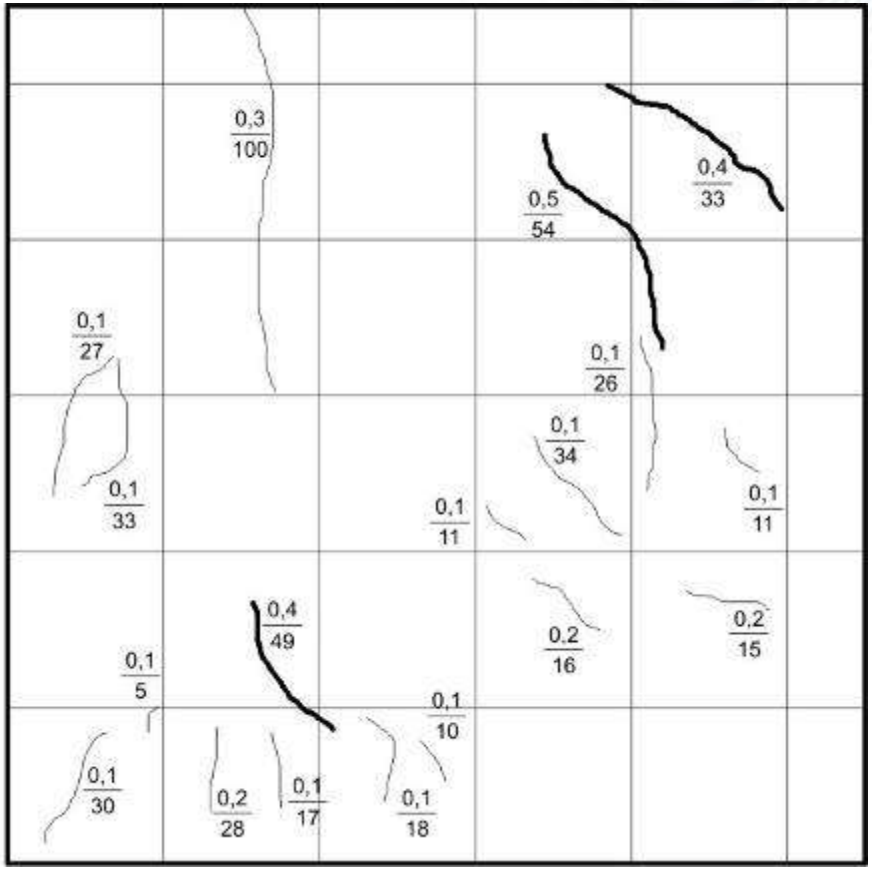


Controlled concrete curing

→ Crack pattern after 24h



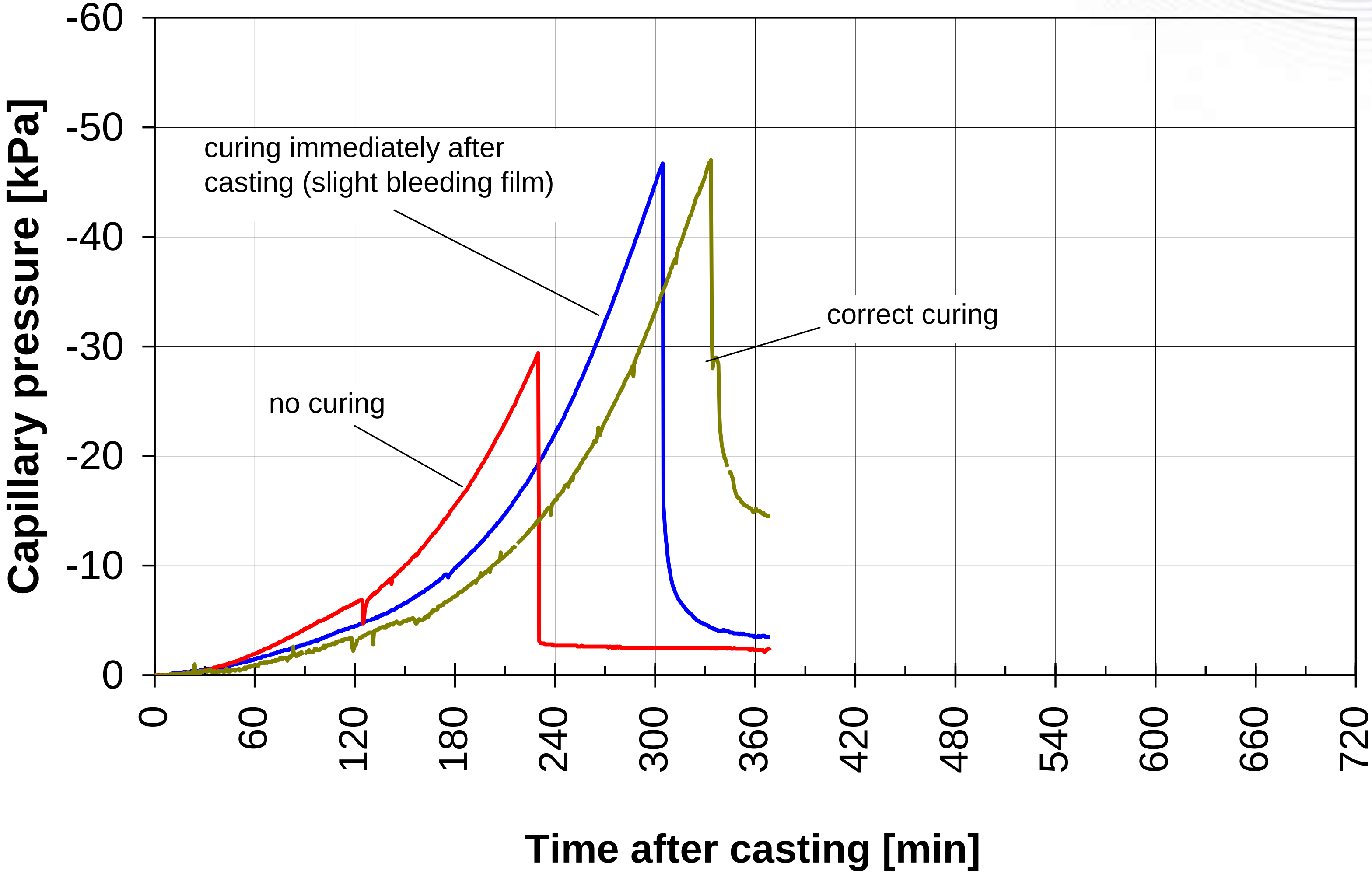
Cured concrete slab



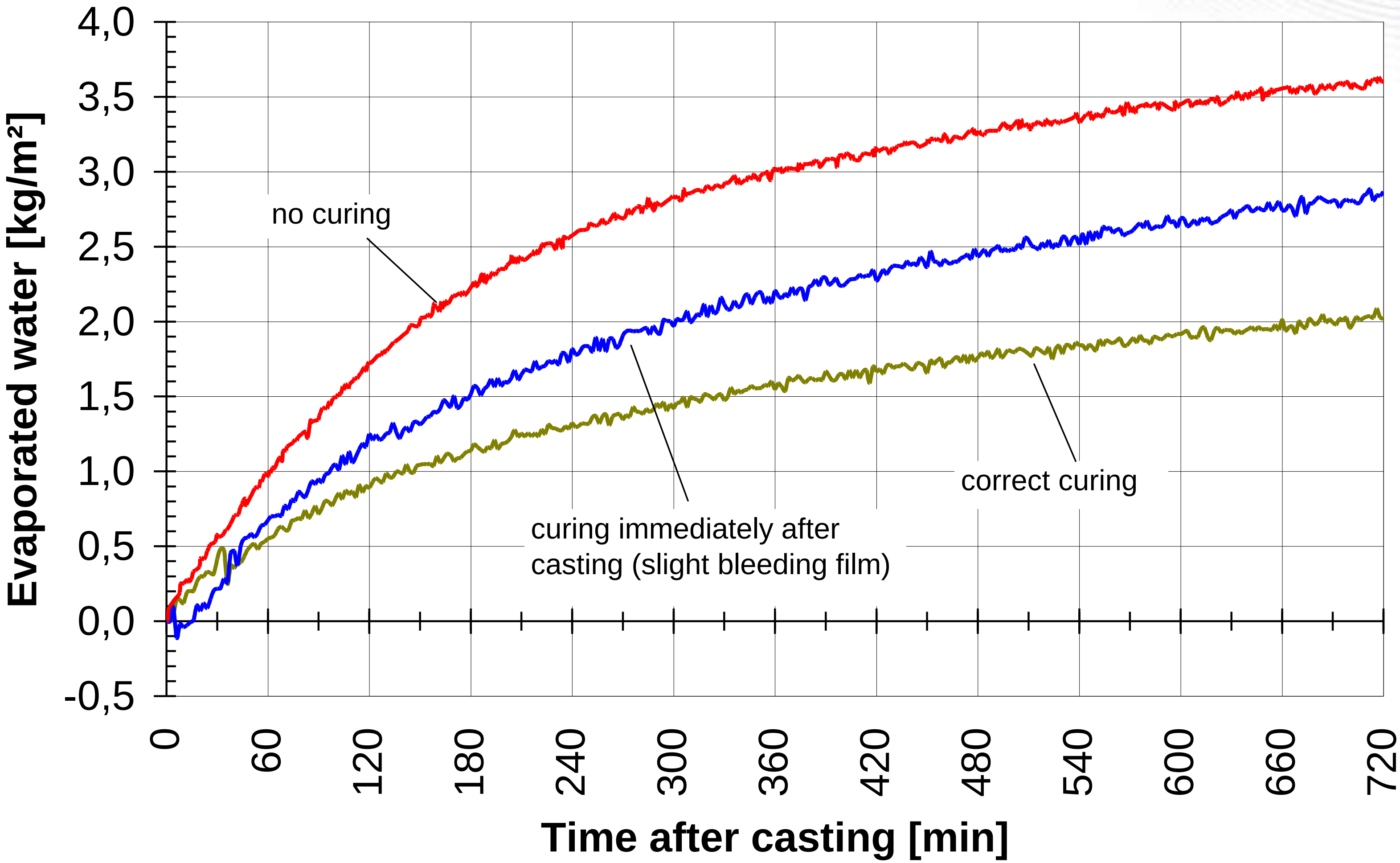
Concrete slab without curing

Capillary pressure measurement

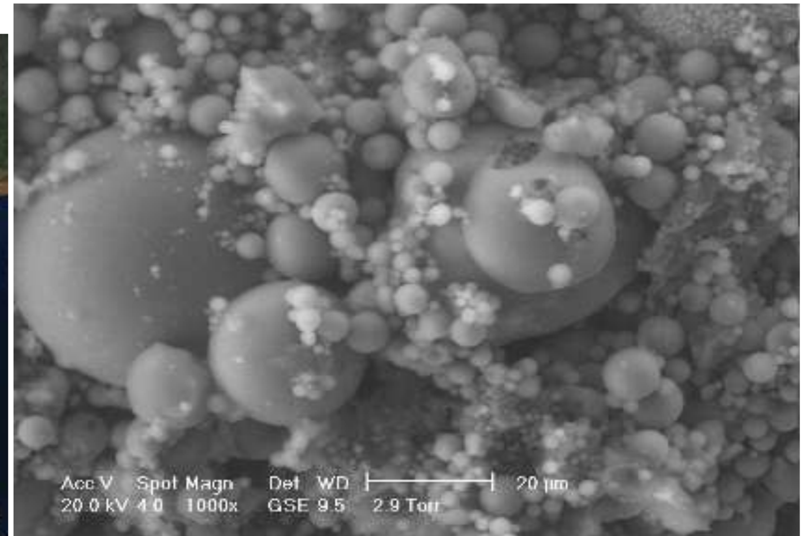
Concrete for road construction (top layer), 420 kg/m³ cement, very stiff

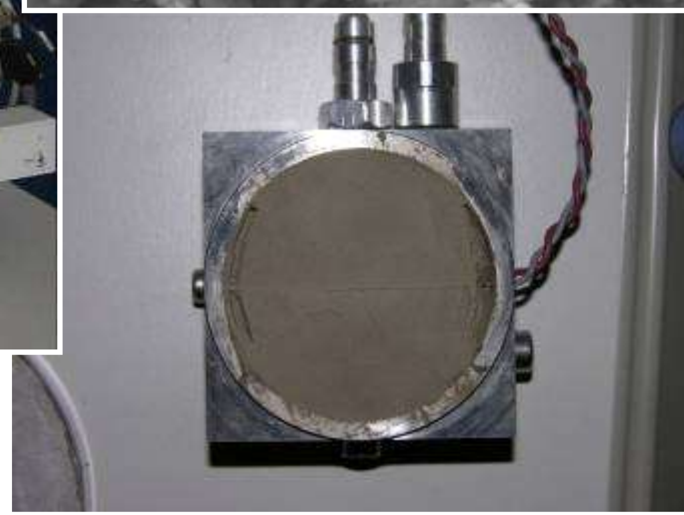


Evaporation



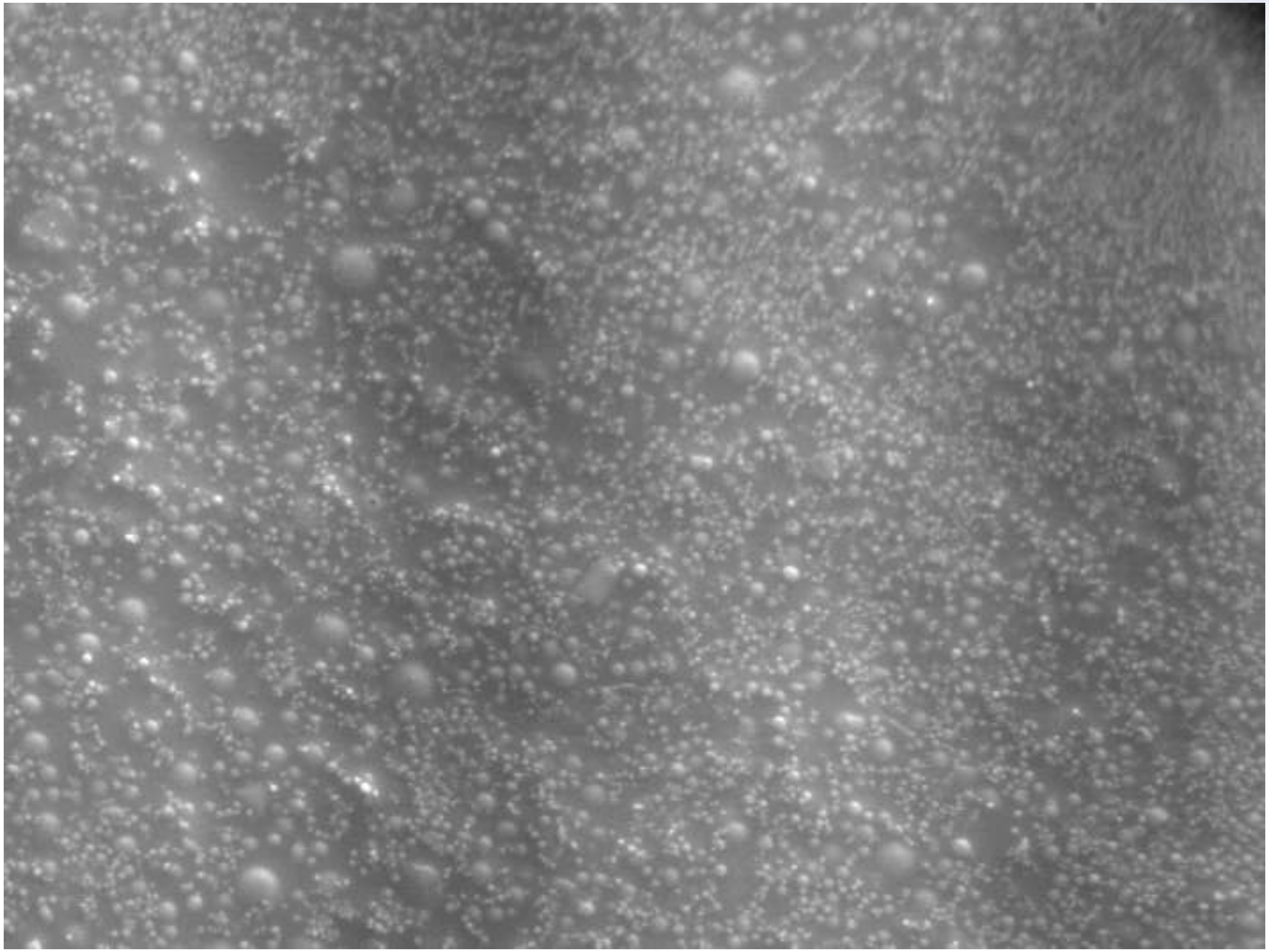
Capillary shrinkage cracking



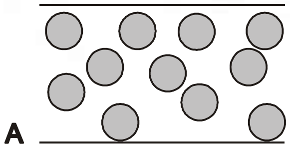


Environmental Scanning Electron Microscope (ESEM)

Capillary shrinkage cracking

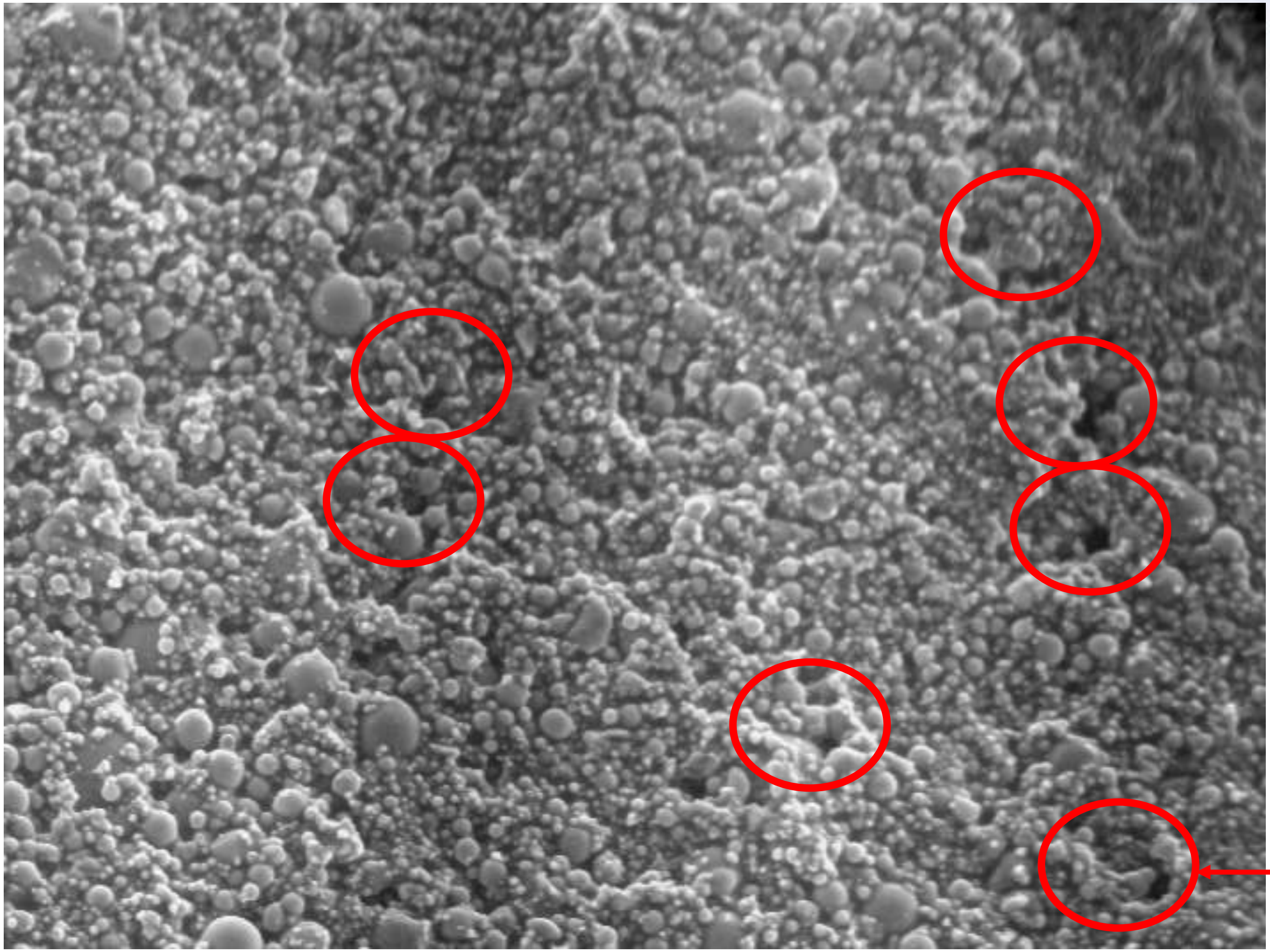


Cross section
(schematic)

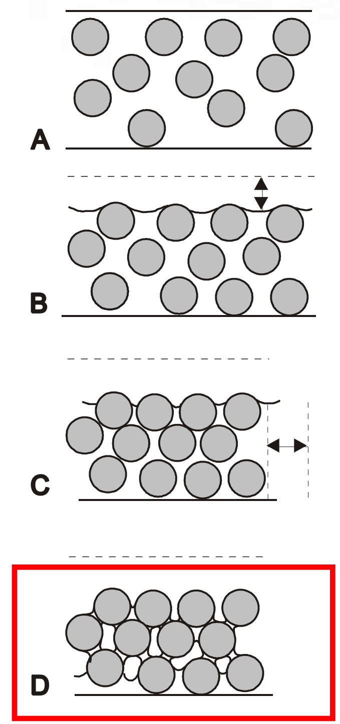


Fly ash / water suspension observed with an ESEM 100 µm

Capillary shrinkage cracking



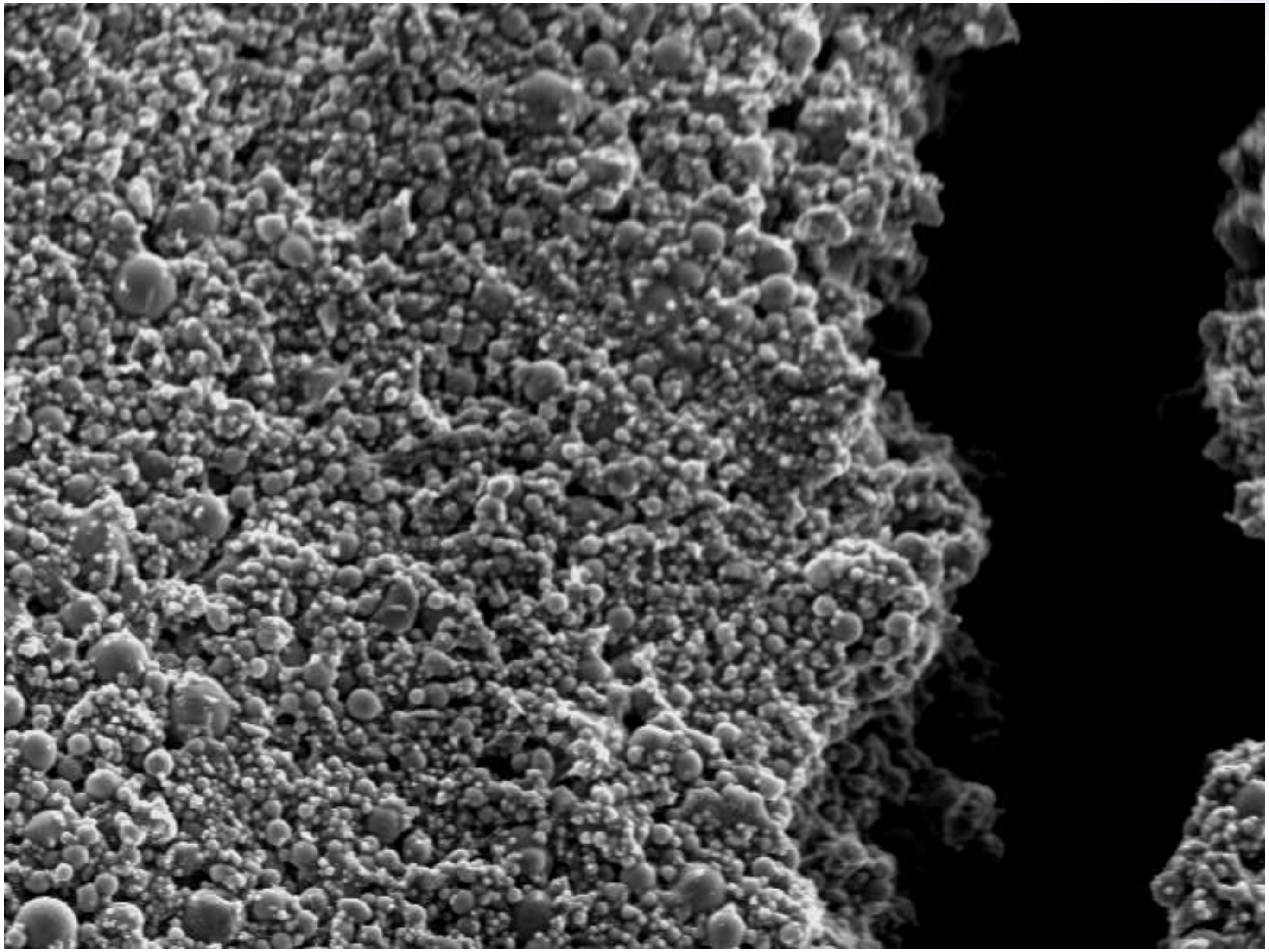
Cross section
(schematic)



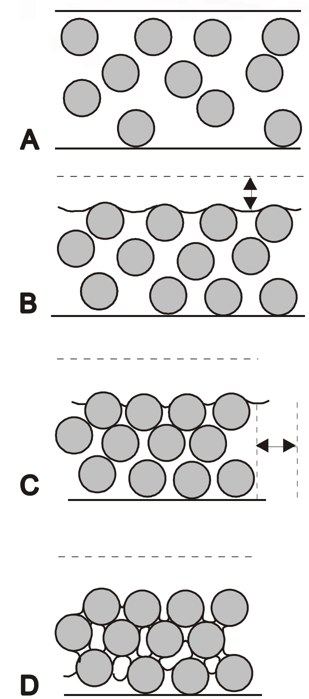
Local
air entry

Fly ash / water suspension observed with an ESEM 100 µm

Capillary shrinkage cracking

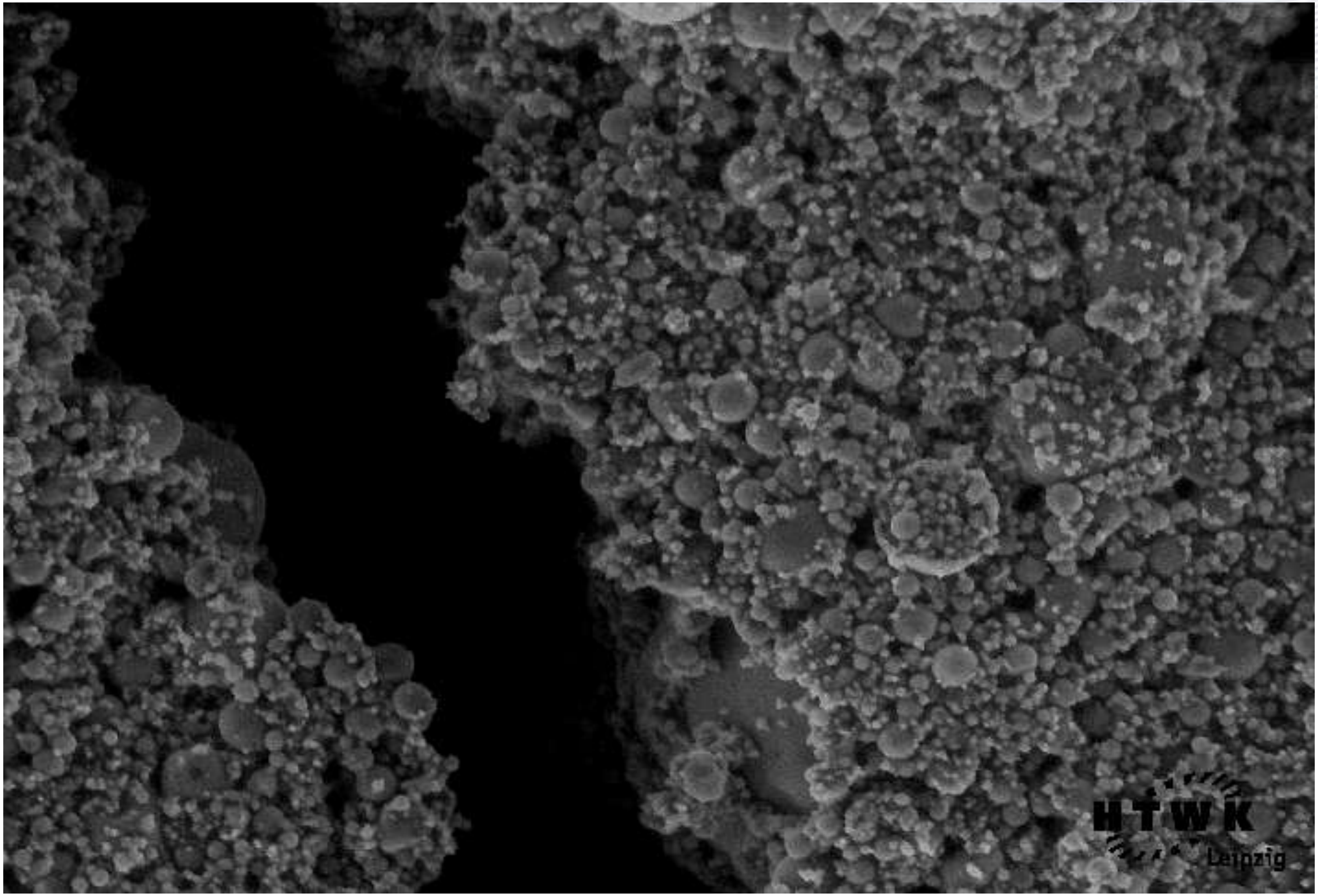


Cross section
(schematic)



Fly ash / water suspension observed with an ESEM 100 µm

Capillary shrinkage cracking



Publications

- Slowik, V., Schmidt, M., Fritzsch, R. (2008a). „Capillary pressure in fresh cement-based materials and identification of the air entry value." *Cement and Concrete Composites* 30(7), 557-565.
- Slowik, V., Schmidt, M., Neumann, A., Dorow, J. (2008b). "Early age cracking and its influence on the durability of concrete structures." In: Proceedings of the 8th International Conference on Creep, Shrinkage and Durability of Concrete and Concrete Structures - CONCREEP 8, September 30 - October 2, 2008, Ise-Shima, Japan, Vol. 1, 471-477.
- Slowik, V., Hübner, T., Schmidt, M., Villmann, B. (2009). "Simulation of capillary shrinkage cracking in cement-like materials." *Cement and Concrete Composites* 31(7), 461-469.
- Schmidt, M., Slowik, V. (2009). "Capillary shrinkage cracking and its prevention by controlled concrete curing." In: Proceedings of the 2nd International RILEM Workshop on Concrete Durability and Service Life Planning - ConcreteLife'09, September 7-9, 2009, Haifa, Israel, 23-30.
- Slowik, V., Schmidt, M. (2010). *Kapillare Schwindrissbildung in Beton.* Bauwerk Verlag, Berlin.
- Slowik, V., Ju, J.W. (2011). "Discrete modeling of plastic cement paste subjected to drying." *Cement & Concrete Composites* 33(9), 925–935.