Field Evaluation of Thermal and Moisture Response of Highly Insulated Wood-frame Walls

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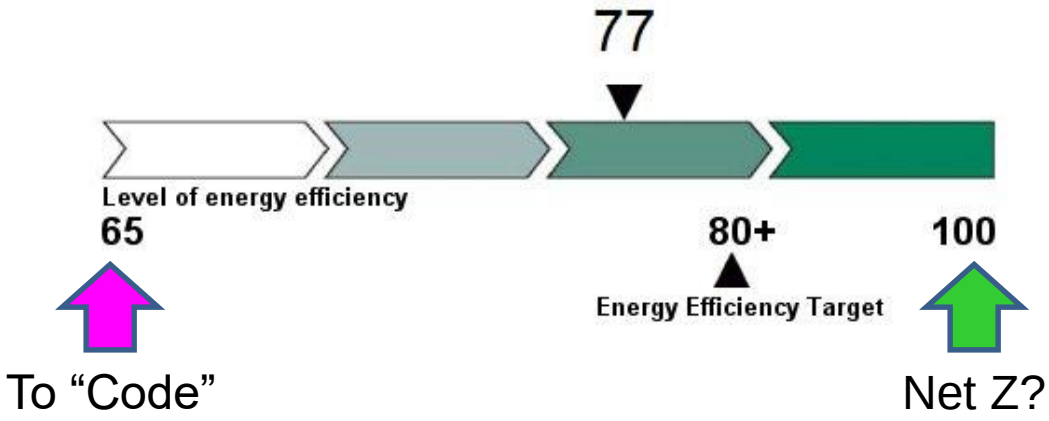
Overview

- *Overview*
- *Project background & motivation*
- *Project approach*
- *Performance assessment*
- *Defining performance attributes*
- *Wall configurations*
- *Test protocol & monitoring period*
- *Results from field study*
- *Summary*

Project background

- ***Background on and motivation for project***
- *Homebuilders* have interest in providing homes that meet or exceed ENERGY STAR® requirements and are "durable"*
  - ENERGY STAR® Program : Intended to promote & advances energy efficiency in Canada - supported by US Environmental Protection Agency
  - ENERGY STAR® qualified new home - 20% more energy efficient than home built to code (on average)



Project background

Key questions of interest to industry and industry stakeholders**

- Demonstrate compliance to NBC code (*NBC § 9.36 / Min. $\mathbf{R}_{eff}$-value for walls)
- Do highly-insulated wall assemblies nominally perform 'adequately'?
  - When compared to a NBC-compliant reference wall
  - Adequate performance as relates to thermal and hygrothermal performance when subjected to Canadian climate extremes

Climate Zone	HDD	e.g. Location	R_{eff}	*NBC compliant Wall assembly 2 X 6-in. @ 16-in. o.c.
Z4	< 3000	Vancouver, Victoria	15.8	R19 (GF batt insulation)
Z5	3000-3999	Toronto	17.5	R22 (GF batt insulation)
Z6	4000-4999	Ottawa, St. John's	17.5	R22 (GF batt insulation)
Z7A	5000-5999	Edmonton	17.5	R22 (GF batt insulation)
Z7B	6000-6999	Whitehorse	21.9	R22 (batt) + R5 (rigid)
Z8	>8000	Yellowknife	21.9	R22 (batt) + R5 (rigid)

**Agencies / Associations supporting adoption of ENERGY STAR® homes:
e.g. CMHC / NRCan / CHBA - Canadian Home builders association

Project background

Key questions of interest to Industry

- Compliance with NBCC
  - i.e. equal or better “performance” for “moisture control” as compared to NBCC specified “**R**eference wall”
- Moisture control ⇨ control of effects of water entry and condensation
- Lack of moisture control ⇨ “Moisture control problems”?

“Moisture control problems”?

- Risk to water uptake and subsequent formation of mold or rot by moisture sensitive components in wall assembly
  - “MEWS cladding study”*

Project objective & approach

- Investigate risk of condensation in wall assemblies having different levels of thermal resistance (R-value)
- Monitor thermal and hygrothermal response of a set of 3 wall assemblies to local climate conditions over ~ 9 month period
- Wall exposed to natural and local climate effects in NRC's Field Exposure of Walls (Test) Facility (FEWF)

Project objective & approach

FEWF
Field Exposure of Walls test Facility

Buildings **XII** (2013) – **VIP** insulation / retrofit
Buildings **XI** (2010) – Insulated concrete forms

- **Wall exposed to local climate effects**
  - Each year monitor 3 wall assemblies over exposure period
  - Exposure period: January to September (cold, mild & warm months)
- **Results from field study**
  - **Phase 1 / Yr 1 – 1st set 3 walls having exterior insulation (R4 – R5)**
  - **Phase 2 / Yr 2 – 2nd set of 3 walls – various insulation types**

Performance assessment

Performance of wall assemblies based on performance attributes of selected areas of interest within wall

- Performance attributes considered : mold risk index*
- Selected areas: e.g., sheathing panel in contact with WRB membrane

Adequate performance for "alternative" code solution:

- Wall assemblies exhibit performance as good or better than **R**eference code-compliant wall assembly
- Should performance of wall assemblies be found inadequate in comparison to **R**eference wall – not a suitable solution

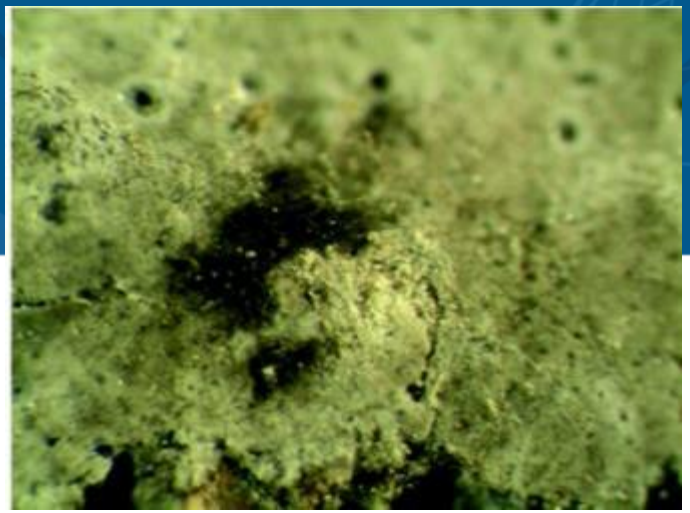
Performance attribute: mold index

- Indicator of risk to formation of mold or rot fungi
  - Based on T, RH conditions and time
- ***Does not predict likelihood of occurrence***
  - Would additionally depend on several other factors

- Mold fungi cause no damage to wood other than discoloration – but considered a precursor to decay
- Decay fungi actually weaken wood structure
- Decay only occurs above fiber saturation point (i.e. >27-30% moisture content of wood or >97% RH)
- Most wood-decay fungi exist at temperatures from 10 to 40 ºC

Anagnost*, S. E. (2011), Wood Decay, Fungi, Stain and Mold, New England Kiln Drying Association Meeting, Oneonta, NY; *Chair and Associate Professor, SUNY, Syracuse, New York

Mould Index criterion



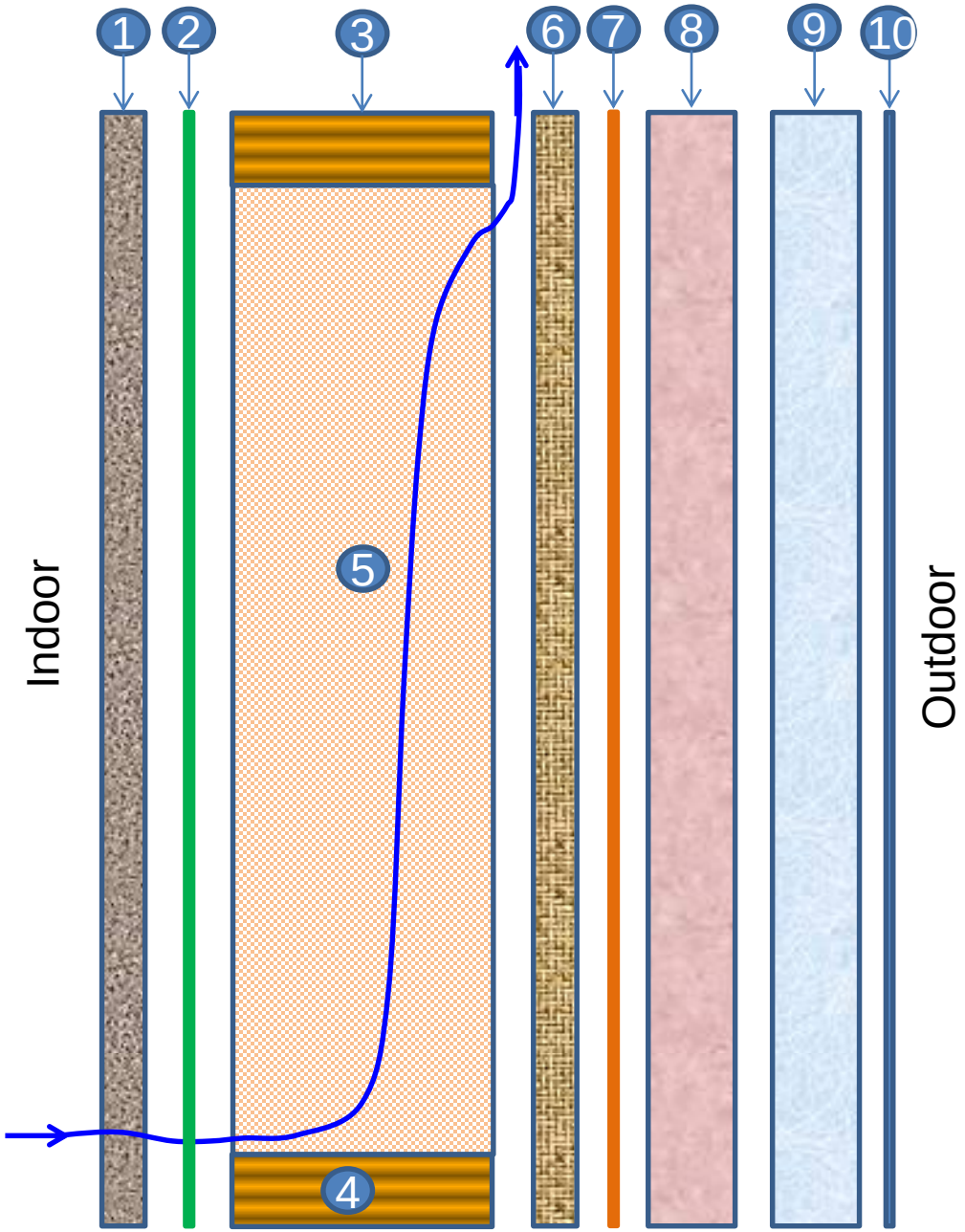
Most recent model by *Viitanen et al

Table 1. Mold Index for Experiments and Modeling
(New Determinations for Index Levels 3 and 4 are Presented in Bold)

Index	Description of Growth Rate
0	No growth
1	Small amounts of mold on surface (microscope), initial stages of local growth
2	Several local mold growth colonies on surface (microscope)
3	Visual findings of mold on surface, < 10% coverage, or < **50% coverage of mold (microscope)**
4	Visual findings of mold on surface, 10%–50% coverage, or > **50% coverage of mold (microscope)**
5	Plenty of growth on surface, > 50% coverage (visual)
6	Heavy and tight growth, coverage about 100%

*Viitanen et al. (2010), “Moisture and Bio-deterioration Risk of Building Materials and Structures”; Journal of BUILDING PHYSICS, Vol. 33(3), pp. 201-224

Wall configurations with structural sheathing

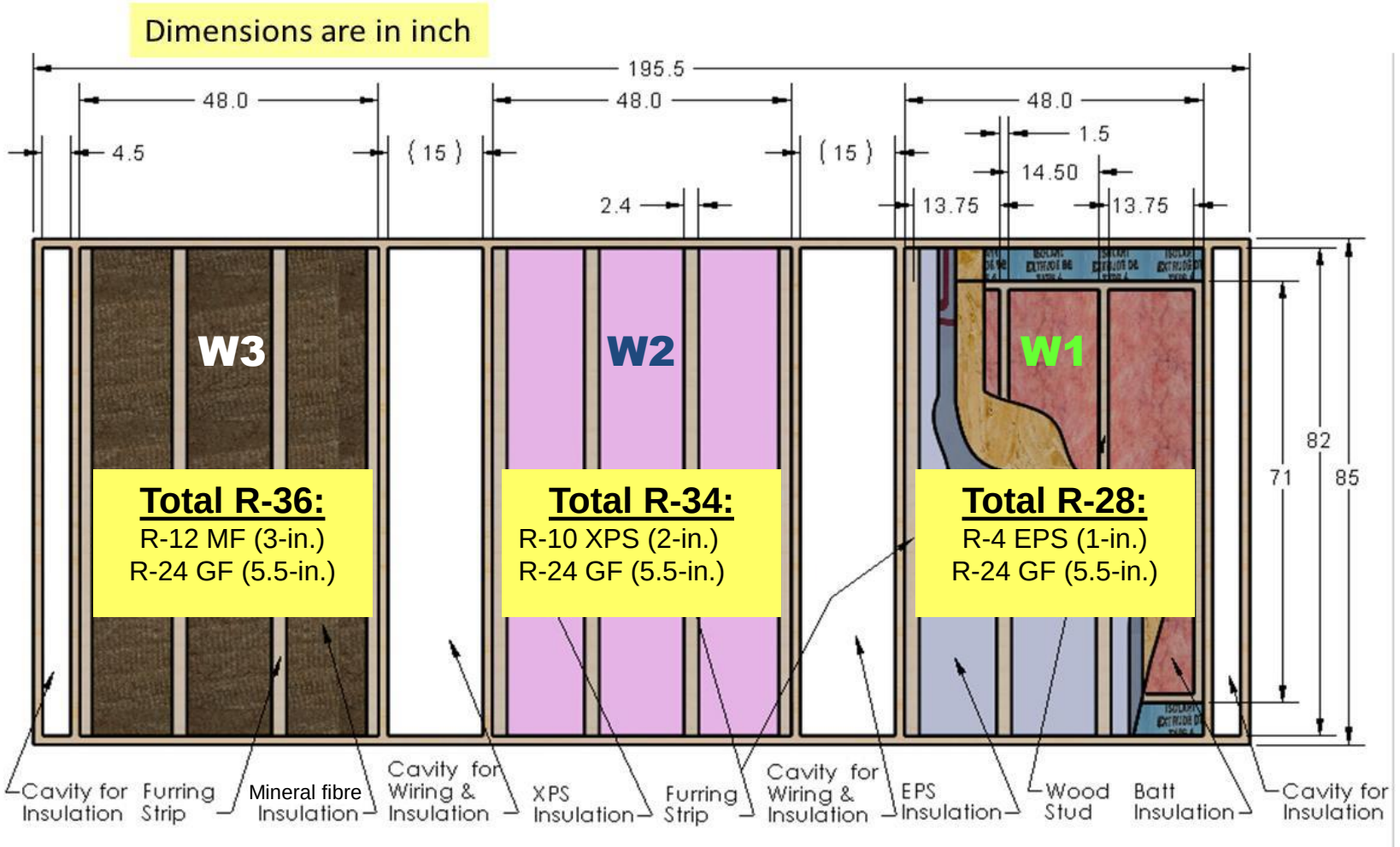


1. Gypsum board
2. Vapour Barrier (WVP = 60 ng/(Pa.s.m^2))
3. Top plate
4. Bottom plate
5. Fiber insulation (R-24)
6. OSB
7. WRB (WVP = 1400 ng/(Pa.s.m^2)
8. **Exterior Insulation:**
   - **(a) EPS of 1 in thick (R4/in.)**
   - **(b) XPS of 2 in thick (R5/in.)**
   - **(c) MF of 3 in thick (R4/in.)**
9. Air
10. Vinyl siding installed on 19 mm strapping (WVP = 40-70 perms, S.V. Glass, Building Science Corporation, 2010)

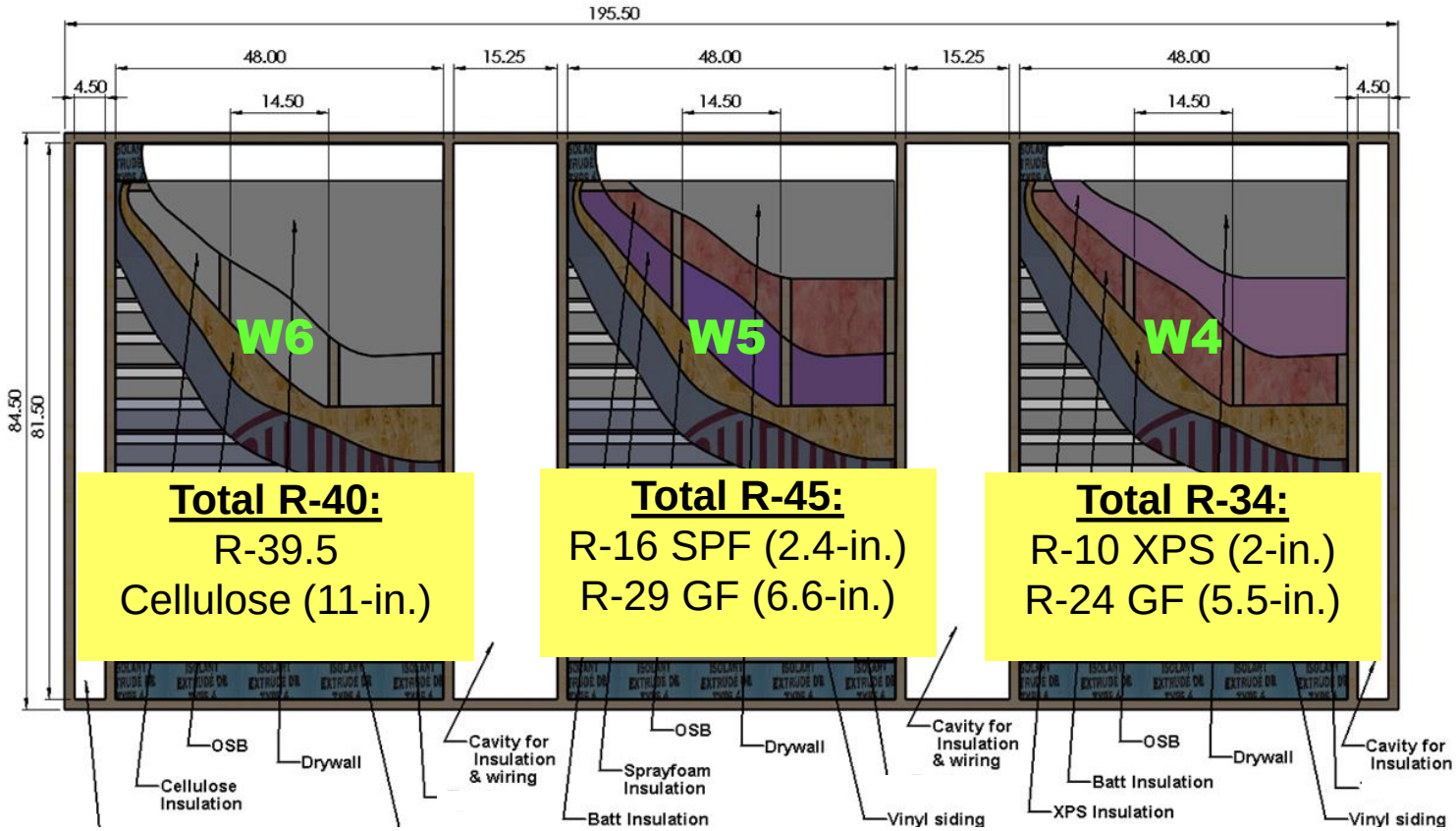
Wall configurations – Nominal R-values

Parameter	Wall 1	Wall 2	Wall 3
2x6 Wood-Framing Cavity Insulation	Batt Insulation of R-24		
Exterior Insulation Details			
Type	EPS	XPS	Mineral Fibre
Thickness (in)	1	2	3
Dry Density (kg/m^3)	18	26	122
Dry Thermal Conductivity (W/(m•K))	0.0369	0.0290	0.0347
Total R-value (ft^2•hr•^oF/BTU)	3.91	9.95	12.47
R-value ((ft^2•hr•^oF/BTU)/in)	3.91	4.97	4.16
Approx. Nominal Total R-Value of Insulation	28	34	36

Phase 1 (WA set: 1, 2, 3)



Phase 2 (WA set: 4, 5, 6)



Test protocol over monitoring period

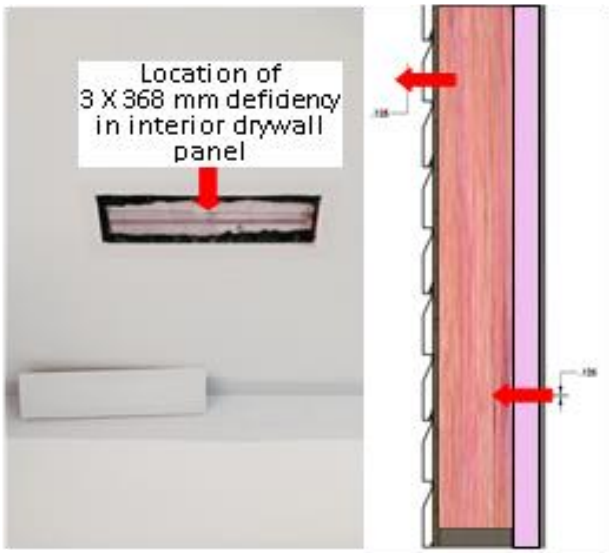
Phase 1 (2013/14)

Period	Interior conditions				Exterior conditions	
	Temperature (°C)	RH (%)	Pressure (Pa)	Deficiency (3mm slit)	Deficiency (3mm slit)	Temperature/ RH
A (175 days)	21	35	0	Closed	Open	Ambient local
B (20 days)	21	50	10	Open	Open	Ambient local
C (40 days)	21	Variable / natural	0	Open	Open	Ambient local
D (100 days)	21	Variable / natural	0	Closed	Open	Ambient local

Phase 2 (2014/15)

Period	Interior conditions				Exterior conditions	
	Temperature (°C)	RH (%)	Pressure (Pa)	Deficiency (3mm slit)	Deficiency (3mm slit)	Temperature/ RH
A (40 days)	21	35	0	Closed	Open	Ambient local
B (9 days)	21	Variable / natural	Variable	Open	Open	Ambient local
C (47 days)	21	Variable / natural	0	Open	Open	Ambient local
D (167 days)	21	Variable / natural	0	Closed	Open	Ambient local

Air leakage measurements / 0.1 L/s–m² @ 75 Pa



Project Phase	Wall	ξ (L/min) = a ΔP^n	
		a	n
Phase 1	W1	73.5	0.320
	W2	75.9	0.316
	W3	53.4	0.300
Phase 2	W4	0.685	0.989
	W5	0.654	0.766
	W6	0.593	0.953

*ΔP in Pa

$$\xi = a\left(\Delta P_{tot}\right)^n$$

$$n\,(avg) = 0.69 \approx 0.7$$

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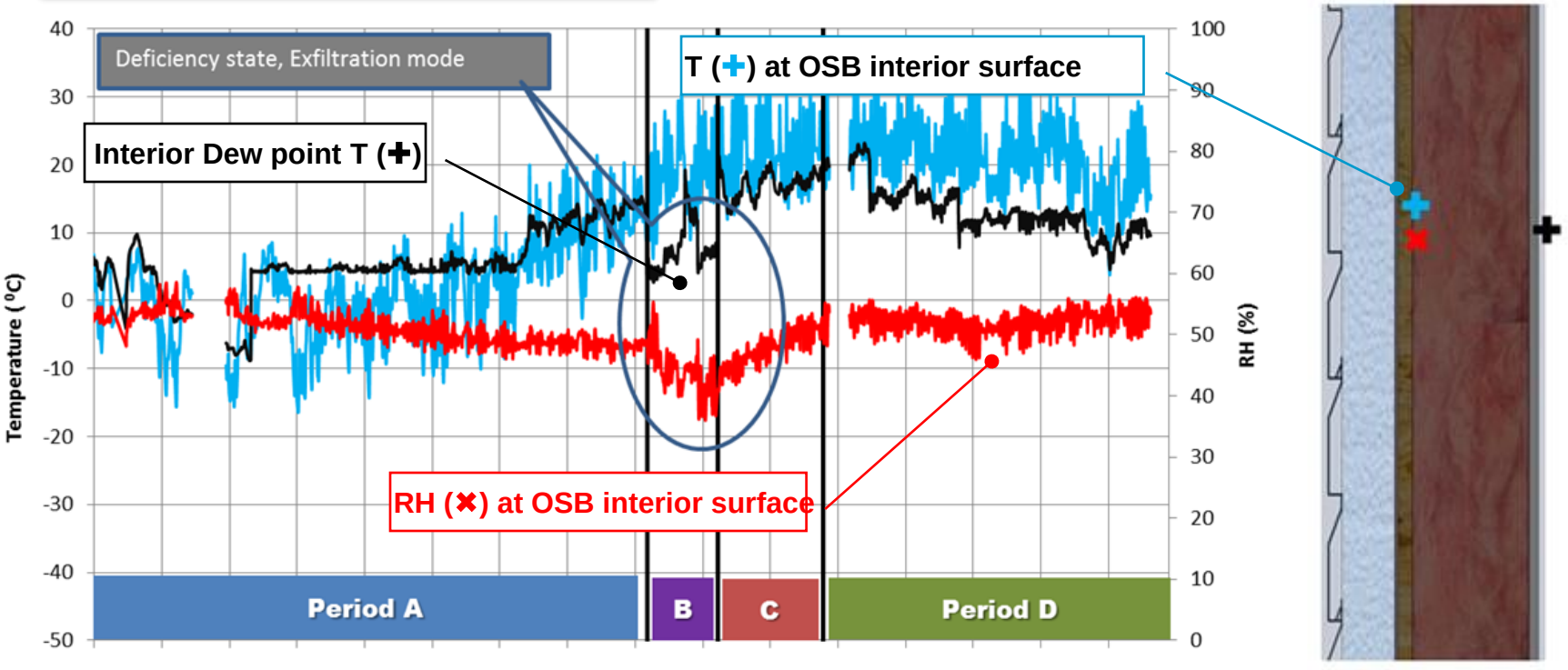
H – *Response of wall assembly W1 (EPS)*

Monitoring period 2013/14

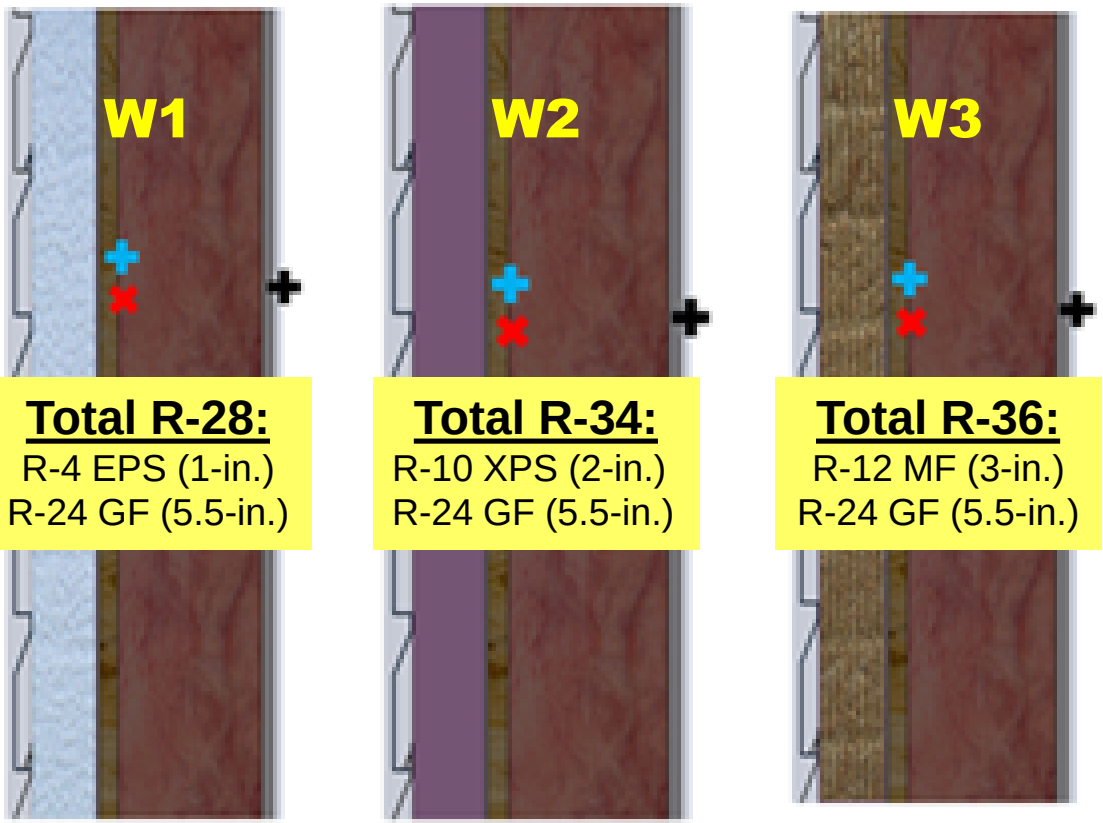


Temperature [T+]; Relative humidity [RH+] @ interior OSB surface; Dew point [T +]

H – Hygrothermal

Results – Phase 1

Phase 1: No condensation evident for any walls; Mold index < 1.1



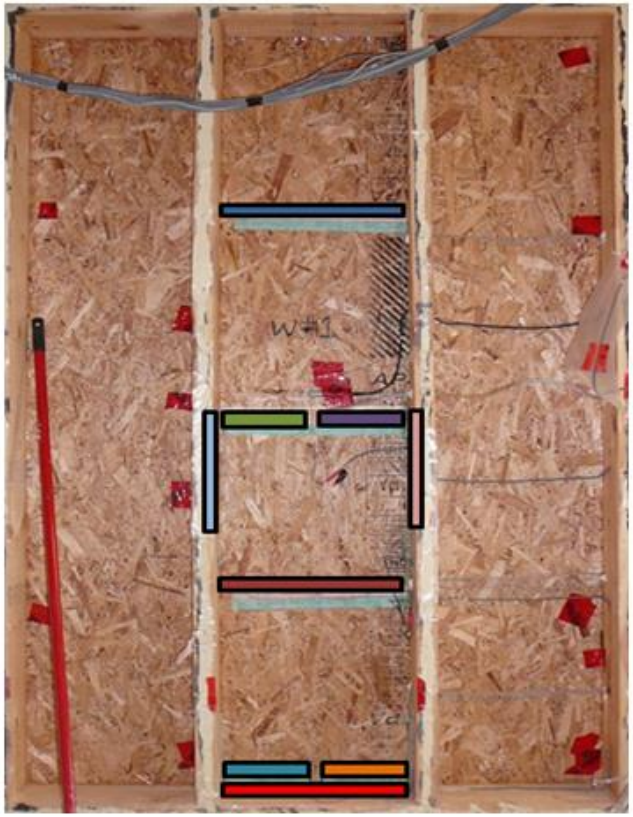
Total R-28:
R-4 EPS (1-in.)
R-24 GF (5.5-in.)

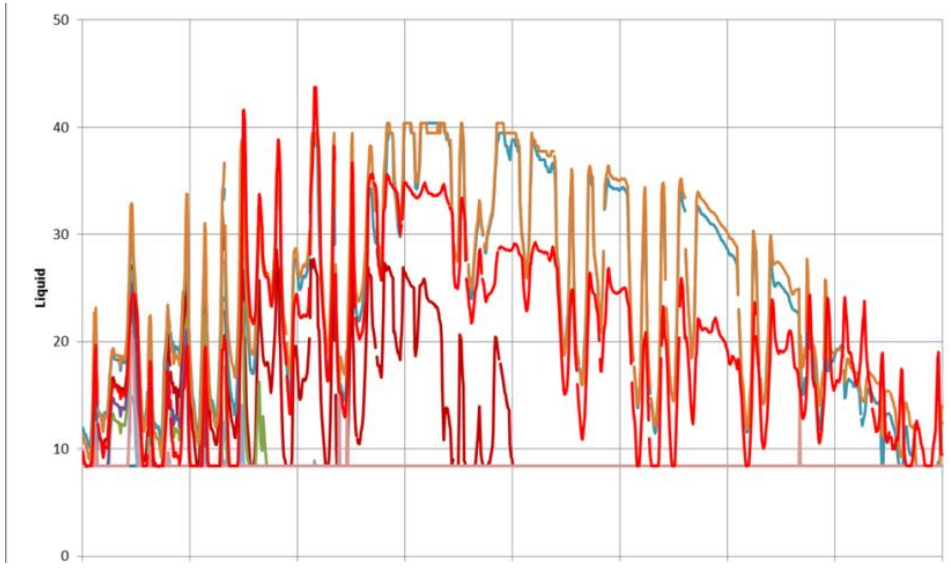
Total R-34:
R-10 XPS (2-in.)
R-24 GF (5.5-in.)

Total R-36:
R-12 MF (3-in.)
R-24 GF (5.5-in.)

H – *Response of W4*

Response of moisture detection strip to presence of moisture in wall

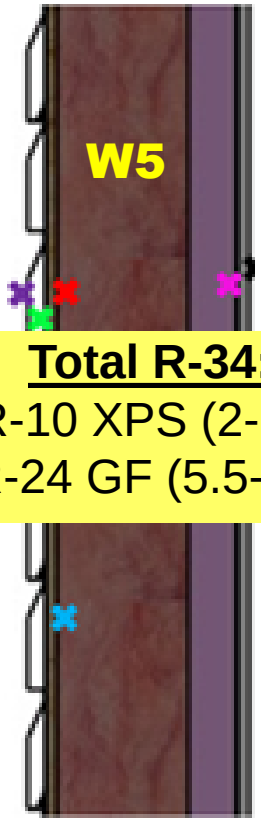




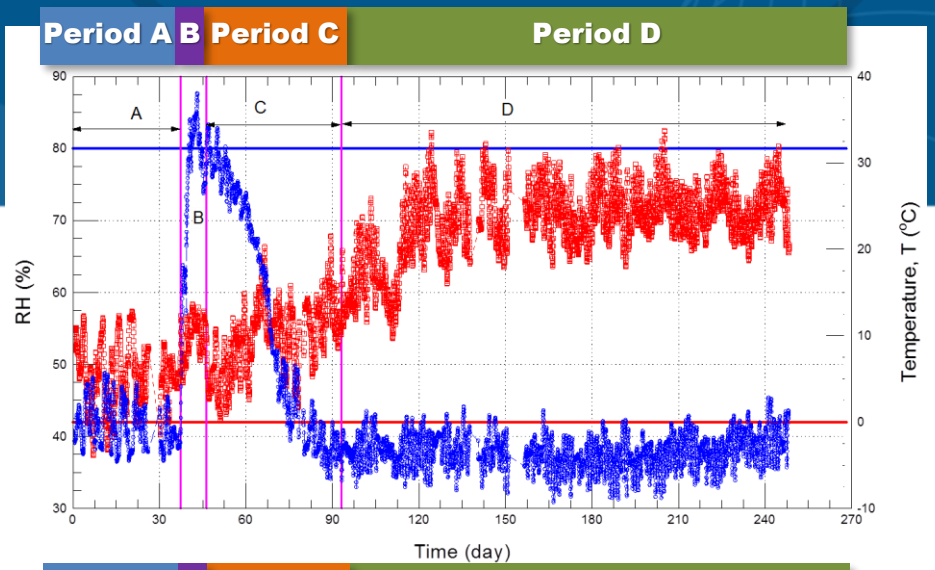
H – Hygrothermal

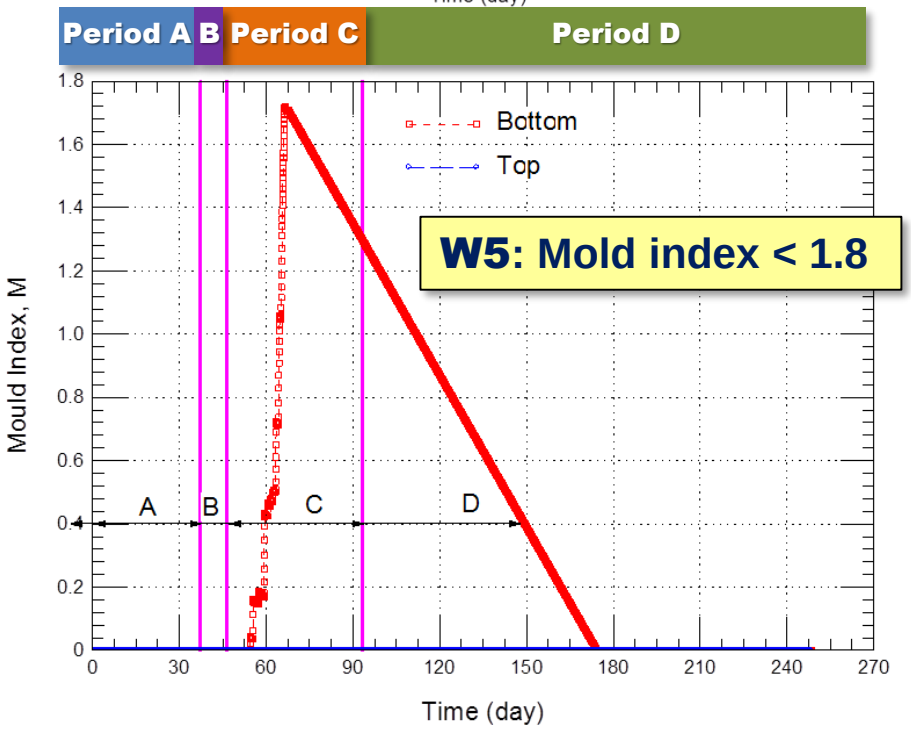
t ⇨

H – *Response of W5*



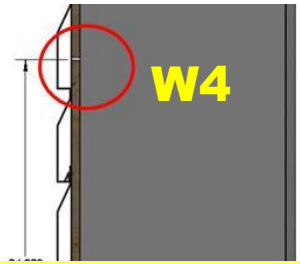
Total R-34:
R-10 XPS (2-in.)
R-24 GF (5.5-in.)



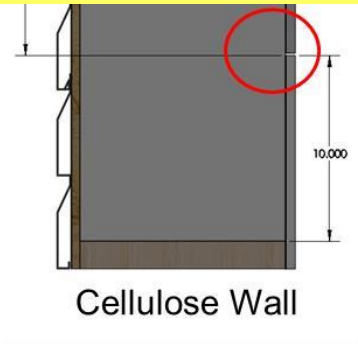


Results – Phase 2

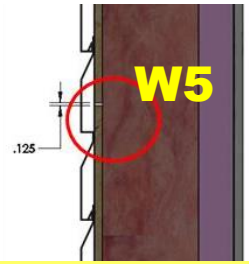
Phase 2: Mold index for all walls < 1.8



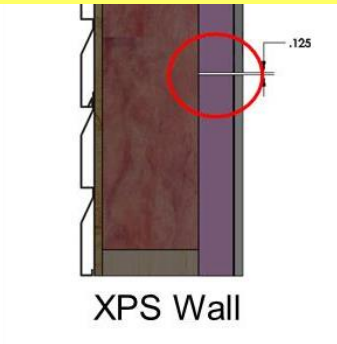
Total R-40:
R-39.5 Cellulose (11-in.)



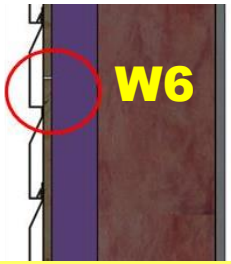
Cellulose Wall



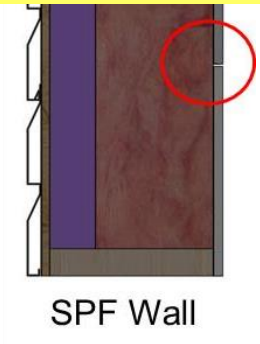
Total R-34:
R-10 XPS (2-in.)
R-24 GF (5.5-in.)



XPS Wall



Total R-45:
R-16 SPF (2.4-in.)
R-29 GF (6.6-in.)

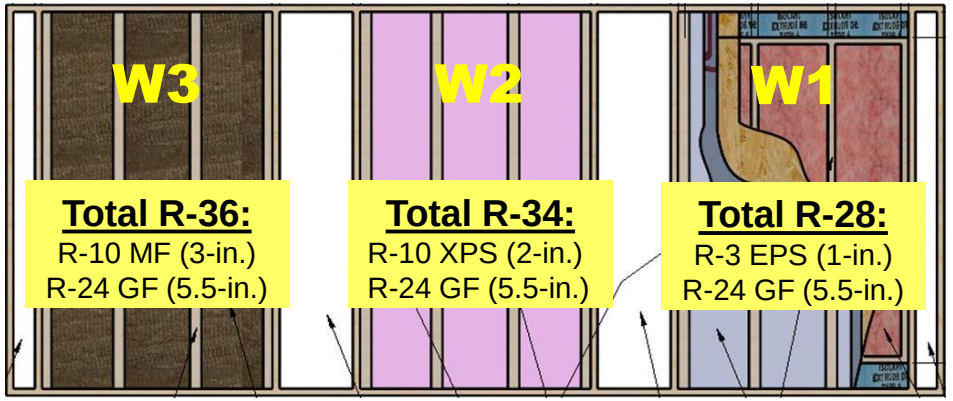


SPF Wall

Summary

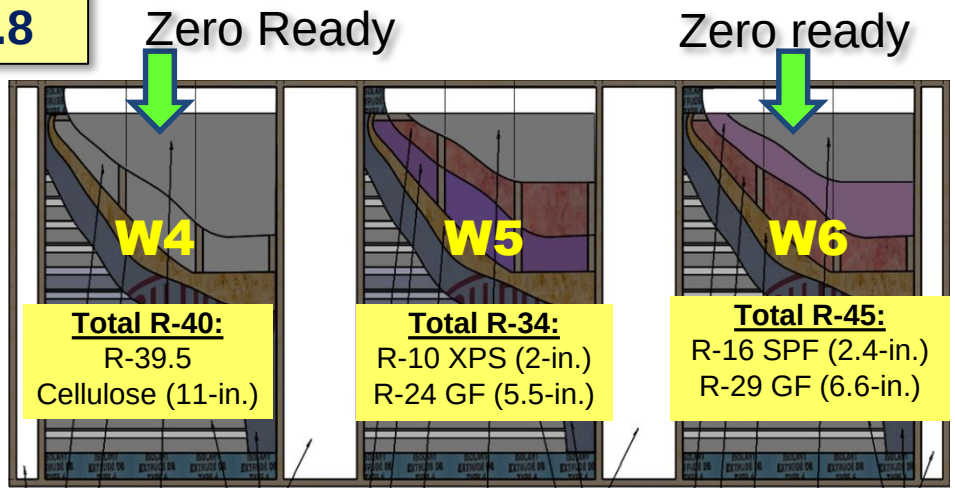
Phase 1: No condensation evident for any walls; Mold index < 1.1

All walls meet or exceed code (NBC §9.36) requirements irrespective of C-Zone

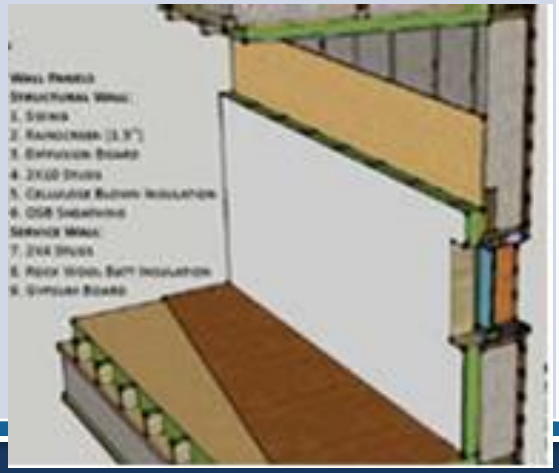


Phase 2: Mold index < 1.8

W4 / W6: Zero Ready



Proposed Walls for Phase III (FY 2015/2016)

2015- 2016 walls	Wall-2015-1 R24 + R5 1 inch XPS	Wall 2015-2 Passivhaus R43	Wall 2015-3 OSB as vapour barrier
	Wall components • Vinyl siding • 1.5 in wide x 7/16” thick furring strip installed vertically • 1 inch XPS rigid foam insulation (exterior insulation) • Sheathing membrane • 11 mm OSB wood-sheathing • 2x6 nominal stud cavity with R24 glass fiber insulation batts • 6 mil poly air/vapour barrier • ½ inch painted drywall Notes: XPS a low permeance product compared to (>60ng) EPS Does not meet inboard-outboard ratio; change requirement in NBC (§ 9.27) & see what happens	Wall components Exterior wythe • Vinyl siding • 1.5 in wide x 7/16” thick furring strip installed vertically • Wood-based diffusion board • 2 x 10 studs • Wood fibre insulation • 11 mm OSB wood-sheathing (interior air and vapour barrier) Service wall interior • 2x4 studs • mineral wool or wood fibre insulation • gypsum board 	• Replace poly vapour barrier with interior OSB taped for one of the walls to demonstrate the effectiveness of a smart vapour barrier. Wall-2015-1 with poly vapour barrier replaced with OSB plywood. BC solution - wood sheathing from between studs and XPS to interior; cost the same.

Thank you !

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