Development of thermally adaptive ECC panels for passive building envelope heat storage

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Introduction

Indoor climate control accounts for over 40% of the energy used in US residential buildings[1], much of which is ultimately lost via the building envelope. To provide passive heat storage in building envelopes, materials exhibiting a phase-change within building operating temperature can be incorporated into the façade material. This provides an effective thermal capacitance peak at the PCM melting temperature.

This project assesses the viability of incorporating a paraffin phase change material (PCM) with a melting point of 23°C into an Engineered Cementitious Composite (ECC). ECC allows formation of thin panels—a favorable geometry for building façades. Inclusion of 3% PCM by mass provided a 40% increase in ECC heat capacity at 23°C while maintaining a 28 MPa compressive strength, and a 4% tensile strain capacity, on average.

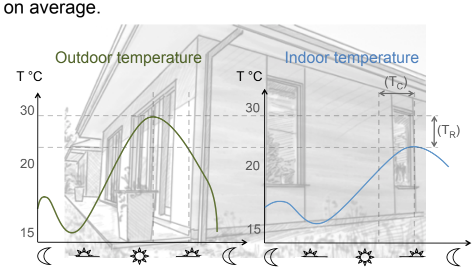


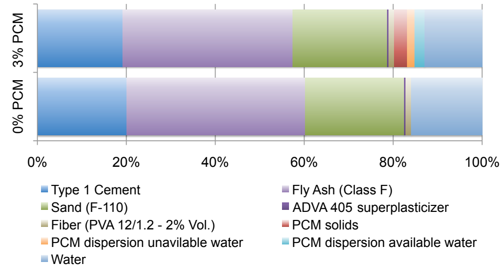
Figure 1. Modeled differences in an outdoor and indoor temperature profile for a building with an envelope of significant thermal capacitance and resistance, such as PCM-ECC. The temperature difference denoted (T_C) is largely caused by the thermal capacitance of the envelope material, and that denoted (T_R) is most related to the thermal resistance.

Approach

In this project, the PCM content of PCM-ECC mixes was varied to produce a number of potential mix designs. Increasing the PCM content improves the hypothesized peak in thermal capacitance. Since ECC achieves its unique compressive and tensile strength by balancing micromechanical parameters such as matrix toughness and fiber-matrix bond, we seek the mix design that provides the greatest benefit to thermal properties while limiting detriment to mechanical properties. Thus far, the mix design that has best achieved this balance is 3% PCM by mass and utilizes a 2:1 fly ash to cement ratio.

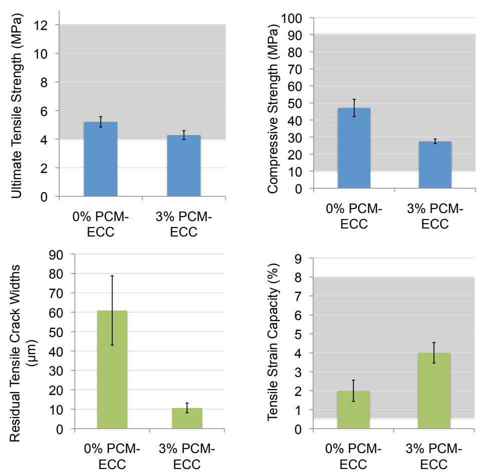
Materials and Methods

The PCM used in this study was the BASF DS 5007x dispersion of paraffin wax microencapsulated in polymethyl methacrylate, each particle near 5 microns in diameter. A comparison of the control mix proportions and those of 3% PCM-ECC are provided below.



Results

The 28-day tensile and compressive behavior were determined using dogbone specimens and 2-inch cubes.



Figures 2-5. Comparison of mechanical properties. PCM caused a drop in ultimate strength but improved tensile strain capacity and reduced residual crack widths. Grey area depicts attainable range with ECC.[2]

The 3% PCM-ECC mix yielded the desired effect of increasing thermal capacitance (fig. 7-8) at 23 °C. This causes a resistance to temperature change in the material near 23°C, close to indoor comfort temperature. The thermal resistance also rose with PCM inclusion.

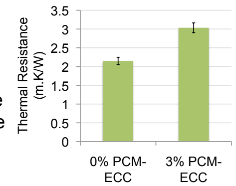
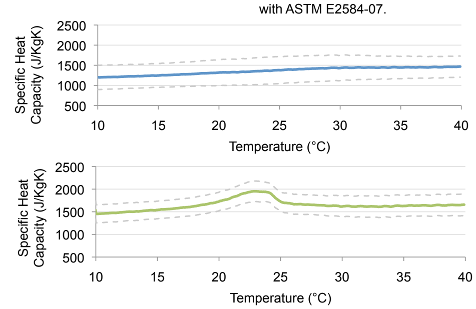


Figure 6. Effect of PCM on thermal resistance, determined in accordance with ASTM E2584-07.



Figures 7-8. Comparison of specific heat capacity profiles of 0% and 3% PCM-ECC. Determined in accordance with ASTM E1269-11. Dotted lines indicate 95% CI.

Conclusions

The results suggest that PCM can be incorporated into ECC to produce a mechanically viable, thermally responsive composite, as has been achieved with PCM addition to conventional concrete.[3] Future work includes continued thermal modeling of PCM-ECC components within buildings and a life cycle analysis to provide design feedback in the development of the material.

Acknowledgements

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References

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3. Hunger, M., Entrop, A.G., Mandilaras, I., Brouwers, H.J.H., Founti, M., " The behavior of self-compacting concrete containing micro-encapsulated Phase Change Materials," Cement and Concrete Composites, Vol. 31, 2009, pp.731-743.

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