Slab Insulation – Finding the Right Details

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Description

Concrete slabs, specifically at slab edges, can be one of the more challenging assemblies to design and construct in the building enclosure. Current energy codes have attempted to address these challenges; however, construction methods have not evolved to the point of full code compliance. This webinar will analyze the implications of slab insulation on building energy consumption and occupant health, identify critical building code requirements that address slabs, and discuss challenges that arise with the design and trade-offs that occur in slab insulation and construction.

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Learning Objectives

1. Understand the impact that slab insulation has on the overall performance of the building enclosure in residential structures.
2. Identify critical building code requirements that dictate the design and construction of concrete slab assemblies.
3. Analyze the effect that structural requirements related to occupant safety have on the energy efficiency of slab edges.
4. Realize the implications of specific design choices related to concrete slabs on the comfort and health of building occupants

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What is Building Science?

- "Building science is the cross-disciplinary collection of knowledge and experience required to understand and predict many aspects of the behavior of buildings and their systems, specifically including *durability, comfort, energy, environmental separation, indoor air quality, acoustics, lighting, economics, and constructability*."

  - Dr. John Straube, 3rd Residential Building Design & Construction Conference

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What is the Building Enclosure?

- "That part of any building that physically separates the exterior environment from the interior environment(s) is called the building enclosure or building envelope."

  - Dr. John Straube, BSD-018: The Building Enclosure

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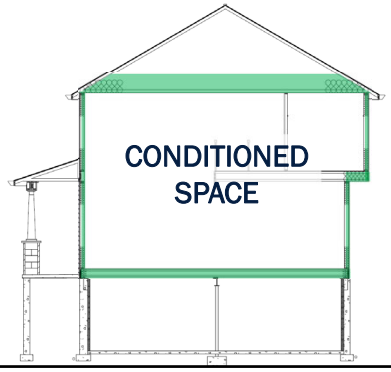

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Building Enclosure Functions

- Support (structural)
- Control (heat, air, moisture, smoke, odor, sound, fire, insects, etc.)
- Aesthetics (exterior and interior finishes)
- Distribution of Services (MEP)

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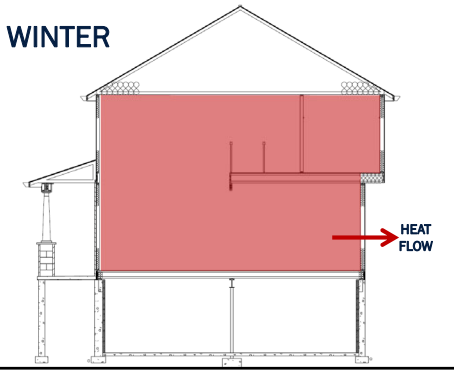

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Building Science Principles

- Heat Flow
- Moisture Flow
- Air Flow

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Heat Flow Mechanisms – Conduction

- Conduction
  - Heat flow through a substance or material by direct contact
  - Conduction takes place within a single material or between materials in direct contact
- Where does conduction occur in a home?

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Relative Humidity (RH)

- Relative humidity = (Partial Pressure) / (Saturation Pressure)
- Relative humidity depends on *TEMPERATURE*
  - An air mass with higher temperature can hold more moisture
    AND
  - An air mass with lower temperature can hold less moisture
    THEREFORE
  - RH drops as temperature increases
    AND
  - RH rises as temperature decreases

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Dew Point

- Dew point
  - Temperature at which saturation vapor pressure equals partial pressure
- Condensation
  - Occurs when RH = 100%
  - Only occurs on a surface cooler than dew point temperature

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Condensation

- When humid air (high RH) comes in contact with a cool surface, condensation can occur
- Where can *condensation* occur in a home?

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Slab Edge Heat Loss

- Temperature of slab perimeter may be below dew point in heating climates for significant periods of time
  - Condensation risk
  - Even with temperature above dew point, slab edge heat loss can elevate relative humidity to levels high enough to support mold growth

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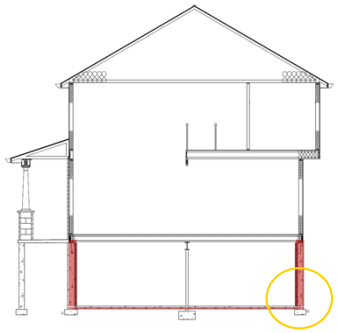

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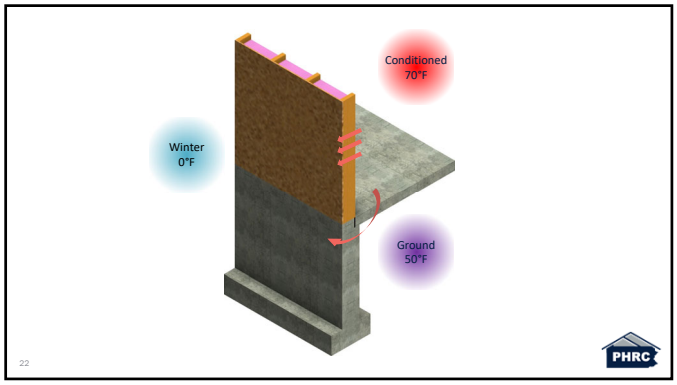
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70°F
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Ground
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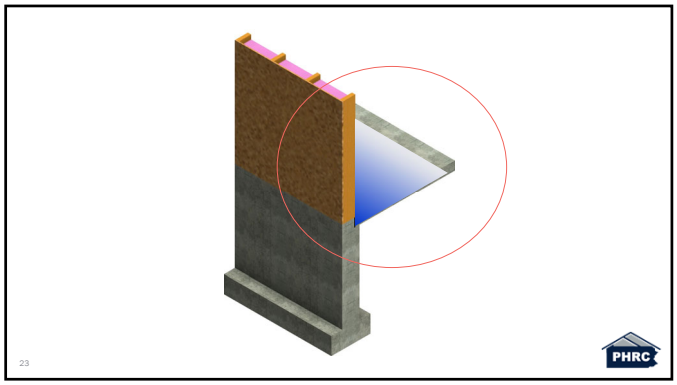
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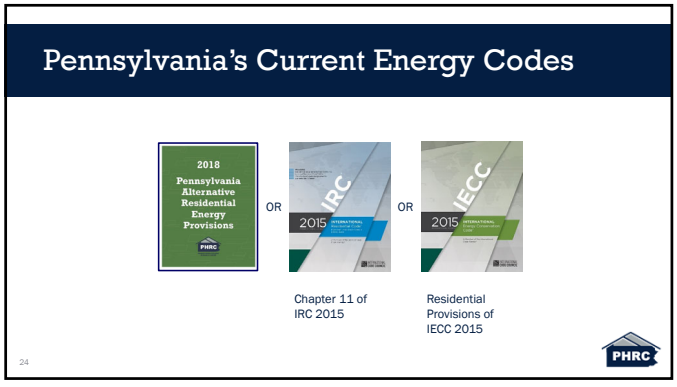
Pennsylvania's Current Energy Codes
2018
Pennsylvania
Alternative
Residential
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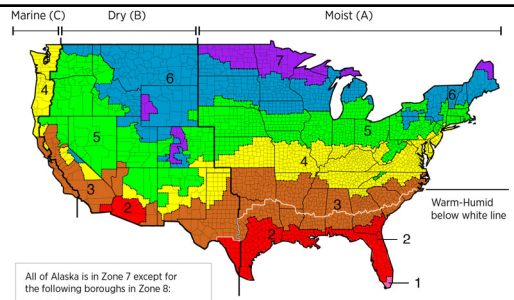

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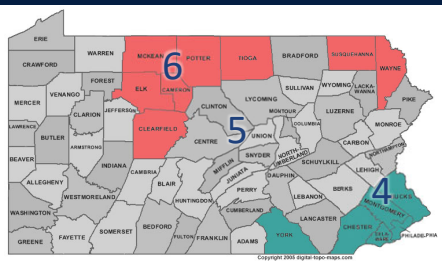
Climate Zones in PA



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2015 IRC Table N1102.1.2

Table N1102.1.2 (R402.1.2)
INSULATION AND FENESTRATION REQUIREMENTS BY COMPONENT a

Climate Zone	Fenestration U-Factor	SKYLIGHT b U-FACTOR	GLAZED FENESTRATION SHGC b, e	CEILING R-VALUE	WOOD FRAME WALL R-VALUE i	MASS WALL R-VALUE i	FLOOR R-VALUE	BASEMENT c WALL R-VALUE	SLAB d R-VALUE & DEPTH	CRAWL SPACE c WALL R-VALUE
1	NR	0.75	0.25	30	13	3/4	13	0	0	0
2	0.40	0.65	0.25	38	13	4/6	13	0	0	0
3	0.35	0.55	0.25	38	20 or 13 + 5 h	8/13	19	5/13 f	0	5/13
4 except Marine	0.35	0.55	0.40	49	20 or 13 + 5 h	8/13	19	10/13	10, 2 ft	10/13
5 and Marine 4	0.32	0.55	NR	49	20 or 13 + 5 h	13/17	30 g	15/19	10, 2 ft	15/19
6	0.32	0.55	NR	49	20 + 5 or 13 + 10 h or 18 + 4.5 h	15/20	30 g	15/19	10, 4 ft	15/19
7 and 8	0.32	0.55	NR	49	20 + 5 or 13 + 10 h	19/21	38 g	15/19	10, 4 ft	15/19

a. R-values are minimums. U-factors and SHGC are maximums. When insulation is installed in a cavity which is less than the label or design thickness of the insulation, the installed R-value of the insulation shall not be less than the R-value specified in the table.

b. The fenestration U-factor column excludes skylights. The SHGC column applies to all glazed fenestration.

Exception: Skylights may be excluded from glazed fenestration SHGC requirements in Climate Zones 1 through 3 where the SHGC for such skylights does not exceed 0.30.

c. "15/19" means R-15 continuous insulation on the interior or exterior of the home or R-19 cavity insulation at the interior of the basement wall. "15/19" shall be permitted to be met with R-13 cavity insulation on the interior of the basement wall plus R-5 continuous insulation on the interior or exterior of the home. "10/13" means R-10 continuous insulation on the interior or exterior of the home or R-13 cavity insulation at the interior of the basement wall.

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 N1101.10 and Table N1101.10.

g. Or insulation sufficient to fill the framing cavity, R-19 minimum.

h. The first value is cavity insulation, the second value is continuous insulation, so "13+5" means R-13 cavity insulation plus R-5 continuous insulation.

i. The second R-value applies when more than half the insulation is on the interior of the mass wall.

j. R-18 insulation shall be permitted in place of R-20 requirement provided the wall framing factor is 23% or less or exterior walls with 24" o.c. nominal vertical stud spacing.

Source: International Code Council (ICC). (2014). 2015 International Residential Code, Country Club Hill, Ill.

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2015 IRC Table N1102.1.2

Table N1102.1.2 (R402.1.2)
INSULATION AND FENESTRATION REQUIREMENTS BY COMPONENT [a]

Climate Zone	Fenestration *U*-Factor	SKYLIGHT[b] *U*-FACTOR	GLAZED FENESTRATION SHGC[b, e]	CEILING *R*-VALUE	WOOD FRAME WALL *R*-VALUE[i]	MASS WALL *R*-VALUE	FLOOR *R*-VALUE	BAWSEMENT[c] WALL *R*-VALUE	SLAB[d] *R*-VALUE & DEPTH	CRAWL SPACE[c] WALL *R*-VALUE
1	NR	0.75	0.25	30	13	3/4	13	0	0	0
2	0.40	0.65	0.25	38	13	4/6	13	0	0	0
3	0.35	0.55	0.25	38	20 or 13 + 5[h]	8/13	19	5/13[f]	0	5/13
4 except Marine	0.35	0.55	0.40	49	20 or 13 + 5[h]	8/13	19	10/13	10, 2 ft	10/13
5 and Marine 4	0.32	0.55	NR	49	20 or 13 + 5[h]	13/17	30[g]	15/19	10, 2 ft	15/19
6	0.32	0.55	NR	49	20 + 5 or 13 + 10[h] or 18 + 6.5[h]	15/20	30[g]	15/19	10, 4 ft	15/19
7 and 8	0.32	0.55	NR	49	20 + 5 or 13 + 10[h]	19/21	38[g]	15/19	10, 4 ft	15/19

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Source: International Code Council (ICC). (2014). 2015 International Residential Code, Country Club Hill, Ill.

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2015 IRC Section N1102.2.10 Slab-On-Grade Floors

- **N1102.2.10 Slab-on-grade floors.** Slab-on-grade floors with a floor surface less than 12 inches (305 mm) below grade shall be insulated in accordance with Table 402.1.2.
  - The insulation shall extend downward from the top of the slab on the outside or inside of the foundation wall
  - Insulation located below grade shall be extended the distance provided in Table N1102.1.2 by any combination of vertical insulation, insulation extending under the slab or insulation extending out from the building
  - Insulation extending away from the building shall be protected by pavement or by a minimum of 10 inches (254 mm) of soil
  - The top edge of the insulation installed between the exterior wall and the edge of the interior slab shall be permitted to be cut at a 45-degree (0.79 rad) angle away from the exterior wall
  - Slab-edge insulation is not required in jurisdictions designated by the code official as having a very heavy termite infestation

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Source: International Code Council (ICC). (2014). 2015 International Residential Code, Country Club Hill, Ill.

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Insulation Placement

- **N1102.2.10 Slab-on-grade floors.** Slab-on-grade floors with a floor surface less than 12 inches (305 mm) below grade shall be insulated in accordance with Table 402.1.2.
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Options For Placement

- Interior/Horizontal
- Interior/Vertical
- Exterior

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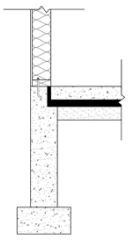
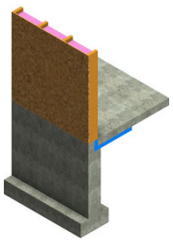
Interior/Horizontal





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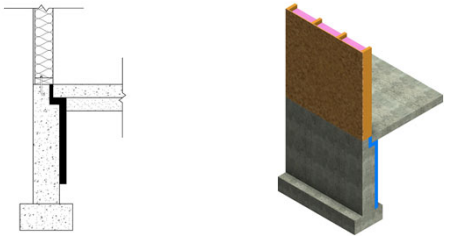
Interior/Vertical



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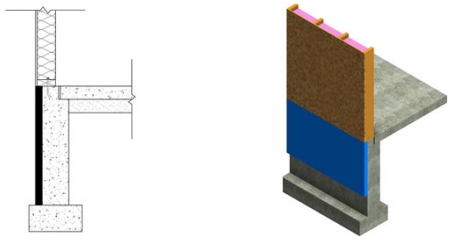
Exterior



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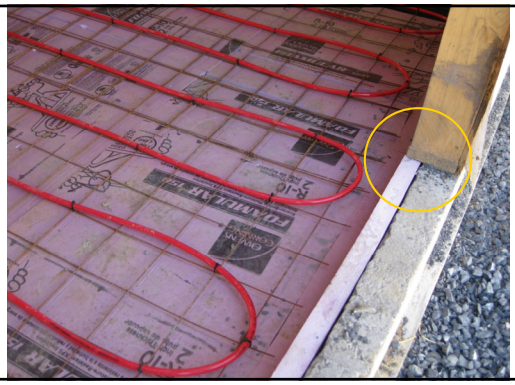

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Cantilevered Sill Plate

- **Structural concerns:**
  - Edge distance of anchor bolts
    - ACI requires 1-1/2" CC for cast-in-place anchor bolts
    - Proprietary equivalent anchorage systems (ICC-ES approved) have differing requirements (i.e. 1-3/4")
  - Bearing area of sill plate
    - If originally 2x6 wall, now with 3-1/2" bearing width, will act as a 2x4 wall
    - Special attention required for stud columns

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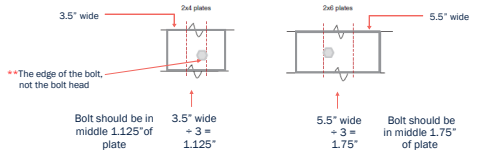
2015 IRC Section R403.1.6 Foundation Anchorage

- Language was added that now requires the anchor bolts to be located within the middle third of the width of the sill plate.



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Source: International Code Council (ICC). (2014). 2015 International Residential Code, Country Club Hill, Ill.
Image Source: International Code Council. (2015). 2015 Significant Changes to the IRC, ICC, Country Club Hill, Ill.

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PA Alternative Residential Energy Provisions

- Compliance allowed by UCC Title 34, Chapter 403
- Intent:
  - simpler to build to and easier to enforce
  - more rational and flexible
  - focused on Pennsylvania in terms of climatic and other conditions; and,
  - equivalent to the provisions of the International Energy Conservation Code (IECC)
- Prescriptive (vs. requiring modeling)
- Allows trade-offs

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PA Alternative Residential Energy Provisions

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Energy Enhancement Options

Table PA104
Energy Enhancement Options

Option	Description		Minimum efficiency by climate zone		
			South (4)	Central (5)	North (6)
1	Ductless heat pumps		8.5 HSPF	8.5 HSPF	8.5 HSPF
2	All air ducts located inside the thermal envelope		Compliant	Compliant	Compliant
3	Solar photovoltaic system installed		1.4 kW	1.7 kW	3.4 kW
4	Geothermal or water source heat pump installed		Compliant	Compliant	Compliant
5	Improved efficiency air source heat pump installed		8.7 HSPF	9.0 HSPF	10.0 HSPF
6	Improved efficiency furnace installed		90 AFUE	90 AFUE	90 AFUE
7	Exterior continuous insulation		R20+10	R20+10	
8	Improved airtightness		3.0 ACH50	3.0 ACH50	3.0 ACH50
9	Improved efficiency windows		U-factor = 0.25	U-factor = 0.23	U-factor = 0.19
10	Package: Improved efficiency windows and higher attic R-value with raised heel truss[a]	Windows	U-factor = 0.27	U-factor = 0.25	U-factor = 0.25
		Attic	R-value = 60	R-value = 60	R-value = 60
11	Package: Improved efficiency windows and heat pump water heater	Windows	U-factor = 0.27	U-factor = 0.25	U-factor = 0.23
		Heat Pump Water Heater	Compliant	Compliant	Compliant

Notes:
a. Full height of uncompressed insulation shall extend over the top plate at the eaves.

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Energy Tradeoffs

3. Slab edge insulation: Thermal break

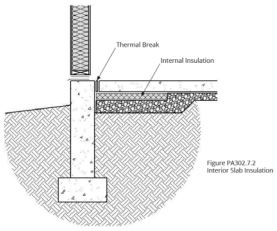

Figure PA302.7.2
Interior Slab Insulation

PA302.7.2 Interior Insulation. Interior insulation shall be installed from the bottom of the slab and extend the distance provided in Table PA301 by any combination of vertical insulation or horizontal insulation extending under the slab. The slab edge shall be separated from the foundation wall by a continuous ½ inch thermal break as per Figure PA302.8.(2) A thermal break shall be created by a material suitable for ground contact, which includes, but is not limited to, asphalt impregnated fiber board or extruded polystyrene. Slab-edge insulation is not required in jurisdictions designated by the code official as having a very heavy termite infestation.

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Common Questions/Concerns

- Floating slab
- Beveled insulation
- Termites
- Vapor barrier placement

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Floating Slabs – Cause for Concern?

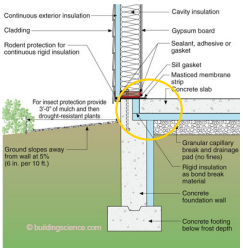

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Image Source: https://www.buildingscience.com/sites/default/files/migrate/jpg/BSI059_Figure_01_web.jpg

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What About Beveled Insulation?

- **N1102.2.10 Slab-on-grade floors.** Slab-on-grade floors with a floor surface less than 12 inches (305 mm) below grade shall be insulated in accordance with Table 402.1.2.
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What About Beveled Insulation?

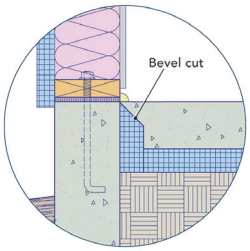

Image Source: https://www.greenbuildingadvisor.com/article/insulating-raised-slab

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What About Termites?

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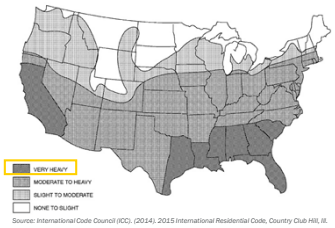
What About Termites?

FIGURE R301.2(5)
GROUND SNOW LOADS, P_g FOR THE UNITED STATES (lb/ft²)



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Source: International Code Council (ICC). (2014). 2015 International Residential Code, Country Club Hill, Ill.

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Where Should the Vapor Barrier Go?

- IRC R506.2.3 – Vapor Retarder
  - *"A 6 mil polyethylene or approved vapor retarder with joints lapped not less than 6 inches shall be placed between the concrete floor slab and the base course or the prepared subgrade where no base course exists."*
- Vapor barrier should be placed in direct contact with concrete (best practice)

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Example: Walkout Basement

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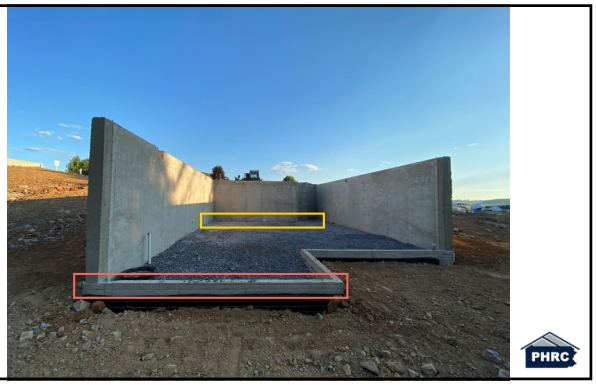

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What's the Best Approach?

- Understand performance goals
- Define and design the building enclosure
- Dig into the details:
  - Prioritize structure
  - Comply with the applicable codes
  - Develop a *complete* detail
- *Communicate* the design!

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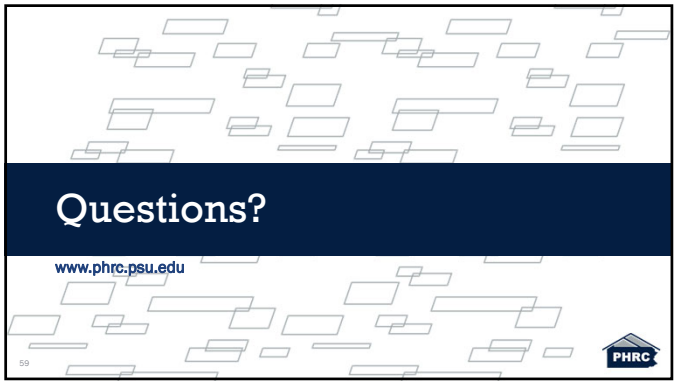

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