J-Form Foundation System Engineering Guide

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Introduction - Frost Protected Shallow Foundations

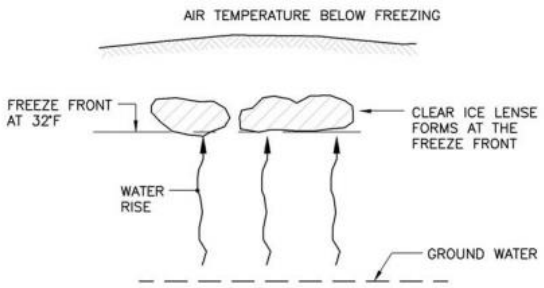


Figure 1. Source: Basics of Frost Protected Shallow Foundation Design by Andrew J. Bibb, P.E.

Since antiquity builders have recognized that, if freezing occurred beneath building foundations, ice in the foundation soils can cause an upward movement of foundations (wall footings, column footings, etc.). Water's somewhat unique property is that it expands approximately 9% as it freezes. As water rises by capillary action, it forms ice lenses at the "freeze front" and accumulates through the freezing season. This upward movement at the freeze front is commonly referred to as "frost heave" and it is a potential to cause of significant damage. The time proven method of preventing frost heave is to place foundation structures below "frost depth" - deep enough below the ground surface that freezing does not take place beneath them – where water saturated soils do not freeze even when air temperatures are well below freezing. Of course, the colder the climate the deeper the frost depth. Every location in the United States and Canada has established the local frost depth. The recognized frost depth in North Dakota is much deeper than in North Carolina. In Florida, frost depth is zero. I.e. the soil does not freeze in Florida.

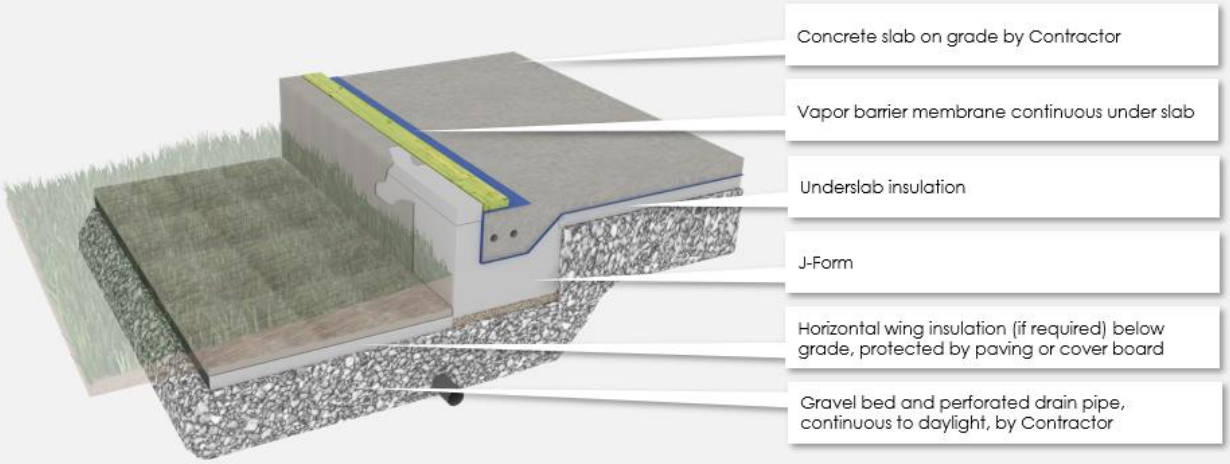
Frost heave protection can be achieved by construction foundations on bedrock, constructing foundations so the bottom of footing is below the frost depth, or by protecting the foundation per ASCE 32. There are three requirements that must all be present for soils to heave: frost susceptible soils, water, and freezing temperatures. Foundations on bedrock are not susceptible to frost heave. For frost susceptible soils to obtain the quantity of water necessary for the growth of large ice lenses, causing frost heave, soils must be both permeable and have voids small enough to support capillary rise. Coarse sand has very poor capillary rise, but very good permeability. Clays have very good capillary rise, but poor permeability. Silts have both good capillary rise and good permeability which is why silts are generally considered frost susceptible. [1] Classification of frost susceptibility of soil is determined by a soils or Geotechnical Engineer.

[1] Basics of Frost Protected Shallow Foundation Design

J-Form Insulated Foundation System

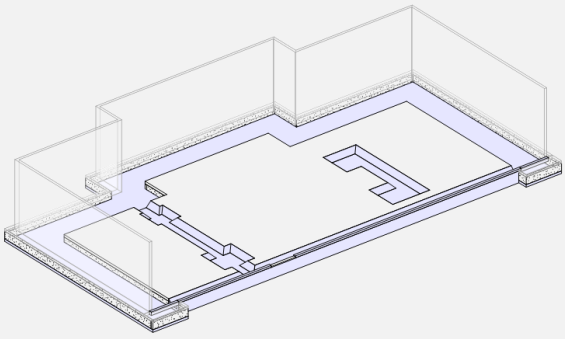
The Build SMART System is a series of mutually supportive elements and construction techniques that achieve a highly energy and labor efficient residential and non-residential building foundation system for slab on grade. The J-Form Foundation System is a permanent part of the foundation structure. It includes:

- J-Form is fabricated per project drawings insulates the exposed vertical face and bottom of the turndown slab edge.
- Underslab insulation significantly reduces heat loss through the slab on grade.
- Horizontal wing insulation (if required)
- Underslab vapor barrier membrane provides for a warm, dry slab and prevents intrusion of soil gas such as radon.



J-Form is custom cut for each project. Dimensions of the slab edge turndown is variable, as determined by project Engineer, and in compliance with applicable codes. J-Form System advantages include improved construction efficiency over conventional practices, increased energy efficiency, minimized site disturbance, and enhanced frost protection.

J-Form System can be used in locales with seasonal freezing but cannot be used in areas with permafrost. Utility cost savings, thermal and comfort benefits are higher in northern climates. The overall simplification and speed of slab and sub-slab vapor barrier membrane installation are important benefits of the J-Form System even in warmer southern climates.

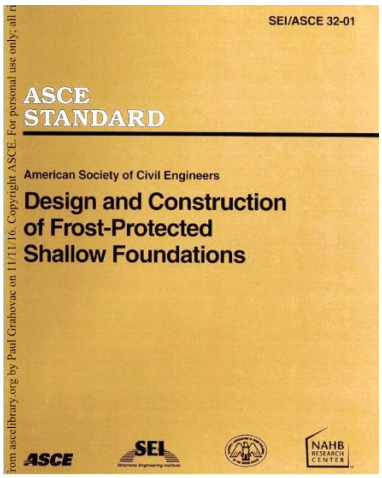


J-Form slab edge, underslab, grade beam and isolated footing insulation configured per project design.

J-Form shapes can be provided for underslab grade beam and isolated footing forms. Provide foundation plan and details to Build SMART. Shop drawings will be created.

J-Form Code Compliance

The J-Form System complies with the International Residential Code (IRC) for single family and duplex projects, and the International Building Code (IBC) for multifamily and commercial projects. Both codes allow frost protection of shallow foundations in accordance with American Society of Civil Engineers Standard 32-01 (ASCE 32).[2] It allows foundations to be designed significantly shallower than the conventionally recognized frost depth in a given locality and to avoid the use of (and the cost of) concrete stem wall or frost footings. Instead, according to ASCE 32, "horizontal wing" insulation is provided (if required) around the perimeter of the building to prevent ground freezing and frost heave at foundations. This design principle is illustrated below. Build SMART does not provide professional project-specific code interpretation services or interface with code officials. Code interpretations indicated in this TechNOTE must be confirmed by project Architects and Engineers to be locally applicable.



Refer also to ASHRAE 90.1 where locally adopted as a referenced standard. It includes provisions similar to ASCE 32.

IRC 2015

R403.1.4.1 Frost Protection.

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

1. Extended below the frost line specified in Table R301.2.(1).
2. Constructed in accordance with Section R403.3.
3. Constructed in accordance with ASCE 32.
4. Erected on solid rock.

IBC 2015

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.

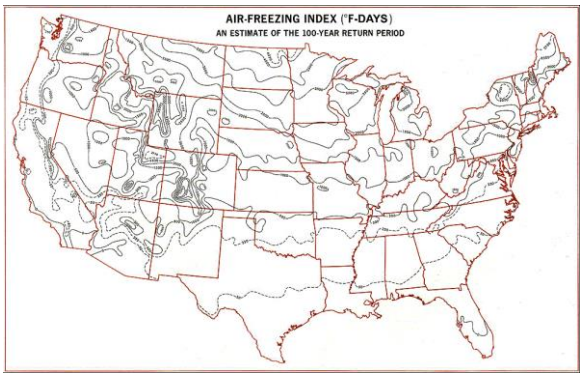
Shallow foundations shall not bear on frozen soil unless such frozen condition is of a permanent character.

The ASCE 32 design process outlined below.

[2] Order print or download ASCE 32 at www.ascelibrary.org.

J-Form Design Process

IRC R403.3 and ASCE-32 identify minimum insulation requirements and do not appear to limit how much insulation can be provided. The following outlines ASCE 32 6.1 FPSF Design Method for Heated Buildings, Slab on Grade Foundations. [4]



AFI Map. Source: ASCE 32 Table A3 and IRC Figure R403.3(2).

Step 1 - Determine the air-freezing index for the project site

Refer to:

- ASCE 32 Appendix A, Table A3
- IRC Figure R403.3(2) Air Freezing Index [5]

Step 2 - Determine the thickness of underslab insulation (Rf)

Neither ASCE 32 nor IRC 403.3 require underslab insulation or limit its R-value (including floor covering). Per ASCE 32, if underslab insulation = R-28, follow the design procedure for unheated buildings. To improve comfort, substantially eliminate heat loss through the slab to the soil below, and considering practical constructability, Build SMART recommends minimum 2" EPS Geofoam (R-8.2).

J-Form insulation type for non-concentrated load locations such as horizontal wing and underslab insulation is termite treated Foam Control Geofoam 150. Refer below to J-Form EPS Geofoam Thermal and Structural Properties.

[4] For HUD projects, refer also to the HUD Design Guide for Frost-Protected Shallow Foundations.
[5] IRC Figure R403.3(2) Air Freezing Index, https://codes.iccsafe.org/content/IRC2015/chapter-4-foundations#IRC2015_Pt03_Ch04_SecR403.3

ASCE 32 Figure 2

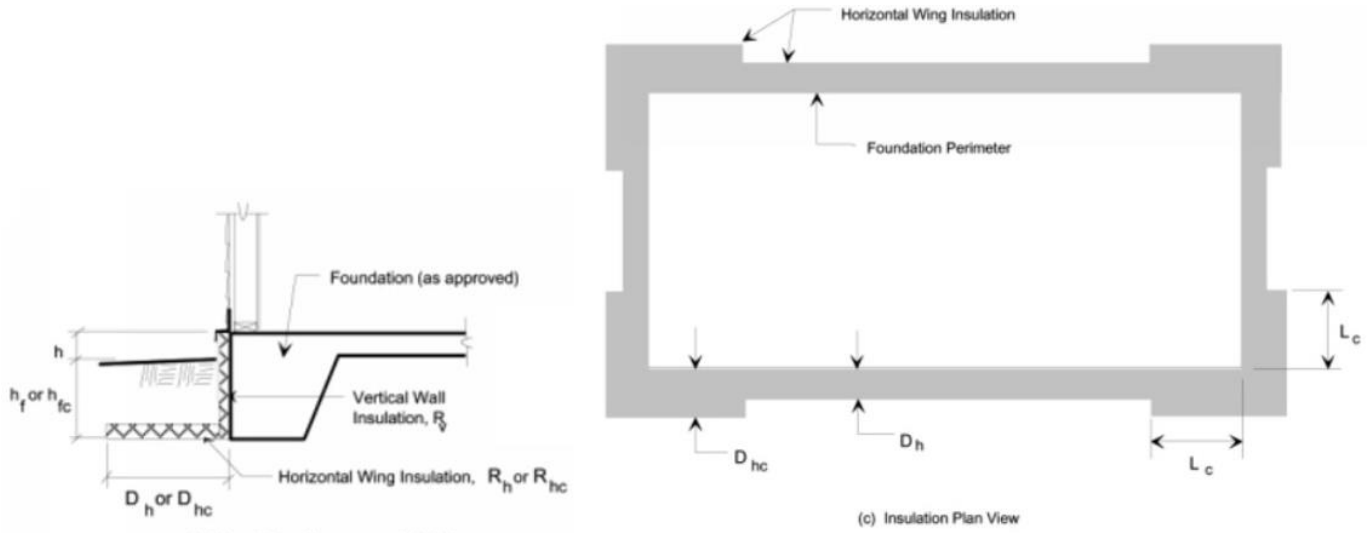


FIGURE 2. Slab-on-Ground Foundation for Heated Buildings

Step 3 - Determine the R-value and insulation thickness vertical leg (R_v) of the J-Form

Refer to ASCE 32 Table A4 and IRC Table 403.3(1).[6] See below.

ASCE 32 Table A4.

TABLE A4. Minimum Thermal Resistance of Vertical Wall Insulation R_v (hr-ft^2-°F/Btu)

F_{100} (°F-days)	$R_f \leq 6.0$		$R_f = 15.0$		$R_f = 28.0$	
	h ≤ 12 in	h = 24 in	h ≤ 12 in	h = 24 in	h ≤ 12 in	h = 24 in
375 or fewer	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

Interpolation shall be permitted.

IRC Table R403.3(1)

TABLE R403.3(1)
MINIMUM FOOTING DEPTH AND INSULATION REQUIREMENTS FOR FROST-PROTECTED FOOTINGS IN HEATED BUILDINGS[a]

AIR FREEZING INDEX (°F-days)[b]	MINIMUM FOOTING DEPTH, D (inches)	VERTICAL INSULATION R-VALUE[c, d]	HORIZONTAL INSULATION R-VALUE[c, e]		HORIZONTAL INSULATION DIMENSIONS PER FIGURE R403.3(1) (inches)		
			Along walls	At corners	A	B	C
1,500 or less	12	4.5	Not required	Not required	Not required	Not required	Not required
2,000	14	5.6	Not required	Not required	Not required	Not required	Not required
2,500	16	6.7	1.7	4.9	12	24	40
3,000	16	7.8	6.5	8.6	12	24	40
3,500	16	9.0	8.0	11.2	24	30	60
4,000	16	10.1	10.5	13.1	24	36	60

For SI: 1 inch = 25.4 mm, °C = [(°F) - 32]/1.8.

a. Insulation requirements are for protection against frost damage in heated buildings. Greater values may be required to meet energy conservation standards.
b. See Figure R403.3(2) or Table R403.3(2) for Air Freezing Index values.
c. Insulation materials shall provide the stated minimum *R*-values under long-term exposure to moist, below-ground conditions in freezing climates. The following *R*-values shall be used to determine insulation thicknesses required for this application: Type II expanded polystyrene-2.4*R* per inch; Type IV extruded polystyrene-4.5*R* per inch; Type VI extruded polystyrene-4.5*R* per inch; Type IX expanded polystyrene-3.2*R* per inch; Type X extruded polystyrene-4.5*R* per inch.
d. Vertical insulation shall be expanded polystyrene insulation or extruded polystyrene insulation.
e. Horizontal insulation shall be expanded polystyrene insulation or extruded polystyrene insulation.

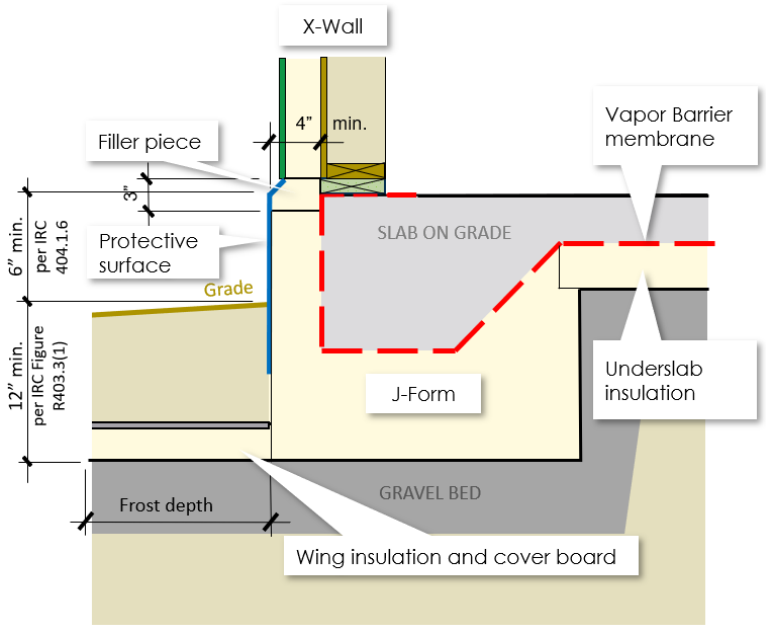
[6] For HUD projects, refer also to HUD Design Guide for Frost-Protected Shallow Foundations.

Step 4: Select Vertical Insulation Type, calculate Thickness, and Provide Protection

J-Form insulation type for concentrated load locations is Foam Control Geofoam EPS46. Refer below to J-Form EPS Geofoam Thermal and Structural Properties. The tabular minimum R_v is less than Build SMART's minimum of 4" (R-18) except for projects where the Air Freezing Index (F_{100}) is 4500 or greater and slab insulation (R_f) is R-28 or greater.

Build SMART's minimum of 4" is for constructability and J-Form strength.

If the project is in a high wind location, confirm foundation design to withstand uplift requirements.



Provide protection for the exterior face of J-Form and 3" filler piece, extending at least 6" below grade. The UV protective surface shall be opaque, weather-resistant, and provide protection from physical damage. Options include, but are not limited to, acrylic co-polymer cement parging with reinforcing mesh (as used with EIFS), sheet metal flashing, and stone or brick veneer (thin brick can be adhered to J-Form).

Protective Parging

The following parging products are identified for consideration.

- DuROCK B2000 parging with alkali-resistant fiberglass mesh. Available from DuROCK 905-856-0133. Product information available online at http://durock.ca/b2000/.
- Finalcrete is a two-part acrylic-cement parging with alkali-resistant fiberglass mesh. Available through CPD Construction Products, 905-669-5013. Finalcrete Product Data Sheet is available online at http://www.finalcrete.com/wp-content/uploads/2012/04/Finalcrete_PDS_e-mail_v20121000.pdf.
- Parge-All AF is a premixed single component acrylic-cement parging available from WR Meadows. Parge information is available online at https://www.wrmeadows.com/parge-all-af-architectural-finishing-mortar/.
- Alkali-resistant fiberglass mesh: 5 oz. mesh over entire parging surface.

Option: For added impact protection, parging may be applied to impact resistant backer board which has been adhered to the exposed J-Form face: provide and install fiber reinforced concrete (FRC) board designed for below grade applications and extend it at least 6" below grade. The following FRC product options are identified for consideration.

- Finex FRC from Foundry Service & Supplies, 909-284-5000, https://www.foundryservice.com/product/finex-fiber-reinforced-cement-composite-building-panels/. Finalcrete is a two-part acrylic-cement parging with alkali-resistant fiberglass mesh.

Available through CPD Construction Products, 905-669-5013. Finalcrete Product Data Sheet is available online at http://www.finalcrete.com/wp-content/uploads/2012/04/Finalcrete_PDS_e-mail_v20121000.pdf.

- EPS Foam/Concrete Adhesive 8178 by AERVOE, 775-783-3100. Download Data Sheet at https://aervoe.com/_files/techdata/38178pds.pdf.

Step 5 - Select Foundation Depth or Horizontal Wing Insulation for Walls.

For climates where F11 is less than 2,250, wing insulation along walls is not required, and the designer may proceed to Step 7. Determine minimum foundation depth and wing insulation R-value to suit project.

Refer to ASCE 32 Table A5 and A6.

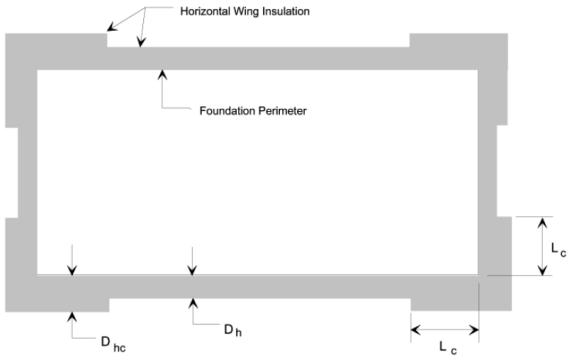


TABLE A5. Minimum Foundation Depths Without Wing Insulation or with Wing Insulation at Corners Only

	Foundation Depth Along Walls with No Wing Insulation	Foundation Depth at Corners with No Wing Insulation		Foundation Depth at Corners with R = 5.7 Wing Insulation at Corners Only		
F_{100} (°F-days)	h_f (in)	L_c (in)	h_{fc} (in)	L_c (in)	h_{fc} (in)	D_{hc} (in)
1,500 or fewer	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

Interpolation shall be permitted.

TABLE A6. Minimum Thermal Resistance of Wing Insulation, R_h, for Use Along Walls with 16-inch (0.4-m) Footing Depth

	R-values for Various Wing Widths Along Walls, D_h (inches)						
F_{100} (°F-days)	12	18	24	30	36	42	48
2,250 or fewer	0.0						
2,625	2.5						
3,000	6.5	6.1	5.3	4.5			
3,375		8.2	7.4	6.5			
3,750			9.1	8.5	7.7		
4,125			11.2	10.2	9.6	8.9	
4,500				12.3	11.4	10.7	10.0

Interpolation shall be permitted.

Step 6 - Select Horizontal Insulation Type, Calculate Thickness, and Provide Protection

J-Form insulation type for non-concentrated load locations such as horizontal wing and underslab insulation is termite treated Foam Control Geofoam 150. Refer below to J-Form EPS Geofoam Thermal and Structural Properties to determine the required insulation thickness (R-4.2 per inch).

For practical constructability, Build SMART recommends that horizontal insulation be a minimum 2" EPS Geofoam (R-8.2). Multiple layers should be installed with joints staggered at least 12 inches.

Provide protection for horizontal insulation placed less than 12 inches below the ground surface, and any portion extending outward more than 24 inches from the foundation edge, shall be protected against damage by concrete or asphalt pavement, or by cementitious board or plywood rated for use below grade, or other approved materials placed directly on the top surface of the horizontal insulation.

Step 7 – Select Foundation Depth or Horizontal Wing Insulation at Corners

Refer to ASCE Table A5 (above).

Where horizontal wing insulation is not desired, select the minimum foundation depth at corners, (h_{fc}). For a uniform foundation depth ($h_f = h_{fc}$) provide minimum R-5.7 wing insulation at corners. As above, Build SMART recommends minimum 2" Eps (R-8.2). If a foundation depth of 16" is desired in severe climates (F_{100} > 2,250), select the minimum width of wing insulation (D_{hc}) and the minimum thermal resistance of the horizontal wing insulation (R_{hc}) from ASCE 32 Table A7. Determine the minimum distance the corner insulation extends from the corners (L_c) from Table A7.

TABLE A7. Minimum Thermal Resistance of Wing Insulation, R_{hc}, for Use at Corners with 16-inch (0.4-m) Footing Depth

		R-values for Various Wing Widths at Corners, D_{hc} (inches)					
F_{100} (°F-days)	L_c (in)	16	24	30	36	42	48
2,250 or fewer	0	0.0					
2,625	40	6.5	4.9	4.0			
3,000	40	9.6	8.6	8.0	7.4		
3,375	60		11.1	10.5	9.8	9.1	
3,750	60		13.1	12.5	12.0	11.2	10.8
4,125	60			14.5	13.7	13.0	12.5
4,500	80				15.9	15.1	14.8

Interpolation shall be permitted.

Provide protection for horizontal wing insulation as above.

Step 8 – Check Compressive Load on Horizontal Insulation

If horizontal wing insulation extends under an adjacent footing, compressive loads from the foundation shall not exceed allowable insulation bearing capacity provided in ASCE 32 Table A1.

TABLE A1. Design Values for FPSF Insulation Materials

Insulation Type per ASTM C578	Minimum Insulation Density per ASTM C578 (pcf)	Effective Resistivity, r_{eff}[1] (R per Inch)		Nominal Resistivity per ASTM C578 (R per inch)	Allowable Bearing Capacity[2] (psf)	Minimum Insulation Thickness (inches)	
		Vertical	Horizontal			Vertical	Horizontal
			Expanded Polystyrene				
Type II	1.35	3.2	2.6	4.0	N/A	2	3
Type IX	1.8	3.4	2.8	4.2	1,200	1.5	2
			Extruded Polystyrene				
Type X	1.35	4.5	4.0	5.0	N/A	1.5	2
Type IV	1.6	4.5	4.0	5.0	1,200	1	1.5
Type VI	1.8	4.5	4.0	5.0	1,920	1	1
Type VII	2.2	4.5	4.0	5.0	2,880	1	1
Type V	3.0	4.5	4.0	5.0	4,800	1	1

[1] Effective resistivity is based on tests from laboratory and field studies of insulation products under long-term exposure to moist, below-ground conditions. 'Vertical' effective resistivity shall be used for insulation placed vertically on exterior foundation walls. 'Horizontal' effective resistivity shall be used for insulation placed horizontally, below ground.
[2] Allowable bearing capacity is based on ASTM C578 compressive strength at 10% deformation divided by a safety factor of 3.0 for conditions without cyclic loading (i.e., highway vehicle loading).
'N/A' prohibits use where structural foundation loads are supported (i.e., insulation below footings).

Environmental Performance

Expanded polystyrene (EPS) is an innovative, high-performance building material engineered to deliver long-term, reliable energy efficiency.

Refer to EPS Industry Alliance, EPS environmental product declaration, www.epsindustry.org/EPS Insulation EPD.pdf

Termite Resistant

Build SMART J-Form System is fabricated from Foam-Control Geofoam with Perform Guard termite resistant molded polystyrene (EPS) insulation which is proven to meet or exceed requirements of IBC 2603.8, IRC 320.5, and complies with ASTM C578, and ICC ES AC239 "Acceptance Criteria for Termite-Resistant Foam Plastics." [7]

Vapor Permeability

Foam Control Geofoam is vapor permeable and its mechanical properties are unaffected by moisture.

J-Form EPS Geofoam Thermal and Structural Properties

EPS used for Build SMART's J-Form System is "EPS Geofoam" manufactured for permanent use in contact with moist earth.

The use of EPS rigid foam as part of the load-bearing component of a foundation structure carries with it a limitation on the bearing pressure between it and the concrete element of the foundation structure. It has been recognized by the industry and design community that EPS, under constant load, undergoes a physical compression, or shrinkage, over time. This compression is directly related to the intensity of the compression stress within it and to the duration of time over which it is under load.

The most common way this characteristic of EPS is expressed is in terms of the compressive stress at which a certain magnitude of compressive strain, or shrinkage, may be expected. The compressive stresses are commonly listed at shrinkage levels of 1%, 5% and 10%. American Society for Testing and Materials (ASTM) has published a specification for EPS foam material, ASTM D6817, in which EPS material is assigned designations for various foam densities. The greater the density, the higher the level of compressive stress the material can sustain for an expected strain of 5%, 10%, etc. The foam material used in load path bearing parts of the Build SMART J-Form System is EPS46 which possess a density of 2.85 pounds per cubic foot (pcf).

Calculate compressive shrinkage by multiplying the thickness of the EPS between the perimeter stiffener, or "turn-down" of the concrete slab-on-grade by the acceptable shrinkage level. For example, if J-Form EPS is 8" thick under the turndown, 1% of this thickness is 0.4", or about 3/32". For the purposes of this

[7] Refer to Perform Guard termite resistance, www.achfoam.com/Foam-Control_Perform_Guard.pdf.

review, 5% EPS strain is taken to be the acceptable criterion for EPS loading. Light frame construction resting on the Build Smart J-Form Foundation can readily sustain this level of downward movement due to compressive strain, or shrinkage of the EPS.

The J-Form System uses two foam types: EPS Type 46 at load path bearing conditions and EPS Type II for underslab i and wing insulation locations.

J-Form EPS Geofoam Properties

Product	**EPS Type**	**Minimum Density** per ASTM C303	**Allowable Compressive Stress** ASTM D1621	**Allowable Soil Bearing Pressure**	**R-value per inch** ASTM C518
Load path bearing conditions: J-Form thickened edge of slab on grade, grade beam forms, isolated footing forms					
Foam Control Geofoam EPS46	EPS Type 46 per ASTM D6817	2.85 pcf	1% deformation: 18.6 psi 5% deformation: 43.5 psi 10% deformation: 50 psi	1% deformation: 2,678 psf 5% deformation: 6,264 psf 10% deformation: 7,200 psf	25°F: R-5.1 40°F: R-4.9 75°F: R-4.5
Non-bearing conditions: underslab insulation					
Foam Control Geofoam 150	EPS Type II per ASTM C578	1.35 pcf	1% deformation: 7.3 psi 5% deformation: 16.7 psi 10% deformation: 19.6 psi	1% deformation: 1,051 psf 5% deformation: 2,404 psf 10% deformation: 2,822 psf	25°F: R-4.8 40°F: R-4.6 75°F: R-4.2

Source: Foam Control Geofoam Physical Properties for EPS type, density and allowable compressive stress at the ACH Foam Technologies website, https://www.achfoam.com/Geofoam/Geofoam-Properties.aspx and Foam Control ASTM C 578 and ASTM D 6817 table at https://www.achfoam.com/ACH/media/ACH/docs/Tech%20Data/Foam-Control-D6817-C578-Summary.pdf.

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