Hygrothermal Analysis: From Intuition to Calculations to Simulation (DRAFT)

Patrick Huelman, University of Minnesota – Building Science & Technology

3/1/16

Step 1. Establish Context, Perspective, & Principles

Supporting Materials: *BSI-039 Five Things – Lstiburek, ASHRAE Handbook*

a. Opening Lab Discussion built on the "Five Fundamental Changes"

b. Building Science Primer

- Introduction to Heat, Air, and Moisture (HAM)
- Basics of Moisture Transport (Liquid and Vapor)
- Functions of the enclosure, environmental separation, and control layers

c. Students select a common wall system

d. Quick Check: Can moisture susceptible materials get wet (by water or condensation)?
If they get wet, can they dry (primarily by vapor diffusion)?

Step 2. Heat Transfer & Thermal Profiles

Supporting Materials*: ASHRAE Handbook, High Performance Enclosures – Straube*

a. Review fundamentals of heat transfer in buildings

b. Develop a temperature profile through the assembly layers (both cavity & framing)

- must select boundary conditions (indoor & outdoor)
  - indoor temperature and relative humidity
  - winter and summer exterior design temperatures are probably too severe
  - monthly average exterior temperature is a reasonable approach
  - depending on material storage capacity a longer average might be used
- simplest approach is to guess the most likely condensation plane and solve for the temperature at that location only
- more detailed approach is to calculate the temperature at each interface based on the temperature drop across each material

c. Compare surface temperature(s) to interior or exterior dewpoint temperatures

- recognize limitation: it assumes the indoor/outdoor air can reach that surface
- ignores liquid transport, phase change, and material storage

Step 3. Psychrometrics & Vapor Pressure Profiles

Support Materials: *Understanding Psychrometrics – Gatley, Water in Buildings – Rose*

a. Review principles and terminology

b. How to use the psychrometric tables, charts, and equations

c. Concept of vapor pressure profile through the assembly layers (cavity and framing)

- use temperature profile through layers above to calculate a saturated vapor pressure condition for each interface
- find the vapor pressure drop across each layer to get calculated vapor pressure
- compare calculated to saturated vapor pressures to determine %RH at each surface
- if greater than 100%, reset that surface to the saturated pressure and recalculate

c. Is there a condensation potential (100% RH) at any surface?

- recognize limitation: this assumes there is no air leakage
- ignores liquid transport, phase change, and material storage

Step 4. Materials Storage & Hygrothermal Modeling

Supporting Materials: *Building Science for Building Enclosures - Straube & Burnett*
Software: *WUFI – ORNL/Fraunhofer IBP*

a. Review states of moisture, material storage, sorption isotherms, etc.

b. Now calculate the vapor flow to and away from the surface of concern; the difference will be net accumulation; compare accumulation potential over time to material storage capacity

c. Move to dynamic hygrothermal simulation with WUFI (or other similar programs)

- recognize limitations: 1-D analysis reflects diffusion, water transport, and material storage; however, without using moisture sources/sinks the flow of air and water between layers is ignored

Step 5: Wrap-up & Analysis

Supporting Material: *BSI-001 The Perfect Wall – Lstiburek*

a. Review strengths and limitations of each approach

b. Compare and contrast results from each approach

c. Step away from the edge – the beauty of exterior insulation!

Key Resources:

ASHRAE Handbook of Fundamentals. ASHRAE. 2013
Building Science for Building Enclosures. John Straube & Eric Burnett. 2005
B[i]SI Series. Building Science Corporation. Available at buildingscience.com
Builder Guides. Joseph Lstiburek. Building Science Press. Available at buildingscience.com
High Performance Enclosures. John Straube. Building Science Press, 2012
Understanding Psychrometrics. Donald Gatley. ASHRAE. 2004
Water in Buildings. William Rose. Wiley Press. 2005
WUFI Pro 5.3 Education. Oak Ridge National Laboratory/Fraunhofer IBP. 2015

Contact Information

Patrick H. Huelman, University of Minnesota
203 Kaufert Lab, 2004 Folwell Avenue
St. Paul, MN 55108
612-624-1286
phuelman@umn.edu

[i] The hygrothermal analysis steps are used in the U MN advanced building science class and also were used for the US DOE Race to Zero Envelope Durability analysis. In general, Step 1 and introductory material for Steps 2 and 3 can be incorporated into such traditional courses as Materials & Methods (Construction Technology) and Environmental Systems.