Searching for
The Perfect Wall
A Closer Look at Cellulose

Prudence Ferreira
PassivScience LLC
www.passivscience.com

* Slide courtesy Thorsten Chlupp
Moisture Control Best Practices

1. Avoid using vapor retarders where vapor permeable materials will provide satisfactory performance. Thereby encouraging drying mechanisms over wetting prevention mechanisms.

2. Avoid installation of vapor retarders on both sides of assemblies – i.e. “double vapor barriers” in order to facilitate assembly drying in at least one direction.

3. Aim for the use of diffusion open and hygroscopic materials over impermeable hydrophobic materials.

4. Layer assemblies so that vapor retarding layers are close to the source of moisture and more sensitive, less durable materials are protected.

5. Promote initial and ongoing drying and short-circuit accumulation by providing ventilation per ASHRAE 62.1, 62.2 or better.
Aim for the use of diffusion open and hygroscopic materials over impermeable hydrophobic materials.

Is cellulose a good idea everywhere?
Residential Wall 1 - REMOTE

- Structural Sheathing
- Furring attached with screws to studs
- 4-6 inches EPS rigid foam
- Exterior siding of your choice
- Exterior membrane
- Metal flashing
- Stud
- Gypsum wall board
- *R11 or R13 batt insulation
- Sill
- Floor joist
Residential Wall 2 – SIPS+

5/8" GYPSUM BOARD, TYP.

PASSIV STRUCTURES WALL PANEL SYSTEM

VINYL SIDING, OR ADHERED STONE (SEE ELEVATIONS)

2 X 6 STUD WALL FRAMING @16" O.C., W/ R-21 INSULATION

PROSOCO MVP
Residential Wall 3 – Ext Foam
1” + WRB, 1 Perm, 0.1 perm | 2”-3” (1 perm, fiberglass)

LATEX PAINT
5/8” INTERIOR GWB
2x6” FRAMED WALL WITH DP CELLULOSE
1/2” EXTERIOR PLYWOOD
BUILDING WRAP
1” EXPANDED POLYSTYRENE (EPS)
3/8” AIR GAP BETWEEN PT STRAPPING
3/4” FIBER CEMENT SIDING
Residential Wall 4 – REMOTE-MW
Fiberglass cavity, fluid applied 17 perm/1 perm membrane on sheathing, 34 perm membrane over MW
ARCTIC WALL

* Slide courtesy Thorsten Chlupp
12” DOUBLE STUD WALL

12” CELLULOSE w/ 10 PERM VR

- Temperature (°F)
  - 95
  - 75
  - 55
  - 35
  - 15
  - 5
- [Btu/h ft²]
  - >400
  - 300
  - 200
  - 100
  - 0

- Water Content (%)
  - >20
  - 10
  - 0.1
  - 0.01
  - 0.001

- [in/h]
  - >10
  - 1
  - 0.1
  - 0.01
  - 0.001

Layers:
- Cement Board
- Air Layer 20 mm; without additional moisture capacity
- Brick vapor retarder
- *Cellulose Fiber Density 3.5pcf complete
- *Plywood CDX 1/2in 0.4 perm
- Interior Gypsum Board
- Air Layer 90 mm; without additional moisture capacity
12” DOUBLE STUD WALL

Case: 11 12" CELLULOSE w/ 10 PERM VR
Case: 12 12" CELLULOSE w/ 5 PERM VR
Case: 13 12" CELLULOSE 1 PERM VR
Case: 14 12" CELLULOSE 10 PERM VR+ INTELLO ON CDX
Case: 15 12" CELLULOSE 5 PERM VR+ INTELLO ON CDX
Case: 16 12" CELLULOSE 1 PERM VR+ INTELLO ON CDX
WUFI Results Data
Specific Risk Thresholds: Mold

Spore presence **MUST** be assumed! But to germinate, fungi need the following conditions:

**Nutrients:** wood, paper, glues, paints, dust, dirt, soap

**Favorable Temperature:** 68°F - 95°F is ideal, outside of 41°F - 122°F growth stops

**Moisture:** Surface RH of 75-80%. Above 90-95% RH lack of oxygen stops fungal growth
Klaus Sedebauer’s Thesis

Mold Growth in mm or Mold Index

Models hygrothermal behavior of a mold spore which consists of envelope and living material inside

Envelope is like a membrane, when humid membrane opens and it can live and germinate, when dry membrane is closed to keep moisture inside

When critical water content is reached, germination is complete

Other models just say when a specific RH and temp are reached then there is risk, this goes further to model hygrothermal behavior or spore and ascertain where germination (growth occurs)

*Use IEA Annex 55 use Hannu Viitanen Mold growth model for more accurate assessment
WUFI BIO Post-Proc
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<th>Description</th>
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<tr>
<td>0</td>
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<tr>
<td>1</td>
<td>some growth visible under microscope</td>
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<tr>
<td>2</td>
<td>moderate growth visible under microscope, coverage more than 10%</td>
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<tr>
<td>3</td>
<td>some growth detected visually, thin hyphae found under microscope</td>
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<tr>
<td>4</td>
<td>visual coverage more than 10%</td>
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<tr>
<td>5</td>
<td>coverage more than 50%</td>
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<tr>
<td>6</td>
<td>tight coverage, 100%</td>
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Wood Decay is due to fungal infections that require:

- **Favorable Temperature**: > 50°F
- **Moisture**: H2O content by weight > 20%-M

In example, temperature is often above 50°F,

H2O Mass % is below 20%

Wood rot risk is absent unless H2O Mass% increases
H2O content per construction layer should initially decrease and thereafter establish a regular pattern of seasonal fluctuation.
Comparative Study Parameters

- 6 locations
  - Philadelphia
  - Chicago
  - NYC
  - Seattle
  - Houston
  - Salt Lake City
- 5 walls residential
- 17 total variations (4 with fiberglass cavity, 13 with cellulose)
Hygro Protocol

- 5 yr simulation
- Exterior - ASHRAE Yr 3
- Cladding ACH based on conservative interpretation of next slide
- 1% DR in whole layer of 1mm “Old Brick” ON WRB
- Sheathing modeled in 1/8” slices
- Interior – ASHRAE 160 Int Method: EN 15026 High Moisture Load
Results Analysis

• WUFI Bio Mold Index analysis @highest RH location in moisture sensitive layers subject to air infiltration/exfiltration. Must have green light at least by yr 2 to pass.

• Evaluate Mass % WC in sheathing layers of safest walls
NYC Wall Comp

[Graph showing mould growth and mould index over time for different materials and coatings, with dates ranging from Oct 2015 to Oct 2020.]
NYC Wall Comp

Mould Growth Mould Index

- SIPS+Cellulose (Class I)
- REMOTE FG (Class I)
- REMOTE-MW FG (Class I)
- SIPS+FG (Class I)

Graph showing mould growth and mould index from Oct 2015 to Oct 2017.
Chicago Wall Comp

Mould Growth  Mould Index

REMOTE-MW FG (Class I)  SIPS+FG (Class I)  REMOTE MW + VR II (Class I)  SIPS+Cellulose (Class I)  REMOTE FG (Class I)

Seattle Wall Comp

Mould Growth

- SIPS+FG (Class I)
- REMOTE FG (Class I)
- SIPS+Cellulose (Class I)
- 1’ EXT FOAM (Class I)
- REMOTE-MW FG (Class I)
- ARCTIC WALL (Class I)
- 1’ EXT FOAM +VB (Class I)
- 2’ EXT FOAM + VR (Class I)
- 3’ EXT FOAM + VR (Class I)
- 3’ EXT FOAM +VR FG (Class I)
- REMOTE MW + VRII (Class I)
- 12’ CELLULOSE w/10 PERM VR (Class I)
- 12’ CELLULOSE 1 PERM VR (Class I)
- 12’ CELLULOSE w/5 PERM VR (Class I)
- 12’ CELLULOSE 10 PERM VR+ INTELLO ON CDX (Class I)
- 12’ CELLULOSE 5 PERM VR+ INTELLO ON CDX (Class I)
- 12’ CELLULOSE 1 PERM VR+ INTELLO ON CDX (Class I)
Seattle Wall Comp
Houston Wall Comp

Mould Growth | Mould Index
---|---
SIPS+FG (Class I) | 1" EXT FOAM (Class I) | REMOTE-MW FG (Class I)
ARCTIC WALL (Class I) | 1" EXT FOAM +VB (Class I) | 2" EXT FOAM + VR (Class I) | 3" EXT FOAM + VR (Class I)
3" EXT FOAM +VR FG (Class I) | REMOTE MW + VRII (Class I) | 12" CELLULOSE w/10 PERM VR (Class I)
12" CELLULOSE w/5 PERM VR (Class I) | 12" CELLULOSE 10 PERM VR+ INTELLO ON CDX (Class I)
12" CELLULOSE 5 PERM VR+ INTELLO ON CDX (Class I) | 12" CELLULOSE 1 PERM VR+ INTELLO ON CDX (Class I)

[Graph showing mould growth and index over time]
SIPS + Cellulose is wetter at start but dries to same level as SIPS+ FG
3" Foam with 1 perm VR on sheathing starts wetter w/ cellulose but gets drier than FG
Remote MW+FG works better with 1 perm VR than with 17 perm fluid-applied
Houston Wall Comp

Mould Growth
Mould Index

3" EXT FOAM + VR (Class I)  REMOTE FG (Class I)  SIPS+Cellulose (Class I)  REMOTE-MW FG (Class I)  3" EXT FOAM +VR FG (Class I)
REMOTE MV + VR II (Class I)  SIPS+FG (Class I)
Salt Lake Wall Comp

3” is not enough ext insulation to manage dewpoint related moisture

…..but with cellulose instead of FG it helps buffer the RH, keeping the framing dryer. In other wetter climates, cellulose would become too wet,
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Conclusions ...

- Any wall that doesn’t have enough exterior insulation to keep dewpoint and related condensation away from sheathing + cavity is higher risk.

- There are several walls that are safest from a moisture standpoint in all locations analyzed... Embodied energy? Local?

- Cellulose can be ‘safe’, as long as its kept dry in outer layers of cavity.

- PHIUS+ static compliance requirements may be met with a wall R-value lower than is needed to ensure hygrothermal safety, esp in MF.

- Double stud walls filled with cellulose are much more risky than all other walls studied for these locations.