If these walls could talk

Dr John Straube, P.Eng.
Building Science Corp
University of Waterloo
www.BuildingScience.com

Better Buildings By Design 2010

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Learning Objectives

- At the end of this program, participants will be able to:
  - Gain insights on high-R value wall systems that can be applied almost immediately.
  - Discuss to the pros and cons of various wall assemblies (wood frame, ICF, SIPS).
  - Understand impact of heat, moisture and air flow in wall assemblies.
  - Gain facts about durability risks, cost factors, assembly, and construction concerns.

Why High R-wall walls

- The planet
- Your wallet
- Your security

- Buildings consume 40% of America's energy
- Heating homes in Vermont uses a lot
- Stop wasting energy. Put on a jacket. Duh.

High R= About 2x Code

TABLE N1102.1
INSULATION AND FENESTRATION REQUIREMENTS BY COMPONENT[a]

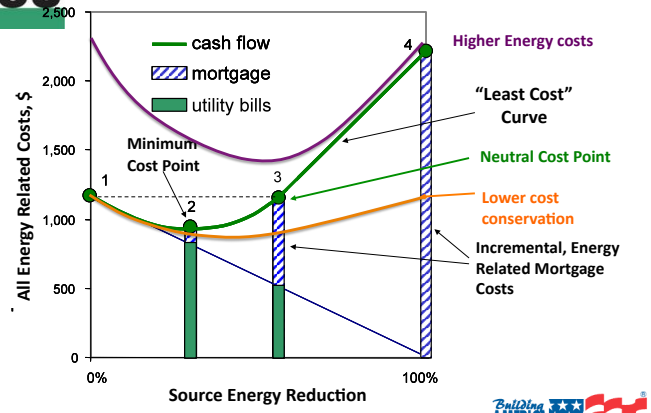
CLIMATE ZONE	FENESTRATION U-FACTOR	SKYLIGHT[b] U-FACTOR	GLAZED FENESTRATION SHGC	CEILING R-VALUE	WOOD FRAME WALL R-VALUE	MASS WALL R-VALUE[k]	FLOOR R-VALUE	BASEMENT[c] WALL R-VALUE	SLAB[d] R-VALUE AND DEPTH	CRAWL SPACE[c] WALL R-VALUE
1	1.2	0.75	0.35[j]	30	13	3/4	13	0	0	0
2	0.65[j]	0.75	0.35[j]	30	13	4/6	13	0	0	0
3	0.50[j]	0.65	0.35[e,j]	30	13	5/8	19	5/13[f]	0	5/13
4 except Marine	0.35	0.60	NR	38	13	5/10	19	10/13	10, 2 ft	10/13
5 and Marine 4	0.35	0.60	NR	38	20 or 13 + 5[h]	13/17	30[f]	10/13	10, 2 ft	10/13
6	0.35	0.60	NR	49	20 or 13 + 5[h]	15/19	30[f]	10/13	10, 4 ft	10/13
7 and 8	0.35	0.60	NR	49	21	19/21	30[f]	10/13	10, 4 ft	10/13

a. *R*-values are minimums. *U*-factors and solar heat gain coefficient (SHGC) are maximums. R-19 batts compressed in to nominal 2 × 6 framing cavity such that the *R*-value is reduced by R-1 or more shall be marked with the compressed batt *R*-value in addition to the full thickness *R*-value.
b. The fenestration *U*-factor column excludes skylights. The SHGC column applies to all glazed fenestration.
c. The first *R*-value applies to continuous insulation, the second to framing cavity insulation; either insulation meets the requirement.
d. R-5 shall be added to the required slab edge *R*-values for heated slabs. Insulation depth shall be the depth of the footing or 2 feet, whichever is less, in zones 1 through 3 for heated slabs.
e. There are no SHGC requirements in the Marine Zone.
f. Basement wall insulation is not required in warm-humid locations as defined by Figure N1101.2 and Table N1101.2.
g. Or insulation sufficient to fill the framing cavity, R-19 minimum.
h. "13+5" means R-13 cavity insulation plus R-5 insulated sheathing. If structural sheathing covers 25% or less of the exterior, R-5 sheathing is not required where structural sheathing is used. If structural sheathing covers more than 25% of exterior, structural sheathing shall be supplemented with insulated sheathing of at least R-2.
i. For impact-rated fenestration complying with Section R301.2.1.2, the maximum *U*-factor shall be 0.75 in zone 2 and 0.65 in zone 3.
j. For impact-resistant fenestration complying with Section R301.2.1.2 of the *International Residential Code*, the maximum SHGC shall be 0.40.
k. The second *R*-value applies when more than half the insulation is on the interior.

Insulation: how much

- How much? Much *more than normal practise*
- Comfort & moisture –
  - **True** 10 is usually enough in Zone 6, but …..
- For energy / environment / economics
  - as much as *practical*
- Practical constraints likely the limit
  - How much space available in studs?
  - Moisture concerns
  - Fastening, windows: exterior sheathing of 1.5”/4”
- Increased insulation can reduce HVAC purchase/ install cost as well as operating!

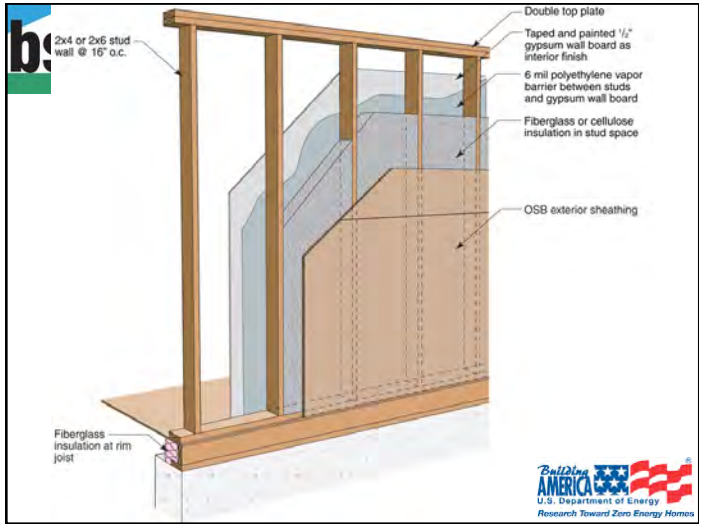
Capital Investment vs Operating Cost



Underlying Source: Dr Ren Anderson, NREL, DOE

But there are Complications

- Add up the R-values of the layers to get the total R-value of the assembly
- **BUT** the actual thermal resistance of an assembly is affected by
  - **Thermal Bridges**
  - **Thermal Mass**
  - **Air Leakage**


Double top plate
2x4 or 2x6 stud wall @ 16" o.c.
Taped and painted ½" gypsum wall board as interior finish
6 mil polyethylene vapor barrier between studs and gypsum wall board
Fiberglass or cellulose insulation in stud space
OSB exterior sheathing
Fiberglass insulation at rim joist
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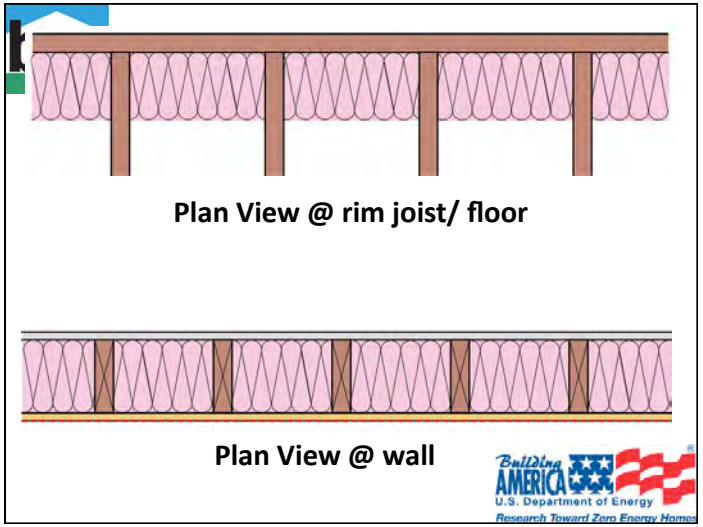
Plan View @ rim joist/ floor
Plan View @ wall
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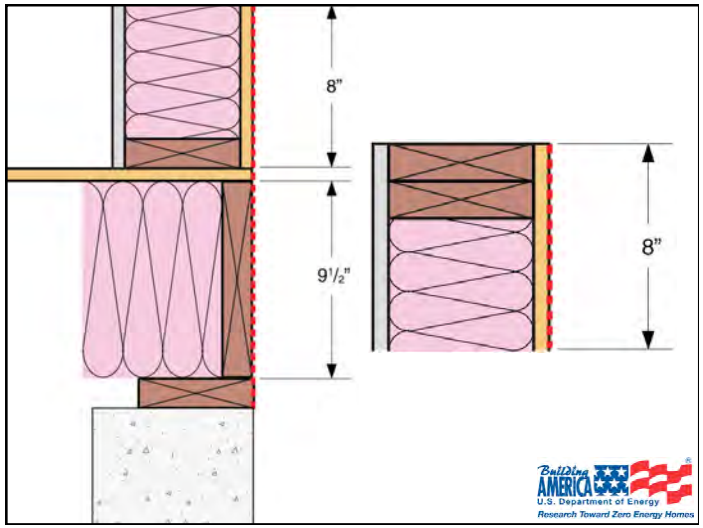
8"
9½"
8"
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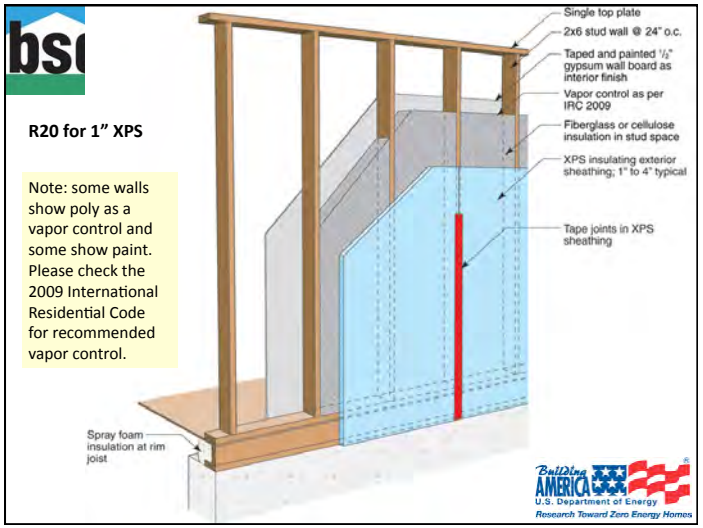
R20 for 1" XPS
Note: some walls show poly as a vapor control and some show paint. Please check the 2009 International Residential Code for recommended vapor control.
Single top plate
2x6 stud wall @ 24" o.c.
Taped and painted ½" gypsum wall board as interior finish
Vapor control as per IRC 2009
Fiberglass or cellulose insulation in stud space
XPS insulating exterior sheathing; 1" to 4" typical
Tape joints in XPS sheathing
Spray foam insulation at rim joist
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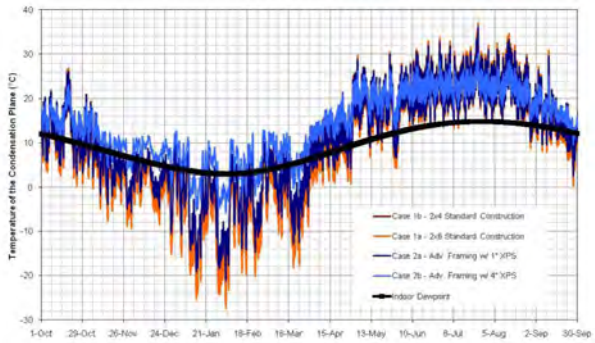
Durability

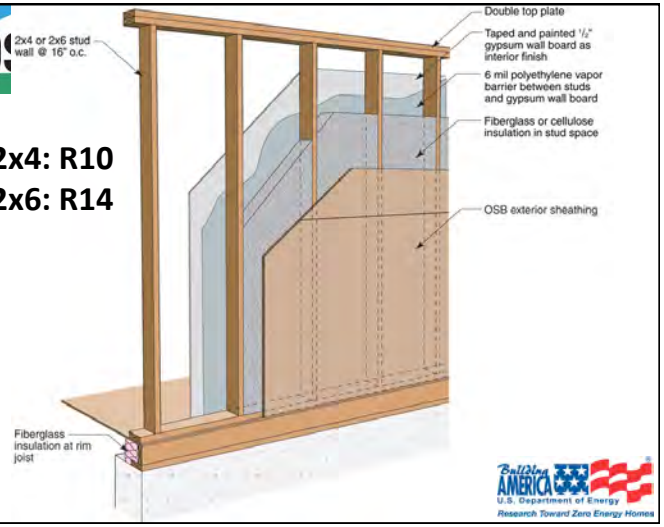
- Insulating exterior surfaces of enclosure
- Condensation occurs on cold surface
- Drying occurs slowly when cold
- Ergo... Insulating makes things wetter!
- Air & water vapor moves through fiberglass and cellulose
- Foam stops air and slows vapor

Air Leakage Condensation Potential

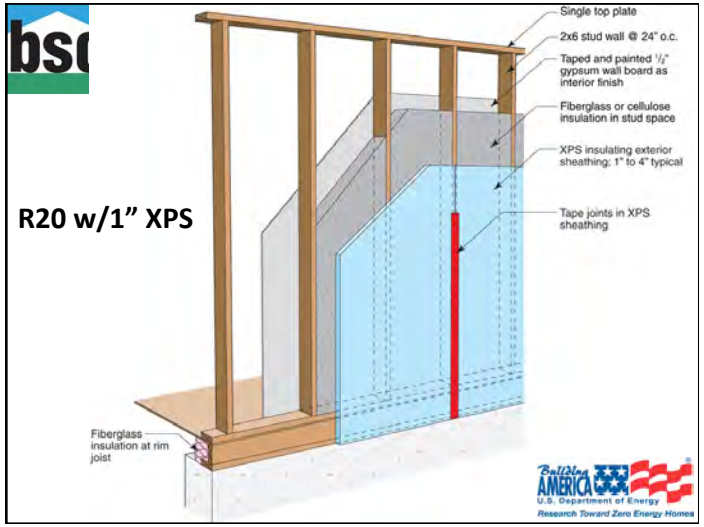


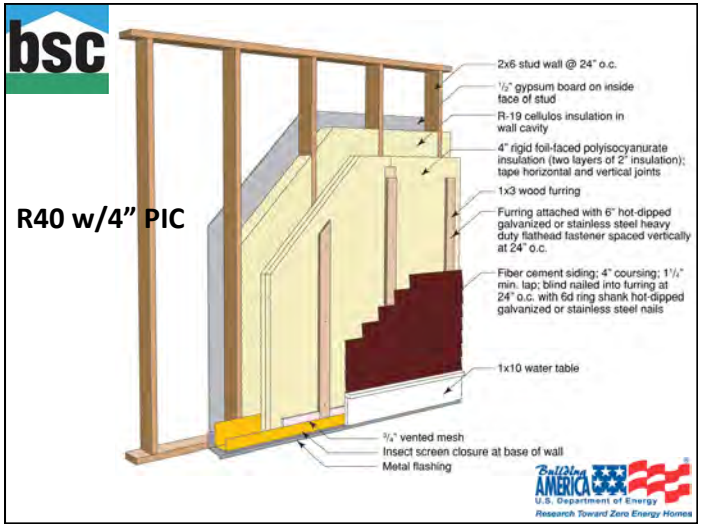
True R-value

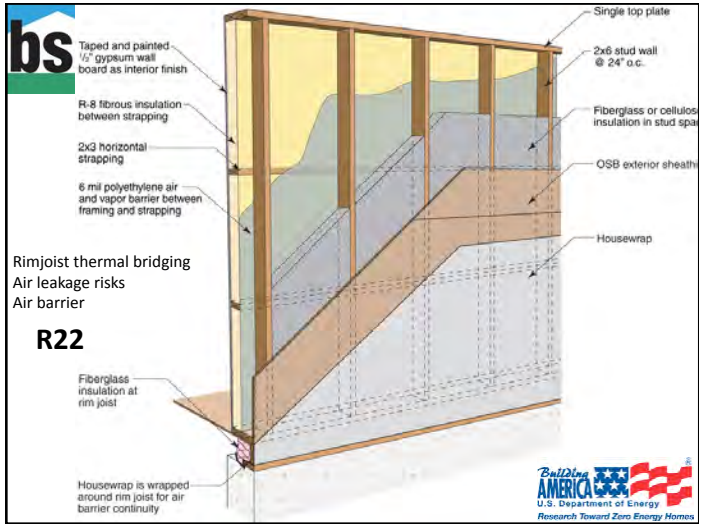
- Includes realistic framing factors
- Should include airtightness
  - We don't have a metric yet



2x4: R10
2x6: R14






Single top plate
Taped and painted ½" gypsum wall board as interior finish
2x6 stud wall @ 24" o.c.
R-8 fibrous insulation between strapping
Fiberglass or cellulos insulation in stud spa
2x3 horizontal strapping
OSB exterior sheathi
6 mil polyethylene air and vapor barrier between framing and strapping
Housewrap
Rimjoist thermal bridging
Air leakage risks
Air barrier
R22
Fiberglass insulation at rim joist
Housewrap is wrapped around rim joist for air barrier continuity
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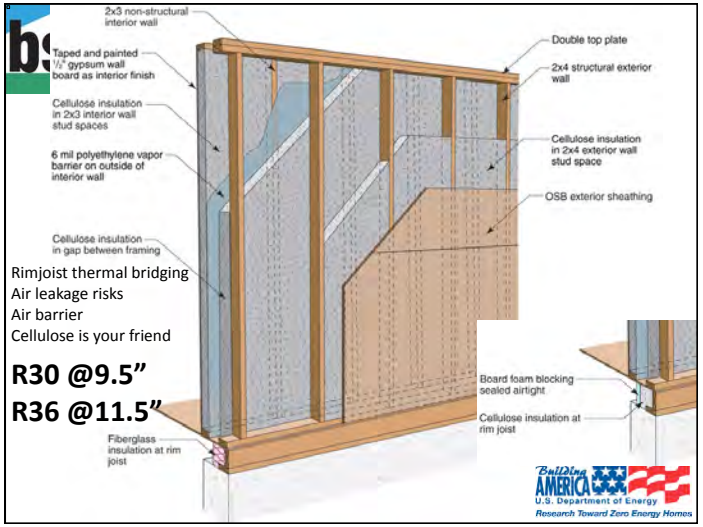
2x3 non-structural interior wall
Taped and painted ½" gypsum wall board as interior finish
Double top plate
2x4 structural exterior wall
Cellulose insulation in 2x3 interior wall stud spaces
Cellulose insulation in 2x4 exterior wall stud space
6 mil polyethylene vapor barrier on outside of interior wall
OSB exterior sheathing
Cellulose insulation in gap between framing
Rimjoist thermal bridging
Air leakage risks
Air barrier
Cellulose is your friend
R30 @9.5"
R36 @11.5"
Board foam blocking sealed airtight
Cellulose insulation at rim joist
Fiberglass insulation at rim joist
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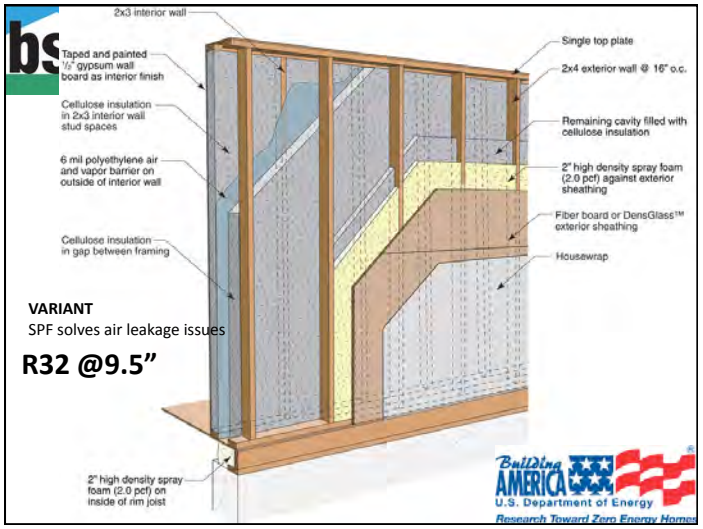
Construction issues


2x3 interior wall
Taped and painted ½" gypsum wall board as interior finish
Single top plate
2x4 exterior wall @ 16" o.c.
Cellulose insulation in 2x3 interior wall stud spaces
Remaining cavity filled with cellulose insulation
6 mil polyethylene air and vapor barrier on outside of interior wall
2" high density spray foam (2.0 pcf) against exterior sheathing
Fiber board or DensGlass™ exterior sheathing
Cellulose insulation in gap between framing
Housewrap
VARIANT
SPF solves air leakage issues
R32 @9.5"
2" high density spray foam (2.0 pcf) on inside of rim joist
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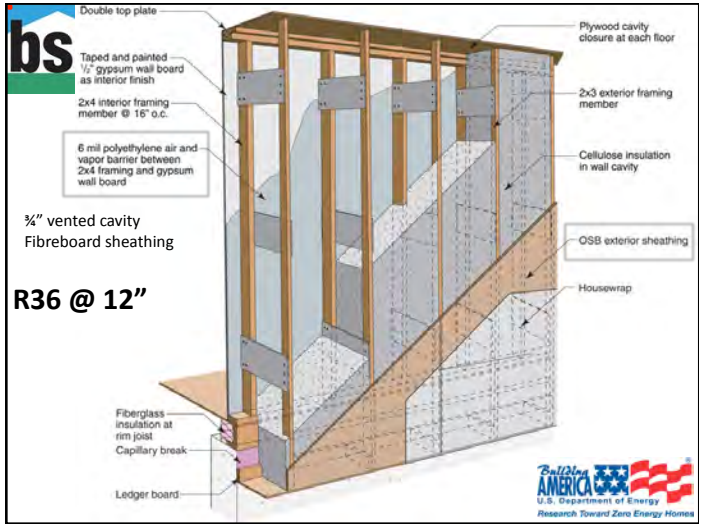
Double top plate
Taped and painted ½" gypsum wall board as interior finish
2x4 interior framing member @ 16" o.c.
6 mil polyethylene air and vapor barrier between 2x4 framing and gypsum wall board
¾" vented cavity
Fibreboard sheathing
R36 @ 12"
Plywood cavity closure at each floor
2x3 exterior framing member
Cellulose insulation in wall cavity
OSB exterior sheathing
Housewrap
Fiberglass insulation at rim joist
Capillary break
Ledger board
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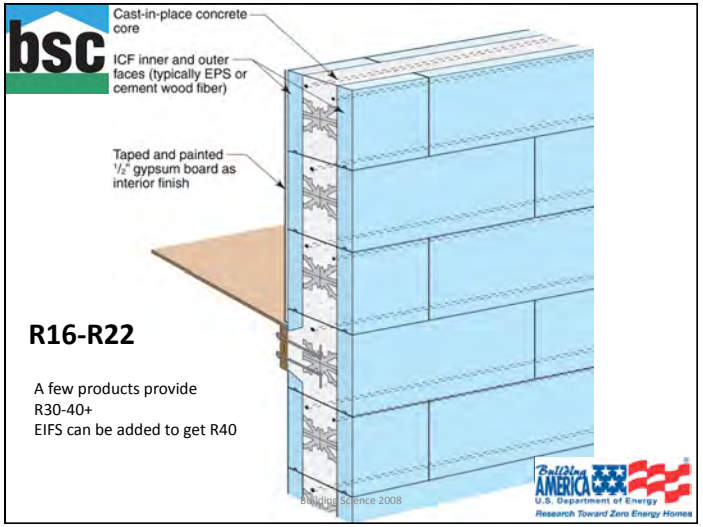
Cast-in-place concrete core
ICF inner and outer faces (typically EPS or cement wood fiber)
Taped and painted ½" gypsum board as interior finish
R16-R22
A few products provide R30-40+
EIFS can be added to get R40
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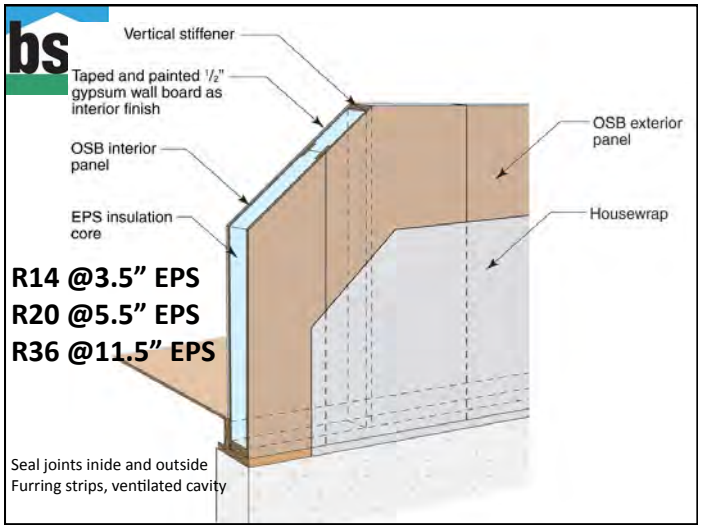
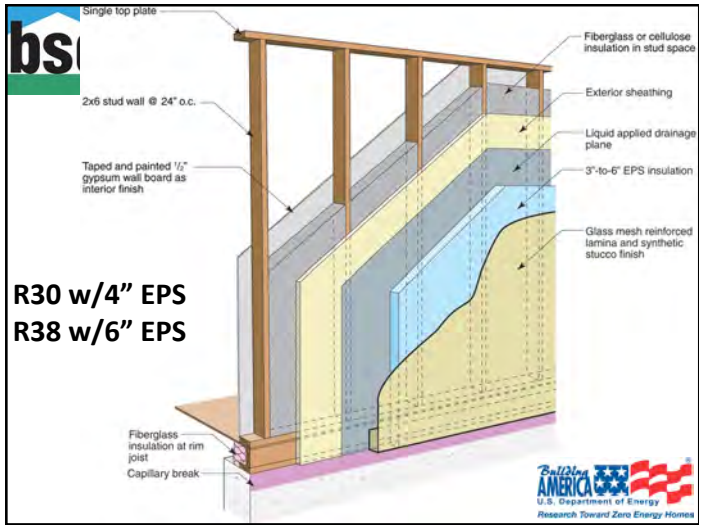
Insulated Concrete Forms
• If you afford it, use them –
– cap break,
– insulation,
– vapor retarder,
– above grade
02/23/2007

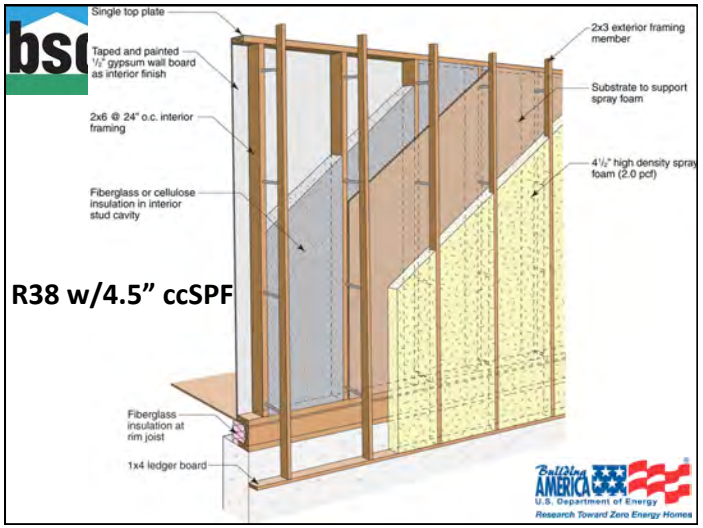

Vertical stiffener
Taped and painted ½" gypsum wall board as interior finish
OSB interior panel
EPS insulation core
OSB exterior panel
Housewrap
R14 @3.5" EPS
R20 @5.5" EPS
R36 @11.5" EPS
Seal joints inide and outside
Furring strips, ventilated cavity

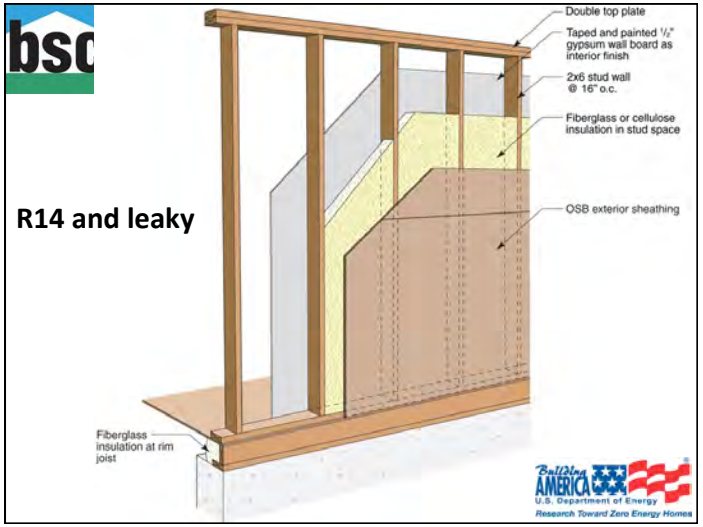
Structural Insulated Panels

- Advantages
  - Superior blanket of insulation
  - if no voids then no convection or windwashing
- Must seal OSB joints for air barrier system
- Therefore, done right = excellent
- Small air leaks at joints in roofs can cause problems
- Don't get them too wet from rain
  - Low perm layers means limited drying: strapped cavity

Building Science 2008 Insulation and Thermal Bridges No. 33/65







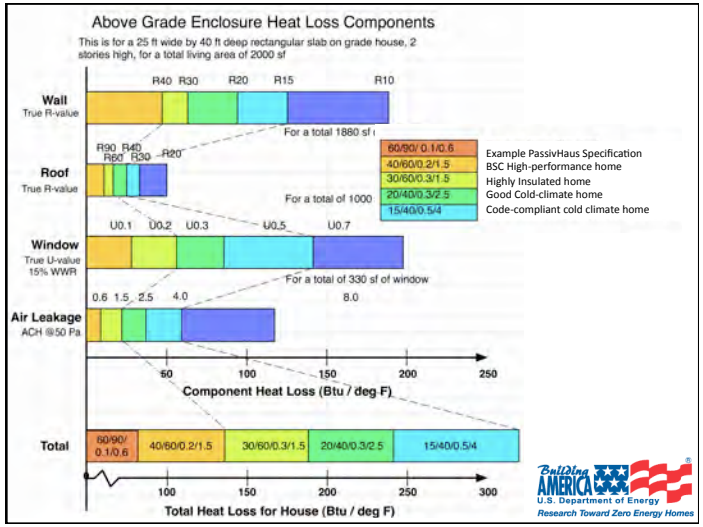
Small changes are easy

Case	Description	Whole Wall R-value	Rim Joist	Clear Wall R-value	Top Plate
1bii	2x4, 16"oc, R13FG + OSB (25%ff)	**10.0**	9.8	10.1	9.8
1b	2x4 AF, 24"oc, R13FG + OSB	**11.1**	9.8	11.5	9.8
1aii	2x6, 16"oc, R19FG + OSB (25%ff)	**13.7**	12.3	14.1	12.5
6a	SIPs (3.5" EPS)	**14.1**	12.3	14.5	10.6
1a	2x6 AF, 24"oc, R19FG + OSB	**15.2**	12.3	16.1	12.5
7a	ICF - 8" foam ICF (4" EPS)	**16.4**		16.4	
8b	2x6 AF, 24" o.c., 5.5" R21 0.5 pcf SPF, OSB	**16.5**	13.1	17.2	16.6
7c	ICF - 14" cement woodfiber ICF with Rockwool	**17.4**		17.4	
9	2x6 AF, 24"oc, 2" SPF and 3.5" cellulose	**17.5**	13.2	18.4	17.7
8a	2x6 AF, 24" o.c., 5" 2 pcf R29 SPF, OSB	**19.1**	13.6	20.3	19.5
2a	2x6 AF, 24"oc R19FG + 1" R5 XPS	**20.2**	18.5	20.6	20.3
7b	ICF - 15" foam ICF (5" EPS)	**20.6**		20.6	
3	2x6 AF, 24"oc, 2x3 R19+R8 FG	**21.5**	13.4	23.5	18.4
4	Double stud wall 9.5" R34 cellulose	**30.1**	14.4	33.5	28.8
12	2x6 AF, 24"oc, EIFS - 4" EPS	**30.1**	23.8	31.4	31.1
10	Double stud with 2" 2.0 pcf foam, 7.5" cell.	**32.4**	15.9	36.2	28.5
2b	2x6 AF, 24"oc R19FG + 4" R20 XPS	**34.5**	29.0	35.6	35.4
6b	SIPs (11.25" EPS)	**36.2**	14	41.6	28.2
5	Truss wall 12" R43 cellulose	**36.5**	18.6	40.5	34.4
11	Offset frame wall with ext. spray foam	**37.1**	18.8	40.6	41.9

*AF - Advanced Framing

Other Components

- R40 Walls are just one component!
  - 5:10:20:40:60-1.5ACH
- Windows often weak link
  - Triple-glazed becoming justified
- Basement
  - Slabs R10 in Vermont is worth it
  - Walls should be R20 or more if easy
- Easy and cheap to upgrade vented attics R60
- Airtightness: aim for 1.5 ACH@50


Above Grade Enclosure Heat Loss Components
This is for a 25 ft wide by 40 ft deep rectangular slab on grade house, 2 stories high, for a total living area of 2000 sf
Wall
True R-value
R40 R30 R20 R15 R10
For a total 1880 sf
Roof
True R-value
R90 R40 R60 R30 R20
For a total of 1000
Window
True U-value
15% WWR
U0.1 U0.2 U0.3 U0.5 U0.7
For a total of 330 sf of window
Air Leakage
ACH @50 Pa
0.6 1.5 2.5 4.0 8.0
50 100 150 200 250
Component Heat Loss (Btu / deg F)
Total
60/90/ 0.1/0.6
40/60/0.2/1.5
30/60/0.3/1.5
20/40/0.3/2.5
15/40/0.5/4
100 150 200 250 300
Total Heat Loss for House (Btu / deg F)
60/90/ 0.1/0.6 Example PassivHaus Specification
40/60/0.2/1.5 BSC High-performance home
30/60/0.3/1.5 Highly Insulated home
20/40/0.3/2.5 Good Cold-climate home
15/40/0.5/4 Code-compliant cold climate home
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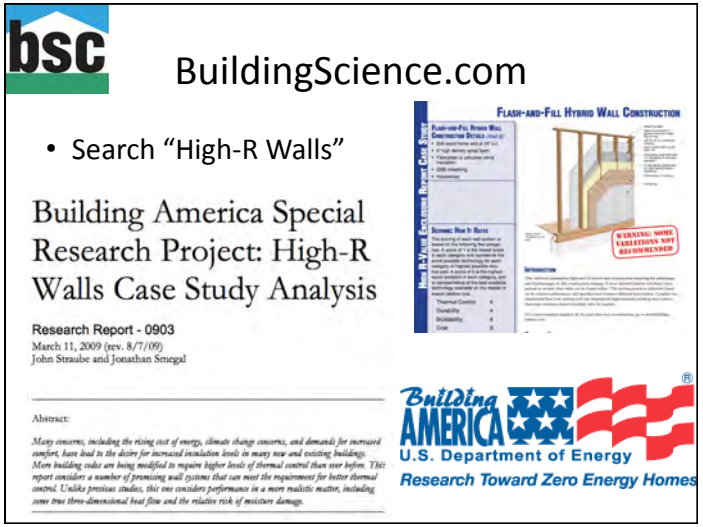
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Building America Special Research Project: High-R Walls Case Study Analysis
Research Report - 0903
March 11, 2009 (rev. 8/7/09)
John Straube and Jonathan Smegal
Abstract:
Many concerns, including the rising cost of energy, climate change concerns, and demands for increased comfort, have lead to the desire for increased insulation levels in many new and existing buildings. More building codes are being modified to require higher levels of thermal control than ever before. This report considers a number of promising wall systems that can meet the requirement for better thermal control. Unlike previous studies, this one considers performance in a more realistic matter, including some true three-dimensional heat flow and the relative risk of moisture damage.
Flash-and-Fill Hybrid Wall Construction
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