Hygrothermal Investigation Of Facade Panel Connections Using A Coupled Heat And Moisture Transport

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Abstract

Innovative materials, such as ultra-high-performance fiber-reinforced-concrete (UHP-FRC), provide an opportunity to reduce building energy loss by developing energy-efficient facade panels. However, investigating the thermal performance of these façade systems without considering the effect of panel connections could be misleading. The oversimplification in representing the hygroscopic behavior of façade systems can lead to either overestimation or underestimation in the energy performance of building façade systems.

In this paper, the effect of panel connections on the hygrothermal performance of façade panels was investigated using a coupled three-dimensional heat and moisture transport in the transient state. Heat and moisture transfer processes in porous construction materials were formulated as a system of two partial differential equations, which derived by imposing the equilibrium balance of mass and energy within a representative elementary volume, using COMSOL Multiphysics® Two-panel corner connections proposed by Precast/Prestressed Concrete Institute (PCI) were selected to illustrate the effect of panel connections on the hygrothermal performance of innovative UHP-FRC facade panels. Then, COMSOL Multiphysics® was used to solve the numerical models. The sensitivity of the model was also investigated concerning UHP-FRC's thermal conductivity and internal relative humidity to observe the influence of material-specific input parameters on the heat and moisture transfer results.

The results of heat transfer analysis showed that steel connections could significantly reduce the thermal resistivity of façade panels by converging heat fluxes and acting as thermal bridges within façade panels. Also, the results of moisture transfer showed that air gaps at the corner had higher moisture flux compared to the other layers in the models. The results show the significant importance of connections in the energy performance analysis of façade systems. They also highlight the importance of devising novel connection designs and materials that consider the transient, coupled heat and moisture transfer in the connections to effectively exploit the potential opportunities provided by innovative materials to improve building energy efficiency.