FROST PROTECTING POST FRAME BUILDINGS

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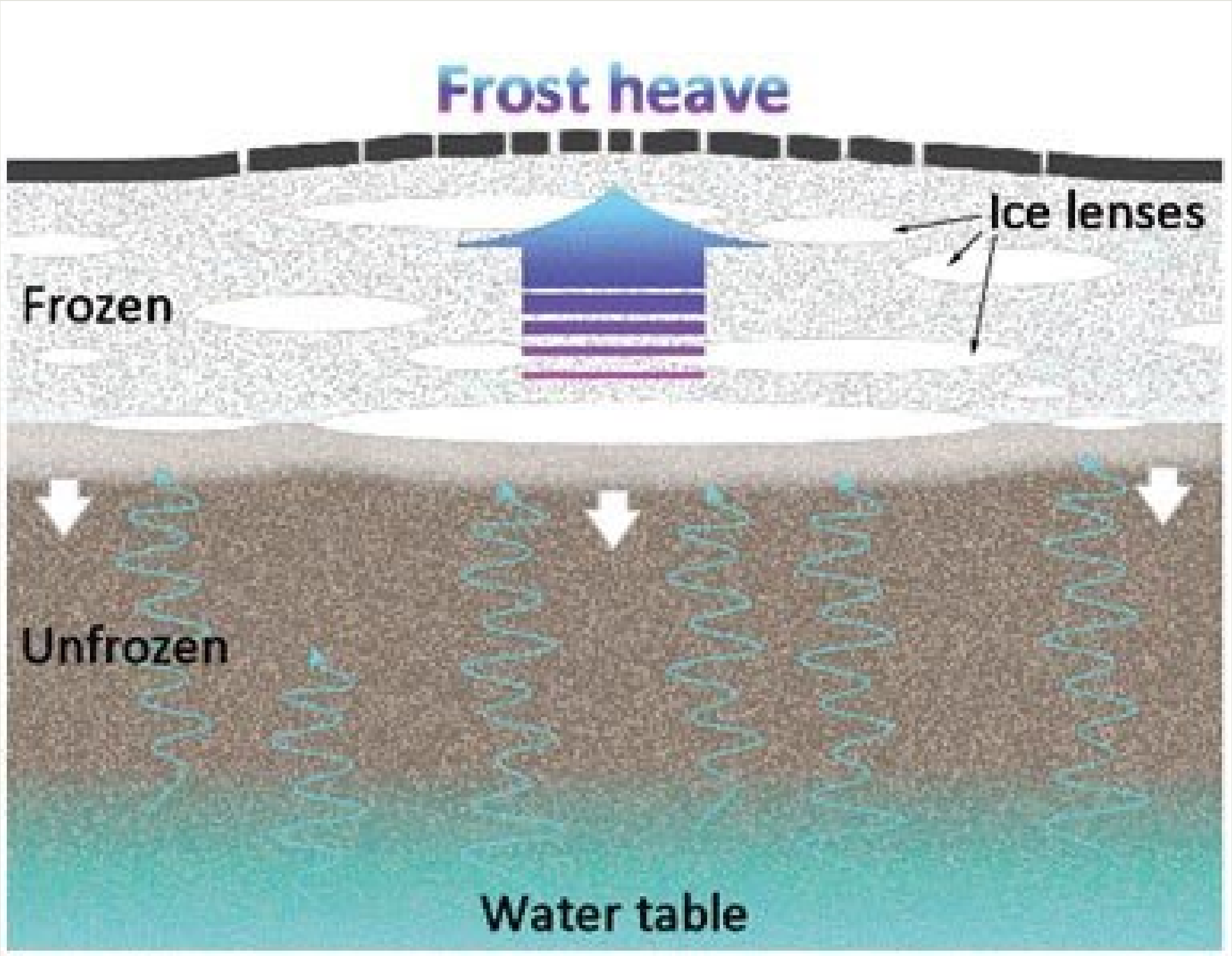
WALTERS BUILDINGS

OUTLINE

- FROST ACTION
- CODE REQUIREMENTS
- CONVENTIONAL FOUNDATIONS
- CONSTRUCTION ON NFS SOILS
- FROST PROTECTED SHALLOW FOUNDATIONS
- SIMPLIFIED METHOD – HEATED BUILDING
- DETAILED METHOD – HEATED BUILDING
- DETAILED METHOD – UNHEATED BUILDING
- SEMI-HEATED BUILDINGS
- THERMAL BRIDGES
- SPECIAL DETAILS
- ENERGY CONSERVATION

FROST ACTION

- **Frost Heave –** Soil under foundation freezes
- **Water Expands 9% of volume**
- **Ice lenses** form from capillary action
- **Capillary action -** pulls water up from water table and then it freezes
- **Ice Segregation**
  - Separation of ice lenses and dry soil
- **Thaw weakening**
  - Significant reduction in soil bearing
  - Cause of potholes in roads
  - Foundation Settlement



SOIL TYPES

Clay - 80” capillary rise

Silt - 40” capillary rise

Fine Sand - 20” capillary rise

Medium Sand - 10” capillary rise

Coarse Sand - 6” Capillary Rise

Gravel – 3” Capillary Rise

Rise relates to smallest particle size, even if it is a small percentage of soil composition (>6%)

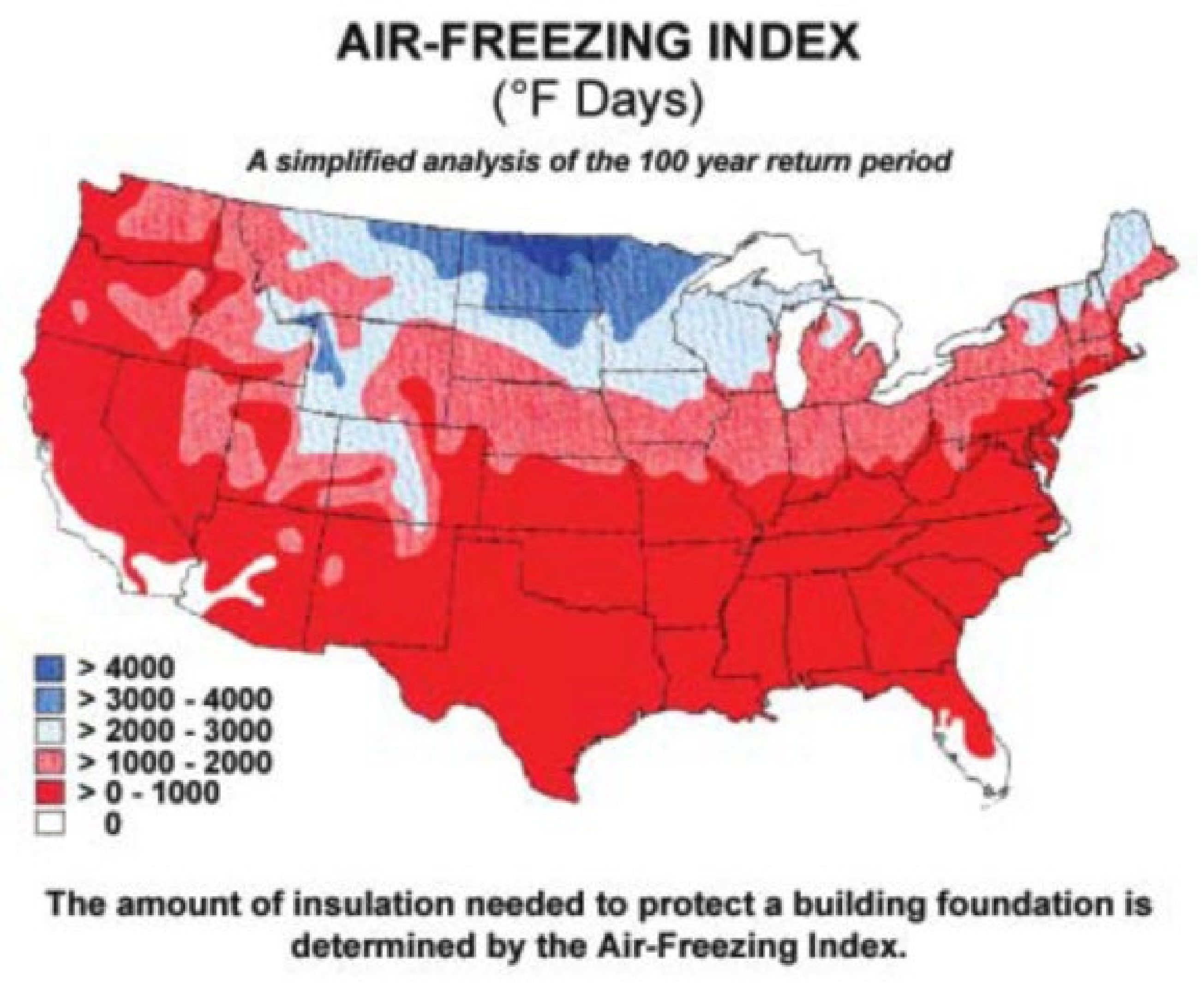
Large distance to water table lowers frost susceptibility

Table 1: Frost-susceptible soils

Frost-susceptiblity	Soil Types
Low	Clean gravels and washed sands
Medium	Unwashed sands with moderate amounts of silty fines
High	Dirty gravels and pure clays
Very High	Silts and silty materials (including most materials called clay in New York State)

AIR FREEZING INDEX (AFI)

- Frost depth & insulation requirements depend on AFI
- Highest accumulation of daily mean temperatures below 32 degrees F during cold season



LOCAL FROST PENETRATION DEPTH

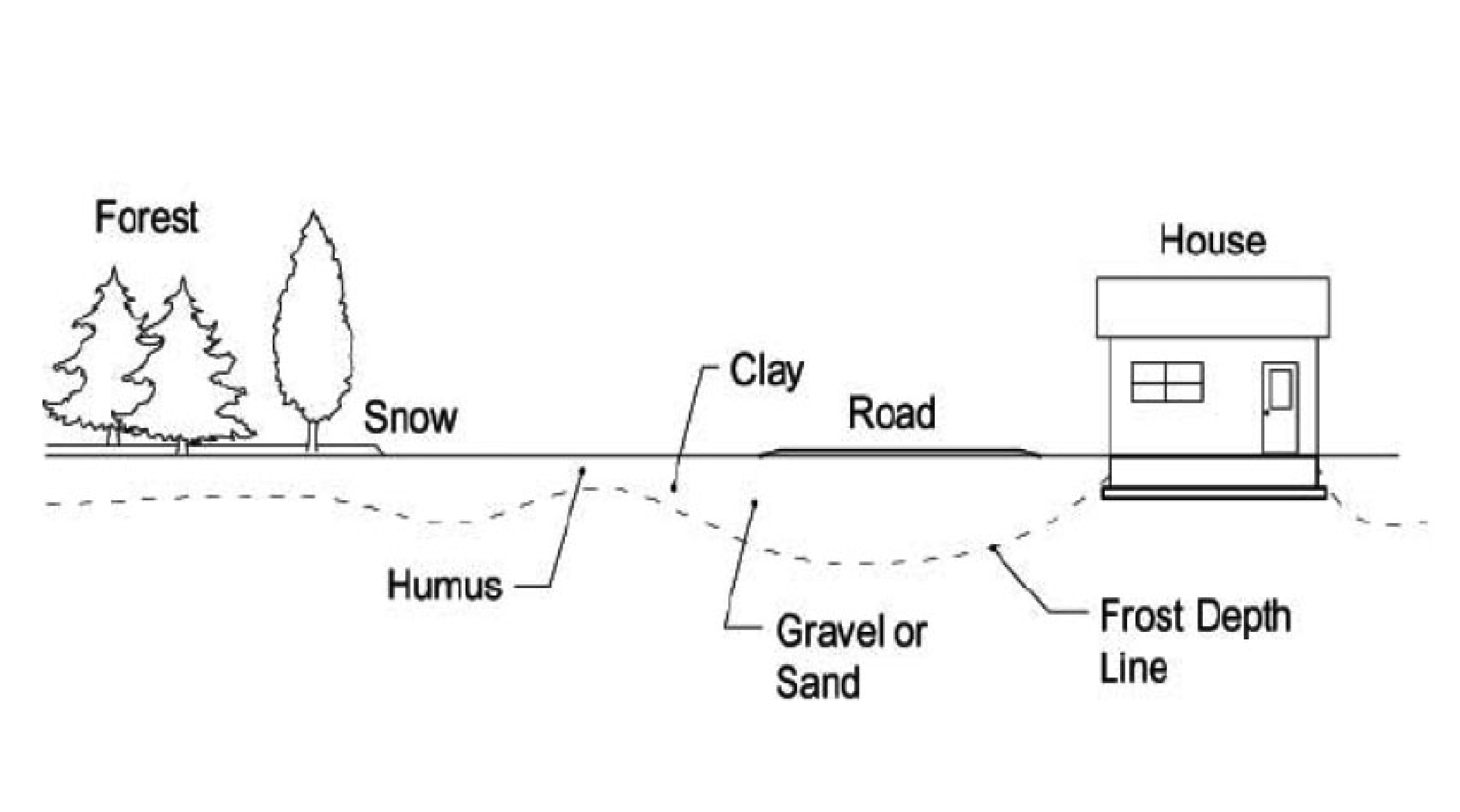
Determined from Air Freezing Index

Ground cover affects frost depth

- Trees & Vegetation
- Snow cover
- Paved Surfaces
- Foundation/Buildings

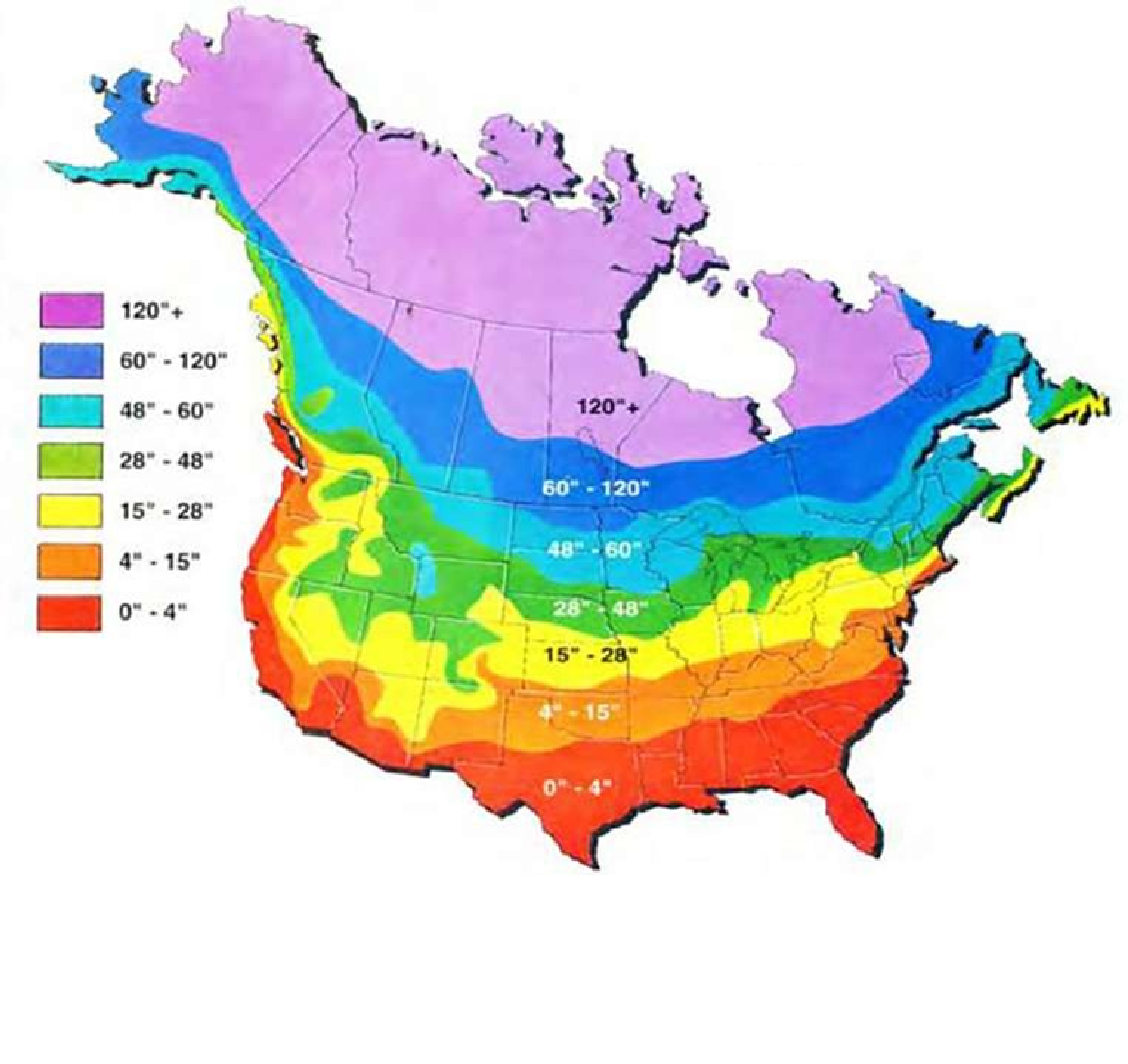
Soil type affects frost depth

- Higher in gravel/sand
  - BETTER CONDUCTORS



FROST DEPTH MAP

- PRIMARILY DRIVEN BY AFI
- LOCAL CODES MAY REQUIRE DESIGNS FOR HIGHER FROST DEPTH



FROST ACTION

- In heated buildings with perimeter insulation, it is common to crack along perimeter of grade beam
  - Heat loss through floor keeps soil below slab from freezing
  - Result of insufficient perimeter insulation

- In unheated buildings, frost heave can happen at foundation edges or in middle of the building

FROST HEAVE AT PERIMETER

FROST HEAVE AT INTERIOR

CAUSE OF FROST ACTION

Needs three things:

1. **Water**
2. **Frost-susceptible soil**
3. **Freezing temps**

Remove any one of these things, frost action is not possible

Code Requirements

International Building Code : Chapter 18 Section 1809.5

1809.5 Frost protection.

Except where otherwise protected from frost, foundations and other permanent supports of buildings and structures shall be protected from frost by one or more of the following methods:

1. Extending below the frost line of the locality.
2. Constructing in accordance with ASCE 32.
3. Erecting on solid rock.

Exception: Free-standing buildings meeting all of the following conditions shall not be required to be protected:

1. Assigned to *Risk Category* I.
2. Area of 600 square feet (56 m^2) or less for light-frame construction or 400 square feet (37 m^2) or less for other than light-frame construction.
3. Eave height of 10 feet (3048 mm) or less.

Shallow foundations shall not bear on frozen soil unless such frozen condition is of a permanent character.

CONVENTIONAL FOUNDATIONS TO FROST DEPTH

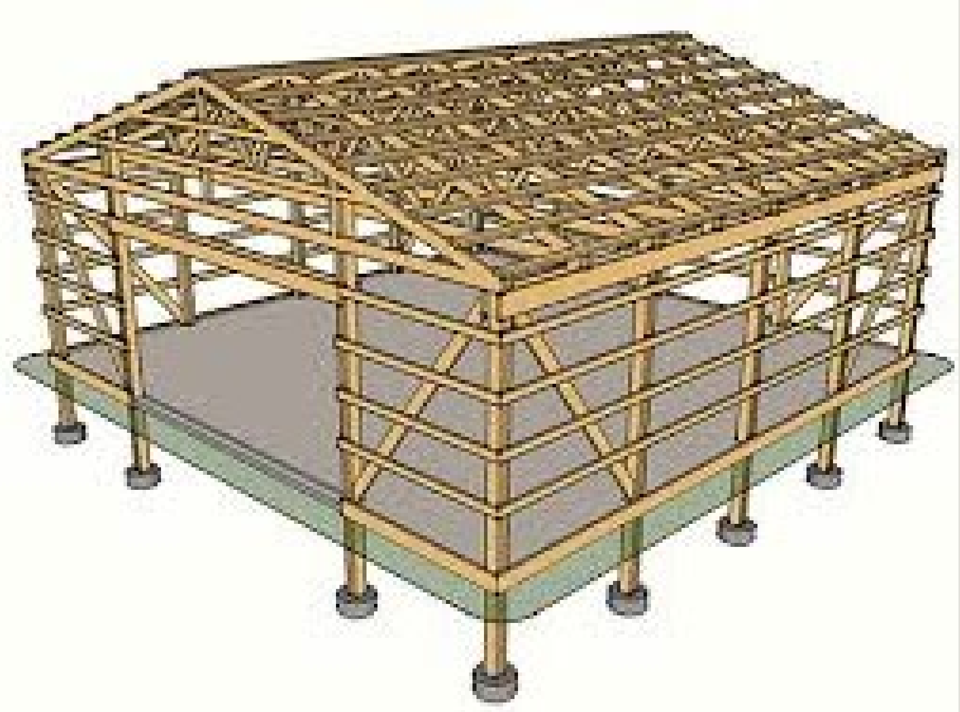
Embedded posts are not shallow foundation

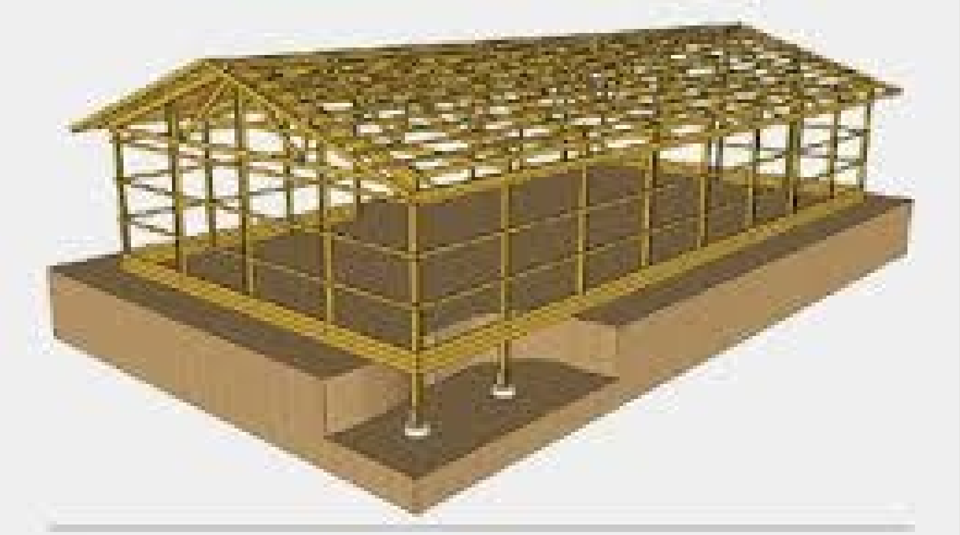
- Posts are designed to extend below frost line and main structural components are frost protected

Concrete foundation walls to below frostline (Frost Walls)

Concrete floors in bldgs. w/ embedded posts

- May be treated as shallow foundations or they can heave independently from main structure
  - Isolate slab from posts if not frost protected
  - Keep end use in mind and impact of frost action on building use
  - Local building official may require slab to be protected





Post-frame building with trusses supported directly by embedded posts.

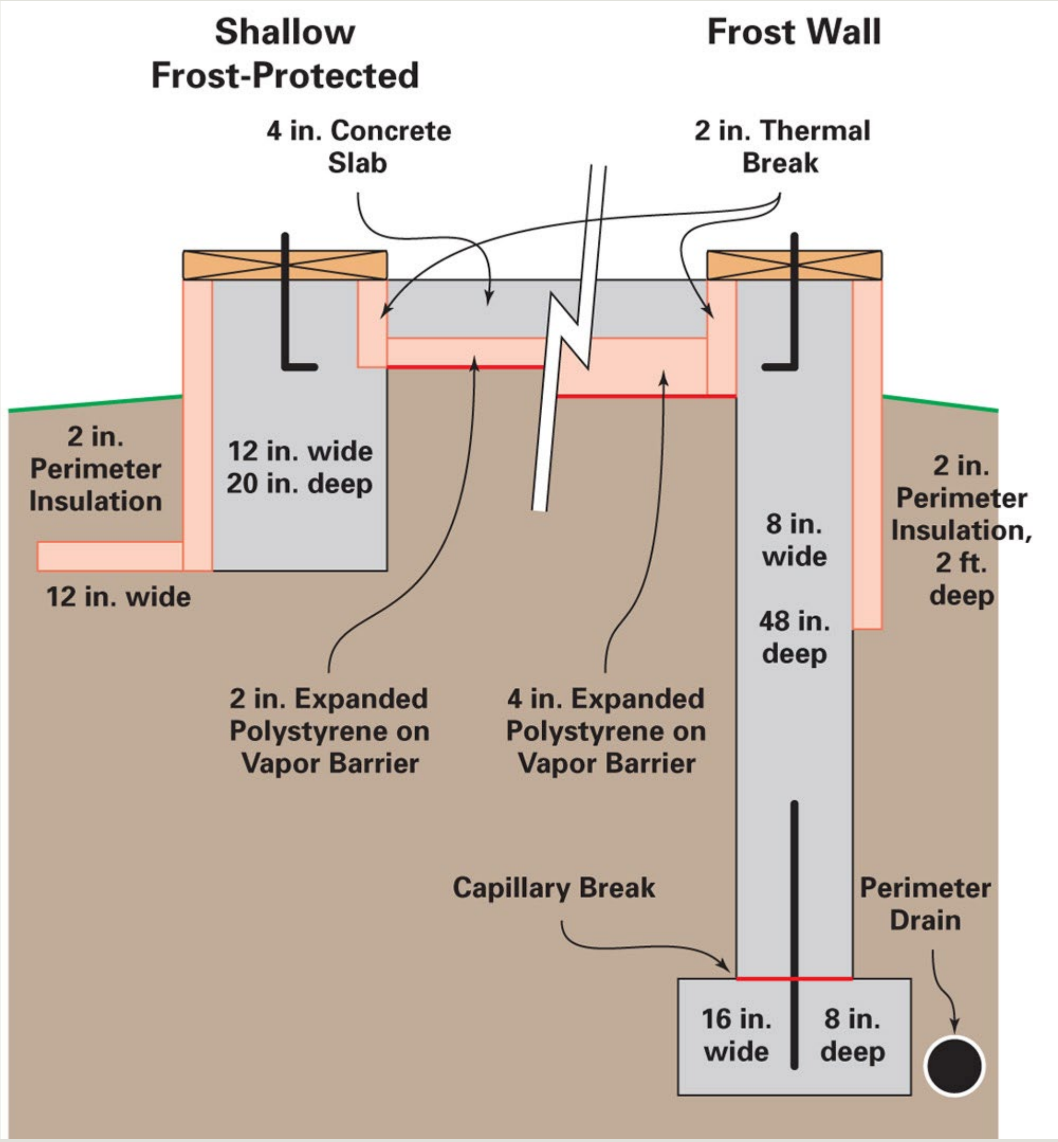
SHALLOW vs. CONVENTIONAL

Conventional Foundations

- Extend below frost line to avoid frost action

Shallow Foundations

- Above frost line
- Less excavation & concrete expense
- Use other methods to prevent frost heaving
  - Insulation - FPSF
  - Non-frost-susceptible subgrade to frost depth
  - Erecting on solid rock



Non-Frost Susceptible Soils

- Per ASCE 32: NFS SOILS ARE
- Soils containing < 6% particles passing #200 sieve (0.075mm)
  - Less than 6% silt or clay
  - It only takes a small amount of fine-grained soil to greatly increase soil frost susceptibility
- GW, GP, SW, SP are acceptable as NFS Soils
- Building on NFS Soils at depth to frost line is adequate frost protection

Determine percentages of sand and gravel from grain-size curve. Depending on percentage of fines (fraction smaller than No. 200 sieve size), coarse-grained soils are classified as follows:

Less than 5 percent .... GW, GP, SW, SP
More than 12 percent .... GM, GC, SM, SC
5 to 12 percent .... Borderline cases requiring dual symbols

UNIFIED SOIL CLASSIFICATION AND SYMBOL CHART

COARSE-GRAINED SOILS (more than 50% of material is larger than No. 200 sieve size.)		
	Clean Gravels (Less than 5% fines)	
GRAVELS More than 50% of coarse fraction larger than No. 4 sieve size	GW	Well-graded gravels, gravel-sand mixtures, little or no fines
	GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines
	Gravels with fines (More than 12% fines)	
	GM	Silty gravels, gravel-sand-silt mixtures
	GC	Clayey gravels, gravel-sand-clay mixtures
	Clean Sands (Less than 5% fines)	
SANDS 50% or more of coarse fraction smaller than No. 4 sieve size	SW	Well-graded sands, gravelly sands, little or no fines
	SP	Poorly graded sands, gravelly sands, little or no fines
	Sands with fines (More than 12% fines)	
	SM	Silty sands, sand-silt mixtures
	SC	Clayey sands, sand-clay mixtures
FINE-GRAINED SOILS (50% or more of material is smaller than No. 200 sieve size.)		
SILTS AND CLAYS Liquid limit less than 50%	ML	Inorganic silts and very fine sands, rock flour, silty of clayey fine sands or clayey silts with slight plasticity
	CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
	OL	Organic silts and organic silty clays of low plasticity
SILTS AND CLAYS Liquid limit 50% or greater	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
	CH	Inorganic clays of high plasticity, fat clays
	OH	Organic clays of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS	PT	Peat and other highly organic soils

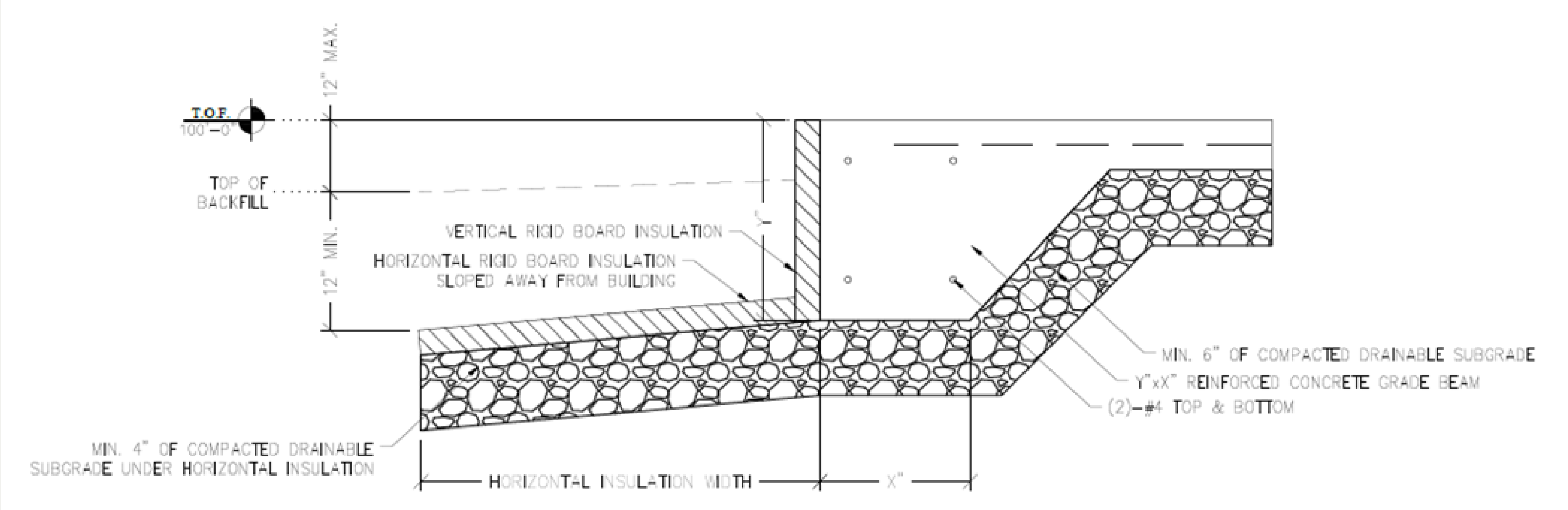
Non-Frost Susceptible Soils

- Per ASCE 32 SECTION 4.2 – Buildings supported by NFS soils to frost depth are adequately protected from frost
- Can be efficient in areas of low frost depth compared to insulation costs
- In areas of high frost depth, this could result in large amounts of removal and replacement with NFS fill and can be cost prohibitive compared to frost protected shallow foundations

Shallow Foundations

- Foundations that do not extend below the frost line

- Examples:
  - Slab on grade
  - Monolithic Slab
  - Grade Beam
  - Stem Wall
  - Trench Footings



FROST PROTECTED SHALLOW FOUNDATIONS

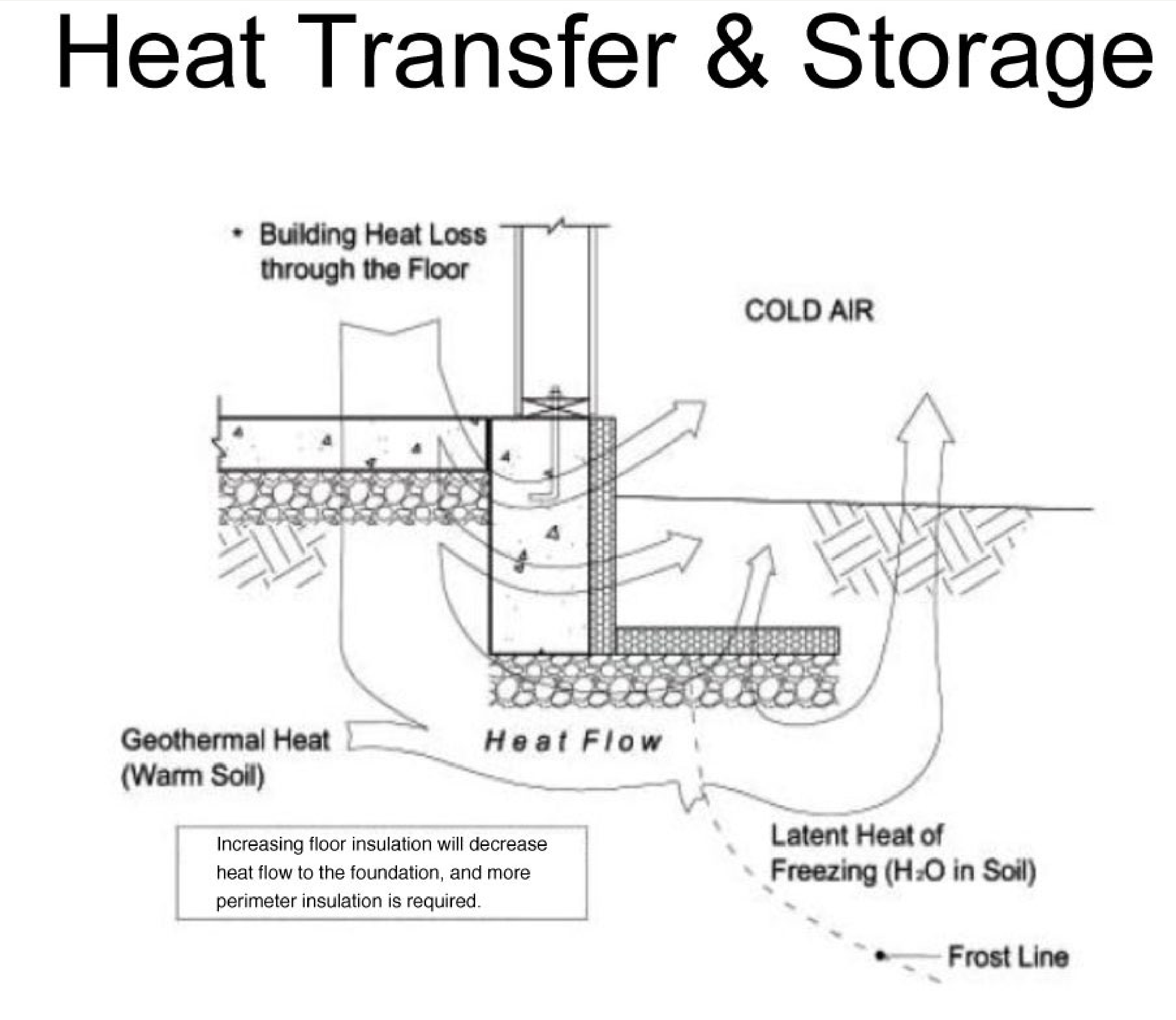
HOW DO THEY WORK?

- **Energy travels from high energy areas to low energy areas in the form of heat**

- **Geothermal Energy**
  - Heat below surface a few feet stays relative constant
  - Insulation helps retain heat below foundation

- **Heat loss from building to soil**
  - Building heat flows to ground, preventing freezing temperature

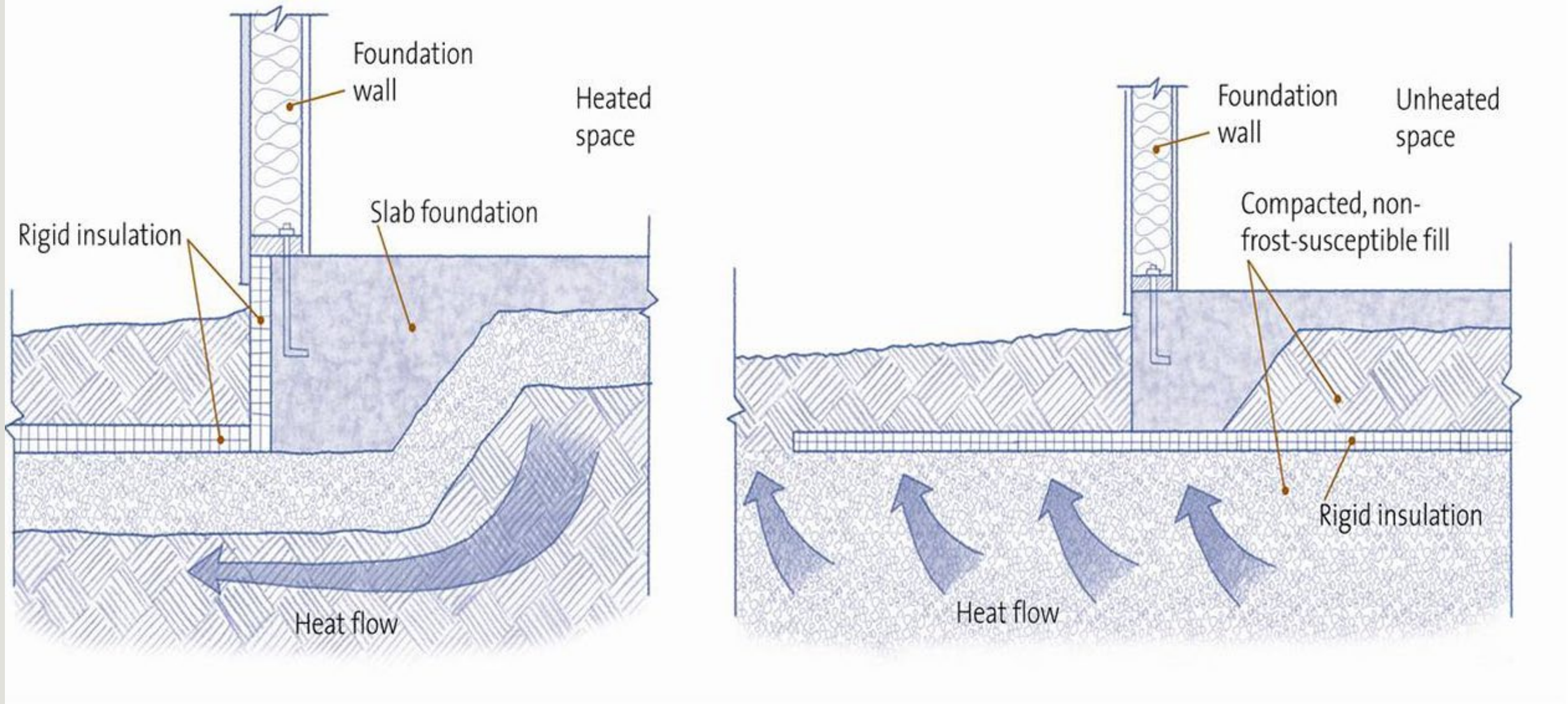
- **Controlling heat flow raises the frost depth around building foundation**



DIFFERENCES IN FPSF SYSTEMS

- **HEATED BUILDINGS USE BUILDING HEAT AND GEOTHERMAL HEAT**
  - PERIMETER INSULATION

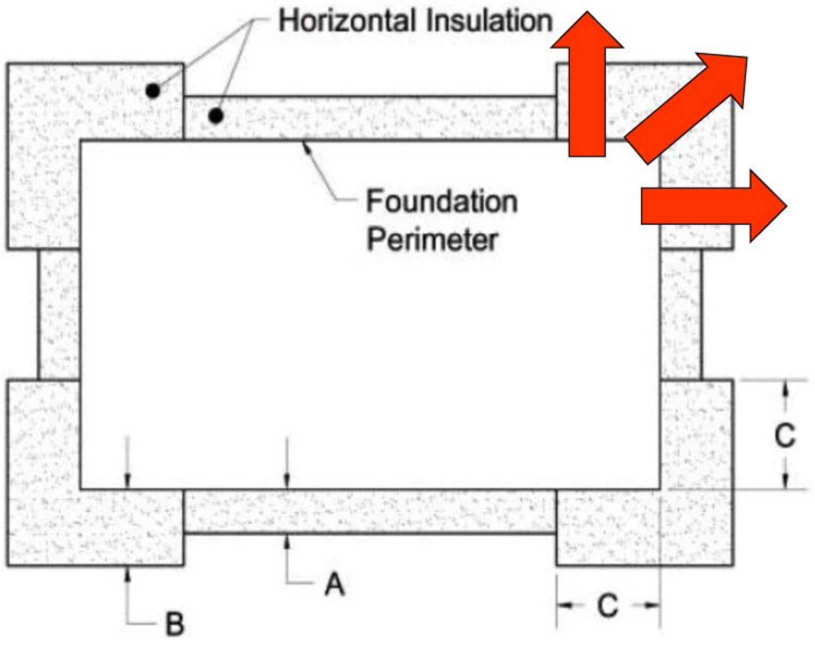
- **UNHEATED BUILDINGS RELY SOLEY ON GEOTHERMAL HEAT**
  - INSULATION UNDER COMPLETE SLAB



HEAT LOSS VARIES BY LOCATION IN HEATED BUILDINGS

- Corners have greater surface area to lose heat to surrounding soils
- Required horizontal insulation width is increased for a distance from corners
- Shape and size of building can greatly influence heat loss

Heat Loss at Corners (3D)



3D heat transfer at outside corners is greater than 2D heat transfer along wall[9]

Foundation Insulation

DUAL PURPOSES:
- 1) FROST PROTECTION
- 2) ENERGY CONSERVATION

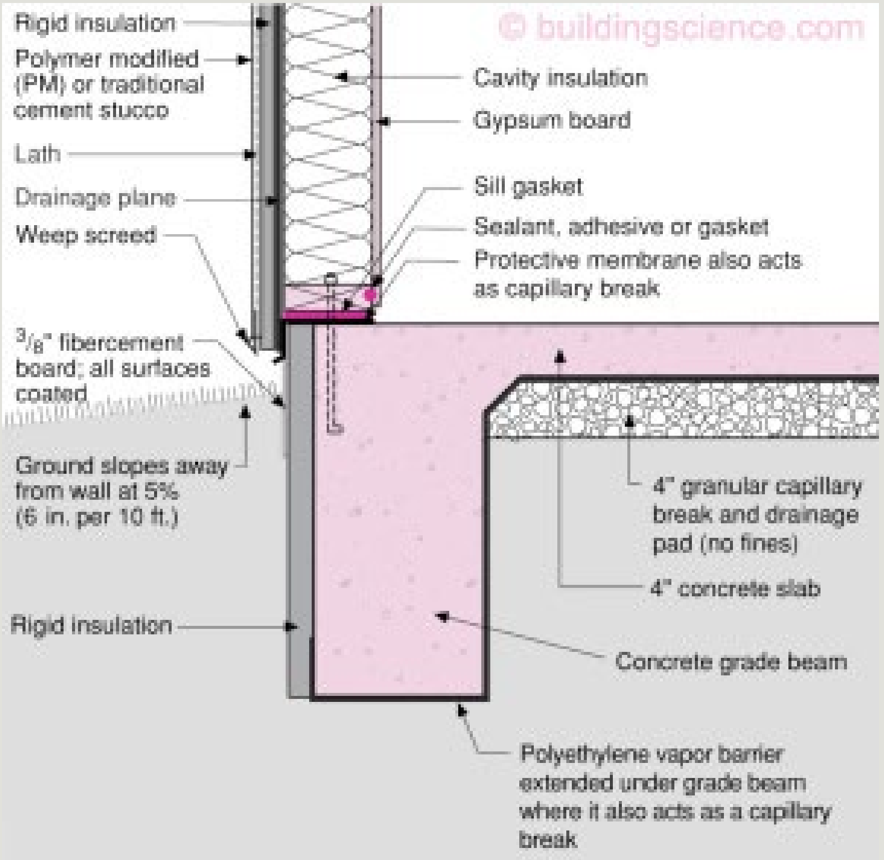
XPS – Extruded Polystyrene Board
- R-5 per inch
- Less permeable
- High Compressive Strength (ideal for load bearing)
- Higher cost

EPS – Expanded Board (Bead Board)
- R-4 per inch
- More permeable
- Lower cost

ICFs – Insulated concrete forms

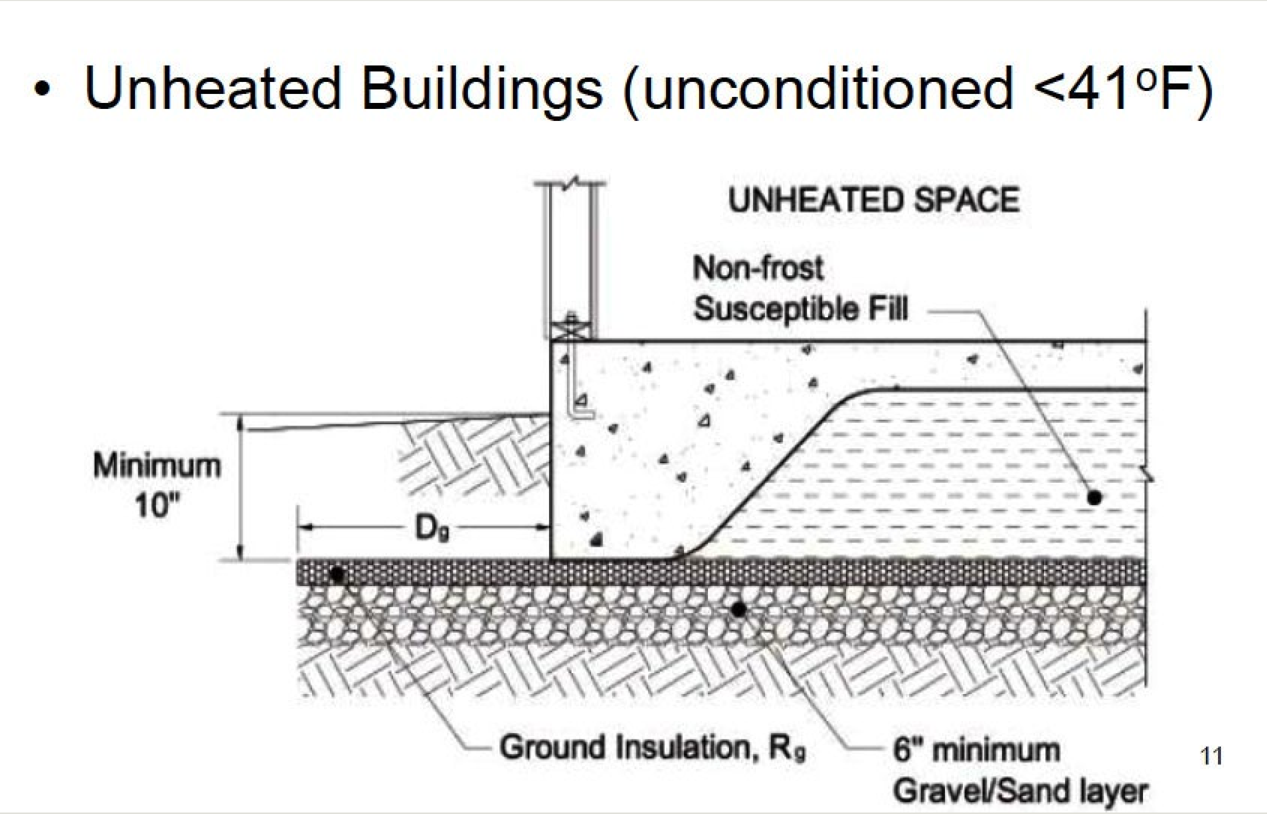
All need to be protected from UV degradation, termite/pest damage, and physical damage. (Weed whackers)

INSULATION CONFIGURATIONS



Vertical Insulation Only - HEATED BUILDINGS w/ AFI < 1,500
(WARMER CLIMATES)

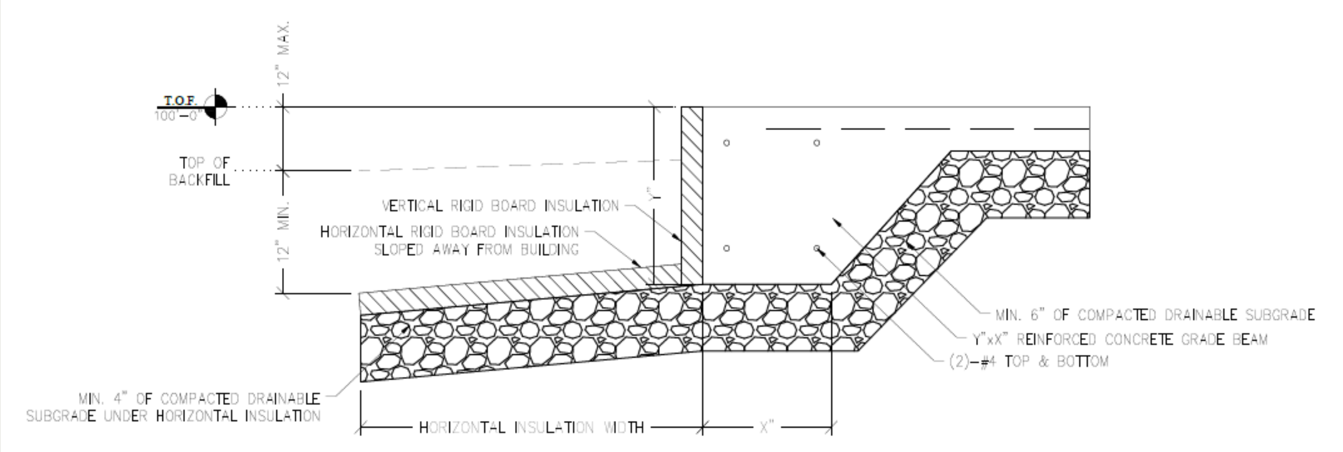
INSULATION CONFIGURATIONS



HORIZONTAL INSULATION ONLY

USED IN UNHEATED BUILDINGS – NOT MANAGING HEAT LOSS FROM BUILDING

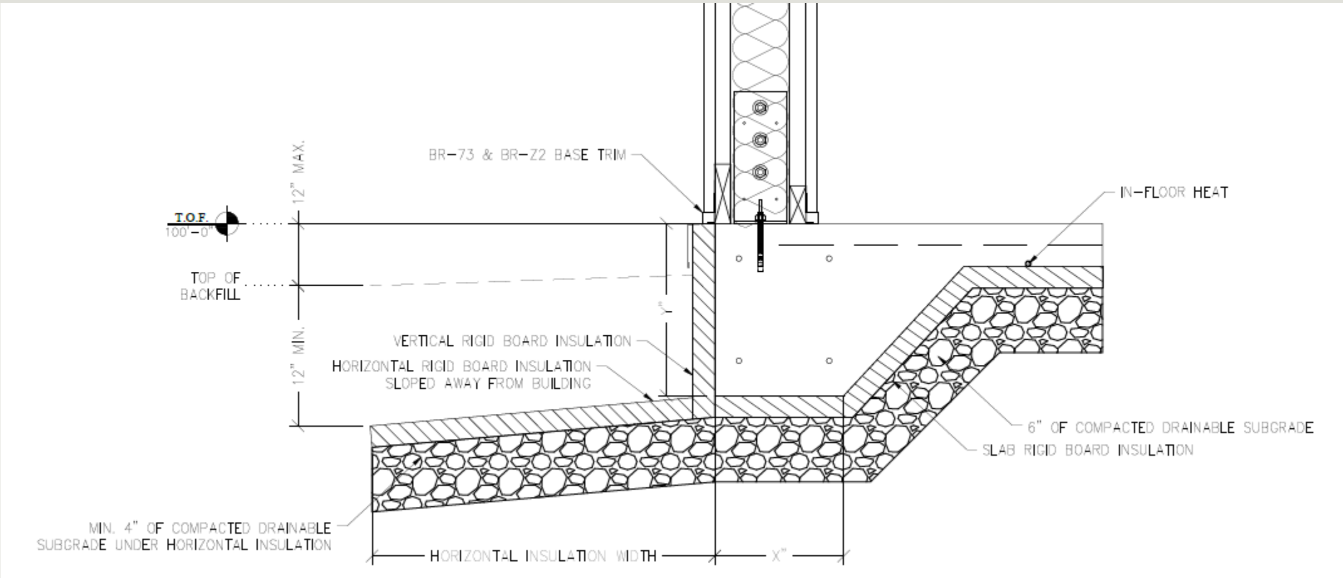
INSULATION CONFIGURATIONS



Vertical & Horizontal Insulation

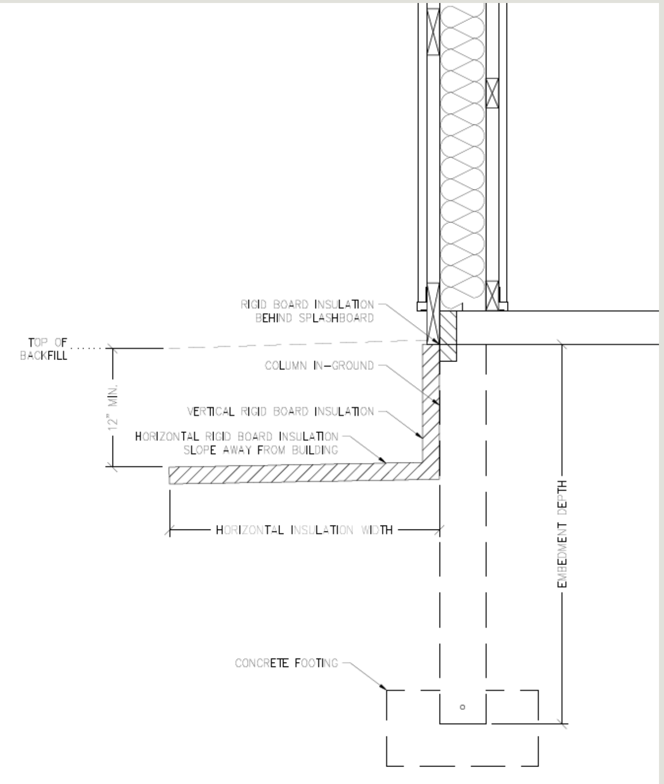
Wing insulation should slope away for drainage

Frost Protected Grade Beam w/unheated slab

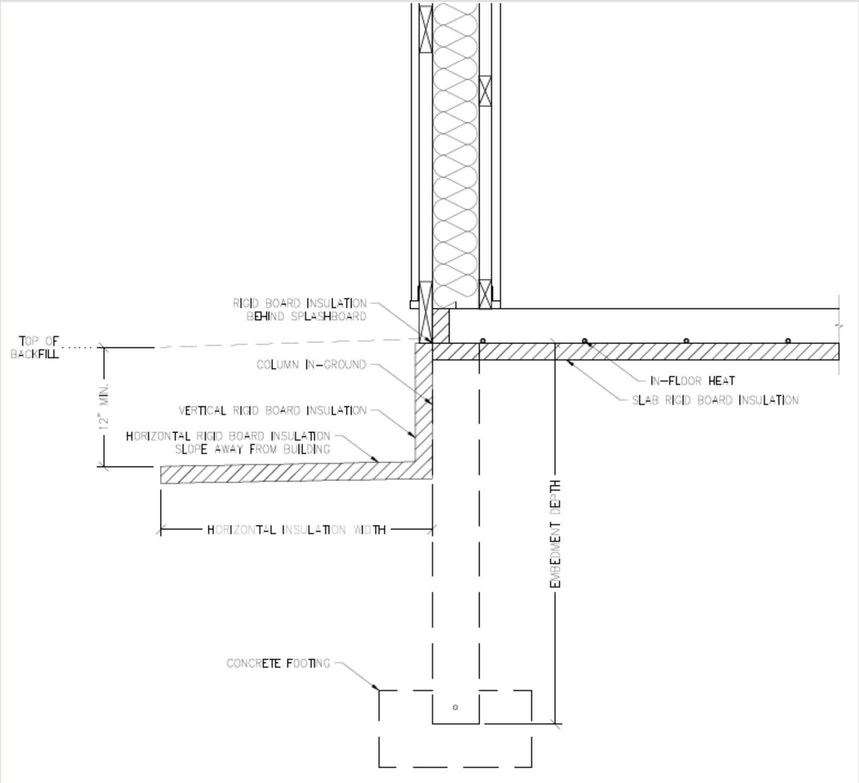


Frost Protected Grade Beam w/heated slab

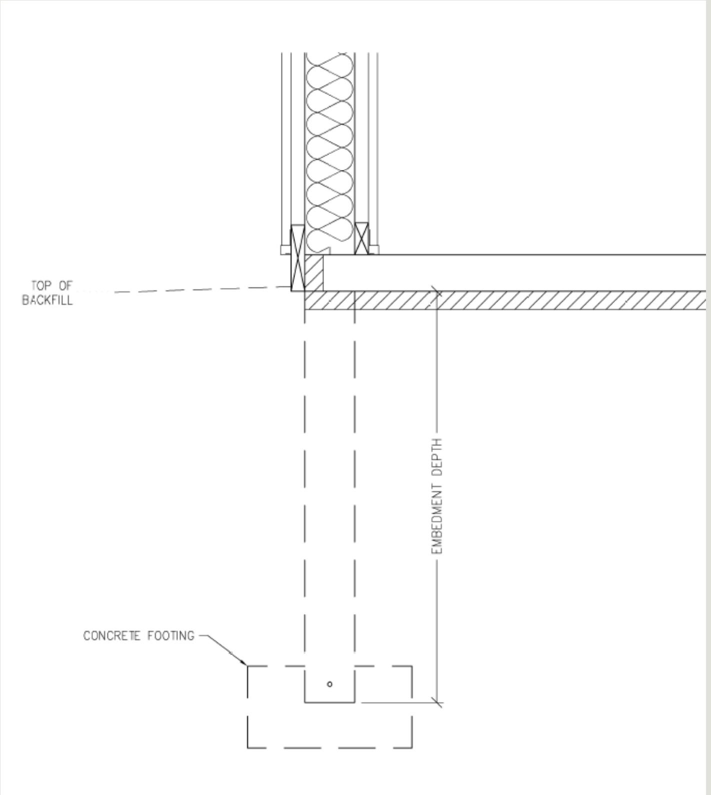
INSULATION CONFIGURATIONS



Column In-Ground
Frost Protected Unheated Slab
Vertical & Wing Insulation



Column In-Ground
Frost Protected Heated Slab
Vertical & Wing Insulation



Column In-Ground
Frost Protected Unheated Slab
Horizontal Wing Insulation
- SLAB IS NOT FROST PROTECTED!

HEATED, UNHEATED, or SEMI-HEATED?

- Determined by monthly average indoor temperature
  - HEATED : GREATER THAN 63°F
  - UNHEATED : LESS THAN 41°F
  - SEMI-HEATED : BETWEEN 41°F & 63°F

SIMPLIFIED METHOD

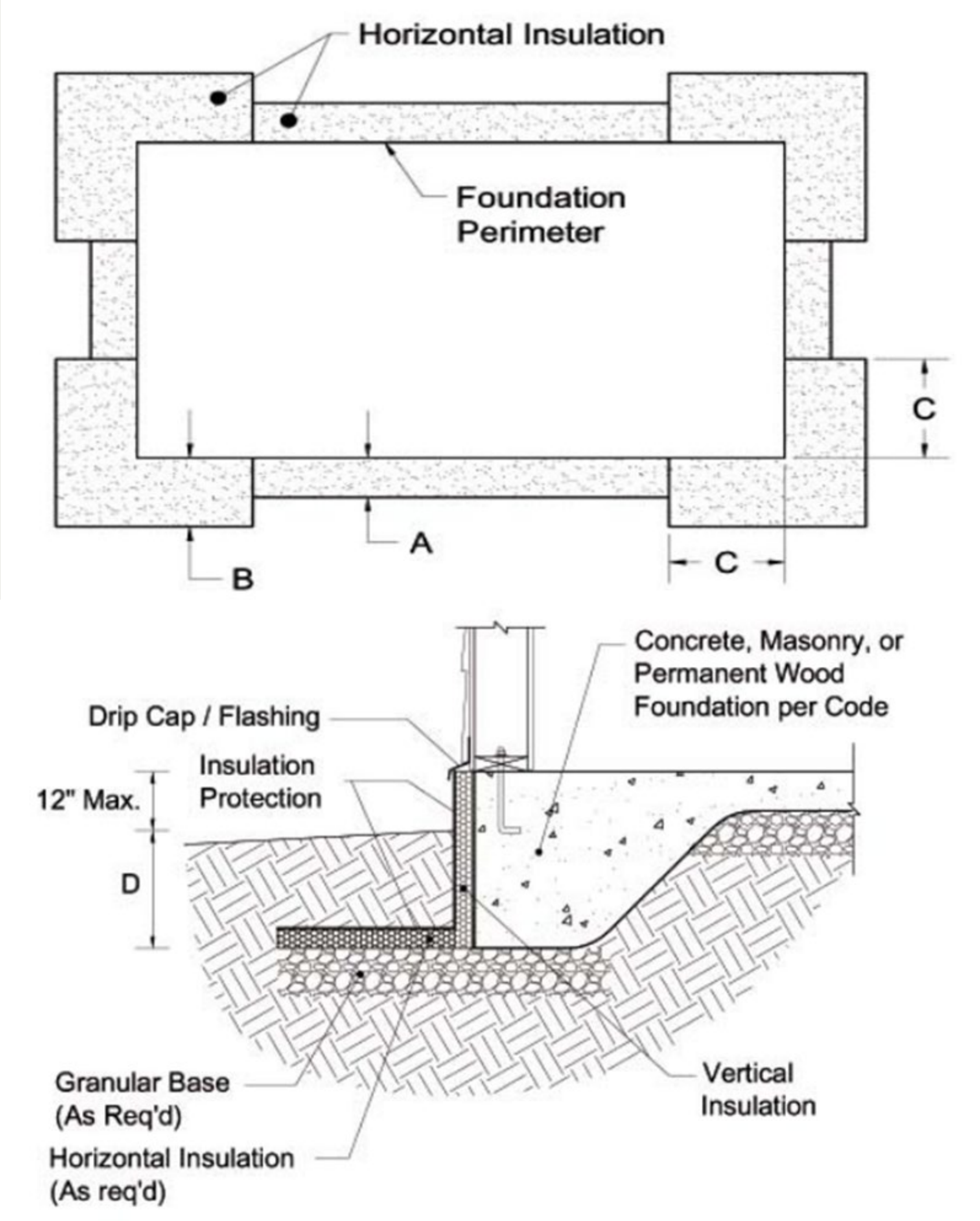
- FOR HEATED BUILDINGS ONLY > 63 DEGREES
- Limited to foundations up to 12” above grade
- TABLES FOUND IN ASCE 32-01 & REVISED BUILDERS GUIDE TO FROST PROTECTED SHALLOW FOUNDATIONS
- BASED ON AFI ONLY

A = HORIZONTAL INSULATION WIDTH ALONG WALLS AWAY FROM CORNERS

B = HORIZONTAL INSULATION WIDTH AT CORNERS

C = LENGTH OF CORNER INSULATION

D = FOOTING DEPTH BELOW FINISH GRADE



SIMPLIFIED METHOD

- DETERMINE AFI: (100 year)
  - https://www.ncei.noaa.gov/sites/default/files/2021-09/Air-Freezing-Index-Return-Periods-and-Associated-Probabilities.pdf
  - National Center for Environmental Information
- EX. WISCONSIN (TYP AFI 2,500 Degree Days)
  From Table : Vertical Insulation R-6.7
  A= Horizontal R-1.7 along walls 12"wide
  B=Horizontal R-4.9 at corners 24" wide for 40" (C) from corners
  Minimum footing depth 16" (D)
- EX. KNOXVILLE – (AFI 1,500 Degree Days)
  R-4.5 Vertical only, 12" Footing Depth

Table 3. Minimum Insulation Requirements for FPSFs in Heated Buildings[1] – Simplified Method

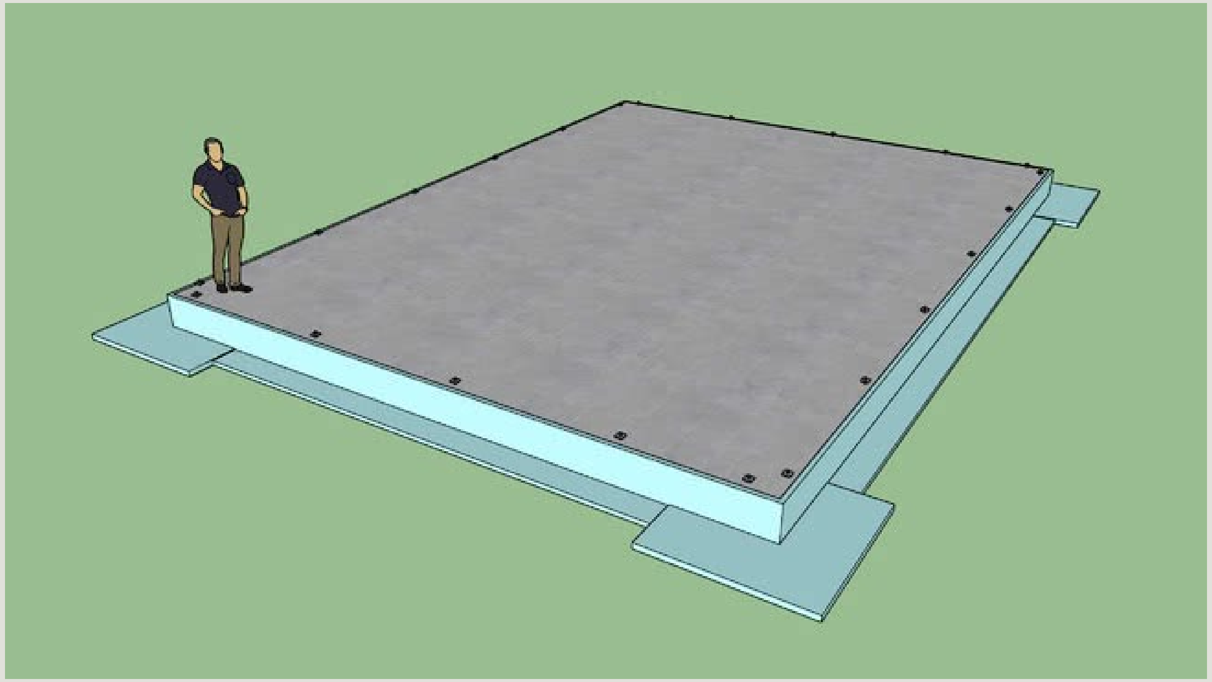
Air Freezing Index ($°F_{100}$)[2]	Vertical Insulation R-Value[3,4]	Horizontal Insulation R-Value[3,5]		Horizontal Insulation Dimensions per Figure 5. (in inches)			Minimum Footing Depth (in inches)
		Along Walls	At Corners	A	B	C	D
≤1,500	4.5	NR	NR	NR	NR	NR	12
2,000	5.6	NR	NR	NR	NR	NR	14
2,500	6.7	1.7	4.9	12	24	40	16
3,000	7.8	6.5	8.6	12	24	40	16
3,500	9.0	8.0	11.2	24	30	60	16
4,000	10.1	10.5	13.1	24	36	60	16
4,500	12.0	12.0	15.0	36	48	80	16

[1] Insulation requirements are for protection against frost damage in heated buildings. Greater values may be required to meet energy conservation standards. See Appendix IV.
[2] See Figure 4 for Air Freezing Index values.
[3] Insulation materials shall provide the stated minimum R-values under long-term exposure to below ground conditions in freezing climates. NR indicates that insulation is not required.
[4] Vertical insulation shall be expanded polystyrene insulation or extruded polystyrene insulation.
[5] Horizontal insulation shall be extruded polystyrene insulation.
[6] Interpolation between values is permissible.
[7] Portions of Table 3 reprinted with permission from SEI/ASCE 32-01, American Society of Civil Engineers, "Design and Construction of Frost-Protected Shallow Foundations," 2001. http://www.PUBS.ASCE.org

SIMPLIFIED METHOD

MORE CONSERVATIVE THAN DETAILED METHOD

- Detailed method may provide more efficient insulation R-values and configurations (common thickness and flexibility in widths to use common board sizes)



DETAILED DESIGN METHOD

ASCE 32-01

STEP 1: DETERMINE AFI (100 year) - LOOKUP TABLE

- https://www.ncei.noaa.gov/sites/default/files/2021-09/Air-Freezing-Index-Return-Periods-and-Associated-Probabilities.pdf

Example: 3,000 degree days

Air Freezing Index- USA Method (Base 32^0 Fahrenheit)

State and Station Name	Station Number	Lat. (Deg. - Min.)	Long. (Deg. - Min.)	Elev. (feet)	Mean Annual Temp. (^{0} F)	Air Freezing Index Return Periods (^{0}F-Days) & Associated Probabilities (%)										
						1.1 Year (10%)	1.2 Year (20%)	2 Year (50%)	2.5 Year (60%)	3.3 Year (70%)	5 Year (80%)	10 Year (90%)	20 Year (95%)	25 Year (96%)	50 Year (98%)	100 Year (99%)
Minnesota																
FOSSTON	212916	N4735	W09545	1299	40.0	1911	2155	2584	2702	2823	2957	3131	3266	3304	3409	3499
GRAND MARAIS	213282	N4745	W09020	688	38.7	1365	1547	1869	1958	2050	2151	2284	2386	2415	2495	2563
GRAND MEADOW	213290	N4342	W09234	1348	43.1	1262	1467	1840	1946	2055	2178	2339	2466	2501	2601	2687
GRAND RAPIDS NC SCHOOL	213303	N4714	W09330	1310	39.5	1881	2087	2440	2536	2633	2740	2879	2986	3015	3098	3168
GULL LAKE DAM	213411	N4625	W09421	1215	41.3	1638	1852	2229	2332	2439	2557	2711	2830	2864	2956	3036
HALLOCK	213455	N4846	W09657	813	37.7	2348	2647	3174	3319	3467	3632	3846	4011	4058	4186	4297
HINCKLEY	213793	N4601	W09256	1035	40.8	1639	1848	2216	2317	2421	2536	2685	2801	2833	2923	3000
INTNL FALLS WSO //	214026	N4834	W09323	1179	36.4	2436	2684	3106	3220	3336	3463	3627	3752	3787	3884	3966
ITASCA STATE PARK SCH	214106	N4713	W09512	1490	38.9	1976	2199	2586	2691	2798	2917	3070	3188	3221	3312	3390
JORDAN 1 S	214176	N4439	W09337	755	43.9	1198	1398	1764	1868	1976	2097	2257	2382	2417	2516	2602

Building Material R-Values

Table 9. Nominal Thermal Resistance of Common Materials

Description	Density (lb/ft³)	Nominal R-value (per inch)
BUILDING MATERIALS		
Plywood/OSB/Subfloor	34	1.25
Particleboard, Low-Density	37	1.41
Particleboard, High-Density	62.5	0.85
Particleboard, Underlayment	40	1.31
Softwoods	35	0.9
Hardwoods	40	0.8
Brick	100	0.25
8" Concrete Masonry Unit (CMU) with Perlite Fill	—	2.1
Cement Mortar	120	0.15
Concrete	140	0.05
6 mil Plastic	—	Negligible
EPS Insulation, Type II	1.3	4.0
EPS Insulation, Type IX	1.8	4.2
XPS Insulation, Types IV, V, VI, VII	1.6 - 3.0	5.0
FINISH FLOORING MATERIALS		
Carpet and Fibrous Pad		2.08
Carpet and Rubber Pad		1.23

DETAILED DESIGN METHOD

STEP 2: Determine R-value of complete floor (including coverings)

- Total R-value is insulation value of each component added together
- Although higher floor R-value conserves building heat loss, less heat goes to soil below foundation and increases insulation for frost protection
- **If average floor exceeds R-28, treat as unheated**

Example – 2” R-10 XPS (2” x R-5/inch) = R-10

DETAILED DESIGN METHOD

Table 4. Minimum Thermal Resistance of Vertical Wall Insulation (R_v)

AFI (°F_{100})	Slab or Floor Assembly R-Value (R_f)					
	$0.0 < R_f < 6.0$		$6.0 < R_f < 15.0$		$15.0 < R_f < 28.0$	
	h ≤ 12 in	h = 24 in	h ≤ 12 in	h = 24 in	h ≤ 12 in	h = 24 in
≤ 375	0.0	3.0	4.5	5.7	5.7	8.5
750	3.0	4.6	5.7	5.7	8.5	11.4
1,500	4.5	5.7	5.7	5.7	8.5	11.4
2,250	5.7	5.7	5.7	7.4	8.5	14.2
3,000	5.7	5.7	6.8	8.5	9.7	15.3
3,750	5.7	6.8	8.0	9.7	11.4	17.0
4,500	6.8	8.0	10.2	11.9	13.6	19.3

STEP 3: Determine Vertical Insulation R-value

- Ex (3,000 degree days) & R-10, h<12”
- Vertical wall R-value = 6.8

STEP 4: Determine Insulation Thickness

- From Step 3
- Depends on type of insulation (XPS or EPS)
- Ex: 6.8/(5/in) = 1.36” XPS

DETAILED DESIGN METHOD

STEP 5: DETERMINE R-VALUE AT WALL AND CORNERS

- Table 6 (Along Walls)
- Table 7 (Corners)
- Options for different insulation configurations

STEP 6: Determine Wing Insulation Thickness

Ex. 12” wide R-6.5 along wall (1.3” XPS)

Ex. 16” wide R-9.6 at corners (1.92” XPS)

Lc = 40 inches

16” Footing Depth

USE DIMENSIONS PROVIDED (SIMILAR VARIABLES AS SIMPLIFIED METHOD, JUST LABELED DIFFERENTLY)

Table 6. Minimum Thermal Resistance of Horizontal Insulation along Walls (R_{hw})[1]

AFI (°F_{100})	R-Values at Various Widths, R_{hw} — Width of Horizontal Insulation, D_{hw} (in inches)							Footing Depth
	12"	18"	24"	30"	36"	42"	48"	
≤ 2,250	0.0							16"
2,625	2.5							16"
3,000	6.5	6.1	5.3	4.5				16"
3,375		8.2	7.4	6.5				16"
3,750			9.1	8.5	7.7			16"
4,125			11.2	10.2	9.6	8.9		16"
4,500				12.3	11.4	10.7	10.0	16"

[1] Design parameters are identified in Figure 6.

Table 7. Minimum Thermal Resistance of Horizontal Insulation at Corners (R_{hc})[1]

AFI (°F_{100})	L_c (inches)	R-Values at Various Widths of Horizontal Insulation — Width of Horizontal Insulation at Corners, D_{hc} (in inches)						Footing Depth
		16"	24"	30"	36"	42"	48"	
≤ 2,250	0.0	0.0						16"
2,625	40	6.5	4.9	4.0				16"
3,000	40	9.6	8.6	8.0	7.4			16"
3,375	60		11.1	10.5	9.8	9.1		16"
3,750	60		13.1	12.5	12.0	11.2	10.8	16"
4,125	60			14.5	13.7	13.0	12.5	16"
4,500	80				15.9	15.1	14.8	16"

[1] Design parameters are identified in Figure 6.

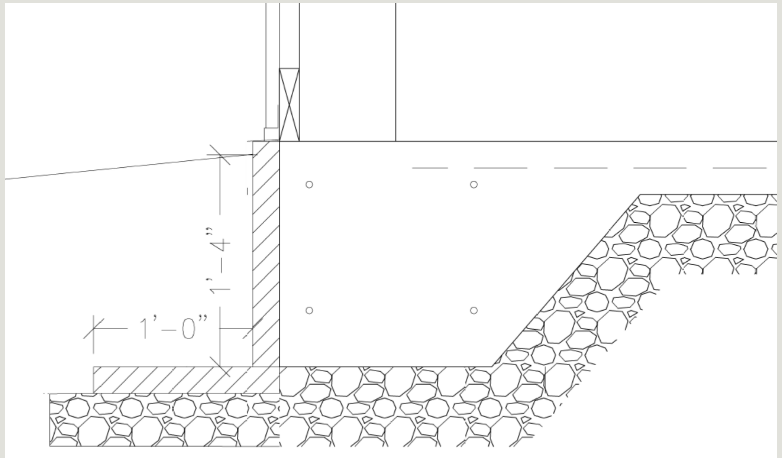
DETAILED DESIGN METHOD

Solution:
R-6.8 VERTICAL SLAB INSULATION (1.36” XPS)
16” FOOTING DEPTH
12” wide R-6.5 along wall (1.3” XPS)
16” wide R-9.6 at corners (1.92” XPS)
Lc = 40 inches

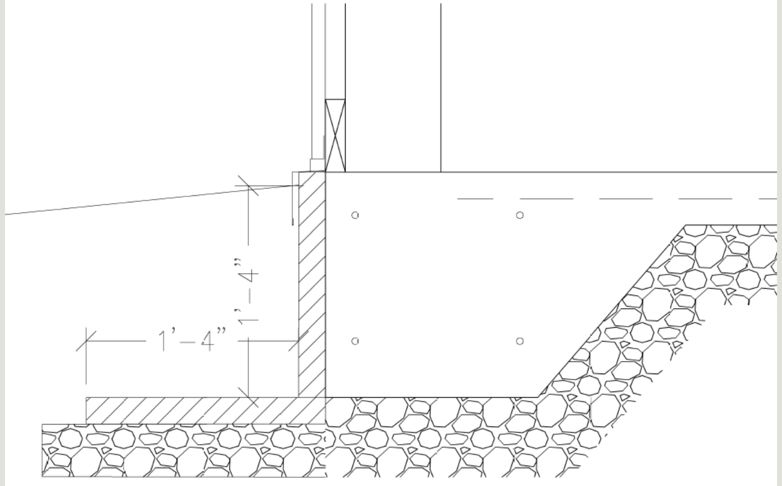
Practical Solution for common XPS thicknesses

1) 1.5” R-7.5 vertical insulation and 12” wing at walls
2” R-10 x 16” wide wing at corners for 40”
-Most material efficient

2) 2” R-10 vertical and 12” wing at wall and 16” wide corner wings for 40”
-Less detailing and one material



INSULATION AT WALL



INSULATION AT CORNERS FOR 40” FROM CORNER

DETAILED DESIGN METHOD

- **OPTIONAL TABLE TO ELIMINATE OR LIMIT HORIZONTAL INSULATION**
- **INCREASED FOUNDATION DEPTHS AT WALLS AND CORNERS**
- **CAN BE USEFUL FOR CERTAIN PROJECTS**

-EX. - 6” deeper foundation along perimeter or 16” deeper at corners

Table 5. Foundation Depths[1]

AFI (°F_{100})	Foundation Depth along Walls (No Horizontal Insulation)	Foundation Depth at Corners (No Horizontal Insulation)		Foundation Depth at Corners with R - 5.7 Horizontal Insulation at Corners, only		
	1	2	3	4	5	6
	h_f (inches)	L_c (inches)	h_{fc} (inches)	L_c (inches)	h_{fc} (inches)	D_{hc} (inches)
1,500 or less	12	—	12	—	12	—
2,250	14	—	14	—	14	—
2,625	16	40	24	40	16	20
3,000	20	40	32	40	20	20
3,375	24	60	40	60	24	20
3,750	30	60	51	60	30	24
4,125	36	60	63	60	36	32
4,500	43	80	71	80	43	32

[1] Without horizontal insulation or with horizontal insulation at corners only. Design parameters are identified in Figure 6.

UNHEATED DETAILED DESIGN METHOD

- **ASCE 32-01**
- **BUILDINGS MAINTAINED < 41 degrees F**
- **Use AFI and Mean Annual Temperature to complete tables**
- **Rely on conserving geothermal energy only**
- **Continuous insulation under entire slab and beyond**

- **Non-frost susceptible layer requirements:**
- **1) Insulation on top of min. 6" NFS base**

OR

- **2) Min. 12" NFS base on top of insulation**

Table 8. Minimum Values for Design of FPSFs in Unheated Buildings

Mean Annual Temperature, MAT (°F)[1]		32	36	38	40	≥ 41
AFI (°F_{100})	D_g (inches)	Minimum Thermal Resistance of Horizontal Insulation, R_g				
≤ 750	30	5.7	5.7	5.7	5.7	5.7
1,500	49	13.1	9.7	8.5	8.0	6.8
2,250	63	19.4	15.9	13.6	11.4	10.2
3,000	79	25.0	21.0	18.2	15.3	14.2
3,750	91	31.2	26.1	22.7	-	-
4,500	108	37.5	31.8	-	-	-

[1] See NOAA website for MAT. http://www.ncdc.noaa.gov/oa/climate/research/cag3/cag3.html

UNHEATED DETAILED DESIGN METHOD

- **Same insulation width at side walls and corners**
  - **NO BUILDING HEAT LOSS, GEOTHERMAL HEAT ONLY**

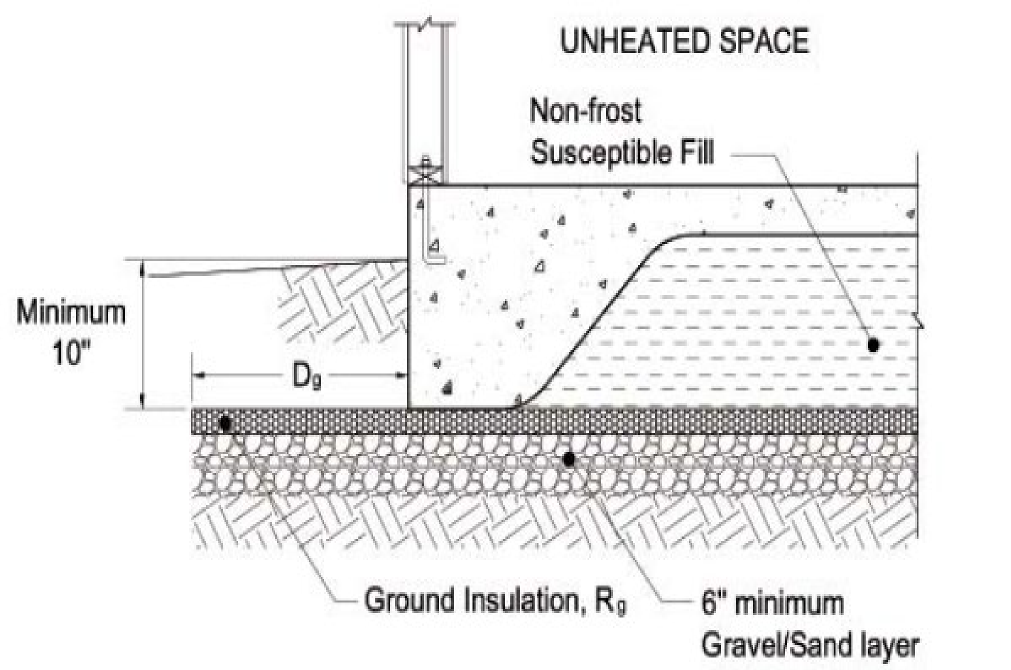
- **Insulation must have 10” soil cover on perimeter**

- **Dg (width from foundation) may be reduced by 1.25 inches for every inch the insulation is buried beyond the 10-inch minimum cover**

- **Rg (required R-value) may be reduced by R-0.3 for every 1" the underlying non-frost susceptible layer is increased beyond the 6" minimum thickness.**

- **Rg may also be reduced by R-0.25 for every 1-inch increase in soil cover over the ground insulation, above the 10" minimum**

- **Increasing soil cover can help optimize for common board widths and R-value**



UNHEATED DETAILED DESIGN METHOD EXAMPLE

Example: Wisconsin :

- 2500 degree F days (will need to interpolate from table)
- Mean Annual Temperature 40 degrees F

- From Table interpolations:
  - Rg = Insulation R-value = 7.9 ~ R-8
  - Dg = insulation width beyond perimeter = 68”

- Concrete Design : 16” Grade Beam

  12” Perimeter Soil Cover (2” more than min.)

  8” Drainable Subgrade below insulation (2” more than min.)

  Dg = 68” – 2 x 1.25” = 65.5”

  Rg = 7.9 – (2 x 0.3) – (2 x 0.25) = R-6.8

- Final Design : R-6.8 under complete slab and 65.5” extension width

- ALTERNATE w/ 2” MORE SOIL COVER. Dg = 63”, R=6.3”

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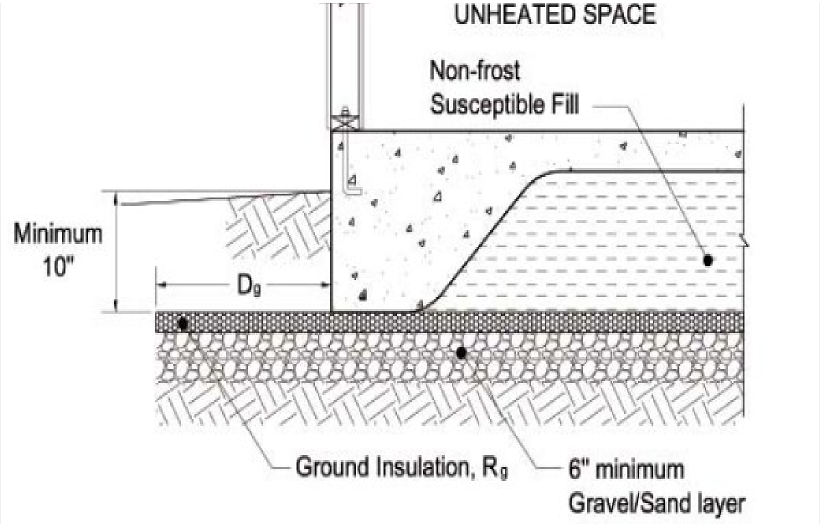
3,750	91	31.2	26.1	22.7	-	-
4,500	108	37.5	31.8	-	-	-

[1] See NOAA website for MAT. http://www.ncdc.noaa.gov/oa/climate/research/cag3/cag3.html



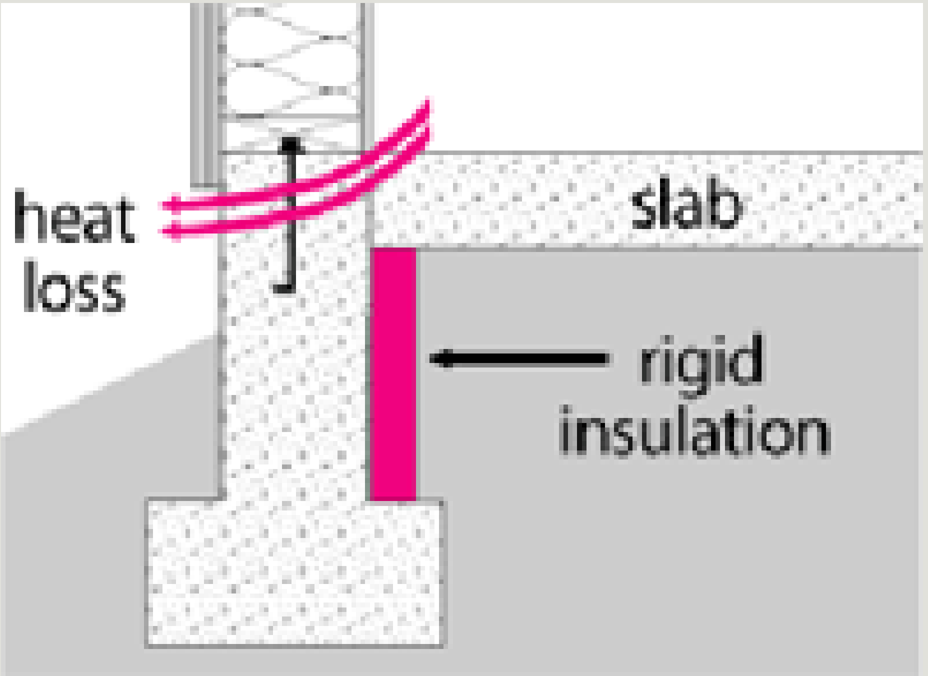
SEMI-HEATED FROST PROTECTION

- DESIGN AS HEATED BUILDING per ASCE 32-01
  - SIMPLIFIED OR DETAILED METHOD

- ADD 8” INCREASE TO VERTICAL INSULATION DEPTH
  - Less heat loss from building to the soil

Thermal Bridging & Other Considerations

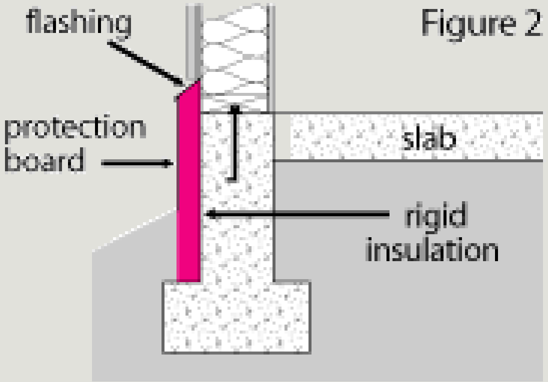
- **Thermal Bridging**
  - **Gap between insulating materials allows rapid heat transfer**
  - **Can Greatly Reduce Building Efficiency**
  - **Similar effect as air leakage above grade**
  - **THERMAL BRIDGERS ARE NOT PERMITTED IN ASCE 32**

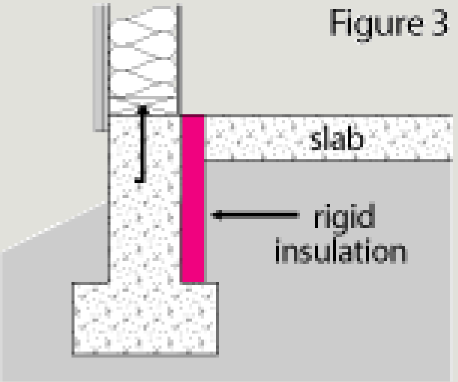


- **Excavation: Consider how the insulation configuration area will be excavated**
  - **If embedded posts, when is floor going in?**
  - **Will you be able to compact sufficiently?**

Thermal Bridging

- Use different insulation configurations and thermal breaks to avoid thermal bridges
- Concrete piers should have thermal breaks between piers and slab





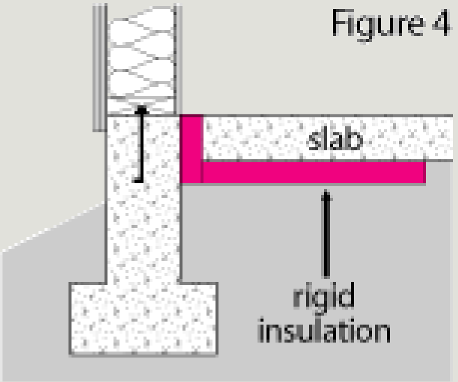


Figure 5

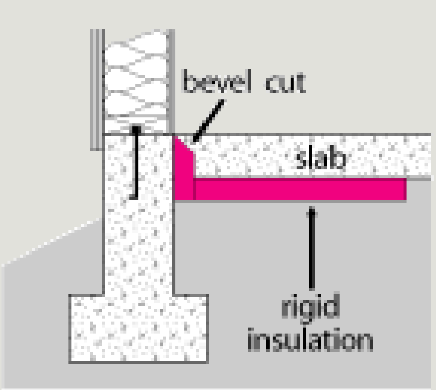


Figure 6

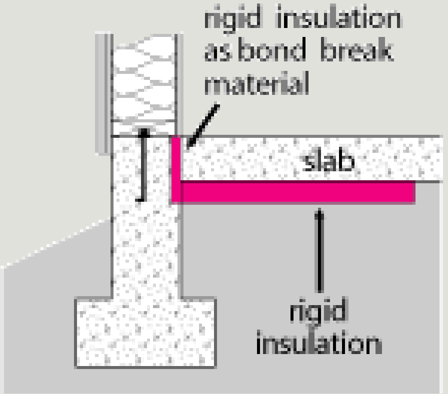
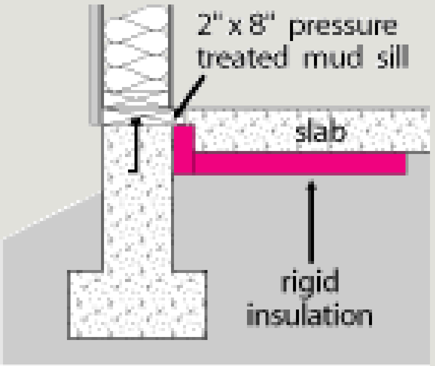
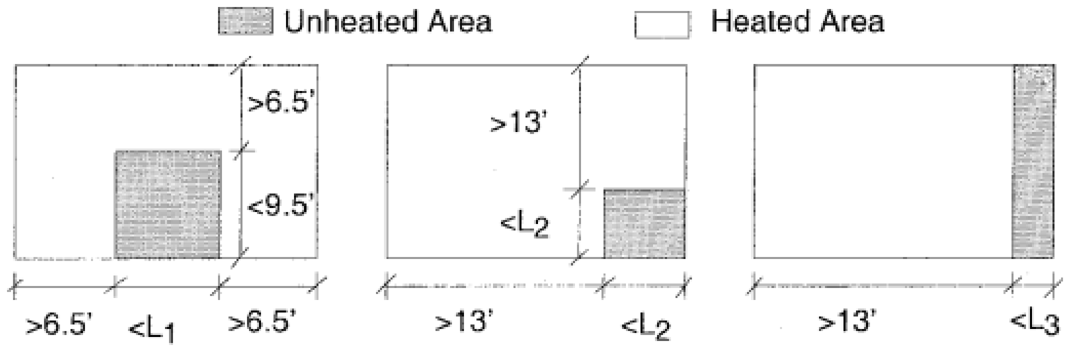


Figure 7



SMALL UNHEATED AREAS IN HEATED BUILDINGS

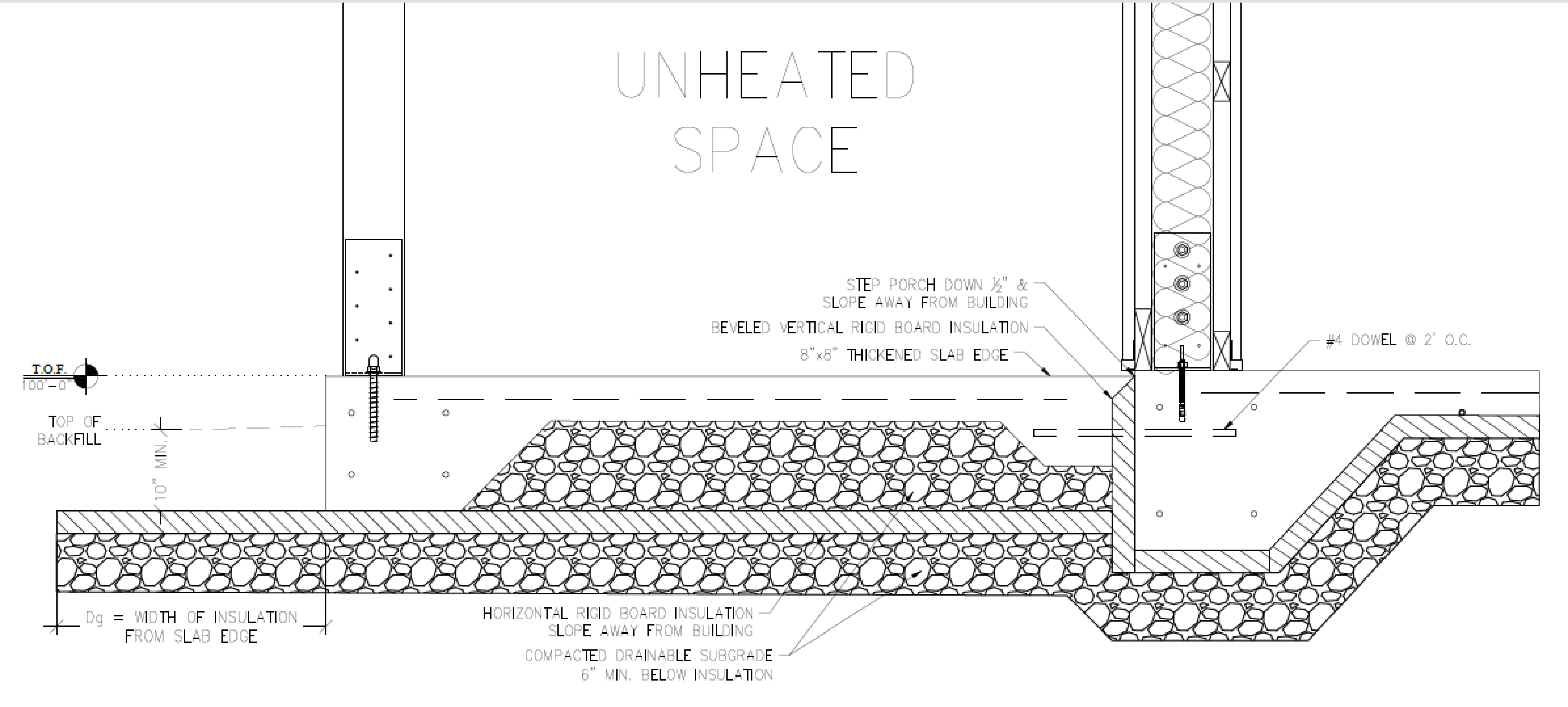
- **TREAT AS BOTH HEATED. USE CORNER INSULATION VALUES FOR UNHEATED AREA**
- **BUILDING HEAT LOSS WILL STILL HELP RAISE SOIL TEMPERATURE IN UNHEATED AREA**
- **SIZE LIMITATIONS: SEE TABLE**
  - **Greater areas permitted at interior as building heat will flow into soil from three sides – highest length**
  - **Corners have building heat from two sides**
  - **Edges have building heat from just one side – smallest lengths**



Maximum Size Limit	F_{100} (°F-days)			
	≤ 2,250	2,251 to 3,000	3,001 to 3,750	>3,750
L_1	13'-0"	11'-6"	10'-0"	6'-6"
L_2	9'-9"	8'-8"	7'-6"	4'-11"
L_3	6'-6"	5'-10"	5'-0"	3'-3"

FIGURE 8. Definition of a Small Unheated Area of a Floor Slab

LARGE UNHEATED AREAS IN HEATED BUILDINGS



- **TREAT AS SEPARATE BUILDINGS. FOLLOW UNHEATED DETAILED METHOD FOR UNHEATED SPACE & HEATED SIMPLIFIED OR DETAILED METHOD FOR HEATED PORTION**
- **AREA TOO LARGE TO ASSUME BUILDING HEAT LOSS WILL INCREASE SOIL TEMP ENOUGH TO PREVENT FROST ACTION**
- **SECTION 8.2 OF ASCE 32**
- **Commonly found at house and garage connection – often misdetailed**

Interior Footings

HEATED BUILDINGS – FROST PROTECTION AT SLAB EDGES ONLY, NO FROST PROTECTION ON INTERIOR FOOTINGS IS REQUIRED. BUILDING HEAT LOSS THROUGH SLAB IS SUFFICIENT

UNHEATED BUILDINGS – NO HEAT LOSS FROM BUILDING TO SOIL, STILL PRONE TO FROST ACTION, MUST HAVE FROST PROTECTION

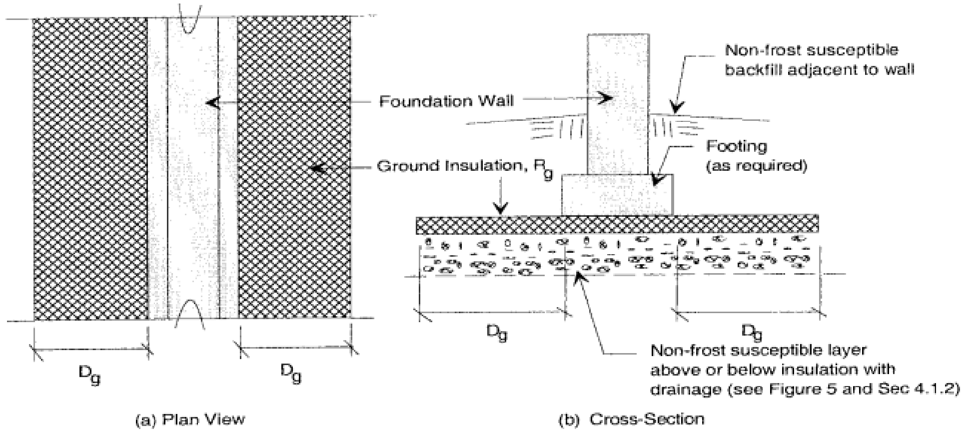


FIGURE 6. Continuous Foundation Wall (Unheated Buildings)

Dg from both sides and ends

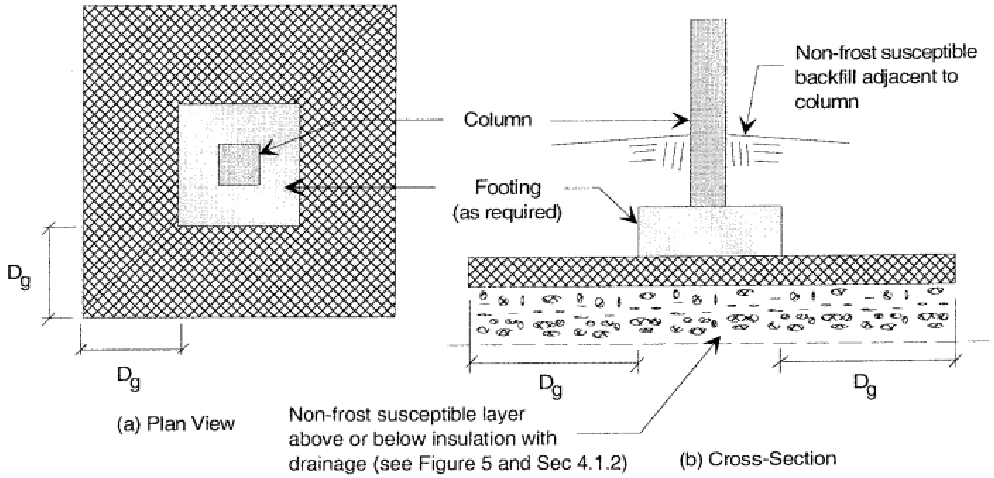


FIGURE 7. Column Foundation (Unheated Building)

Dg from all four sides

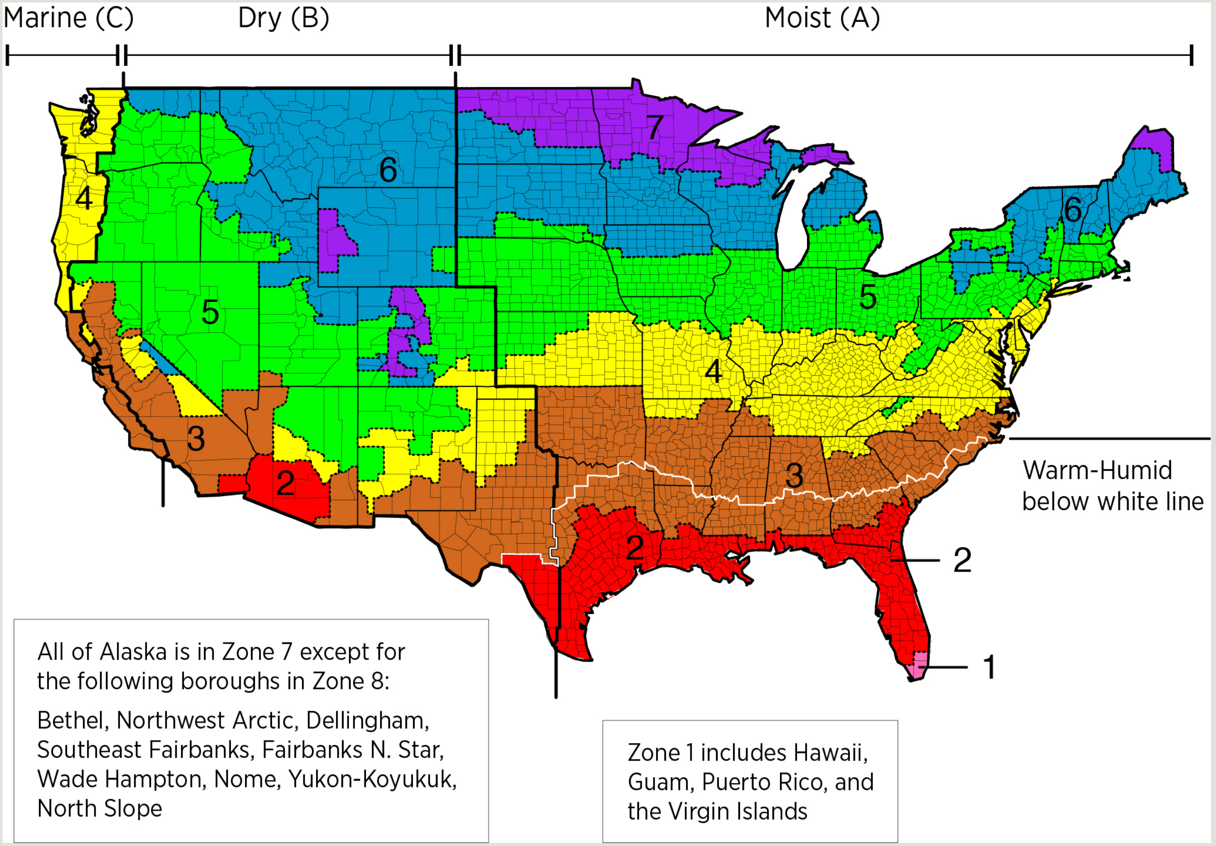
ADDITIONAL FROST PROTECTION TIPS

- **Place foundation on non-frost susceptible soils bases – well-draining**
- **Foundation drainage below grade**
- **Site grading away from building**
- **Overhangs shed water away from buildings**
- **Gutters with downspouts discharging away from building**

- **EVEN IF ASCE 32 PROVISIONS ARE NOT COMPLETELY FOLLOWED, THESE FEATURES CAN GREATLY REDUCE FROST ACTION POTENTIAL.**
- **NO WATER = NO FROST POTENTIAL**

ENERGY CONSERVATION

- Heated buildings in IRC/IBC must meet thermal performance
  - Frost protection insulation often not enough
- Minimizing heat loss through foundation
- Driven by temperature difference from soil to indoor
- Need to know climate zone
  - Determine insulation requirements
  - F-Factor Requirements



FPSF vs. Energy Code

- **PRESCRIPTIVE CODE IN TABLE FOR COMPARISON**
- **UA TRADEOFF – COMCHECK/RESCHECK**
  - **More flexible**
  - **Can add wall/attic insulation in exchange for lower slab insulation (FPSF must still be met) & vice versa**
- **FPSF INSULATION MAY NOT BE SUFFICIENT FOR ENERGY CODE**

Table 10. Insulation Requirements for FPSFs vs. Insulation Requirements for Energy Conservation in Heated Buildings[1]

Requirement for FPSF Design				Requirement for Energy Conservation Design[2]			
Air Freezing Index (°F $_{100}$)[3]	Vertical Insulation R-Value[4,5]	Horizontal Insulation R-Value[4,5]		Heating Degree Days (HDD)[6]	Nominal Vertical Insulation R-Value[5]		
		Along Walls	At Corners		Basement	Slab	Crawlspace
1,500	4.5	NR	NR	< 2,000	Requirement is less than or approx. equal to FPSF		
1,500	4.5	NR	NR	2,000-2,999	6	4	7
				3,000-3,999	8	5	10
				4,000-4,999	9	6	17
				5,000-5,999	10	9	19
				6,000-6,999	11	11	20
				7,000-8,499	11	13	20
2,000	5.6	NR	NR	6,000-6,999	11	11	20
				7,000-8,499	11	13	20
2,500	6.7	1.7	4.9	7,000-8,499	11	13	20
				8,500-8,999	18	14	20
				9,000-12,999	19	18	20
3,000	7.8	6.5	8.6	7,000-8,499	11	13	20
				8,500-8,999	18	14	20
				9,000-12,999	19	18	20
3,500	9.0	8.0	11.2	7,000-8,499	11	13	20
				8,500-8,999	18	14	20
				9,000-12,999	19	18	20
4,000	10.1	10.5	13.1	7,000-8,499	11	13	20
				8,500-8,999	18	14	20
				9,000-12,999	19	18	20

HEATED SLAB

- **Minimum R-5 Under Slab**
  - **To meet prescriptive code maximum F-factor from tables**

- **Rule of Thumb : Add 5 to R-value prescribed for non-heated slabs**

- **R-10 under slab insulation recommended**

References

ASCE 32-01

ASHRAE 90.1-07

Dave Bohnhoff, "Below Grade Insulation for Post-Frame Buildings Part 1 &2" Wood Design Focus, Volume 1, Number 1. 2014

IBC – INTERNATIONAL BUILDING CODE 2015

REVISED BUILDERS GUIDE TO FROST PROTECTED SHALLOW FOUNDATIONS

http://www.phrc.psu.edu/assets/docs/Publications/Frost-Protected-Shallow-Foundations-FINAL.pdf

http://www.concreteconstruction.net/how-to/site-prep/frost-protected-shallow-foundations-reduce-costs-save-energy_o

https://pdhonline.com/courses/s231/s231content.pdf

FROST PROTECTING POST FRAME BUILDINGS

QUESTIONS?