Hygrothermal Investigation of Facade Panel Connections Using a Transient Coupled Heat and Moisture Transport Model

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INTRODUCTION: Wall framings and connections are examples of components that may act as thermal bridging in a facade system accelerating heat transfer between indoor and outdoor environments resulting in heat loss in the buildings. Similarly, vapor condensation may occur within building facade systems and their connections [1], which can decrease the service life of the system by degrading materials and increase the risk of mold growth within facade systems. Therefore, it is essential to investigate the heat and moisture transfer within the facade connections. In this study, 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.

COMPUTATIONAL METHODS: A coupled three-dimensional moisture and heat transfer (HAM) was modeled in the transient state and solved simultaneously in COMSOL Multiphysics®.

GOVERNING EQUATIONS:

Moisture Transfer

$$\frac{\partial w}{\partial \varphi}\frac{\partial \varphi}{\partial t} = \nabla \cdot (K_l \nabla P_C) + \nabla \cdot \delta_P (\frac{P_v}{P_l} \nabla P_C + (\varphi \frac{\partial P_{sat}}{\partial T} - \frac{P_v ln\varphi}{T}) \nabla T) - v \cdot \nabla \rho_v \quad (1)$$

Heat Transfer

$$(\rho C_p)_{eff} (\frac{\partial T}{\partial t}) = \nabla \cdot (k_{eff} . \nabla T) + L_v \nabla \cdot (\delta_P \nabla p_V) - v \cdot (L_v \nabla p_V + \rho_a C_{P,a} \nabla T) \quad (2)$$

CASE STUDY: Two panel corner connections proposed by Precast/Prestressed Concrete Institute (PCI) [2] were selected as examples to illustrate the effect of panel connections on the hygrothermal performance of innovative ultra-high-performance fiber-reinforced-concrete (UHP-FRC) facade panels [3] (Figure 1)

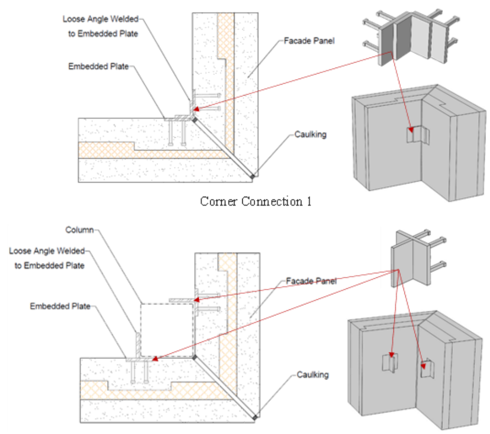

Figure 1. Cross-section and 3D views of the UHP-FRC corner connections

Parameter	Unit	Interior	Exterior
θ	K (°C)	292.15 K (19°C)	T(t)
φ	%	50	φ(t)
α	W/m2K	5	25
β	s/m	8e-8	25e-8

Table 1: Boundary conditions

RESULTS: Temperature distribution within the cross-section of both connections (Figure 2) shows that the insulation layers in both connection types could regulate the temperature distribution within the cross-sections.

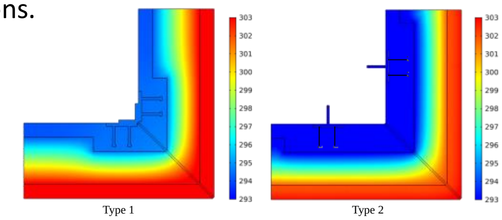

Figure 2: Temperature distribution within the cross-section of both panel corner connections on July 31st

Heat flux magnitude within the cross-section of both corner connections (Figure 3) at the location of steel connectors shows how the steel connectors reduces the thermal resistivity within facade panels by converging heat fluxes and acting as thermal bridges. However, magnitude of heat flux within the steel connector in Type 1 connection is much higher than of those in the Type 2 connection.

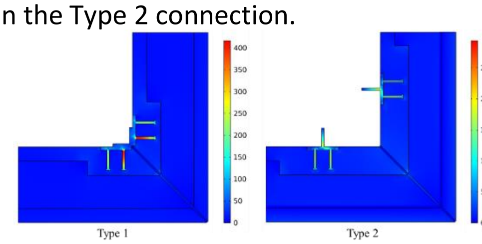

Figure 3: Heat flux magnitude within the cross-section of both panel corner connections on July 31st

The results of moisture transfer with both connections (Figure 4) also showed that the relative humidity passes the threshold (i.e., 85%) at 294.9 K (21.75°C) in Type 1 connection, but not Type 2 connection, and reaches to critical level of 92.5% indicating a high risk of mold growth at the corner of the connection.

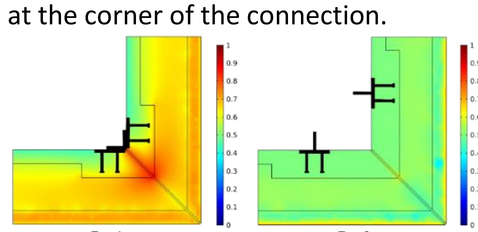

Figure 4: Relative humidity within the cross-section of both panel corner connections on July 31st

CONCLUSIONS: The results presented in this study showed the significant importance of panel connections in the energy performance analysis of facade systems.

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