Moisture Fundamentals

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Dr John F Straube
Assistant Professor
Dept of Civil Engineering & School of Architecture
University of Waterloo, Ontario, Canada

Outline of Presentation

- Mould, Moisture, and Temperature
- Moisture Control Fundamentals
- Surface Humidity
- Interior Moisture Loads
- Air barriers and Rain control

Fungi & Buildings

- We often make buildings of dead plants
  - sustainable
  - inexpensive and plentiful
- Fungi have evolved to eat dead plants
- We have a conflict of interest

Fungi

- 1.5 million types -- only 400 cause disease
- fungi = mould + yeasts
- No photosynthesis
- Why avoid mould?
  1. staining
  2. illness - spores, mycotoxins, VOCs
  3. decay

Mould

- Mould growth requires all of:
  1. infestation,
  2. temperature,
  3. nutrients,
  4. moisture
- cant avoid 1, hard to avoid 2 or 3.
- Therefore, control moisture!
- Use radiation and alkalinity

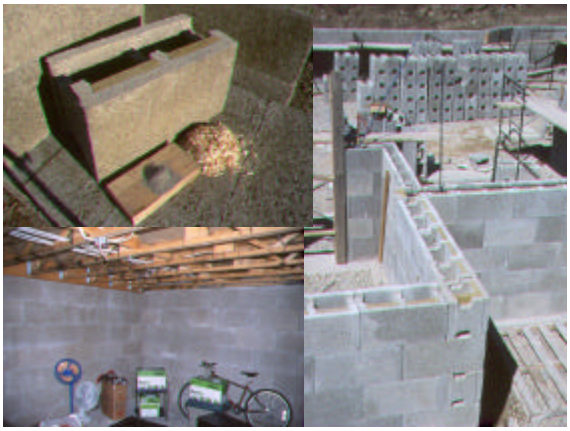
Innovative Building Systems & Materials

Example: PVC encapsulated concrete
Fully insulated on exterior
No food source

Basement

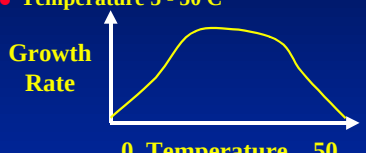
Clinic

Example: Cement-bonded wood shavings
alkaline material, uniform insulation
petrified wood = no food source

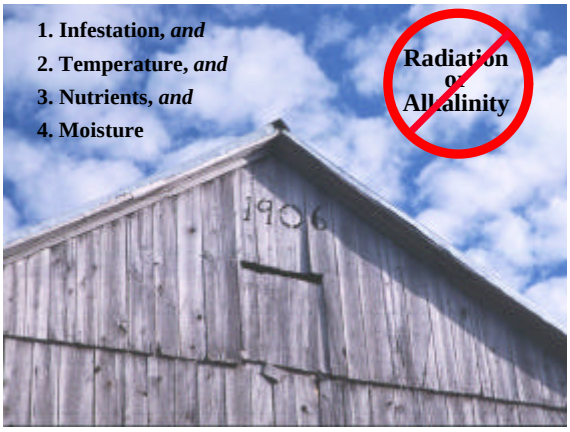


Mould Growth On Surfaces

- *Surface* Humidity > 80%RH
- Temperature 5 - 50 C

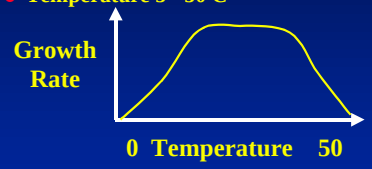


- Food Source (cellulose, soap, wood, oil)
- pH - usually less than 8 - 10



Wood Decay

- Material Humidity > 95%RH, MC>30%
- Temperature 5 - 50 C



- Highly species, sample, exposure dependent

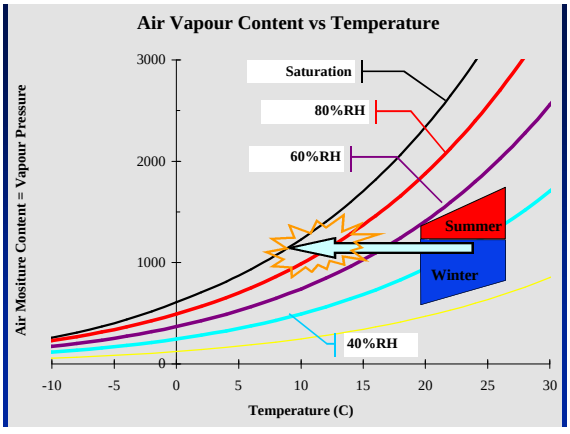
Mould Control

- Control conditions = moisture

1. keep RH at interior surfaces low
2. avoid wetting from bulk water
3. isolate interior air from inside enclosures

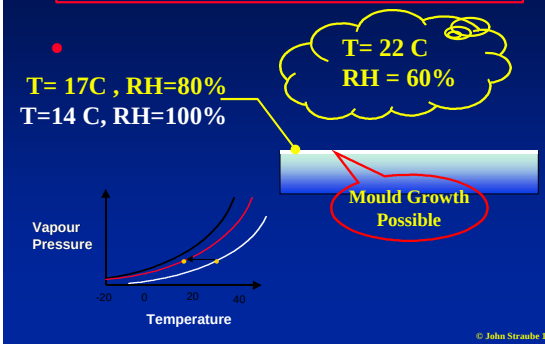
- Surface RH is NOT the same as interior RH

Surface Humidty



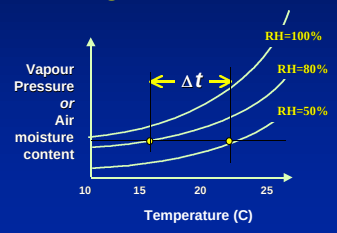
Microclimate: Surface Humidity

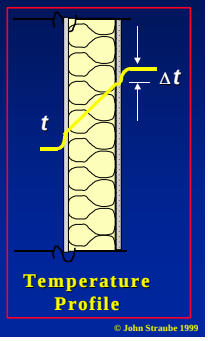
- T= 17C , RH=80%
  T=14 C, RH=100%



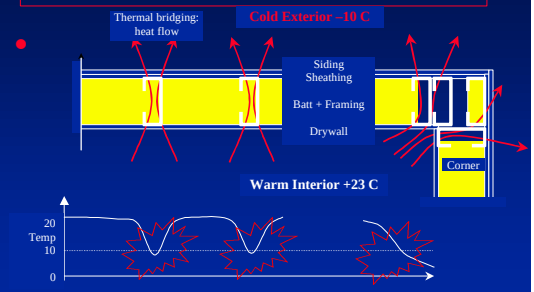
Wall Temperatures and RH

Poor insulation
= cold surface
= high RH





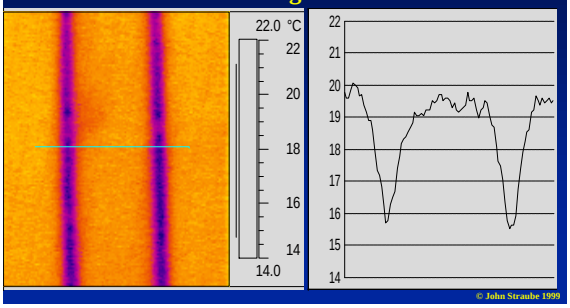
Thermal Bridges

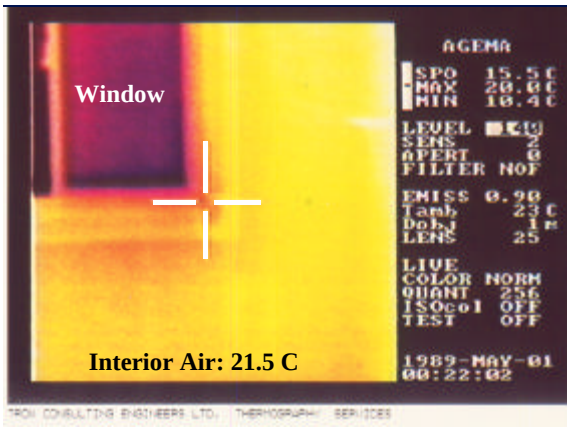


Plot of Temperature Along wall Mid-height

Infra-Red Photos

From inside a building at 22 C



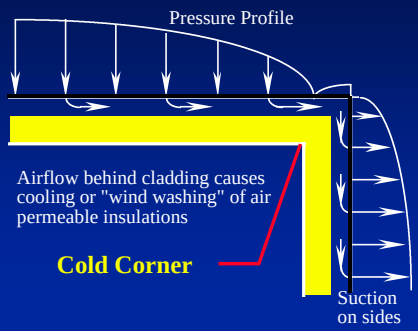


Interior Air at 22 C

Surface temperatures cannot be less than:

Interior RH	Condensation Temperature	Temperature @80%RH
20	-2	1
40	8	11
50	11	14
60	14	17
80	18	22

Wind Washing



Moisture Fundamentals

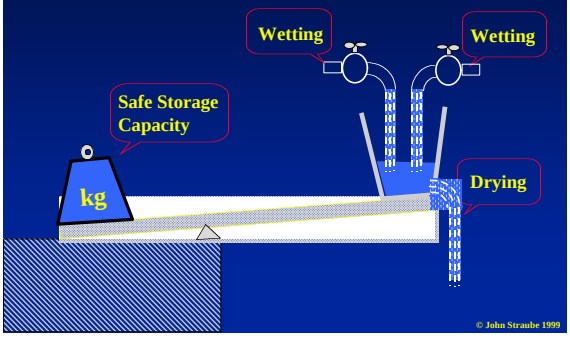
Moisture and Buildings

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

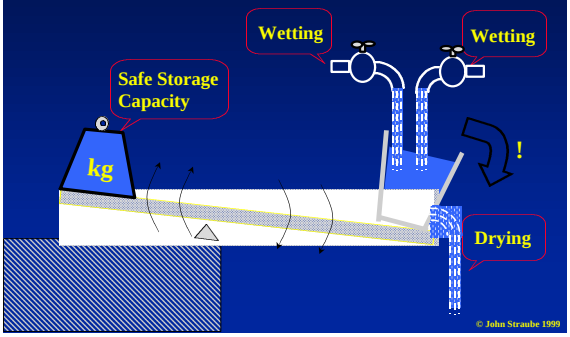
Moisture Control

- **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**
- **Practise: control *as many as possible***

The Moisture Balance



When Wetting Exceeds Drying



The Moisture Balance

- Wetting & Drying
  - What are the sources
  - What are the mechanisms
- Storage
  - How much needed? What is "safe storage"?
- Design Philosophy:
  - avoid wetting? Or balance with drying?

Wetting

- We are not perfect.
- Our buildings are not perfect.
- Therefore, our buildings get wet
- Hence, drying is also important

Wetting - Sources & Mechanisms

1. Interior *and* Exterior Air (Vapour)
   - by diffusion and air leakage *(convection)*
2. Driving Rain (Liquid)
   - by absorption ("wicking") and rain penetration
3. Soil Moisture (vapour & liquid)
   - by diffusion, absorption and liquid penetration
4. Built-in Moisture (solid, liquid, vapour)
   - not transported - *stored* in masonry/concrete, green lumber, construction rain/snow

Drying - Sinks and Mechanisms

1. To Exterior (liquid)
   - drainage *free liquid water only*
   - stops leaving materials saturated
2. To Exterior or Interior Air (vapour)
   - first, evaporation *then*:
   - air leakage (convection)
     - ventilation (e.g. for vapour resistant cladding)
   - diffusion
     - vapour barriers slow inward drying
     - vapour resistant claddings slow outward drying

Storage

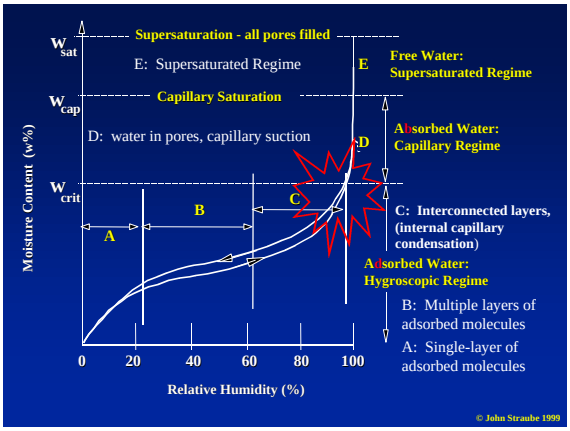
- Bridges gap in time between wetting and drying
- How much moisture for how long before damage
  - I.e. *Safe* storage
- *Amount* of storage
  - e.g. steel stud, vs wood stud vs concrete block
- Basic mechanisms
  - capillary pores (*bound liquid*)
  - sorption (*vapour*)
  - pools and puddles (*free liquid*)

Safe Storage Capacity

- Different materials react differently
- Primary environmental variables
  - temperature, time of wetness, RH (=MC)

Approximate Thresholds

- Mould, fungi, corrosion, etc.:
  - Over 80%RH, > 0 C "for some time"
- Freeze-thaw, dissolution:
  - from 100%RH to saturated



Materials

- Define performance, e.g., no mould growth
- Must know "loads" = microclimate
- E.g. Cannot expose drywall to any moisture, concrete can be built underwater
- Steel corrodes, wood rots, gypsum dissolves

"No Wrong Material,
Just Materials Used Wrong"

Enclosure Design for Durability

- Balance wetting, drying and storage potentials
- Durability:
  - choice of materials and
  - their arrangement for
  - the microclimates expected
- Use moisture susceptible materials in the proper microclimate

Summary of Materials

- Material Performance Thresholds
  - Depends on materials, layers, sub-assembly, assembly, enclosure
  - Beware sub-micro-climate
  - Mould, corrosion : all *begin* at >80%RH, long-term

Interior Moisture Loads

Internal Moisture Loads

- Mould grows well inside because it is warmer and no sun
- Interior mould is closer to occupants
- Hence, beware interior surfaces and hidden but connected spaces
- Keep interior spaces dry!

Major Sources of Interior Moisture

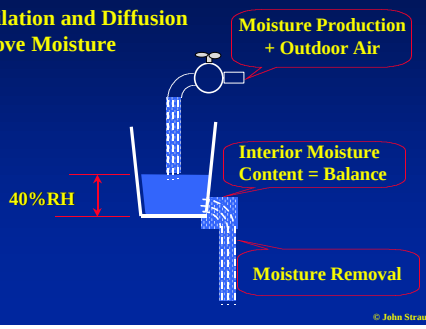
- Occupant Activity
  - Total for Family of 4: 5 to 20 kg/day
- Drying out of rain wetting
- Wet basements and crawlspaces
- Leaky plumbing
- Floor washing

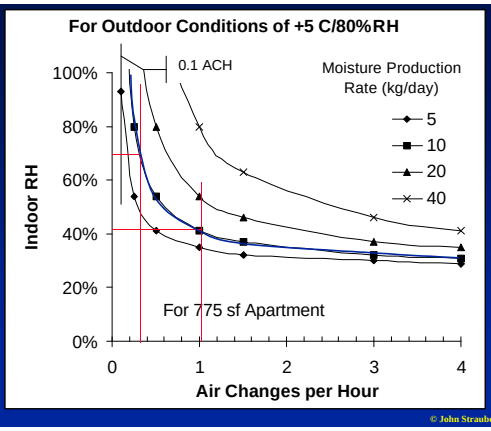
Sources of Moisture Within Buildings

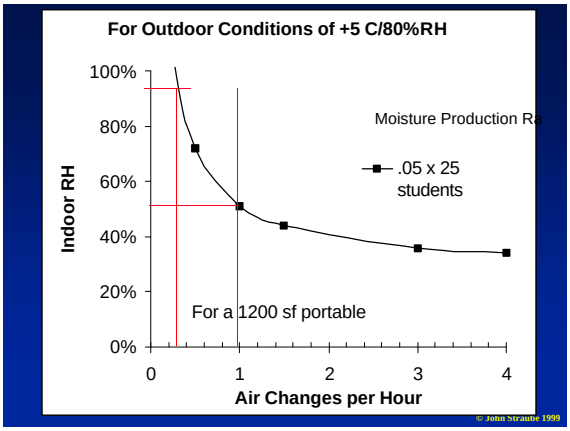
Source	Strength kg per day
People - evaporation per person	0.75 (sedate) to 5 (heavy work)
Humidifier	2-20+
Hot tub, Whirlpool	2-20+
Firewood, per cord	1-3
Washing floors, counters, etc.	0.2
Dishwashing	0.5*
Cooking for four	0.9 to 2 (3 with gas range)*
Defrosting (frost free) Fridge	0.5*
Typical bathing/washing per person	0.2 to 0.4*
Shower (ea)	0.5
Bath (ea)	0.1+
Uncovered Crawlspace	0.5 / m^2
Unvented Gas Appliance (ea)	1
Seasonal Desorption	3-8 depends on the type of construction
Plants/Pets	0.2 - 0.5 (five small plants or one dog)
Total (Typical Family of 4)	**About 10 , but potential ranges 3 to 40**

Interior Air Moisture

- Ventilation and Diffusion Remove Moisture







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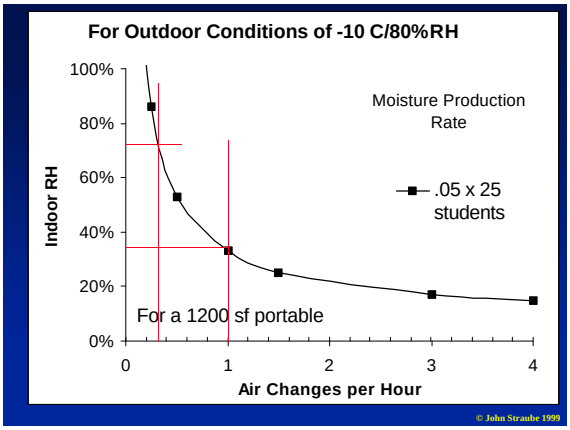


Interior Humidity

- Interior humidity will be higher in swing season than winter
- Interior surface temperatures lowest in winter
- Insufficient ventilation *will* encourage mould growth in most cases

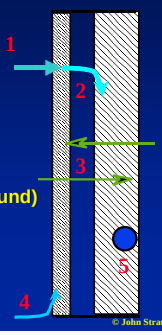
Interior Humidity

- Fewer air changes = higher interior humidity
- More moisture production = higher interior humidity
- More airtight construction = interior RH is more sensitive to moisture production rate
- Solution: Controlled Ventilation

Other Issues

Internal Wall Wetting

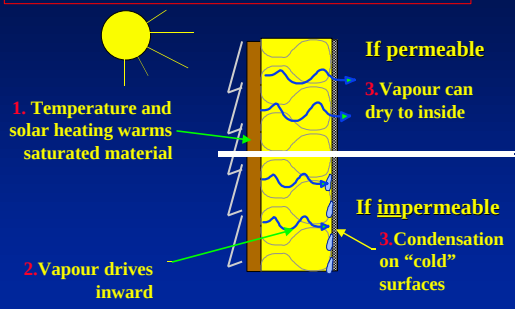
1. Rain Absorption
2. Rain Penetration
3. Water Vapour
   i) Diffusion
   ii) Convection
4. Splash/ Wicking (from ground)
5. Plumbing Leaks



Rain Control

- Often largest source of moisture
- A large topic in its own right
- Maintenance and repair important
- Use overhangs, drips, etc.
- Usually causes mould inside enclosure
- Solar driven vapour can cause *interior* wetting

Inward Diffusion Drying



Air Barrier Systems

- Air barrier systems (ABS) control air flow
  - ABS prevent air leakage condensation
- Not the same function as vapour barriers
  - vapour barriers rarely important
- Interior air barriers protect occupants from mould growth within the enclosure
- A good ABS requires careful detailing
- "Build Tight, Ventilate Right"

Solutions

- Materials are not a simple answer
- *But*, paper-faced gypsum and ceiling tiles can not be allowed to get wet!
- Painted concrete block, plaster, exposed ceilings are *definitely* more moisture tolerant

Solutions

- *Control humidity*: ventilation /dehumidification
- Provide *timely* maintenance and repair
- Durable High performance buildings should be given credit over temporary buildings

Conclusions

- Mould Control = Moisture Control
- Moisture Control includes
  - interior humidity
  - rain penetration
  - plumbing leaks
  - maintenance activities
- Choose materials for expected conditions
- Controlled ventilation is important