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.

Heddal stave church, Norway, early 13th c.
Robust Design vs. Perfect Design

- Perfection on the construction site?
- How much control does a designer have?
- Need to design for moisture tolerance

*The Perfect Wall* by Joe Lstiburek
www.buildingscience.com

Defensive Design

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)
Hazards

- Rain water intrusion
  - 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
- Air leakage
- Damp foundations

Loads

Outdoor environment
- Rain, snow
- Solar radiation
- Wind

Indoor environment
- Heat
- Water vapor
- Air pressure differences
- Ground water

Special Report: *Minnesota's Rotting Stucco Walls* by Martin Holladay
Energy Design Update, May 2006
**Moisture loads – precipitation**

Typical annual values for Twin Cities

<table>
<thead>
<tr>
<th>Surface Type</th>
<th>Wet Loads (lb/ft²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal</td>
<td>150</td>
</tr>
<tr>
<td>Vertical</td>
<td>50</td>
</tr>
</tbody>
</table>

East-facing wall

Depends on:
- Orientation
- Building geometry
- Exposure

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**Moisture loads – vapor flow**

Typical annual values for Twin Cities

**Air leakage**

- Outdoors: cold
- Indoors: warm

1 lb/ft²

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

**Vapor diffusion**

- Outdoors: cold, low p_v
- Indoors: warm, high p_v

0.1 lb/ft²

Depends on:
- Indoor/outdoor vapor pressure
- Vapor permeance

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**Drivers**

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

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**Moisture storage capacity of wood**

![Graph showing moisture content vs. relative humidity]

- Equilibrium moisture content (%) vs. Relative humidity (%)
**Damage functions**

- Decay
- Corrosion of embedded fasteners
- Mold growth

**Further information**

[Wood Handbook](www.fpl.fs.fed.us)

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**Defensive Design**

1. Recognize the hazard
2. Understand the defense
3. Minimize wetting and maximize drying

**Exterior water management**

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

Stack effect
Air leakage in foundations

Basements:
- Stack effect in winter can cause buildings to inhale through the soil, bringing in water vapor, radon, odors
- FPL research demonstration house: 20-40 lbs of moisture per day during cold weather plus high radon levels
- Sub-slab ventilation effectively solves the moisture issue as well as the radon issue

Crawl spaces:
- Wall-vented crawl spaces in southeastern U.S. conducive to mold growth
- Mold spores from crawl space infiltrate into the living space via air leakage through the floor

Air leakage in walls and roofs

Cold climate examples
- Wall case study in Montana
  - Highly insulated, tight house (1.2 ACH at 50 Pa)
  - Moisture content of sheathing measured in 120 locations
  - Huge variation: most readings <20% but some >40% MC
  - IR thermography and pressurization/depressurization showed that air leakage paths corresponded with locations of high MC
- SIP roofs in Alaska
  - Major moisture accumulation in multi-unit residential buildings from air leakage at roof panel joints

Hot-humid climate examples
- Negative pressure (wind, stack effect, exhaust fan) brings humid outdoor air into wall or roof assemblies cooled by air-conditioning
- Moldy hotels in Florida

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

Vapor diffusion

Principled approach:
- Assess the interior and exterior environments
- Provide only as much vapor diffusion resistance as necessary
- Make the assembly as vapor permeable as possible to maximize drying capability without making it vulnerable to moisture accumulation
- Need for interior VR may depend on whether exterior insulation is included in the assembly
Vapor permeance categories

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

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
• Consider moisture tolerance

Wood-frame examples

• Strengths/vulnerabilities
• Vapor management
• Exterior insulation
Cross-laminated timber

Further information

www.masstimmer.com
www.fpinnovations.ca
Questions?

This concludes The American Institute of Architects Continuing Education Systems Course

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