Wall Assemblies

Where are we in the big picture
• Wall assemblies are complex but stand to be one of the most effective approaches to performance.

• Spray foam has a major role in this, but when will SPF get the true energy efficiency rating it deserves?

• Are wall assembly designs taking advantage of the increased strength potential of SPF?
Residential Walls
  – Retrofit
  – New Construction

Commercial Walls
  – The Perfect Wall

The Big Picture

High Performance Walls
  – Shear Strength
  – Air Sealing

Quirky Walls
  – Hybrid Walls
  – Inside-Out Walls

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Residential – New Construction

• Advantages
  – Air barrier material
  – Expands to fill cavities
  – High R-Value

• Challenges
  – Adequate thickness
  – Vapor control
  – Infiltration bypass
  – Dimensional stability

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Residential – New Construction

Wood Frame
Within \( \frac{1}{4} \)" of spec

Complete Air Seal Package

Electric boxes properly masked
Residential – New Construction

Steel Studs
Another way to fill wall cavities

PJT PANELS
Up to 250% increase in resistance to racking

SHEAR STRENGTH
Racking Test – Lateral Deformation

Empty Framing

Fiberglass, Cellulose and Open-Cell SPF Insulations

Closed-Cell SPF Insulation
Racking Strength With SPF

- **OSB: 2x4 steel 24" oc (3)**: 4800 lbs
- **drywall: 2x4 steel, 24" oc (3)**: 2400 lbs
- **plywood: 2x4 wood 16" oc (2)**: 2920 lbs
- **plywood: 2x4 wood 16" oc (1)**: 2890 lbs
- **vinyl: 2x4 wood 16" oc (1)**: 913 lbs

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Racking Strength With SPF

- **OSB: 2x4 steel 24" oc (3)**
  - With SPF: 4800 lbs
  - Without SPF: 6000 lbs
- **drywall: 2x4 steel, 24" oc (3)**
  - With SPF: 5380 lbs
  - Without SPF: 2400 lbs
- **plywood: 2x4 wood 16" oc (2)**
  - With SPF: 2920 lbs
  - Without SPF: 5300 lbs
- **plywood: 2x4 wood 16" oc (1)**
  - With SPF: 2890 lbs
  - Without SPF: 2800 lbs
- **vinyl: 2x4 wood 16" oc (1)**
  - With SPF: 913 lbs
  - Without SPF: 2800 lbs

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 Thermal Index
Wall Energy Rating

THERMAL PERFORMANCE
“The Thermal Index”
WER
Wall
Energy
Rating
NRC
Canada

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Wall – 1 FG Batt

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Table 4 Summary of WER calculations for WER-1 and WER-2

<table>
<thead>
<tr>
<th>Wall ID</th>
<th>Measured RSI $m^2.K/W$</th>
<th>Measured air leakage rate $L/(s.m^2)$</th>
<th>Derived factor of interaction $f_i$</th>
<th>$RSI_{wer}$ $m^2.K/W$</th>
<th>WER $W/m^2$</th>
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<td>WER-1</td>
<td>3.25</td>
<td>0.369</td>
<td>0.56</td>
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<td>29.7</td>
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<td>WER-2</td>
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<td>0.013</td>
<td>0.07</td>
<td>3.42</td>
<td>38.3</td>
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</tbody>
</table>
Figure 36 – Wall 2, Wall 5, and Wall 6 Air Transfer Rates in Watts
Be careful with hybrid systems in the north.

HYBRID WALLS
Potential problems with Hybrids

• When the ratio of ccSPF R-Value to fibrous insulation R-Value is too low, the assembly may not control condensation.

• Condensation generally occurs on the surface of the foam, not in the fiberglass or other fibrous insulation.

• Problems are often blamed on the foam when actually the assembly design and installation was at fault.
Potential problems with Hybrids

• Poorly executed Hybrid applications:
  – Improper design – Ratio is not correct
  – Lumpy foam
  – ccSPF sprayed too thin
  – ccSPF sprayed unevenly so fibrous insulation batts don’t fit the cavity.
Hybrid Insulation in Cold Climates Must Be Engineered

• We have seen several failures of hybrid insulation systems

• Air Permeable Insulation cannot control movement of moisture laden air to the condensing surface

Mold Growing in Batt Insulation

ccSPF very uneven and too thin to control condensation in places

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Hybrid Insulation in Cold Climates Must Be Engineered

Any Hybrid Insulation System in Zones 4C, 5, 6, 7 or 8 must be carefully engineered for condensation avoidance.

Mold Growing in Batt Insulation

ccSPF very uneven and too thin to control condensation in places

moisture laden air to the condensing surface
Adequate Attic Ventilation Must Be Maintained

ocSPF or ccSPF
Either works

Loose Fill Insulation added to Prescriptive R-Value

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Methods of Design

• WUFI
  – Pinpoint through-the-assembly hygro-thermal analysis modeling tool
  – Very powerful
  – Very complex
  – Requires high skill level

• Dew Point Method
  – Simple
  – Usually overly conservative

• Modified Dew Point
  – BSC method
  – Uses average temp of two or three coldest months to calculate outdoor design temp

• Experience
  – Could take years or decades for failure to occur or be seen
  – Variations in building materials can change performance dramatically
WUFI

- Developed by Fraunhofer Institute in Germany and Oak Ridge National Lab in the US.
- Currently the industry standard
- Highly documented
- Poor materials library

Example showing initial drying and year-over-year seasonal repeatability

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Dew Point Method

• Uses simple calculation, often based on 68°F indoor temp with 40% RH
• Psychrometric chart is used to find dew point

• If ASHRAE winter design temp is used, it’s often too conservative as this low temp rarely lasts long enough to actually allow condensation.
Psychrometric Chart
Psychrometric Chart

43° F Dew Point

68° F 40% RH

68° F Indoor

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Dew Point

• There are two ways of controlling condensation on the inner surface of the foam:
  – Reduce the water vapor concentration (Relative Humidity) in the interior air.
  – Design the assembly to have an interior foam surface temperature higher than the dew point of the interior air.

The dew point of the room air is reached when fog forms on windows or mirrors.

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Ratio of Hybrid

- 1” of ccSPF 4-1/2” of conventional, air permeable insulation at R-3.5 per inch
- Surface of foam is well below the dew point at 0°F outside and 70°F/40% RH inside
Ratio of Hybrid

- 2-1/2” ccSPF plus 3” of conventional, air permeable insulation at R-3.5 per inch
- Surface of foam is at the dew point at 0°F outside and 70°F/40% RH inside, and this is considered safe except in Zone 8 (Alaska)
COMMON PROBLEMS WITH HYBRIDS
Gravity

- Attaching the fibrous insulation to the spray foam is often very difficult.
- Over time the fibrous insulation will settle or pull away from the foam.
Vapor Retarders

• The building code requires interior vapor retarders in cold climates.
• The foam is a strong vapor retarder but it’s on the cold side of the assembly.
• Using a second vapor retarder on the interior side of the assembly can contribute to problems.
Lumpy foam and less than meticulous fiberglass installation leads to failure
Anything unusual in the wall cavity can cause problems.
RECOMMENDATIONS FOR HYBRID INSULATION SYSTEMS
Proper design

• Hybrids in DOE climate zones I – III are generally not a problem.
• Hybrid assemblies in DOE climate zones IV – VIII must be carefully engineered
• Attic hybrids where the insulation is applied to the floor of the attic are fine no matter the ratio.
• Better to use a full-filled wall cavity of ocSPF in most applications. Pay attention to vapor.
Proper Execution

• Foam must be as smooth as possible if batts are used. Blown-in (wet or dry) is better than batts.
• Pay attention to thickness.
• Consider using ocSPF and a vapor retarder. It’s one trade and product, not two.

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Follow the SPFA Best Practice Guides for Hybrids

- SPFA Technical Papers on Hybrids:
  - AY 146 Climate Zones I – III
  - AY 147 Climate Zones IV – VII
- Industry Vetted and approved.
RESIDENTIAL RETROFIT
Residential – Retrofit

- Walls are often the first thought for improving home performance.....but are they?
- Typically represent only 15-20% of heat loss.
If we stop the air leakage through the attic/roof system, we stop the coincident infiltration through the walls and window assemblies.
Residential – Retrofit

1. Seal the attic floor or roof deck first
2. Seal the crawlspace or floor next
3. Seal the wall penetrations, window and door assemblies last
Case Study - Kansas City Retrofit
The House- Before

• Typical 1950’s suburban Ranch on a daylight basement.
• No Insulation whatsoever in the 2x4 walls, rim-joist, or concrete foundation.
• Various types of blown in attic insulation over the years, most recently fiberglass was installed to R-30 in 2000 (According to the sticker in the attic)
The House Before

• Original single pane windows in good condition with average aluminum storm windows

• Approximately 1950 sq ft on the main level with a partially finished basement. Currently used for storage.
Issues

• West-facing back of Home was extremely hot during summer months, with the AC often running constantly to keep 76 degrees during afternoons.

• Attic temps over 150 degrees often til 4-5 AM in hottest months.
Spray Foam Can Help!
The business end of a 100k + Spray Foam Rig.
Blower Door Testing
Proper ventilation is mandatory in enclosed attic applications.
Removing 60 years of Insulation and filth from Attic.. A very DIRTY job!
Attic Vacuum and Bag
After all the prep works finished.. the easy part.
The Insulated Rim Joist
Prepping the interior for Wall injection

• All occupants of Home should be out for a minimum of 24+ hours. Ideally, 48 hours and reoccupy after home has been completely cleaned and dusted.

• Any loose drywall needs to be identified and screwed to studs 12” on center.

• All studs (and other framing) are marked with painters tape
Prepping the interior for Wall injection

• All outlets and switches on affected walls need to be pulled from box. Box is stuffed with Fiberglass and taped tightly to prevent Foam from coming through.

• Baseboards, window casings, ¼ round, crown moldings, wainscoting, paneling joints, and any other areas also need to be taped.
This wall was injected from the exterior since it is paneling. Painted cedar shake shingles will repair more easily than paneling.
This section of wall was also injected from the exterior due to the tile surround in the bathroom and inaccessible closets.
Studs marked before Plastic was draped over everything and holes were drilled.
After wall injection
After wall injection
Plan on a few Blow Outs. While rare among skilled Contractors, sometimes they are unavoidable.
Sealing from the Inside
Sealing from the inside
Sealing from the inside
Blower Door Results

CFM

Baseline 4460
Attic Foamed 3360
Rimjoist Foamed 2340
Walls Injected 2026

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The Blower Door numbers

• BEFORE 4460 CFM
• AFTER ATTIC 3360 CFM
• AFTER RIMJOIST 2340 CFM
• AFTER WALLS 2026 CFM
• That’s a 2,434 CFM improvement! We tightened this homes envelope by 53%.
PROS AND CONS

• PROS- Save $$$ on utility bills. Quieter, cleaner, more comfortable home, extend life of HVAC system

• CONS- Expensive. Invasive. Cost to repair and repaint entire outside walls of home. Must be out of house for several days at least.
The future of SPF

COMMERCIAL WALL ASSEMBLIES
Commercial – New Construction

Exterior
The Perfect Wall

- Cladding
- Control layers
- Structure

© buildingscience.com
Control Layers

• Air Barrier
• Weather Resistant Barrier
  (Rain Screen or Drainage Plane)
• Vapor Retarder
• Thermal Insulation
The Clever Wall

- Brick veneer cladding
- Drained and vented cavity
- Spray-applied closed-cell high-density foam (2 lb/ft³) water control layer (also air control layer, vapor control layer and thermal control layer)
- Concrete masonry unit wall
- Metal channel
- Gypsum board interior lining
- Latex paint
Bethke Elementary School – Nation’s First LEED For Schools Building

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1,000,000 Square Foot Airplane Factory
Why Insulate Outside?

• Excellent Hygrothermal Capacitance
  – Thermal and Moisture absorption and redistribution

• No Thermal Bridging

• Perfect Air Seal
Exterior Insulation
Retail Space
Retrofit Office Space
University Dormitory
Conventional Air Barrier Membrane

- Brick Ties Through Air Barrier
Cold Weather
Full-coverage application
Metal Application

Metal buildings sprayed on the exterior then covered by metal siding
Hospitals
Starship Project – Fort Leonard Wood, MO
Unusual but effective applications
Can you charge enough?

QUIRKY WALLS
120 Miles North of the Arctic Circle
No one makes money in the Spray Foam Business unless someone is pulling the trigger!

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