SCHOOL OF CONSTRUCTION AND THE ENVIRONMENT
Building Science Graduate Program, BCIT

Transient Three-Dimensional Heat, Air and Moisture Transfer in Multi-Layered Building Envelope Details

Acknowledgements

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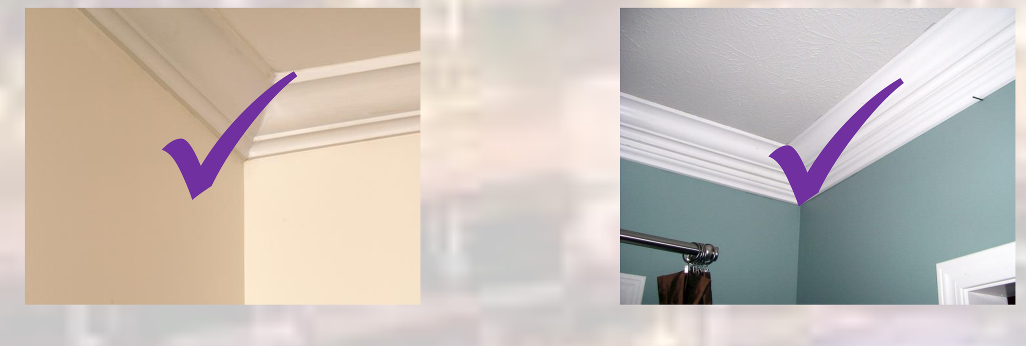
Introduction

The currently available one and two-dimensional models for Hygrothermal Performance of building envelope details are not capable of assessing variations on energy consumption and functional performance of three-dimensional building envelope assemblies. In fact, in three-dimensional building envelope details, significant heat loss and moisture problems are taking place. Therefore, building industry needs to adopt designs based on three-dimensional models which can take into account complicated mechanisms such as temperature gradient, relative humidity gradient, and air pressure gradient in building envelope assemblies.

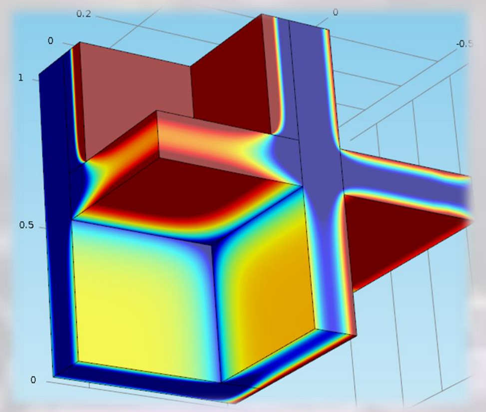
Objective

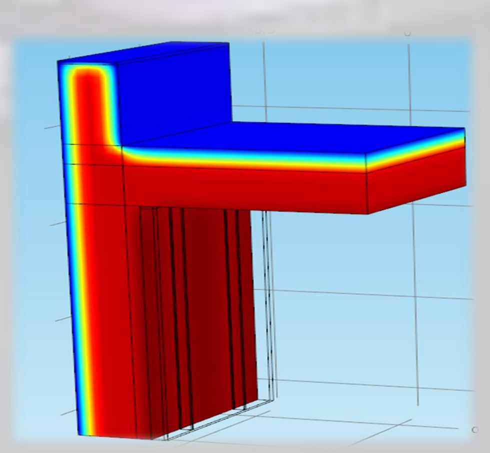
Main focus of this study is to develop a model that can predict the complicated heat, air and moisture (HAM) pattern in the three-dimensional building envelope details, and develop a relationship between the 3D and 1D/2D HAM models results.

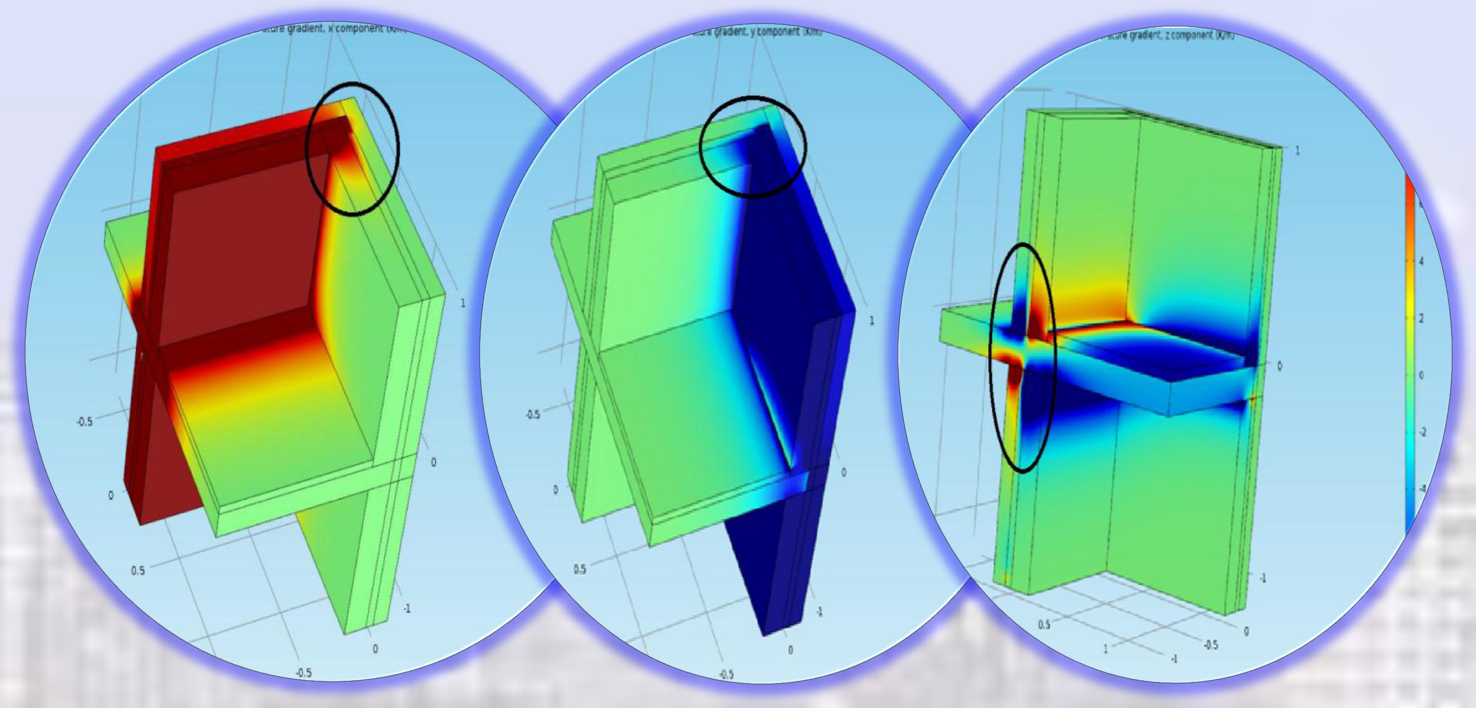


Methodology

Validated HAMFit 2D [Tariku, 2008] will be upgraded into three-dimensional, which will be used as a numerical model to simulate complicated building envelope assemblies. The 3D HAM model will be validated with experimental results. Relationship between 3D HAM simulation results and 1D/2D model results will be developed.



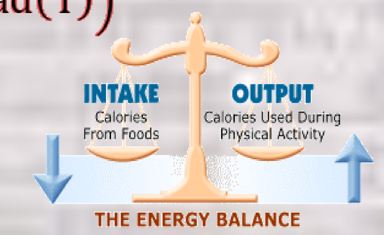




There are two main equations that were considered while modeling the Building Envelope details, which are **Conservation of Mass** and **Energy Balance**.

Energy Balance

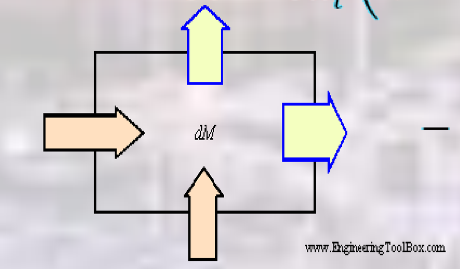
$$\rho_m C_{P_{eff}} \frac{\partial T}{\partial t} + \rho_a (C_{P_a} + \omega C_{P_v}) \mathrm{div}(VT) + \mathrm{div}\left(-\lambda_{eff} \mathrm{grad}(T)\right) = \dot{m}_c h_{fg} + \dot{m}_c T (C_{P_v} - C_{P_l}) + \dot{Q}$$



Three-dimensional Model

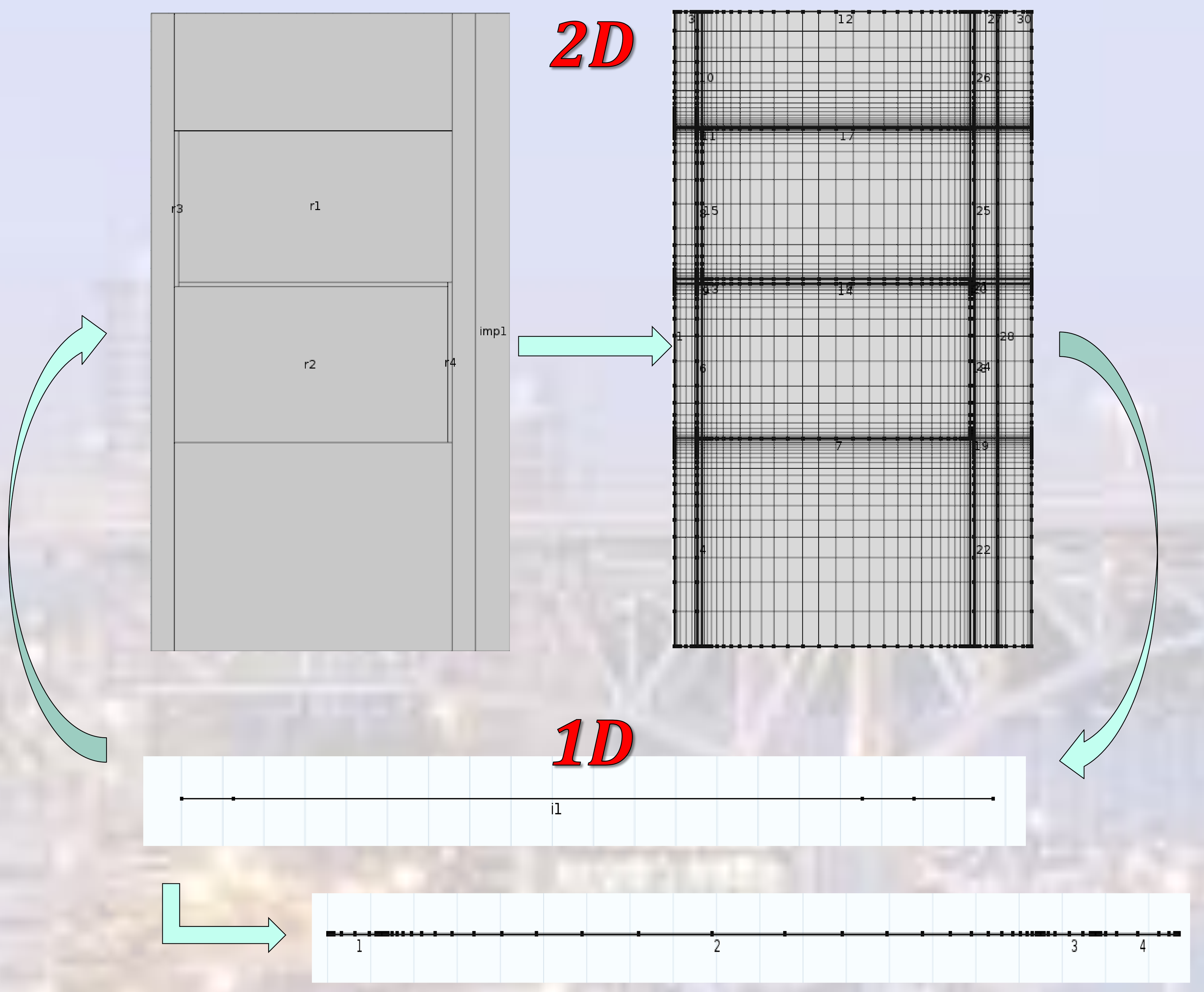
Mass Balance

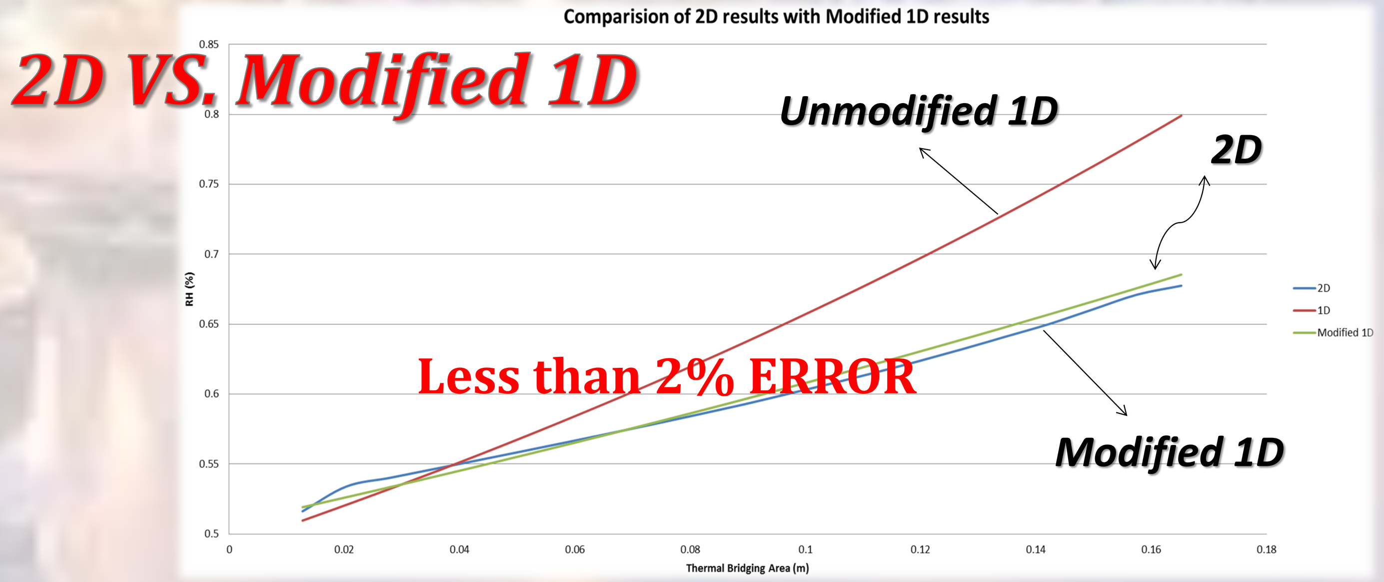
$$\Theta \frac{\partial \varphi}{\partial t} = \frac{\partial}{\partial x_i}\left(\left(\delta_v \hat{P} + D_l \frac{\rho_w R}{M}\frac{T}{\varphi}\right)\frac{\partial \varphi}{\partial x_i} + \left(\delta_v \varphi \frac{\partial \hat{P}}{\partial T} + D_l \frac{\rho_w R}{M}\ln(\varphi)\right)\frac{\partial T}{\partial x_i}\right) - \frac{\partial}{\partial x_i}\left(D_l \rho_w \vec{g} + \rho_a V (C_c \hat{P} \cdot \varphi)\right)$$



Three-Dimensional Modeling is Time Consuming

Several sources have provided thermal correction factors regarding common thermal bridging areas; however, moisture correction factors have not been developed yet. In this study, moisture coefficient factors will be developed, which can be used to convert 3D models into **2D** and even **1D** to solve the time of simulation issue.





Expected Findings

Its expected that the final results reveal the unpredicted hygrothermal behaviours of 3D building envelope details. Corresponding coefficients will be provided to convert time consuming three-dimensional model into 2D and even 1D. Error value will be reduced into less than 2%. This coefficients can be used by building envelope designers to improve the energy and moisture performances of more complicated building envelope assemblies that have less risk of moisture damage.

Time dependent
Heat and Moisture