On design paradigm for durable, energy efficient buildings with excellent indoor environment

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The sustainable value of building

- Is determined by its energy efficiency, durability and the indoor environment
- It may or may not include use of the “green” materials
- Process is focused on design of interactive systems instead of the traditional focus on miraculous one-issue solution
- Changes in socio-economic conditions brought us to the point when despite of a vast industrial know-how based on tradition we need a new vision of the integration process
Building is treated as a system

1. Rain Penetration Control element
2. Heat, Air, Moisture control & Structural element

- Macro-climate
- WRB membrane
- Thermal insulation
- Interior finish
- AIR BARRIER
- Vapor retarder
- Wall frame structure
- Sheathing structural thermal
- Rain screen drainage
- Building site exposure
The term “high performance building” means a building that integrates and optimizes all major high-performance building attributes, including energy efficiency, durability, life cycle performance, and occupant productivity.
Performance is always defined on the level of built assemblies

- Building codes and standards always ascribe a required function to a specific material.
- WRB, water vapor retarder, air barrier, rain-screen, functions and materials are mentally coupled.
- Some materials can perform multiple functions, e.g. closed-cell spray polyurethane foam functions as insulation. WRB, vapor retarder” are produced as composites and designed to perform multiple functions e.g., OSB with liquid applied water resistive barrier (ses. EE9)
1. OSB and WRB, 2 - Verti. edges taped, 3 - All outer edges taped, 4 - all gaps taped, 5 - vinyl siding added
Why integrated design process (design charette) is needed?

- The outcome of an architectural design is modified by interactions between different materials and the trades involved in installing them in an assembly.
- Design and construction are holistic processes that involve highly specialized people – how should they collaborate during this process?
- How do we link the design intent and system performance?
How to link the design intent and system performance?

- This aspect of design is so important that we stress the importance on mock-up evaluation and continuous commissioning as separate activities included in the construction process.

- This is to ensure that the design concept is buildable and that all the trades learn what they must do to achieve the intent of the design.
Three areas of focus in BEST 2

Design process for high performance buildings is integrated and focused on design and control of performance of building enclosures (commissioning) in three areas:

1. Air flow control (energy, durability, IAQ)
2. Thermal insulation (effect of thermal bridges)
3. Moisture management (durability, IAQ)
Airtightness of the assembly

- tested in the laboratory is different from that tested in the field conditions
  (The situation in the field involves complicated pathways, between different zones and though interior partitions)
- Two types of airtightness; (1) overall (blower door, BD) and (2) local BE (BE + models, 2BD method, tracer gas etc)
## Energy related airtightness criteria

<table>
<thead>
<tr>
<th>Description</th>
<th>Cfm/ft² 1.57 psf</th>
<th>L / (s m²) 75 Pa</th>
<th>Cfm/ft² 1.57 psf</th>
<th>L / (s m²) 75 Pa</th>
<th>Cfm/ft² 1.02 psf</th>
<th>L / (s m²) 50 Pa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assembly, Lab</td>
<td>0.04</td>
<td>0.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Enclosure: field</td>
<td></td>
<td></td>
<td>0.4</td>
<td>2</td>
<td>0.3</td>
<td>1.5</td>
</tr>
<tr>
<td>Pressure equiv.</td>
<td>0.3 in</td>
<td>0.3 in</td>
<td>0.3 in</td>
<td>0.3 in</td>
<td>0.2 in</td>
<td>0.2 in</td>
</tr>
<tr>
<td>Measured, SU</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.13 or (0.07)</td>
<td>0.89 or (0.45)</td>
</tr>
<tr>
<td>Best1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ASTM standard</td>
<td>ASTM E 1677</td>
<td>ASTM E 1677</td>
<td>N/A</td>
<td>N/A</td>
<td>ASTM E 779</td>
<td>ASTM E 779</td>
</tr>
</tbody>
</table>
Three reasons for AB systems

- **Energy**: to reduce the heat gain or loss caused by the air entry with different temperatures
- **Durability**: to reduce uncontrolled air flow (UAF) that may carry moisture into the wall assembly and its effect on performance
- **IAQ**: To reduce the amount of VOC, particulate or mold spores carried from the outdoor or from the construction to the indoor space
MC in glass fiber wood frame wall, 0.9 l/(m²s), 21 °C, 35%RH; Ojanen & Kumaran (1996)
Example of the bungalow 1100 ft$^2$

- The rate of 0.9 l/(m$^2$s) is only 10% higher than the values recommended in Table 1.
- Location Vancouver, BC nothing happens,
- Ottawa, ON condensation is on the border of the wall drying potential
- Winnipeg, Manitoba, the amount of condensate exceeds the drying ability indicating probable moisture damage of the building assembly.
Air barriers are necessary for assuring proper interaction between building enclosures and the HVAC systems. They are needed in design of building enclosures in all climates.

One should require testing air tightness during the construction (as the QA measure) and use the energy-related criteria as benchmark for comparative purposes.
Check of the AB system is necessary for many reasons

- Requiring AB continuity warrants review of detailed drawings enhancing care during design stage and commissioning during construction.

- Requiring AB continuity warrants field and mock-up testing and enhance understanding of construction details.

- Postulated energy-related criteria must be fulfilled for LEED and other environmental programs.
External insulating systems are needed in HP buildings

- The higher is the thermal insulation level, the higher is the reduction of thermal efficiency caused by a thermal bridge.

- Two criteria are used for assessment of the thermal bridge effects:
  1. Temperature depression on the interior surface of the thermal bridge
  2. Heat loss or gain increase in comparison to “nominal R-value”
Reduction of the nominal R-value for 2x4 wood frame walls (SI units in parenthesis)

<table>
<thead>
<tr>
<th>Class of ins., resistivity of insulation $\frac{\text{hr ft2 oF}}{\text{Btu in}}$</th>
<th>k-factor of the cavity insulation $\frac{\text{Btu in}}{\text{hr ft2 oF}}$</th>
<th>Nominal R-value of the wall $\frac{\text{hr ft2 oF}}{\text{Btu in}}$</th>
<th>Mean R-value from 2-D code $\frac{\text{hr ft2 oF}}{\text{Btu in}}$</th>
<th>Reduction from nominal R-value, percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.15 (21.8)</td>
<td>0.32 (0.046)</td>
<td>12.85 (2.26)</td>
<td>11.39 (2.00)</td>
<td>11.3</td>
</tr>
<tr>
<td>3.75 (26.0)</td>
<td>0.27 (0.039)</td>
<td>14.95 (2.63)</td>
<td>12.81 (2.26)</td>
<td>14.3</td>
</tr>
<tr>
<td>5.0 (34.7)</td>
<td>0.20 (0.029)</td>
<td>19.33 (3.40)</td>
<td>15.48 (2.73)</td>
<td>19.9</td>
</tr>
<tr>
<td>6.0 (41.6)</td>
<td>0.17 (0.024)</td>
<td>22.83 (4.02)</td>
<td>17.38 (3.06)</td>
<td>23.9</td>
</tr>
</tbody>
</table>
## Effects of thermal bridges (Sandin, 1990)

<table>
<thead>
<tr>
<th>Drawing</th>
<th>Description</th>
<th>Additional heat flux including bridge</th>
<th>U-value Excl thermal bridge</th>
<th>Temperature decrease on thermal bridge</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="draw1.png" alt="Drawing" /></td>
<td>a) Floor joining woof frame wall</td>
<td>0.16</td>
<td>0.28</td>
<td>0.38</td>
</tr>
<tr>
<td><img src="draw2.png" alt="Drawing" /></td>
<td>b) Interior thermal insulation of 1(\frac{1}{2}) brick wall</td>
<td>0.17</td>
<td>0.30</td>
<td>0.38</td>
</tr>
<tr>
<td><img src="draw3.png" alt="Drawing" /></td>
<td>c) Exterior thermal insulation of 1(\frac{1}{2}) brick wall</td>
<td>0.005</td>
<td>0.30</td>
<td>0.30</td>
</tr>
</tbody>
</table>
Interior or exterior insulation this is the question!

- Interior insulation made the situation worse. No change in additional heat flux but reduced temperature on the surface of thermal bridge from 17.9 to 12.6°C (64.2 to 54.7°F).

- Exterior insulation (case c) - no change in the temperature depression but the additional heat flux caused by thermal bride reduced to less than 3% of the previous case.
**Insulation placement**

- Two conclusions can be derived from this section:
  - All frame walls in all climates should use external insulation
  - Wood frame wall should use at least R6 exterior insulation
  - High performance thermal insulation such as cc SPF should not be used in cavities but on the exterior of the frame wall
Change in moisture management

- BEST 1 highlighted that changes such as:
  1. Increased levels of thermal insulation
  2. Increased level of water vapor resistance
  3. Increased air tightness of the walls
  4. Reduced moisture buffer capability
  5. Introduction of more moisture sensitive materials

  Reduced moisture tolerance and we need to make walls that dry to each side (breathable!)
Materials for new moisture management principles

- OSB boards with integrated WRB – 6 different systems on market
- Air retarding but highly moisture permeable new types of glass fiber blown-in-blanket, dense pack and spray systems
- Air barrier, moisture permeable bio-fiber rigid and flexible boards (two of them in session 9)
- Moisture permeable peel-and-stick air and water barriers.
Conclusions

- Last two years brought us significant progress in integrated design process and commission bringing large buildings in line with energy efficient houses (see session 14).

- Several demonstrated that using existing technology + QA process during construction and one can reduce energy consumption by 30 to 40 percent of the 2004 benchmark with no cost increase.