Phase Change Material in concrete

The multifunctional material concrete as indoor-climate-keeper

Subject

Thermal mass activation of massive structural elements turns out to be more and more interesting as the demand for thermal comfort is continuously growing. Due to its high heat storage capacity, concrete is a suitable material for thermal activation. When now using Phase Change Materials (PCM) in combination, heat peaks can be buffered and latent stored heat will be released when temperatures fall under the solidification temperature of the applied PCM. As a result the indoor climate will be more constant.

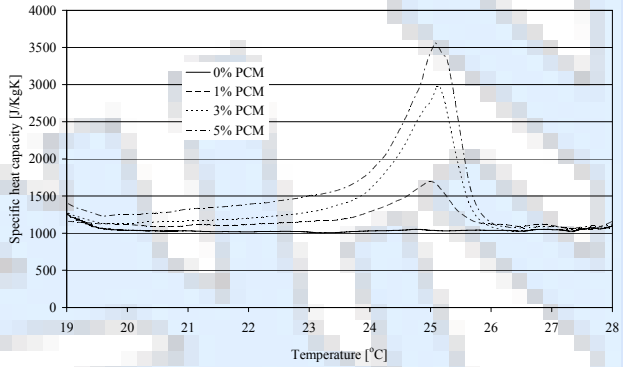

Figure 1: Specific heat capacity of concrete samples containing PCM in different amounts.

Goals

This research is focused on the possibilities of how to change the thermal properties of concrete while using PCM. Thereby the selection of suitable microencapsulated PCMs which can withstand the mixing process requires special attention.

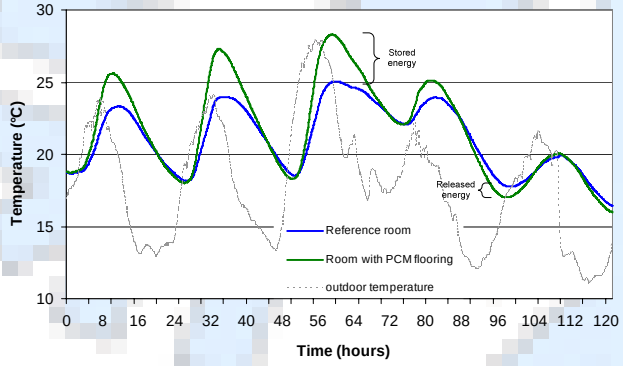

Figure 2: Floor surface temperature in two identical test rooms under the influence of the cyclic outside temperature, whereby one room is having a concrete floor and the other a PCM-containing concrete floor.

Expected Results

Depending on the amount and choice of PCM type (melting temperature) the indoor climate can be specifically controlled and stabilized. This would result in increased thermal comfort and notably decreased energy costs. For selected outside applications, such as in bridge decks, a reduction of the effective number of experienced frost/thaw events is expected. Furthermore, this research has shown that, similar to ice, PCM can effectively reduce the hydration peak temperature in massive curing concrete elements.

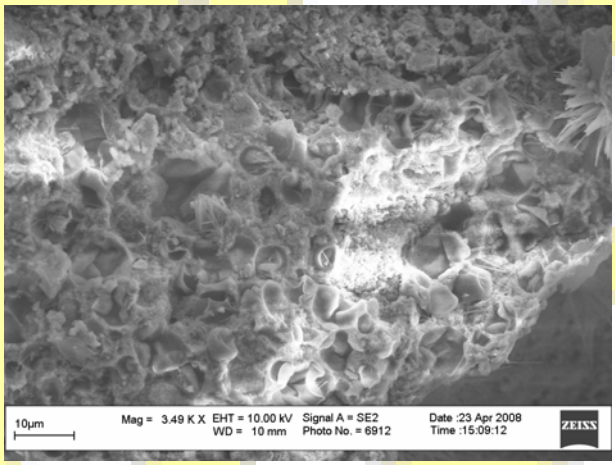

Figure 3: Microencapsulated PCM spheres (partly deformed/ destroyed) in the matrix of the tested concrete

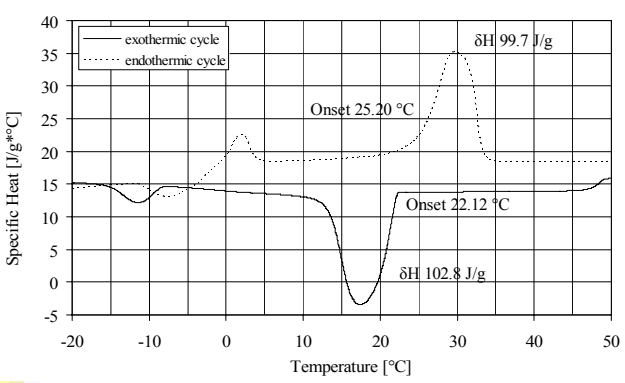

Figure 4: Plot of specific heat as a function of temperature for the heating (endothermic) and cooling (exothermic) cycles of the applied PCM

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Subject

Thermal mass activation of massive structural elements turns out to be more and more interesting as the demand for thermal comfort is continuously growing. Due to its high heat storage capacity, concrete is a suitable material for thermal activation. When now using Phase Change Materials (PCM) in combination, heat peaks can be buffered and latent stored heat will be released when temperatures fall under the solidification temperature of the applied PCM. As a result the indoor climate will be more constant.

Goals

This research is focused on the possibilities of how to change the thermal properties of concrete while using PCM. Thereby the selection of suitable microencapsulated PCMs which can withstand the mixing process requires special attention.

Research Question

- Influence of micro-encapsulated PCM on the concrete matrix
- Design of a setup for semi-adiabatic curing and monitoring of the hydration temperature development
- Development of a computational model for the prediction of PCM performance in concrete
- Research on more resilient PCM shells to withstand the shear stress during mixing
- Micro-analysis on the phase interfaces of PCM shell and matrix

Strategy

In the first instance material characterization, such as DSC measurements, on the PCM was carried out. After the characterization of the thermal properties, PCM was combined with a self-compacting mixture to a PCM concrete. Different mixtures with varying amounts of PCM are produced and analyzed regarding their thermal and mechanical properties. The analysis of these results should lead to durable concrete formulations with enhanced thermal properties.

Expected Results

Depending on the amount and choice of PCM type (melting temperature) the indoor climate can be specifically controlled and stabilized. This would result in increased thermal comfort and notably decreased energy costs. For selected outside applications, such as in bridge decks, a reduction of the effective number of experienced frost/thaw events is expected. Furthermore, this research has shown that, similar to ice, PCM can effectively reduce the hydration peak temperature in massive curing concrete elements.

Preferred Partners Applications / Sponsors

The research project is sponsored by the integrated project for SMEs (EU 6th FP): “Re-engineering of natural stone production chain through knowledge-based processes, eco innovation and new organizational paradigms” (Acronym: I-STONE) and the user/sponsor group “Cement-Immobilisates-Concrete research” at the University of Twente.

Prime Publication / Prototyping

- Hunger M., Entrop A.G., Mandilaras I., Brouwers H.J.H., Founti M. (2008), The behavior of a micro-encapsulated Phase Change Material in concrete, submitted to Cement and Concrete Research, CEMCON-D-08-00579
- Hunger M., Brouwers H.J.H., Flow analysis of water–powder mixtures: Application to specific surface area and shape factor, Cement Concrete Comp (2008), doi:10.1016/j.cemconcomp.2008.09.010, accepted
- Hunger M., Brouwers H.J.H. (2008) Improved microstructure by optimized water requirements, Proceedings of 1st International Conference on Microstructure related Durability of Cementitious Composites, October 13-15, Nanjing, China, 51-60, Eds. W. Sun, K. van Breugel, C. Miao, G. Ye and H. Chen.
- Hunger M., Brouwers H.J.H., Ballari M. (2008) Photocatalytic degradation ability of cementitious materials: A modeling approach, Proceedings of 1st International Conference on Microstructure related Durability of Cementitious Composites, October 13-15, Nanjing, China, 1103-1112, Eds. W. Sun, K. van Breugel, C. Miao, G. Ye and H. Chen.
- Hunger M., Brouwers H. J. H. (2008), Concrete – for a sustainable future, Hedgepensions Review 2008(2):18-19.
- M. Hunger, G. Hüsken and H.J.H. Brouwers (2008), Photocatalysis applied to concrete products - Part 2: Principles and test procedure, ZKG 61(10):76-84.

Research Period

February 2005 - February 2009