Building Envelope Design and Moisture Performance

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Learning Objectives

At the end of this program, participants will be able to:

1. Understand the functions of materials used to achieve control of heat, air, and moisture in the building envelope.
2. Understand the mechanics of moisture movement in building assemblies.
3. Understand the properties of wood and wood products that relate to heat, air, and moisture transfer and the conditions that can lead to mold and decay.
4. Evaluate various building envelope designs for moisture performance strengths and potential risks.

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Buildings that endure

Hōryū Gakumonji temple, Japan, 8th c.
Perfect design?

- Perfect execution on the construction site?
- Perfect building operation and maintenance?
- How “robust” or “tolerant” is the design?
- Able to recover from unexpected conditions?

The Perfect Wall by J. Lstiburek
www.buildingscience.com
Defensive Driving

• R-U-A Defensive Driver?
• Collision prevention formula
  – Recognize the hazard that can cause a collision
  – Understand the defense to avoid the hazard
  – Act correctly, in time

National Safety Council  
www.SafetyServe.com

Defensive Design

1. Recognize hazards that can cause moisture damage  
   (Nuisance – health risk – structural damage)
2. Minimize risk of wetting
3. Maximize drying capability

Courtesy of Steve Easley
Hazards

- Rain water intrusion
  - Risky roof design
  - Flashing errors (windows, doors, deck ledgers, roof-wall intersections)
- Reservoir claddings not adequately separated from structural sheathing
- Untreated framing/sheathing below grade
- Ice dams
- Unusually high indoor humidity levels
- Damp foundations
- Construction moisture

Drivers

- Liquid water flow
  - Gravity, momentum, air pressure differences
- Capillary action
- Vapor transfer by air flow
  - air pressure difference
- Vapor diffusion
  - vapor pressure difference

Loads

Outdoor environment

- Rain, snow
- Solar radiation
- Wind

Indoor environment

- Heat
- Water vapor
- Air pressure differences
- Ground water
Moisture loads – precipitation

Typical annual values for Baltimore

<table>
<thead>
<tr>
<th>Surface Type</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal</td>
<td>200 lb/ft²</td>
</tr>
<tr>
<td>Vertical</td>
<td>100 lb/ft²</td>
</tr>
</tbody>
</table>

Depends on:
- Orientation
- Building geometry
- Exposure

Moisture loads – vapor flow

Typical winter values for Baltimore

<table>
<thead>
<tr>
<th>Vapor Diffusion</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outdoors cold</td>
<td>1 lb/ft²</td>
</tr>
<tr>
<td>Indoors warm</td>
<td>0.1 lb/ft²</td>
</tr>
</tbody>
</table>

Depends on:
- Indoor humidity levels
- Leakage paths
- Pressure difference

Design walls to dry in both directions

Further information: Joni Mitchell, Water and Walls by J. Lstiburek
www.buildingscience.com
Moisture storage capacity of wood

Damage functions

Mold growth limiting conditions

Exterior water management

- Deflection
- Drainage
  - Water shedding surface
  - Water-resistant barrier
- Drying
- Durable materials

Courtesy of APA, www.apawood.org
Water management risk factors

- Climate
  - Precipitation
  - Drying potential
- Building height
- Roof overhangs
- Type of cladding
- Quality of workmanship/detailing

Benefits of drained/ventilated cladding

- Improved water management:
  - Drainage
  - Capillary break
  - Pressure moderation
- Improved drying of cladding and sheathing
- Reduced inward vapor drive from reservoir claddings

Problems with uncontrolled air leakage

- High energy cost
- Comfort issues
- Noise issues
- Air quality issues
- Moisture problems

Further information:
- All About Rainscreens by M. Holladay
  www.greenbuildingadvisor.com
- Air Flow Control in Buildings by J. Straube
  www.buildingscience.com
Air barrier systems

- Must be continuous, durable, rigid or supported, able to withstand pressure in both directions
- Approaches
  - Airtight drywall approach
  - Sealed polyethylene
  - Spray polyurethane foam
  - Taped rigid sheathing
  - Exterior membranes
    - Building wraps
    - Self-adhered membranes
    - Fluid-applied membranes

Further information: Air Barrier Association of America
www.airbarrier.org

Vapor diffusion

- Make the assembly as vapor permeable as possible to maximize drying capability without making it vulnerable to moisture accumulation

Vapor permeance categories

<table>
<thead>
<tr>
<th>Vapor impermeable</th>
<th>Vapor semi-permeable</th>
<th>Vapor semi-permeable</th>
<th>Vapor permeable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class I VR</td>
<td>Class II VR</td>
<td>Class III VR</td>
<td>(not considered a VR)</td>
</tr>
<tr>
<td>0.1 perm</td>
<td>1 perm</td>
<td>10 perms</td>
<td></td>
</tr>
</tbody>
</table>

- polyethylene
- aluminum foil
- vapor retardant paint
- 1" XPS
- 1" EPS
- building wraps
- gypsum board
- fibrous insulation
Vapor permeance can depend on RH

- Solid wood, plywood, OSB, “smart vapor retarders” become more permeable as RH increases
- This allows assemblies to dry more rapidly

Classic wood-frame wall

- Lap siding
- Felt
- Plywood
- Kraft-faced batt insulation
- Gypsum board

Vapor diffusion in wood

- Softwood tracheid
  - Length: 1/8 inch
  - Diameter: 0.001 inch

Wood based panels

- Perm rating at 1/2 inch thickness

Effects of exterior insulation

1. Thermal effect
   - exterior insulation reduces risk of cold weather moisture accumulation by warming materials such as wood structural sheathing

2. Vapor diffusion effect
   - Low-perm exterior foam
     • impedes outward drying
     • reduces inward vapor drive from moisture reservoir claddings
   - Vapor permeable exterior insulation (rigid mineral wool, wood fiber insulation board) – opposite

Evaluating design robustness

• Desired moisture performance:
  – Minimize vulnerability to rain penetration
  – Minimize vulnerability to air leakage
  – Minimize vulnerability to vapor diffusion
  – Maximize drying capability

Which is more robust?

Wall A
• Drywall
• Latex paint (Class III vapor retarder)
• Batt insulation/wood framing
• Wood structural panel
• Permeable WRB
• Lap siding

Wall B
• Drywall
• Smart vapor retarder
• Batt insulation/wood framing
• Wood structural panel
• Permeable WRB
• Lap siding
Latex paint: not reliable for interior vapor control

- Recent measurements from multiple labs: vapor permeance of gypsum board with two coats latex paint 20 perms or greater
- Home Innovation Research Labs test structure (climate zone 4A) showed OSB moisture contents around 25% in winter and mold growth

Which is more robust?

Wall C
- Drywall
- No VR except interior paint
- R-13 cavity insulation
- Wood structural panel
- Permeable WRB
- R-5 extruded polystyrene
- Lap siding

Wall D
- Drywall
- No VR except interior paint
- R-13 cavity insulation
- Wood structural panel
- Permeable WRB
- R-5 mineral wool
- Lap siding

Cross-laminated timber (CLT)

www.fpl.fs.fed.us
Cross Laminated Timber Makes its Mark with The Long Hall

It happened so quickly that most design and construction professionals probably missed it. But when the first commercial building project in the US, constructed with cross laminated timber (CLT) was completed in 2011, it opened the door for green building innovation. The Long Hall in Helena, Montana, epitomizes many of the benefits of CLT construction — speed of construction, environmental and aesthetics benefits, and reduces wind exposure. The two-story wood structure took just five days to erect, and gave the former sustainable, energy-efficient building.
A 'Company of Discovery' Discovers Wood

Promega Uses Innovative Mix of Cross Laminated Timber and Glulam for New Facility

You can tell a lot about a company by the way they treat their clients and employees. You can also tell a lot by the way they build their buildings.

Promega, a leader in biotechnology, is headquartered in Madison, Wisconsin. It's also a company of discovery. "That's our business, biological discovery, and this philosophy of discovery crosses over into everything they do," said Dave Koontz, Promega's director of facilities. "Promega wanted to build a new building that fit into their culture. They asked an architecture firm and a design consultant to design their new lab and staff center, called The Crossroads, through a process of discovery...and their decision to use wood was one of those discoveries. In the end, we created glulam beams and cross laminated timber (CLT) to make a statement that this is a special and unusual space."

woodworks.org
Laboratory research in progress

Chamber for Analytic Research on Wall Assemblies exposed to Simulated weather (CARWASH)
Questions?

This concludes The American Institute of Architects Continuing Education Systems Course.

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