Using Cellulose in Superinsulated and Passive House Construction, Lessons Learned

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Using these techniques, we can:

• Construct simpler building assemblies that are familiar to people in the trades.
• Reduce the heating /cooling loads enough to allow shifting of costs from the mechanical systems to the building envelope.
• Do this in a thoughtful way. If projects are designed in this manner from the start, they can be completed for about the same cost as non-super insulated buildings.

High Performance Buildings

<table>
<thead>
<tr>
<th></th>
<th>ICC 2012 Code Built</th>
<th>Super Insulation</th>
<th>Passive House*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walls</td>
<td>R-20</td>
<td>R-40</td>
<td>R-60</td>
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<tr>
<td>Ceiling</td>
<td>R-49</td>
<td>R-80</td>
<td>R-90</td>
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<tr>
<td>Foundation**</td>
<td>R-15</td>
<td>R-30</td>
<td>R-60</td>
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<tr>
<td>Slab **</td>
<td>R-10</td>
<td>R-20</td>
<td>R-60</td>
</tr>
<tr>
<td>Windows***</td>
<td>R-3.1</td>
<td>R-7</td>
<td>R-10</td>
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<tr>
<td>Air Leakage @50Pa</td>
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<td>1</td>
<td>0.6 (1)**</td>
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<td>HERS Rating</td>
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<td>30</td>
<td>20</td>
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<tr>
<td>Home Heating Index (Btu/Sqft / HDD)</td>
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<td>1.5</td>
<td>0.5</td>
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</tbody>
</table>

Notes: * Passive House R-values and air leakage numbers are site specific
**Foundation / Slab R-values are for under slab and for below grade wall areas
***Window R-values are for entire unit including the frame
****PHI EnerPHit Retrofit Standards

Why Cellulose Insulation?

• All borate cellulose:
  – Thermal performance is stable over time
  – Resists insects
  – Is compatible with all other building materials
  – Improves building durability due to the hygroscopic and anti-microbial properties
  – Is VOC compliant (NF & GF products)
  – Has a high recycled content, 85%
  – Low embodied energy and global warming potential
Loose-fill or Dense Pack?

- Loose fill cellulose for open attics and scissor trusses.
  - An approved ignition barrier over spray foam
- Dense pack cellulose for enclosed cavities:
  - is a code approved fire block
  - an excellent airflow and sound attenuator
  - a deterrent against pests
  - adds significant thermal mass to the building
  - dimensionally stable for the lifetime of the building

Hygroscopic v Hydrophobic

- Hygroscopic materials act as buffers that promote drying.
- Hydrophobic materials inhibit drying.

Vapor

- In mixed heating and cooling climates:
  - Wintertime: vapor is driven to the exterior
  - Summertime: vapor is driven to the interior
- In above grade assemblies, vapor retarding/barrier materials will be on the “wrong” side of the building assembly for part of the year and allow moisture buildup behind them.
- The most durable buildings are those that can dry in either direction.
- Always use vapor barriers in below grade assemblies.

Hygroscopic Materials

- The hygroscopic properties of cellulose allow moisture buffering and redistribution which protects the insulation and adjacent materials.
- Cellulose can be used in buildings with appropriate RH levels:
  - Without vapor retarders or barriers
  - In building cavities with non-insulated sheathing
  - In unvented roof assemblies
- Helps to stabilize interior humidity levels.
Moisture Testing Results

This data indicates that the rate of drying is higher than the rate of wetting for all types of exterior sheathing when the assembly is insulated with dense pack cellulose.

Progressive Density

- The density of the cellulose needs to correspond to the thickness of the cavity being filled.

Cellulose Specifications

- **Material**
  - National Fiber cellulose insulation shall contain an all borate fire retardant. Cellulose must comply with the CDPH/EHLB/Standard Method v1.1-2010 for Volatile Organic Compounds (VOC’s) and conform to ASTM C-739 and ASTM C-1149 standards.

- **Installation**
  - Cellulose insulation must be installed by a certified National Fiber applicator in accordance with manufactures specifications.
  - In flat attics: Loose-fill cellulose to provide the rated R-value and depth at manufacturers settled density.
  - In enclosed framing: Dense pack cellulose to a minimum installed density of 3.5 lbs/cuft using the tube insertion method.
  - Dry application in open wall framing: Dense pack cellulose behind Insulweb fabric to a minimum installed density of 3.5 lbs/cuft. Insulated areas to be rolled flat by installer after insulation.

*Installed density will vary according to cavity depth, consult Expanded Bag Coverage Chart.*
Airflow Attenuation

- Super efficient buildings require a dedicated air barrier.
- No matter what type of air barrier is used, dense pack cellulose will improve the performance of the assembly.
- Examples:
  1. 6,831 sqft new building with a fluid applied air barrier on the exterior sheathing:
     Pre dense pack 1450 cfm@50Pa,
     post dense pack behind Insulweb 870 cfm@50Pa;
     40% cfm reduction
  2. 2,500 sqft new building with an interior air barrier membrane installed:
     671 cfm@50Pa pre dense pack,
     234 cfm@50 Pa post dense pack;
     65% reduction

Super Insulated Buildings

- The goal is 1.0 ach@50 Pa for super insulated buildings and 0.6 ach@50 Pa for passive house buildings
- We have found that air sealing the building’s exterior sheathing or using exterior air impermeable fabrics are the most cost effective methods for achieving an air tight envelope.

When to Blower Door Test?

- Blower door test the building after the shell is weathered in (air tight), but just before the insulation work is started. This allows access to the framing and the air leaks.
- Use the back of your hand, an infrared camera, and/or fog machine to locate the air leaks.
- The most common air leak locations are the wall to foundation; wall to roof connections; and around windows and doors.
Air Sealing Products

- Need to be flexible for long term durability.
- Silicone based caulks work well for sealing cracks.
- Non-expanding canned foam from a foam gun or gaskets work best for cracks up to one and a half inches. When using foam to seal around windows/doors, install in several small lifts to improve performance.
- Spray foam can be used to seal wider cracks, but should not be sprayed in continuous large areas (over six inches in width) since it is not flexible enough to move with the building. Remember, spray foam is a line of sight product. “If you can’t see it, you can’t seal it.”
- A new generation of acrylic adhesive air sealing tapes are gaining popularity (Pro Clima Tescon Vana, Siga Wigluf, 3M 8067 or ZipWall Tape).
- Fluid applied air barriers such as Tremco Exo-Air 220R or 230 are also effective.

Air Sealing the Exterior Sheathing
Connecting the “Dots”

- Air seal all connections:
  - All sheet to sheet seams of OSB or plywood
  - Around each corner
  - The wall to the foundation
  - The wall to the roof
  - Into each of the window and door openings
- The air barrier fabrics need this same attention to detail!
- Pay particular attention to air sealing between dissimilar materials (i.e. exterior sheathing to foundation with primer and super tape).
- Don’t mix and match products. They are usually not interchangeable.
Air Sealing Existing Buildings

• A continuous/“perfect” air barrier is the goal.
• A discontinuous/“imperfect” (but good) air barrier is usually the reality.
• Exterior?
• Interior?
• In between?
• Transitions?

Locating Air Barriers For Superior Insulation Performance

• When using dense pack cellulose, the air barrier can be on either side of the assembly.
• The cellulose must be in direct contact with the continuous air barrier.

Use an Interior Vapor Control Air Barrier Fabric if:

• You expect wintertime relative humidity levels will exceed 60% for significant periods of time during the winter months.
• For retrofits, if you are not going to be able to air seal the exterior sheathing of the building, or you cannot get the building below 1.0 ACH@50 Pa before the insulation is installed.
• This allows you to blower door test before installing the insulation and drywall in buildings with an interior air barrier.
• May decouple the hygric buffer of the cellulose from the interior.
Cellulose Containment

- These fabrics allow you to see and/or feel the cellulose density behind them.
- Air Barriers: ProClima Intello Plus (interior) & Mento Plus (exterior), Siga Majpal 5 (interior) & Majvest (exterior), etc.
  - More expensive; the reinforced “plus” fabrics hold better with staples while the non-reinforced fabrics typically need to be strapped before dense packing.
  - Three inch air relief slits need to be cut into the fabric every four vertical feet on each edge of the cavity. These are sealed with the appropriate tape afterwards.
  - Air barrier fabrics tend to bulge and need to be strapped prior to insulating or rolled flat afterwards to allow for drywall installation.
- Air Permeable: Insulweb. Less expensive, translucent, does not bulge as much as the other fabrics.

Moisture Concerns in Basements Retro-fits

- Bulk water: Manage it.
- Water vapor and wicking: Minimize it.
- Source control is critical.
- Do not neglect this even if it’s “too expensive”.

Retro-fitting Basement Slabs

- Install a vapor barrier and insulation on top of the slab.
- Use multiple layers and stagger joints of high density EPS, Gutex, or Roxul ComfortBoard IS to achieve desired insulation value.
- Subfloor: 2 layers of 5/8 plywood or OSB with the joints staggered and screwed together with 1 ¼ inch deck screws.
Retrofitting Vented Crawl Spaces

- Build down floor joists with plywood gussets with a 2 x 4 at the bottom (Larsen Truss).
- Staple Solitex Mento Plus or equivalent to the underside of the truss; air seal along the edges.
- Install strapping 16 inches on center perpendicular to the floor joists.
- Install dense pack cellulose.
- Cover ground with a durable vapor barrier and ballast if necessary.

Foundations

- Foundation walls:
  - install a vapor barrier against the foundation (concrete/stone/etc.).
  - frame a 2 x 4 wall out from the foundation to the desired cavity depth.
  - dense pack the cavity to block thermal bridging through the footing.
- Moisture testing has demonstrated that the cellulose remains dry throughout the assembly.
Band and Rim Joists

- If the exterior air sealing does not encapsulate this area; air seal the wood to wood joints with a good flexible caulk.
- Attach fabric to the top of the wall, staple the other end up to the subfloor and staple the sides to the floor joists making a pouch for the dense pack cellulose.

Continuous or Separate Cavities?

- To establish bag counts for quality control purposes:
  - Wall cavities less than 12 inches deep, separate one wall from the next with Insulweb.
  - For cavities exceeding 12 inches deep, separate each bay with Insulweb.
  - Prefill cavities 50 – 75%, reset machine for dense pack and finish installing the cellulose with a two inch aluminum tube.
  - Concentrate on each of the cavity corners using a star pattern until you cannot easily push the tube back through.
Walls: Innie or Outie?

- In new construction or retrofit, building a double wall to the inside can be more cost effective and easier for framing crews to understand.
  - Air seal exterior sheathing plane.
- When retrofitting buildings with large overhangs build outward with Larsen Trusses, I-joists, or parallel chord trusses (R-44 = 12", R-60 = 16")
  - If the original sheathing is exposed, you can air seal that, otherwise use an moisture permeable air barrier fabric on the exterior.
- Don’t forget the rain screen details: tar paper or Typar with vertical strapping or polypropylene mesh.

Flat Ceilings and Raised Heel Scissor Trusses

- Most cost effective insulation option.
- Install the drywall.
- Use flush mount light fixtures, or if you must, IC air tight fixtures.
- Air seal all penetrations.
- Install loose fill cellulose. (R-80 = 21.5", R-100 = 26.5")
- Attic space above the insulation must be vented.
**Cathedral Ceilings**

- Size rafters for roof loads (use structural engineer) and then fatten down with plywood gussets and 2 x 4s (Larsen Truss); deep I-joists; or parallel cord trusses (R-60 = 16", R-80 = 21.5"). Separate rafter bays with Insulweb.
- Install Insulweb (unvented) or air barrier fabric (vented) to underside and strap ceiling horizontally every 16 inches on center.
- Pre-fill the cavity. When dense packing; insert the tube perpendicular to roof deck every 16 inches for each rafter bay or with multiple passes of the hose to build the density both laterally and vertically.

**Unvented Roofs**

- Unvented roofs work when the dense pack cellulose is installed to self supporting densities and is in direct contact with the underside of the roof sheathing.
- The air barrier can follow the exterior of the walls and the exterior of the roof. Sometimes the roof soffits are added on afterwards.
- Use tar paper or a moisture permeable roof underlayment with a perm rate of 20 or above.
- Light colored roofs can reduce summertime heat gain.
- Metal roofs are more reflective than asphalt shingles; Some colors are Energy Star rated.
- Installed density is critical, use an experienced installer.
Vented Roofs

- Venting can be helpful by reducing some summertime solar heat gain.
- For walls with an exterior air barrier, you will need to transition the barrier across the top of the walls to the interior to maintain continuity.
- Build down at least an inch and install moisture permeable venting baffles such as air impermeable fabrics or double wall cardboard supported every 8 inches along the center.
- Uninterrupted airflow from soffit up to ridge is a must.

Mechanical Ventilation

- A ventilation system is critical, short and straight duct runs are best for performance and cost.
- Use parallel cord trusses between floors to run HRV/ERV distribution system.
- Use separate bathroom fans and kitchen range hoods for source control of odor and moisture removal.

Our Top 40+ List

1. Insulate where you plan ahead.
2. Increase performance opportunities early in the process.
3. Minimize your building, as better buildings perform better.
4. Encourage your community to learn and build better.
5. Ventilate your building, as better buildings perform better.
6. Use high performance building materials, as better buildings perform better.
7. Insulate your building, as better buildings perform better.
8. Provide better ventilation, as better buildings perform better.
9. Build down at least an inch and install moisture permeable venting baffles such as air impermeable fabrics or double wall cardboard supported every 8 inches along the center.
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39. Use high performance ventilation tubes, as better buildings perform better.
40. Encourage your community to learn and build better.
Questions? Comments? Feedback?

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