Concrete/Construction Chemistry Laboratory

Empa, Swiss Federal Laboratories for Materials Science and Technology

Empa is an interdisciplinary research and services institution for material sciences and technology development within the ETH Domain, Switzerland, employing about 1000 people from 50 countries. Empa's research and development activities are oriented to meeting the requirements of industry and the needs of the society, and link together applications-oriented research and the practical implementation of new ideas, science and industry, and science and society. Empa employs about 1000 people from 50 countries.

The *Concrete/Construction Chemistry Laboratory* performs fundamental and application oriented research and development in the field of cementitious materials in order to improve their sustainability. By studying alternative binder systems and concrete of improved durability, we aim at reducing the energy consumption and the CO_2-emission.
A team of 9 senior scientists, several PhD students/PostDocs and 7 technicians is devoted to topics of durability, thermodynamic modeling of cement hydration and interaction phenomena, 3-D studies of microstructure and transport.

Partner project: Plastic Shrinkage Cracking in Concrete
From mechanisms to mitigation strategies

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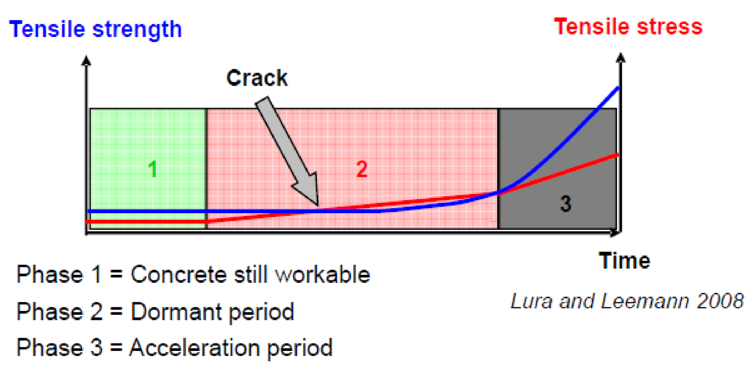
Introduction

Fresh concrete undergoes ***plastic shrinkage*** during the first few hours after placing, which may lead to ***cracks*** that jeopardize durability and reduce service life of concrete structures.


Plastic shrinkage cracking (photo: A. Leemann, Empa)

Plastic shrinkage is influenced by:
- concrete composition
- environment (RH, Temperature, wind speed)



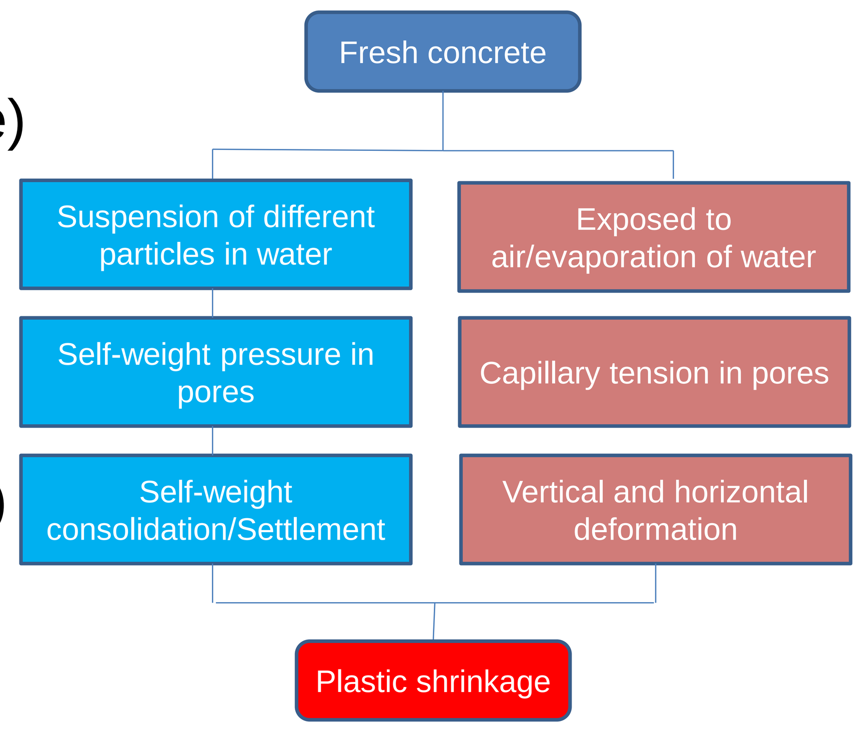
Driving forces

Mechanisms responsible :
- settlement (saturated phase)

$$\frac{\partial \varepsilon_{vol}}{\partial t} = -\nabla \cdot \left(\frac{\kappa}{\mu}\nabla p\right)$$

- Capillary pressure development (drying phase)

$$p_{cap} = -\frac{2\gamma \cdot \cos\vartheta}{r}$$

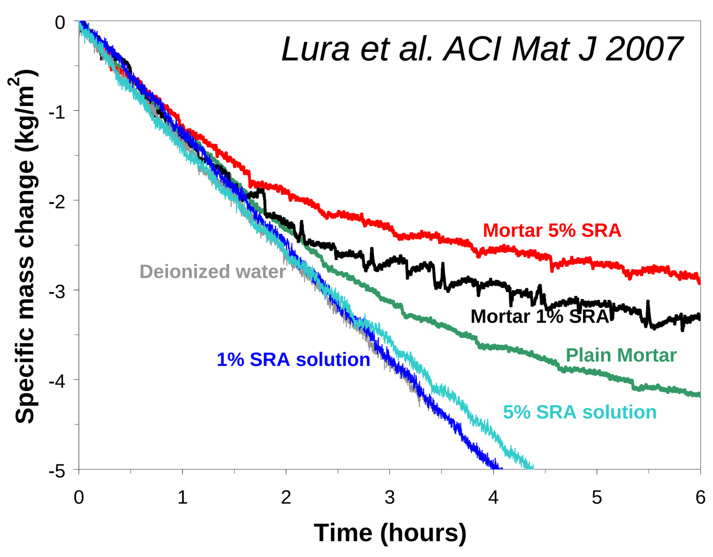


Mitigation strategies

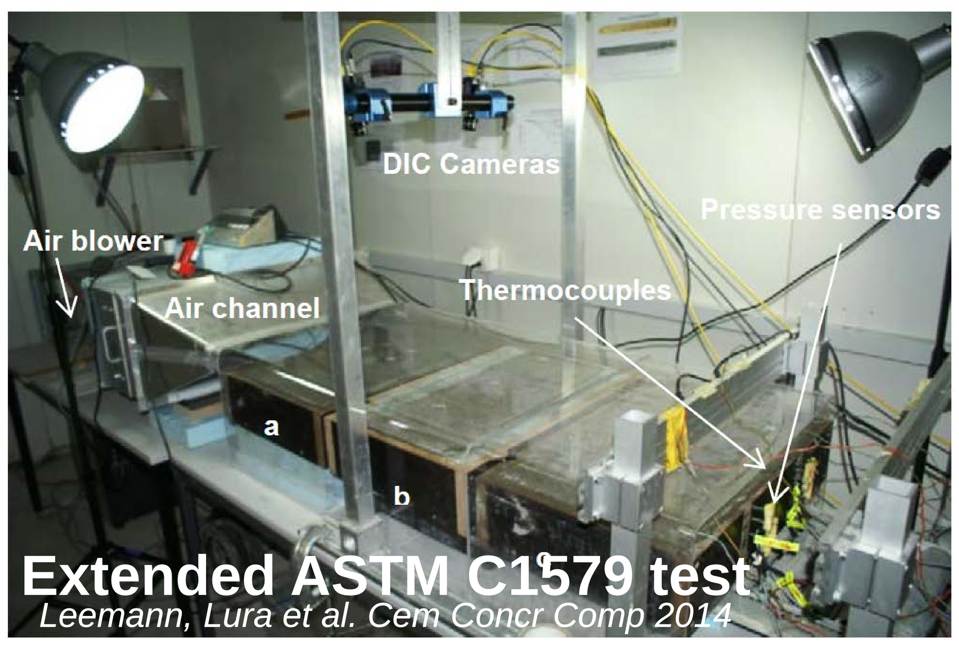
Understanding of fundamental mechanisms is necessary for effective crack mitigation

Active solutions (wetting, surface covering, etc.) against plastic shrinkage are not always applicable and are labor and cost expensive

Passive solutions are based on modifying concrete mic composition with (see corresponding driving forces):
- Viscosity Modifying Agents
- Shrinkage Reducing Admixtures
- Internal Curing (offset of drying)
- Fibers
- Using Coarser Particles
- Low cement paste content



Experiments

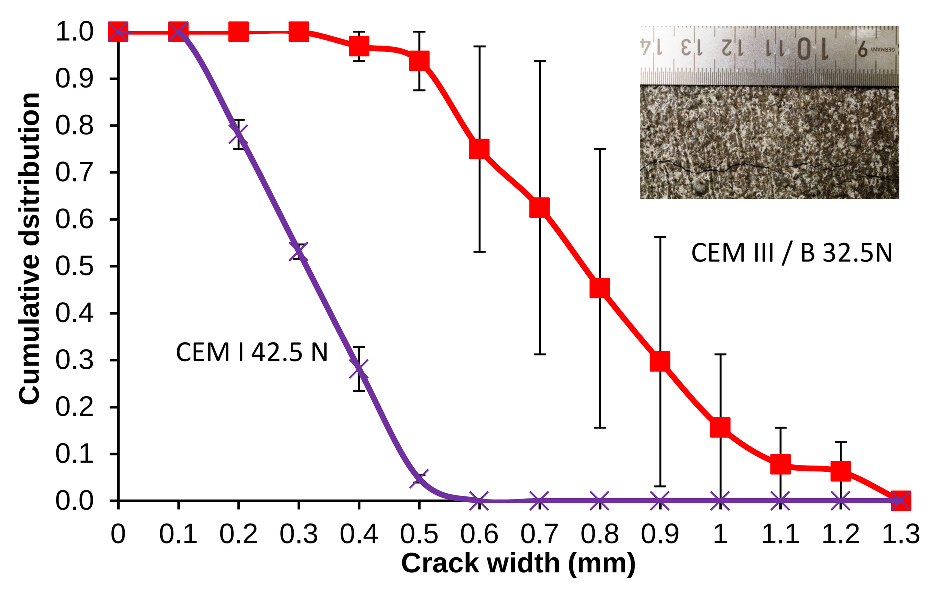


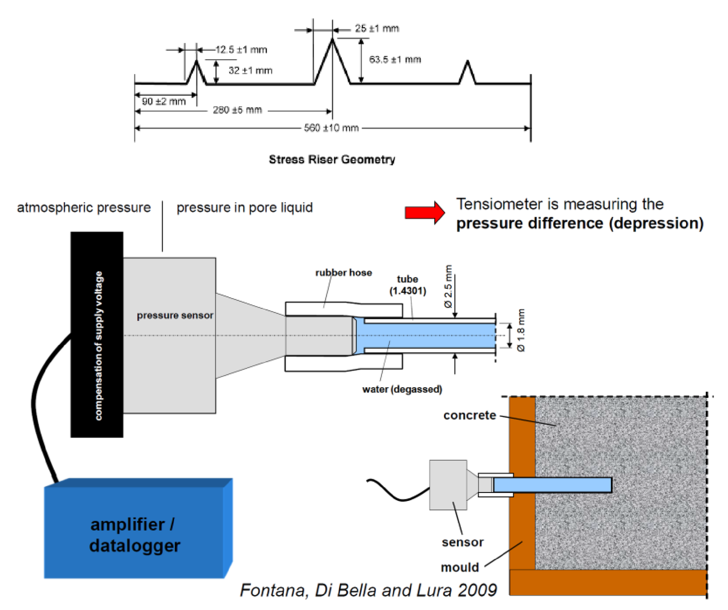
Basic data:

ASTM C1579: Crack width on stress riser

Complementary data:

1 - Pressure development
2 - Temperature Evolution
3 - 3D Deformations by DIC





Poromechanical modelling

Model equations

$$(\lambda+\mu)\frac{\partial \varepsilon_{vol}}{\partial x} + \mu\nabla^2 u_x - \frac{\partial p}{\partial x} = 0$$

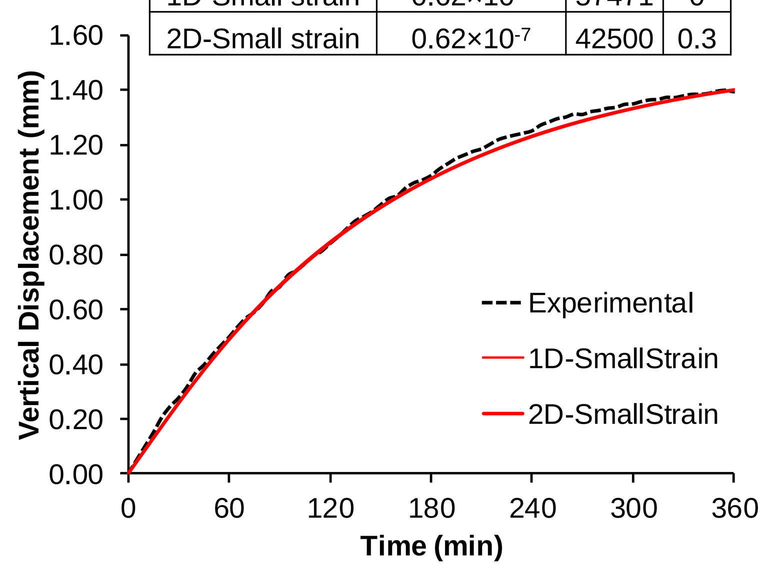
$$(\lambda+\mu)\frac{\partial \varepsilon_{vol}}{\partial y} + \mu\nabla^2 u_y + f_y - \frac{\partial p}{\partial y} = 0$$

Mechanical equilibrium (2D)

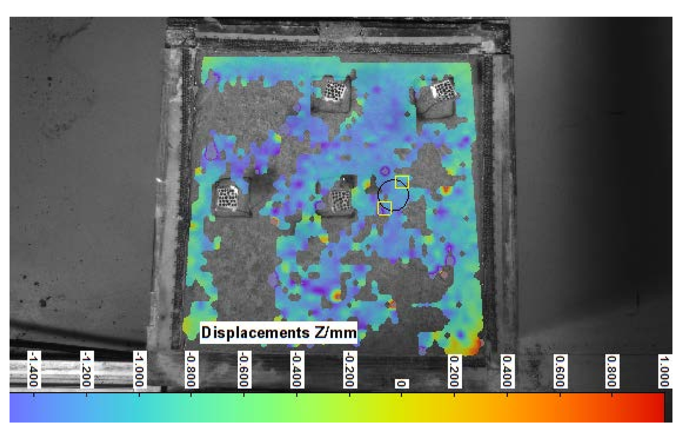
$$\frac{\partial w}{\partial t} = \nabla.\left(\frac{k}{\gamma_w}\nabla p\right)$$

Water mass conservation

Model	k_0(m/s)	E (Pa)	ν (-)
1D-Small strain	0.62×10^{-7}	57471	0
2D-Small strain	0.62×10^{-7}	42500	0.3



Measured (DIC) and modeled vertical displacement of inert mortar



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