Fuzzy Solutions:
Safe, High-performance Enclosures with No Foam

Dr John Straube, P.Eng.
Principal, RDH Building Science
Associate Professor, University of Waterloo

RDH BUILDING SCIENCE

UNIVERSITY OF WATERLOO
Department of Civil and Environmental Engineering
Architectural Engineering

2

Outline

RDH Building Science

- Why foam
- Alternate designs with no foam
- Walls
- Roofs
- Basements
- Retrofits
- Field measurements of performance

WATERLOO ENGINEERING

3

Why foam?

- XPS, EPS, ccSPF, ocSPF, PIC
- Stiff, easy to handle
- Vapor resistant (most)
- Air resistant
- Water resistant
- Often cheapest

WATERLOO ENGINEERING

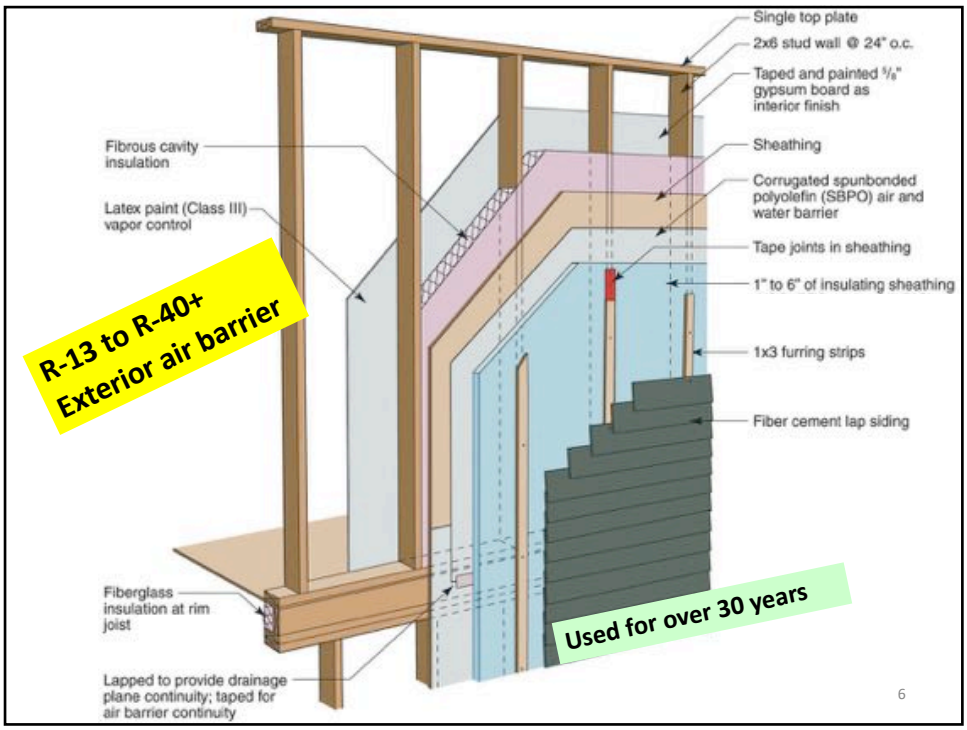
4

Non-foam designs

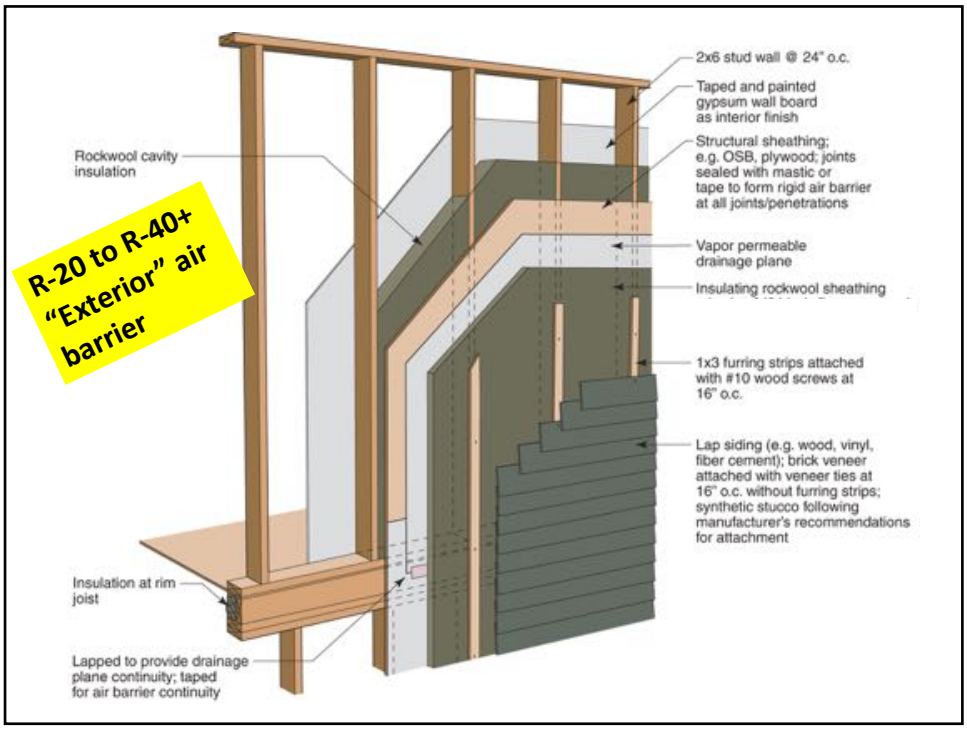
- Often can use rigid stonewool
  - stiff and strong boards depends on density
  - stonewool is moisture tolerant
- But…
  - Cellulose, straw, and batt need to be protected
  - All fibrous insulation designs need to adjust for lack of vapor resistance

WATERLOO ENGINEERING

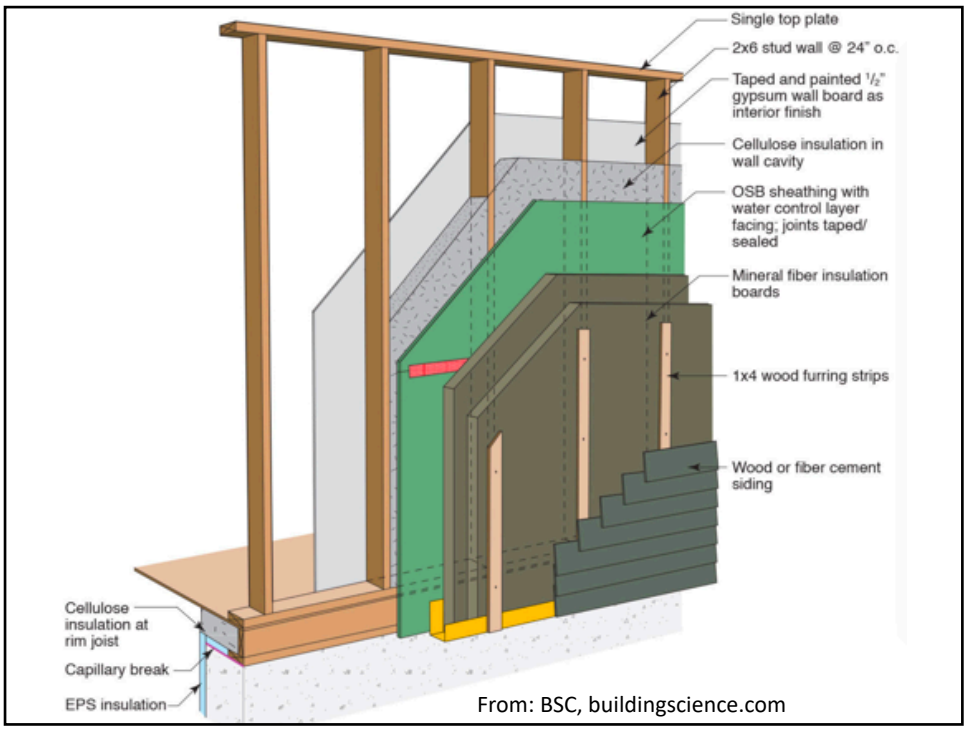
5


Single top plate
2x6 stud wall @ 24" o.c.
Taped and painted ⅝" gypsum board as interior finish
Sheathing
Corrugated spunbonded polyolefin (SBPO) air and water barrier
Tape joints in sheathing
1" to 6" of insulating sheathing
1x3 furring strips
Fiber cement lap siding
Fibrous cavity insulation
Latex paint (Class III) vapor control
R-13 to R-40+ Exterior air barrier
Used for over 30 years
Fiberglass insulation at rim joist
Lapped to provide drainage plane continuity; taped for air barrier continuity
6

6


2x6 stud wall @ 24" o.c.
Taped and painted gypsum wall board as interior finish
Structural sheathing; e.g. OSB, plywood; joints sealed with mastic or tape to form rigid air barrier at all joints/penetrations
Vapor permeable drainage plane
Insulating rockwool sheathing
1x3 furring strips attached with #10 wood screws at 16" o.c.
Lap siding (e.g. wood, vinyl, fiber cement); brick veneer attached with veneer ties at 16" o.c. without furring strips; synthetic stucco following manufacturer's recommendations for attachment
Rockwool cavity insulation
R-20 to R-40+ "Exterior" air barrier
Insulation at rim joist
Lapped to provide drainage plane continuity; taped for air barrier continuity

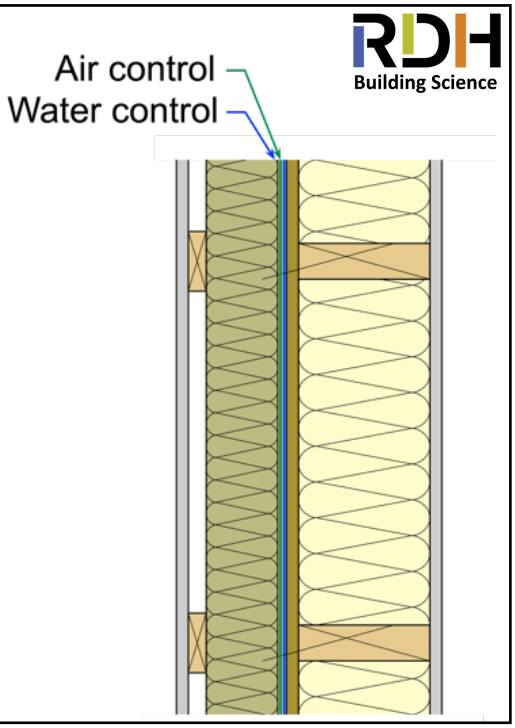
7



8

Effective Assembly R-value of Split Insulation Wall Assembly [ft²·°F·hr/Btu]		
	2x4 Stud Wall (R-12 Batts)	2x6 Stud Wall (R-19 Batts)
Thickness of Exterior Insulation	R-value/inch of Exterior Insulation	
	R-4.0	R-4.0
0"	11.3	16.2
1/2"	13.3	18.2
1"	15.3	20.2
1 1/2"	17.3	**22.2**
2"	19.3	**24.2**
2 1/2"	21.3	**26.2**
3"	**23.3**	**28.2**
3 1/2"	**25.3**	**30.2**
4"	**27.3**	**32.2**
4 1/2"	**29.3**	**34.2**
5"	**31.3**	**36.2**
5 1/2"	**33.3**	**38.2**
6"	**35.3**	**40.2**

A 23% framing factor is assumed which is consistent with standard 16" o.c. stud framing practices.

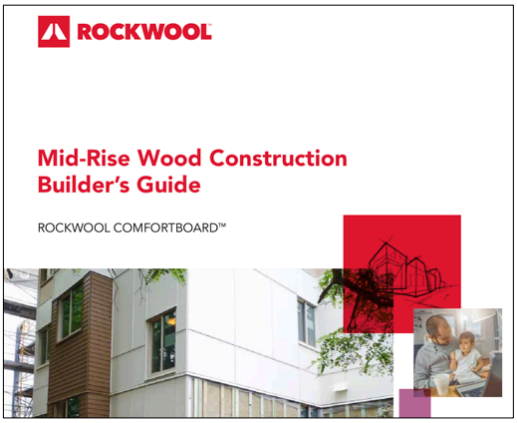


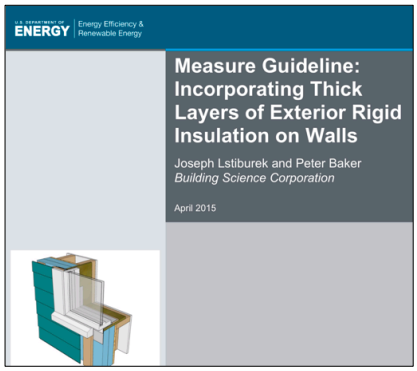
9

10

11

Resources



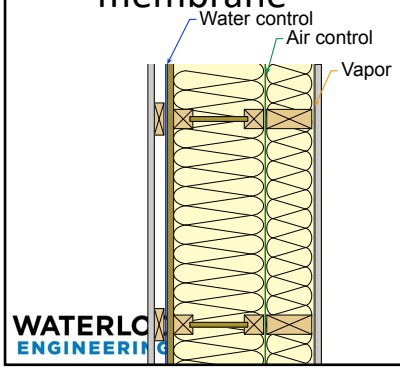


12

Service wall

RDH Building Science

- Locates air (maybe vapor) membrane inside structure
- Harder to seal flexible unsupported membrane

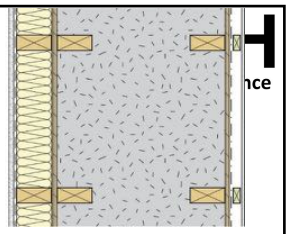


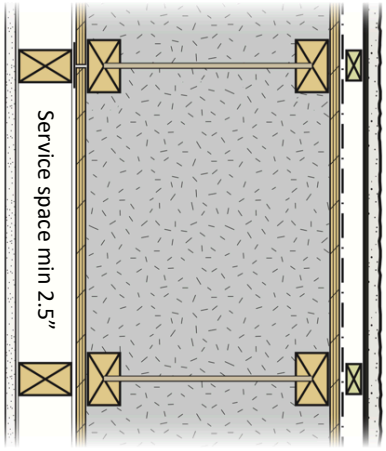
13

Deep stud w/service wall

Effective Assembly R-value for Deep Stud Walls [ft²·°F·hr/Btu]					
	Uninsulated Service Wall			Insulated (R-12) 2x4 Service Wall	
Thickness of Wall Framing	R-value/inch of Insulation				
	R-3.4	R-4.0		R-3.4	R-4.0
2x6	17.7	18.9		**25.2**	**26.3**
2x8	21.9	**23.5**		**29.4**	**31.0**
2x10	**26.7**	**28.7**		**34.2**	**36.2**
2x12	**31.6**	**34.0**		**39.0**	**41.5**
9.5" I-joist	**28.4**	**31.2**		**35.9**	**38.7**
11-7/8" I-joist	**35.4**	**39.2**		**42.9**	**46.7**
14" I-joist	**41.7**	**46.3**		**49.1**	**53.8**
16" I-Joist	**47.6**	**53.0**		**55.0**	**60.5**

A 23% framing factor is assumed which is consistent with standard 16" o.c. stud framing practices. Reduced framing factors may be possible.





Floor joist details will often degrade these values

WATERLOO ENGINEERING

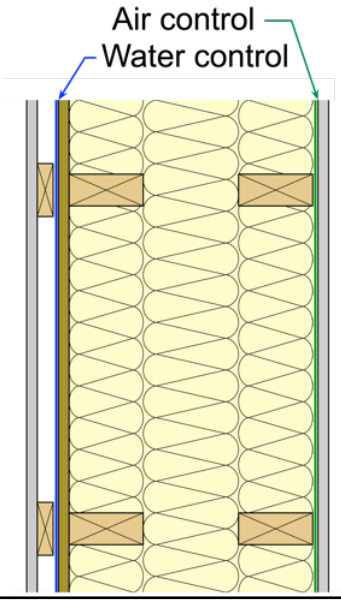
14

Double stud

RDH Building Science

Effective Assembly R-value for Double 2x4 Stud Wall* [ft²·°F·hr/Btu]			
Thickness of Gap Between Stud Walls	R-value/inch of Insulation		
	R-3.4	R-4.0	R-5.0
0"	19.7	21.2	
1/4"	20.5	**22.2**	
1/2"	21.4	**23.2**	
1"	**23.1**	**25.2**	
1 1/2"	**24.8**	**27.2**	
2"	**26.5**	**29.2**	
2 1/2"	**28.2**	**31.2**	
3"	**29.9**	**33.2**	
3 1/2"	**31.6**	**35.2**	
4"	**33.3**	**37.2**	
4 1/2"	**35.0**	**39.2**	
5"	**36.7**	**41.2**	

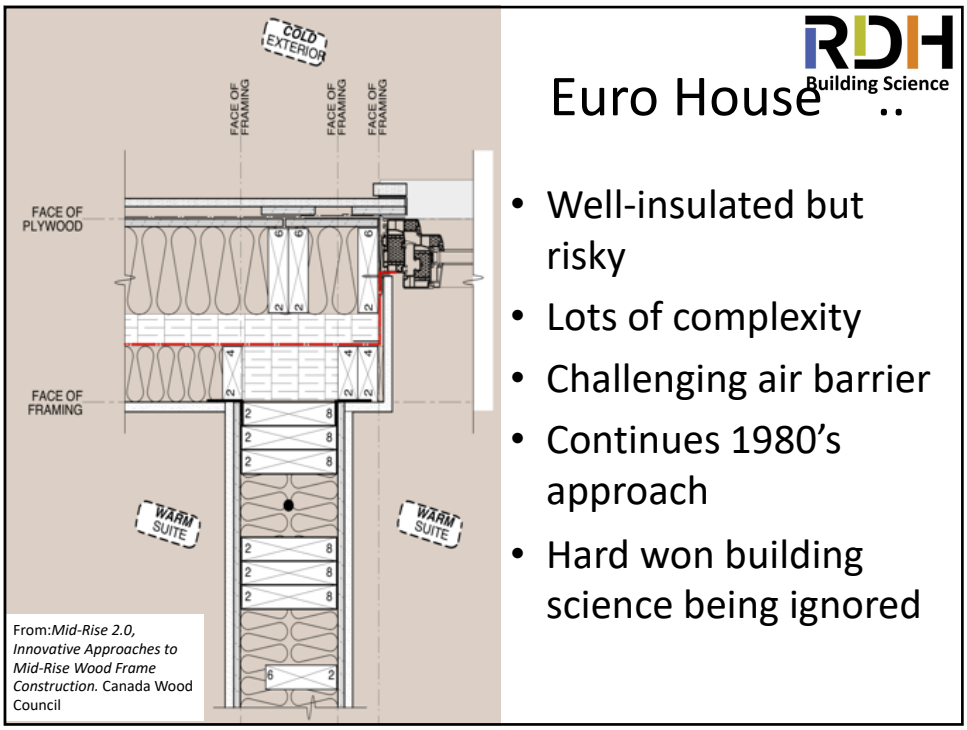
Assumes interior stud wall has the same 23% framing factor as the exterior stud wall, though it may require less framing



Floor joist details can degrade these values

WATERLOO ENGINEERING

15



From:*Mid-Rise 2.0, Innovative Approaches to Mid-Rise Wood Frame Construction.* Canada Wood Council

RDH Building Science

Euro House ..

- Well-insulated but risky
- Lots of complexity
- Challenging air barrier
- Continues 1980's approach
- Hard won building science being ignored

16

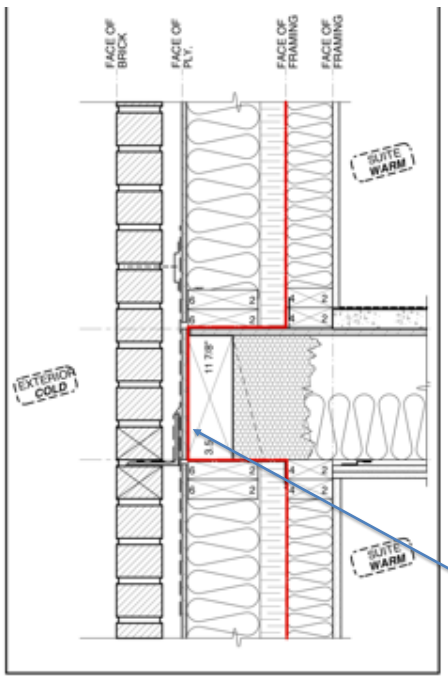


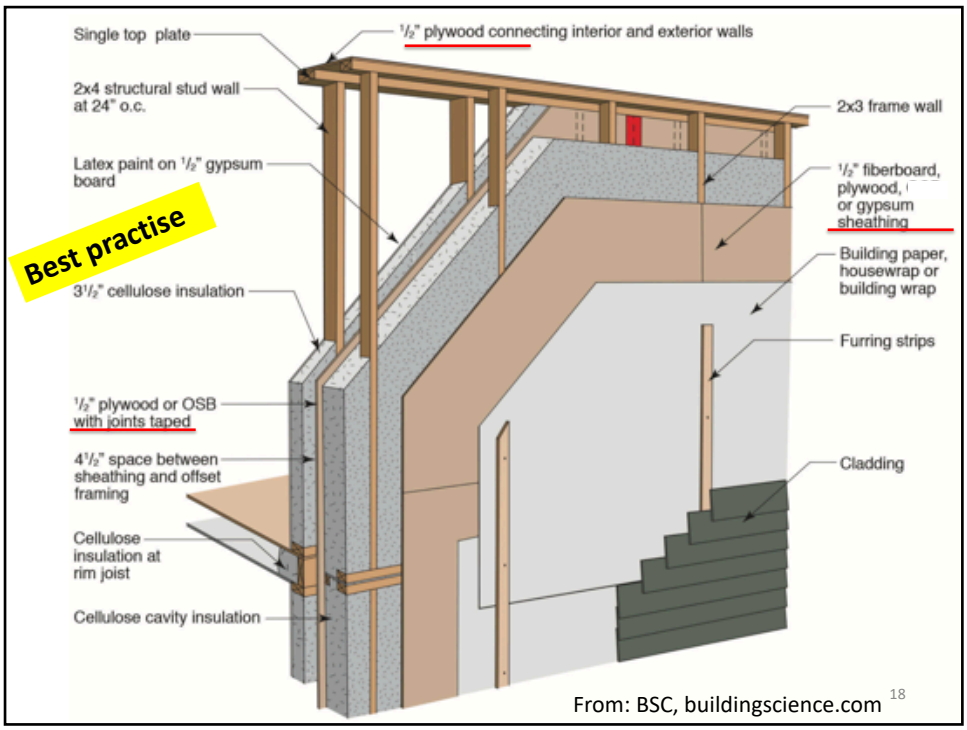
Fig. 2.4: Floorline junction

From:*Mid-Rise 2.0, Innovative Approaches to Mid-Rise Wood Frame Construction.* Canada Wood Council

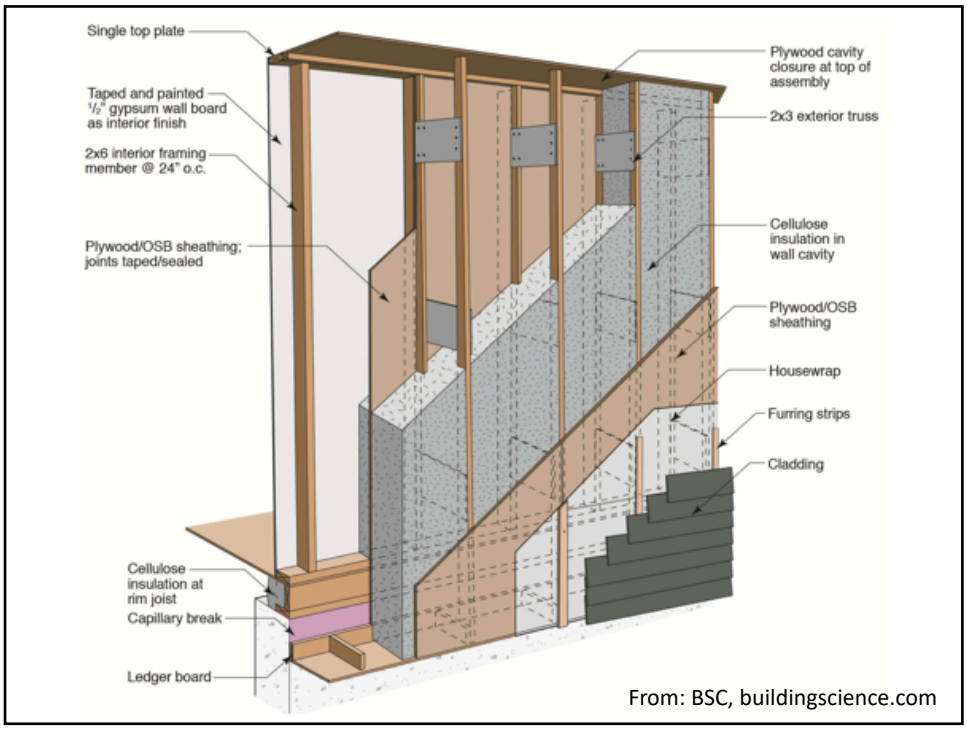
were installed reducing costs. only responsible for the HRV installation from the roof, down the vertical shafts to the silencer box located on the inside wall of each suite (Fig. 2.6).

Fig. 2.5: View showing vapour barrier wrapped over floor lines

17


Single top plate
½" plywood connecting interior and exterior walls
2x4 structural stud wall at 24" o.c.
2x3 frame wall
Latex paint on ½" gypsum board
½" fiberboard, plywood, or gypsum sheathing
Best practise
Building paper, housewrap or building wrap
3½" cellulose insulation
Furring strips
½" plywood or OSB with joints taped
Cladding
4½" space between sheathing and offset framing
Cellulose insulation at rim joist
Cellulose cavity insulation
From: BSC, buildingscience.com
18

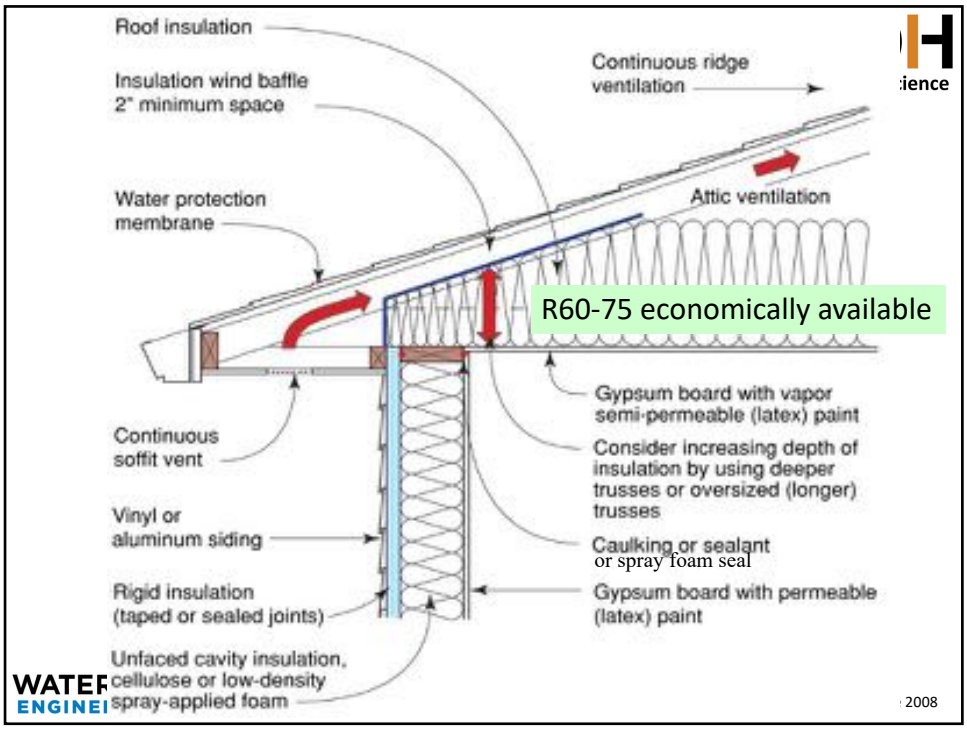
18


Single top plate
Plywood cavity closure at top of assembly
Taped and painted ½" gypsum wall board as interior finish
2x3 exterior truss
2x6 interior framing member @ 24" o.c.
Cellulose insulation in wall cavity
Plywood/OSB sheathing; joints taped/sealed
Plywood/OSB sheathing
Housewrap
Furring strips
Cladding
Cellulose insulation at rim joist
Capillary break
Ledger board
From: BSC, buildingscience.com

19

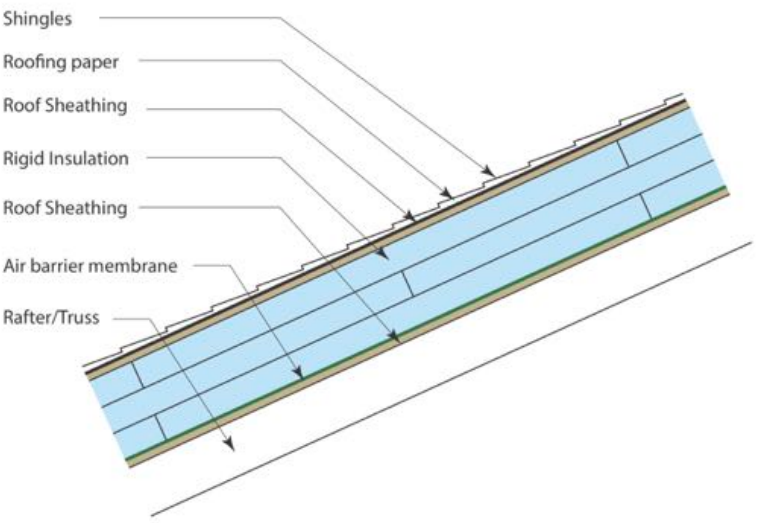
ROOFS

20


Roof insulation
Insulation wind baffle
2" minimum space
Water protection
membrane
Continuous
soffit vent
Vinyl or
aluminum siding
Rigid insulation
(taped or sealed joints)
Unfaced cavity insulation,
cellulose or low-density
spray-applied foam
Continuous ridge
ventilation
Attic ventilation
R60-75 economically available
Gypsum board with vapor
semi-permeable (latex) paint
Consider increasing depth of
insulation by using deeper
trusses or oversized (longer)
trusses
Caulking or sealant
or spray foam seal
Gypsum board with permeable
(latex) paint
2008

21

"Traditional" Unvented Roof

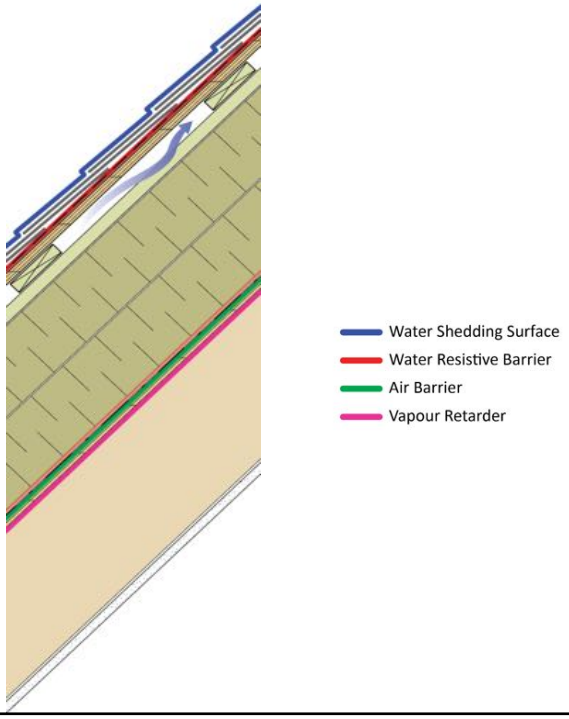
- 

WATERLOO ENGINEERING

22

Insulating Sloped & Compact Roofs

New Challenges:
- Getting to higher R-values (R-60 to R-100+)
- Roof Venting
- Air Barrier & Air Permeable insulation
- Constructability & Thickness



23

Cathedral ceilings

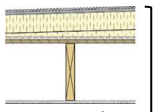
- Strap- and counter-strap allows ventilation even around valleys, dormers etc

WATERLOO ENGINEERING

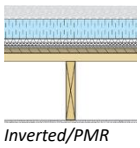
24

Low-slope Roof Assemblies

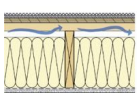
Wood-framed Insulated Low-Slope Roofs



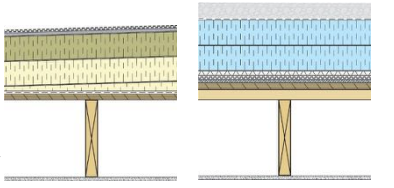
Conventional



Inverted/PMR

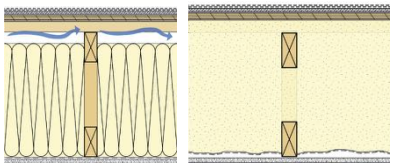


Vented



Exterior Insulated+ ***(conventional or inverted/PMR)***

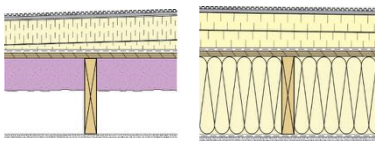
- Best durability but most expensive
- Some challenges with more layers of insulation & detailing
- Simple design



Deeper Joist/Truss – ***(vented or unvented)***

Least durable but least expensive

- Simple design
- Standard details with deeper structure



Split Insulated ***(unvented)***

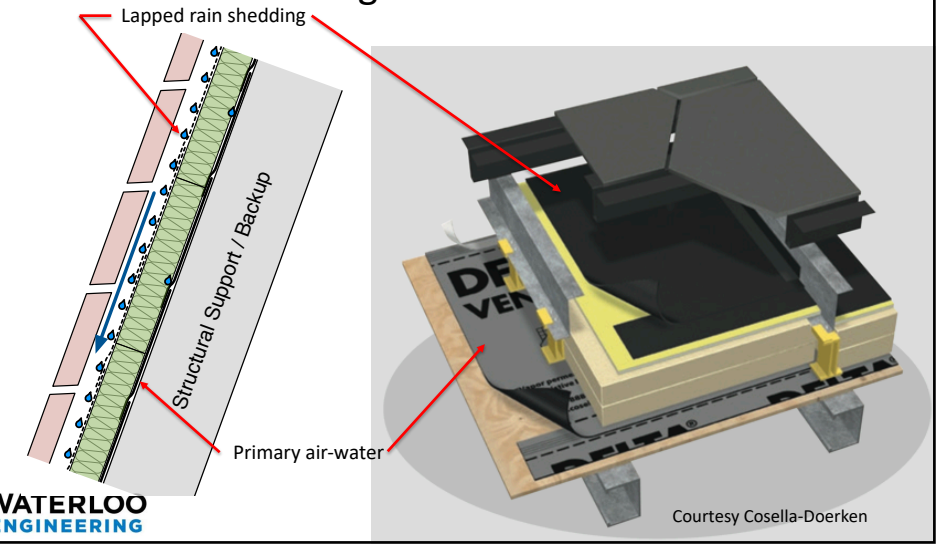
- Decent durability
- Moderate cost
- More complex design

25

Doing it right

RDH Building Science

Hidden rain shedding



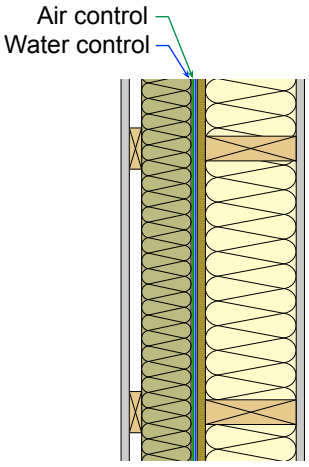
WATERLOO ENGINEERING

26

Unvented roof

RDH Building Science

- Similar to wall design



WATERLOO ENGINEERING

27

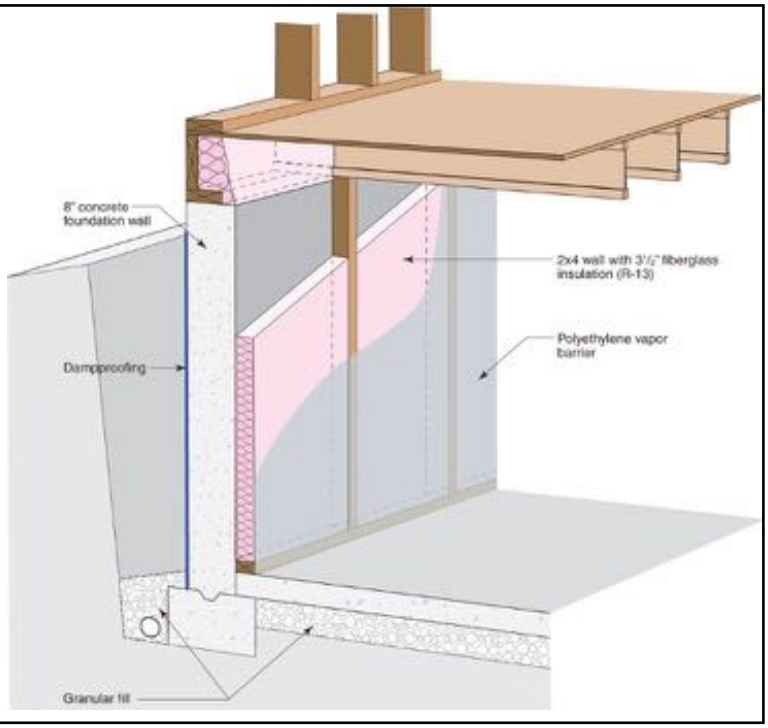
Exterior insulation, roof underlayment

28

29

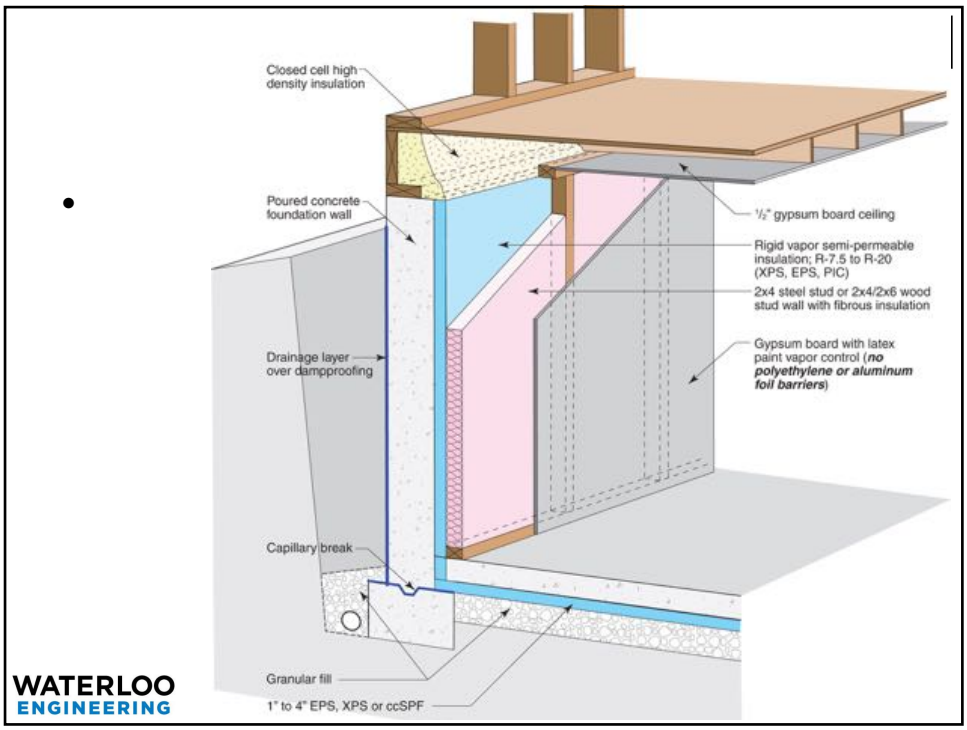
BASEMENTS

30

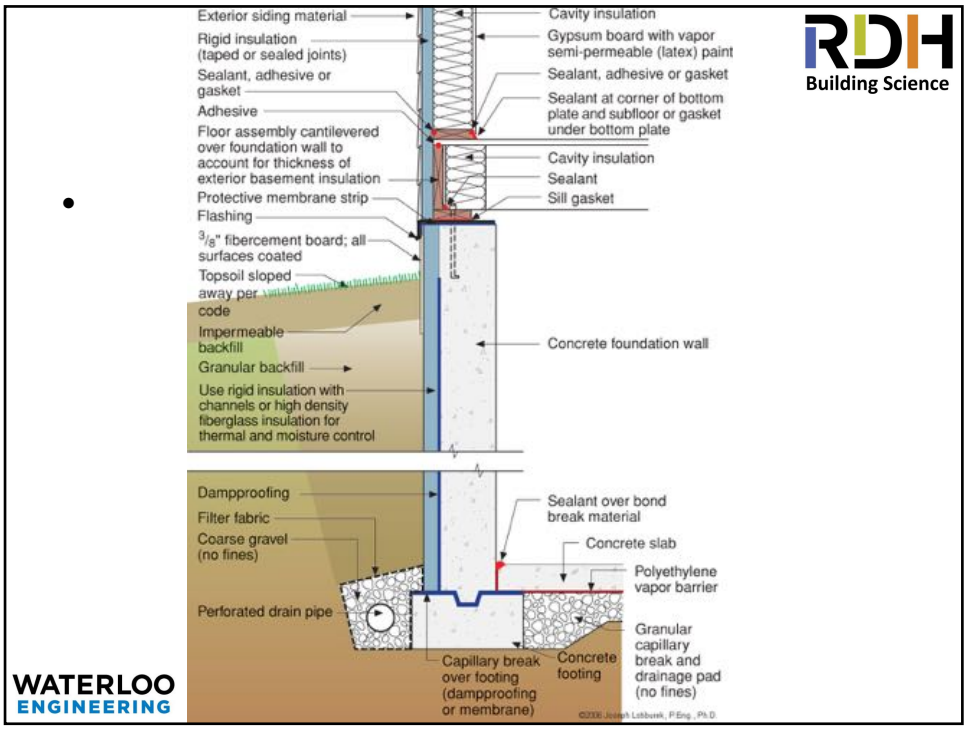
- 

WATERLOO ENGINEERING

31


Closed cell high density insulation
Poured concrete foundation wall
½" gypsum board ceiling
Rigid vapor semi-permeable insulation; R-7.5 to R-20 (XPS, EPS, PIC)
2x4 steel stud or 2x4/2x6 wood stud wall with fibrous insulation
Drainage layer over dampproofing
Gypsum board with latex paint vapor control (no polyethylene or aluminum foil barriers)
Capillary break
Granular fill
1" to 4" EPS, XPS or ccSPF
WATERLOO ENGINEERING

32


Exterior siding material
Rigid insulation (taped or sealed joints)
Sealant, adhesive or gasket
Adhesive
Floor assembly cantilevered over foundation wall to account for thickness of exterior basement insulation
Protective membrane strip
Flashing
3/8" fibercement board; all surfaces coated
Topsoil sloped away per code
Impermeable backfill
Granular backfill
Use rigid insulation with channels or high density fiberglass insulation for thermal and moisture control
Cavity insulation
Gypsum board with vapor semi-permeable (latex) paint
Sealant, adhesive or gasket
Sealant at corner of bottom plate and subfloor or gasket under bottom plate
Cavity insulation
Sealant
Sill gasket
Concrete foundation wall
Dampproofing
Filter fabric
Coarse gravel (no fines)
Perforated drain pipe
Sealant over bond break material
Concrete slab
Polyethylene vapor barrier
Granular capillary break and drainage pad (no fines)
Capillary break over footing (dampproofing or membrane)
Concrete footing
RDH Building Science
WATERLOO ENGINEERING

33

Science

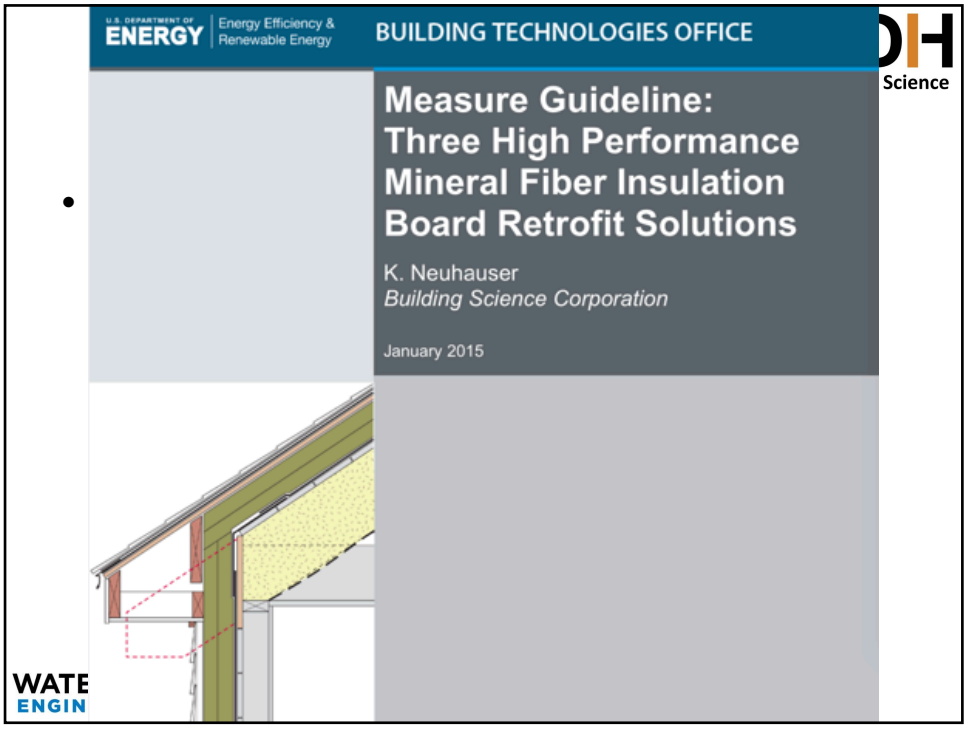
WATERLOO
ENGINEERING

34

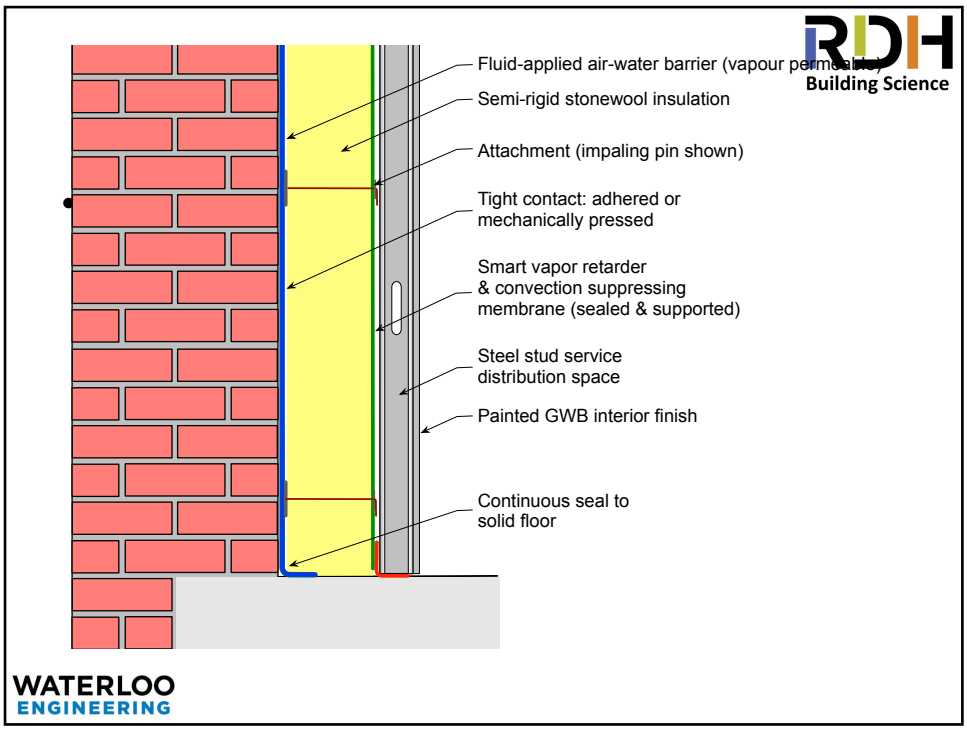
35

RETROFIT

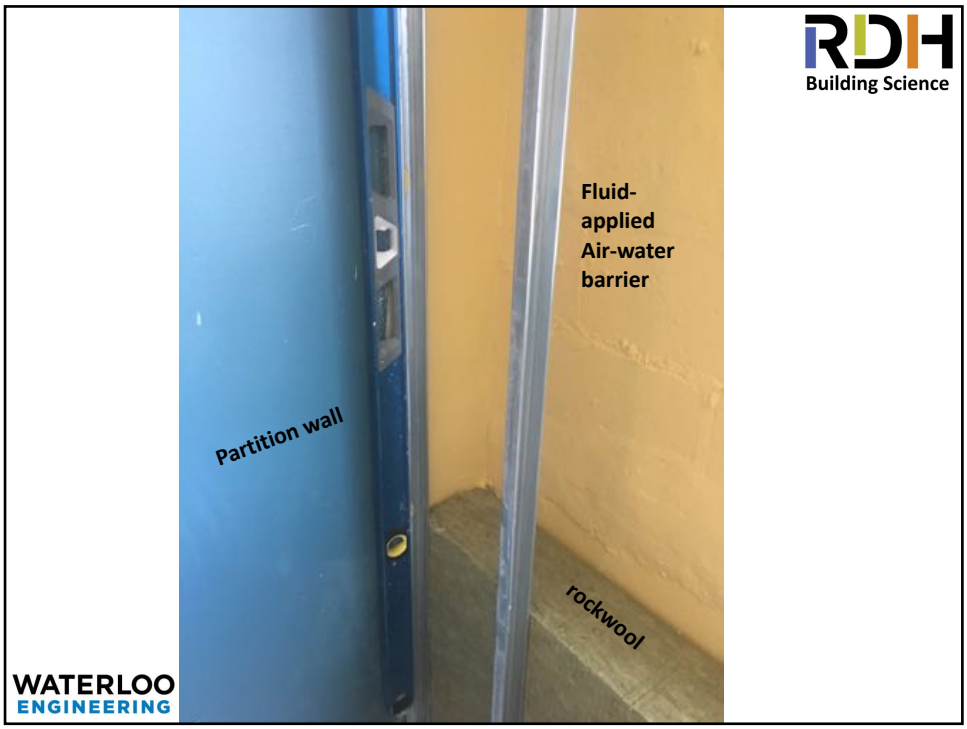
36



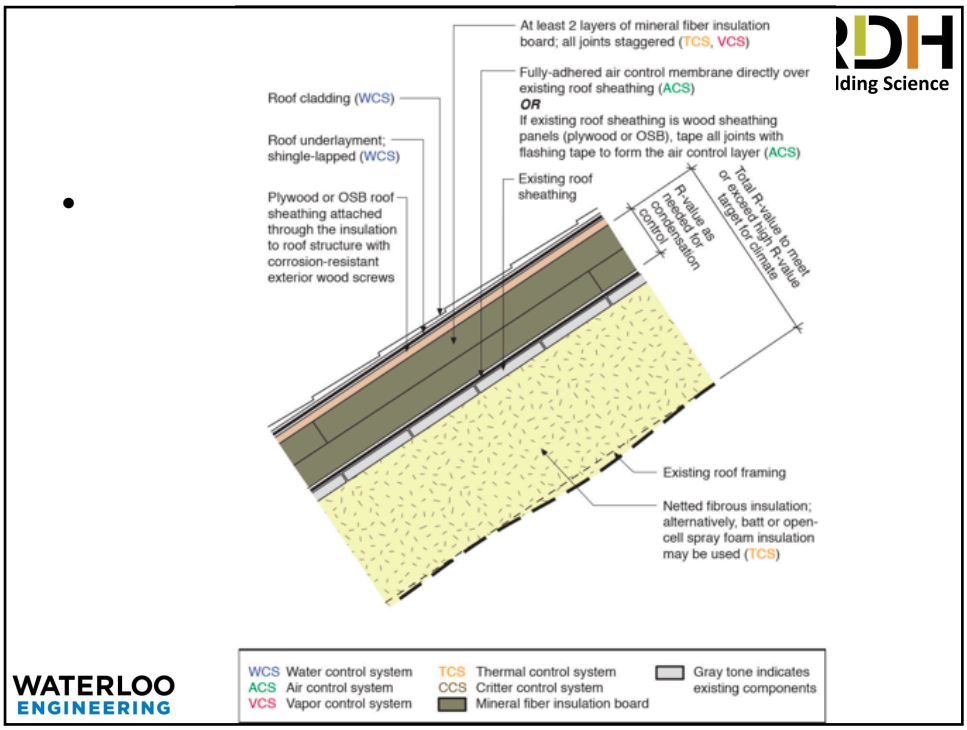
37


Fluid-applied air-water barrier (vapour permeable)
Semi-rigid stonewool insulation
Attachment (impaling pin shown)
Tight contact: adhered or mechanically pressed
Smart vapor retarder & convection suppressing membrane (sealed & supported)
Steel stud service distribution space
Painted GWB interior finish
Continuous seal to solid floor
RDH Building Science
WATERLOO ENGINEERING

38


Fluid-applied Air-water barrier
Partition wall
rockwool
RDH Building Science
WATERLOO ENGINEERING

39



40

FIELD STUDY

41

U of Waterloo Field study

RDH Building Science

- Assess high R-value walls of future
- Moisture performance
  - Risk of condensation?
  - Tolerance to wetting (drying)?
- Included all fibrous solutions

WATERLOO ENGINEERING

42

42

R-values

RDH Building Science

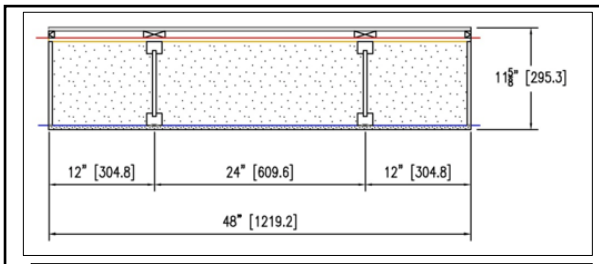
- Four fibrous insulations
- Walls 5 & 6 have no 6 mil poly vapor barrier

Wall	Cavity W/m2K	Stud W/m2K	Effective U W/m2K	R-imp
1. Double Stud R44	0.124	0.256	0.150	37.7
2. I-Joist R44	0.156	0.213	0.167	33.9
3. 2x6 Datum	0.228	0.602	0.303	18.7
4. 2x8 ccSPF R40	0.148	0.492	0.217	26.2
5. 2x6 PIC R22 batt	0.154	0.264	0.176	32.2
6. 2x6 2.5" XPS	0.153	0.261	0.175	32.5
7. 2x6 3" MFI	0.152	0.257	0.173	32.8

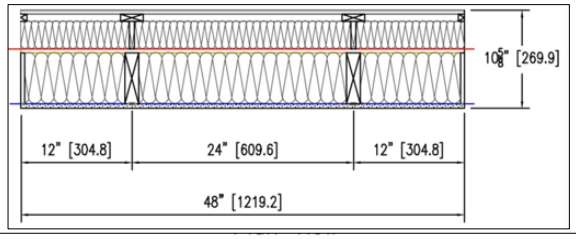
WATERLOO ENGINEERING

43

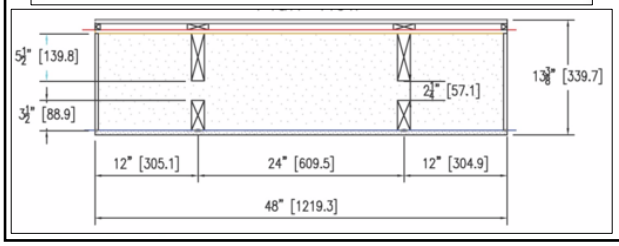
43



I-joist w/cellulose



Rockwool sheathing



Double-stud w/cellulose

44

Wall isolated from each other

45

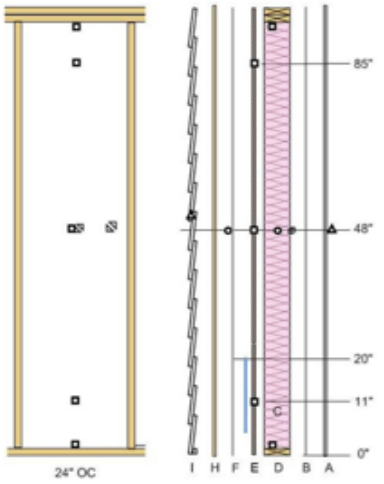
All walls installed

46

Instrumentation

-

Datum	Fibre Cement, Tyvek, OSB, 2x6, R-22 fibreglass batt, 6 mil poly, latex paint (Base Wall)



Assembly

Layer	Function	Description
A	Interior Finish	Painted gypsum board
B	Vapor Control	6 mil poly
C	Studspace	R-22 fiberglass batt
D	Framing	2x6
E	Sheathing	7/16" OSB
F	Membrane	Tyvek
G	Insulation	none
H	Drainage	1x3
I	Cladding	Cement fibre lap siding

Sensor Package

Layer	Code	Location
A	taem	Interior finish, interior face, 48"
C	r/tcnm	Studspace, interstitial, 48"
D	m/tdet	Framing, exterior edge, top plate
D	m/tdel	Framing, exterior edge, bottom plate
E	m/teiu	Sheathing, interstitial, 80"
E	m/teim	Sheathing, interstitial, 48"
E	m/teil	Sheathing, interstitial, 16"
G	r/tinm	Drainage space, interior, 48"
I	tjem	Cladding, interstitial, 48"

- Relative Humidity and Temperature Sensor Package
- Moisture Content Pins and Temperature Sensor Package
- Temperature Sensor
- Heat Flux Transducer

47

Results

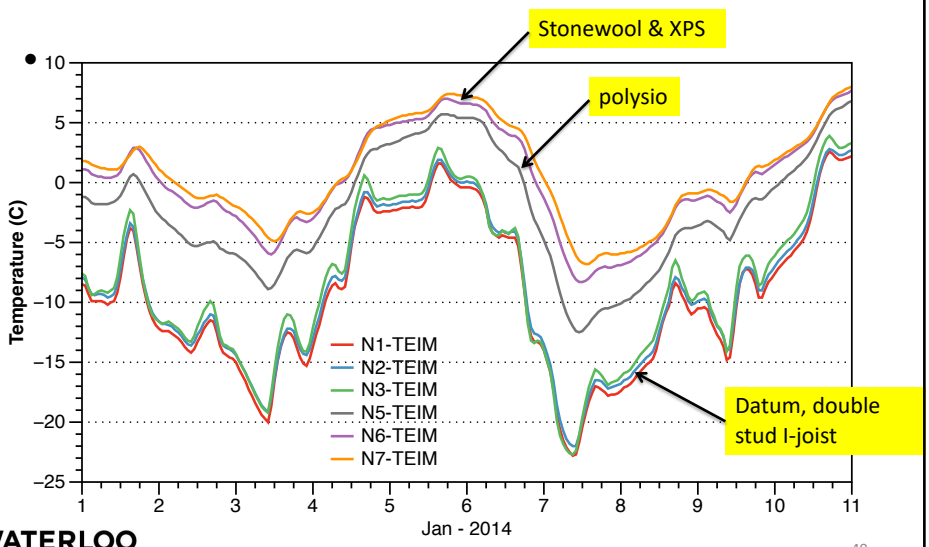
- Measured for over two years
  - Currently undergoing spring rain wetting
  - Drill down on drying performance
- More results will be developed

WATERLOO ENGINEERING

48

48

OSB Sheathing Temperature

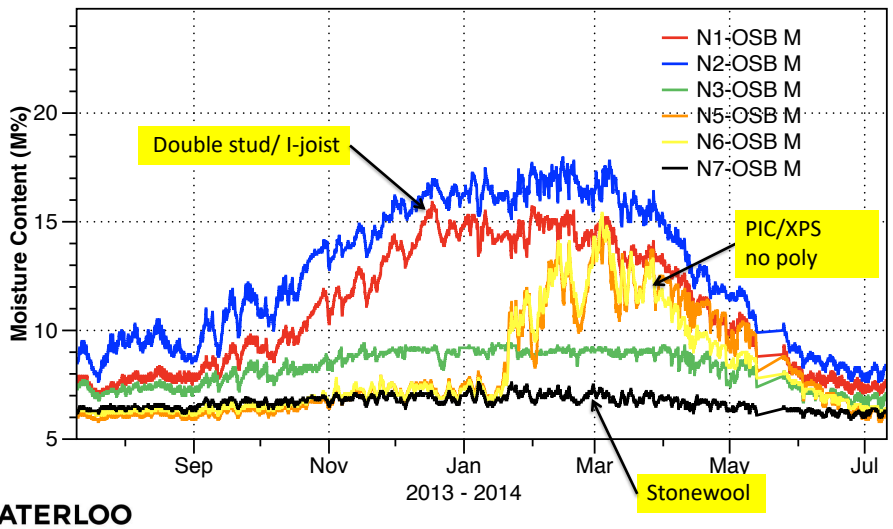


WATERLOO ENGINEERING

49

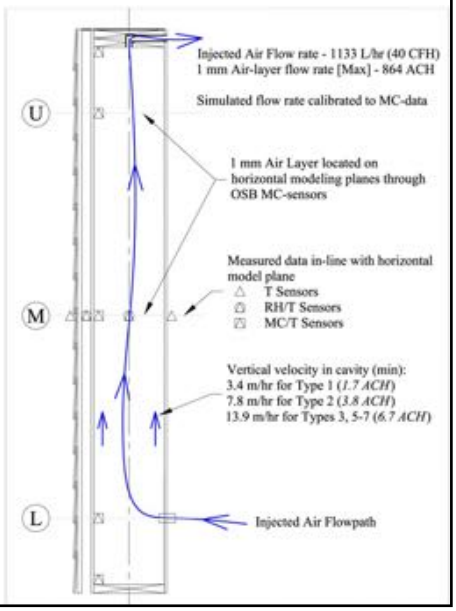
49

North OSB MC



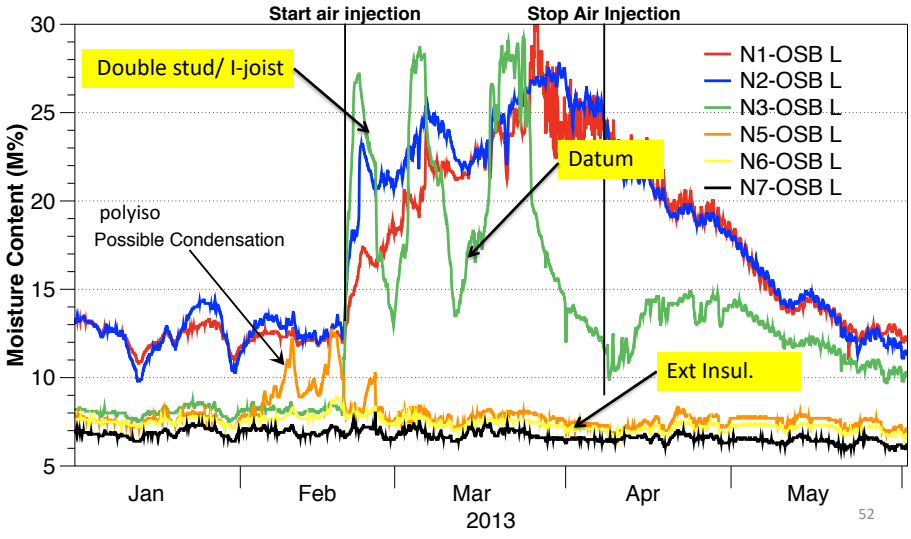
50

Calibrated Air leak



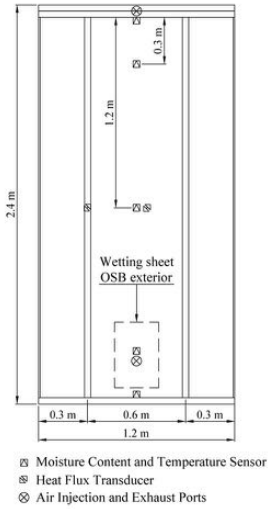
51

Air Leakage



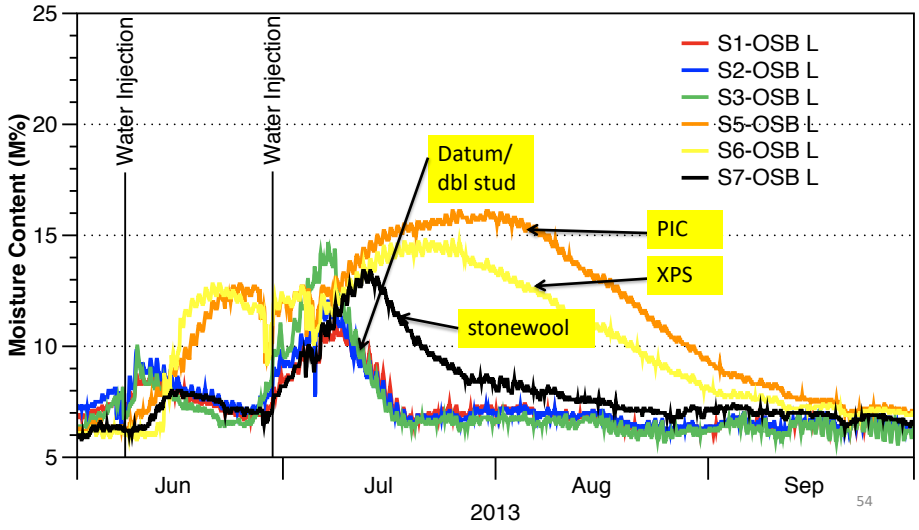
52

Calibrated water leak



53

Water leakage



54

55