Adding Building Science Education to Professional Programs at University of Waterloo

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Associate Professor, University of Waterloo
University of Waterloo

• Civil Engineering
  – Dedicated elective 4\textsuperscript{th} year course since 1983
  – Additional Graduate courses since 2000
• School of Architecture
  – 2\textsuperscript{nd} year Architecture \textit{core}
  – Graduate school \textit{elective}
• Mechanical Engineering
  – Students can take course in CE
Adding Building Science Knowledge

• **Not** creating Building Scientists in UG
  – Create awareness and some simple skills
• A few Building Scientists as grad students annually
• Exposing 175-200 students per year to 39 contact hours of building science
  – Awareness of building science
  – Some skills, some knowledge
What building science?

• Engineers
  – Calculate/Predict heat gain, loss, surface temperatures, radiative effects, condensation, thermal bridging, airflow, stack effect

• Architects
  – Understand thermal bridging, solar control
  – Select insulation, rain control, air barriers, cladding, vapor control
  – Calculate R-values, simple heat loss/gain
Teaching Resources/Methods

- Perfect Wall and Control layers are useful teaching tools ....

Figure 1: Diagram of the “Perfect” Wall showing ideal sequence of assembly layers
(From John Straube, High Performance Enclosures, Building Science Press)
Coordinate Function of Materials/Layers with Construction Technology Courses

- Framed wall (1960s):
  - Support Distribution
  - Fire Control
  - Air Control
  - Vapor Control
  - Thermal Control
  - Water Control

- Precast (2000s):
  - Support Distribution
  - Fire Control
  - Air Control
  - Vapor Control
  - Thermal Control
  - Water Control

- Modern Masonry (1980s):
  - Support Distribution
  - Fire Control
  - Air Control
  - Thermal Control

- Hybrid Framed wall:
  - Support Distribution
  - Fire Control
  - Air Control

- Exterior Insulated Framed:
  - Support Distribution
  - Fire Control
  - Air Control

- Improved 1960s:
  - Support Distribution
  - Fire Control
  - Air Control

- Historic Loadbearing:
  - Support Rain Control
  - Thermal Control
  - Vapor Control

- Retrofit Loadbearing:
  - Support Rain Control
  - Thermal Control
  - Vapor Control

Legend:
- Support
- Fire Control
- Air Control
- Thermal Control
- Vapor Control
- Water Control
- Distribution
- Airflow control
Realistic drawings for teaching construction technology
Simpler Psychrometric Chart for Building Science applications
Multiple Units

<table>
<thead>
<tr>
<th>C</th>
<th>F</th>
<th>Pa</th>
<th>g/kg</th>
<th>gr/lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>-40</td>
<td>-40</td>
<td>13</td>
<td>0.079</td>
<td>0.553</td>
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<tr>
<td>-20</td>
<td>-4</td>
<td>103</td>
<td>0.638</td>
<td>4.47</td>
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<tr>
<td>0</td>
<td>32</td>
<td>611</td>
<td>3.79</td>
<td>26.5</td>
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<tr>
<td>20</td>
<td>68</td>
<td>2340</td>
<td>14.8</td>
<td>104</td>
</tr>
<tr>
<td>40</td>
<td>104</td>
<td>7380</td>
<td>49.1</td>
<td>344</td>
</tr>
<tr>
<td>60</td>
<td>140</td>
<td>19900</td>
<td>154</td>
<td>1080</td>
</tr>
<tr>
<td>80</td>
<td>176</td>
<td>47400</td>
<td>553</td>
<td>3870</td>
</tr>
</tbody>
</table>
Worked Quantitative Examples

Practical example:

- Calculate the total thermal resistance, $R$, and overall heat transfer coefficient ($U$) of the wall shown below. Use conductivity values from tabulated values.

Figure 5.12: Example Building Enclosure for Heat Flow
Hand/Spreadsheet Calculations

Answer:

<table>
<thead>
<tr>
<th>Layer material</th>
<th>Conductivity</th>
<th>Thickness</th>
<th>Conductance</th>
<th>Resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interior film\textsuperscript{1}</td>
<td>N.A.</td>
<td>N.A.</td>
<td>8.3</td>
<td>0.120</td>
</tr>
<tr>
<td>Concrete</td>
<td>1.8</td>
<td>0.150</td>
<td>12</td>
<td>0.083</td>
</tr>
<tr>
<td>Type 4 XPS</td>
<td>0.029</td>
<td>0.075</td>
<td>0.39</td>
<td>2.56</td>
</tr>
<tr>
<td>Airspace\textsuperscript{2}</td>
<td>N.A.</td>
<td>0.025</td>
<td>N.A.</td>
<td>0.17</td>
</tr>
<tr>
<td>Brick</td>
<td>1.3</td>
<td>0.090</td>
<td>14.4</td>
<td>0.069</td>
</tr>
<tr>
<td>Exterior film\textsuperscript{1}</td>
<td>N.A.</td>
<td>N.A.</td>
<td>34</td>
<td>0.029</td>
</tr>
</tbody>
</table>

Computer apps and/or Websites etc. Only after demonstrated Knowledge and competence

\textsuperscript{Notes}

1. Since the interior and exterior films are fictitious, they do not have a thickness, and so no conductivity. Hence, tables typically contain only conductances or resistances for the layer. These values can be quite variable but, as can be seen, the effect of the value of the film resistance on the total resistance of a wall is small if the wall is a modern, insulated assembly.

2. The flow of heat through an airspace is complicated by convection (airflows) and radiation, so tabulated values of conductance are used instead. Like surface films, these values are variable but are not important to accuracy in the calculation in most modern walls. Interpolation and iteration should be used.
Proper vapor diffusion analysis – usually only in Engineering

<table>
<thead>
<tr>
<th>Layer Material</th>
<th>Mᵢ (ng/Pa·s·m²)</th>
<th>Rᵥ,i (Pa·s·m²/ng)</th>
<th>T (°C)</th>
<th>Pᵥ,sat (Pa)</th>
<th>Pᵥ (Pa)</th>
<th>RH (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interior</td>
<td></td>
<td></td>
<td>21.0</td>
<td>2497</td>
<td>1249</td>
<td>50.</td>
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<tr>
<td>Interior film</td>
<td>15000</td>
<td>0.000067</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Concrete</td>
<td>17.3</td>
<td>0.058</td>
<td>19.6</td>
<td>2287</td>
<td>1248</td>
<td>55.</td>
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<tr>
<td>Type 4 XPS</td>
<td>26.7</td>
<td>0.038</td>
<td>18.6</td>
<td>2155</td>
<td>631</td>
<td>29.</td>
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<tr>
<td>Air space</td>
<td>7200.</td>
<td>0.00014</td>
<td>-10.9</td>
<td>268</td>
<td>230</td>
<td>86.</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>-12.9</td>
<td>229</td>
<td>229</td>
<td>100.</td>
</tr>
<tr>
<td></td>
<td>ΣRᵥ</td>
<td>0.0954</td>
<td></td>
<td>ΣΔPᵥ</td>
<td>1020</td>
<td></td>
</tr>
<tr>
<td>Flow to:</td>
<td>ΔP/ΣRᵥ</td>
<td>10689.</td>
<td>129.</td>
<td>229</td>
<td>229</td>
<td>100.</td>
</tr>
<tr>
<td>Brick</td>
<td>111.1</td>
<td>0.0090</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exterior film</td>
<td>75000.</td>
<td>0.000013</td>
<td>-13.7</td>
<td>215</td>
<td>167</td>
<td>78.</td>
</tr>
<tr>
<td>Exterior</td>
<td></td>
<td></td>
<td>-14.0</td>
<td>209</td>
<td>167</td>
<td>80.</td>
</tr>
<tr>
<td></td>
<td>ΣRᵥ</td>
<td>0.0090</td>
<td></td>
<td>ΣΔPᵥ</td>
<td>62</td>
<td></td>
</tr>
<tr>
<td>Flow away:</td>
<td>ΔP/ΣRᵥ</td>
<td>6862.</td>
<td>3827.</td>
<td>ng/s·m²</td>
<td>ng/s·m²</td>
<td></td>
</tr>
<tr>
<td>Net Accumulation:</td>
<td></td>
<td>3827.</td>
<td></td>
<td>ng/s·m²</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Architecture Students

• Requires far less quantitative analysis skills
• Understanding of physical laws, available materials, design strategies
• **Focus**: Selecting layers, and designing details

• Key is interaction with studio and communication via drawings
Hand Drawings

- Roof ballast
- Extruded polystyrene insulation
- Drainage mat
- Fully adhered root membrane
- Plywood
- Metal deck
- GWSJ
- Suspended Act on Top

- Parapet flashing c/w drip edge
- Weep
- Brick tie at 6 course
- Steel stud w/minimal wool insulation
- Optional mineral wool insulation

Group 1
- William Penticost (20304118)
- Edmund Chen (20396915)
- Paul McMurchy (20316718)

- Brick veneer
  25 mm min. airspace
  R25 expanded polystyrene
- A.W.V. control layer (preferably fully a 190 concrete block)
- Steel stud wall for service
- Gypsum interior finish
3rd yr Architecture

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**A DETAIL @ SPANDREL PANEL**
SCALE 1:5

**B DETAIL @ WINDOW SILL**
SCALE 1:5

**C DETAIL @ PARAPET**
SCALE 1:5
Possible, but risky...

- 2x3 WOOD BLOCKING
- PLYWOOD
- RIVER-WASHED STONE
- WOVEN POLYOLEFIN FILTER FABRIC
- 2x4" (100 mm) EXTRUDED POLYSTYRENE INSULATION
- DRAINAGE MAT
- 2-PLY TREMCO TRA ELASTOMERIC SHEETING (AIR, WATER AND VAPOUR CONTROL LAYER)
- 2 1/2" WOOD DECK
- 4 1/2" WOOD PURLINGS

SLOPE 2% TO DRAIN

6" BURMESH REINFORCING MESH EMBEDDED IN TREM-LAR LRM-V JOINT DETAILING

WOOD TRUSS
ROOF SUPPORT SYSTEM

SIMPSON GALVANISED STEEL FRAMING CLIP CONNECTOR ALLOWS FOR VERTICAL/HORIZONTAL MOVEMENT/ADJUSTMENT

CONTROL LAYERS:
- WATER, AIR AND VAPOUR
- AIR AND WATER
- AIR
- THERMAL

METAL PARAPET FLASHING
FULLY-ADHERED WATER CONTROL MEMBRANE (TREMCO TRA MEMBRANE FLASHING)
PEEL AND STICK AIR BARRIER TRANSITION MEMBRANE
VERTICAL METAL STUDS FASTENED TO SLOTTED TRACK ALLOWS FOR VERTICAL COMPRESSION/EXPANSION

KEIL MECHANICAL FIXING SYSTEM STAINLESS STEEL @25" SPACING
WATER, AIR AND VAPOUR CONTROL MEMBRANE (BLUESKIN SA)
1/2" DU PONT CORIAN EXTERIOR CLADDING PANEL, GLACIER WHITE
2½" AIR GAP

BACKER ROD DETAILING ALLOWS SPACE FOR SHEATHING TO MOVE
5" XPS RIGID BOARD INSULATION w/ SHIP LAPPED SEAMS

1/4" [14.00mm]
5" [127.00mm]
6" [150mm]
4" [100mm]
7 3/4" [200mm]
Real World Experience

• Co-operative work terms... jobs related to their practise
• Faculty who have real-world experience in practise
Resources

- **World Wide Web. Danger danger**
  - Massive resource of almost every aspect of building science knowledge at many levels
  - Remarkably high proportion is wrong
  - No levels of authority / quality control

- **Textbooks** *(paper and e-media)*
  - Growing numbers of textbooks and reference books
  - Lab demo’s available from some sources
Resources

• ASHRAE Handbook of Fundamentals
  – Good and getting better each edition
  – Various guides and books on specific topics
• Numerous advanced textbooks
  – Physics of heat, air, moisture storage and transport
  – Various levels of mathematical treatment / practical application & experience
  – Building Science for engineers
  – Advanced text for training building scientists

  – Excellent, now dated, and no larger buildings, modern constructions

  • European view, highly mathematical/academic treatment

  – Great, but most practice examples and performance targets superseded
  – Excellent overview of the physics, quite quantitative

  – hard to get, great info but dated....

• Lstiburek, J. *Builder’s Guide for xxx Climates*, Building Science Corp, Westford, MA.
  – Excellent applied technology and practice, little science

  – Applied technology, simplified science, little math
Summary

• Teach fundamentals, then move to advanced
  – Not digital models, java apps
• Many resources available
  – Textbooks, handbooks, guides
Contact me at:

jfstraube@uwaterloo.ca

Download the presentation in .pdf format from:

buildingsciencelabs.com/presentations

RDH Building Engineering Ltd. and Building Science Consulting and Labs Inc. are merging. Effective November 1, 2015, we will operate as one integrated firm. The merger brings two of the leading building science firms in North America together to provide a combination of cutting-edge research with leading design and implementation capabilities. The result is a unique offering for our clients—an ability to explore new and innovative ideas based on science and our practical knowledge of what can be built. We are excited about the possibilities as we launch the new firm.