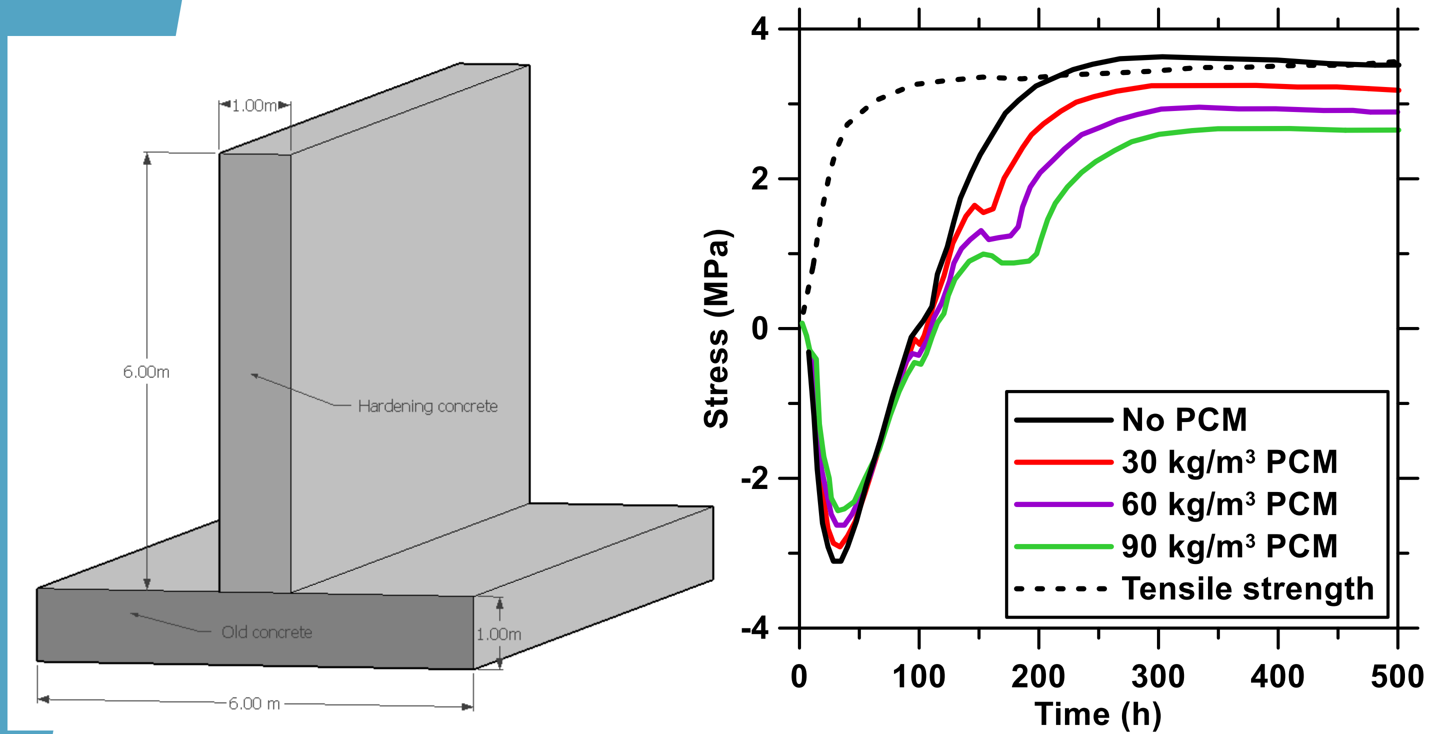

Numerical simulation of stress development in hydrating concretes showing the influence of PCMs in reducing the stresses and thus the cracking potential

Partnering institutions:

Arizona State University

Empa Materials Science and Technology

tecnalia Inspiring Business

UCLA

TU Delft Delft University of Technology

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ECLIPS

Enhancing Concrete Life in Infrastructure through Phase Change Systems

A multi-national collaboration

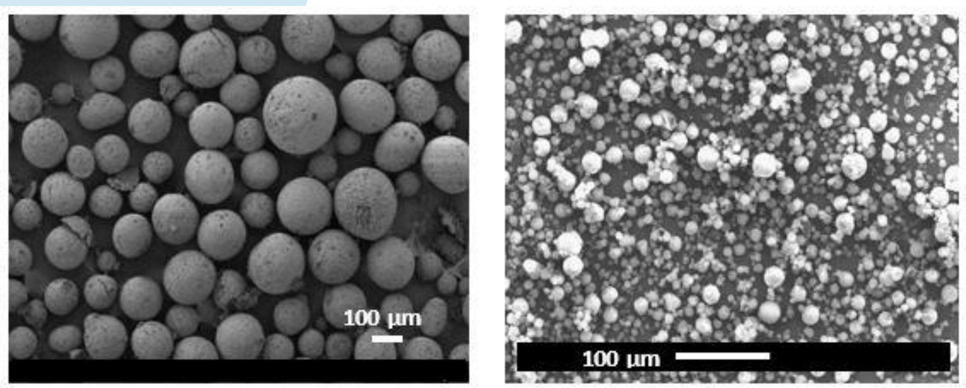
Made possible with funding provided by:

Infravation

An Infrastructure Innovation Programme

ECLIPS
Enhancing Concrete Life in Infrastructure through Phase Change Systems

ECLIPS is an acronym for ENHANCING CONCRETE LIFE IN INFRASTRUCTURE THROUGH PHASE-CHANGE SYSTEMS and is a multi-national project carried out by Arizona State University and University of California Los Angeles (in the US), Swiss Federal Laboratories for Materials Science (Empa) in Switzerland, Technical University-Delft in Netherlands, and TECNALIA in Spain, funded through the Infravation grant of the European Union. The main objectives are to limit temperature rise and the associated early-age deformations in concrete to reduce risk of thermal cracking, restrict the magnitude of deformations of restrained concrete elements over a long-time scale to limit damage due to thermal fatigue, and provide self-thawing/warming capabilities to concrete thereby rendering them more resistant to freeze-thaw related damage.

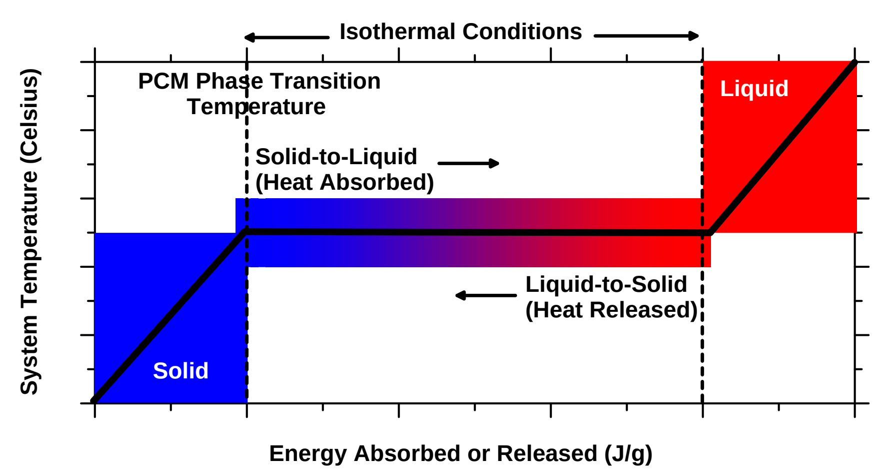


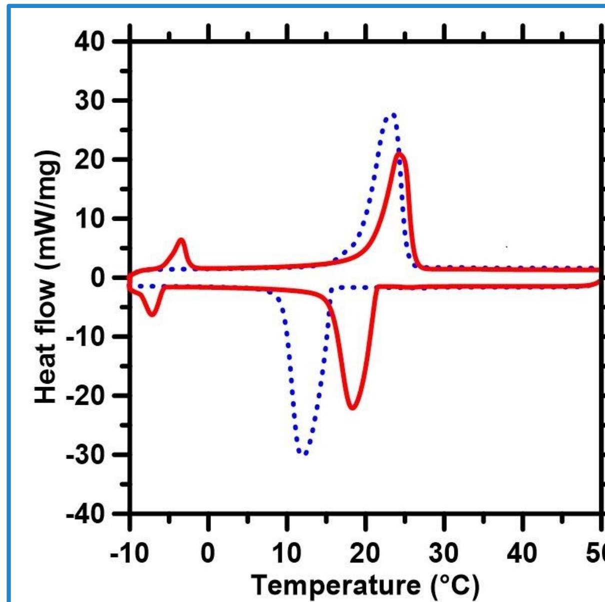
Phase change materials encapsulated in a polymeric shell. Two different sizes of PCMs are shown here, which results in distinctly different thermo-mechanical performance of concretes incorporating these PCMs.

Early and late age thermal cracking in reinforced concrete transportation structures and freeze-thaw related deterioration in concrete exposed to temperatures cycling around the freezing point of water are sources of concern to owners and managers of infrastructure assets around the world. The Infravation funding has brought together this multinational team to tackle this problem through a unique method by which phase change materials (PCMs) are incorporated into concretes.

PCMs can be used to store and dissipate energy in the form of heat. When subjected to an increase in temperature, they absorb heat until their phase transition temperature is reached, thus acting as latent energy storage media. They release heat when their temperature drops below their transition temperature. This heat absorption and release response helps to maintain a constant internal system temperature until the phase-transition is completed.

A schematic illustration of the temperature-heat energy response of a PCM and the associated processes. Energy absorption/release occurs under isothermal conditions.





Heat flow as a function of temperature for two different microencapsulated PCMs, indicating the phase change temperature range and the heat storage/release capacity of the PCMs. Desired phase transition temperatures can be achieved by changing the chemistry of the PCM. A number of phase change materials are commercially available.

The ability to incorporate PCMs into the concrete matrix has implications on enhancing concrete performance. The temperature-sensitive storage or release of thermal energy by PCMs provides concrete with the capability to regulate its internal thermal environment. This limits temperature rise at early ages and reduces the risk of thermal cracking, restricts the impact of diurnal/seasonal temperature variations and limits damage due to thermal fatigue, and provides self-thawing/warming capabilities to concrete.

An example of the capability of PCMs in reducing the propensity of cracking is shown with the help of numerical simulations of hydrating concrete in a massive wall-slab system. The use of PCMs reduce the stress in the hydrating concrete, thereby making it less susceptible to early age cracking. Reducing the propensity of early age cracking is vital towards ensuring long-term durability of reinforced concrete structures.

Three-dimensional view of the distribution of different sizes of PCM particles in the cement composite. 3D images extracted from x-ray microtomography and color thresholded for phase contrast.