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Residential Exterior Wall Superinsulation Retrofit Details and Analysis

Thermal Performance of the Exterior Envelopes of Whole Buildings XI International Conference

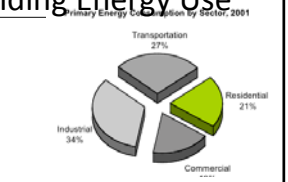
December 8, 2010

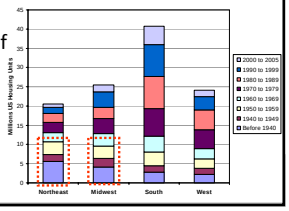
bsc Building Science Corporation

Buildings XI CONFERENCE DEC. 5-9, 2010 Clearwater Beach, Florida

Background/Building Energy Use

- Residential and commercial energy use
- 120 million housing units (current existing stock); 70% built before energy codes
- Greatest concentration of oldest housing stock in Northeast/Midwest (heating-dominated)





Exterior Insulation Retrofits

- Residential wood-frame walls
- Going beyond nominal R-13/R-19 walls (R-8/R-13 whole-wall R values)
- Exterior retrofit advantages
  - Insulation outboard of vulnerable structure
  - Interior is habitable during retrofit
  - Retain interior finishes (lose exterior finishes)
  - No loss in interior square footage
  - Can inspect condition of enclosure (during cladding removal)
  - Exterior stairwells (code minimum widths)

Previous Work (Exterior Retrofits)

- Insulation exterior to structure well-established technique (Hutcheon, Baker and Makepeace, Lstiburek, CCHRC)
- Dumont & Orr "Chainsaw Retrofit" 1987 (R-40+ enclosure; 3.0 ACH 50→0.3 ACH 50)
- ORNL 2007 hot box & airtightness measurements of exterior insulation; included foam up to 1" thick (10-15% energy savings)

Overview of Case Study Houses

Concord, MA
"Four Square"

Single family house
2800 + 800 sf
circa 1915

Local energy-conscious general contractor

All new mechanicals

Arlington, MA
"Duplex"

Duplex (over/under)
1280 + 1800 + 1280 sf
circa 1930

Local energy-conscious general contractor

Retained steam system

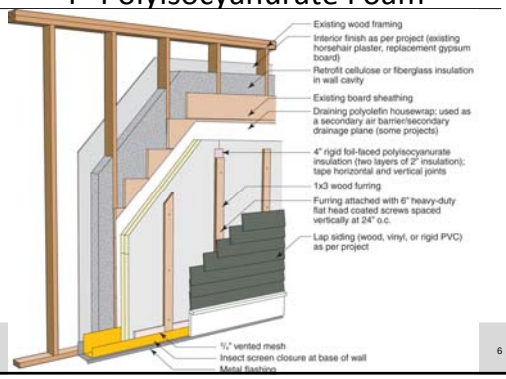
Bedford, MA
"Farmhouse"

Single family house
1500 + 1060 sf
circa 1850

Habitat for Humanity (volunteers & technical high school)

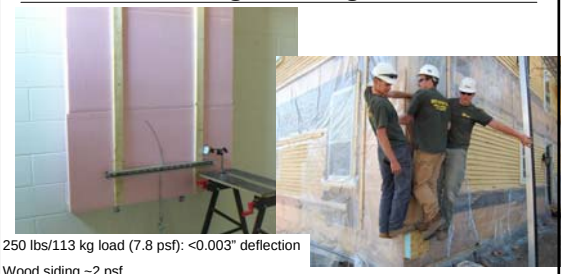
All new mechanicals

4" Polyisocyanurate Foam



Arlington Duplex Retrofit

Foam Sheathing Cladding Attachment

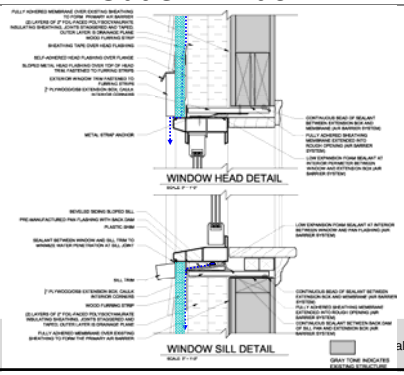


250 lbs/113 kg load (7.8 psf): <0.003" deflection

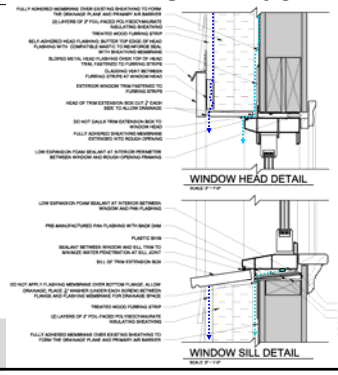
Wood siding ~2 psf
Fiber cement 2-3 psf
Stucco 8-10 psf

"Innie" and "Outie" Windows

"Outie" Window



"Innie" Window



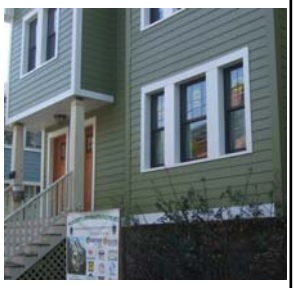
Recommend placing drainage plane at window location (whichever method used—innie or outie)!

"Innie" vs. "Outie" Windows

- "Outie" Advantages
  - Simpler drainage plane connections/geometry
  - Lower cost (extension trim is interior material)
  - Similar appearance to conventional construction
  - Simpler window replacement

"Innie" vs. "Outie" Windows

- "Innie" Advantages
  - Window supported by lumber frame (foam install)
  - Greater protection from wind-driven rain (inset)
  - Less condensation risk (?)
  - Thermal performance (?)
  - Can use existing window trim
  - Solar shading (advantage or disadvantage)



Retrofitting Exterior Air Barriers



Concord, MA "Four Square"	Arlington, MA "Duplex"	Bedford, MA "Farmhouse"
3.1 ACH 50	5.0 ACH 50	6.2 ACH 50
Mechanical penetrations, porch attachments, replacement sash windows	Basement compartmentalized? (1000 CFM 50 vs. 2129 CFM 50 total)	No secondary air barrier (housewrap w. connections); mediocre roof-wall connections

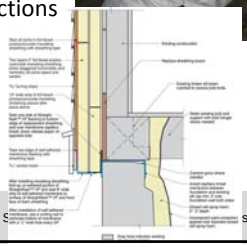
Retrofitting Exterior Air Barriers



St. Agatha, ON	Utica, NY (NYSERDA)	Belmont, MA
~1 ACH 50	2.3 ACH 50	0.9 ACH 50
Spray foam on exterior; all windows well air sealed; casement/ awning typical	Rigid air barrier layer under foam/over board sheathing; spray foam roof-wall & bsmt rim joist (non-"chainsaw")	Rigid foam as air barrier, "chainsaw" retrofit of roof overhangs/eaves, meticulous air barrier, blower door tests in progress

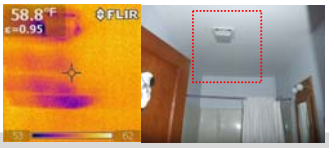
Retrofitting Exterior Air Barriers

- Roof-wall connections
- Wall-foundation connections
- Wall-window connections
- Windows (actual units)— installation flaws?

Retrofitting Exterior Air Barriers

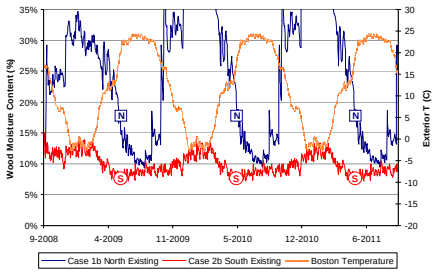
- Structural attachments
- Mechanical system penetrations
- Trades knowledge?

Retrofits and Water Intrusion

- Generally improves wall durability
  - Rebuilt drainage plane; redundant layers
  - Ventilated drainage gap (3/4" cavity)
  - Reduced risk of interstitial condensation
- Reduced vapor permeability due to foam
  - Reduced drying to exterior of bulk water events
  - Reduced airflow → reduced drying?
- Hygrothermal simulations of "survivable" leak in pre- & post-retrofit walls
  - Limited applicability—"bounding exercise"

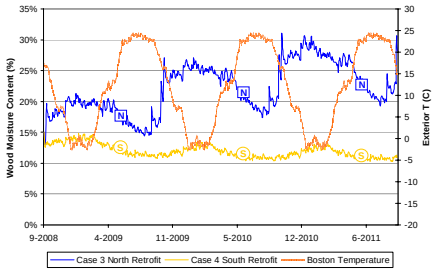
"Survivable" leak (Existing Wall)



0.5% incident rain penetration ≈ 20-25% peak north MCs

1% incident rain penetration ≈ 35-40% peak north MCs → "unsurvivable" leak

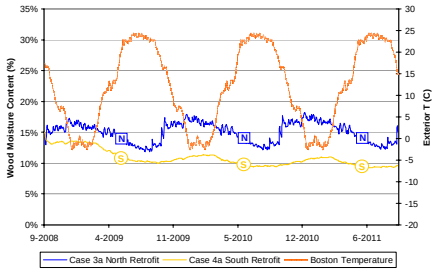
0.5% Leak in Retrofit Wall



0.5% incident rain penetration → upwards "ratcheting" wood MCs

Previously survivable leak becomes "unsurvivable"

0.25% Leak in Retrofit Wall



Reducing rain leakage to half (0.5% → 0.25%) keeps wood MCs stable; same range as existing wall. Rain control critical for retrofits.

More permeable exterior rigid insulation? XPS→ minimal. EPS → Improvement

Economic Analysis

- Diminishing returns at greater insulation levels
- Original analysis $4/gallon → $2.50-$3.50/gal
- $4/sf incremental cost of opaque wall upgrade not including recladding costs
- Airtightness as part of calculated energy benefit

Oil $		Install cost	Annual Savings	Simple Payback	Payback w/o airtight
$2.50	Inner 2"	$8,200	$510	16	25
$2.50	Outer 2"	$4,100	$118	35	59
$4.00	Inner 2"	$8,200	$816	10	15
$4.00	Outer 2"	$4,100	$188	22	37

Conclusions

- Excellent opportunity for retrofit during periodic exterior cladding replacement
- Air barrier detailing and technology can use improvement; examine more options
  - Fully adhered membrane
  - Exterior spray foam
- Impermeable exterior insulation reduces available drying

Questions?

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Building America SM U.S. Department of Energy

DOER Massachusetts Department of Energy Resources

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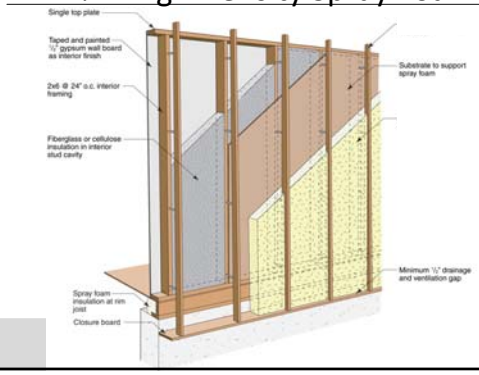
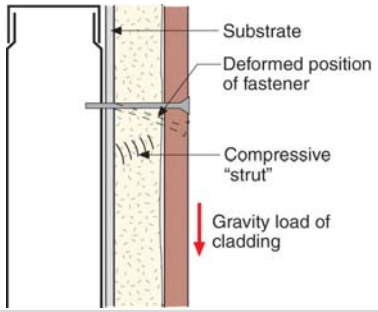
4-½” High Density Spray Foam



Cladding Support over Foam



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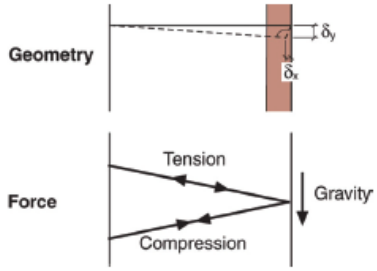
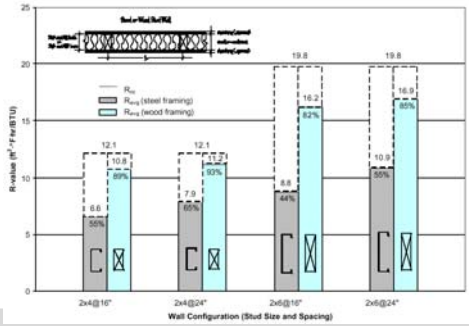


Nominal vs. Actual R Value

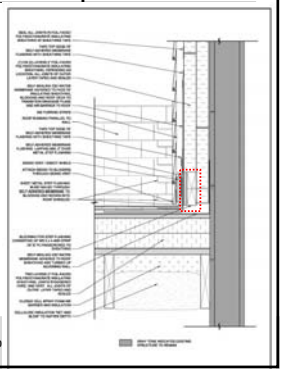


Taped Sheathing Air Barrier

New England Region Modular PassiveHaus: 0.7 ACH 50

Arlington Duplex Retrofit

Exterior Retrofit Complications



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