Moisture and Buildings

- Moisture is involved in almost all building envelope performance problems
  - In-service .... Durability
- Examples:
  - rot,
  - corrosion,
  - mould (IAQ)
  - termites, (!),
  - staining
  - etc.

Moisture Damage

- Damage caused by
  - Very high humidity for a long time
  - Wet (100%RH) for a shorter time
- Time required depends
  - on material
  - Temperature
- Temperature
  - Accelerates slows or stops process
Moisture Control

- Moisture-related Problems
  1. Moisture must be available
  2. There must be a route or path
  3. There must be a force to cause movement
  4. The material must be susceptible to damage

- Theory:
  – eliminate any one for complete control

- Practice:
  – control as many as possible
Moisture Balance

- Wetting
- Drying
- Safe Storage Capacity

Wall + Roof Wetting Sources/Mechanisms

1. Rain
   - absorption
   - penetration
   - splash and drips
2. Water Vapor Movement
   - Diffusion
   - Convection (air leaks)
3. Built In
4. Ground
   - Capillary (wick)
   - Gravity
   - Diffusion

Condensation
- air convection
- vapor diffusion

Rain
- absorption
- penetration
- Drainage
- Air convection
- Evaporation-Diffusion

Flood

Built-in
Wall + Roof Drying
Sinks and Mechanisms

1. Surface Evaporation
   - Wicking to surface

2. Vapor Movement
   i) Diffusion
   ii) Convection

3. Drainage

4. Intentional Convection = Ventilation Drying

Ventilation Drying

- Ventilation provides drying to the exterior
- Can be important for:
  1. vapor impermeable cladding
     - metal panels
     - most roofing
  2. systems which retain rainwater
     - Improves survivability of small rain leaks and condensation

Storage

- Bridges gap in time between wetting and drying
- How much moisture for how long before damage
- Safe storage: safe against what?
  - mold, rot, freeze-thaw, corrosion

- Basic mechanisms
  - Absorbed into materials = capillary pores (bound liquid)
  - Adsorbed to materials = sorption (vapor)
  - pools and puddles (free liquid)

Moisture Storage in Assemblies

1. Trapped / undrained
2. Surface tension
   - Liquid or solid
3. Adsorbed
4. Absorbed
5. Vapor
   - Small
Design Choices

- Either avoid wetting
- Or, provide enough drying to accommodate wetting
- Depending on the storage provided

The balance has shifted over time
- Amount of storage has changed over last 100 yrs
  - e.g. steel stud, vs wood stud vs concrete block
  - 1: 10 : 100+
- Wetting is usually less
- Drying is often much less

Design Solutions

- Balance wetting, drying, and storage
- Practical Rules
  - Provide a continuous plane of rain control including each enclosure detail
  - Provide continuous air barriers and insulation to control condensation problems
  - Allow drying of built-in and accidental moisture – beware drying retarders

The Water Molecule

- Asymmetrical = polar
- Small: one billion = one foot
  \[0.28 \text{ nm} \cong 3 \text{ Å}\]

The Polar Molecule

- Hydrogen end is “more” positive
- Oxygen end is “more” negative
Surface Tension: Wettable

- Water attracted to surface more than self
  \[ \theta < 90^\circ \]
- Water attracted to self more than surface
  \[ \theta > 90^\circ \]

- normal material: “wettable”
- hydrophobically treated: “non-wettable”

Capillary Pressures

- Result of surface tension = attraction to surfaces
  – pressure varies with pore size
  – e.g., height rise in a glass tube

Capillary rise between glass sheets

- Surface tension up
- Gravity Down

- Elastic band
- Paper clip
Water: Liquid vs Vapor

- Vapor is a single molecule
- Liquid is molecular clumps, 60 or more
- Tyvek vs asphalt

Vapor Pressure: water as a gas

Water vapor in Air
Powerful means of controlling condensation in cold climate buildings

Control interior RH

0 C 32 F 100%RH
10 C 50 F 50%RH
21 C 70 F 25%RH
95 F 12%RH

0 C 32 F 100%RH
10 C 50 F 50%RH
21 C 70 F 25%RH
95 F 12%RH

Dehumidification

0 C 32 F
50 F 72 F 50%RH
10 C 22 C
95 F 35 C 35%RH

Warm weather condensation

0 C 32 F
10 C 50 F
72 F 95 F
22 C 35 C
100% 75%

Retrofit increases airtightness -> Increases RH
Cooling to get Condensation

Psych Chart: Air Vapour Content vs Temperature

Indoor Conditions
- 68 – 78 F (20-26 C)
- 25 to 60%RH
(Could be 20 to 70%)

Saturation

100% RH
75% RH
50% RH
25% RH

Air Moisture Content

Temperature

Air Moisture Content

Saturation

100% RH
75% RH
50% RH
25% RH

Indoor Conditions
- 68 – 78 F (20-26 C)
- 25 to 60%RH
(Could be 20 to 70%)
### Outdoor Conditions

**Summer / Winter**
- January 10-30°F / -10°C & 80-100%
- July 75-95°F / 24-35°C & 50-90%

### Indoor vs Outdoor Conditions

- Inward drive bigger than outward
- Tighter control of T/RH increases drive

### Air leakage

- Much more vapor can be carried on back of air flow than diffusion
- Condensation only happens if air flows towards cold surface
Water Vapor in Walls

\[ T_{\text{back of sheathing}} = T_{\text{interior}} - \left( T_{\text{interior}} - T_{\text{exterior}} \right) \frac{R_{\text{batt}}}{R_{\text{total}}} \]
No exterior sheathing

- Wood-based siding
- Building paper
- Exterior sheathing
- 0.10 cavity insulation in wood frame wall
- Vapor barrier will vary based on wall construction

With exterior insulation

- Wood-based siding
- Insulation/shedding/sheathing
- Insulation/sheathing surface temperature
- 0.10 cavity insulation in wood frame wall
- Gypsum board with semi-permeable latex paint and adhesive, gasket or sealant on top plate and bottom plate interior (air barrier system)

- The inside face of the insulating sheathing is the first condensing surface

Vinyl or aluminum siding (perforations along bottom edge allow drainage and drying to the exterior)

- Building paper drainage plane (permeable)
- Asphalt-impregnated fiberboard or gypsum sheathing (permeable)

Unfaced cavity insulation in wood frame wall (permeable)
Water Vapour Transport

- **Vapour Diffusion** (like heat conduction)
  - more to less vapor
  - No air flow
  - Flow through tiny pores
- **Air Convection** (like heat convection)
  - more to less air pressure
  - flow through visible cracks and holes
  - vapour is just along for the ride
Summer Condensation:
1. Air-conditioning
2. Interior vapor barrier
3. Permeable exterior layer
4. Humid exterior OR wet cladding

Require:
1. Wet cladding
2. Cool interior
3. Poly or equiv.
4. Vapor permeable insulation/sheathing

Valid for Diffusion or Air Leakage (Convection)
Conclusions

- Air can store much more water vapor as temperature increases
- Water vapor moves in two modes
  - Diffusion (vapor control)
  - Air Leakage (air control)
- Vapor control is less important
- Air control requires all holes sealed
Liquid Transport: Capillary Flow

- Surface tension drives water uptake
- Flow rate depends on size of opening
  - Small pores – high suction, low flow
  - Large pores – low suction, high flow

Capillary Flow

- Solution: use gaps
- Large pores - no suction (no “wicking”)
- Eg. : Crushed stone, air gaps
- Gravity flow allows drainage

Example: Sand, siding laps
Smaller pores
- some wicking (inches to feet)

Capillary Flow- concrete sucks

Example: Clay or silt
Wicking (dozens - hundreds of ft)