Building a Better Wall

[Support from DOE Building America Program]

EEBA: High Performance Home Summit
October 10, 2017

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Introductions

- Patricia K. Gunderson
  - Sustainability Research Engineer
  - P.E., LEED AP BD+C, CPHC
  - Home Innovation Research Labs
- Patrick H. Huelman
  - Cold Climate Housing Coordinator
  - NorthernSTAR Project Lead
  - University of Minnesota

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Audience Poll

Raise your hand if you‘re a…

- Builder
- Program manager
- Home rater/energy prof
- Manufacturer/supplier

IF you're builder, then are you building to…

- Energy Star
- Net-Zero ready
- LEED, NGBS, Passive House

Wall System: Desired Outcomes

- Easy to Build
- Cost Effective
- Energy Efficient
- Durable
- Comfortable
- Readily available
- Healthy
- Resilient

The Modern Enclosure Conundrum

Build it to avoid every kind of moisture.	But imperfections happen in design, execution, and operation!!!

- It gets wet from outside in and inside out!
- Therefore, all moisture susceptible materials must be able to dry in the proper direction.
  - – that can be outward in winter; inward in summer
  - – except below grade, which can only dry inward.

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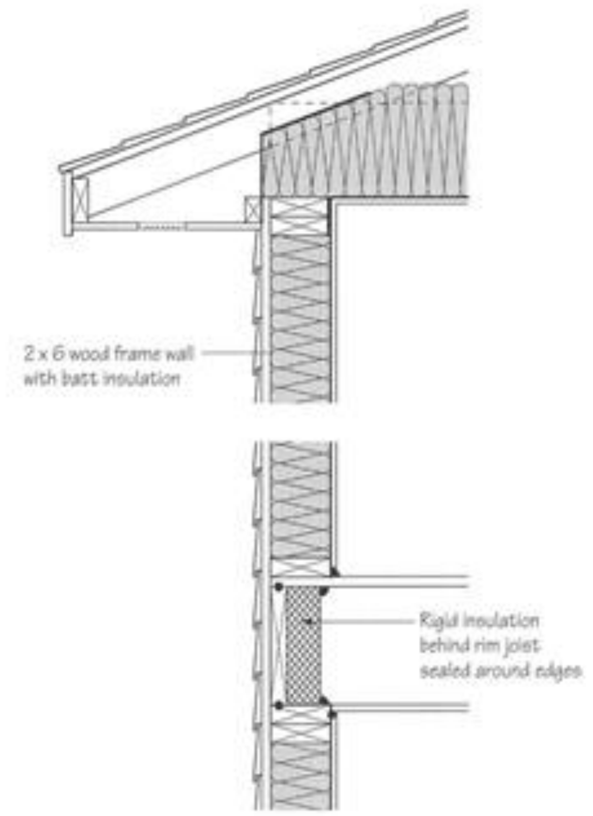
The Modern Enclosure Conundrum

- Has the traditional 2x6 cavity wall hit the end of the road?
  - Too little thermal insulation
  - Too little drying potential
    - in cold and/or humid climates
  - Too risky / not robust
    - requires high-end execution



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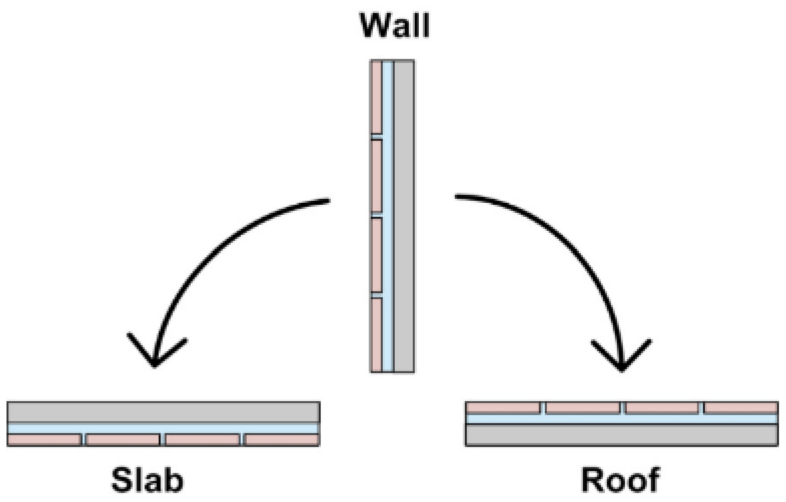
The Modern Enclosure Conundrum

- The Risks Go Way Up With …
  - Poor exterior bulk water control
  - Cladding that is not drained & vented
    - especially for reservoir claddings
  - Significant air-conditioning use
    - increased and longer use
    - lower indoor temperature and RH

High-Performance Enclosures

- A New Approach for …
  - Walls
  - Roof
  - Slab
  - Foundation



- Move the structure to the inside and move the control layers to the outside …
  - It simply works and works everywhere!!!

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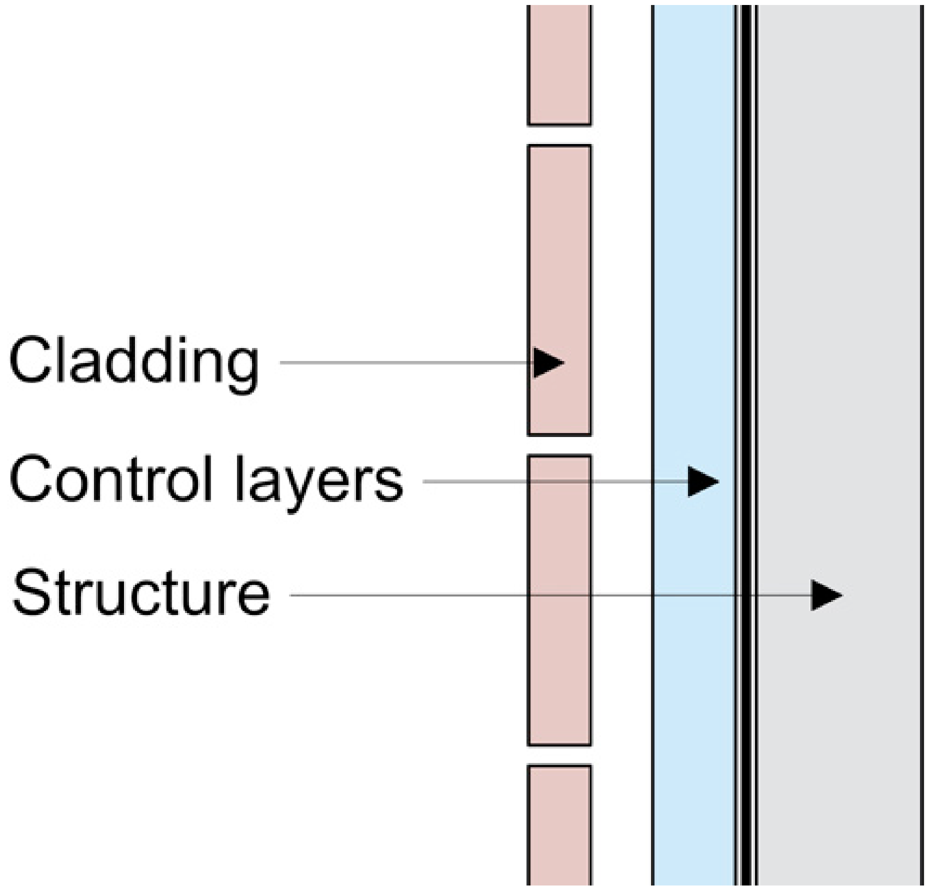
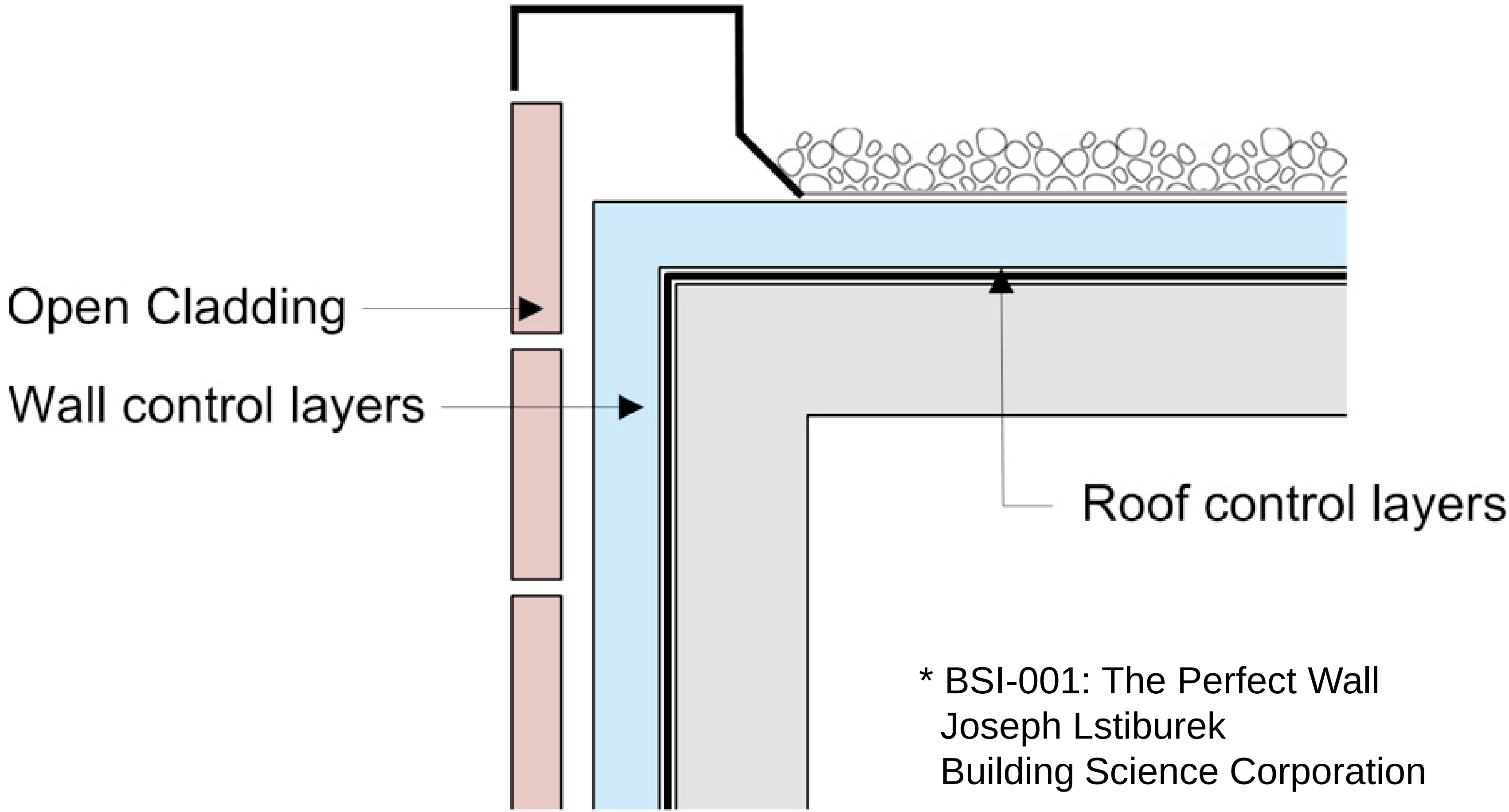
The “Perfect Wall”*



* BSI-001: The Perfect Wall
Joseph Lstiburek
Building Science Corporation

Connections Are Critical, Too!



* BSI-001: The Perfect Wall
Joseph Lstiburek
Building Science Corporation

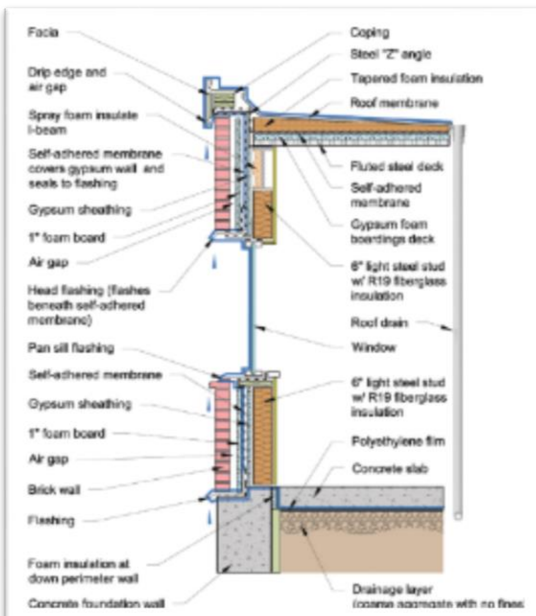
The 4 Control Layers

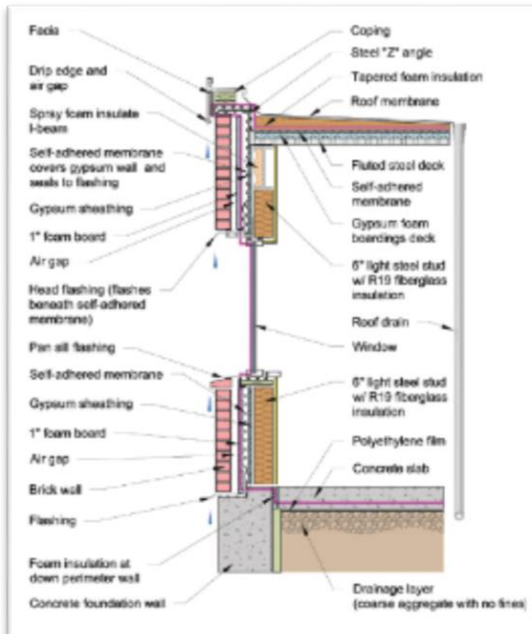
- Every enclosure element must have four control layers …
  - Water control
  - Air control
  - Thermal control
  - Vapor control

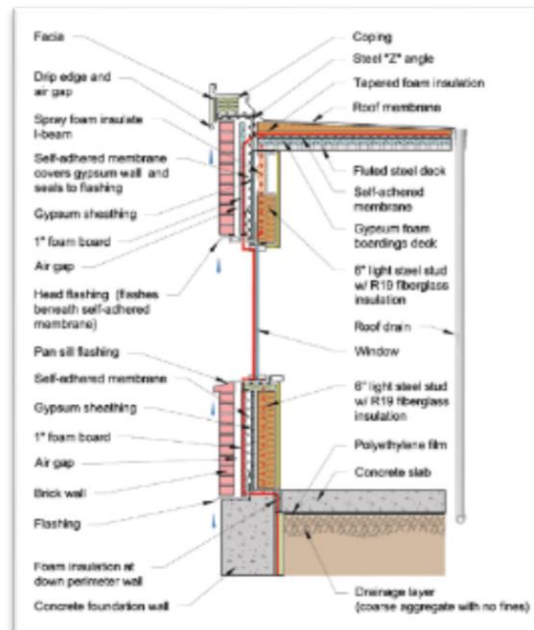
The 4 Control Layers

- Take the time to examine your schematics …

Apply the pen line test…







Water Control Layer(s)

- General Overview
  - The intent is to keep water from reaching any moisture susceptible layers.
    - Primary drivers are gravity, wind, capillarity.
    - You can (should) take steps to reduce the drivers.
- This is absolutely essential,
  - especially as we remove drying potential with increased insulation, reduced air flow, and multiple vapor retarders!

Water Control Layer(s)

- Theoretical Framework: 3 D's
  - Deflect
  - Drain
  - Dry

Air Control Layer(s)

- General Overview
  - The intent is to keep air from moving across the building enclosure carrying heat and moisture to locations that can create problems.
    - Primary driver is air pressures.
    - You can (and must) manage the pressure differences.
- This is absolutely critical in modern construction.

Air Control Layer(s)

- Where does it belong?
  - Inside
  - Outside
  - In between
  - Both

- In the past, it was generally thought the air control layer should be on the inside for cold climates and outside for hot-humid climates.

Thermal Control Layer(s)

- Goal: slow the transmission of thermal energy
  - The drive is from warm to cold
  - Defined by indoor and outdoor conditions
  - Temperature difference (delta T) defines the potential
- This is the easy one – R-value!
  - How much?
  - Where?
  - What type?
  - Geometry governs – weighted area

Vapor Control Layer(s)

- Goal: control vapor diffusion through wall materials.
  - The drive is from moist to dry
  - Defined by indoor and outdoor conditions
  - Vapor pressure difference defines the potential
- Pay special attention in …
  - Very cold climates
  - Hot humid climates
  - High humidity environments
    - Follow code requirements

Vapor Control Layer(s)

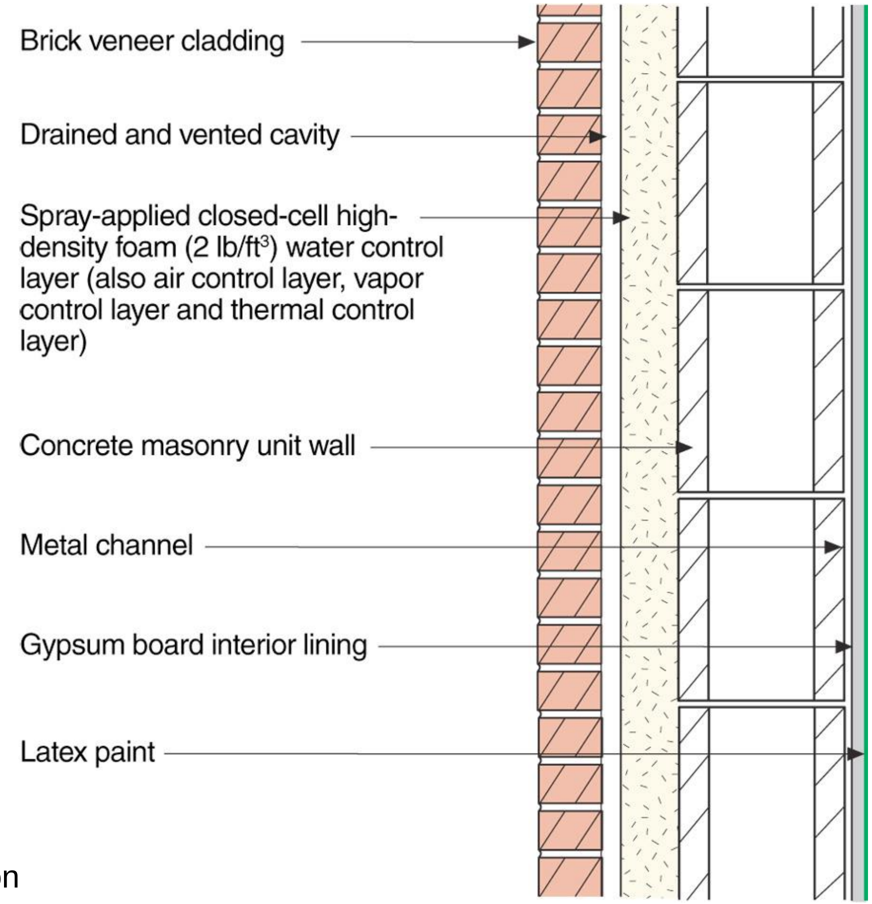
- This is more of a strategy than a specific layer.
  - Higher potential vapor drive requires more care
  - The prevalence of air-conditioning means sometimes you must manage vapor from humid outdoors.
  - There must always be a clear drying direction
    - If anything gets wet, the only possibility for drying is by vapor diffusion

Vapor Control Layer(s)

- Theoretical Framework
  - Class 1 = < 0.1 perm "impermeable"
  - Class 2 = 0.1 to 1.0 perm "semi-impermeable"
  - Class 3 = 1.0 to 10 perm "semi-permeable"
  - Class 4 = > 10 perm "permeable"

- Follow local code
- Consider a variable-perm material, like "smart" vapor retarders or kraft facing

It’s Not That Complicated
(Cladding/Drainage/4 in 1 Control Layer/Structure)



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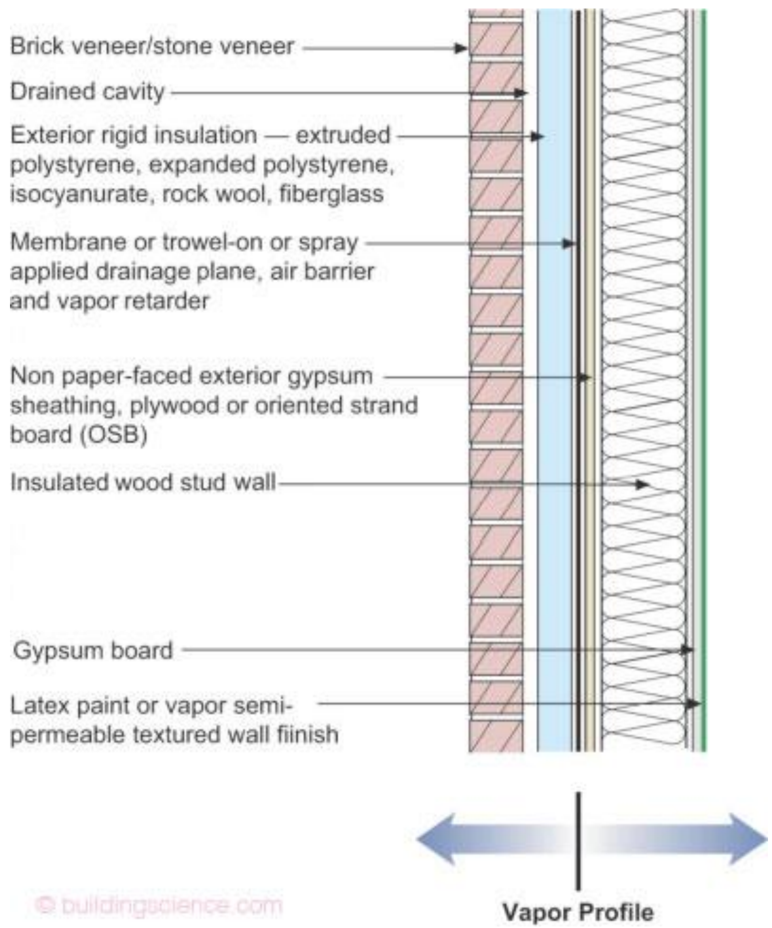
A Residential Variation



* BSI-001: The Perfect Wall
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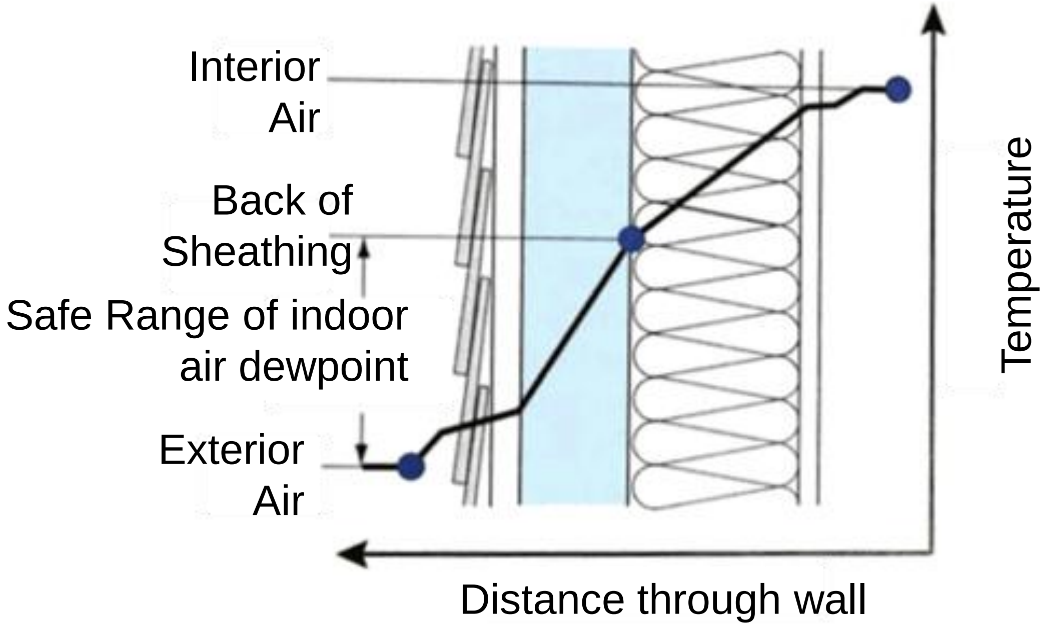
How Much Exterior Insulation?

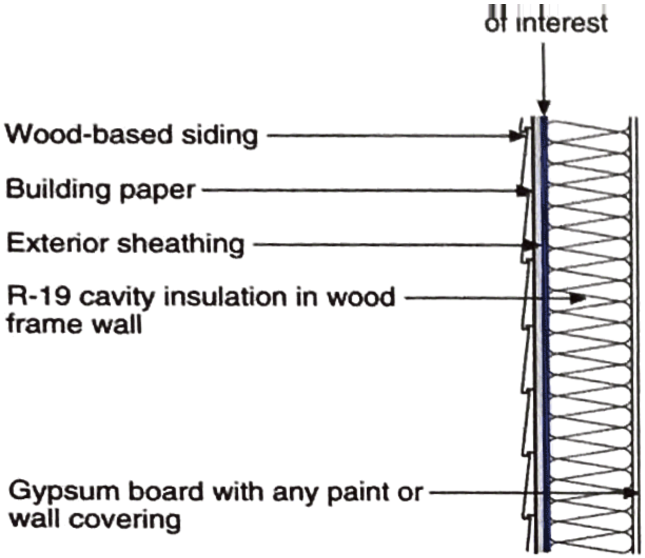
Thermal resistance (and boundary temps) govern the temperature of the surfaces within the assembly layers.

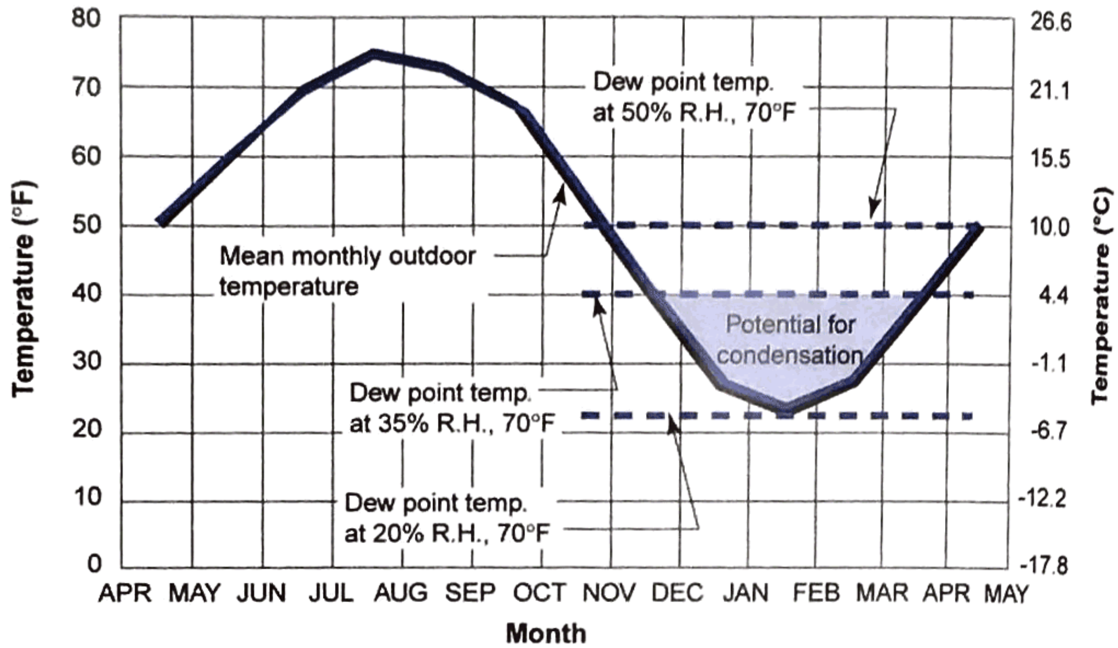
$$T_{back\ of\ sheathing} = T_{interior} - (T_{interior} - T_{exterior}) \times \left(\frac{R_{batt}}{R_{total}}\right)$$



Condensation Potential

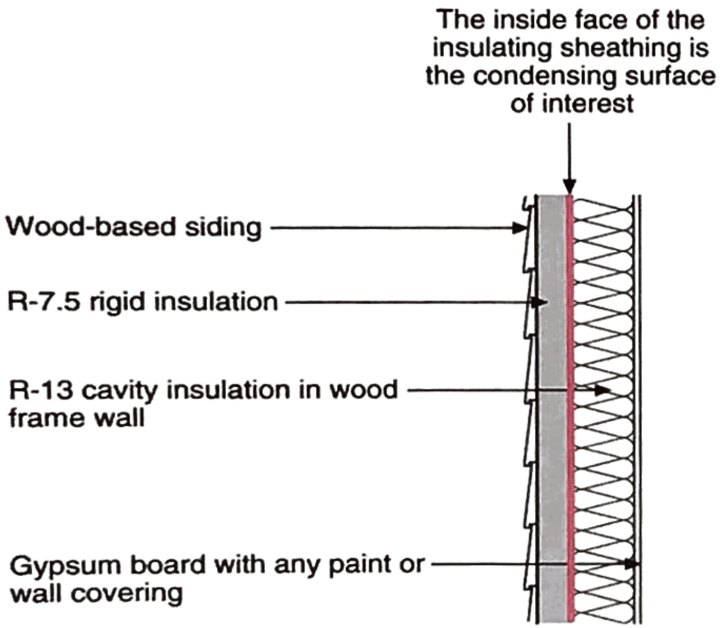
- Typical 2x6 cavity insulated wall in Chicago, IL

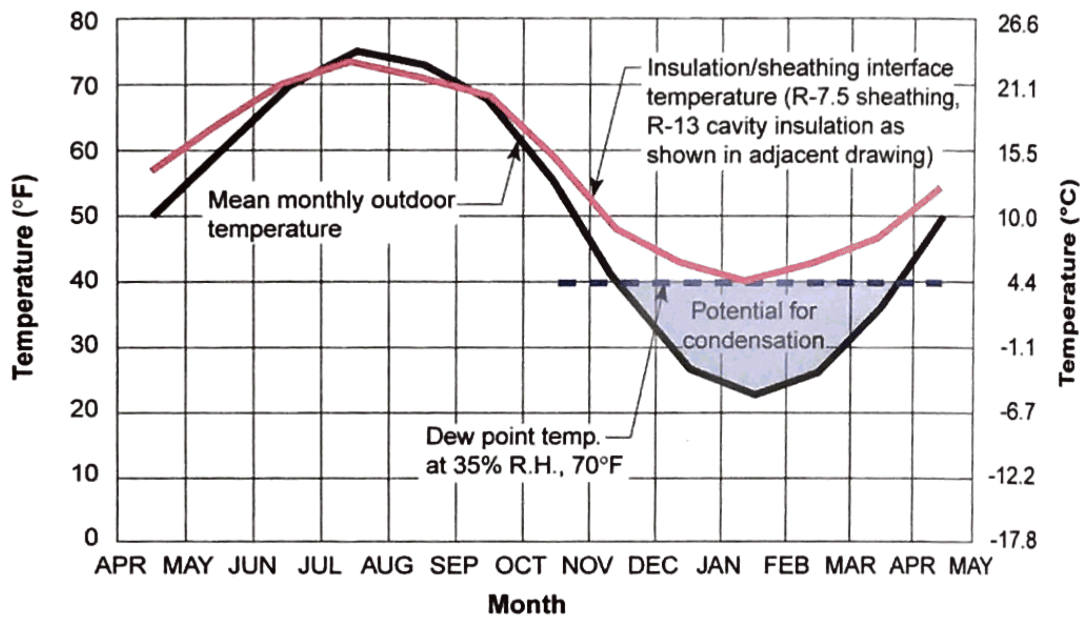




Condensation Potential

- 2x4 cavity insulated wall w/ R-7.5 in Chicago, IL





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Ratio of Exterior to Interior R-Value*

(Heating season vapor drive and condensation potential)

Indoor		RH	20	25	30	35	40	50	60
Dew point		°C	-3.0	0.0	2.5	4.7	6.6	9.9	12.7
		°F	26.6	32.0	36.6	40.5	44.0	49.9	54.8
$T_{outdoor}$	°C	°F							
	0	32	0.00	0.00	0.12	0.23	0.32	0.47	0.60
	-5	23	0.08	0.19	0.29	0.37	0.45	0.57	0.68
	-10	14	0.23	0.32	0.40	0.48	0.54	0.64	0.73
	-15	5	0.33	0.42	0.49	0.55	0.60	0.69	0.77
	-20	-4	0.41	0.49	0.55	0.60	0.65	0.73	0.80
	-25	-13	0.48	0.54	0.60	0.65	0.69	0.76	0.82

Note that higher interior relative humidity combined with lower outdoor temps (larger delta T) requires more exterior insulation.

* High Performance Enclosures: John Straube, 2012

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Extended Plate & Beam Wall System

EEBA, Atlanta, GA

October 2017

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EP&B: *Overview of Presentation*

- The Problem
  - Why are existing solutions not good enough?
- The Solution
  - How does it meet industry's needs?
  - What are the advantages?
  - What performance targets must it meet?
- The Research
  - Constructability
  - Structural Lab Testing
  - Moisture Monitoring
  - Cost Comparison
- Summary
  - Recommendations and Design Guidance

The Problem

- Need for energy efficiency
  - Stricter code requirements
  - Rising energy costs
- Lack of market penetration for High-R walls
  - Cost
  - Complexity
  - Training
  - Manufacturer resistance
  - Low market adoption for exterior c.i. (~11%, residential, all thicknesses) and SIPs (< 5%)
- Need a basic option that can perform and be flexible (field-framing and panelization)

A Solution: EP&B

Interior view

Exterior view

High-R walls with
rigid foam insulation interior to the
wood structural sheathing

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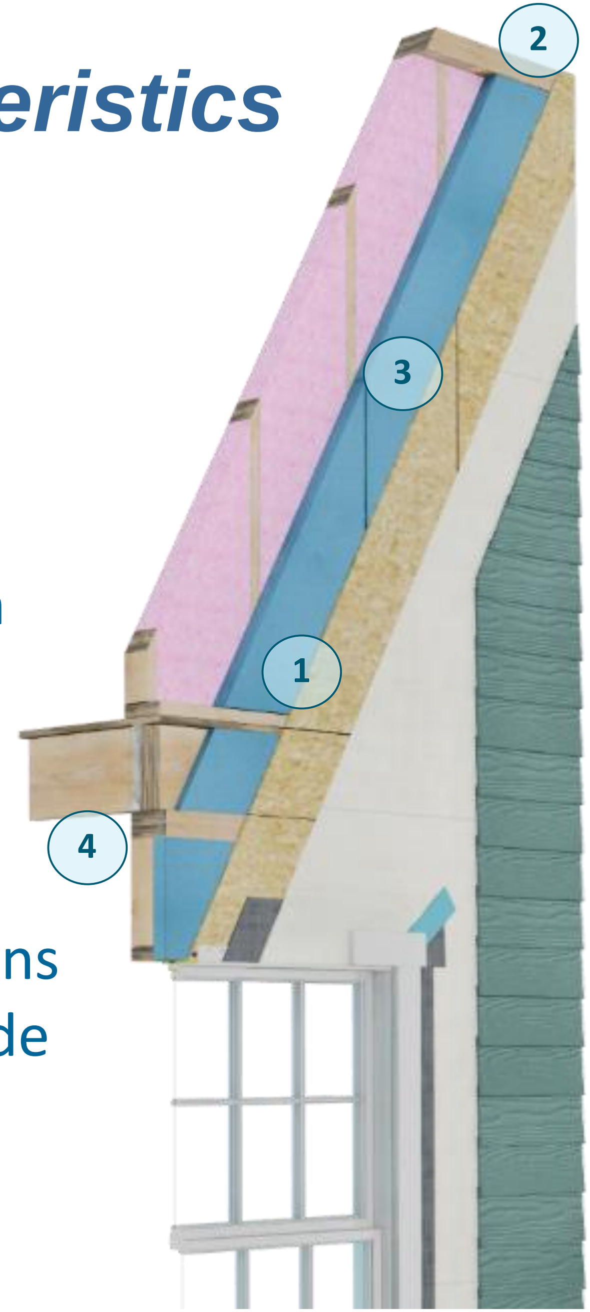
EP&B: *Characteristics*

1. The bottom plate is one dimension larger than the studs.

2. The top plates are one dimension larger than the studs.

3. There is a layer of rigid insulation in the two-inch space between the stud framing and OSB sheathing.

4. Double rim board (beam) functions as a header, and is inset to provide space for a continuous insulation thermal break



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EP&B: *Control Layers*

Water –

- WRB, shingle-applied, fastened to OSB sheathing

OR

- Treated OSB sheathing detailed properly (liquid-applied or taped seams)

EP&B: *Control Layers*

Air –

- Rigid foam and framing, sealed as described, performs as the air barrier in addition to the vapor barrier

OR

- WRB, taped to itself and to transition members

EP&B: *Control Layers*

Thermal – two layers of insulation

- Rigid foam (1) protects cavity fill (2)
- Extended plates constitute <5% thermal bridge
- Can perform as the air barrier in addition to the vapor barrier

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EP&B: *Control Layers*

Vapor – Two lines of defense:

- Rigid foam, sealed with caulk or ccSPF, is a distinct, centrally-located vapor control plane with effective drying to the direction from which the source moisture originated – exterior to the exterior and interior to the interior.

- Variable or Class II interior vapor retarder recommended in cold climates and any building with high indoor humidity: Kraft or "smart" vapor retarders
  - avoid a dual vapor retarder condition: HI recommends against poly sheeting or a Class I vapor retarder
  - follow local code requirements

EP&B: *Advantages*

- Suitable for use in all climate zones
- Flexible configurations to achieve above-code thermal performance even in CZ 8
- 95% of the wall area is free of thermal bridging
- Estimated cost: comparable to exterior c.i., $/sf of wall; in some cases $0.50 to $1.00 less than a comparable code wall with exterior c.i.
- Can be panelized for packaged delivery to the site

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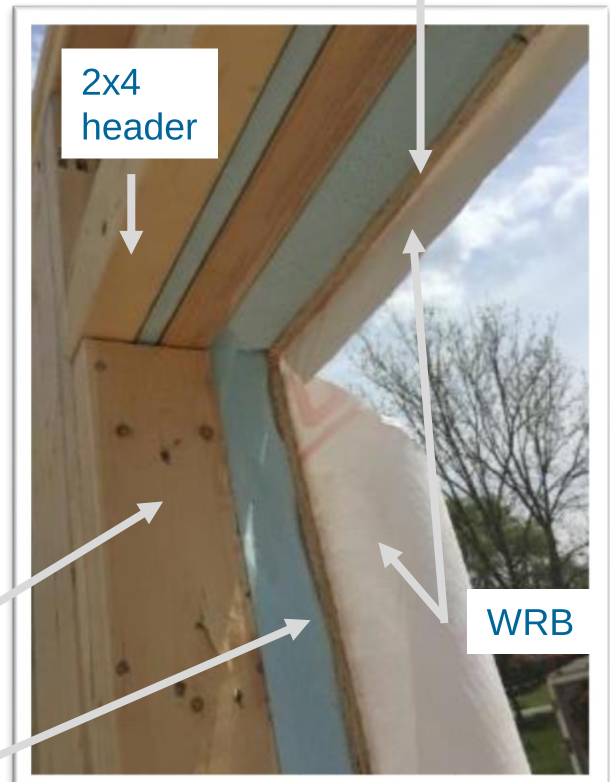
EP&B: *Advantages*

- Standard framing and air sealing techniques
- Relies on extended bottom and double top plates for wood structural panel attachment
- Uses standard nails in a common fastening schedule (3-1/2-in @ 3/6)
- Exterior OSB allows conventional methods for
  - Drainage plane treatment
  - Window installation
  - Cladding attachment



EP&B: *Advantages*

Exterior OSB allows use of IRC Table R703.3.2

APPLICATION	NUMBER AND TYPE OF FASTENER	SPACING OF FASTENERS[b]
Exterior wall covering (weighing 3 psf or less) attachment to wood structural panel sheathing, either direct or over foam sheathing a maximum of 2 in. thick.[a] Note: Does not apply to vertical siding.	Ring shank roofing nail (0.148" min dia.)	12 in. o.c.
	Ring shank nail (0.148" min dia.)	15 in. o.c.
	#6 screw (0.138" min dia.)	12 in. o.c.

[a] Fastener length shall be sufficient to penetrate back side of the wood structural panel sheathing by at least 1/4 in. The wood structural panel sheathing shall be not less than 7/16 in. in thickness.

[b] Spacing of fasteners is per 12 in. of siding width. For other siding widths, multiply "Spacing of Fasteners" above by a factor of 12's, where "s" is the siding width in inches. Faster spacing shall never be greater that the manufacturer's minimum recommendations.

Instead of the complexity of Tables R703.15.1 and 703.15.2

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The Research: Test Homes: *Grand Rapids, MI*

Finished houses appear conventional with clean sight lines

Two EP&B Test Homes: *Grand Rapids, MI*

Once the EP&B walls are up, finish and detail just as you would a typical light-frame wall

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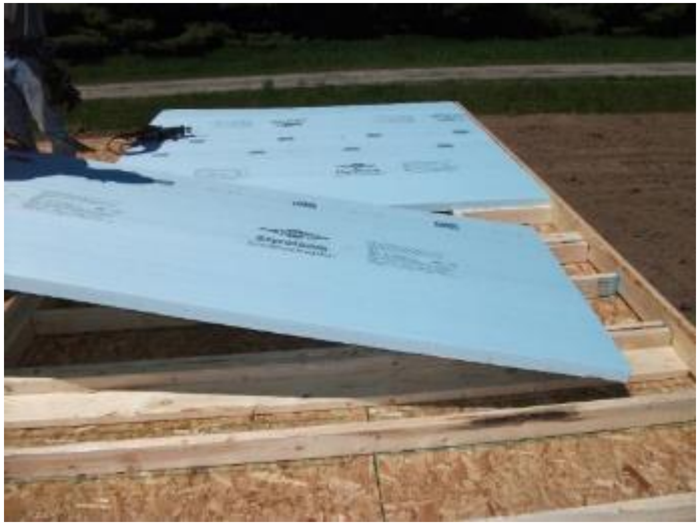
Two EP&B Test Homes: *Building the Walls*



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Two EP&B Test Homes: *Detailing*

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Observation: *tips and tricks*

- Caulk or spray foam all connections and transitions (or tape WRB as air barrier)
- Stagger sheathing joints and maintain thermal breaks at corners
- Control nailing angles at sheathing joints

- Pay attention to connections between factory-produced panels (not specific to EP&B!)

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EP&B Construction Guide: *Draft*

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EP&B Construction Guide: *Sample Pages*

Planning: Insulating Rigid Foam Layer

A table saw or circular saw is best for vertical cuts (rips) in the rigid foam sheathing that provides the thermal break. Cross-cut the foam to fit between the plates using the table saw; cut to match the full length of the studs. Consider the kerf and ensure that the rigid foam will be snug; 90-degree cuts avoid gapping. Lay the pre-cut rigid foam into place between the top and bottom plates, atop the studs. Don't worry about a small bow in the rigid foam—the OSB will be stiff enough to overcome that, once it is nailed on.

Behind headers and cripples, take advantage of scrap foam pieces, and tack them into place with a few cap nails. All rigid foam joints should land on studs.

In the EP&B configuration, the foam sheathing installed on the interior side of the OSB provides a distinct, centrally-located vapor control plane with effective drying to the direction where the source moisture come from – exterior to the exterior and interior to the interior. To ensure this layer is uninterrupted, used manufacturer-approved tape (such as DOW Weathermate) to seal all seams between rigid foam panels and where they meet framing at the top and bottom plates. Check the spec sheet to make sure the tape is approved for use on wood. A single line of 2-7/8-in. tape at the top of the wall can seal both the foam/plate connection and the plate/plate connection. Taping the seams adds a level of protection where interior vapor drive is higher, such as winter conditions in climate zones 6, 7, and 8. Fully detailed taping also allows the rigid foam layer to serve as the air barrier.

Precutting lengths of rigid foam is preferred, but if you do have to trim foam in place next to an extended plate, be sure to adjust the guide plate of the circular saw to ensure you do not cut into the lumber below.

A table saw trims 2-in. rigid foam cleanly, with little waste or debris.

Measure and cut rigid foam for a snug fit between the EP&B wall's top and bottom plates.

ALTERNATE. If you do not have a table saw on site, you can use a circular saw to cut the rigid foam sheathing in place atop the walls. Lay the foam onto the wall, snugged to the bottom plate and overlapping the top plates. Use a few cap nails to hold the FPIS in place, then snap a chalk line along the top edge coincident with the bottom of the first top plate. Use a circular saw to cut away the excess foam. Take care to set the guide plate for 2-in. depth and seat the guide of the saw flat against the foam's surface for a square cut to ensure a snug fit when the foam is pressed into place between the plates and against the studs.

Cap nails can keep the rigid foam in place until the OSB is fastened over the top.

Adjust the height of the circular saw blade to protect the framing.

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Planning: Wood Structural Panel (WSP)

For required structural bracing to match the performance of the IRC prescriptive wall, the OSB must always be oriented vertically – no horizontal joints are allowed. All OSB and rigid foam joints must occur at studs, but not at the same stud – plan your sheet placement to avoid the occurrence of an OSB seam at the same stud where two sheets of rigid foam meet. Butt rigid foam joints tightly together, but provide the typical 1/8 in. gap when installing OSB (a 10p box nail works great).

When building a single long wall in two sections that will be attached once the walls are tipped up, plan for the overlap of the rigid foam and OSB, to maintain the staggered vertical joints (two photos, bottom left).

For the first two walls, generally the long walls at opposite sides of the building, you can fully complete all wall layers (including rigid foam and OSB) while the wall is laying flat on the floor deck. When building the perpendicular short walls, plan your outside corners to maintain the thermal break, which probably means leaving some gaps in both the rigid foam and the OSB, to be filled in after the wall is erected.

Plan your cheat: if the pre-cut studs are at 92-5/8 in., the raw wall height with three 2x plates will be 97-1/8 in. A 4x8 sheet of plywood is 95-7/8 in. x 47-7/8 in., which makes it 1-1/4 in. short. You can apply that entire gap at the top and fasten to the first top plate (rather than the second top plate) for structural bracing, or you can split the difference by leaving a 5/8-in. gap at both top and bottom.

OSB sheathing must always be oriented vertically, for structural bracing.

Two adjacent sections of wall must be planned to stagger the vertical joints of the rigid foam and OSB.

Two adjacent sections of wall must be planned to stagger the vertical joints of the rigid foam and OSB.

ALTERNATE: A third option for OSB placement vertically is to do what the Grand Rapids framing crew did. The first floor rim was 10 in. engineered lumber inset from the outside plane to accommodate 1 in. of continuous insulation. To simplify air-sealing at the rim band, our crew designed the walls so that the OSB would lap the sole plate and extend down across the rim; this required using 9 ft. OSB and some care during tip-up.

The bottom edge of the OSB can be nailed to the sill plate, completing the bracing connection. Additional nails at the sole plate can be much less frequent. This technique can be used even if the pigtail of OSB does not extend all the way down to the sill plate for connection. The structural connection will then be made at the sole plate, as usual, and the lap over the rim is non-structural, but useful for air-sealing. Occasional nails through the CI into the rim band keeps the connection tight, and a ripper can be added at the bottom to support the siding.

EP&B Construction Guide DRAFT December 2016

EP&B Construction Guide: *Sample Pages*

Snap chalk lines and drill holes.

Sink the circular saw to catch the first drill hole; do not overcut at corners.

Remove OSB.

Cut corners of remaining rigid foam with a hand blade or reciprocating saw.

Remove the foam from the opening.

Window and Door Openings

Removing both the rigid foam and the OSB in a single operation is the preferred method, saving time and effort. Double check that your penciled notes for window and door openings will still be visible on the top face of the second top plate once the OSB is placed and nailed. Lay the OSB over the rigid foam and attach with 3-1/2-in. nails. Economize by using foam scraps at header and cripple locations. Snap chalk lines at all vertical and horizontal opening edges.

CIRCULAR SAW: The cleanest cuts with the least debris will be made with a circular saw. A 7-1/4-in. blade is required to cut the full depth of the 2-in. rigid foam and the 7/16-in. OSB. Drill all four corners and snap chalk lines. Start the saw a few inches from the drilled corner and sink the blade into the OSB. Follow the chalk line on all four sides. Cut the OSB all the way to the drilled corner, but do not overcut – the short sections of rigid foam in each corner can be removed later with the 4-in. blade or a reciprocating saw. Follow similar steps if using a track saw.

ROUTER: Use a 4-in. (or longer) pilot panel bit with a self-driving tip and a cutting depth (flute) of at least 2-3/4 in. Punch through each opening near a corner and use the 2x framing below the rigid foam as a guide. A long bit with a solid guide head is necessary to reach the full depth and seat against the 2x4 so the path will be true. A router creates more debris than a circular saw.

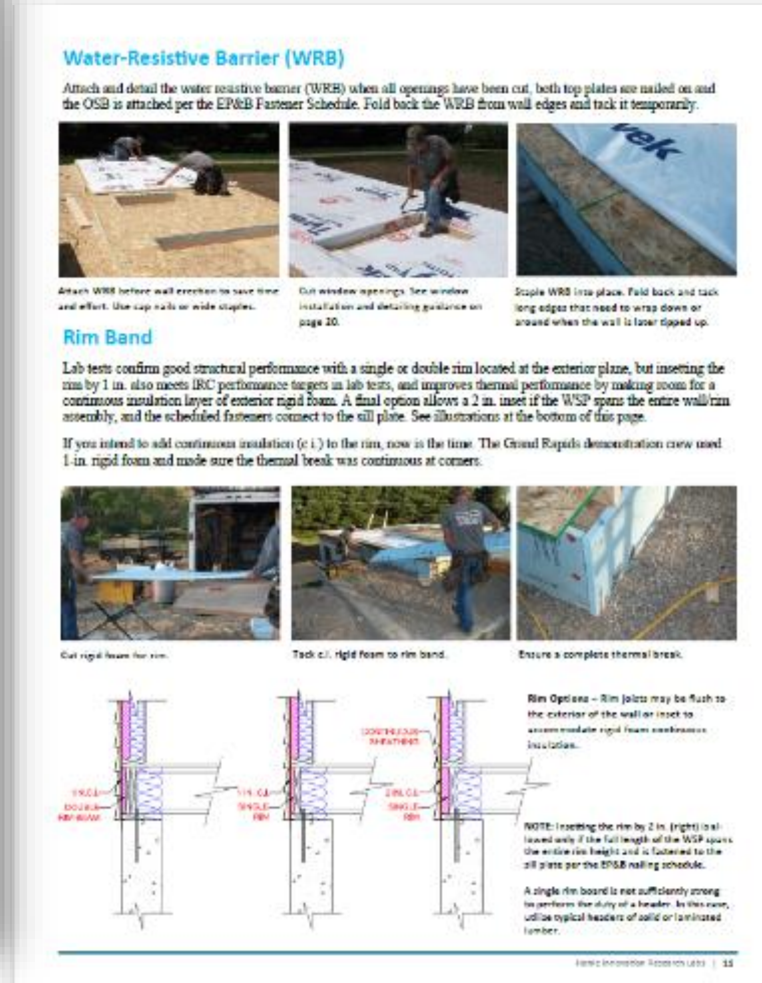
ALTERNATE: Two Separate Steps. Cut the rigid foam first with a reciprocating saw, and then make a second pass with the circular saw to cut the OSB. This is more time-consuming, but has the advantage of providing some limited view of the framing, and is thus more forgiving. With practice, this can be done with very little time taken for measurement.

Once the rigid foam is in place and before laying in the OSB, cut the openings out of the foam with the reciprocating saw. Use the 2x4 framing to guide the saw's path – this is done both by eye and by feel. Although the cut is not crisp, it's clean enough to provide a good connection to the wood framing, if you keep the blade perpendicular and don't remove too much material. Initially, you'll guide the saw along the 2x4 by feel. Once the foam rectangle is removed from the opening, you may need to tidy up some edges. Then lay in and nail on the OSB, and snap your chalk lines. Use a circular saw set to 1/2-in. depth. Having already removed the rigid foam, once the first opening is made by the circular saw, you'll be able to see the 2x4 framing below, and use that as an additional visual guide.

Use the 2x4 framing to guide the reciprocating saw to cut out FPIS.

Sweep away debris and lay in OSB, careful to stagger joints vs foam.

Nail OSB at top and bottom plates and use circular saw to cut OSB at opening.



Water-Resistive Barrier (WRB)

Attach and detail the water resistive barrier (WRB) when all openings have been cut, both top plates are nailed on and the OSB is attached per the EP&B Fastener Schedule. Fold back the WRB from wall edges and tack it temporarily.

Attach WRB before wall erection to save time and effort. Use cap nails or wide staples.

Cut window openings. See window installation and detailing guidance on page 20.

Staple WRB into place. Fold back and tack long edges that need to wrap down or around when the wall is later tipped up.

Rim Band

Lab tests confirm good structural performance with a single or double rim located at the exterior plane, but insetting the rim by 1 in. also meets IRC performance targets in lab tests, and improves thermal performance by making room for a continuous insulation layer of exterior rigid foam. A final option allows a 2 in. inset if the WSP spans the entire wall/rim assembly, and the scheduled fasteners connect to the sill plate. See illustrations at the bottom of this page.

If you intend to add continuous insulation (c.i.) to the rim, now is the time. The Grand Rapids demonstration crew used 1-in. rigid foam and made sure the thermal break was continuous at corners.

Cut rigid foam for rim.

Tack c.i. rigid foam to rim band.

Ensure a complete thermal break.

Rim Options – Rim joists may be flush to the exterior of the wall or inset to accommodate rigid foam continuous insulation.

NOTE: Insetting the rim by 2 in. (right) is allowed only if the full length of the WSP spans the entire rim height and is fastened to the sill plate per the EP&B nailing schedule.

A single rim board is not sufficiently strong to perform the duty of a header. In this case, utilize typical headers of solid or laminated lumber.

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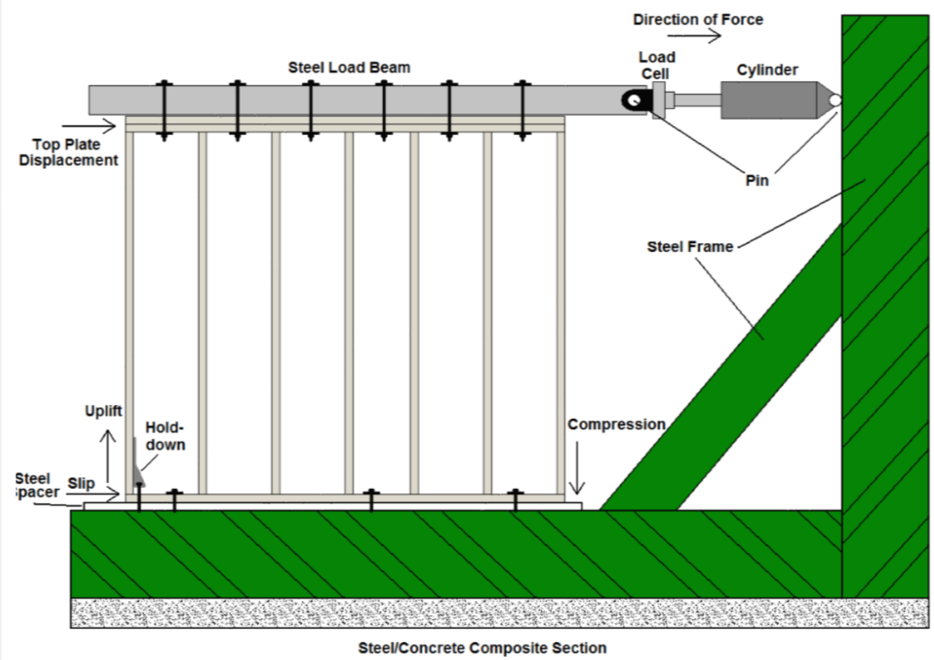
EP&B: ***Status***

- Shear wall testing results:
  - Calculated Allowable Design Racking Shear Load Value is 256 lbs/ft. (plf)
  - AC269.1 2013: demonstrated IRC braced-wall equivalent
  - Meets baseline performance for both intermittent and continuous braced wall performance
  - Code language will be proposed to the IRC to include EP&B as a prescriptive braced wall

Structural Testing: *Braced Walls / Shear Walls*



- Avg maximum unit shear load: **857 lbs/ft**; exceeds the **560 lbs/ft** target by **53%**
- Engineered Design: Allowable Racking Shear Load Value: **256 lbs/ft**

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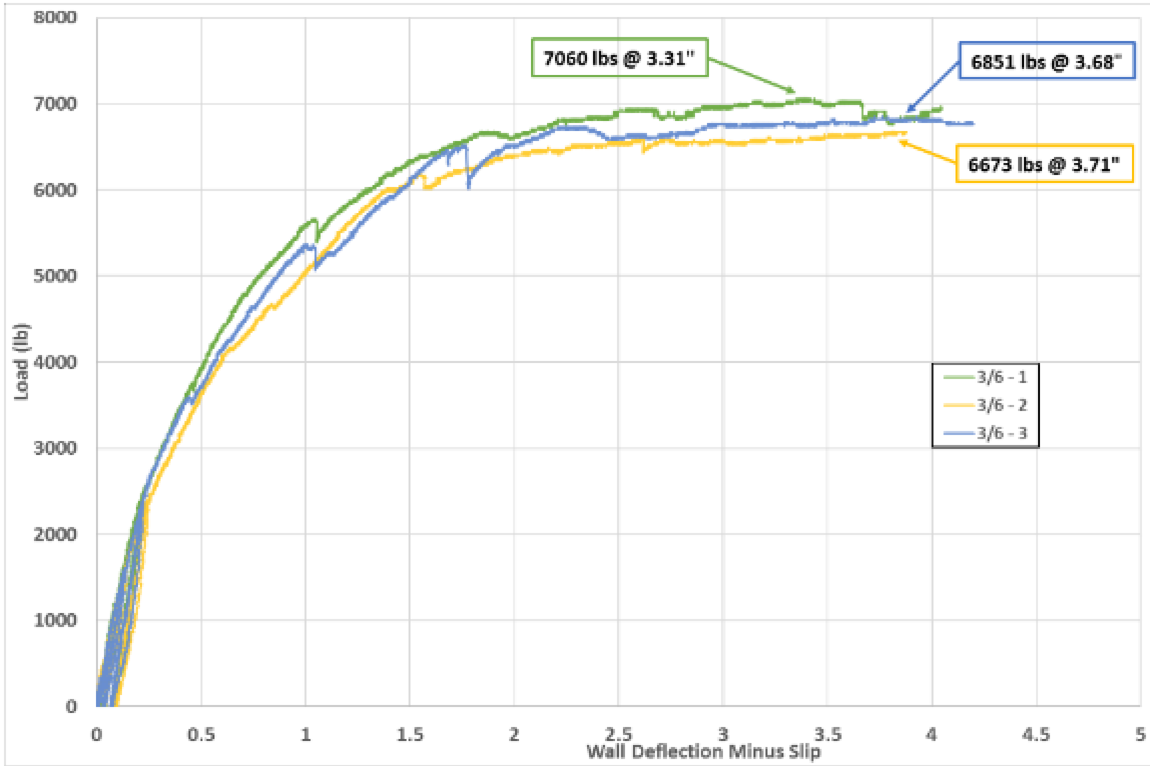
Intermittent Braced Walls: *AC269.1 / ASTM E72*



Wall Type	Max Shear Load (lb) (Peak)	Net Defl at Peak Load (in.)	Unit Shear, lbs/ft (plf)	Deflection at 23% load	Deflection at 46% load	Deflection at 200 plf	Deflection at 400 plf
AC269.1 Criteria:	*>4,480*	*>0.75*	*>560*	*<0.2*	*<0.6*	*<0.2*	*<0.6*
EPB 3/6-1	7,060	3.35	882	0.134	0.353	0.127	0.348
EPB 3/6-2	6,673	3.77	834	0.134	0.386	0.139	0.409
EPB 3/6-3	6,851	3.73	856	0.135	0.336	0.135	0.352
EPB 3/6-Average	6,861	3.62	858	0.134	0.359	0.127	0.348

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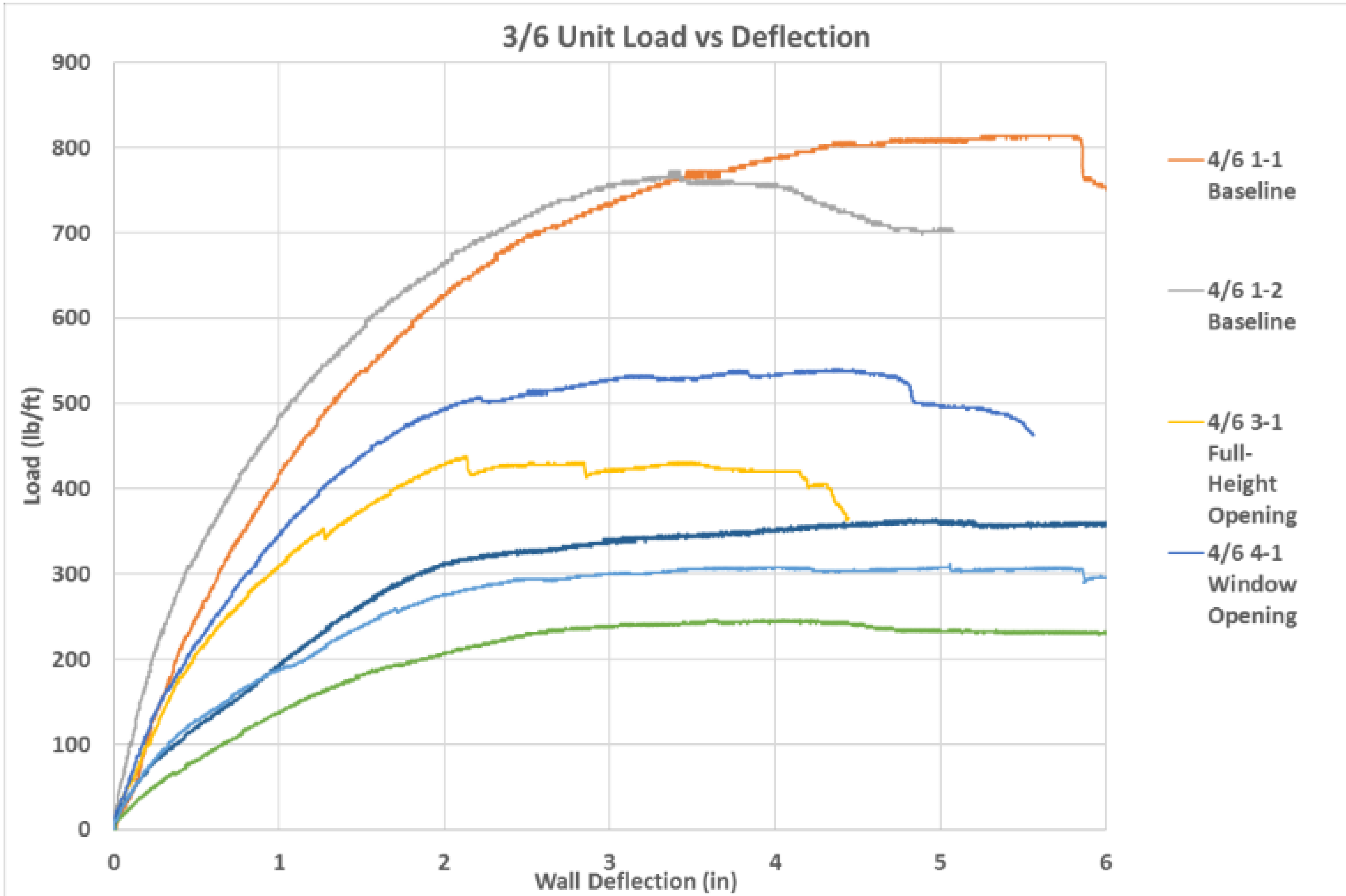
Continuous Braced Walls: *AC269.1 / ASTM E564*



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EP&B Moisture Data: *Two Test Houses*

Generally – accepted threshold indicating potential for moisture risk is 20% MC.

- 60+ sensors monitor moisture content and temperature in Studs, Plates and OSB
- RH and Dewpoint of various locations within the wall are tracked
- Average peak OSB moisture content less than 15%, well below accepted levels of risk

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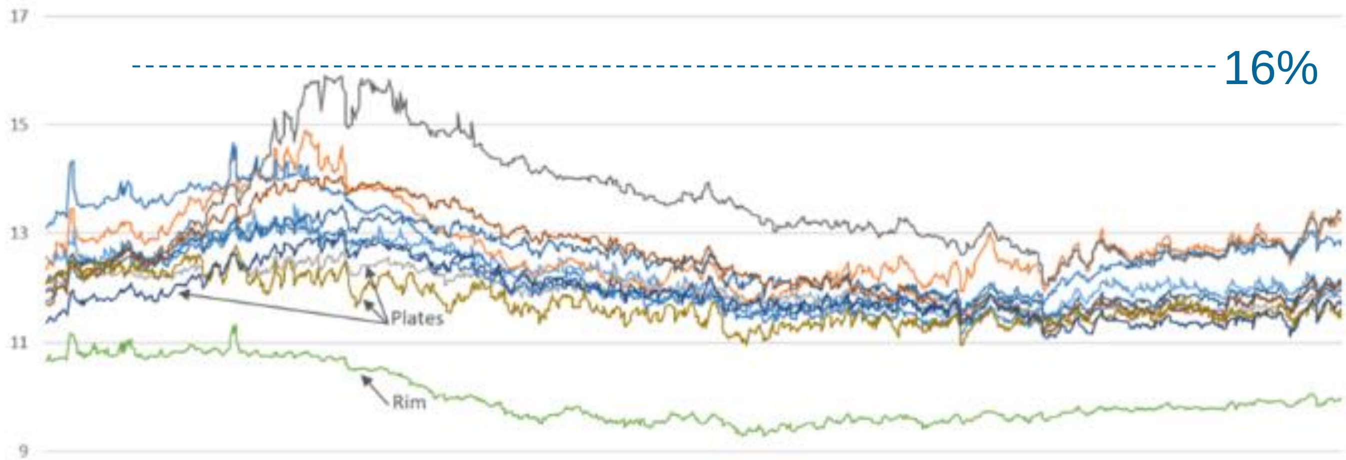
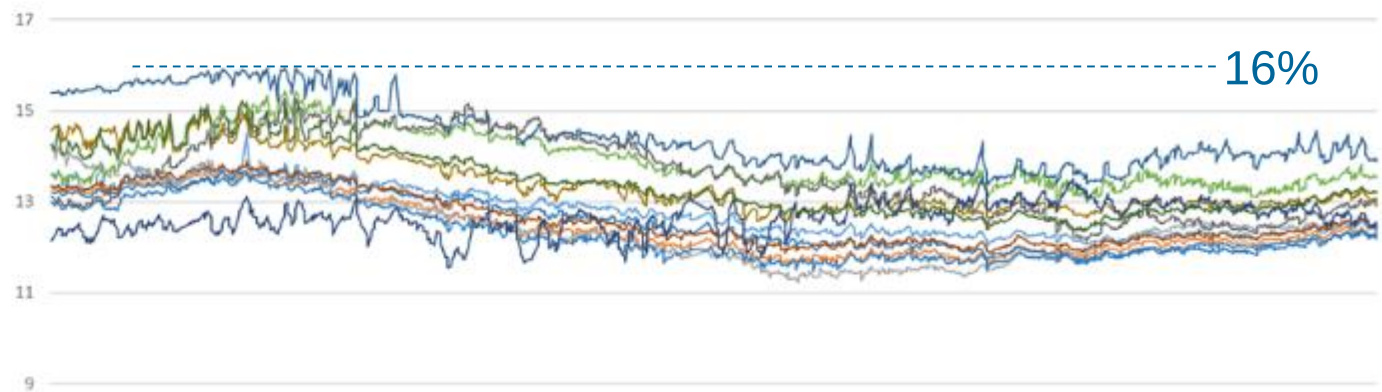
EP&B Moisture Data: *Two Test Houses*

August 2016 to August 2017: Framing ≤ 16% MC

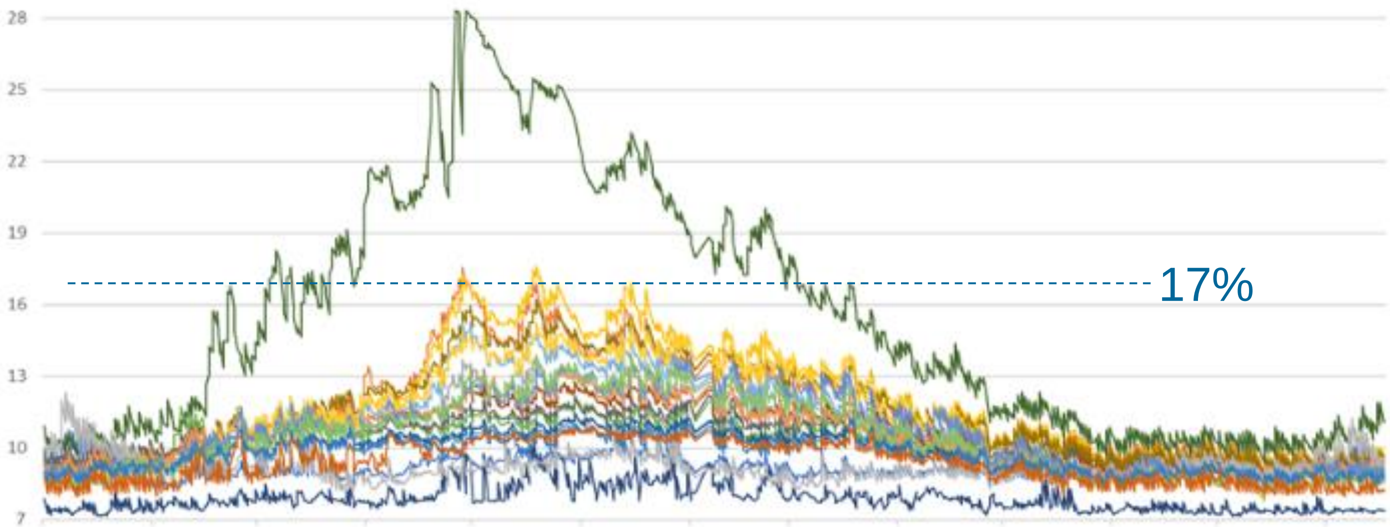


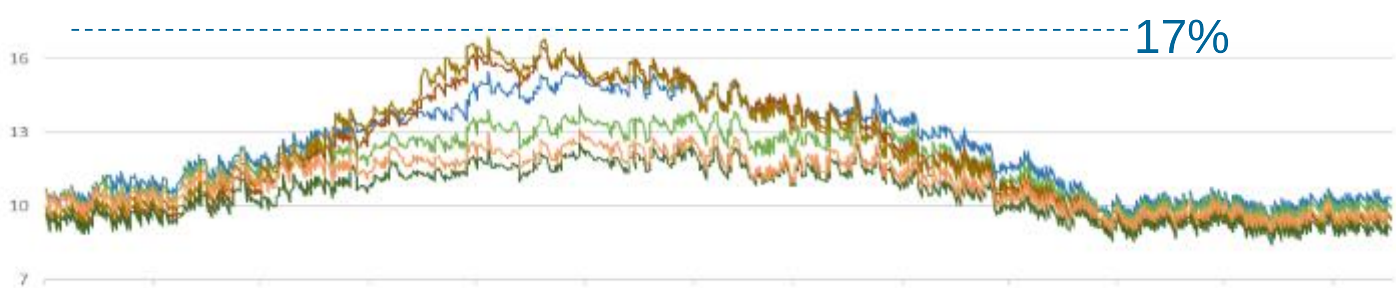


Good moisture performance for framing with both ccSPF flash and blown fiberglass AND R-15 Kraft-faced fiberglass batts

EP&B Moisture Data: *Two Test Houses*

August 2016 to August 2017: OSB ≤ 17% MC





Good moisture performance for framing with both ccSPF flash and blown fiberglass AND R-15 Kraft-faced fiberglass batts

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EP&B Moisture Data: *OSB Outlier*

August 2016 to August 2017

***Outlier*: rises above 25% OSB MC, dries to 11%, nearby stud performing well, 3 out of 4 OSB sensors in same bay show good performance.**

***Presumption*: a construction imperfection (or damage to sensor)**

***Conclusion*: Even with local intrusion of moisture, EP&B walls can still dry out adequately**

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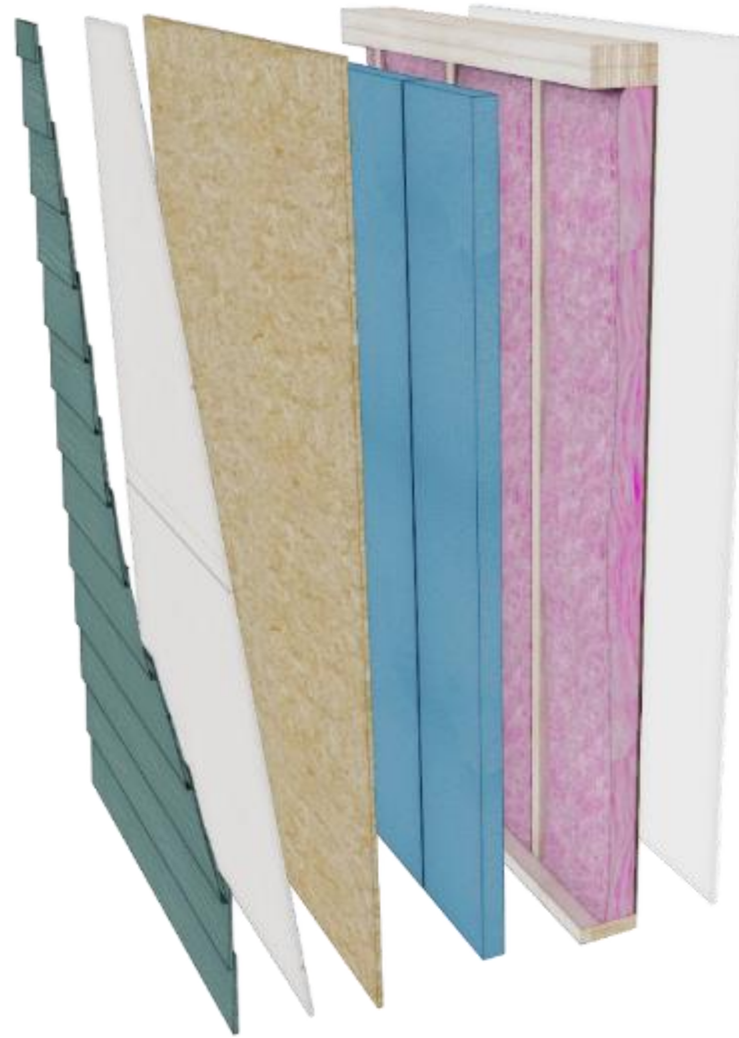
EP&B: *Summary*

- Highly Constructable
- Good structural performance
- Good thermal performance
- Good moisture performance
- Cost effective
- Simplicity with low risk
- Can be factory-panelized



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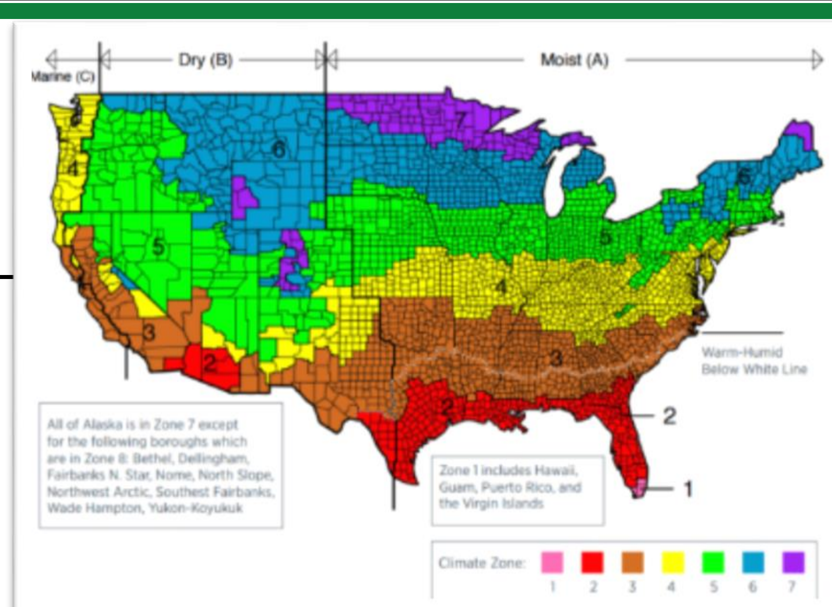
EP&B Summary:

	Configuration	EP&B 2x4/2x6			EP&B 2x6/2x7.5*		
	Rigid Insulation Choice	EPS	XPS	PIC	EPS	XPS	PIC
	EP&B Nominal Insulation	13+8	13+10	13+12	20+8	20+10	20+12
Climate Zone	IECC Minimum Requirement						
CZ 1, 2	13	Exceeds	Exceeds	Exceeds	Exceeds	Exceeds	Exceeds
CZ 3, 4, 5	20 or 13+5#	Exceeds	Exceeds	Exceeds	Exceeds	Exceeds	Exceeds
CZ 6, 7, 8	20+5# or 13+10#	→	Meets	Exceeds	Exceeds	Exceeds	Exceeds

* Denotes actual dimension of 7.5-in (ripped from a 2x10)

For compound requirements ("+") the first value is cavity insulation, the second is continuous insulation or insulated siding



An EP&B wall can provide above-code performance in every US climate zone

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EP&B: *Making the Case*

- Who should consider EP&B?
  - Builders looking to incorporate rigid foam for the first time
  - Builders who already use exterior c.i. but would like a more conventional approach that can reduce cost, complexity and risk
  - Builders who would like to deliver rigid foam insulation through factory panelization, with associated time savings and quality control
- How to find design guidance?
  - DOE Building America website
  - Home Innovation website

Building a Better Wall

[Support from DOE Building America Program]

Patrick H. Huelman

University of Minnesota &
Northern*STAR*

Affordable, Solid Panel "Perfect Wall" System

Team and Partners	Topic Area
NorthernSTAR University of Minnesota	Topic 1: Moisture Risk Management and High-Performance Envelope Systems

Research Project Update – Quarter 4

- Developed two complete MonoPath house designs (bid sets)
- Completed modeling for ZERH, energy, and moisture performance
- Began construction of Twin Cities - Habitat for Humanity home
  - new enclosure contractor/builder was trained with this house
  - panel erection observed by other partners and potential builders
  - structure completed in 2 days; dried-in and secure in 8 days
- Partners onboard to build eight more houses by winter
  - bringing on a new community/building partner

Project Partners:
MonoPath
Twin Cities Habitat for Humanity
Urban Homeworks
Thrive Builders (Denver, CO)
City of Minneapolis
Building Knowledge, Inc
Huber Engineered Woods & Unico

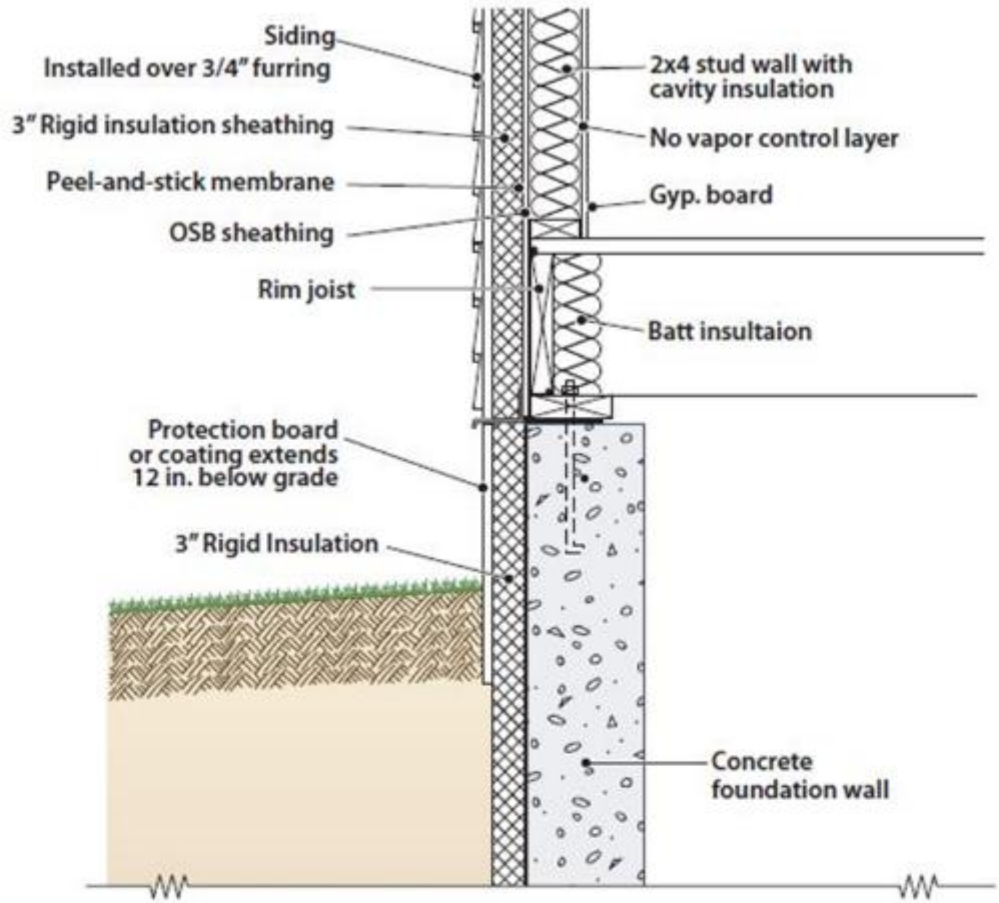
MonoPath (SEP-ETMMS)

- The primary objective is to validate:
  - a new enclosure technology
  - an innovative single enclosure contractor delivery
- The project will measure and compare:
  - performance (energy, moisture, air)
  - constructability and quality control
  - Costs (materials, labor, etc.)
- Demonstrate market acceptance
  - focus on affordable housing

Wall Comparisons

- MonoPath (SEP-ETMMS) will be compared to:
  - – Base Code
  - – Energy Star v3.
  - – DOE Zero Energy Ready Home
  - – Hybrid Wall (Opti-MN)

Hybrid Wall



Siding
Installed over 3/4" furring
3" Rigid insulation sheathing
Peel-and-stick membrane
OSB sheathing
Rim joist
Protection board
or coating extends
12 in. below grade
3" Rigid Insulation
2x4 stud wall with
cavity insulation
No vapor control layer
Gyp. board
Batt insultaion
Concrete
foundation wall

Review of Opti-MN Control Layers

- Water Control
  - Drainage behind cladding
  - “Peel & stick” membrane on sheathing
- Air Control
  - “Peel & stick” membrane on sheathing
- Vapor Control
  - “Peel & stick” membrane on sheathing
- Thermal Control
  - R-15 fiberglass in cavity
  - R-15 extruded polystyrene on exterior

University of Minnesota's

Team Opti-MN

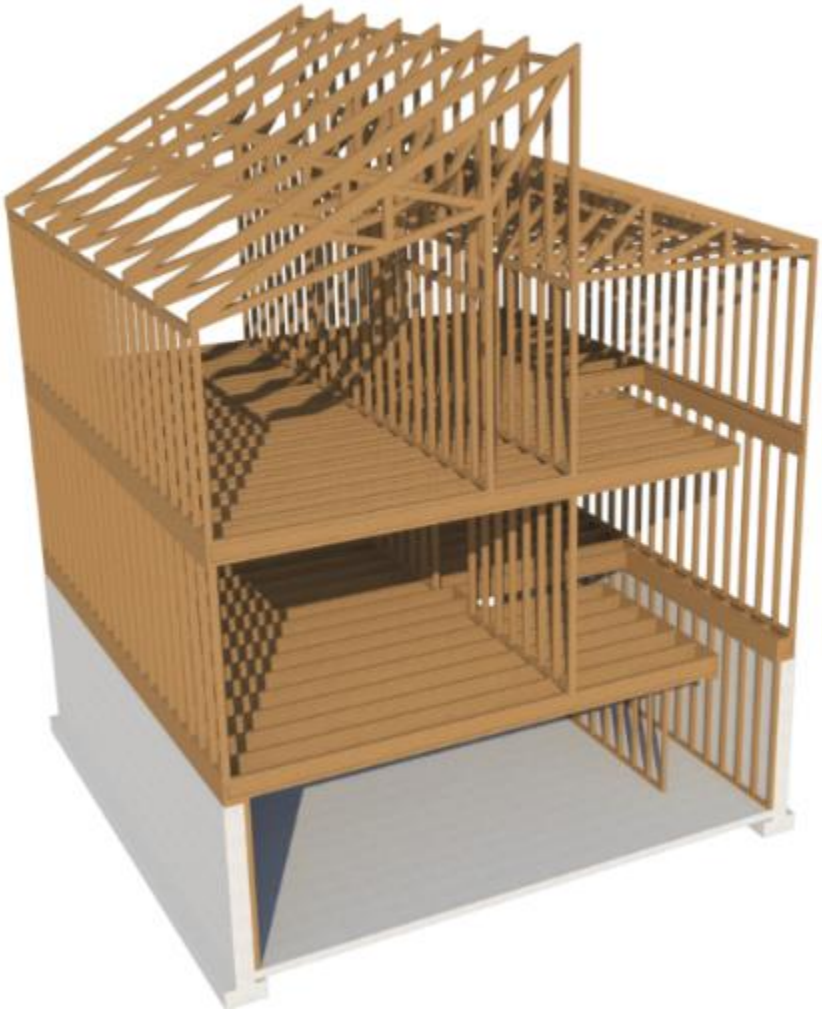
WINS TOP AWARD

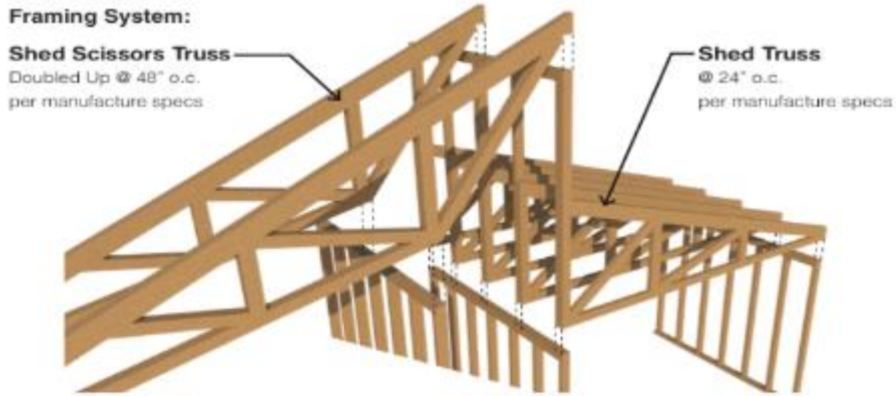
In DOE's "Race to Zero"

Student Design Competition

INTRODUCING | The Impact Home

OPTI-MN HYBRID WALL | Robust & Easy to Construct



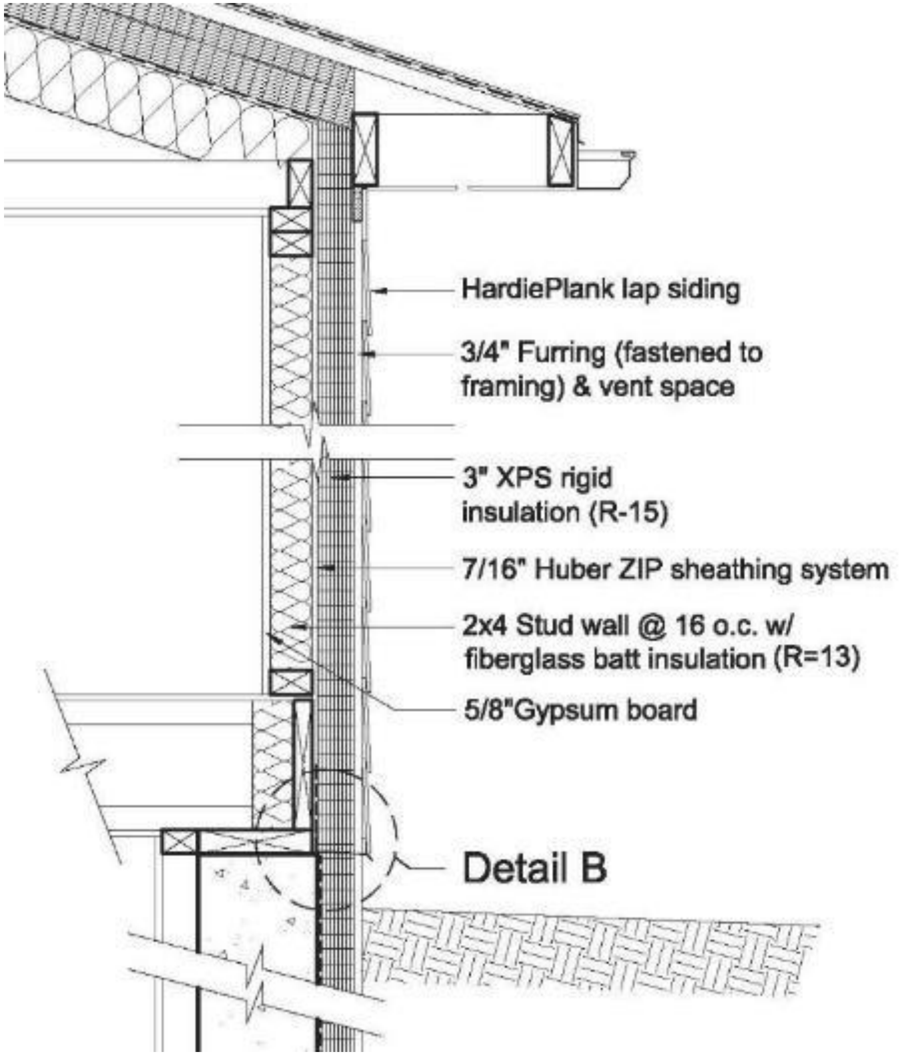


Approachable and Appropriate Construction Materials and Methods

- Simplified design and shape
- Based on traditional construction materials and techniques
- Simplified ducting and hot water systems

OPTI-MN HYBRID WALL | Robust & Easy to Construct

- The air, water, and vapor control layer is over a traditional wood-frame wall
- Then rigid insulation, vented rainscreen, and siding is added to the exterior
- This approach limits moisture movement, yet facilitates bi-directional drying



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Opti-MN (Hybrid) Summary

- Pros
  - Simple and familiar framing
  - No interior air sealing required; can glue drywall
  - High R-value; superior airtightness
  - Very robust; good drying potential both inside & out
- Cons
  - Cost of exterior control layers
  - Must hit the framing with exterior furring strips

MonoPath (SEP-ETMMS)

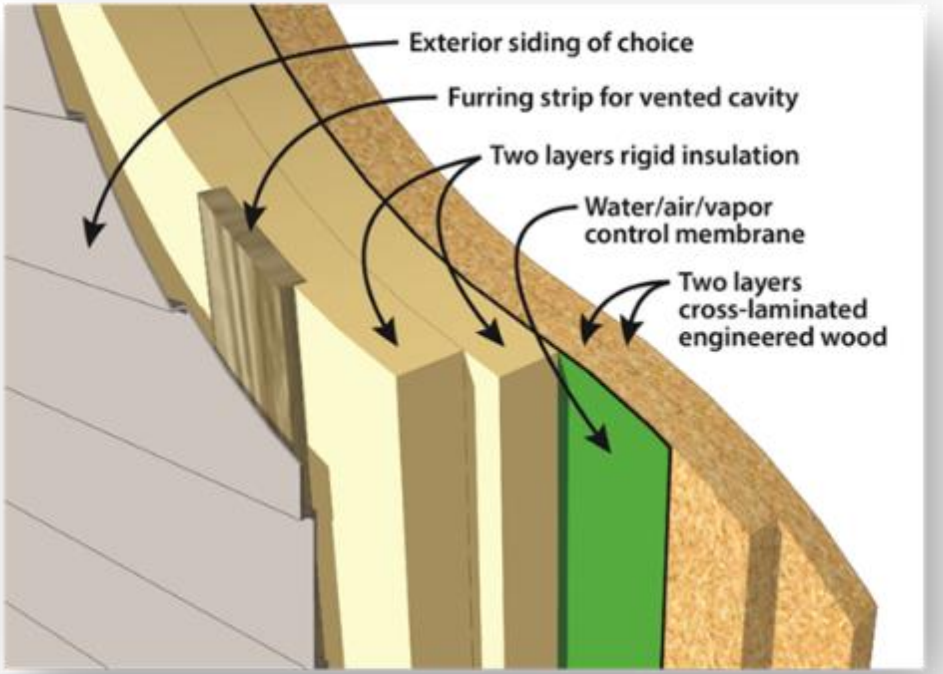
- Our working motto is simple:
  - Better Design, Better Systems, and Better Delivery
  - Provide Better Performance
  - At Lower Cost!
- Research hypotheses are straightforward:
  - *This innovative building enclosure system outperforms conventional wood-frame construction at lower cost.*
  - *This innovative building delivery system ensures better QA/QC.*
  - *This optimized whole building system can deliver cost-effective Zero Energy Ready Homes for affordable housing*.

Benefits of "Perfect Wall"

- Structure is kept warm/dry
- Control layers are simplified
- Continuous exterior insulation
- Critical control layers and materials are protected
- Back-ventilated cladding
- Sensitive materials can dry
- Can be used in any climate

Benefits of "Solid Panel"

- Reduces costs of the "Perfect Wall"
- Simplifies application of exterior insulation
- Requires less labor and less skill
- Speeds enclosure time (esp. dry-in)
- Stronger with enhanced protection (resilient)



Benefits of Single Enclosure Contractor

- Building process developed by MonoPath
  - reduces installation errors
  - speeds overall construction time
  - reduces overall construction cost
- More consistent performance outcomes
  - reliable insulation quality and performance
  - improved moisture management
  - remarkable and repeatable airtightness

Review of MonoPath Control Layers

- Water Control
  - Drainage behind cladding
  - “Peel & stick” membrane on wall panel
- Air Control
  - “Peel & stick” membrane on wall panel
- Vapor Control
  - “Peel & stick” membrane on wall panel
- Thermal Control
  - R-20 extruded polystyrene on exterior

Four homes built between 2001-2004; three in St. Paul and one in Minneapolis

Seven MonoPath homes built in St. Paul in 2014.

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MonoPath Video

https://www.youtube.com/watch?v=lKpTf9u71dc

MonoPath Video Recap

- Foundation = typical with best practices
- Floor deck = mostly typical
- Enclosure (walls & roof) = 1 to 2 days w/ crane
  - Dried-in & Secure = 3 to 5 days
    - walls = primer, membrane windows, & insulation
    - roof = papered & shingled
- Interior framing & finishing = mostly typical
  - knock-down finish for exterior walls
  - electrical integrated in the baseboard and trim


DOW
Styrofoam
Carroll


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GRACE
Perm-A-Barrier®

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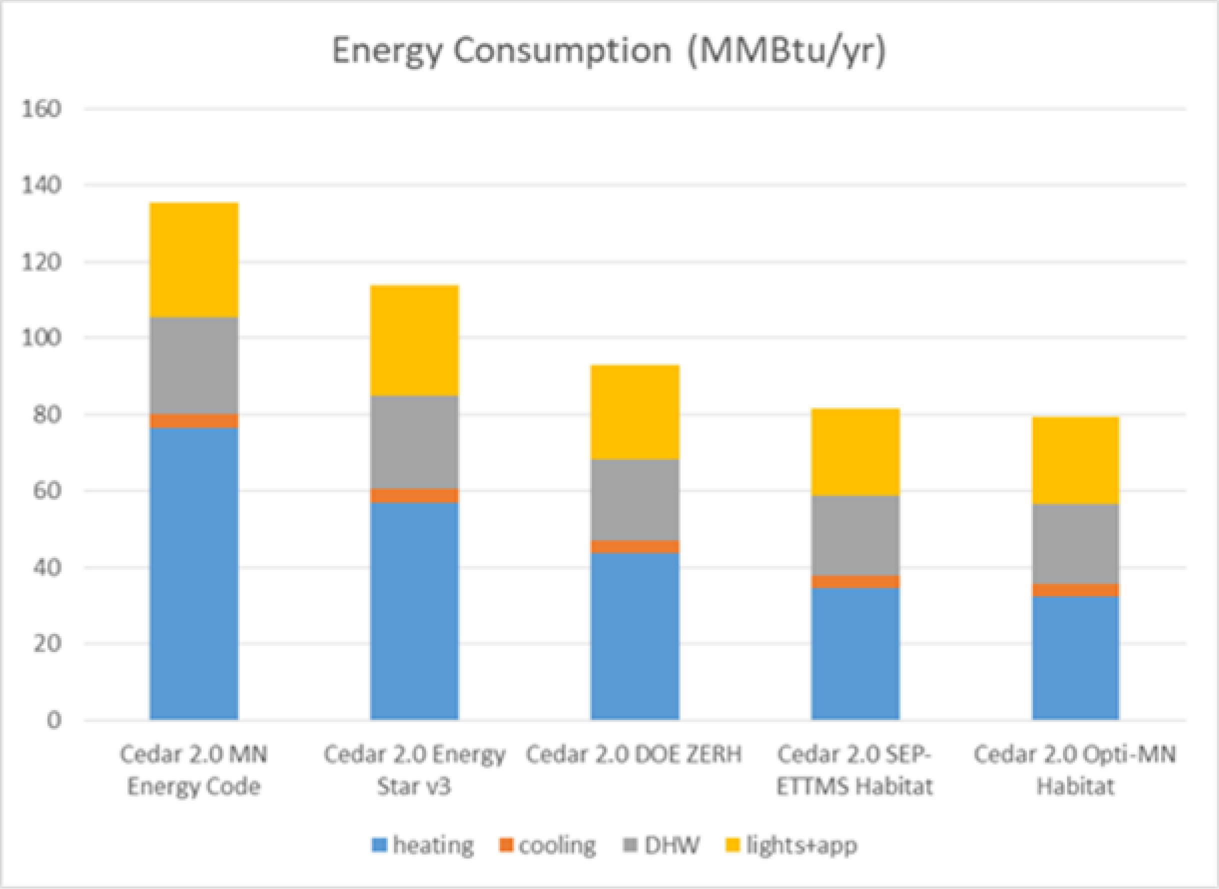
MonoPath Summary

- Pros
  - Quick erection to dried-in & secured
  - Can use lower-skilled labor
  - Extremely robust
  - Significant strength advantages, but still testing?
- Cons
  - Certain design limitations until system is validated
  - Current upfront engineering costs

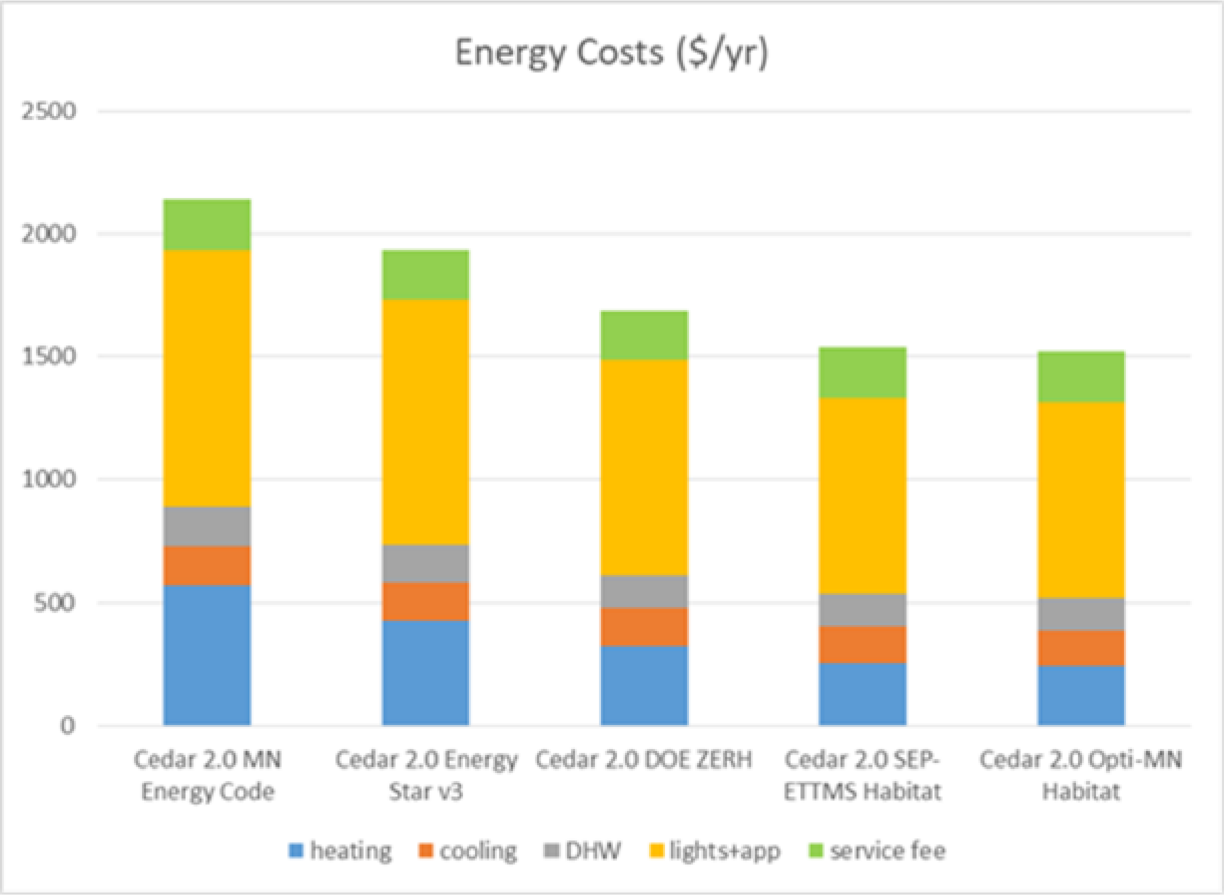
Wall Comparison – Energy

	HERS	Total Energy		Heating & Cooling	
Plan = Cedar 2.0		Energy (MMBtu)	Costs ($)	Energy (MMBtu)	Costs ($)
2015 MN Energy Code	70	135.6	$ 2140	80.0	$ 729
Energy Star v3 (minimum)	60	114.0	$ 1935	60.6	$ 579
DOE ZERH (minimum)	49	92.8	$ 1689	47.2	$ 476
MonoPath (for TC-HfH)	44	81.5	$ 1536	37.7	$ 400
Opti-MN (for TC-HfH)	43	79.3	$ 1521	35.5	$ 385

Wall Comparison – Energy



Wall Comparison – Energy



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Wall Comparison – Condensation Analysis

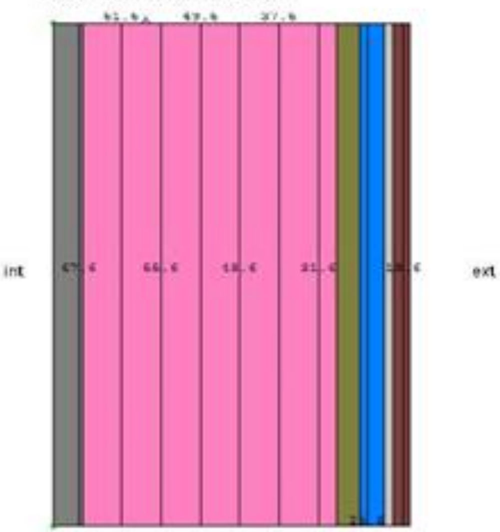
Energy Star v3

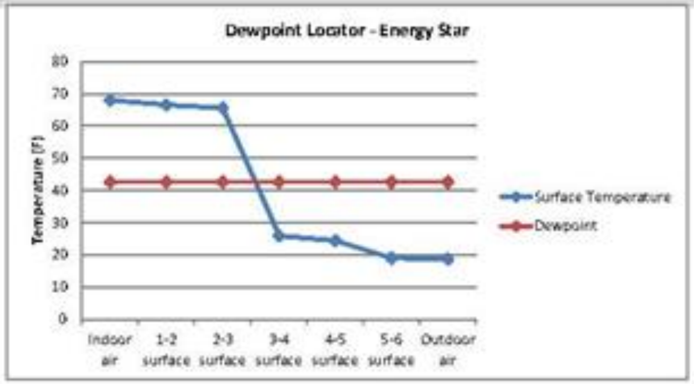
Energy Star

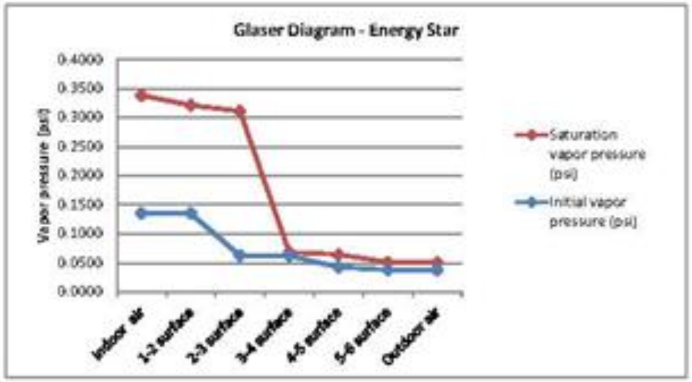
Layers

1	inside air film	
2	gypsum + latex paint + 4 mil poly	dark gray
3	fiberglass insulation	pink
4	OSB sheathing + Tyvek	olive
5	XPS	blue
6	outside air film	light gray

THERM Model - winter conditions







Conditions

Exterior	Temp	RH	**Interior**	Temp	RH
Winter	18.7	75%	Winter	68	50%
Summer	86	55%	Summer	75	60%

Wall Comparison – Condensation Analysis

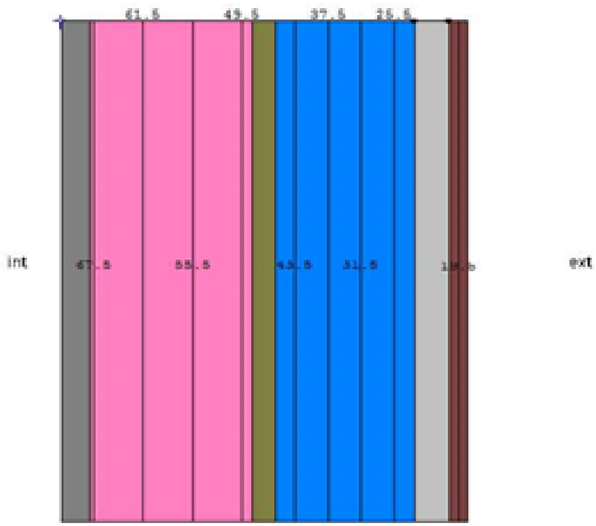
Opti-MN (hybrid)

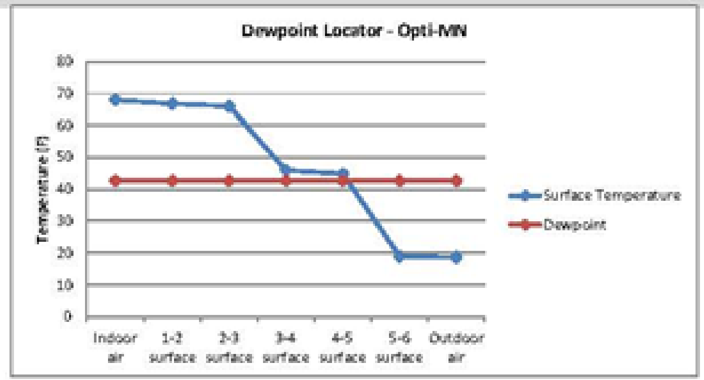
Opti-MN

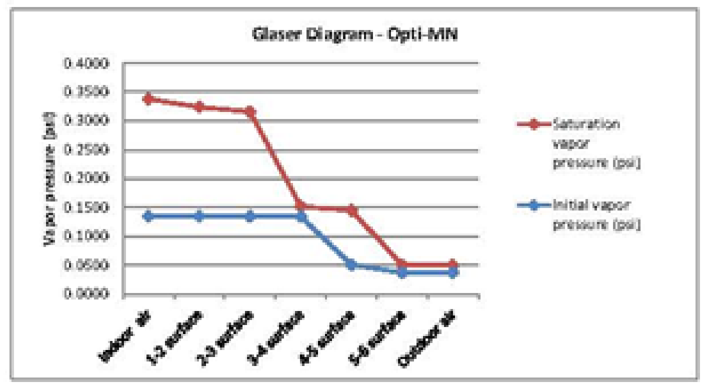
Layers

1	inside air film	-
2	gypsum+latex paint	dark gray
3	fiberglass insulation	pink
4	OSB sheathing + Perm-a-Barrier	olive
5	XPS	blue
6	outside air film	light gray

THERM Model - winter conditions







Conditions

Exterior	Temp	RH	**Interior**	Temp	RH
Winter	18.7	75%	Winter	68	50%
Summer	86	55%	Summer	75	60%

Wall Comparison – Condensation Analysis

MonoPath

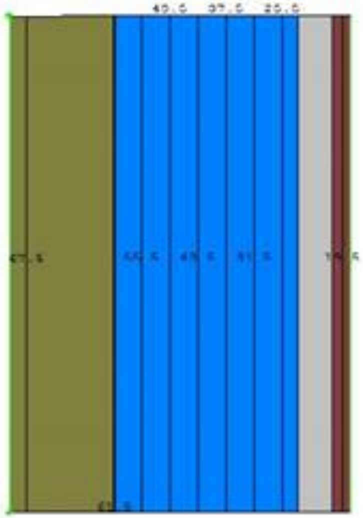
SEP ETMMS

Layers

1	inside air film	-
2	SEP Panel + paint + Perm-a-Barrier	olive
3	XPS	blue
4	outside air film	light gray

THERM Model - winter conditions

int



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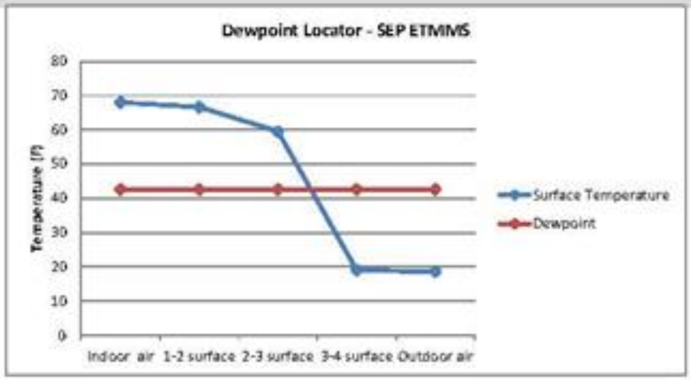
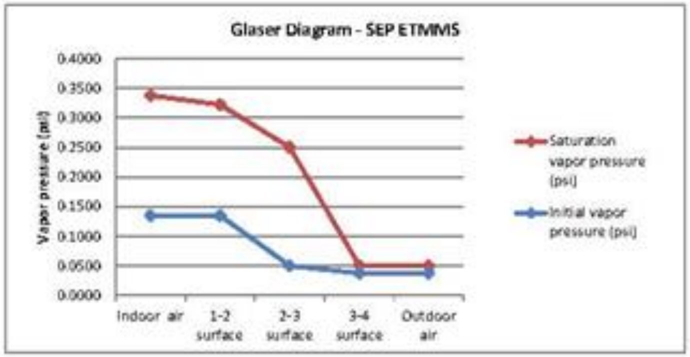


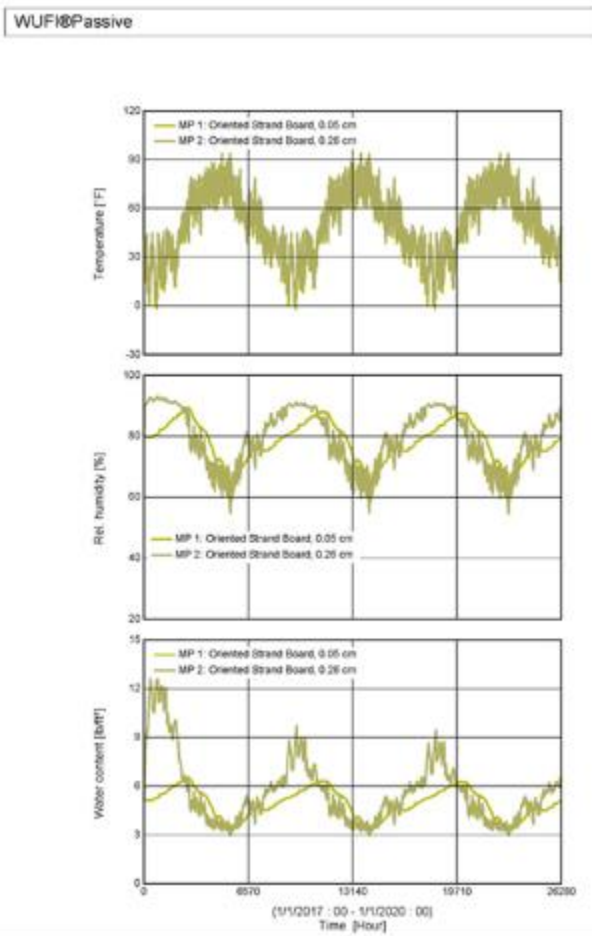


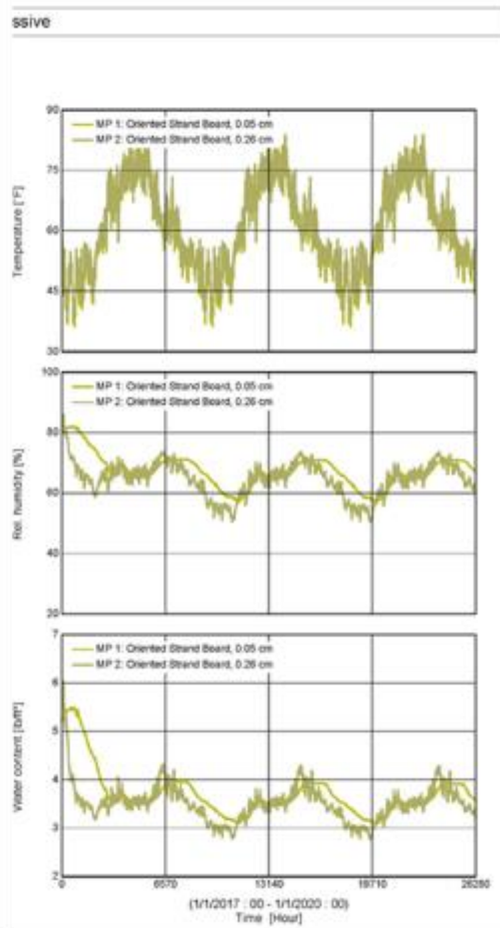
Conditions

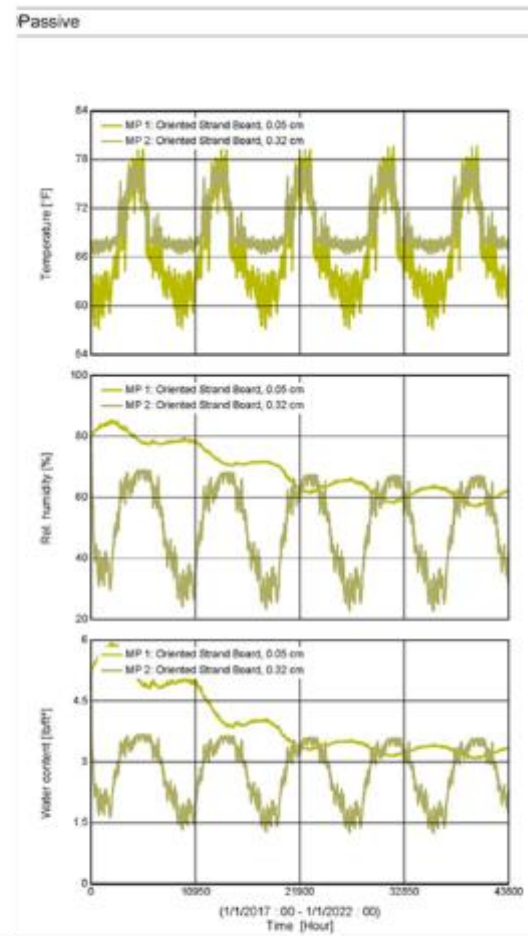
Exterior	Temp	RH	**Interior**	Temp	RH
Winter	18.7	75%	Winter	68	40%
Summer	86	55%	Summer	76	60%

Wall Comparison – WUFI

Energy Star   Opti-MN (hybrid)   MonoPath







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Wall Comparison – Costs

- Work in progress…
  - The Opti-MN costs more than the code minimum and base Energy Star.
  - The MonoPath cost less than the Opti-MN
    - Primarily due to framing material and labor savings.
  - We believe MonoPath will approach the same cost as the Energy Star, with a couple of caveats…
    - There is an upfront engineering cost premium.
    - There is a learning curve to capture labor savings.
    - Its superior airtightness demands a MUA system.

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Building a Better Wall

[with support from DOE Building America Program]

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MonoPath

http://www.mono-path.com/

Opti-MN

https://tinyurl.com/y9ssow8e

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EP&B

https://tinyurl.com/y7xaf6pg

New Construction Guide to be published soon! Find it at the websites:

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