Foundation Insulation and Moisture Control

Contractor's Breakfast Seminar

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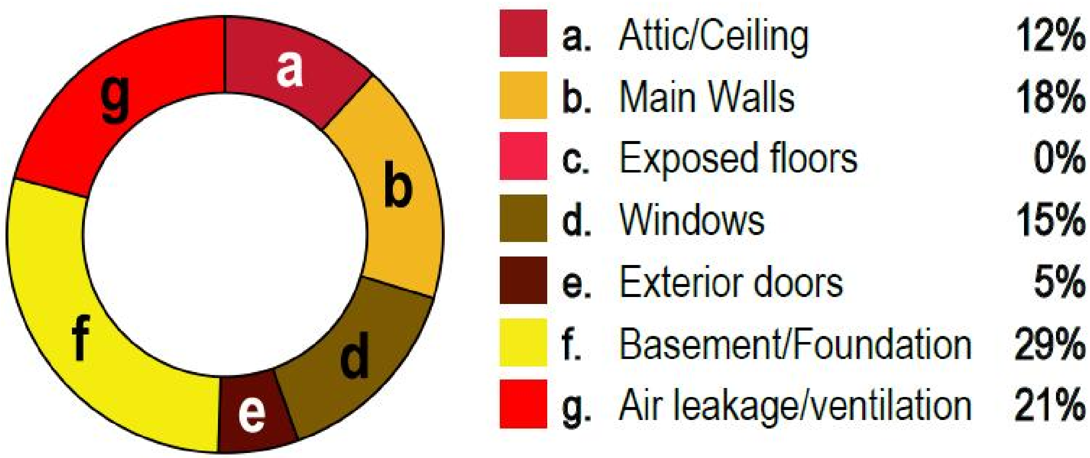
Why this topic?

- Foundations, crawlspaces, basements can account for 30% or more of the heat loss in a home



*EnerGuide is an official mark of Natural Resources Canada.
Refer to the glossary section for an explanation of relevant terms.

Why this topic?

- Foundations are a major source of moisture and mould problems



Moisture Problems

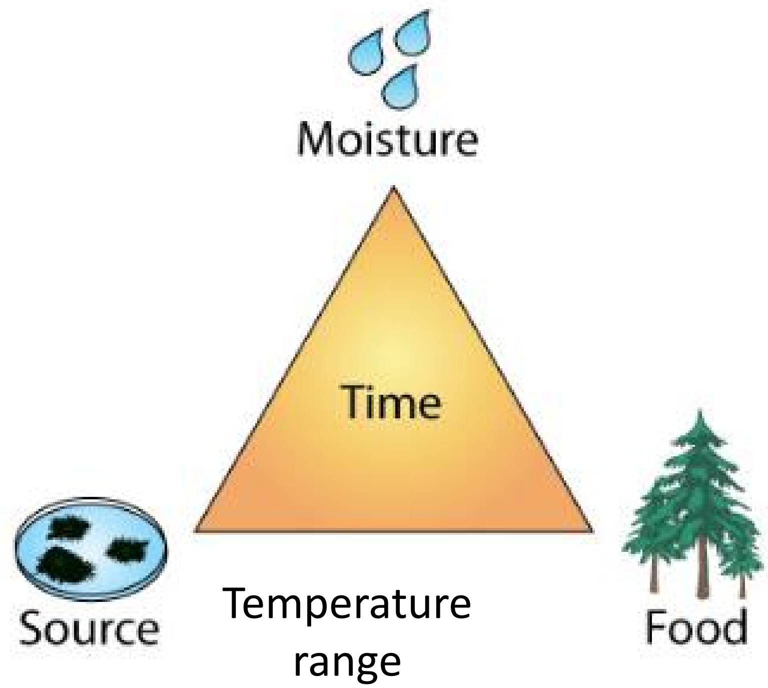
- **Moisture and mould is the biggest problem in housing**
- Over 3000 housing units in Yukon are in need of major repairs or replacement
- Over 50% of houses in Canada have moisture problems
  - Likely worse in the north
- Most insurance claims and 70 % of litigation in housing involve moisture problems and water damage

Moisture is involved in most building problems:

- Freeze-thaw damage - spalling
- Frost heaving – foundation failure
- Damage to moisture sensitive interior and exterior finishes.
- High cost of repairs
- Can make people sick
- Mental health and financial implications

Control Mould
by controlling moisture:

- Mould is everywhere
- Food is virtually everywhere in a house
- Moisture is needed
- Control the moisture, control the mould
- Mould can start in 24 hrs. in the right conditions



Mould in housing is <u>completely</u> avoidable

All buildings get wet:

- Problems occur if they get **too** wet for **too** long
- Always need to:
  - limit wetting
  - encourage drying

Functional Requirements of Foundations:

- Structural
  - Point and distributed loads from above
  - Lateral loads or pressure from soil,
  - Water pressure?
  - Seismic events
- Thermal barrier – above and below grade
- Air barrier – soil gas, moisture, radon, energy
- Moisture barrier – liquid water
- Vapour control – from soil, outside and inside

Enclosure Design Principles

- Design a complete structural load path
    - Roof, floors, walls, window openings
    - All loads go to ground
- Understand site, use, and climate loadings
    - Rain, sun, residential, office, pool...
- Control liquid water
    - Keep roof and surface water away from building
    - Water drainage plane from the roof to below the footings
    - Capillary break around all underground surfaces
    - No places for water to pool inside, outside or within the enclosure

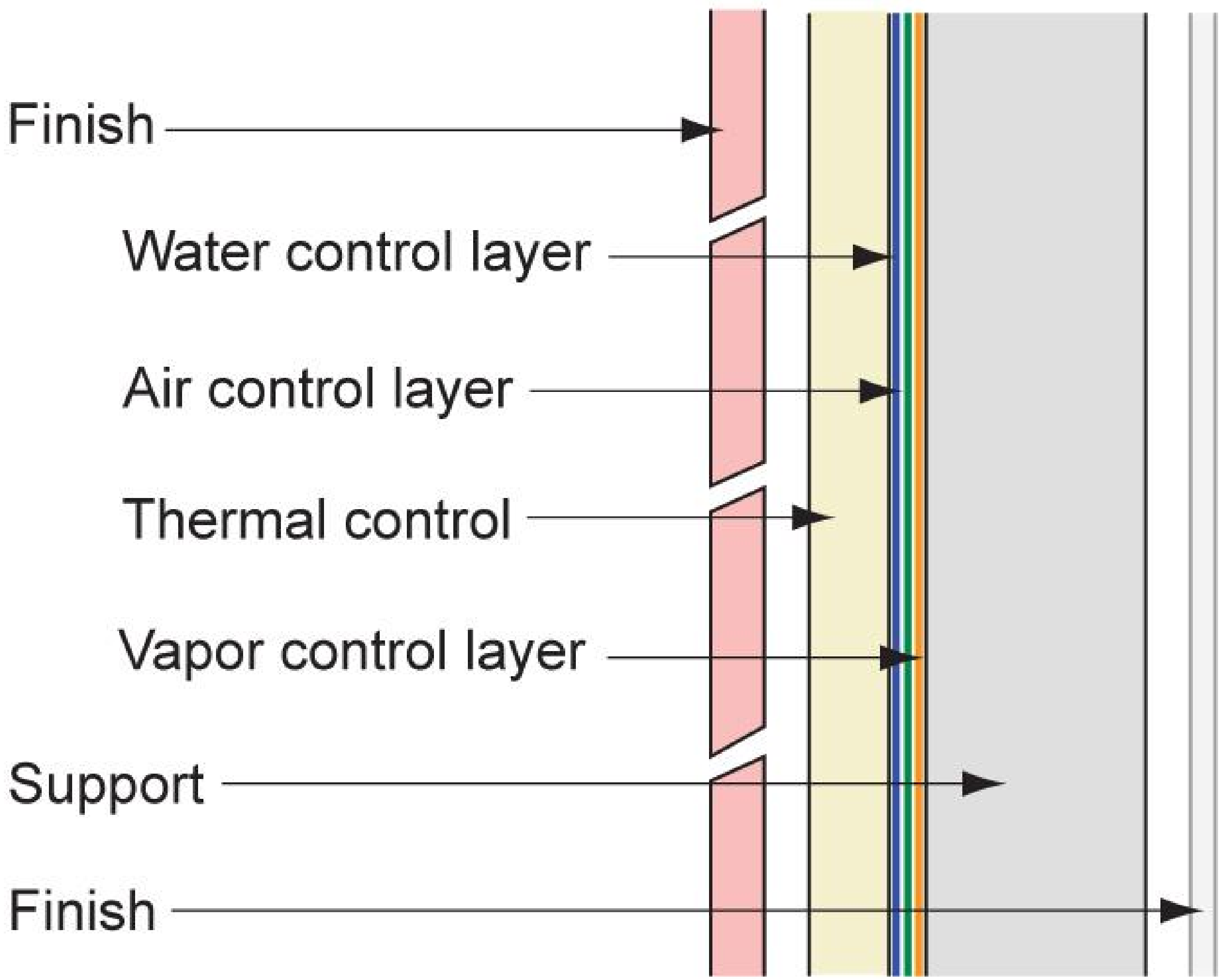
Enclosure Design Principles

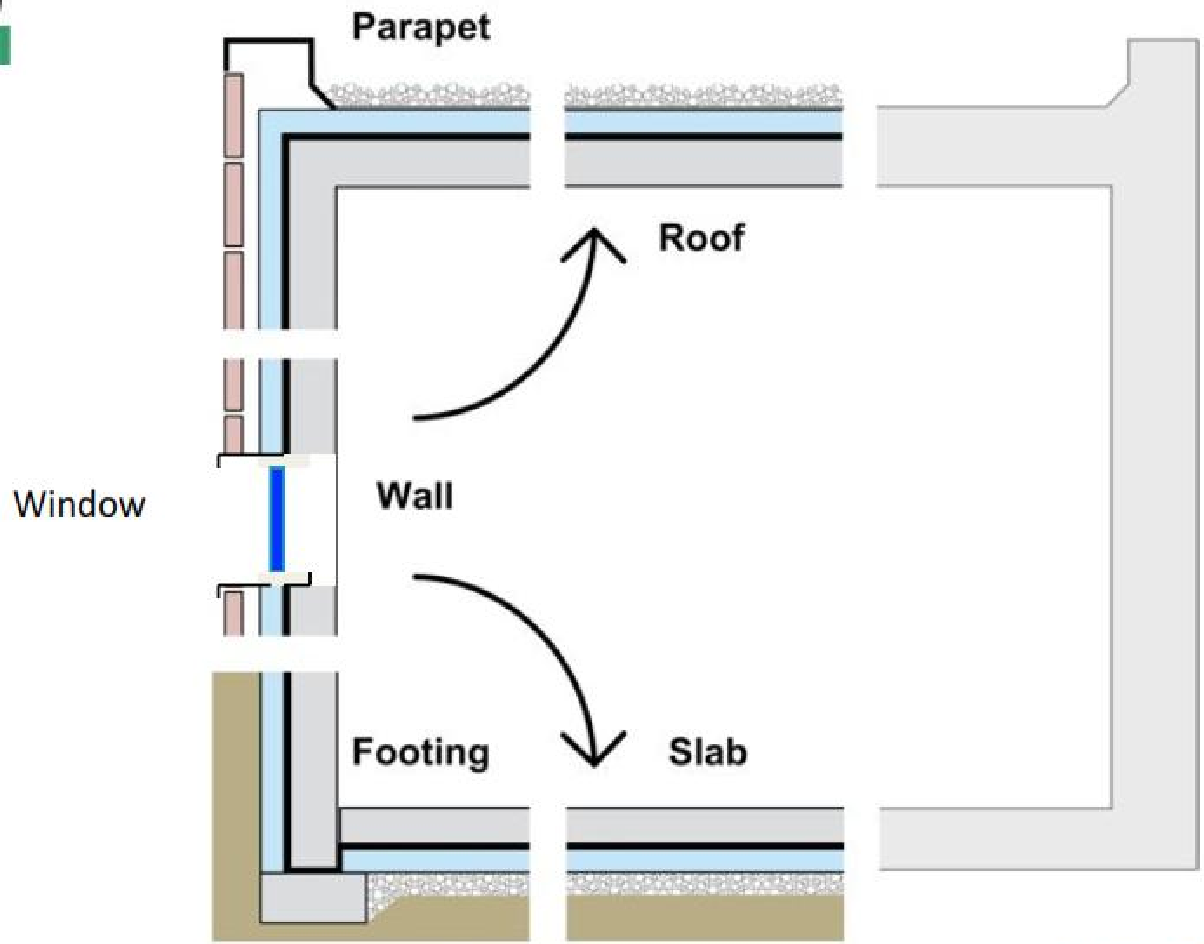
- Continuous and complete thermal control above and below grade – eliminate thermal bridges
- Ideally separate structure from enclosure - keep moisture susceptible materials (like wood) inside - where it is warm and dry
- Continuous and complete air flow control – a perfect air barrier
  - Energy Loss; Water vapour transport; Soil gas control
  - Fastidious attention to detail in 3-D
- Vapour flow control - Appropriate amounts in appropriate places
  - No cold vapour retarders, and allow drying

Enclosure Design Principles

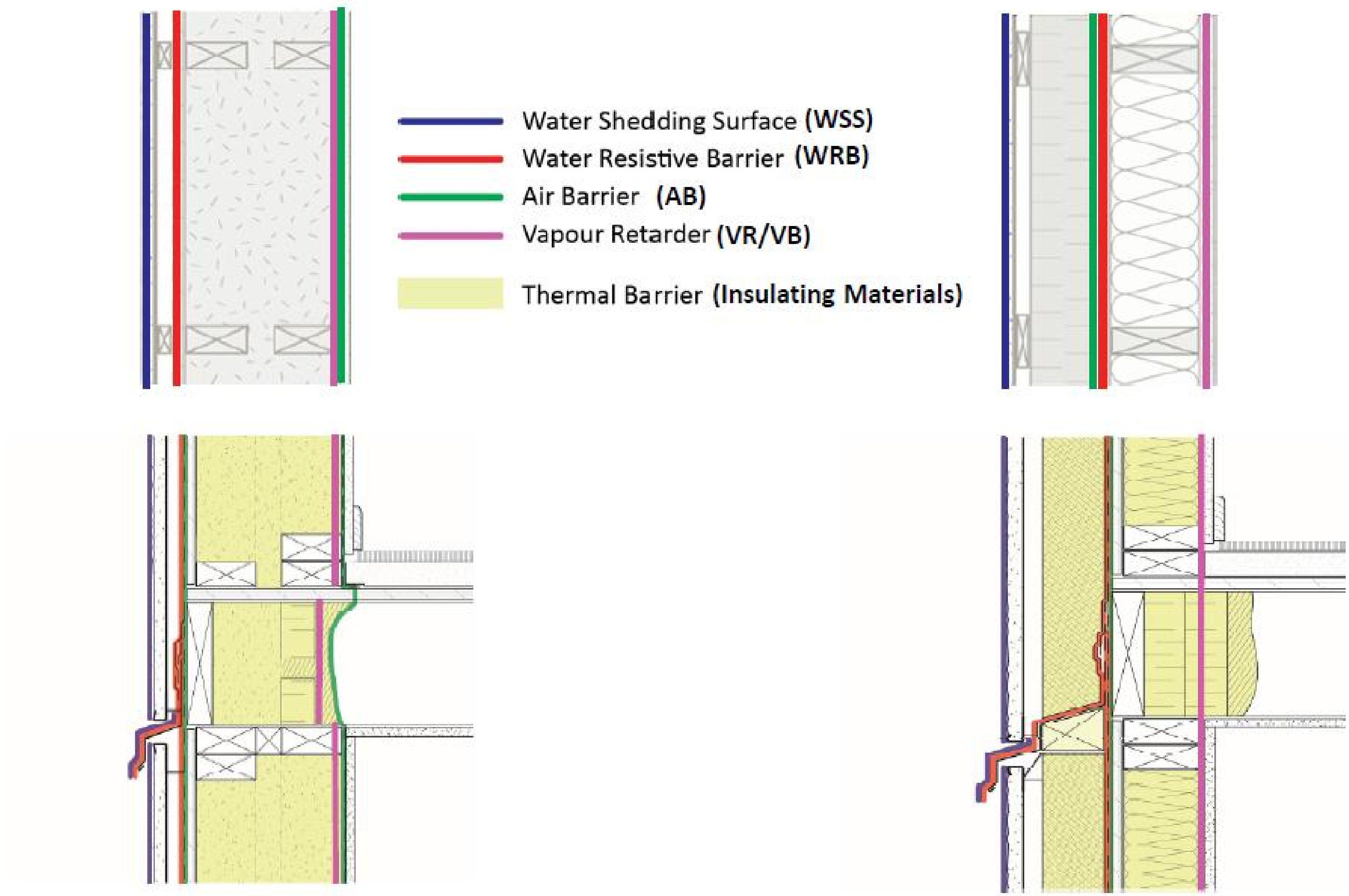
- Build in redundancy – safety factors
- Accommodate movements and tolerances
- Draw all of the details – if you can't draw it, how can you build it?

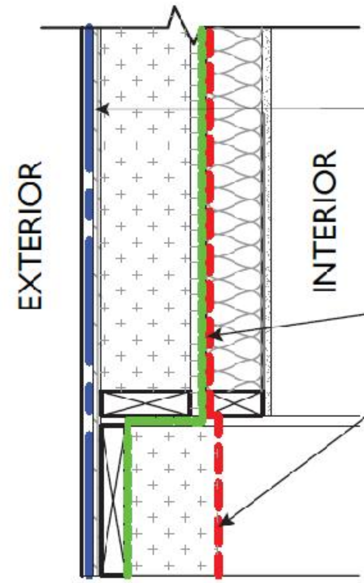
The Perfect Wall Concept



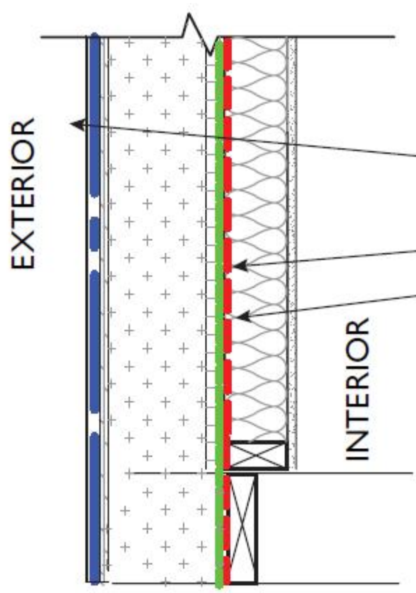

Parapet
Roof
Window
Wall
Footing
Slab

Building Enclosure Assembly Critical Barriers



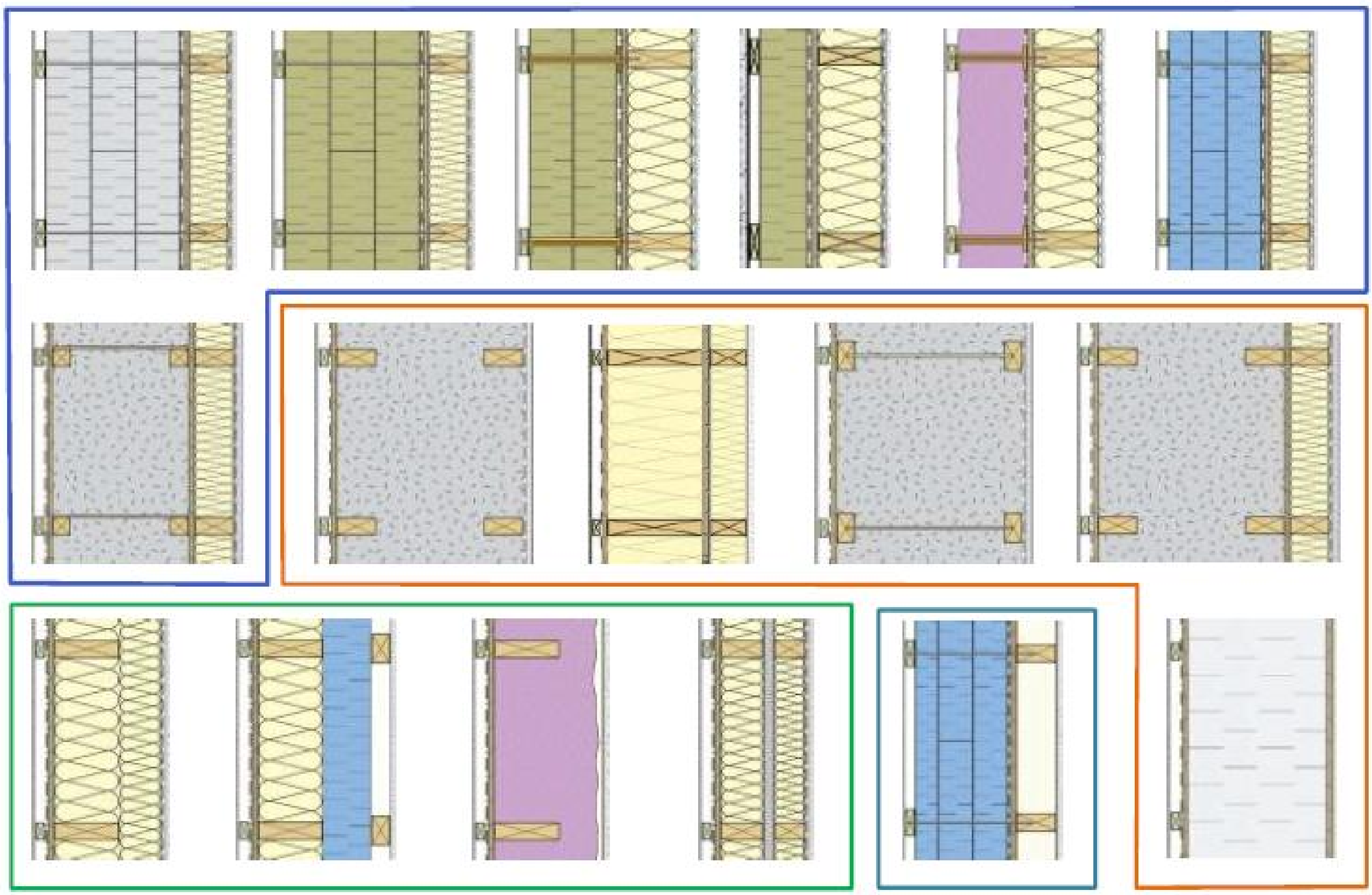


SIDING – fibre cement board
WIND/RAIN BARRIER – building paper
SHEATHING – 13 mm [½ in.] plywood
STRUCTURAL WALL – 38x184 mm [2x8 in.] at corners & windows
– 38x140 mm [2x6 in.]
with 38x64 mm [2x3 in.] strapping between
INSULATION – fill cavity with type IV EPS
AIR BARRIER – 6 mil poly (Continuous with Rim Joist Foam)
VAPOUR BARRIER – 6 mil poly
MECHANICAL WALL – 38x89 mm [2x4 in.] @ 600 mm [24 in.] O.C.
INSULATION – fill stud with mineral wool batt
WALL FINISH – 13 mm [½ in.] drywall taped & painted
RIM JOIST – 2 lb. Spray foam completes air, vapour barrier and insulation detail



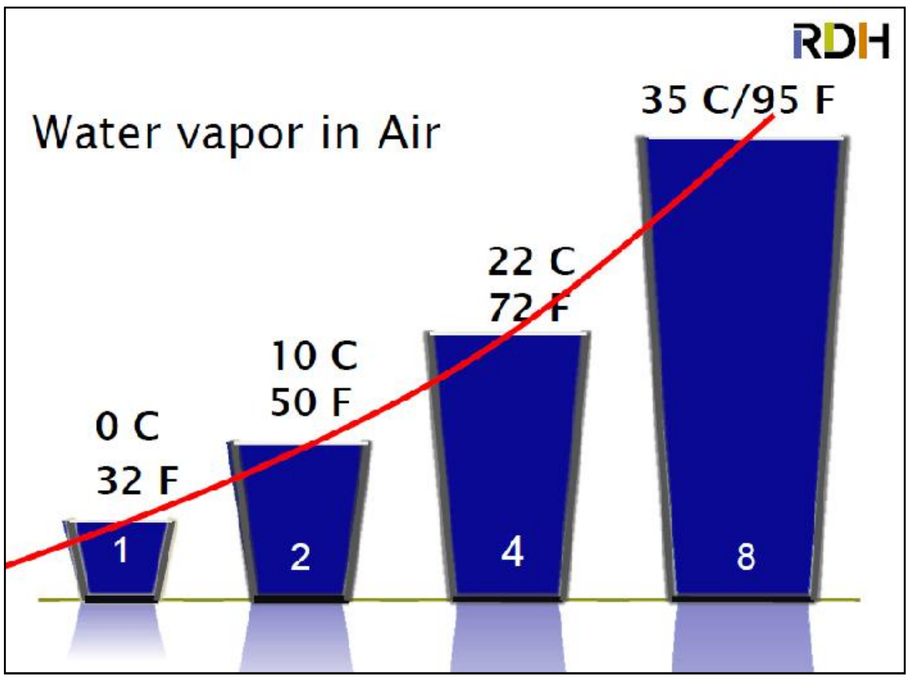
SIDING – metal
RAINSCREEN – 15x89 mm [1x4 in.] wood strapping
WIND/RAIN BARRIER – EPS (noted below as Insulation)
INSULATION – 2 layers 76 mm [3 in.] type IV EPS
AIR BARRIER – Continuous self adhered poly
VAPOUR BARRIER – (Continuous with Air Barrier noted above)
SHEATHING – 13 mm [½ in.] plywood
STRUCTURAL WALL – 38x89 mm [2x4 in.] @ 400 mm [16 in.] O.C
INSULATION – fill stud with mineral wool batt
WALL FINISH – 13 mm [½ in.] drywall taped & painted

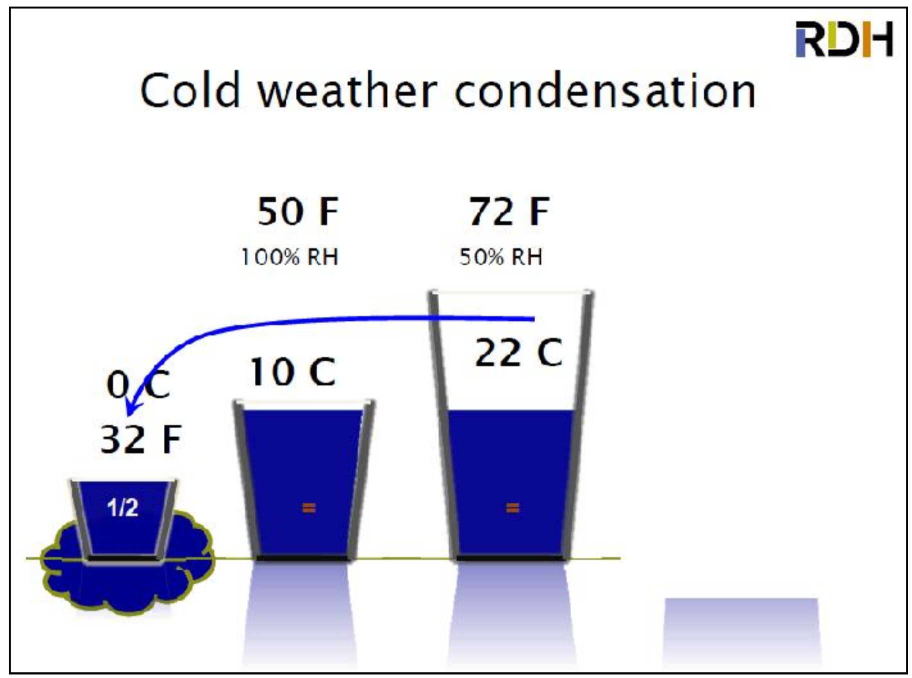
Way Too Many Choices – How to Decide & Why?



Some essential physics:

- Warm air can hold far more moisture than cold air





Condensation:

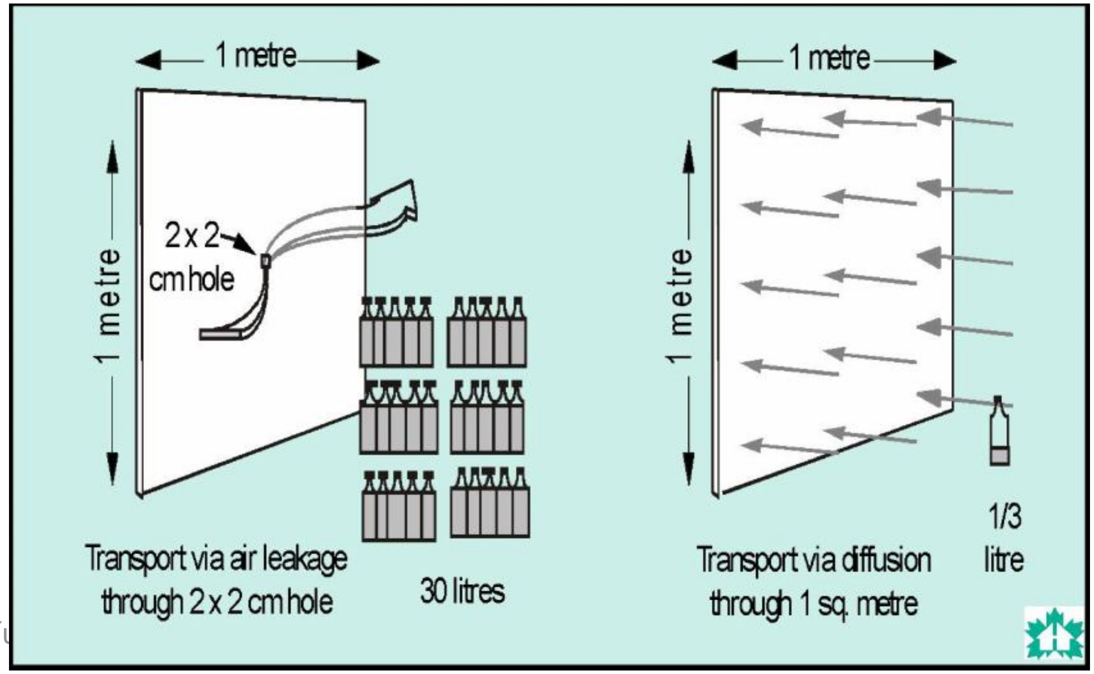
Water vapor converting to liquid

to solid

Why does this happen?

Some essential physics:

- Liquids, gases, vapours, move from areas of high pressure to low pressure
- Far more moisture can be transported by air leaks than by diffusion



Some essential physics:

- Heat moves from hot to cold
- Heat does not rise, but moves in all directions
- Hot air rises

Some essential physics:

- Air in soil is virtually always at 100% RH
- Warmer things are generally drier than colder things, and colder things are generally wetter than warm things
- Even closed cell foam insulation will absorb water, and transmit small amounts of water vapour

Some essential physics:

- Vapour drive is inward below grade, and outward above grade
- Below grade – drying to the inside – heat flow to outside
- Above grade – drying to the outside – heat flow to outside
- Wood can store and release a significant amount of moisture without damage (about 10% by weight) by adsorption and desorption

Drying wetted materials:

- Drainage is not enough
- Drying must begin immediately after wetting – 24 hours can be the start of some nasty things
- Must reduce relative humidity
- Capillary and adsorbed moisture can only be dried by evaporation, and then by desorption and diffusion.

Some essential physics:

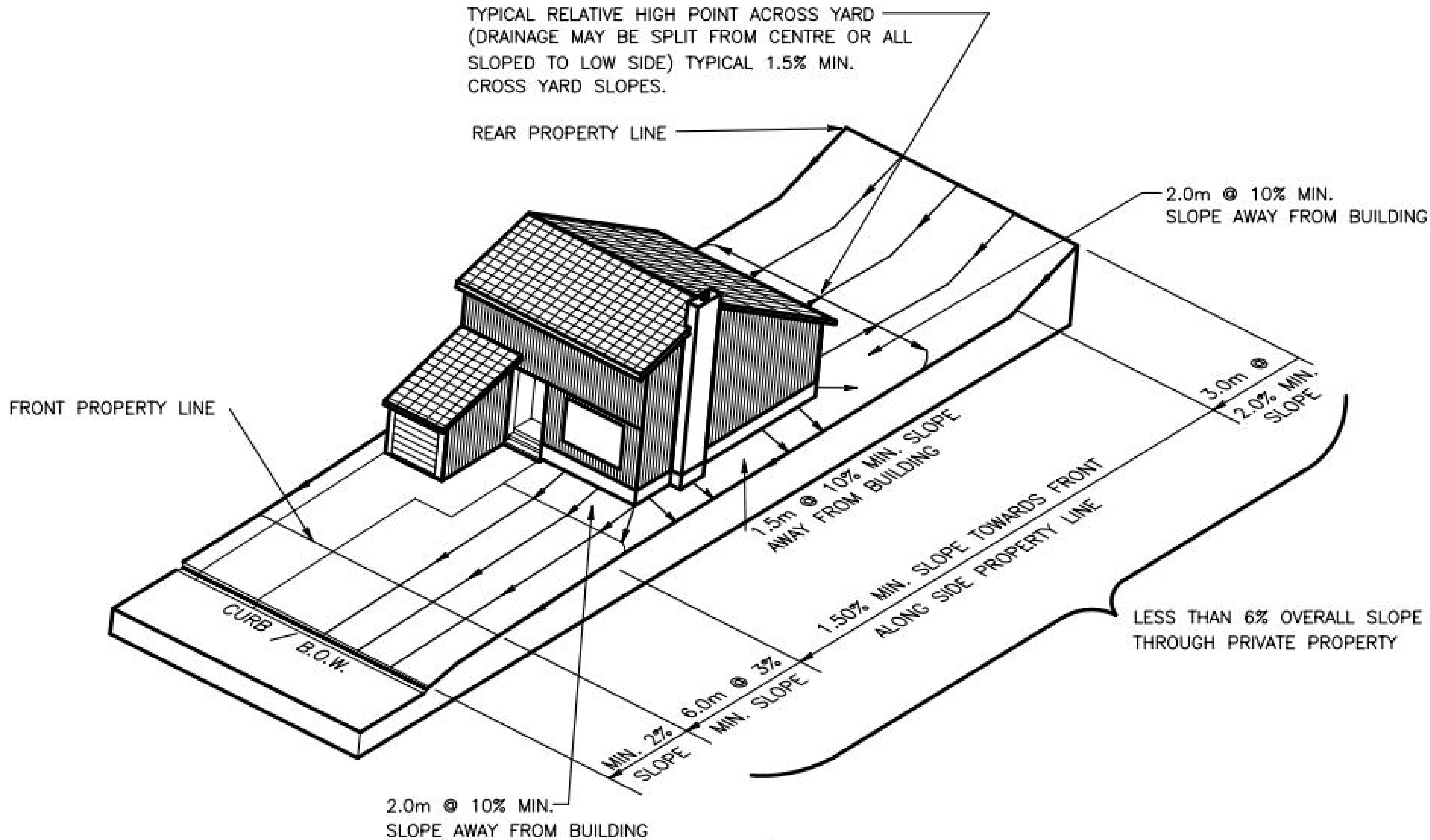
- The smaller the soil particles, the stronger the wicking forces – capillary action; and the more frost susceptible the soil
- Deep ground temperature is about equal to the average annual air temperature
- Annual frost penetration can be as much as 4 meters in April (under exposed surfaces like roads)
- Ground temperatures lag air temperatures by months

Some essential physics:

- Three options to prevent problems with seasonal frost in ground:
  - Keep the soil warm
  - Keep the soil dry
  - Use non-frost susceptible fill
  - Also, keep permafrost frozen

Rain Volume

- **1 mm of rain on 1 square meter = 1 litre of water**
- **Assume:** 1000 sqft home has a roof = 120 sqm
- **25 mm of rain = 3 m^3 = 3000 litres of water = 120 x 5 gal jerry cans or 15 x 45 gallon drums**
- This will result in nearly 10 times more saturated soil – unless site and foundation drainage is provided



City of Whitehorse
Engineering Department

TYPICAL URBAN LOT DRAINAGE
TYPE 'A' – REAR TO FRONT DRAINAGE
LESS THAN 6% OVERALL LOT SLOPE

STD DWG D2.0

DATE: JANUARY 2007

Handling rain water:

- Direct water
  - off of,
  - out of,
  - and away from
- **Don't allow surface water to become ground water**
- Keep the soil dry
- Keep the structure dry

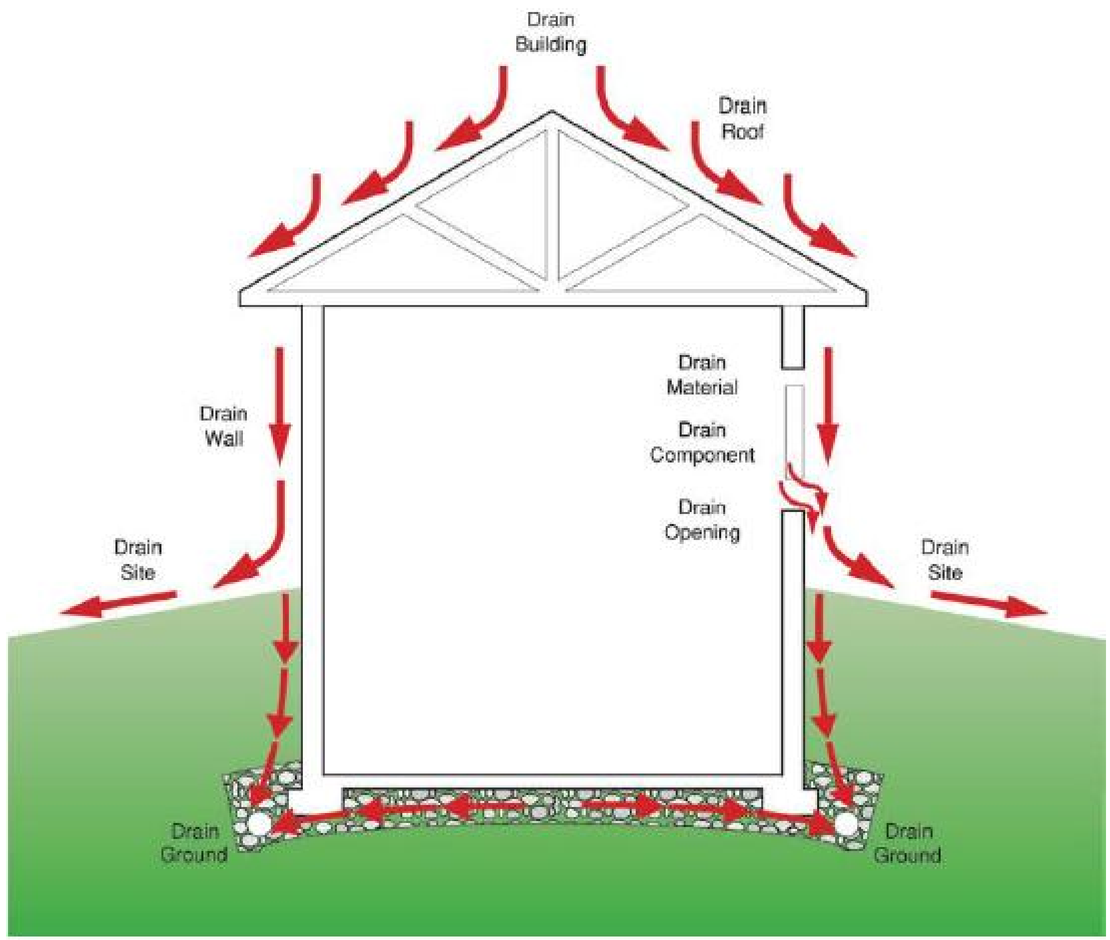


Figure 1. Foundation Bulk Water Control Overall Concepts

http://www.buildingscience.com/documents/bareports/ba-1015-bulk-water-control-methods-for-foundations

Built to stay Dry

Swiss residence and barn built in 1700’s

Rain water and snow melt:

- From the roof
- Eaves trough
- Down spouts
- Ground sloped away from house

Moisture in basements and crawlspaces:

Downspout solutions

Below Grade:
Basement Insulation and Moisture Video

- https://www.youtube.com/watch?v=kwn0Vjw_ji0

Damp proofing and drainage

Figure 14. Air gap membrane applied over dampproofing on cast concrete wall

Figure 15. Air gap membrane applied over waterproofing membrane and insulation

Damp proofing and drainage

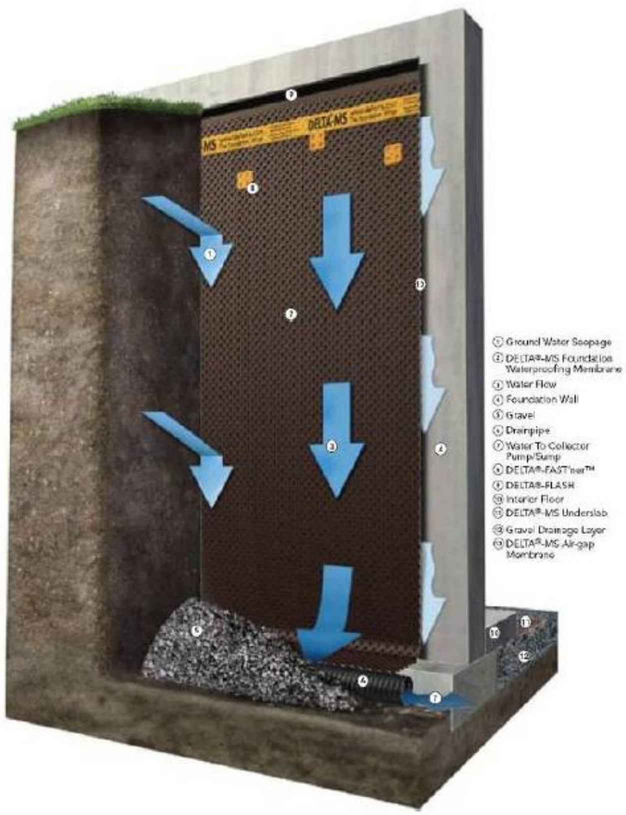
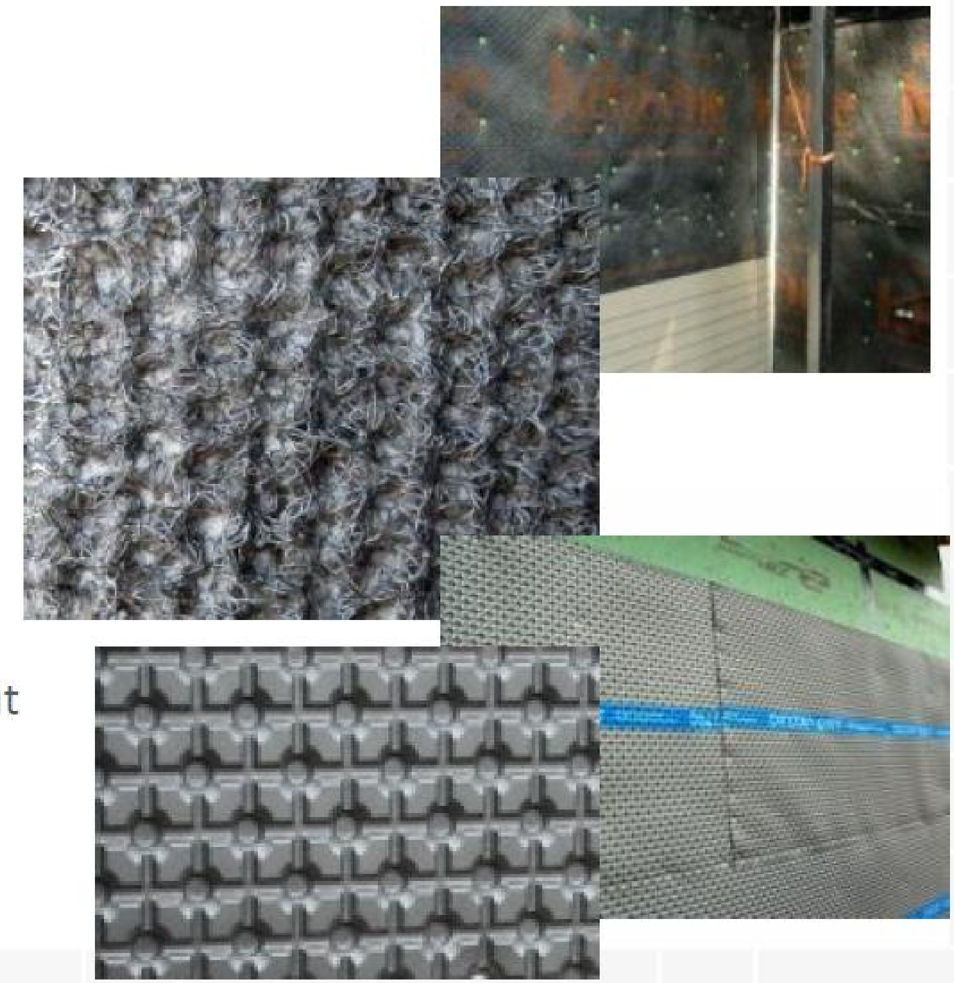


Figure 12. Air gap membrane/drainage board, showing drainage paths (c/o Cosella Dörken)

Figure 13. Exterior foundation insulation using draining rigid fiberglass board

Damp proofing and drainage

- Drain Mat Products create 10 mm code minimum gap
- But -Unsealed Holes through WRB (and possible AB)
- Careful with absorptive claddings
  - Insufficient ventilation to dry out moisture
- Watch details



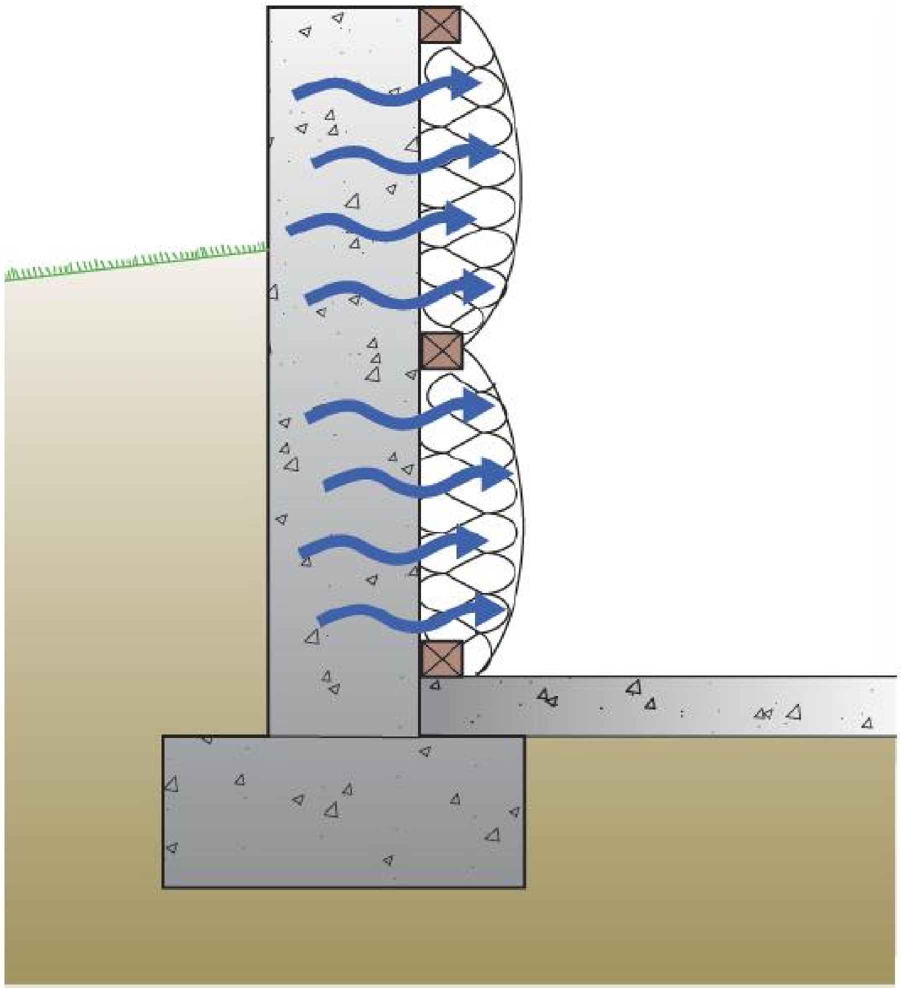


Figure 7: Moisture of Construction

- Interior insulation layer is typically water sensitive and prevents inward drying
- Several thousand pounds of water in freshly placed concrete attempts to dry inward

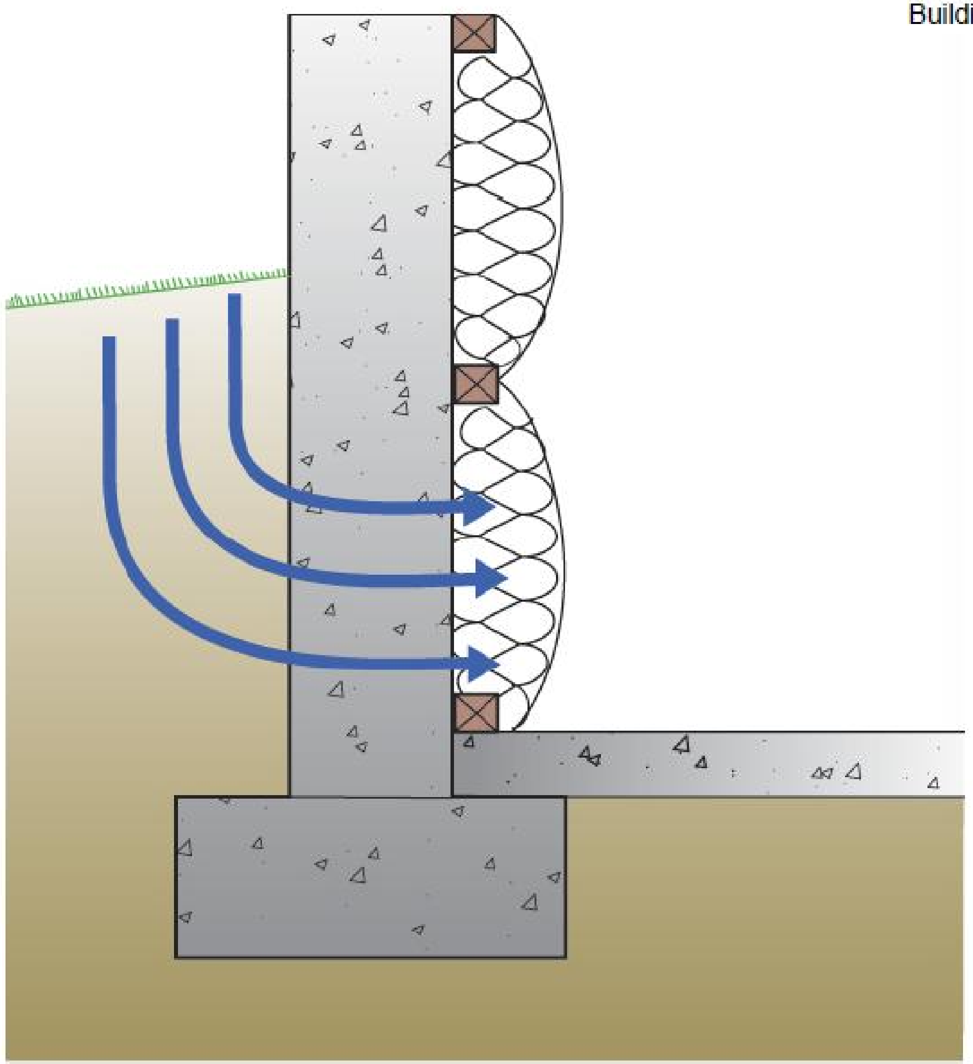


Figure 6: Groundwater Entry

- Interior insulation layer is typically water sensitive and prevents inward drying

Capillary rise through footing

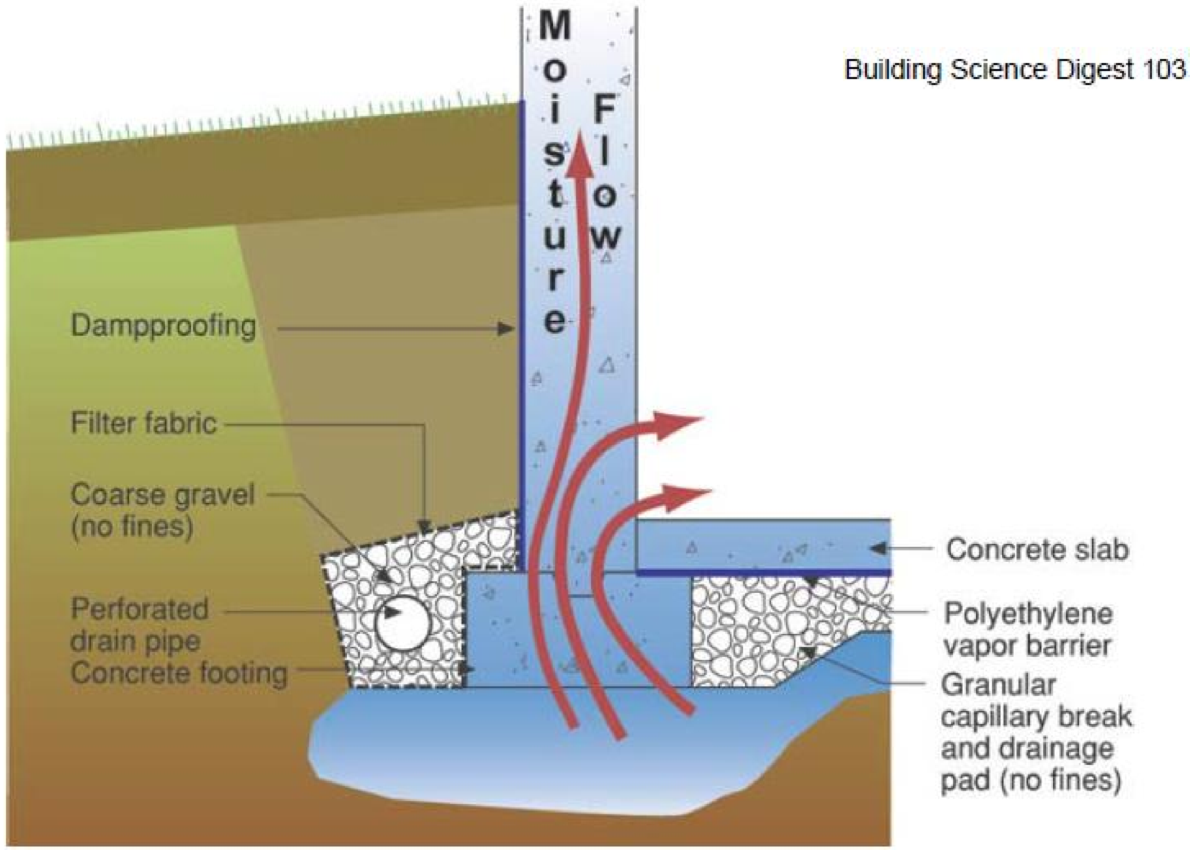


Figure 21. Capillary uptake of water through footing-to-foundation-wall connection

Concrete sealed in can wick moisture up a few stories

http://www.buildingscience.com/documents/bareports/ba-1015-bulk-water-control-methods-for-foundations

Poly on the warm side of basement wall

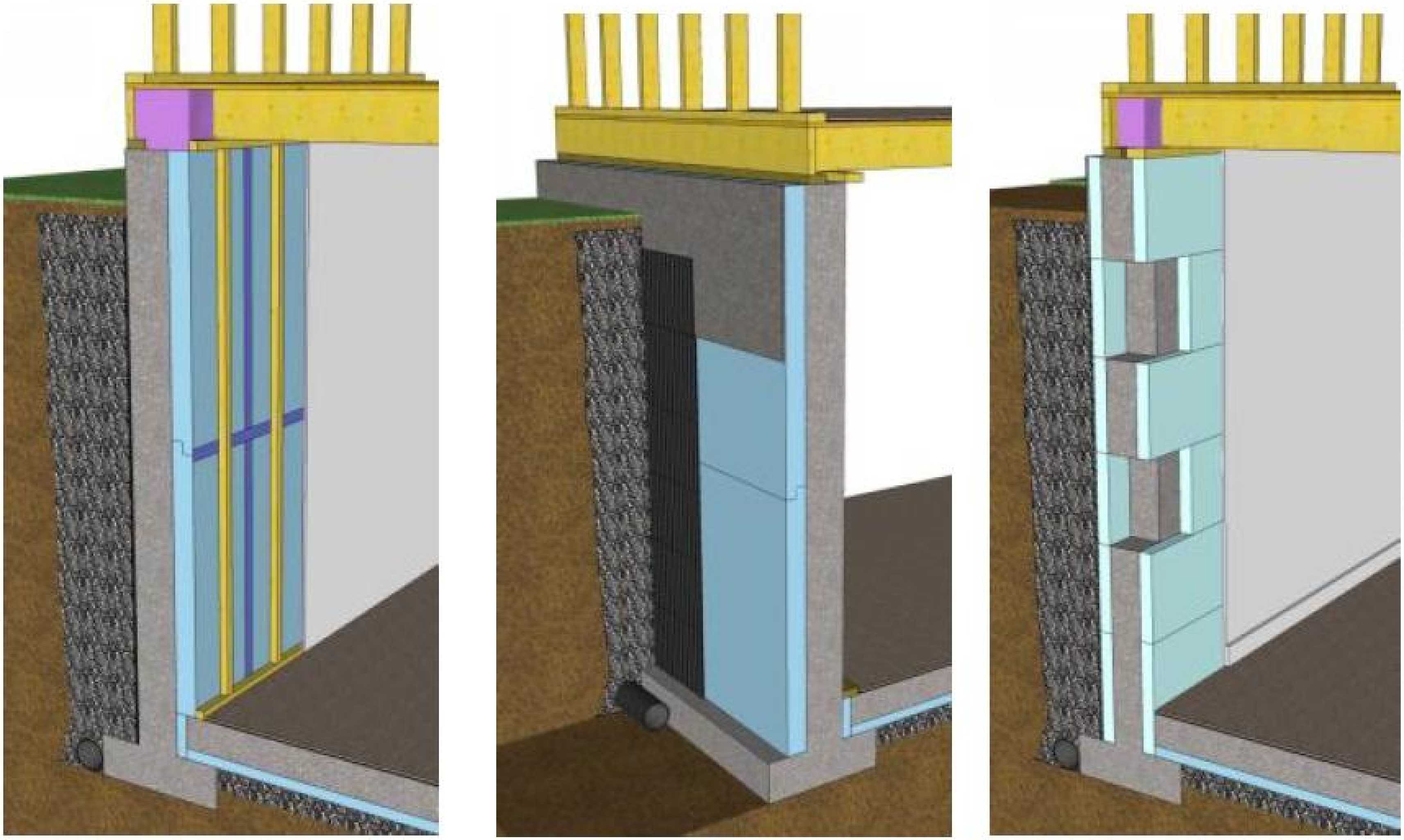
Capillary Breaks:

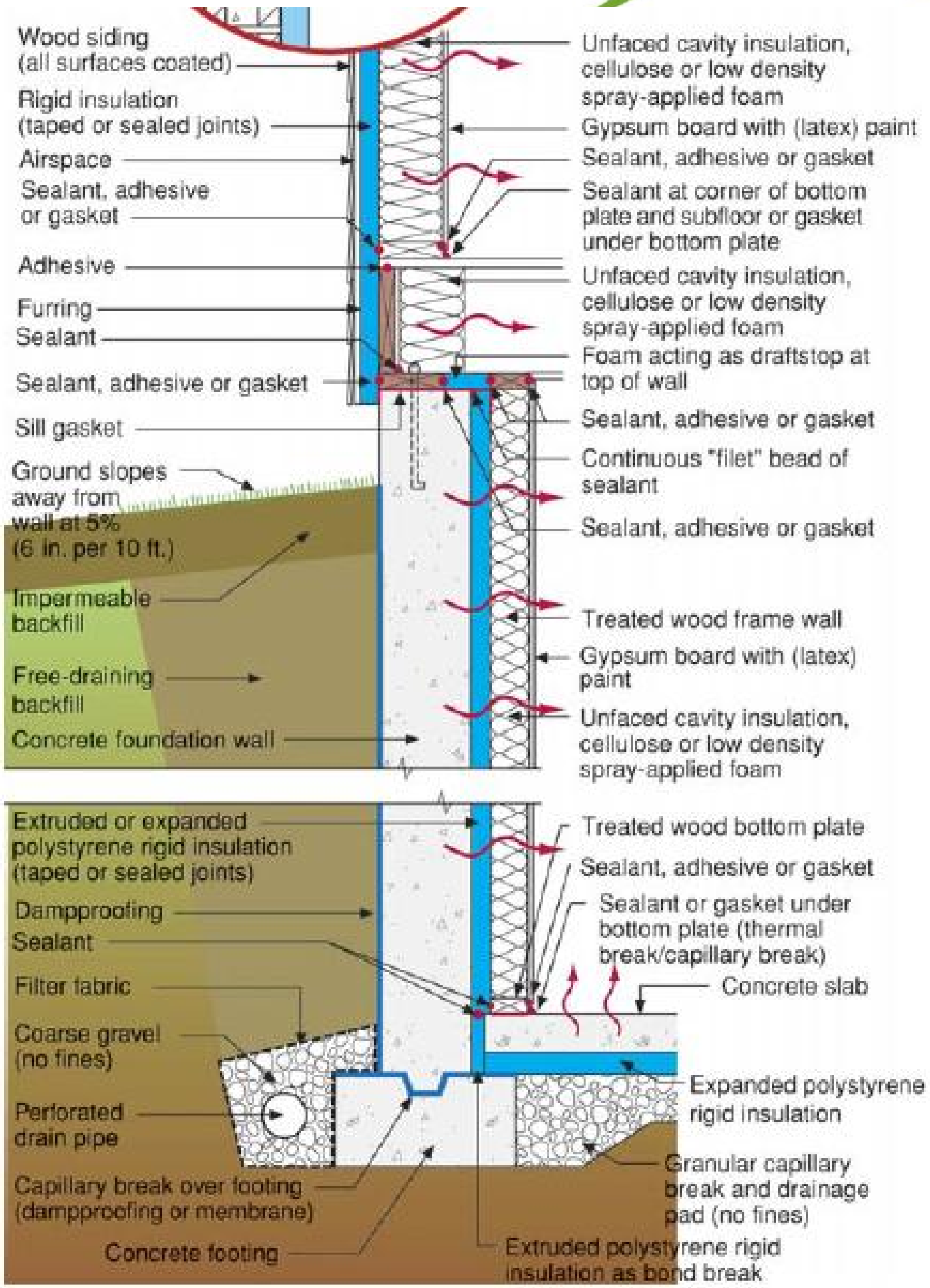
Figure 22. Capillary break using liquid-applied dampproofing on top of footing

Figure 23. Capillary break using proprietary roll-applied material during casting of footing

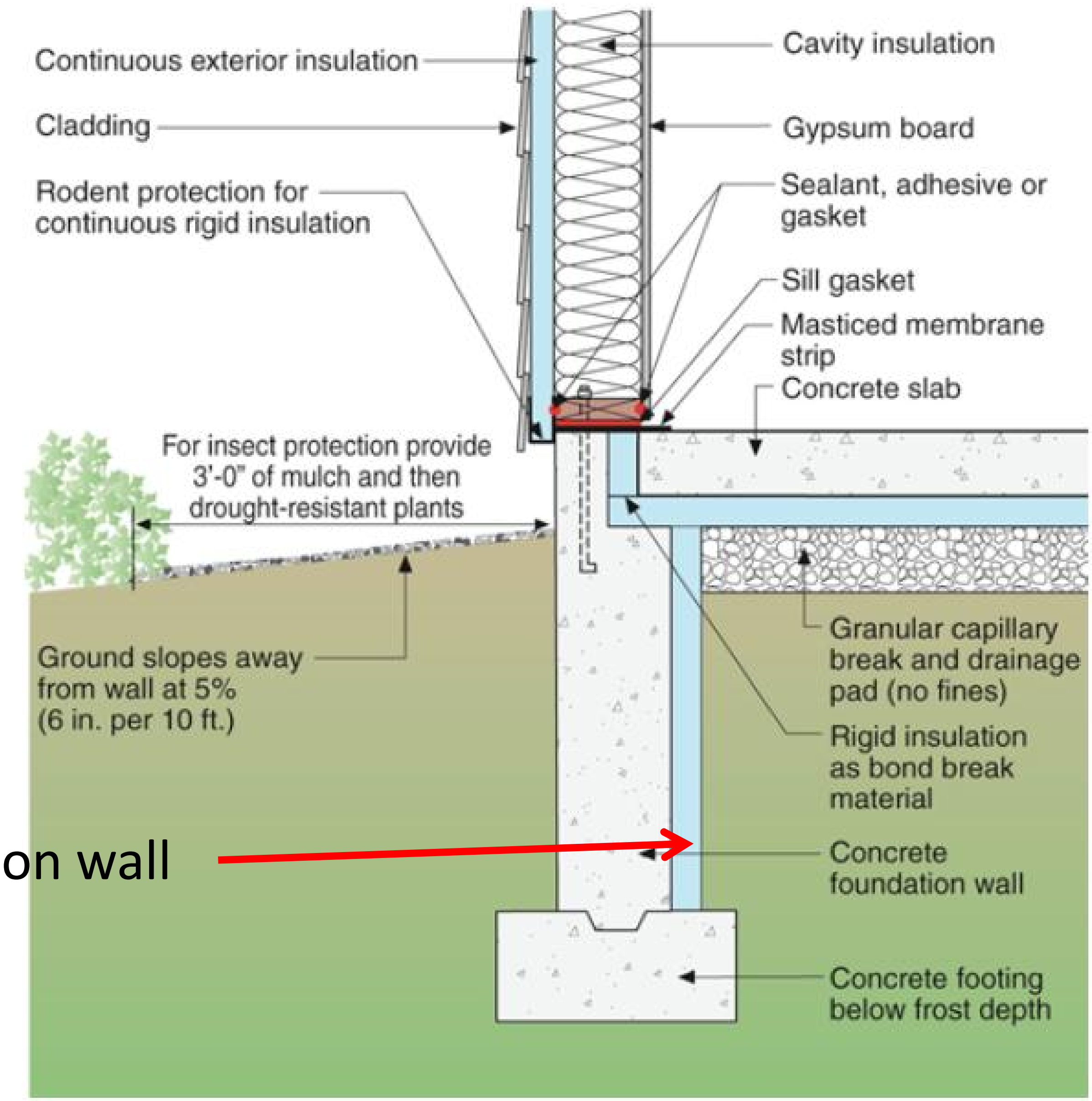
http://www.buildingscience.com/documents/bareports/ba-1015-bulk-water-control-methods-for-foundations

Basement Wall & Floor Insulation Best Practices





Wood siding (all surfaces coated)
Rigid insulation (taped or sealed joints)
Airspace
Sealant, adhesive or gasket
Adhesive
Furring
Sealant
Sealant, adhesive or gasket
Sill gasket
Ground slopes away from wall at 5% (6 in. per 10 ft.)
Impermeable backfill
Free-draining backfill
Concrete foundation wall
Extruded or expanded polystyrene rigid insulation (taped or sealed joints)
Dampproofing
Sealant
Filter fabric
Coarse gravel (no fines)
Perforated drain pipe
Capillary break over footing (dampproofing or membrane)
Concrete footing
Unfaced cavity insulation, cellulose or low density spray-applied foam
Gypsum board with (latex) paint
Sealant, adhesive or gasket
Sealant at corner of bottom plate and subfloor or gasket under bottom plate
Unfaced cavity insulation, cellulose or low density spray-applied foam
Foam acting as draftstop at top of wall
Sealant, adhesive or gasket
Continuous "filet" bead of sealant
Sealant, adhesive or gasket
Treated wood frame wall
Gypsum board with (latex) paint
Unfaced cavity insulation, cellulose or low density spray-applied foam
Treated wood bottom plate
Sealant, adhesive or gasket
Sealant or gasket under bottom plate (thermal break/capillary break)
Concrete slab
Expanded polystyrene rigid insulation
Granular capillary break and drainage pad (no fines)
Extruded polystyrene rigid insulation as bond break

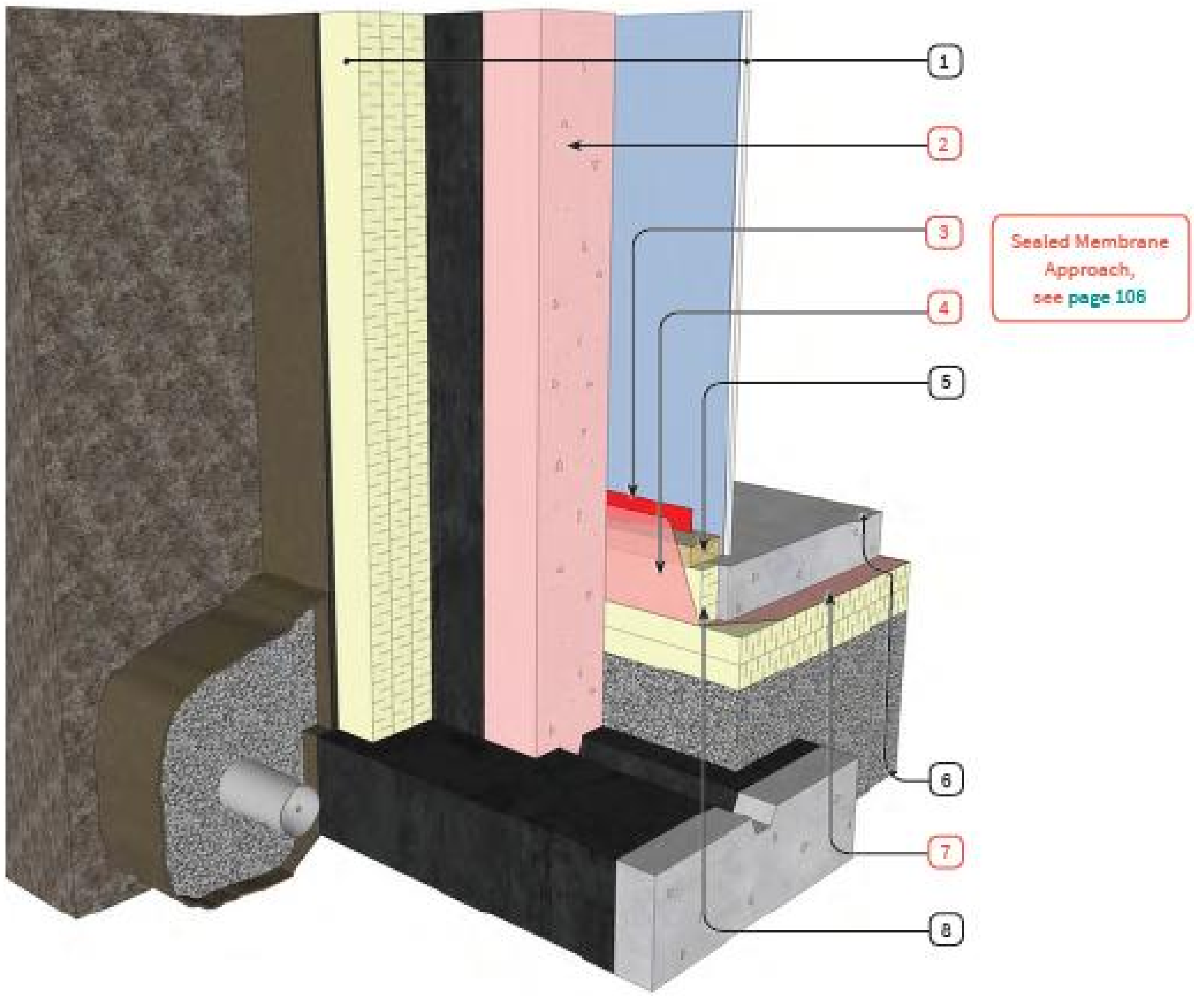


Move outside foundation wall

Foundation Details:

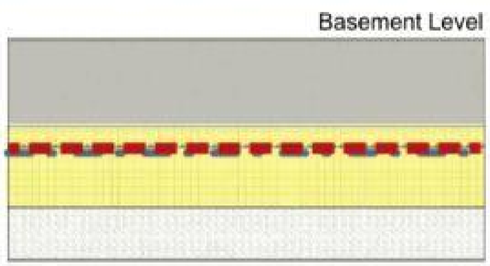
Detail 28

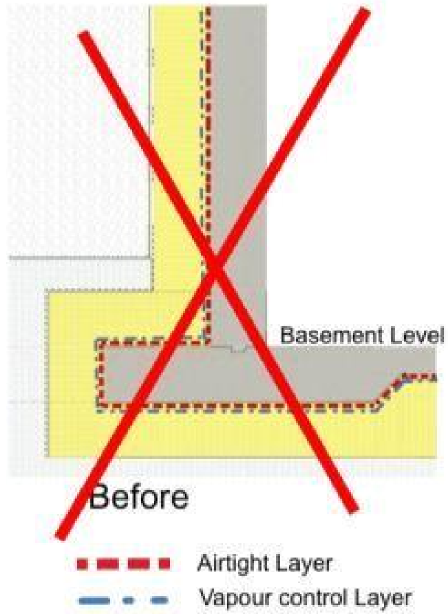
Transition Between Exterior-Insulated Foundation Wall and Exterior-Insulated Slab

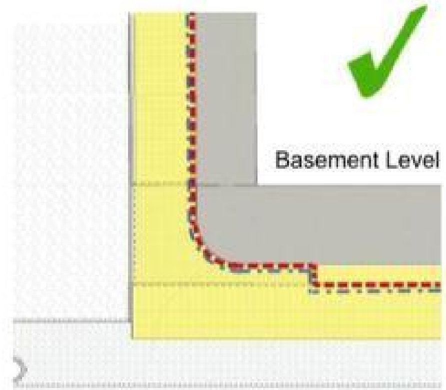


Basement Slab on Grade Assembly

- Finish
- Concrete
- Insulation
- Vapour and airtightness control layers
- Insulation
- Granular A
- Compacted fill



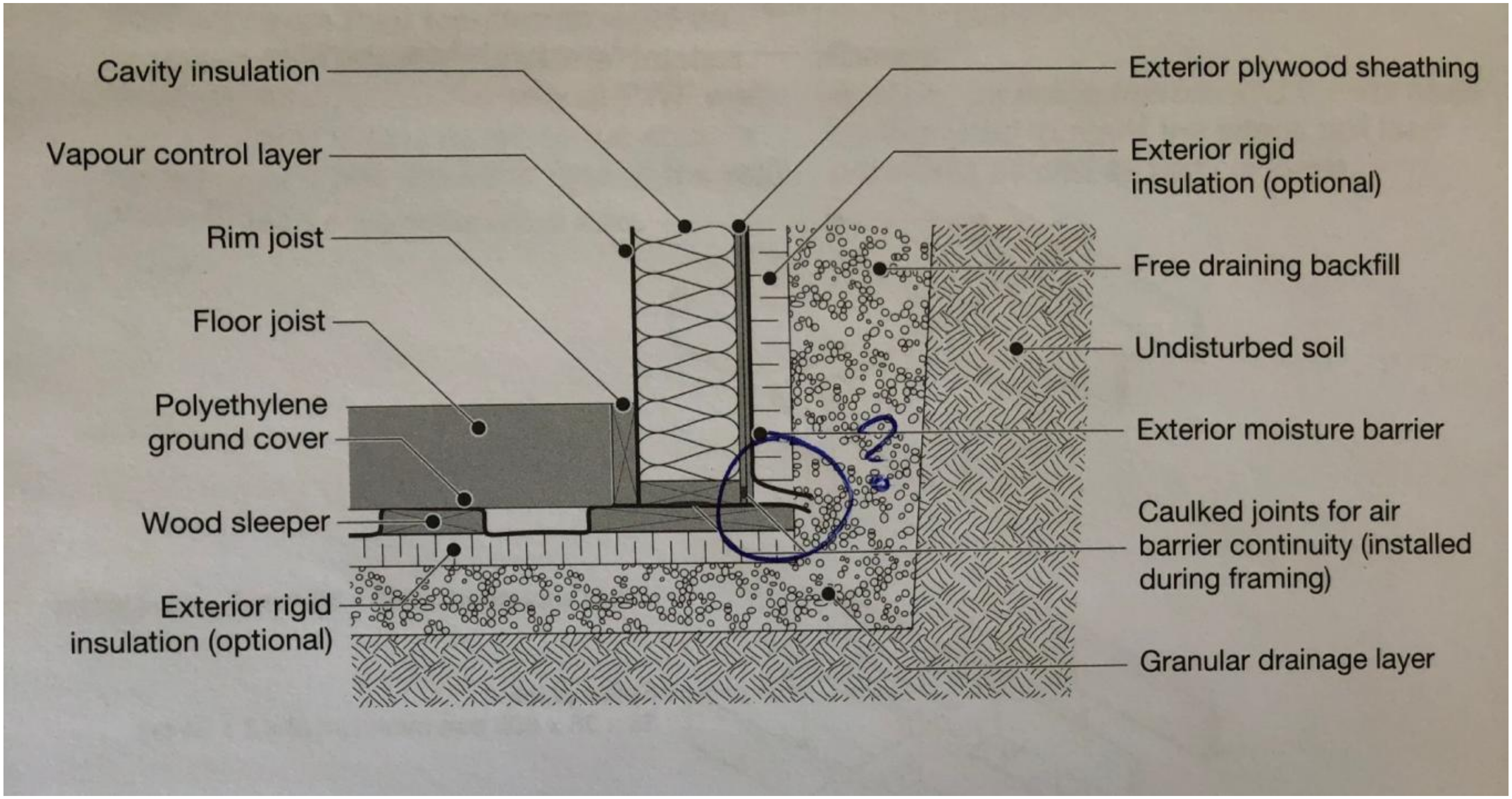




After: Tray Slab Foundation

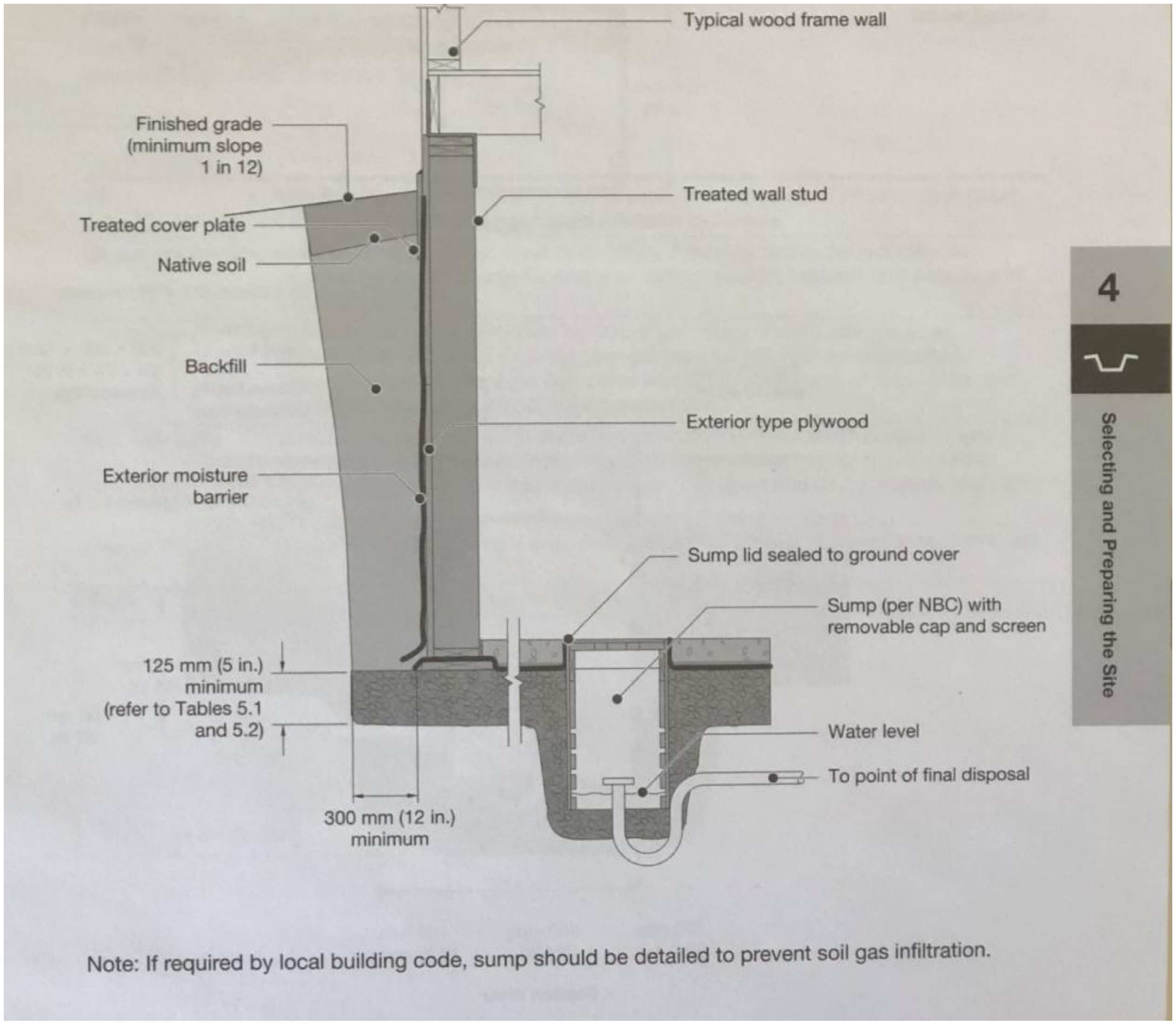
- ***No thermal bridging***
- ***No formwork required***
- ***Just retaining fill***
- ***Thermal mass!***

Preserved Wood Foundations



Preserved Wood Foundations – Canadian Wood Council - 2016

Preserved Wood Foundations



Preserved Wood Foundations – Canadian Wood Council - 2016

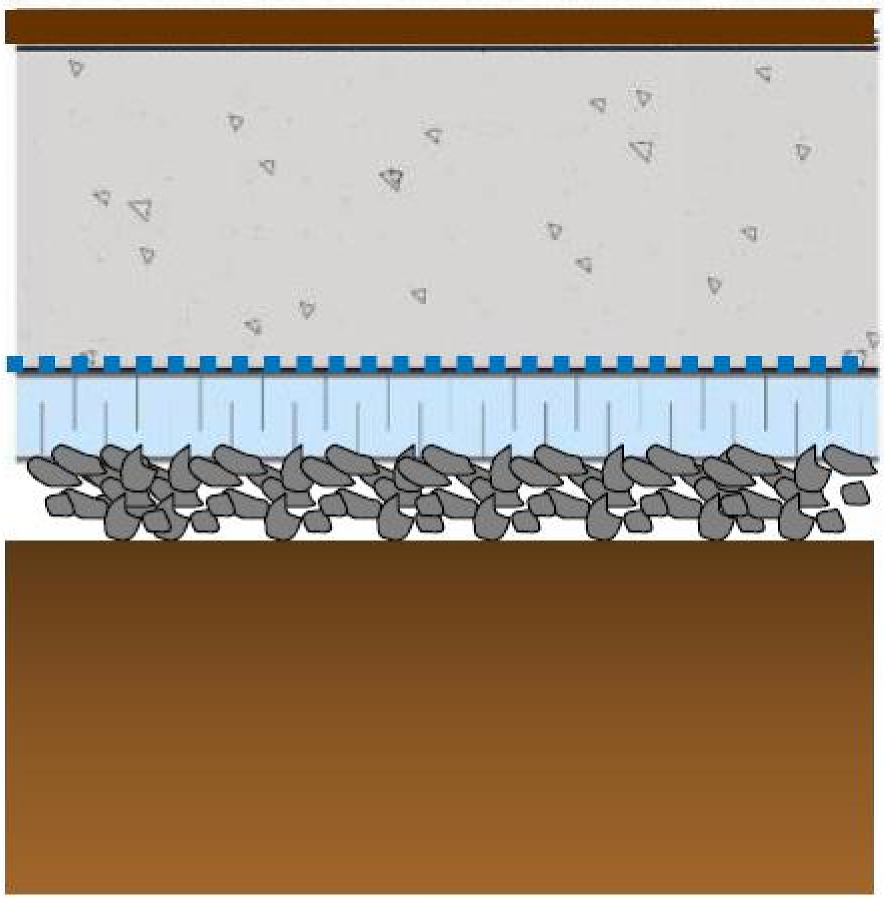
Sleeper floors and crawlspaces

Are often mouldy before the roof is on

Slab Insulation

(Designed not to store water)

- Poly below slab (capillary break/vapour barrier/soil gas barrier)
- Insulate below poly
- Free draining crushed gravel capillary break beneath insulation (reduce insulation saturation)
- Insulation below slab has greater benefit in keeping slab warmer and at lower risk for condensation than often energy savings



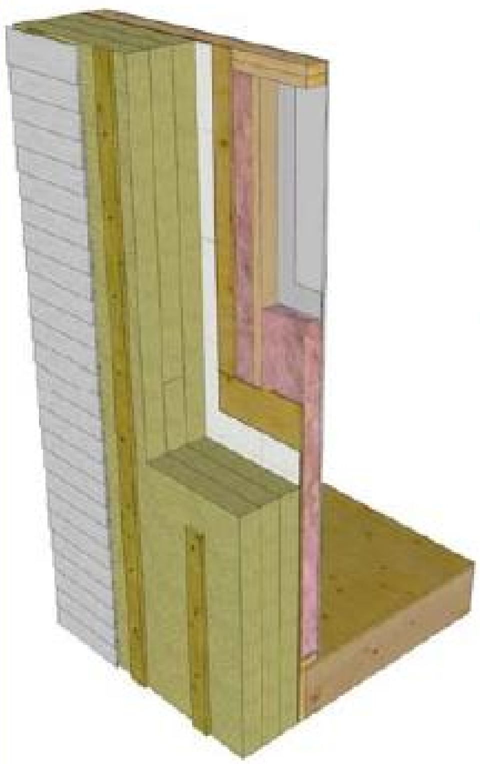
R-value of Soil

	K	$R=\frac{1}{k}$
	Thermal Conductivity $\frac{\text{Btu ft}}{\text{hr ft}^{2\,0}\text{F}}$	R-value of 1 ft of earth
Very dry soil	0.1-0.2	5-10
Wet soil	0.7-2.0	.5-1.43
Dry sand	0.1	10
Wet sand	1.0	1
Sandy clay (15% moisture)	0.6	1.67
Organic soil	0.8	1.25
Granite rock	0.26	3.85

Cost Optimization Study

RDH

Split Insulated

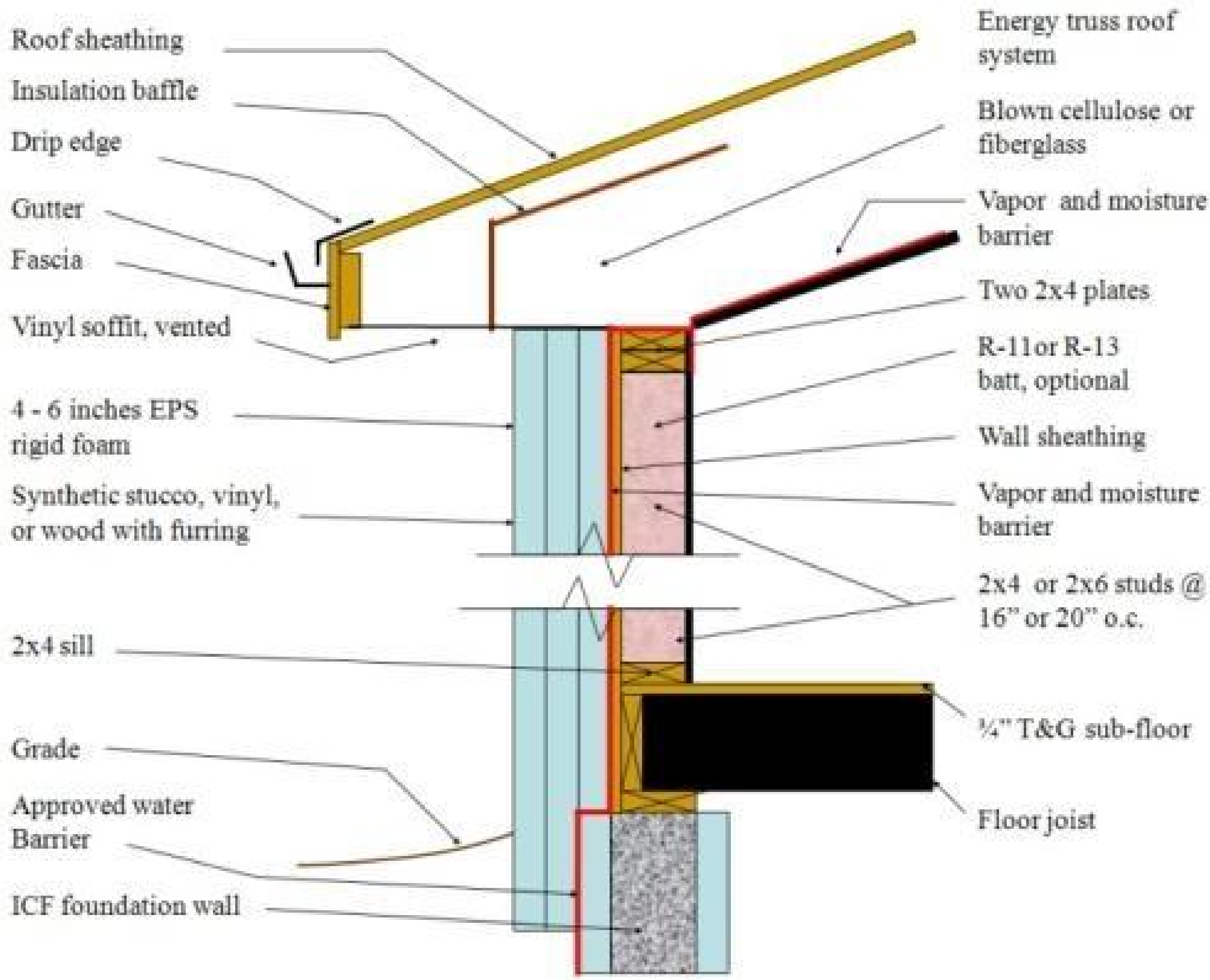


- Water Control:
  - Drained/ventilated rainscreen cladding with synthetic housewrap WRB & surface of exterior insulation
- Vapour Diffusion Control:
  - Poly/VB paint or plywood sheathing
- Air Control:
  - Taped & sealed plywood or sealed sheathing membrane
- Cost/Constructability*:
  - Rigid insulation is expensive (high shipping and labour handling costs), though less than all exterior insulated
  - Thicker insulation results in unique wall penetration details & cladding attachments

(Some builders prefer other wall systems)

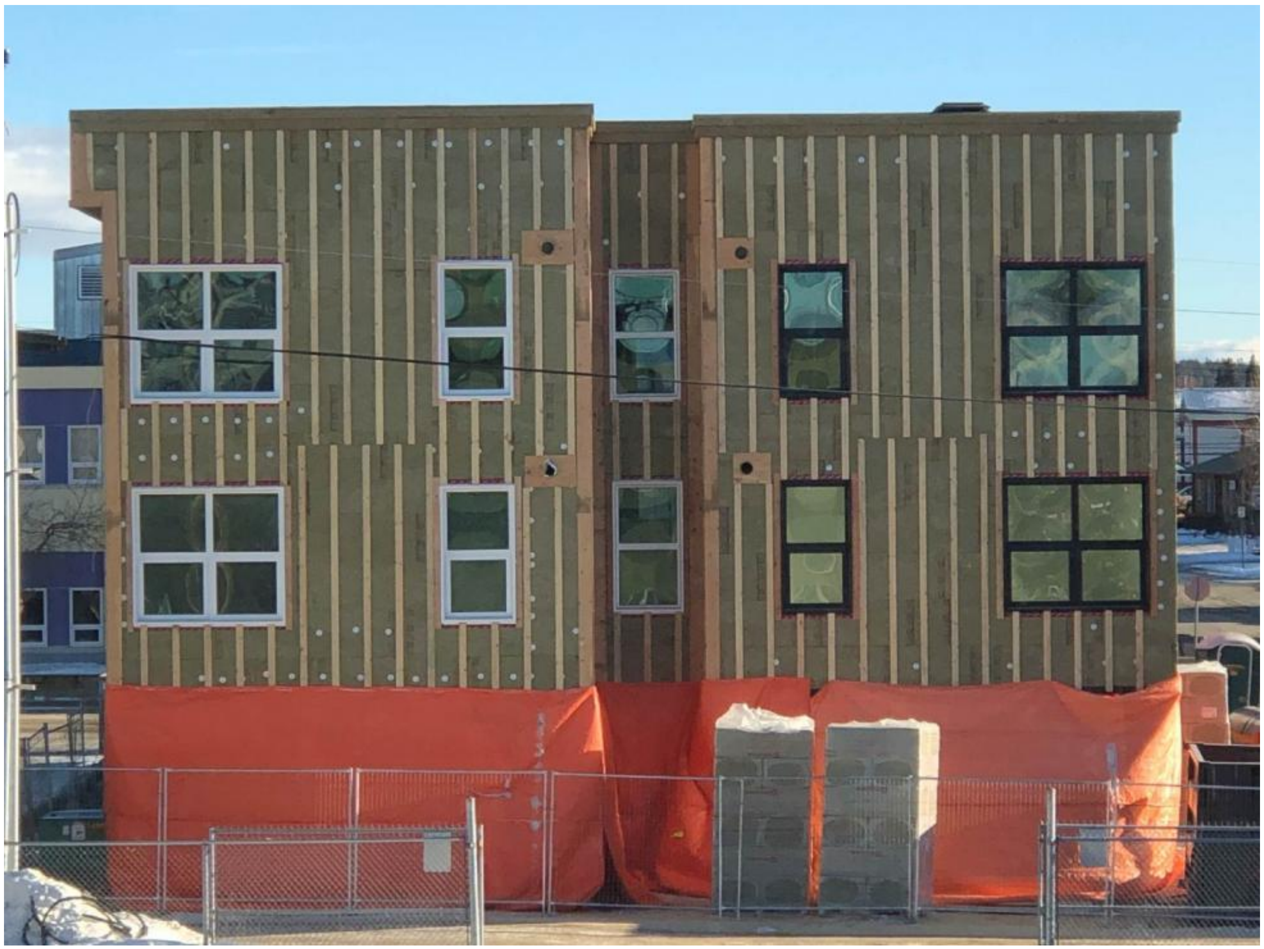
Below Grade Wall to Above Grade Wall

REMOTE System with EPS



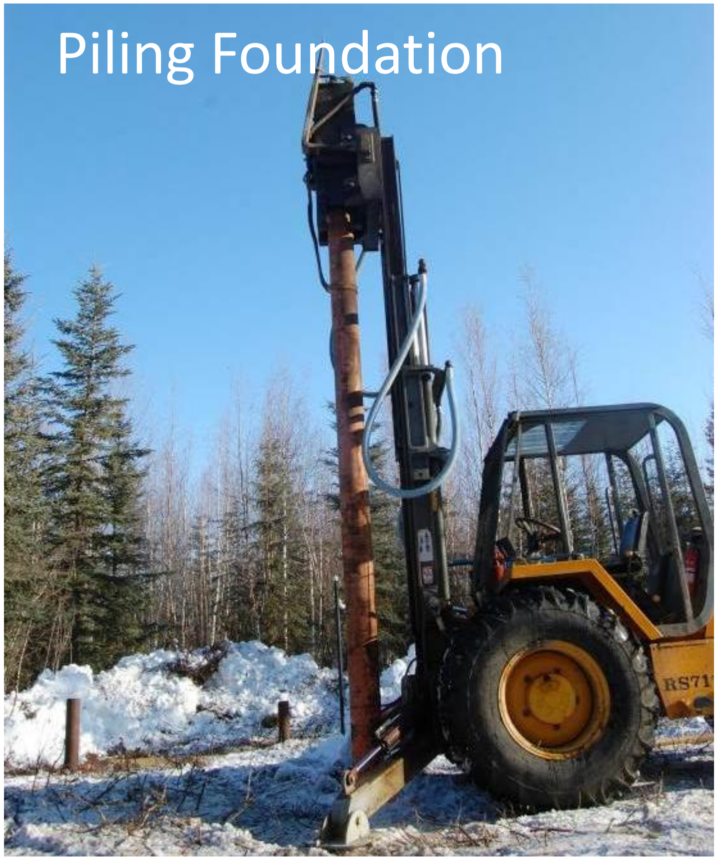
Split Insulated Wall:

- Riverdale Affordable Housing 8 Plex and Watson Lake 12 Plex
- 2x6 batt insulated
- 6” EPS foam
- Nominal R50 wall
- Slab on grade




GWM

2 Foundation Types



Insulation in foundation walls

9.25.2.3. Installation of Thermal Insulation

1) Insulation shall be installed so that there is a reasonably uniform insulating value over the entire face of the insulated area.

2) Insulation shall be applied to the full width and length of the space between furring or framing.

3) Except where the insulation provides the principal resistance to air leakage, thermal insulation shall be installed so that at least one face is in full and continuous contact with an element with low air permeance. (See Note A-9.25.2.3.(3).)

4) Insulation on the interior of *foundation* walls enclosing a crawl space shall be applied so that there is not less than 50 mm clearance above the crawl space floor, if the insulation is of a type that may be damaged by water.

5) Insulation around concrete slabs-on-ground shall be located so that heat from the *building* is not restricted from reaching the ground beneath the perimeter, where exterior walls are not supported by footings extending below frost level.

- All these approaches have weaknesses
- Especially in northern frost susceptible soils

A-9.36.2.8.(4) Unheated Floors-on-ground Above the Frost Line. Figure A-9.36.2.8.(4) illustrates the insulation options for unheated floors-on-ground that are above the frost line.

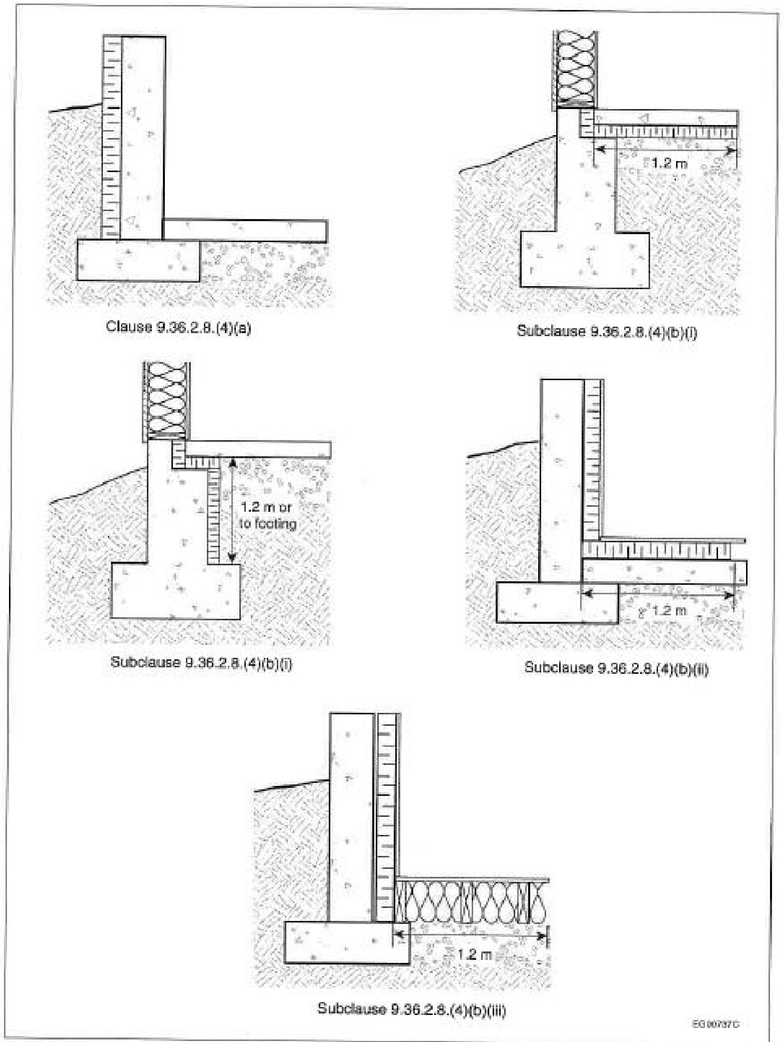


Figure A-9.36.2.8.(4)
Options for insulating unheated floors-on-ground

Skirt Insulation

A-9.36.2.8.(9) Skirt Insulation. "Skirt insulation" refers to insulation installed on the exterior perimeter of the foundation and extended outward horizontally or at a slope away from the foundation. In cold climates, skirt insulation is typically extended 600 to 1000 mm out from the vertical foundation wall over the footings to reduce heat loss from the house into the ground and to reduce the chance of frost forming under the footings.

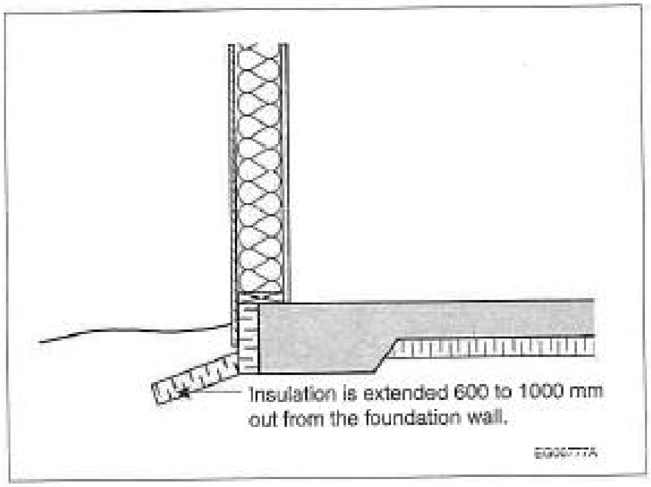
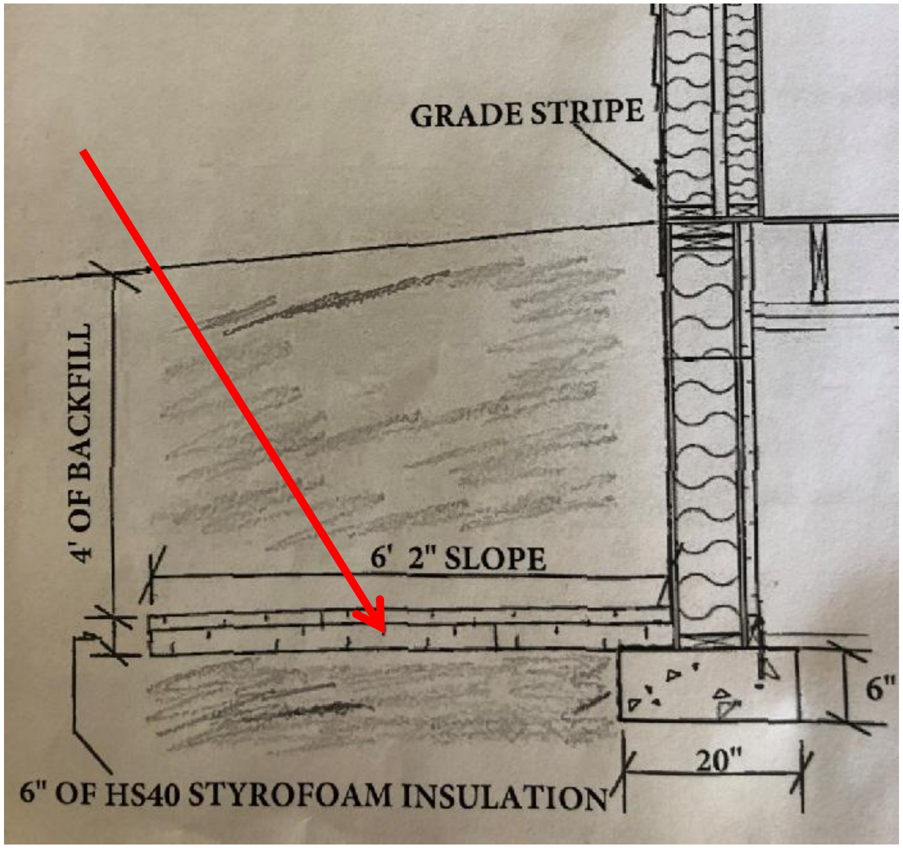
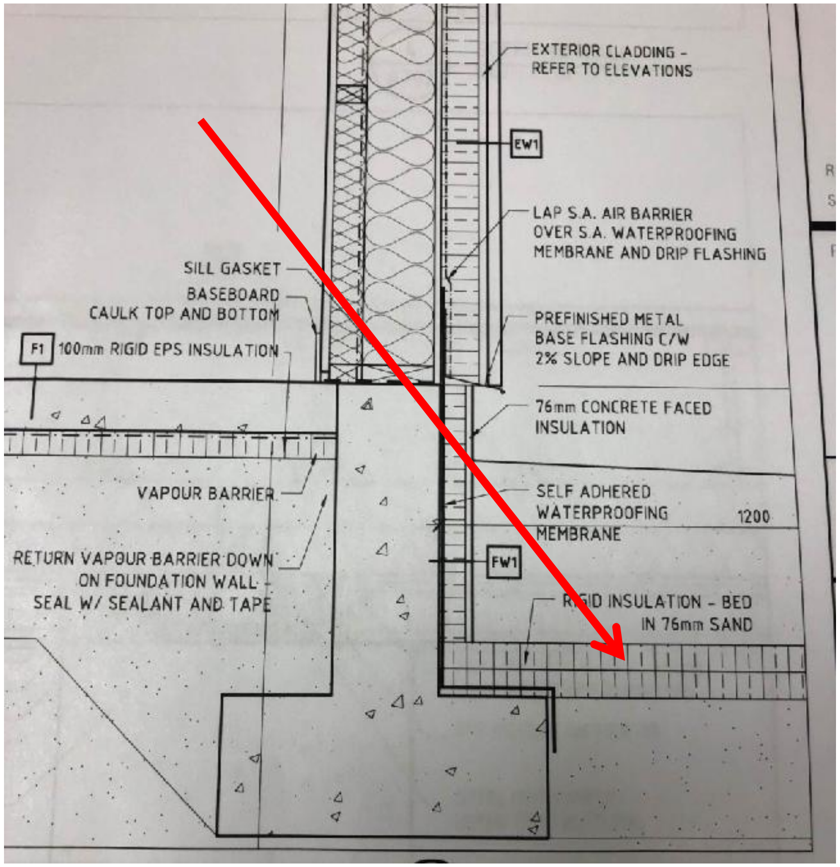


Figure A-9.36.2.8.(9)
Skirt insulation

Skirt Insulation





Insulating perimeter of slabs

9.25.2.3. Installation of Thermal Insulation

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How much insulation?

GREEN BUILDING STANDARDS

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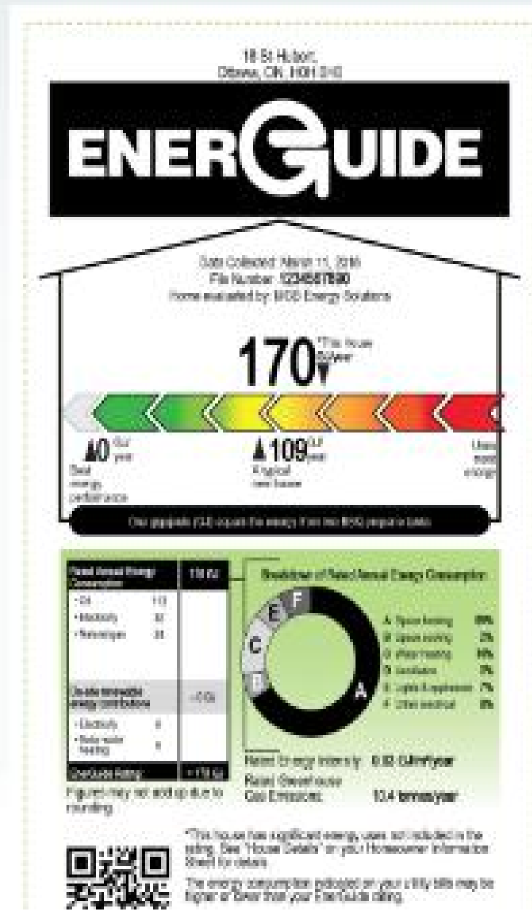
The City of Whitehorse requires an EnerGuide rating label on all new homes. Energy efficiency requirements included in the Building and Plumbing Bylaw are summarized below.



Minimum Thermal Insulation Values

New heated buildings and additions (excluding accessory buildings such as sheds and detached garages) must have insulation values as follows:

- Walls including foundations above and below grade R28
- Attics R60*
- Floors above unheated spaces R28
- Slabs on ground R10
- Slabs on ground containing radiant heat R20
- Concealed floor space or crawl space from grade R10
- Doors R12
- Windows R4.0
- Freeze protection for footings R10 extending 2' from building face.

Table 9.36.2.8.-B
Effective Thermal Resistance of Assemblies Below-Grade or in Contact with the Ground in Buildings with a Heat-Recovery Ventilator
Forming Part of Sentences 9.36.2.8.(1) to (9)

Building Assembly Below-*Grade* or in Contact with the Ground[1]	Heating Degree-Days of *Building* Location,[2] in Celsius Degree-Days					
	Zone 4 < 3000	Zone 5 3000 to 3999	Zone 6 4000 to 4999	Zone 7A 5000 to 5999	Zone 7B 6000 to 6999	Zone 8 ≥ 7000
	Minimum Effective Thermal Resistance (RSI), (m²·K)/W					
Foundation walls	1.99	2.98	2.98	2.98	2.98 R-17	2.98
Unheated floors[3]						
below frost line[4][5]	uninsulated	uninsulated	uninsulated	uninsulated	uninsulated	uninsulated
above frost line[5]	1.96	1.96	1.96	1.96	1.96 R-11	1.96
Heated and unheated floors on permafrost	n/a	n/a	n/a	n/a	4.44 R-25	4.44
Heated floors[6]	2.32	2.32	2.32	2.84	2.84 R-16	2.84
Slabs-on-grade with an integral footing[6]	1.96	1.96	1.96	2.84	2.84 R-16	3.72

Notes to Table 9.36.2.8.-B:

(1) See Note A-Tables 9.36.2.8.-A and -B.

(2) See Article 1.1.3.1.

(3) Does not apply to below-grade floors over heated crawl spaces.

(4) Typically applies to floors-on-ground in full-height *basements*.

(5) Refers to undisturbed frost line before house is constructed.

(6) See Sentence 9.25.2.3.(5) for requirement on placement of insulation. The design of slabs-on-grade with an integral footing is addressed in Part 4 (see Article 9.16.1.2.).

2) Where an entire floor assembly falls into two of the categories listed in Tables 9.36.2.8.-A and 9.36.2.8.-B, the more stringent value shall apply. (See Note A-9.36.2.8.(2).)

3) Where the top of a section of *foundation* wall is on average less than 600 mm above the adjoining ground level, the above-ground portion of that section of wall shall be insulated to the effective thermal resistance required in Table 9.36.2.8.-A or 9.36.2.8.-B.

4) Unheated floors-on-ground that are above the frost line and have no embedded heating pipes, cables or ducts shall be insulated to the effective thermal resistance required in Table 9.36.2.8.-A or 9.36.2.8.-B

a) on the exterior of the *foundation* wall down to the footing, or
b) on the interior of the *foundation* wall and, as applicable,
   i) beneath the slab for a distance not less than 1.2 m horizontally or vertically down from its perimeter with a thermal break along the edge of the slab that meets at least 50% of the required thermal resistance,
   ii) on top of the slab for a distance not less than 1.2 m horizontally from its perimeter, or
   iii) within the wooden sleepers below the floor for a distance not less than 1.2 m horizontally from its perimeter.

(See Note A-9.36.2.8.(4).)

5) Except as provided in Sentence (6), floors-on-ground with embedded heating ducts, cables or pipes shall be insulated to the effective thermal resistance required in Table 9.36.2.8.-A or 9.36.2.8.-B under their full bottom surface including the edges.

6) Where only a portion of a floor-on-ground has embedded heating ducts, cables or pipes, that heated portion shall be insulated to the effective thermal resistance required in Table 9.36.2.8.-A or 9.36.2.8.-B under its full bottom surface to 1.2 m beyond its perimeter including exterior edges if applicable.

7) In addition to the requirements stated in Sentences (5) and (6), heated floors-on-ground shall be insulated to the effective thermal resistance required in Table 9.36.2.8.-A or 9.36.2.8.-B vertically

a) around their perimeter, or
b) on the outside of the *foundation* wall, extending down to the level of the bottom of the floor.

8) Floors on permafrost shall be insulated to the effective thermal resistance required in Table 9.36.2.8.-A or 9.36.2.8.-B under the entire slab and around all edges, and under the integral perimeter footing.

9) Slabs-on-grade with an integral perimeter footing shall

a) be insulated to the effective thermal resistance required in Table 9.36.2.8.-A or 9.36.2.8.-B under the entire slab and around all edges, but not under the integral perimeter footing, and
b) be constructed with skirt insulation having the same effective thermal resistance as the insulation installed under the slab.

(See Note A-9.36.2.8.(9).) (See also Sentences 9.25.2.3.(5) and 9.36.2.5.(8).)

10) Junctions between below-*grade* assemblies shall be protected from the ingress of *soil* gas in conformance with Subsection 9.25.3.

Foundation Drainage Standards

City of Whitehorse

BUILDING ADVISORY - OCTOBER 25, 2010

City of Whitehorse
Planning and Development Services Department

RE: Building Advisory October 25, 2010 – Drainage Standards for Building Foundations

Effective October 25, 2010

As a result, please be advised that PWF dwelling unit foundations with pressure treated wood footings will require a minimum 125mm (5") compacted drainage layer beneath the foundation and extending 12" beyond the footing. A sump pit must be installed, with provision for a sump pump to facilitate the removal of excess ground water should it prove necessary. Out-flow from this pump must be directed to the surface away from the building, and not to a side which may impact neighbouring properties.

CAN/CSA S-406-92 "Construction of Preserved Wood Foundations" also allows for concrete footings to be placed on undisturbed ground which would allow water to pass through by the installation of 60mm (2 ¼") diameter pipe at 1200mm (48") intervals around the perimeter footing. Again the installation of the sump pit is necessary.

F:Forms/All Counter Forms/Foundation Advisory October 25 2010 FINAL.docx

Please do not hesitate to contact a Building Official for further information @ 668-8340.

Foundation Drainage Standards cont’d

Full depth concrete foundations with concrete footings are required to have perimeter drainage tile which terminate in a now required sump pit. A sump pump is to be installed to assist in the removal from the foundation area should water accumulation in the sump pit warrant it.

Existing City of Whitehorse bylaws do not allow connections to the sanitary sewer infrastructure for this drainage.

Alternatives

If you wish to pursue an alternative to the prescriptive standards outlined, there are options that can be proposed. One option is to provide site specific soil analysis that meets the conditions for a “free draining” soil type verified by a stamped report from a Yukon licensed engineer experienced in soils analysis. When this “free draining” soil type designation is obtained, the drainage layer and sump assembly can be omitted.

Another option available is for a building designed under Part 4 of the NBC. This prescriptive requirement foundation drainage may be omitted/altered by a structural engineer’s letter of design assurance and field review.

Lastly a building constructed “slab on grade” need not provide the sump pit and associated equipment.

Please do not hesitate to contact a Building Official for further information @ 668-8340.

Summary

- Water comes in liquid and vapour – managing both, above and below grade, is critical
- Poly interior finishes cause elevated moisture conditions
- Retrofitting an existing basement will require very careful planning to avoid problems
- Care needs to be taken at rim joists and footings
- Plan for a flood or leak

Conclusions

- Building in the ground is hard
- Build in redundancy – multiple safety factors
- The best solution is to:
  - Wrap the complete structure on the outside with appropriate air barrier and moisture control membranes – REMOTE wall
  - Wrap the outside of the structure with lots of appropriate insulation
- Every other system compromises – energy, durability, cost, and comfort
- Need to work out a few details that work for all builders

Other resources:

Yukon Housing Corp. – https://yukon.ca/en/housing-and-property

Guides and handbooks

- Energy efficient northern housing guide - Energy optimized
- Energy efficient northern housing guide - Cost optimized
- Guide to home heating oil tanks (English / French)
- Northern housing retrofit guide
- Optimal northern wall design guidelines

Studies and evaluations

- 2017 CMHC Research Report - Super Insulated Housing in Yukon
- Comprehensive review and assessment of housing issues in Yukon (Pomeroy and Zanasi, 2013)
- NRG oil burning appliances final report 2010 (inspection period March 13—30, 2010)

Other resources:

- https://www.youtube.com/watch?v=kwn0Vjw_ji0
- www.energy.gov.yk.ca
- www.RDH.com
- https://buildingsciencelabs.com/technical-library/
- www.buildingscience.com
- www.greenbuildingadvisor.com
- CMHC, NRCan websites
- CCHRC, BC Housing
- Many other very great sources of info.

Thank you!