Continuous Insulation & Foam Plastics in the Building Envelope

Colorado Chapter ICC – Educational Institute
Class #483
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Course Outline

I. Introductory Topics
II. Fire Safety
III. Above Grade Walls
IV – VI. Foundations, Roofs, Floors, Existing Buildings

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Your Speakers

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I. Introduction

A. The Building Thermal Envelope (BTE)
B. Foam Plastic Materials
C. BTE Insulation Applications
D. Multi-functional Capabilities
E. General Code Requirements (Labeling & Installation)

NOTE: Code section references based on 2024 Editions of IBC/IRC/IECC

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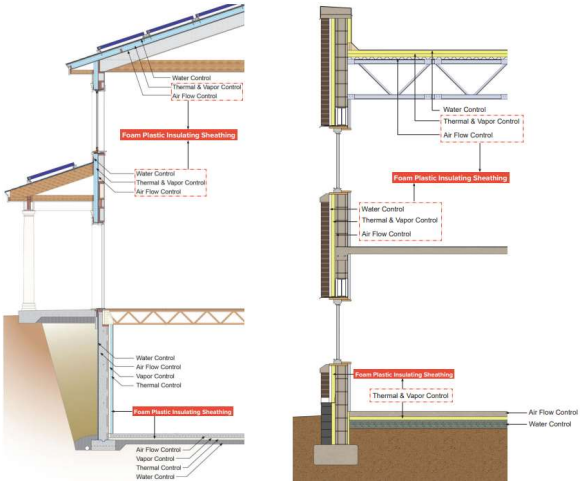
A. What is the building thermal envelope (BTE)?

- The BTE separates the indoor from the outdoor environment.
- The BTE is an integrated system which also supports the design and function of other building systems.

IECC Definition:

BUILDING THERMAL ENVELOPE. The basement walls, exterior walls, floors, ceilings, roofs and any other building element assemblies that enclose *conditioned space* or provide a boundary between *conditioned space* and exempt or unconditioned space.

Also known as "building enclosure"



Source: www.continuousinsulation.org

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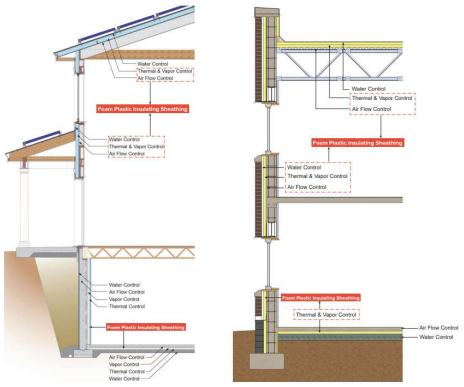
Why is the BTE important?

- Allows indoor environment (conditioned space) to be controlled for comfort, productivity, and health
- Major factor in sizing HVAC equipment
- Protects the structure, its occupants, and its contents from the outdoor environment (wind, rain, U/V radiation, temperature and humidity cycling, etc.)
- Determines the life-cycle operational cost, energy use (heating/cooling), and carbon footprint/handprint for the building.



Source: www.continuousinsulation.org

"Without a good building envelope, …HVAC system and design actions become more difficult and costly, and uncertain in their effectiveness [to control the indoor environment]."

Source: ABTG RR No. 2006-01, p10, https://www.continuousinsulation.org/topical-library/healthy-buildings

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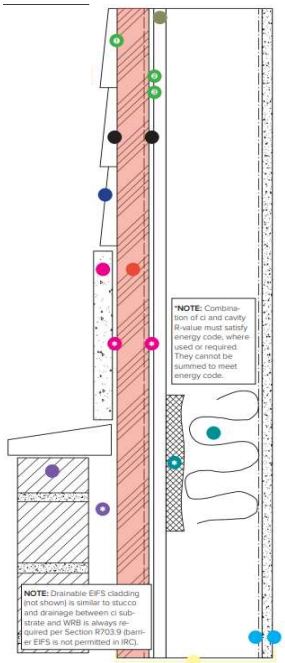
Functions of the BTE

- In addition to fire safety, structural safety, sound control, and durability the BTE must address the following control layers (functions):
  - **Water** control layers [cladding + continuous water-resistive barrier (WRB) + flashing to control water intrusion]
  - **Air** control layer [continuous air barrier (AB) to control air leakage]
  - **Thermal** control layer [continuity of thermal insulation to control heat loss/gain and surface temperatures]
  - **Water vapor** control layer [use of vapor retarders (VR) in coordination with insulation strategy and climate]
- All functions must be satisfied at least to the minimum extent required by the building and energy code.
- Some "layers" or materials can perform multiple functions depending on design approach and material properties
- **FUN FACT:** 5 VR x 5 AB x 5 ci x 5 cavity x 6 WRB x 5 str shtg x 9 cladding = **168,750** possibilities to configure a wall! (and not all are equal, though most may be code compliant)



Source: www.continuousinsulation.org

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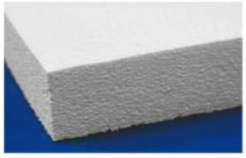
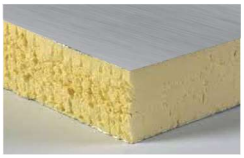
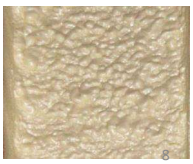
B. Foam Plastic Materials

- **Foam Plastic Insulating Sheathing (FPIS)**
  - "Rigid board", "foam panel", "foam sheathing", etc.
  - 10-100 psi compressive resistance; ~R4-R7 per inch
  - ASTM C578 – Standard specification for rigid, cellular polystyrene thermal insulation (XPS – extruded polystyrene; EPS – expanded polystyrene)
  - ASTM C1289 – Standard specification for faced rigid cellular polyisocyanurate thermal insulation board (Polyiso or PIR)
  - ASTM C1126 – Standard specification for faced or unfaced rigid cellular phenolic thermal insulation
- **Spray Polyurethane Foam (SPF)**
  - "Spray foam"
  - Open cell spray polyurethane foam (ocSPF)
  - Closed cell spray polyurethane foam (ccSPF)
  - Variable densities and R-values for different applications
  - ICC 1100 – Standard for spray-applied polyurethane foam plastic
- Main Code Sections for Foam Plastics: IBC Section 2603; IRC Section R303/R316
- NOTE: Various insulation materials can be used, but this presentation focuses on appropriate, code-compliant use of foam plastics.







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ANSI FS200.1 Standard for FPIS Applications

- Scope
  - Above-grade frame walls
  - Labeling & Quality Assurance
  - Wind resistance
  - WRB (water resistance)
  - Vapor Control
  - Window installation
  - Cladding installation
- Addresses
  - Performance criteria (design)
  - Evaluation/testing criteria by application
  - Prescriptive criteria ("cook-book" design and installation)
- Exclusions
  - Refer to locally applicable code for fire safety requirements (e.g., IBC Chapter 14 and 26; IRC Section R303/R316)
  - Refer to FPIS manufacturer data to demonstrate compliance (ASTM E84, ASTM E119, NFPA 285, etc. – as applicable)

6300 Enterprise Lane
Madison, Wisconsin 53719
608-310-6710

ABTG
Applied Building Technology Group, LLC

ANSI/ABTG FS200.1 – 2022

Standard for Use of Foam Plastic Insulating Sheathing (FPIS) in Building Envelopes: Above-grade Walls

ANSI

https://www.appliedbuildingtech.com/standards

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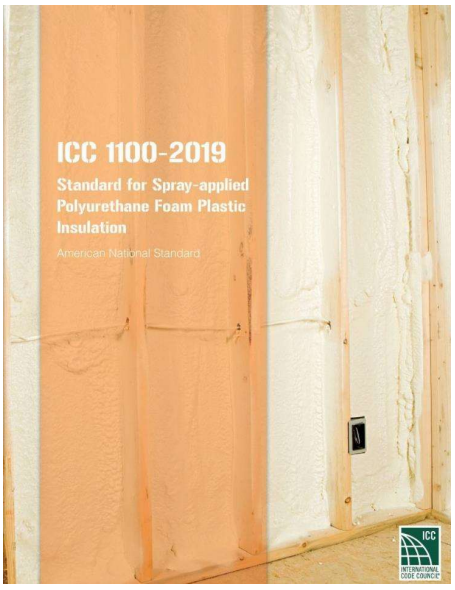
ICC 1100 Standard for SPF

- Scope:
  - minimum physical property and performance requirements
  - demonstrate compliance with the intent of the model building codes
  - variety of construction applications
  - basic installation requirements
  - single- and multiple-component SPF insulation
  - nonstructural building construction applications.



Source: https://codes.iccsafe.org/

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C. BTE Insulation Applications

- Two building thermal envelope insulation applications are defined in the IECC:
  - **CAVITY INSULATION.** Insulating material located between framing members.
  - **CONTINUOUS INSULATION (ci):** Insulation that is {uncompressed and} continuous across all structural members without thermal bridges other than fasteners and service openings. It is installed on the interior or exterior or is integral to any opaque surface of the building envelope.
- **FPIS** is typically used as continuous insulation, but can be cut to fit cavities.
- **ccSPF** is typically used as cavity insulation, but can also be applied as continuous insulation, also as air sealant
- **ocSPF** is typically used as cavity insulation

Cavity

Continuous

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What is the main difference between Cavity insulation and Ci insulation?

- Location, location, location
- Continuity

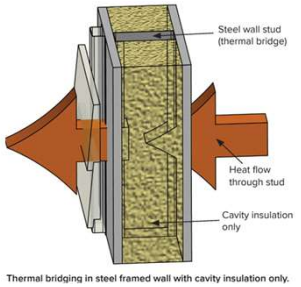
Without Ci

Cavity insulation only

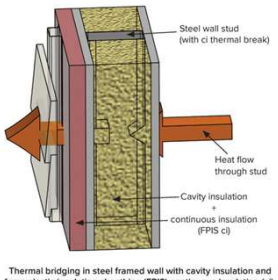
With Ci

Cavity + Ci insulation (or Ci only)

Source: Dryvit/Dow



Thermal bridging in steel framed wall with cavity insulation only.



Thermal bridging in steel framed wall with cavity insulation and foam plastic insulating sheathing (FPIS) continuous insulation (ci).

Source: www.continuousinsulation.org

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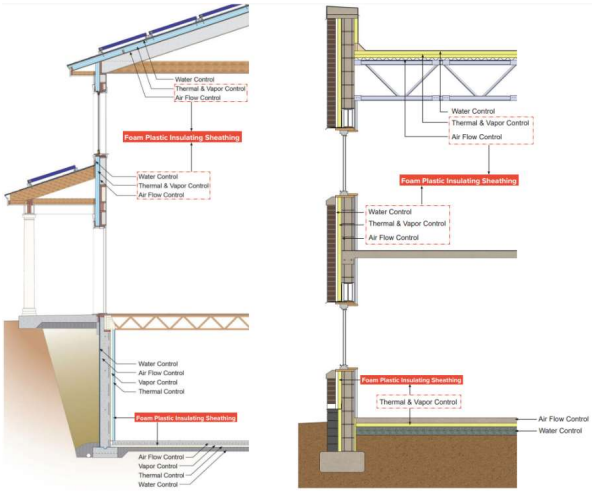
D. Multi-functional Capabilities of FPIS

- BTE Applications: walls, roofs, floors, and foundations (residential and commercial)
- BTE Functional Capabilities
  - IECC - Thermal Insulation (continuous and cavity)
  - IECC - Air barrier (AB)
  - IBC/IRC – Water vapor control/retarders (VR)
  - IBC/IRC – Water-resistive barrier (WRB) system
  - IBC/IRC – Foundation/footing frost protection
  - IBC/IRC – Wall bracing (proprietary structural insulating sheathings)
- More multi-functional capabilities =
  ➔ satisfy multiple code requirements
  ➔ simpler assembly
  ➔ optimized cost vs. performance
- For additional information refer to:
  - https://www.continuousinsulation.org/applications-continuous-insulation
  - https://www.americanchemistry.com/industry-groups/spray-foam-coalition-sfc



Source: www.continuousinsulation.org

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Multi-functional Capabilities of SPF

Air sealing & insulation for floor perimeter

Cavity insulation/AB/VR (www.energyefficientsolutions.com)

Ci/WRB/AB on school (masonry cavity wall)

- Insulation
- Air sealing
- Adhesive
- Enhanced wall structural properties

https://www.americanchemistry.com/industry-groups/spray-foam-coalition-sfc

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FPIS structural composite sheathings

- Multi-functional Sheathing (Structural Sheathing + FPIS ci + WRB + AB + vapor control)
- 5 in 1 product
- Several code-approved products

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E. General Code Requirements

- Product Labeling
- Installation Requirements

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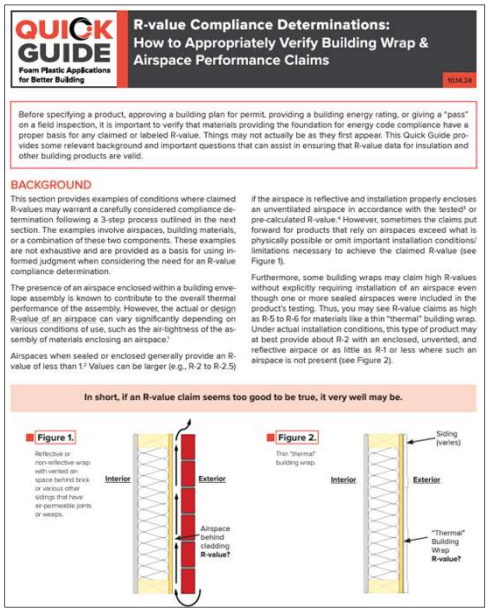
IECC on Product Labeling

(Testing, Labeling, Marking, Verification)

- **IECC C303.1/R303.1 Identification**
  - Insulation materials must be identified in a manner to allow determination of compliance with the code.
  - RECOMMENDATION: Verify label (insulation mark) and product test data is certified by an *approved agency*
    - *NOTE: This is discretionary and not a clear code requirement for R-value verification. Use where R-value claims are questionable.*
- **IECC C303.1.1/R303.1.1 Building thermal envelope insulation**
  - R-value mark on each piece or certification (including installation details of sprayed or blown-in insulation for R-value, thickness, etc.)

    Exception: Above-deck roof insulation per Table 1508.2 of IBC (material standards which address product marking or use of package label or certificate)
- **IECC C303.1.2/R303.1.2 Insulation mark installation**
  - The above information must be readily observable or certificate left on site immediately after installation (with same exception as above)
- **IECC C303.1.4 Insulation product rating**
  - R-value determined in accordance with FTC R-value Rule and its referenced test methods (generally ASTM test standards)
  - For insulated siding, code requires ASTM C1363 testing


QUICK GUIDE
Foam Plastic Applications for Better Building

R-value Compliance Determinations: How to Appropriately Verify Building Wrap & Airspace Performance Claims

1014.24

Before specifying a product, approving a building plan for permit, providing a building energy rating, or giving a "pass" on a field inspection, it is important to verify that materials providing the foundation for energy code compliance have a proper basis for any claimed or labeled R-value. Things may not actually be as they first appear. This Quick Guide provides some relevant background and important questions that can assist in ensuring that R-value data for insulation and other building products are valid.

BACKGROUND

This section provides examples of conditions where claimed R-values may warrant a carefully considered compliance determination following a 3-step process outlined in the next section. The examples involve airspaces, building materials, or a combination of these two components. These examples are not exhaustive and are provided as a basis for using informed judgment when considering the need for an R-value compliance determination.

The presence of an airspace enclosed within a building envelope assembly is known to contribute to the overall thermal performance of the assembly. However, the actual or design R-value of an airspace can vary significantly depending on various conditions of use, such as the air-tightness of the assembly of materials enclosing an airspace.[1]

Airspaces when sealed or enclosed generally provide an R-value of less than 1.[2] Values can be larger (e.g., R-2 to R-2.5) if the airspace is reflective and installation properly encloses an unventilated airspace in accordance with the tested[3] or pre-calculated R-value.[4] However, sometimes the claims put forward for products that rely on airspaces exceed what is physically possible or omit important installation conditions/limitations necessary to achieve the claimed R-value (see Figure 1).

Furthermore, some building wraps may claim high R-values without explicitly requiring installation of an airspace even though one or more sealed airspaces were included in the product's testing. Thus, you may see R-value claims as high as R-5 to R-6 for materials like a thin "thermal" building wrap. Under actual installation conditions, this type of product may at best provide about R-2 with an enclosed, unvented, and reflective airpace or as little as R-1 or less where such an airspace is not present (see Figure 2).

In short, if an R-value claim seems too good to be true, it very well may be.

Figure 1.
Reflective or non-reflective wrap with vented air space behind brick or various other sidings that have air-permeable joints or weeps.
Interior
Exterior
Airspace behind cladding
R-value?

Figure 2.
Thin "thermal" building wrap.
Interior
Exterior
Siding (varies)
"Thermal" Building Wrap
R-value?

https://www.continuousinsulation.org/resources/quick-guides

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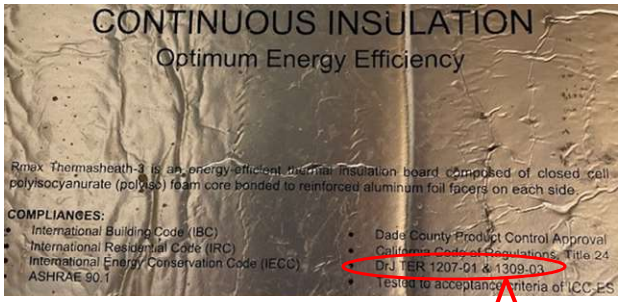
IBC/IRC on Product Labeling for Foam Plastics

- **2024 IBC Section 2603.2 / IRC Section R303.2**

Labeling and identification. Packages and containers of foam plastic insulation and foam plastic insulation components delivered to the job site shall bear the *label* of an *approved agency* showing the manufacturer's name, product listing, product identification and information sufficient to determine that the end use will comply with the code requirements.

NOTE: This addresses performance for other than R-value

Example Product Marking/Label for FPIS ci:



Examples of approved agencies & sources…


ES ICC EVALUATION SERVICE®

ICC-ES Listing Report

ESL-1126
Reissued April 2023
This listing is subject to renewal April 2024.

www.icc-es.org | (800) 423-6587 | (562) 699-0543
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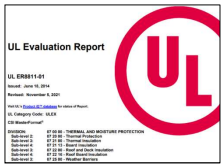
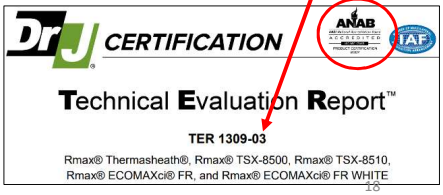
CSI: DIVISION: 07 00 00—THERMAL AND MOISTURE PROTECTION


UL Evaluation Report

UL ER8811-01


DrJ CERTIFICATION

Technical Evaluation Report™

TER 1309-03

Rmax® Thermasheath®, Rmax® TSX-8500, Rmax® TSX-8510, Rmax® ECOMAXci® FR, and Rmax® ECOMAXci® FR WHITE

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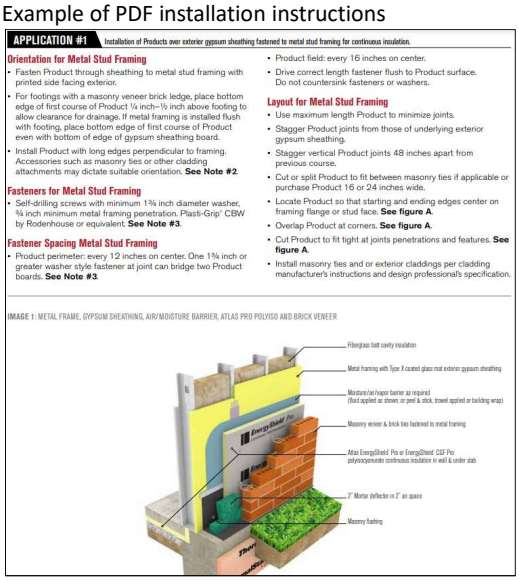
Installation Requirements

- **C303.2/R303.2** All materials, systems and equipment shall be installed in accordance with the manufacturer's installation instructions and the *International Building Code / International Residential Code*.
- **C303.2.1/R303.2.1** Protection of exposed foundation insulation
  - Applies to exterior insulation on foundations
  - Rigid, opaque, weather-resistant protective covering required for exposed insulation and it shall extend not less than 6 inches below grade
- **C303.2.2** Multiple layers of continuous insulation (not in IECC-R, but should be)
  - Where two or more layers of continuous insulation are used, follow manufacturer's instructions or if no instruction, edge joints must be staggered (later required for above-deck roof insulation).

Example of PDF installation instructions



APPLICATION #1 Installation of Products over exterior gypsum sheathing fastened to metal stud framing for continuous insulation.

Orientation for Metal Stud Framing
- Fasten Product through sheathing to metal stud framing with printed side facing exterior.
- For footings with a masonry veneer brick ledge, place bottom edge of first course of Product ¼ inch–½ inch above footing to allow clearance for drainage. If metal framing is installed flush with footing, place bottom edge of first course of Product even with bottom of edge of gypsum sheathing board.
- Install Product with long edges perpendicular to framing. Accessories such as masonry ties or other cladding attachments may dictate suitable orientation. **See Note #2.**

Fasteners for Metal Stud Framing
- Self-drilling screws with minimum 1⅝ inch diameter washer, ¾ inch minimum metal framing penetration. Plasti-Grip® CBW by Rodenhouse or equivalent. **See Note #3.**

Fastener Spacing Metal Stud Framing
- Product perimeter: every 12 inches on center. One 1⅝ inch or greater washer style fastener at joint can bridge two Product boards. **See Note #3.**
- Product field: every 16 inches on center.
- Drive correct length fastener flush to Product surface. Do not countersink fasteners or washers.

Layout for Metal Stud Framing
- Use maximum length Product to minimize joints.
- Stagger Product joints from those of underlying exterior gypsum sheathing.
- Stagger vertical Product joints 48 inches apart from previous course.
- Cut or split Product to fit between masonry ties if applicable or purchase Product 16 or 24 inches wide.
- Locate Product so that starting and ending edges center on framing flange or stud face. **See figure A.**
- Overlap Product at corners. **See figure A.**
- Cut Product to fit tight at joints penetrations and features. **See figure A.**
- Install masonry ties and or exterior claddings per cladding manufacturer's instructions and design professional's specification.

IMAGE 1: METAL FRAME, GYPSUM SHEATHING, AIR/MOISTURE BARRIER, ATLAS PRO POLYISO AND BRICK VENEER

Source: https://www.atlasrwi.com/resources

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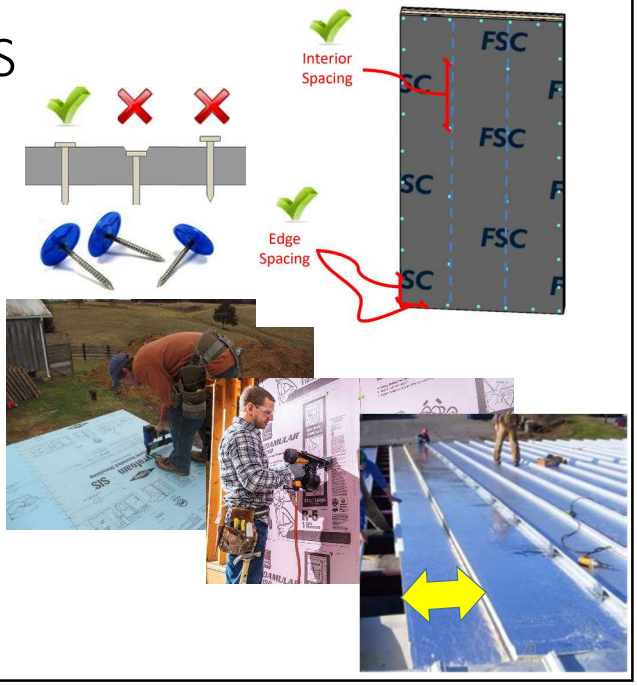
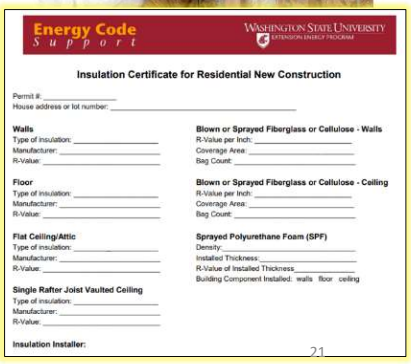
Basic Installation of FPIS

- #1 - Follow manufacturer's installation instructions
  - Basics often printed on the product
  - Illustrated PDF free downloads
- Cut to size with power/hand saws, utility knife, etc.
- Drive specified nails, staples, or screws flush and snug (w/ cap washers preferred)
- No substantial gaps
- If using an FPIS WRB system, be sure to use joint tape and flashing materials specified in manufacturer's instructions.
  - NO SUBSITUTES UNLESS APPROVED BY MANUFACTURER AS COMPATIBLE AND CONSISTENT WITH PRODUCT APPROVAL TEST DATA!



Installation of SPF

- #1 Follow manufacturer's instructions
  - Industry program available to certify installers
  - Manufacturers also provide installer training
  - Installers provide jobsite installation certificate
- Instructions should be based on ICC 1100 standard
- In general:
  - Refer to installer's installation certificate
  - Measure thickness using a probe or depth of structural members
  - The SPF shall have no signs of shrinkage, including pulling away from the substrate or framing
  - Cracks or gaps shall not exceed 1/16" in width
  - Visible cracks less than 1/16" in width shall be sealed with one-component polyurethane foam or similar
  - No cracks shall extend from the substrate to the surface of the SPF
  - SPF shall be well-adhered to the substrate



Energy Code Support — Washington State University Extension Energy Program

Insulation Certificate for Residential New Construction

Permit #: _____
House address or lot number: _____

Walls
Type of insulation: _____
Manufacturer: _____
R-Value: _____

Floor
Type of insulation: _____
Manufacturer: _____
R-Value: _____

Flat Ceiling/Attic
Type of insulation: _____
Manufacturer: _____
R-Value: _____

Single Rafter Joist Vaulted Ceiling
Type of insulation: _____
Manufacturer: _____
R-Value: _____

Blown or Sprayed Fiberglass or Cellulose - Walls
R-Value per Inch: _____
Coverage Area: _____
Bag Count: _____

Blown or Sprayed Fiberglass or Cellulose - Ceiling
R-Value per Inch: _____
Coverage Area: _____
Bag Count: _____

Sprayed Polyurethane Foam (SPF)
Density: _____
Installed Thickness: _____
R-Value of Installed Thickness: _____
Building Component Installed: walls floor ceiling

Insulation Installer:

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II. Residential & Commercial Fire Safety

A. Fire Science and Fire Safety
B. Principles of Fire Safety
C. Fire Safety in the Built Environment
D. IBC/IRC – Fire Safety for Foam Plastic

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A. Fire Science and Fire Safety

- **Fire Science is:**
  - Study of fire
    - Causes
    - Effects
    - Chemistry
    - Behavior
    - Evaluation / Testing
  - "Fire Triangle" is an example of fire science
  - Does not change based on jurisdictional boundaries

- **Fire Safety is:**
  - The prevention or reduction of fire and effects of fire
  - Derived from
    - Policies and procedures
    - Practices and designs
    - Regulation**
    - Systems and devices
    - Education

** Regulation most often requires fire performance testing

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B. Principles Fire Safety

- *International Fire Safety Standards: Common Principles (2020)*
  - Published by the International Fire Safety Standards Coalition
  - Universally applicable framework of five (5) common principles of fire safety for application to regulatory schemes:
    - **Prevention** - Safeguarding against the outbreak of fire and/or limiting its effects
    - **Detection and Communication** - Investigating and discovering of fire followed by informing occupants and the fire service
    - **Occupant Protection** - Facilitating occupant avoidance of, and escape from, the effects of fire
    - **Containment** - Limiting of fire and all of its consequences to as small an area as possible
    - **Extinguishment** - Suppressing of fire and protecting of the surrounding environment

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C. Fire Safety in the Built Environment

- Fire safety in the built environment is…
  - …based on our knowledge and application of fire science
  - …important throughout the building life cycle and construction value chain
  - …a result of compliance with applicable regulations and standards
  - …affected by regional and local needs, norms, et al

- Fire safety regulatory *provisions* and *requirements* should satisfy one or more *principles* of fire safety.
  - They prescribe design, testing, and performance requirements.
  - What fire risk(s) do they address?
  - How are they organized or structured?

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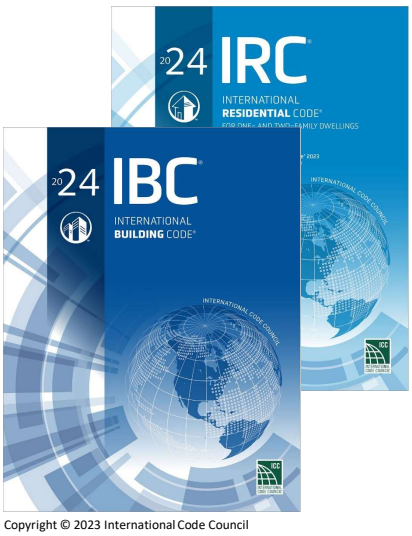
D. IBC/IRC Fire Safety - General

REMINDER: Unless noted otherwise, the information and code references are in context of the *2024 Eds. of the IBC & IRC* and *for uses in the building thermal envelope.*

- The stated *Purpose* of both the IBC and IRC is to establish minimum requirements to, among other things, provide a reasonable level of life safety and property protection from the hazard of fire.
  - IBC Section 101.3
  - IRC Section R101.3
- The other International Codes (I-Codes) may also contain fire safety provisions in context of the respective code.
- Coordination of requirements in other applicable codes or standards with IBC/IRC fire safety requirements is necessary to ensure compliance with both.



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D. IBC/IRC Fire Safety - General

- Fire safety under the IBC/IRC is achieved through compliance with multiple coordinated and reinforcing layers of prescribed requirements for building design and for fire performance / fire testing.
  - Design requirements include:
    - Passive fire protection
      - Materials of construction
      - Fireblocking / firestopping
      - Fire-resistance-rated construction
      - Fire separation distance
      - Ignition resistance from radiant heat
      - Vertical and lateral flame propagation
      - Interior finish classes
      - Thermal / ignition barriers
    - Active fire protection
      - Automatic sprinkler systems
      - Sensing & notification systems
      - Other fire and life-safety systems
  - Fire testing and performance requirements include:
    - Material tests – e.g., ASTM E84, UL 723, ASTM E136, NFPA 259, and others
    - Assembly tests – e.g., ASTM E119, UL 263, NFPA 268, NFPA 285, and others
  - Tests evaluate performance such as:
    - Combustibility
    - Surface burning characteristics
    - Ignition resistance from radiant heat exposure
    - Vertical and lateral flame propagation
    - Fire resistance

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D. IBC/IRC Fire Safety - General

- The scope of buildings regulated by the IBC and IRC differ…
  - IBC Section 101.2 Scope
    - Every building, structure, or any appurtenances connected to such buildings or structures … except:
      - Detached one- and two-family dwellings and townhouses, and their accessory structures, that are three stories or less in height and with separate means of egress are required to comply with the IRC
  - IRC Section R101.2 Scope
    - Detached one- and two-family dwellings and townhouses, and their accessory structures, that are three stories or less in height and with separate means of egress

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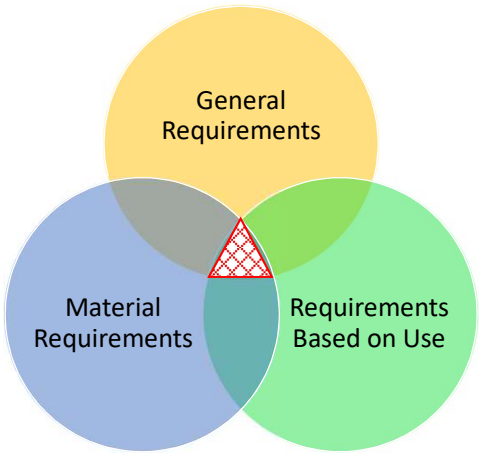
D. IBC/IRC Fire Safety - General



- Compliance of foam plastic and its uses with code requirements related to fire safety lies at the intersection of:
  - General requirements
  - Material requirements
  - Requirements Based on Use
- This intersection is influenced by all applicable codes and standards, e.g.:
  - Building *and* energy
  - Building *and* energy *and* mechanical
  - Residential *and* energy *and* wildfire

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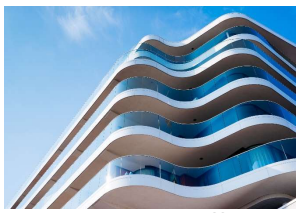
D. IBC/IRC Fire Safety - General

- Foam plastic / foam plastic insulation is generally treated the same by both IBC and IRC in terms of fire safety and fire performance, however,…
  - The IBC's broader scope results in more and more complex fire safety provisions than the IRC, e.g.: Construction Type and Occupancy Group classifications; height and area limitations; requirements based on Type, Occupancy, building location, etc.
  - Fire safety provisions of the IBC are, at times, more stringent than those of the IRC, e.g.: multiple assembly tests for exterior wall assemblies; higher and varied fire-resistance ratings; opening protections; etc.



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D. IBC/IRC Fire Safety - General

- IBC (Chapters 3, 5, and 6)
  - Separates buildings into five (5) *Construction Type* classifications based on:
    - Materials of construction…
      - Noncombustible or any material
    - …and min. fire-resistance ratings…
    - …of primary building elements
      - Structural frame, bearing & nonbearing walls (both interior & exterior), roofs and floors (and associated secondary structural members)
  - Separates buildings into *Occupancy Classifications* and *Groups* based on:
    - Building's intended use and the associated hazards/risks to occupants
- IBC – cont'd
  - Type and Occupancy together influence other requirements, including:
    - Allowable building heights and floor areas
    - Fire-resistance ratings
- IRC, in contrast:
  - Does not separate the homes into multiple classifications
    - In many ways the IRC is seen as analogous to IBC Type V construction
  - Only covers buildings containing one or two *dwelling units* that are occupied only for living purposes
  - Is silent on allowable floor area

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D. IBC/IRC Fire Safety - General

- IBC Construction Types (Chapter 6)

Building Element	Type of Construction							
	I (602.2)	II (602.2)	III (602.3)	IV (602.4) IV-A (602.4.1)	IV (602.4) IV-B (602.4.2)	IV (602.4) IV-C (602.4.3)	IV (602.4) IV-HT (602.4.4)	V (602.5)
Primary Structure	NC*	NC*	Any	MT or NC	MT or NC	MT or NC	HT	Any
Bearing walls								
Exterior	NC*	NC*	NC**	MT or NC	MT or NC	MT or NC	MT, NC, or HT	Any
Interior			Any	MT or NC	MT or NC	MT or NC	MT, NC, or HT	
Nonbearing walls & partitions								
Exterior	NC*	NC*	NC**	MT or NC	MT or NC	MT or NC	MT, NC, or HT	Any
Interior			Any	MT or NC	MT or NC	MT or NC	MT, NC, or HT	
Floor & secondary members	NC*	NC*	Any	MT or NC	MT or NC	MT or NC	MT, NC, or HT	Any
Roof & secondary members	NC*	NC*	Any	MT or NC	MT or NC	MT or NC	MT, NC, or HT	Any

* - Except as permitted in Section 603 and other sections of the code.
** - Exterior walls of Type III and Type IV-HT permitted to be constructed of other certain materials other than NC (see code).
NC - Noncombustible material.
Any - Any material permitted by the IBC.
HT - Heavy Timber (solid wood, laminated heavy timber or *structural composite lumber*).
MT - Mass Timber (solid, built-up, panelized, or engineered wood products meeting minimum dimensions in IBC Section 2304.11).

- IBC 603 prescribes an extensive list of combustible materials & applications permitted in Types I and II, including: *foam plastics in accordance with Chapter 26*, *Class A, B, or C roof coverings*, and *combustible exterior wall coverings.*

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D. IBC/IRC Fire Safety - General

- IBC Construction Types (Chapter 6)
  - IBC Table 601 prescribes minimum fire-resistance ratings required for the different building elements.

TABLE 601
FIRE-RESISTANCE RATING REQUIREMENTS FOR BUILDING ELEMENTS (HOURS)

BUILDING ELEMENT	TYPE I		TYPE II		TYPE III		TYPE IV				TYPE V	
	A	B	A	B	A	B	A	B	C	HT	A	B
Primary structural frame[f] (see Section 202)	3[a, b]	2[a, b, c]	1[b, c]	0[c]	1[b, c]	0	3[a]	2[a]	2[a]	HT	1[b, c]	0
Bearing walls												
Exterior[e, f]	3	2	1	0	2	2	3	2	2	2	1	0
Interior	3[a]	2[a]	1	0	1	0	3	2	2	1/HT[g]	1	0
Nonbearing walls and partitions Exterior	See Table 705.5											
Nonbearing walls and partitions Interior[c]	0	0	0	0	0	0	0	0	0	See Section 2304.11.2	0	0
Floor construction and associated secondary structural members (see Section 202)	2	2	1	0	1	0	2	2	2	HT	1	0
Roof construction and associated secondary structural members (see Section 202)	1 1/2[b]	1[b, c]	1[b, c]	0[c]	1[b, c]	0	1 1/2	1	1	HT	1[b, c]	0

For SI: 1 foot = 304.8 mm.
a. Roof supports: Fire-resistance ratings of primary structural frame and bearing walls are permitted to be reduced by 1 hour where supporting a roof only.
b. Except in Group F-1, H, M and S-1 occupancies, fire protection of structural members in roof construction shall not be required, including protection of primary structural frame members, roof framing and decking where every part of the roof construction is 20 feet or more above any floor or mezzanine immediately below. Fire-retardant-treated wood members shall be allowed to be used for such unprotected members.
c. In all occupancies, heavy timber complying with Section 2304.11 shall be allowed for roof construction, including primary structural frame members, where a 1-hour or less fire-resistance rating is required.
d. Not less than the fire-resistance rating required by other sections of this code.
e. Not less than the fire-resistance rating based on fire separation distance (see Table 705.5).
f. Not less than the fire-resistance rating as referenced in Section 704.9.
g. Heavy timber bearing walls supporting more than two floors or more than a floor and a roof shall have a fire-resistance rating of not less than 1 hour.

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D. IBC/IRC Fire Safety - General

- IBC/IRC sections governing foam plastic insulation are:
  - IBC – Chapter 26 Plastic; Section 2603 Foam Plastic Insulation (2000 through 2024 IBC)
  - IRC – Section R303 Foam Plastic
    - Section R316 – 2009 through 2021 IRC
    - Section R314 – 2003 and 2006 IRC
    - Section R318 – 2000 IRC
- The provisions and requirements of IBC 2603 and IRC R303 are predominantly related to fire safety.
- IBC Chapter 26, IBC 2603 and IRC R303 are regularly referenced throughout the IBC/IRC when the use of foam plastic is permitted.

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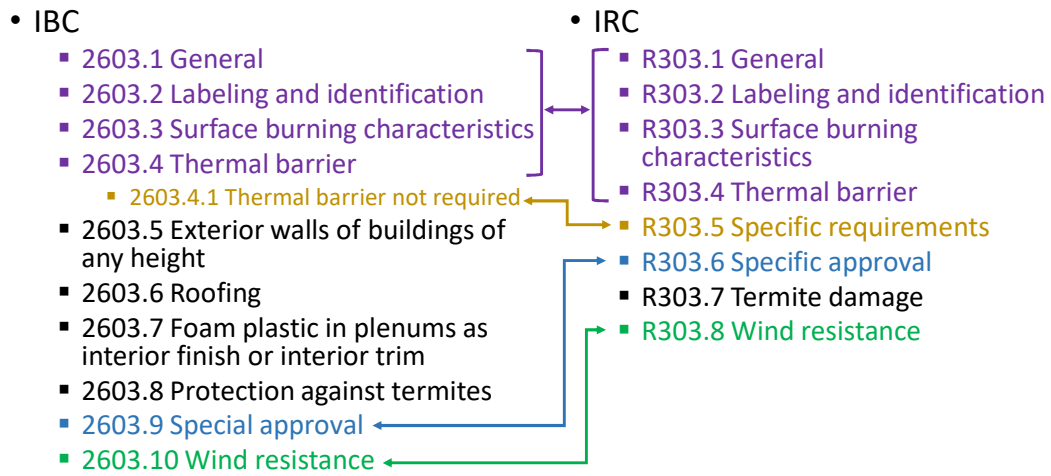
D. IBC/IRC Fire Safety - General



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D. IBC/IRC Fire Safety - General

- IBC & IRC begin with two, base requirements for all products & uses:
  - Material – Surface burning characteristics – IBC 2603.3 / IRC R303.3
  - Design – Thermal barrier protection – IBC 2603.4 / IRC R303.4
- Other IBC/IRC sections modify or add requirements depending on the specific use; e.g., different elements of the building thermal envelope:
  - Exterior wall assemblies
  - Roof assemblies and/or roof coverings
  - Attics, crawl spaces, foundations
  - Fire-resistance-rated assemblies

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D. IBC/IRC Fire Safety - General

- Both IBC & IRC require labeling of foam plastic / foam plastic insulation.
  - Labeling and Identification – IBC 2603.2 / IRC R303.2

    "Packages and containers of *foam plastic insulation* and *foam plastic insulation* components delivered to the job site shall bear the *label* of an *approved agency* showing the manufacturer's name, product listing, product identification and information sufficient to determine the end use will comply with the code requirements."
- Fire test performance is a very common within the labeling of foam plastic / foam plastic insulation.
  - Comes in the form of listing reports and code evaluation reports published by accredited third-party organizations to online directories.

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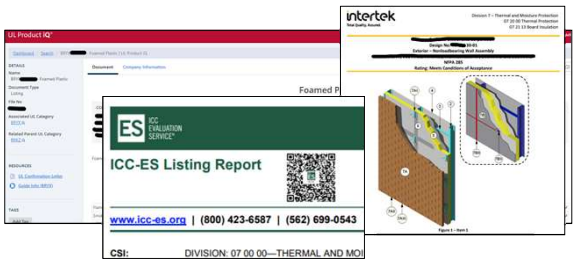
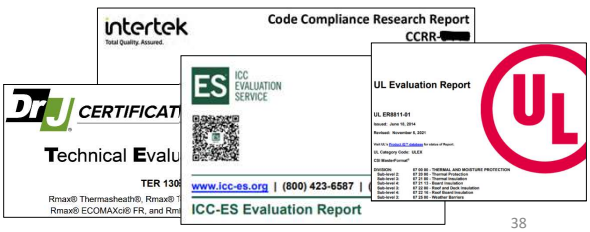
D. IBC/IRC Fire Safety - General

- Listing Reports
  - Describe how a product performs in specific, identified tests; e.g., ASTM E84, NFPA 285, UL 263, etc.
  - Depending on the test, the listed performance may apply to the product itself or for an assembly that contains the product.
- Code Evaluation Reports
  - Describe how a product complies with requirements of identified codes; e.g., IBC, IRC, IFC, IECC, etc.
  - Fire performance and associated code provisions are a key component of code evaluation reports for foam plastic and foam insulations.





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D. IBC/IRC Fire Safety - General

- Important items to remember regarding fire performance testing of foam plastic and foam plastic insulation
  - The as-tested thickness and density of foam plastic are typically considered worst-case for fire testing and subsequently become maximum quantities recognized.
    - This is the case for both material and assembly fire tests.
    - IBC and IRC requirements often include language regarding foam thickness and density.
  - Additionally, in fire tests of assemblies:
    - The observed performance is limited to the materials tested, in the configuration tested.
    - There are opportunities for qualified persons to extend test results/data to assemblies that are based on (i.e., similar to) the tested assembly.
  - Listings and code evaluation reports from *approved agencies* will include information regarding limitations to recognized thickness, density, and assembly configurations.

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D. IBC/IRC Fire Safety - General

- Examples of limitations to thickness / density;
  - Surface burning characteristics – IBC 2603.3 / IRC R303.3
    - Test is ASTM E84 or UL 723.
    - Flame Spread Index (FSI) </= 75.
    - Smoke Developed Index (SDI) </= 450.
    - When tested at the maximum thickness intended for use.
  - Both IBC/IRC sections include provisions when foam thickness exceeds 4 inches.
    - Related to certain uses / conditions.
    - Incorporates large-scale tests in addition to ASTM E84 / UL 723.
  - The IBC includes several exceptions that modify / add to the base requirements:
    - When used as interior trim.
    - When used in certain cold-storage buildings.
    - When a part of a certain Class A, B, or C roof covering assemblies.
    - When intended use is greater than 4 inches.
    - When used in certain interior signs.
  - The IRC provides an exception that allows thickness >4 in. if FSI </=25 and SDI </= 450 at 4 inches and the max. density intended for use, and the foam is protected by a thermal barrier* [*-see next slide]

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D. IBC/IRC Fire Safety - General

- For foam plastic and foam plastic insulation, both IBC & IRC require
  - Thermal barrier protection – IBC 2603.4 / IRC R303.4
    - Foam plastic must be separated from the interior of the building by a thermal barrier consisting of…
      - Prescriptive – …min. 1/2 inch (12.7 mm) gypsum wallboard
      - Performance – …a material tested to, and meeting, both the Temperature Transmission Test and Integrity Fire Test of NFPA 275
  - Note the following:
    - IBC also recognizes:
      - *Mass timber* or Heavy timber (HT) in accordance with IBC 2304.1 a prescriptive thermal barriers.
    - IRC also recognizes:
      - Min. 23/32 inch (18.2 mm) *wood structural panel* as a prescriptive thermal barrier.

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D. IBC/IRC Fire Safety - General

- IBC & IRC allow installation of foam plastic ***without*** the prescribed thermal barrier in several specific uses, subject to certain limitations and requirements.

- IBC 2603.4.1 Thermal barrier not required
  - 2603.4.1.1 Masonry or concrete construction
  - 2603.4.1.2 Cooler and freezer walls
  - 2603.4.1.3 Walk-in coolers
  - 2603.4.1.4 Exterior walls, one-story buildings
  - 2603.4.1.5 Roofing
  - 2603.4.1.6 Attics and crawl spaces
  - 2603.4.1.7 Doors not required to have a fire protection rating
  - 2603.4.1.8 Exterior doors in buildings of Group R-2 or R-3
  - 2603.4.1.9 Garage doors
  - 2603.4.1.10 Siding backer board
  - 2603.4.1.11 Interior trim
  - 2603.4.1.12 Interior signs
  - 2603.4.1.13 Type V
  - 2603.4.1.14 Floors
  - 2603.4.1.15 Separately controlled climate structures
- IBC 2603.9 Special approval
- IRC R303.5 Specific requirements
  - R303.5.1 Masonry or concrete construction
  - R303.5.2 Roofing
  - R303.5.3 Attics
  - R303.5.4 Crawl spaces
  - R303.5.5 Foam-filled exterior doors
  - R303.5.6 Foam-filled garage doors
  - R303.5.7 Foam backer board
  - R303.5.8 Re-siding
  - R303.5.9 Interior trim
  - R303.5.10 Interior finish
  - R303.5.11 Sill plates and headers
  - R303.5.12 Sheathing
  - R303.5.13 Floors
- IRC R303.6 Specific approval

New in 2024

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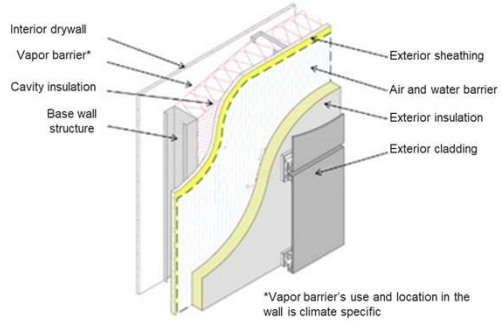
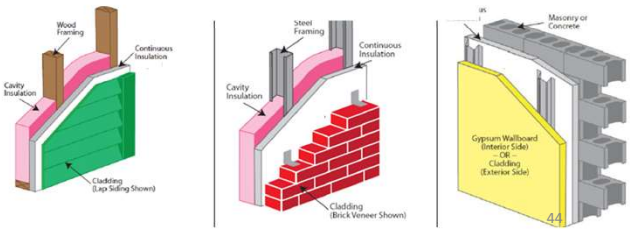
D. IBC/IRC Fire Safety – Exterior Walls

D. IBC/IRC Fire Safety – Exterior Walls

- The IBC has significantly more and detailed fire safety requirements for exterior wall assemblies than the IRC.
- In addition to requirements established by Construction Type classifications, fire safety provisions applicable to exterior wall assemblies are also located in:
  - IBC Chapter 7 Fire and smoke protection features
    - Secs. 703, 705 (705.7.1 [New]), 711, and 718
  - IBC Chapter 14 Exterior walls
    - Secs. 1402.4 through 1402.8, and 1405 through 1409
  - IBC Chapter 26 Plastic
    - Sec. 2603.5

1402.5, 1402.7, 1402.8, and 1409 are New in 2024





D. IBC/IRC Fire Safety – Exterior Walls

- Presence of foam plastic insulation in assemblies often drives / leads requirements for fire testing. (See IBC 2603.5.)
  - IBC 2603.5 Exterior walls of buildings of *any height*
    - 2603.5.1 Fire-resistance-rated walls (ASTM E119 / UL 263)
    - 2603.5.2 Thermal barrier
    - 2603.5.3 Potential heat (NFPA 259)
    - 2603.5.4 Flame spread and smoke developed indices (ASTM E84 / UL 723)
    - 2603.5.5 Vertical and lateral flame propagation (NFPA 285)
    - 2603.5.6 Label required
    - 2603.5.7 Ignition (NFPA 268)
    - Important to know / remember:
      - Sec. 2603.5 requirements supersede other requirements allowing walls up to 40-ft in height without NFPA 285.
      - Different requirements for construction Types I-IV and Type V.
        - Types I-IV ext. walls – Must comply with 2603.5.1 through 2603.5.7.
        - Type V ext. walls – Must comply with *only* 2603.2, 2603.3, and 2603.4.

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D. IBC/IRC Fire Safety – Exterior Walls

- IRC fire safety provision and requirements for exterior wall assemblies are more limited than those in the IBC.
  - Applicable requirements are located in:
    - IRC R303 Foam plastic
    - IRC R302 Fire-resistant construction
      - Largely determined by Fire Separation Distance and the presence or absence of an automatic sprinkler system.
      - Includes fire-resistance ratings, fireblocking, interior finishes, etc.
  - IRC *does not* contain provisions or requirements for resistance to ignition from radiant heat exposure (NFPA 268)

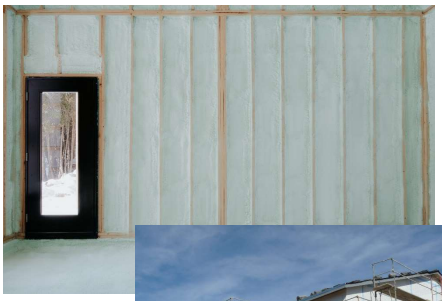

Image courtesy of Huntsman

Image courtesy of Atlas

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D. IBC/IRC Fire Safety – Roofs

D. IBC/IRC Fire Safety – Roofs

- IBC Chapter 15 IBC deals with roof assemblies and rooftop structures
  - IBC 1505
    - Establishes min. fire classifications for roof assemblies for each Construction Type
    - Requires the listing of Class A, Class B, and Class C roof assemblies:
      - Listed assemblies / coverings shall tested in accordance with either ASTM E108 or UL 790.
    - Sec. 1511.9 (New) for *raised-deck systems* installed over roof assemblies.
  - ASTM E108 and UL 790 tests evaluate an exterior fire exposure (i.e., an above-deck fire).

Image courtesy of PIMA

Image courtesy of Huntsman

D. IBC/IRC Fire Safety – Roofs

- Exposure of roof assemblies to interior fires.
  - Thermal barrier
    - IBC 2603.4 requirement applies to roof assemblies.
    - Sec. 2603.4.1.5 permits no thermal barrier if:
      - The foam plastic is part of a Class A, B, or C, roof covering ***and***
      - The foam plastic is separated from the interior by min. 0.47 in (11.9 mm) wood structural panel sheathing with supported edges (blocking, tongue-and-groove joints, other *approved* support), or an equivalent material, ***or***
      - The assembly has been tested and passes either NFPA 276 or UL 1256 (expose under-side of decks).
  - Fire resistance
    - IBC 711 provides additional guidance and requirements applicable to all floor and roof assemblies.

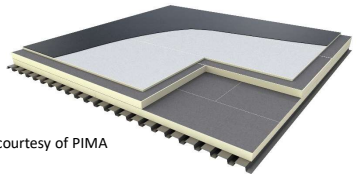

Image courtesy of PIMA

Image courtesy of Atlas

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D. IBC/IRC Fire Safety – Roofs … Attics

- IRC requirements for roofing are less complex than in the IBC.
  - IRC R902 requires Fire Classification (Class A, B, or C) of roof assemblies determined through ASTM E108 or UL 790 tests.
    - *Listing* is required on if the adopting jurisdiction requires.
  - There are no provisions in the IRC for fire-resistance-rated roof assemblies.
- **Note:** If the foam plastic is installed to the underside of the roof deck, then IBC/IRC provisions for interior uses, uses in attics, or enclosed rafter assemblies, as applicable, will govern:
  - IBC 2603
  - IRC R303

Image courtesy of CPI

Image courtesy of Huntsman

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D. IBC/IRC Fire Safety – Foundations

D. IBC/IRC Fire Safety – Foundations

- Where used in or on below-grade foundation walls, there no additional fire tests required beyond the basic requirements of
  - IBC 2603
  - IRC R303
  - Fireblocking

Images courtesy of Atlas

Additional Resources

- North American Modern Building Alliance (NAMBA) –
  - *NAMBA Notes*, articles, whitepapers, and fact sheets - https://www.modernbuildingalliance.us/resources/
  - Education materials – Live and self-paced – https://www.modernbuildingalliance.us/education/
- Center for the Polyurethanes Industry (CPI)
  - *Polyurethane Products: Overview of U.S. Model Building Code Fire Performance Requirements*
  - *Fire Safety Guidelines for Use of Rigid Polyurethane and Polyisocyanurate Foam Insulation in Building Construction*

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III. Residential & Commercial Above-grade Wall Continuous Insulation

A. IECC – Thermal envelope compliance
B. IECC – Thermal bridging compliance
C. IECC/IBC/IRC – Water/Air/Vapor control compliance
D. IBC/IRC – Window installation
E. IBC/IRC – FPIS Wind pressure compliance
F. IBC/IRC – Cladding attachment compliance
G. IBC/IRC – Vinyl siding installation over FPIS
H. IBC/IRC – Wall bracing compliance

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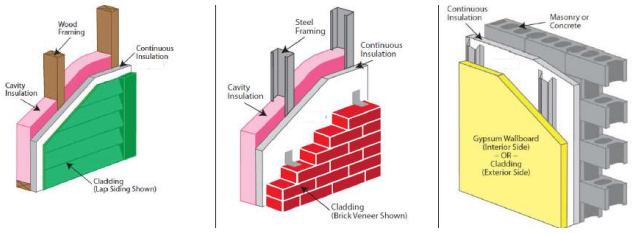
A. IECC – Thermal Envelope Compliance

- Prescriptive R-value & U-factor Requirements
- Insulation Methods



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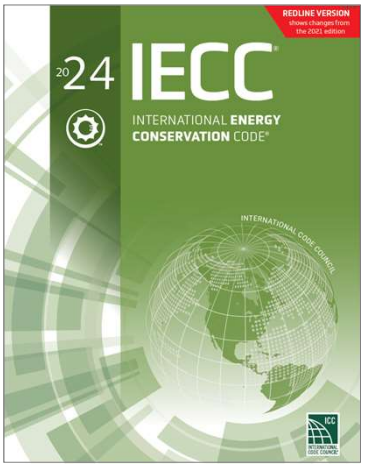

Source: https://codes.iccsafe.org/content/IECC2024P1

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C301 Climate Zone & C302 Design Conditions

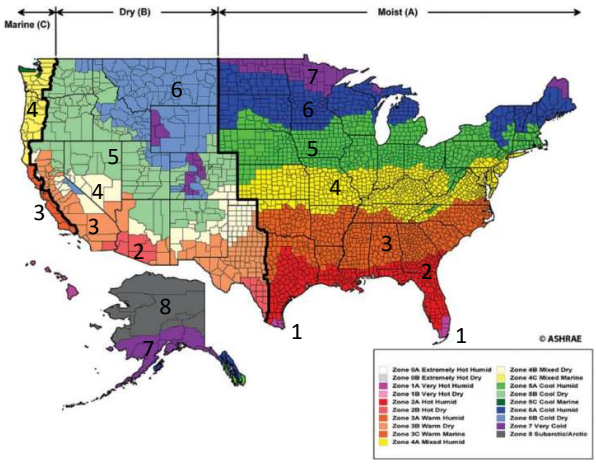

Figure 3.4.2. U.S. Climate Zone Map
(Source: ©ASHRAE www.ashrae.org Standard 169, 2013)

IECC Figure C301.1 & R301.1

SECTION C302
DESIGN CONDITIONS

C302.1 Interior design conditions. The interior design temperatures used for heating and cooling load calculations shall be a maximum of 72°F (22°C) for heating and minimum of 75°F (24°C) for cooling.

Same for IECC-R and IRC Ch.11

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Choose your compliance path

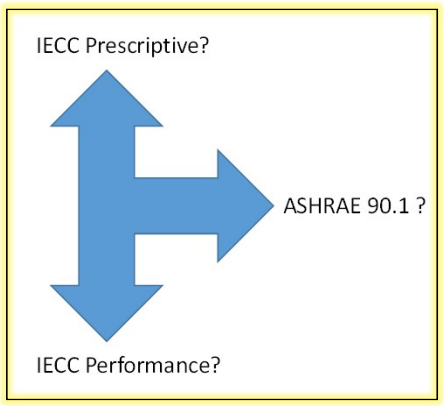
- **C401/R401 International Energy Conservation Code**
  1. Prescriptive Compliance
     For BTE, the following choices:
     - **Prescriptive minimum R-values ←**
     - **Prescriptive maximum assembly U-factor**
     - **Prescriptive component performance trade-offs (i.e. COMcheck)**

     + Additional Efficiency Credits

     OR
  2. Total Building Performance (Section C407/R405) or ERI (R406)

     OR

- **C401.2.2 ASHRAE 90.1-2022 (commercial & residential > 3 stories**
  - Also has prescriptive and performance paths for compliance



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IECC-C Prescriptive R-value & U-factor Requirements for Walls

2024 IECC-C - Tables C402.1.2 & C402.1.3 (prior - Tables C402.1.3 & C402.1.4)

Climate Zone	Building Use	Mass	Metal Framed			Wood Framed		
		2018/2021/2024 IECC	2018 IECC	2021 IECC	2024 IECC	2018 IECC	2021 IECC	2024 IECC
0 and 1	All other	R-5.7ci (U-0.151)	R13+5ci (U-0.077)	R13+5ci (U-0.077)	R0+10ci or R13+5ci or R20+3.8ci (U-0.077)	R13+3.8ci or R20 (U-0.064)	R13+3.8ci or R20 (U-0.064)	R0+12ci or R13+3.8ci or R20 (U-0.064)
	Group R							
2	All other							
	Group R	R-7.6ci (U-0.123)	R13+7.5ci (U-0.064)					
3	All other			R13+7.5ci (U-0.064)	R0+12.6ci or R13+7.5ci or R20+6.3ci (U-0.064)			
	Group R	R-9.5ci (U-0.104)						
4 Except Marine	All other							
	Group R	R-11.4ci (U-0.090)						
5 and Marine 4	All other			R13+10ci (U-0.055)	R0+15.2ci or R13+10ci or R20+9ci (U-0.055)		R13+7.5ci or R20+3.8ci (U-0.051)	R0+16ci or R13+7.5ci or R20+3.8ci or R27 (U-0.051)
	Group R	R-13.3ci (U-0.080)				R13+7.5ci or R20+3.8ci (U-0.051)		
6	All other			R13+12.5ci (U-0.049)	R0+17.3ci or R13+12.5ci or R20+11ci (U-0.049)			
	Group R	R-15.2ci (U-0.071)						
7	All other							
	Group R		R13+15.6ci (U-0.052)	R13+15.6ci (U-0.042)	R0+21ci or R13+15.6ci or R20+14.3ci (U-0.042)			
8	All other	R-25ci (U-0.037)	R13+7.5ci (U-0.064)	R13+18.8ci (U-0.037)	R0+24ci or R13+18.8ci or R20+17.5ci (U-0.037)	R13+15.6ci or R20+10ci (U-0.036)	R13+18.8ci (U-0.032)	R0+27.5ci or R13+18.8ci or R20+14ci (U-0.032)
	Group R		R13+17.5ci (U-0.045)					

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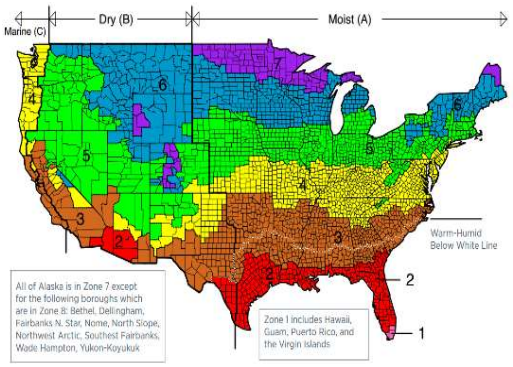
Prescriptive R-value & U-factor Requirements

IECC-R Residential Provisions
Tables R402.1.2 & 402.1.3

Climate Zone	Wood Frame Walls	
	2018 IECC	2021/2024 IECC
0, 1 and 2	R13 (U-0.084)	R13 or R0+10ci (U-0.084)
3	R20 or R13+5ci (U-0.060)	R20 or R13+5ci or R0+15ci (U-0.060)
4 except Marine		R30 or R20+5ci or R13+10ci or R20ci (U-0.045)
5 and Marine 4		
6	R20+5ci or R13+10ci (U-0.045)	
7 and 8		



Source: Energy.Gov Building America Solutions Center

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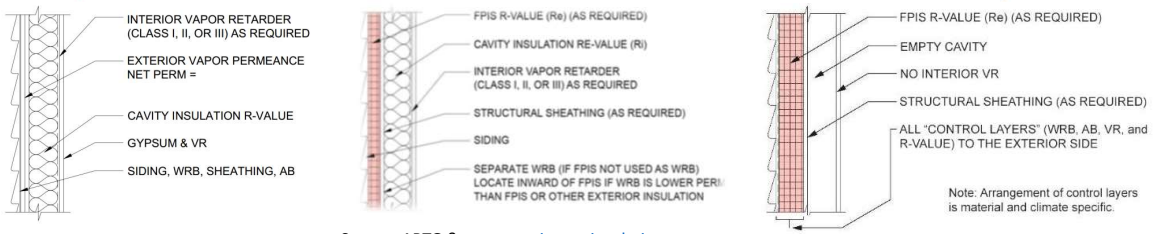
Typical Methods for Insulating *Exterior Walls*

1. ***Cavity insulation only*** (traditional method)
2. ***Cavity insulation + continuous insulation*** (common choice for modern code-compliant or high-performance walls)
3. ***Continuous insulation (ci) only*** (the "perfect wall" with all control layers to the exterior – maximum protection and thermal performance)

CAVITY INSULATION ONLY ➔ CAVITY + CONTINUOUS HYBRID ➔ CONTINUOUS ONLY



Source: ABTG & www.continuousinsulation.org

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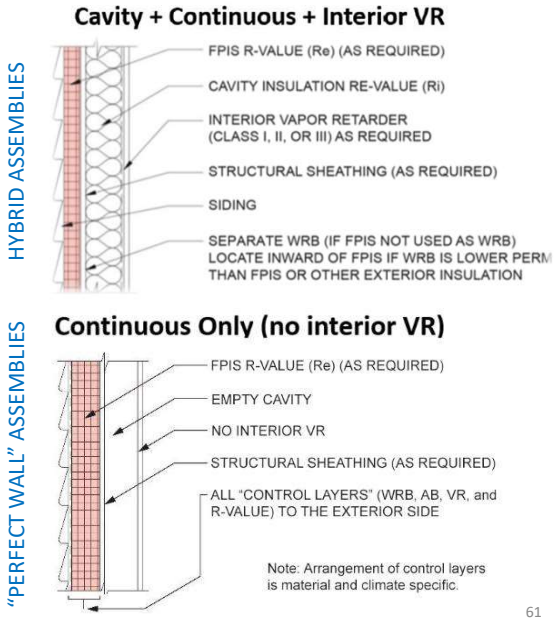
- ***Continuous Insulation*** (ci):
  Insulation that is <u>uncompressed</u>
  …and <u>continuous</u> across
  all structural members
  …<u>without thermal bridges</u>
  other than fasteners and service openings.

  (IBC, IRC, IECC and ASHRAE 90.1 definition)



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Methods for Mass Walls (Concrete & CMU)

- Exterior continuous insulation (ci)
  - ccSPF or FPIS
- Interior continuous insulation (ci)
  - If not continuous due to floor-wall intersections, then must use U-factor to comply and account for floor-wall thermal bridge impact.
- Integral Insulation
  - Cavity insulation in core of blocks (e.g., vermiculite)
  - Continuous insulation in concrete sandwich panel

ccSPF (ci + WRB + AB)
for Masonry Cavity Wall
(school addition)

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Methods for Metal Buildings

- Examples with ci (e.g., FPIS, IMPs or SPF)

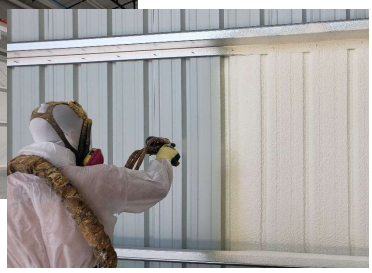
FPIS

DuPont Performance Building Solutions

IMP

Nucor Buildings Group

SPF



Huntsman Building Solutions

- Example with Blankets*

*Blankets are continuously draped over purlins but are compressed at purlins – doesn't meet definition of ci (reduced R-value at purlins)

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Coordinate with Building Code – Vapor Control

- Location and type of insulation in an assembly in coordination with climate and vapor retarder is crucial for water vapor control and moisture management in general.
- This check is important for both commercial and residential buildings (required in IBC and IRC), but only referenced in IECC-R:

> **R402.1.1 Vapor retarder.** Wall assemblies in the *building thermal envelope* shall comply with the vapor retarder requirements of Section R702.7 of the *International Residential Code* or Section 1405.3 of the *International Building Code*, as applicable.

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B. IECC –Thermal Bridging Compliance

- Types of thermal bridges & their impact
- Calculation methodology
- Energy use implications of thermal bridges
- 2021 IECC – Thermal Bridging
- 2024 IECC – Thermal Bridging
- Mitigation methods and details

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Types of Thermal Bridges

Clear-field thermal bridge

Linear thermal bridge

Point thermal bridge

A thermal bridge is not a burning bridge…

Source: Steve Dadds; as published in azfamiliy.com by 3TV/CBS 5, posted Aug. 17, 2015.

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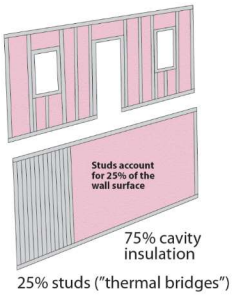
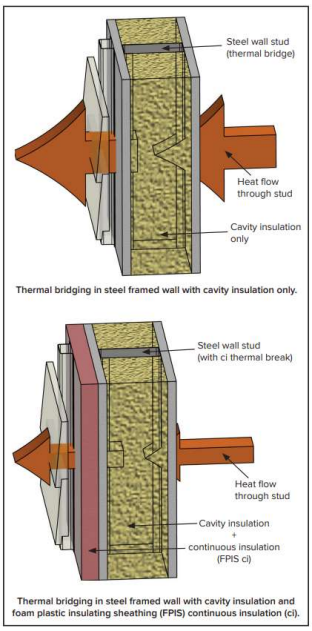
Clear-Field Thermal Bridge

- Thermal pathways inherent to a building assembly and its surface area
  - Generally accounted for in U-factor calculations, R-value prescriptions, and assembly thermal test methods for energy code compliance.
  - Examples: Wood and steel studs and plates (framing), headers, webs of concrete blocks, etc.
- Impact:
  - For example, cavity insulation in steel framing is only ~35-50% effective (more than 50% loss of nominal R-value)
    - R-21 cavity insulation has effective R-7.4 to 9.0 for 16"oc and 24"oc framing (studs & tracks only)
  - For comparison, cavity insulation in wood framing is about 85% effective
- **SOLUTION:** Continuous insulation mitigates heat loss through framing "clear-field" thermal bridges





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Clear-Field Thermal Bridge – Wood Frame Wall Comparison

	U-factor Comparison		
Wall Component	R20	R25	R20+5ci
Outside winter air	0.17	0.17	0.17
Siding	0.62	0.62	0.62
Continuous insulation	0	0	5
OSB - 7/16	0.62	0.62	0.62
SPF stud	6.875	6.875	6.875
SPF header	6.875	6.875	6.875
Cavity insulation	20	25	20
1/2 drywall	0.45	0.45	0.45
Inside air film	0.68	0.68	0.68
R-value stud path	9.42	9.42	14.42
R-value header path	9.42	9.42	14.42
R-value cavity path	22.54	27.54	27.54
Framing factor - studs	21%	21%	21%
Framing factor -header	4%	4%	4%
Framing factor - cavity	75%	75%	75%
U-factor	**0.060**	**0.054**	**0.045**
Effective R of wall	**17**	**19**	**22**

R25 ≠ R20 + 5ci
(U-0.054 > U-0.045)

The R20+5ci wall is 15% more efficient (less conductive) than the R-25 wall.

This demonstrates that R-value of cavity and continuous insulation cannot be added (and this is prohibited as a means of compliance).

Source: Dryvit/Dow

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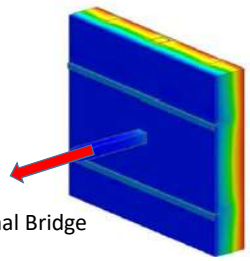
2024 IECC Definitions

- **THERMAL BRIDGE.** An element or interface of elements that has a higher thermal conductivity than the surrounding *building thermal envelope*, which creates a path of least resistance for heat transfer.
- **CHI-FACTOR (χ-FACTOR).** The heat loss factor for a single thermal bridge characterized as a **point element** of a *building thermal envelope* (Btu/h x °F)[W/K].
- **PSI-FACTOR (ψ-FACTOR).** The heat loss factor per unit length of a thermal bridge characterized as a **linear element** of a *building thermal envelope* (Btu/h × ft × °F)[W/(m × K)].

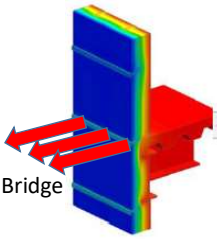


Point Thermal Bridge

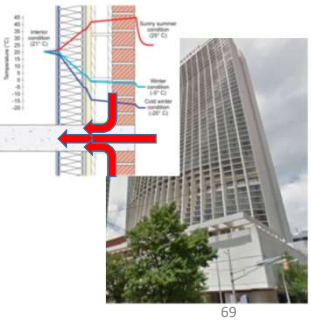
Point Element

Source: Morrison Hershfield LTD
ASHRAE RP 1365

Photo by Shaunna Mozingo



Linear Thermal Bridge



Linear Element

Source: Morrison Hershfield LTD
ASHRAE RP 1365

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What are the building energy use implications of unaccounted thermal bridges?

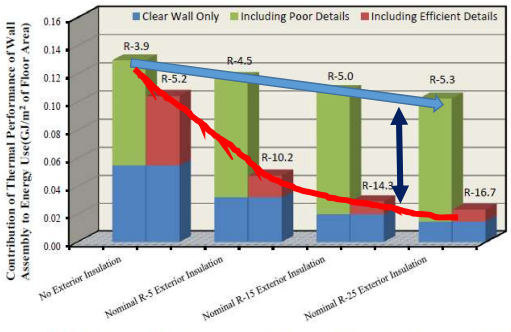

Figure 4.7: Additional building energy use based on thermal performance of the building wall assembly for varying amounts of nominal exterior insulation for a mid-rise MURB in Edmonton (overall assembly thermal resistance in ft²·°F·h/Btu also given)

Source: Morrison Hershfield Ltd

- Unaccounted thermal bridges can result in significantly over-estimated building performance (under-estimated energy use).
- Inaccurate heating and cooling loads for HVAC equipment sizing
- Moisture problems (condensation, corrosion, mold, rot).
- Diminished effective R-value of insulation materials (devalues insulation to extent bridged)
- Use of continuous insulation with good detailing to mitigate thermal bridges is key to meeting intended performance.

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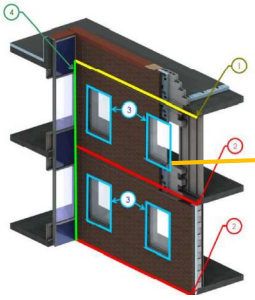
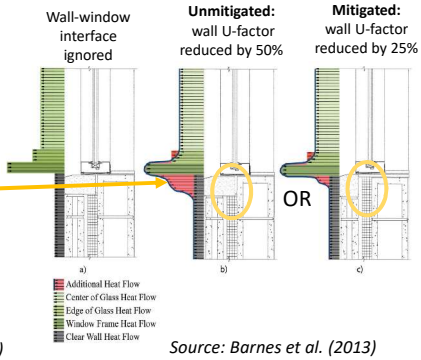
Thermal Bridging Impacts of Window-Wall Interface

- Linear thermal bridge around perimeter of window opening
  - Not accounted for in window component U-factor
  - Not accounted for in wall clear-field assembly U-factor



Source: Morrison-Hershfield (2020)



Source: Barnes et al. (2013)

Comparison of "Poor" and "Efficient" Thermal Bridging Details at the Window-to-Wall Interface[1]

Thermal Bridge Condition		Clear-field Wall Thermal Performance (R13+7.5ci steel frame)[2]		Adjusted Wall Thermal Performance including Window-Wall Interface		Reduction in Wall Thermal Performance
Detailing Practice	Linear Thermal Transmittance (Psi-factor, Btu/hr-ft-F)	U-factor (Btu/hr-ft²-F)	Effective R-value (1/U)	U-factor (Btu/hr-ft²-F)	Effective R-value (1/U)	
"Poor"	0.3	0.064	R-15.6	0.134	R-7.5	52%
"Efficient"	0.1	0.064	R-15.6	0.088	R-11.4	27%

TABLE NOTES:
1. Table is based on a typical 3-story office building (168'x109') with 21,400 sf of gross above-grade wall area of cold-formed steel frame construction having R13 cavity insulation and R-7.5 continuous insulation on the exterior (i.e., R13+7.5ci wall per code as typical for moderate climate zones). The window-to-wall area ratio is assumed to be 33% for ribbon windows or 20% for punched window openings resulting in a total of about 3,200 ft of window perimeter interface with the wall assembly.
2. As a point of reference, a similar wall without the R7.5ci and having only R13 cavity insulation would have a U-factor of 0.125 Btu/hr-ft²-F (effective R-value of 8) because in that case the steel frame thermal bridging in the clear-field of the assembly and at the fenestration perimeter would not be mitigated.

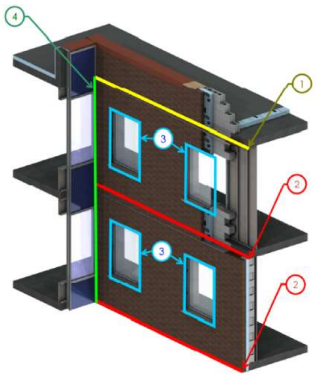
KEY: Continuity of continuous insulation and alignment with fenestration.

2021 IECC - Thermal Bridging

- 2021 IECC Above-grade Wall Definition:

  WALL, ABOVE-GRADE. A wall associated with the *building thermal envelope* that is more than 15 percent above grade and is on the exterior of the building or any wall that is associated with the *building thermal envelope* that is not on the exterior of the building. This includes, but is not limited to, between-floor spandrels, peripheral edges of floors, roof knee walls, dormer walls, gable end walls, walls enclosing a mansard roof and skylight shafts.

- Revised definition clarifies thermal bridges must be considered in determining wall overall U-factor and compliance, usually with one of the following approaches:
  1. Use of ci and appropriate detailing is often the most efficient way to mitigate thermal bridges
  2. Simply adding more insulation to compensate (without mitigating thermal bridges) is another approach, but generally less efficient use of insulation.



Source: BC Hydro BETB Guide / Morrison Hershfield LTD

But, 2021 IECC lacks provisions for implementing this definition

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2024 IECC-C Code Provisions for Thermal Bridging

- **C105.2 Information on construction documents.**
  - Requires thermal bridges per C402.7 to be identified on plans
- **C402.7 Thermal bridges in above-grade walls.**
  - Provides prescriptive insulation & detailing solutions (with exemptions, exceptions, and design alternatives) for:
    - C402.7.1 Balconies and floor decks
    - C402.7.2 Cladding supports
    - C402.7.3 Structural beams and columns
    - C402.7.4 Vertical fenestration
    - C402.7.5 Parapets
    - C402.1.2.1.8 Mechanical equipment penetrations.
    - C402.1.4 Component performance method (includes thermal bridges in envelope trade-offs)
    - Table C407.4.1(1) – includes thermal bridging in whole building simulation

Similar thermal bridging provisions also in ASHRAE 90.1-2022

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Mitigating Clear-Field Thermal Bridges

- Some ways to mitigate clear field thermal bridges include:
  - Reduce "framing factor" where structurally feasible (wider frame spacing, double stud framing, etc.)
  - Use low conductivity structural materials
  - Apply continuous insulation over structure/framing members (minimize discontinuity at floor/wall/roof intersections)
  - Mount metal or wood furring over (not through) continuous insulation layer
  - Use low conductivity fasteners or devices to attach cladding, furring, etc. to framing (e.g., stainless steel, carbon fiber, thermally-broken brick ties, etc.)

Before

Cavity insulation only

After

Cavity + Continuous Insulation

Source: Dryvit/Dow

https://www.trufastwalls.com/thermal-grip-masonry-veneer-anchor

Fig1: Solid metal fastening solution

Fig. 2: Version with plastic sleeve and shorter fastener

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Mitigating the Big Point Thermal Bridges

- Some ways to mitigate point thermal bridges include:
  - Minimize penetrations of high thermal conductivity materials through the building envelope.
  - Encapsulate the penetrating element with insulation for at least 2 feet inward or outward from the envelope.
  - Use lower conductivity materials
    - Stainless steel
      - 3x lower thermal conductivity than carbon steel
      - 5x lower thermal conductivity than aluminum
      - More durable (benefit for cladding attachments)
  - Various proprietary thermal break materials and devices (carbon fiber, fiberglass, structural thermal breaks, etc.)

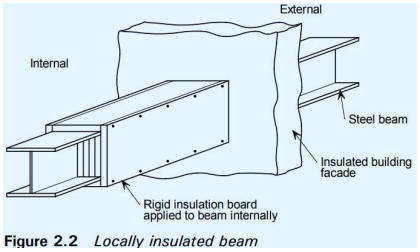
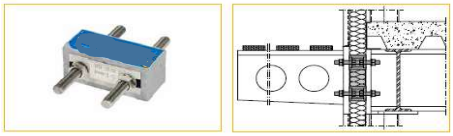


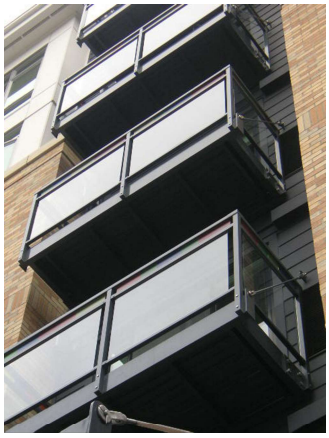
Figure 2.2 *Locally insulated beam*

Avoidance of Thermal Bridging in Steel Construction
https://www.steelconstruction.info/images/5/53/SCI_P380.pdf



Structural thermal block for steel beam projections through building envelope Source: Google search

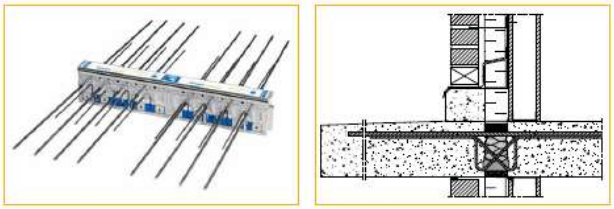
Examples of Mitigated Linear Thermal Bridges (Balconies)



Suspended and separately supported balconies with shear tab or offset shelf-angle point connection to building

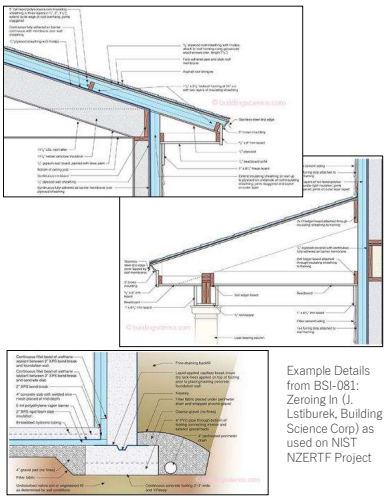
OR…

Cantilevered Balcony Structural Thermal Break

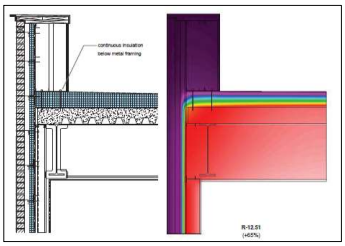


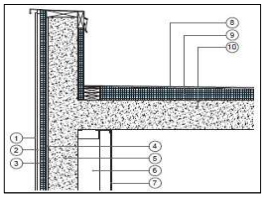
Source: Google search

More Examples of Mitigated Linear Thermal Bridges
(non-exhaustive "commodity" details)

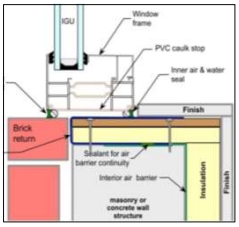


Example Details from BSI-081: Zeroing In (J. Lstiburek, Building Science Corp) as used on NIST NZERTF Project

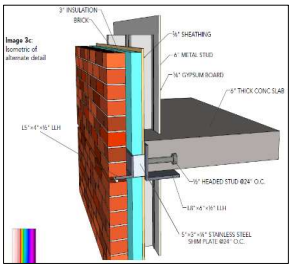




INSULATED PARAPET DETAILS (Payette/AIA report)



INSULATED WINDOW ROUGH OPENING DETAIL (USACE report)



OFFSET SHELF ANGLE (AISC/SEI article)

NOTE: Coordinate detailing at floor-wall and fenestration with NFPA 285 tested assemblies and approved engineering analysis details (applies to Type I-IV buildings, not Type V wood frame).

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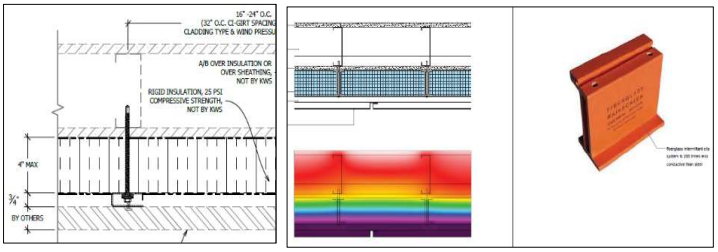
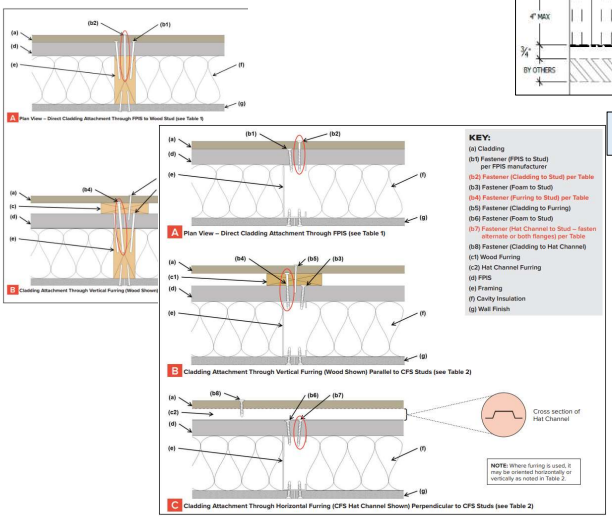
Cladding Connections and Supports





Low thermal conductivity furring/cladding/ledger supports

Sources: Payette/AIA report and product info from Google search

See 2024 IRC Section 703.15/16/17 and IBC Section 1404.5 (formerly 2603.12/.13) for fastening cladding or furring through FPIS ci. Z-furring penetrating through exterior insulation is cavity insulation – doesn't meet continuous insulation definition. See also: https://www.continuousinsulation.org/cladding-connections

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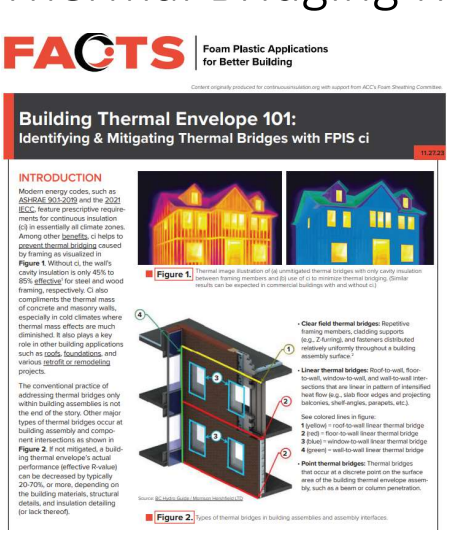
Thermal Bridging Resources

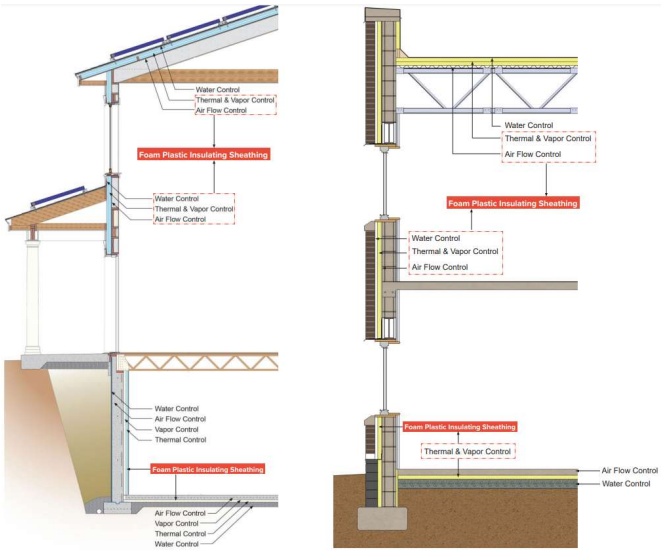

FACTS Foam Plastic Applications for Better Building

Building Thermal Envelope 101:
Identifying & Mitigating Thermal Bridges with FPIS ci

INTRODUCTION

Figure 1

Figure 2



- https://www.continuousinsulation.org/thermal-bridging-prevention

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C. Water/Air/Vapor Control – Code Compliance

i. Fundamentals of moisture control
ii. Water Vapor Control
iii. Air Leakage Control (AB)
iv. Rain Water Control (WRB & Flashing)

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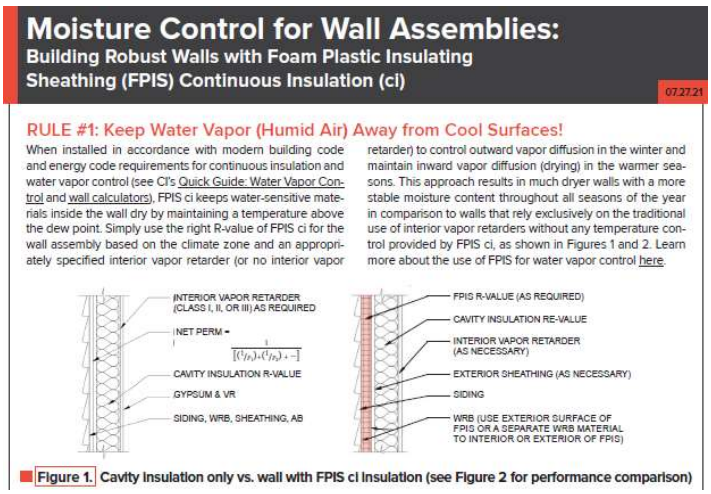
i. Fundamentals of Moisture Control

- Successful moisture control requires an integrated approach to 5 key building science concepts:
  1. **Control Rain Water Intrusion** (e.g., continuous water-resistive barrier (WRB))
  2. **Control Air Leakage** (e.g., continuous air barrier (AB))
  3. **Control Indoor Relative Humidity** (e.g., building ventilation & de-humidification)
  4. **Control Water Vapor** (e.g., optimized balance of wetting and drying through strategic use of insulation and vapor retarders)
  5. **Control Initial Construction Moisture** (e.g., prevent enclosure of wet materials)
- All are important, all vary in significance, all have inter-dependencies.
- These 5 concepts are captured in the following 3 rules:
  1. **Keep water vapor (humid air) away from cool surfaces**
  2. **Minimize air leakage into and through building envelope assemblies**
  3. **Avoid rain water intrusion**

RULE #1 of 3



Moisture Control for Wall Assemblies:
Building Robust Walls with Foam Plastic Insulating Sheathing (FPIS) Continuous Insulation (ci)

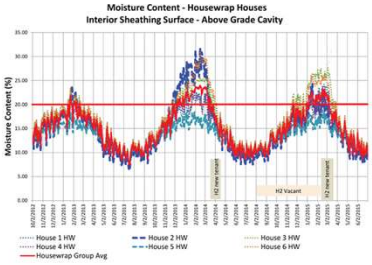
07.27.21

RULE #1: Keep Water Vapor (Humid Air) Away from Cool Surfaces!

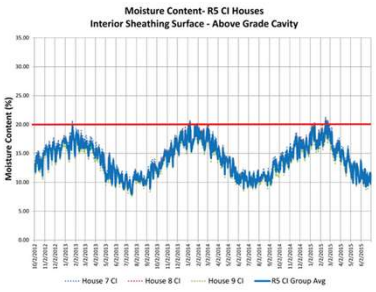
When installed in accordance with modern building code and energy code requirements for continuous insulation and water vapor control (see CI's Quick Guide: Water Vapor Control and wall calculators), FPIS ci keeps water-sensitive materials inside the wall dry by maintaining a temperature above the dew point. Simply use the right R-value of FPIS ci for the wall assembly based on the climate zone and an appropriately specified interior vapor retarder (or no interior vapor retarder) to control outward vapor diffusion in the winter and maintain inward vapor diffusion (drying) in the warmer seasons. This approach results in much dryer walls with a more stable moisture content throughout all seasons of the year in comparison to walls that rely exclusively on the traditional use of interior vapor retarders without any temperature control provided by FPIS ci, as shown in Figures 1 and 2. Learn more about the use of FPIS for water vapor control here.

Figure 1. Cavity Insulation only vs. wall with FPIS ci Insulation (see Figure 2 for performance comparison)

https://www.continuousinsulation.org/resources/facts-ci



(A) Walls with R20 cavity insulation only consistently experiencing wet OSB.



(B) Walls with R5 FPIS ci keeping OSB sheathing dry

Figure 2. Comparison of 12 actual walls with and without R5 FPIS ci

Rule #2 of 3

RULE #2: Minimize Air Leakage!

Leakage of moist air from the indoors or outdoors into or through a building assembly can easily override the function of vapor retarders. Minimize air leakage by following energy code requirements for use of continuous air barriers and sealing of joints and gaps. It's not just an energy code concern (although it does save a lot of energy).

When RULE #1 is followed and the FPIS ci is installed per Figure 3 as a code compliant air barrier, walls are less vulnerable to the consequence of air leakage for two reasons: (1) the FPIS ci will help limit air infiltration from the exterior (especially if it is also used as the WRB system, see RULE #3), and (2) it will also reduce the potential for moist air to condensate on or be adsorbed by moisture-sensitive materials inside the wall because it controls the temperature of those materials. Find more information on use of FPIS as an air barrier here.

https://www.continuousinsulation.org/resources/facts-ci

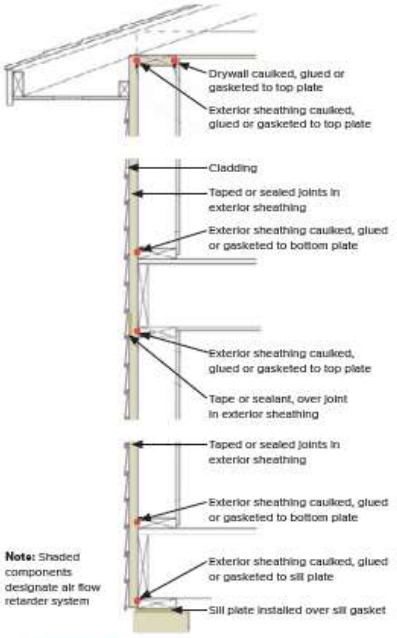


Figure 3. FPIS ci installed as an air barrier exterior sheathing.

Rule #3 of 3

RULE #3: Avoid Rain Water Intrusion!

Most importantly, keep rain water out of walls by proper use of cladding, drainage, water-resistive barrier (WRB), and flashing as required by the building code and good practice. Many FPIS ci products can be used as a code-approved WRB system when installed in accordance with the manufacturer's installation instructions. Approved FPIS WRB systems use durable joint treatments (e.g., joint tapes) and flashing materials (e.g., adhered or fluid-applied flexible flashings) as shown in Figure 4. FPIS WRB systems are subject to some of the most stringent wall assembly water-resistance test requirements. Find more information on FPIS WRB systems here.

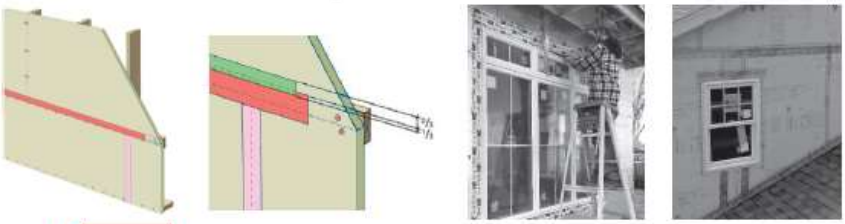


Figure 4. FPIS WRB System installation using joint tapes and adhered flashings; refer to manufacturer installation instructions for specific details.

https://www.continuousinsulation.org/resources/facts-ci

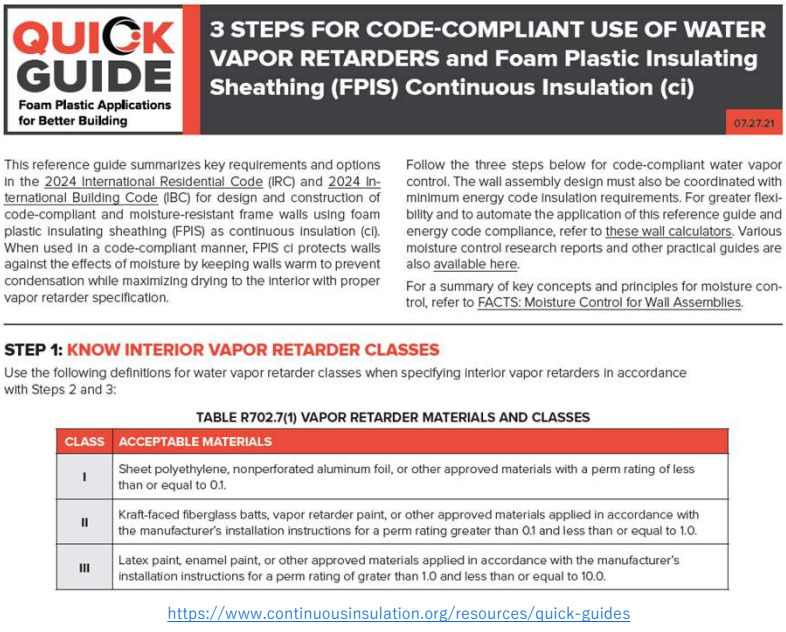
ii. Water Vapor Control

- IBC Section 1404.3 Vapor Retarders
- IRC Section R702.7 Vapor Retarders
- 2021 code includes major improvements
- 2024 code includes some incremental enhancements/options
- Water vapor control per building code must be coordinated with energy code insulation requirements
  - Insulation and vapor retarders work together and vary in application by climate
  - The code has taken a complicated building science matter and simplified it into prescriptive rules or “look-up” tables
  - Use of continuous insulation provides a simple and robust way to address thermal and water vapor control performance

3-Step Guide for Water Vapor Control Code Compliance

(based on 2024 IBC/IRC)

Satisfies Rule #1 of 3 – Keep Water Vapor Away from Cool Surfaces



QUICK GUIDE
Foam Plastic Applications for Better Building

3 STEPS FOR CODE-COMPLIANT USE OF WATER VAPOR RETARDERS and Foam Plastic Insulating Sheathing (FPIS) Continuous Insulation (ci)

07.27.21

This reference guide summarizes key requirements and options in the 2024 International Residential Code (IRC) and 2024 International Building Code (IBC) for design and construction of code-compliant and moisture-resistant frame walls using foam plastic insulating sheathing (FPIS) as continuous insulation (ci). When used in a code-compliant manner, FPIS ci protects walls against the effects of moisture by keeping walls warm to prevent condensation while maximizing drying to the interior with proper vapor retarder specification.

Follow the three steps below for code-compliant water vapor control. The wall assembly design must also be coordinated with minimum energy code insulation requirements. For greater flexibility and to automate the application of this reference guide and energy code compliance, refer to these wall calculators. Various moisture control research reports and other practical guides are also available here.

For a summary of key concepts and principles for moisture control, refer to FACTS: Moisture Control for Wall Assemblies.

STEP 1: KNOW INTERIOR VAPOR RETARDER CLASSES

Use the following definitions for water vapor retarder classes when specifying interior vapor retarders in accordance with Steps 2 and 3:

TABLE R702.7(1) VAPOR RETARDER MATERIALS AND CLASSES

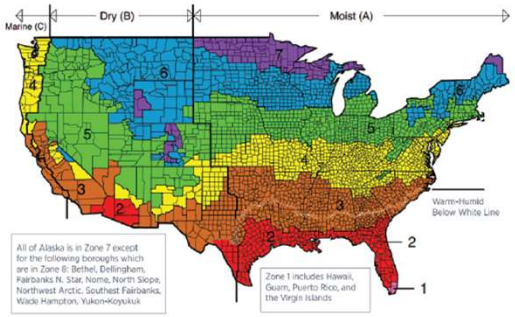
CLASS	ACCEPTABLE MATERIALS
I	Sheet polyethylene, nonperforated aluminum foil, or other approved materials with a perm rating of less than or equal to 0.1.
II	Kraft-faced fiberglass batts, vapor retarder paint, or other approved materials applied in accordance with the manufacturer’s installation instructions for a perm rating greater than 0.1 and less than or equal to 1.0.
III	Latex paint, enamel paint, or other approved materials applied in accordance with the manufacturer’s installation instructions for a perm rating of grater than 1.0 and less than or equal to 10.0.

https://www.continuousinsulation.org/resources/quick-guides

3-Step Guide (cont'd)

STEP 2: CONSIDER PERMITTED INTERIOR VAPOR RETARDERS

Select a "permitted" vapor retarder for the interior side of frame walls based on the Climate Zones as outlined in IRC Table R702.7(2), paying attention to footnotes and other table references. In Climate Zones 4-8, no interior vapor retarder is required where complying with Table R702.7(5).



U.S. Climate Zones

RESPONSIVE VAPOR RETARDER is defined as a "material complying with a *vapor retarder class* of Class I or Class II but which also has a vapor permeance of 1 perm or greater in accordance with ASTM E96, water method (Procedure B)."

TABLE R702.7(2) VAPOR RETARDER OPTIONS

CLIMATE ZONE	VAPOR RETARDER CLASS		
	CLASS I[a]	CLASS II[a]	CLASS III
1, 2	Not Permitted	Not Permitted	Permitted
3, 4 (except Marine 4)	Not Permitted	Permitted[c]	Permitted
Marine 4, 5, 6, 7, 8	Permitted[b]	Permitted[c]	See Table R702.7(3)

a. A responsive vapor retarder shall be allowed on the interior side of any frame wall in all climate zones.

b. In frame walls, use of a Class I interior vapor retarder that is not a responsive vapor retarder on the interior side with a Class I vapor retarder on the exterior side shall require an approved design.

c. Where a Class I or II vapor retarder is used in combination with foam plastic insulating sheathing or insulated siding installed as continuous insulation on the exterior side of frame walls, the continuous insulation shall comply with Table R702.7(4) and the Class I or II vapor retarder shall be a responsive vapor retarder.

3-Step Guide (cont'd)

- **Example 1:** CZ 5 with Class III VR
  - IRC Table R702.7(3) or IBC 1404.3(3):
  - Use min. R-5ci on a R13 2x4 wood frame wall (e.g., R13+5ci)
    - Energy code requires R13+7.5ci (OK, exceeds minimum Ci R-value for vapor control)
  - Use min. R-7.5ci on a R20 2x6 wood frame wall
    - Exceeds energy code R20+3.8ci which doesn't work for vapor control (unless flash & batt in cavity, e.g., R13 batt + R7 ccSPF in cavity with R3.8ci on exterior)
    - Alternatively consider using Class I or II RVR (Example 2)
- **Example 2:** CZ 5, Class I or II Responsive Vapor Retarder
  - IRC Table R702.7(4) or IBC Table 1404.3(4):
  - Use min. R-5ci on 2x6 wall with R20 cavity (e.g., R20+5ci wall)
  - Exceeds minimum energy code for 2x6 WFW (i.e., R20+3.8ci) and could use R19+5ci to get closer to minimum energy code (by equivalent U-factor compliance)
  - Class I or II VR must be "responsive vapor retarders" (RVR) to minimize outward diffusion wetting while promoting inward diffusion drying
    - Class II RVR = kraft paper facer
    - Class I RVR = proprietary membranes
- Generally, steel frame walls require more Ci R-value in energy code and thus usually satisfy these vapor control requirements.

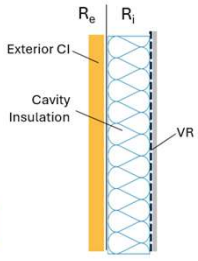
STEP 3: DETERMINE MINIMUM R-VALUE REQUIREMENTS FOR CI

TABLE R702.7(3) CLASS III VAPOR RETARDERS
(only requirements for ci are shown)

CLIMATE ZONE	CLASS III VAPOR RETARDERS PERMITTED FOR:
4 Marine	ci with R-value ≥ 2.5 over 2 x 4 wall
	ci with R-value ≥ 3.75 over 2 x 6 wall
5	ci with R-value ≥ 5 over 2 x 4 wall
	ci with R-value ≥ 7.5 over 2 x 6 wall
6	ci with R-value ≥ 7.5 over 2 x 4 wall
	ci with R-value ≥ 11.25 over 2 x 6 wall
7	ci with R-value ≥ 10 over 2 x 4 wall
	ci with R-value ≥ 15 over 2 x 6 wall
8	ci with R-value ≥ 12.5 over 2 x 4 wall
	ci with R-value ≥ 20 over 2 x 6 wall

TABLE R702.7(4) CONTINUOUS INSULATION (ci) WITH CLASS I or II RESPONSIVE VAPOR RETARDER

CLIMATE ZONE	PERMITTED CONDITIONS
3	ci with R-value ≥ 2
4, 5, 6	ci with R-value ≥ 3 over 2 x 4 wall
	ci with R-value ≥ 5 over 2 x 6 wall
7	ci with R-value ≥ 5 over 2 x 4 wall
	ci with R-value ≥ 7.5 over 2 x 6 wall
8	ci with R-value ≥ 7.5 over 2 x 4 wall
	ci with R-value ≥ 10 over 2 x 6 wall



3-Step Guide (cont'd)

- **Example 3:** CZ 5, No interior vapor retarder, exterior Ci only
  - 2024 IRC Table R702.7(5) or IBC 1404.3(5)
  - Generally, the minimum ci R-values for moisture control are less than the energy code requires for exterior Ci-only walls.
  - Therefore, if complying with energy code minimums these vapor control requirements are met.
- Footnotes are important!
  - There still must be a max 1 perm vapor retarder but on the exterior side of the wall and to the interior side of the Ci insulation, unless the Ci insulation or its interior facer is a vapor retarder.

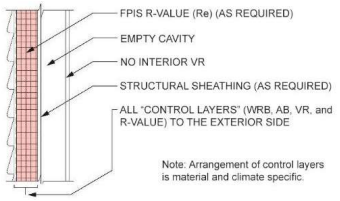
STEP 3: DETERMINE MINIMUM R-VALUE REQUIREMENTS FOR CI

TABLE R702.7(5) CONTINUOUS INSULATION (ci) ON WALLS WITHOUT A CLASS I, II OR III INTERIOR VAPOR RETARDER[a]

CLIMATE ZONE	PERMITTED CONDITIONS[b,c]
4	ci with R-value ≥ 4.5
5	ci with R-value ≥ 6.5
6	ci with R-value ≥ 8.5
7	ci with R-value ≥ 11.5
8	ci with R-value ≥ 14

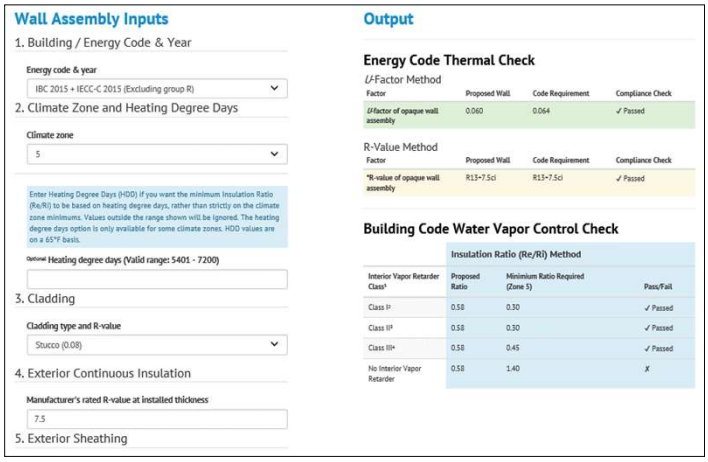
a. The total insulating value of materials to the interior side of the exterior continuous insulation, including any cavity insulation, shall not exceed R-5. Where the R-value of materials to the interior side of the exterior continuous insulation exceeds R-5, an approved design shall be required.

b. A water vapor control material layer having a permeance not greater than 1 perm in accordance with ASTM E96 Procedure A (dry cup) shall be placed on the exterior side of the wall and to the interior side of the exterior continuous insulation. The exterior continuous insulation shall be permitted to serve as the vapor control layer where, as its installed thickness or with a facer on its interior face, the exterior continuous insulation is a Class I or II vapor retarder.



Simplified Energy & Water Vapor Code Compliance

- Implements R-value and U-factor checks per IECC & ASHRAE 90.1
- Vapor control check per IBC/IRC (including insulation ratio and permeance ratio checks)
- Flexible, More Solutions than Code, More Precise
- Wood and Steel framing
- 2-minute wall design and optimization (or compliance check)
- LIVE DEMO…(as time allows)



https://www.continuousinsulation.org/calculators

Optimize energy and building code compliance

- Energy code compliance decisions impact structural framing and moisture control compliance decisions and vice-versa.
- Walls must be treated as integrated, multi-functional systems.

FACTS | Foam Plastic Applications for Better Building

Content originally produced for continuousinsulation.org with support from ACC's Foam Sheathing Committee.

2x4 vs. 2x6 Walls:
Getting the Most Bang for Your Buck with Foam Plastic Insulating Sheathing (FPIS) Continuous Insulation

02.26.21

Is it time to consider returning to a modern version of 2x4 walls?

Table 1. Comparison of 2x6 and 2x4 Wall Construction[1]

Item for Comparison	2x6	2x4	Result
Framing Cost	$$$	$$	2x4 less costly/less wood (verify local lumber pricing)
Framing Code Compliance			
1 story (16"oc or 24"oc)	YES	YES	Both comply, 2x4 uses less wood
2 story (16"oc)	YES	YES	Both comply, 2x4 uses less wood
Wall Bracing	YES	YES	Both comply, no difference
Wall Headers	YES	YES	Both comply, no difference
Energy Code Compliance[2]			
Climate Zone Applicability	1-5	1-5	Both comply in same climates
R-value	R20	R13+5ci	Both comply
U-factor (max. 0.060)	0.060	0.057	Both comply, but R13+5ci is more efficient (lower U-factor)
Air barrier	Wrap w/tape	FPIS w/tape	Both comply
Water & Vapor Control Code Compliance[3]			
Water-resistive barrier (WRB)	Felt/Wrap/Other	FPIS w/tape	Both comply, FPIS w/tape higher performing (see Table 2)
Vapor Retarder	Varies by climate	Varies by climate	FPIS has better water vapor performance (see Figure 2)

https://www.continuousinsulation.org/resources/facts

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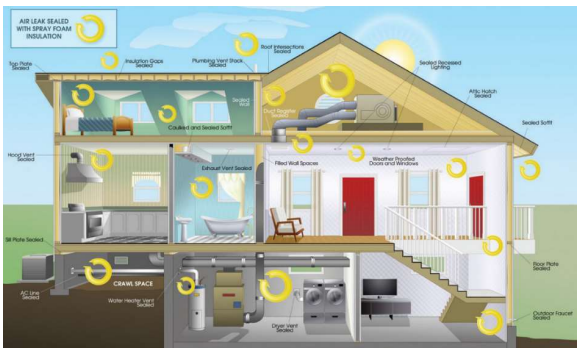
iii. Air Leakage Control

- 2021/2024 IECC-C Section C402.5/C402.6 (testing sometimes, air barrier always)
- 2021/2024 IECC-R Section R402.4/R402.5 (testing always, air barrier always)
  - See code for details for AB installation, test methods (blower door), and maximum leakage rates (cfm/ft^2) or air-changes per hour (ACH)
- *NOTE: While mainly an energy code compliance concern, air barriers also play an important role in control of water vapor in coordination with IBC/IRC vapor retarder provisions.*



https://www.americanchemistry.com/industry-groups/spray-foam-coalition-sfc

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FPIS ci & SPF as Air Barriers

- Air Barrier (AB)
  - Most foam sheathing products meet air barrier material requirements (air permeability test)
    - Check manufacturer data/label
  - IECC C402.5.1.3 lists "deemed-to-comply" products, e.g.:
    - FPIS (XPS and Polyiso of min ½" thick)
    - ccSPF of min. 1.5" thick and 1.5 pcf density
    - ocSPF of min. 4.5" thick and 1.5 pcf density
  - Key to good air barrier system is sealing of joints, penetrations, and transitions.
  - Best practice is dual air barrier to encapsulate air-permeable insulation (if used) – code only requires on one side insulation.
  - Single component/canister SPF is used as an air sealant for joints & cracks (not insulation)

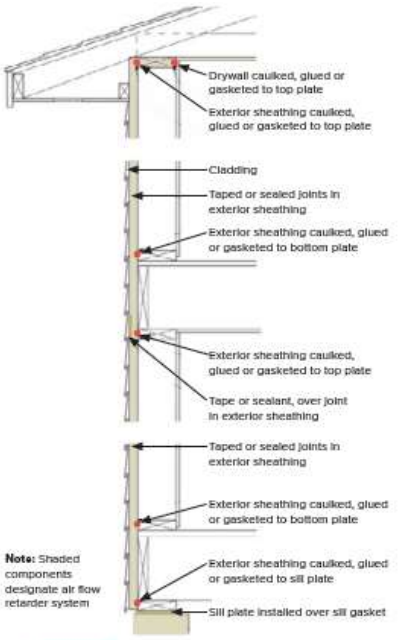

Figure 3. FPIS ci installed as an air barrier exterior sheathing.

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iv. Rainwater Control

- Control of Water Intrusion
- 2024 IBC/IRC Water-resistive Barrier (WRB) requirements
- 2024 IBC/IRC Flashing requirements
- FPIS ci as WRB systems
- Spray foam as WRB

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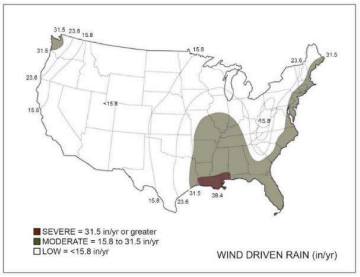
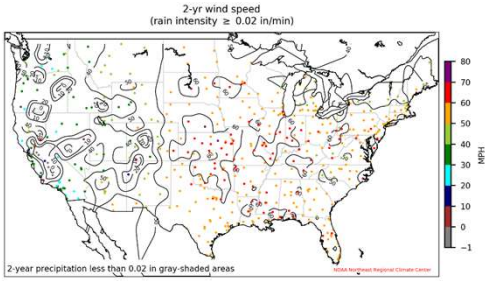
Control of Water Intrusion

- Rain water intrusion is often the primary factor associated with observed failure or success of moisture control
  - Wind driven rain (WDR) is the primary hazard
- If rain water is not adequately controlled, other control measures can be rendered ineffective (air barriers, vapor retarders, drying potential, etc.)
- Concept is simple:
  Keep water out!



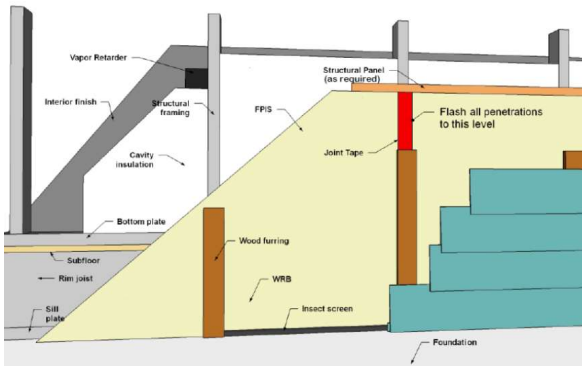
Annual Average Wind Driven Rain Receipt (in/yr)
(map based on UofGA research)
(http://www.huduser.gov/portal/publications/reports/Guide-Durability-by-Design.html)



WDR Hazard Maps for US (2027 IBC/IRC Proposal)
Source: https://journals.ametsoc.org/view/journals/apme/62/7/JAMC-D-22-0156.1.xml

WRB & Flashing Code Requirements

- Use of a code-compliant water-resistive barrier (WRB) and flashing details are required by code (since the 2006 IBC/IRC)
  - Why? We finally learned that claddings and windows leak.
- Code approved methods include:
  - No. 15 felt
  - Grade D paper
  - Various building wraps
  - Sheathing types (e.g., FPIS w/taped joints)
  - ccSPF



https://www.drjengineering.org/report/download/58

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WRB Performance Testing of FPIS WRB Systems

ABTG Research Report No. 1504-03
http://www.appliedbuildingtech.com/rr/1504-03

ASTM E331, 2hrs @ 6.24psf with 5gph/ft^2 spray

No. 15 Felt = 5-7min @ 2.86psf (code benchmark)

Comparison of water resistance tests for WRB materials			
	15# Felt	Housewraps	FPIS
Weathering		✓	✓
AATCC 127		✓	✓
Taped Joints			✓
Full Assembly Water Penetration			✓

Water head test after accelerated aging of tape joint

Foam WRB & Flashing Tape (3-yr exposure)

Tape joints in-service performance (~15 years after install)

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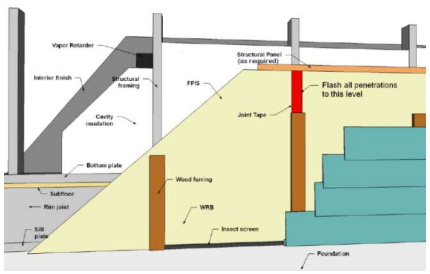
IBC/IRC WRB Code Requirements

IBC 1403.2 / IRC R703.2 Water-resistive barrier. …continuous…flashed… shall comply with one of the following:

1. No. 15 felt complying with ASTM D226, Type 1.
2. ASTM E2556, Type I or II.
3. Foam plastic insulating sheathing water-resistive barrier systems complying with Section 1402.2 and installed in accordance with manufacturer's installation instructions.
4. ASTM E331 in accordance with Section 1402.2.
5. Other approved materials installed in accordance with the manufacturer's installation instructions.

NEW 2024

FPIS ci can be used as WRB, air barrier, and means to control water vapor (multi-functional)



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IRC Flashing Requirements

- **R703.4 Flashing.** Approved corrosion-resistant flashing shall be applied in a manner to prevent entry of water … shall be installed at the following locations: *(various listed)*

- **R703.4.1 Flashing installation at exterior window and door openings.** Flashing at exterior window and door openings shall extend to the **surface of the exterior wall finish** or to a **water-resistive barrier** complying with Section 703.2 for subsequent drainage. **Air sealing** shall be installed around all window and door openings on the interior side of the rough opening gap. … Flashing at exterior window and door openings shall be installed in accordance with one or more of the following:
  1. The **fenestration manufacturer's installation and flashing instructions**, or for applications not addressed in the fenestration manufacturer's instructions, in accordance with **the flashing or water-resistive barrier manufacturer's instructions**. Where flashing instructions or details are not provided, pan flashing shall be installed …
  2. In accordance with the flashing design or method of a **registered design professional**.
  3. In accordance with **other approved methods**.

NEW in 2024 IRC

Pan flashing is not required by code, except in the absence of installation instructions which are required by code. Huh? Sometimes considered a best practice – but only if good air sealing of rough opening.

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IBC Flashing Requirements

2024 IBC Flashing provisions:

1404.4 Flashing. Flashing shall be installed in such a manner so as to prevent moisture from entering the *exterior* wall or to redirect that moisture to the surface of the exterior wall *covering* or to a *water-resistive barrier* complying with Section 1403.2 and that is part of a means of drainage complying with Section 1402.2.

Flashing shall be installed at the perimeters of exterior door and window assemblies in accordance with Section 1404.4.1, penetrations and terminations of *exterior wall* assemblies, *exterior wall* intersections with roofs, … etc.

1404.4.1 Fenestration flashing. Flashing of the fenestration to the wall assembly shall comply with the fenestration manufacturer's instructions or, for conditions not addressed by the fenestration manufacturer's instructions, shall comply with one of the following:

1. The water-resistive barrier manufacturer's flashing instructions;
2. The flashing manufacturer's flashing instructions;
3. A flashing design or method of a registered design professional; or,
4. Other approved methods.

New in 2024 – to match 2024 IRC

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Four WRB strategies with FPIS ci

- Simplest and most efficient solution uses FPIS ci as WRB System
  - Simplifies window flashing for finned fenestration
- Other strategies may be necessary depending on window location (inny vs. outty window) and window, cladding, and trim detailing

WRB Strategy	Pros	Cons
FPIS-ci used as the WRB	1. System resistance to water penetration (highest of all WRB criteria) 2. Simple flashing detailing when used with flanged fenestration units (see STEP 3B). 3. Cost-effective (eliminates a separate WRB material layer) 4. Can be used to effectively control water vapor in coordination with vapor retarder selection (STEP 3C)	1. Only applies to FPIS-ci products that have been tested and approved for WRB application (refer to manufacturer code compliance data - DrJ FSC report). 2. Must use manufacturer specified joint sealing treatments (joint tapes and adhered flashing) 3. Requires proper conditions for application of joint sealing treatments.
Separate WRB layer applied behind FPIS on wall substrate	1. Separate WRB layer is protected by FPIS-ci. 2. With proper R-value of FPIS-ci, the permeance of the WRB and sheathing is less of a concern when coordinated with interior vapor retarder selection (STEP 3C). 3. With reservoir claddings like stucco or adhered veneers the FPIS-ci layer prevents inward vapor drives through higher perm WRBs.	1. Additional cost of WRB separate from FPIS-ci 2. Potential for more complex and less reliable flashing details at windows if flanges are flush with FPIS-ci and back of siding as usually detailed while WRB is recessed from the flange (STEP 3B). 3. May need to use more expensive wrap to create small gap for drainage behind FPIS-ci.
Separate WRB layer applied over FPIS and directly behind cladding	1. Easier to flash windows to WRB if window flanges are placed flush with outside of wall (on plane with FPIS-ci outer surface). 2. Not preferred location for WRB behind stucco and adhered veneers which will prevent drainage unless an additional drainage layer or gap is provided between the WRB and stucco.	1. Additional cost of WRB separate from FPIS-ci 2. Difficulty attaching WRB layer through FPIS-ci layer. 3. WRB should be higher perm than FPIS-ci layer in cold climates or mixed climates. 4. WRB layer is not protected by FPIS-ci. 5. Added metal penetrations/thermal bridges through FPIS-ci layer.
Dual WRB: FPIS-ci is used as the primary WRB layer with a separate WRB layer applied behind FPIS	1. Perhaps the most "fail-safe" installation. 2. Otherwise Pros are similar to Strategy #2.	1. The most costly WRB installation. 2. Otherwise Cons are similar to Strategy #2.

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FPIS ci WRB Systems, Joint Tape, & Flashing

Also serves as air barrier.

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Spray Foam as WRB/AB

- Refer to manufacturer for code-compliance data

Source: BASF

School Addition – Masonry/SPF/Brick cavity wall

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Code-compliant FPIS WRB Systems

- Listing of code-compliant FPIS WRB systems: https://www.drjengineering.org/drr/1410-05
- Resources for use of FPIS ci as a WRB: https://www.continuousinsulation.org/applications/WRB

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ANSI FS200.1 Standard for FPIS ci Applications

- Scope
  - Above-grade frame walls
  - Labeling & Quality Assurance
  - Wind resistance
  - WRB (water resistance)
  - Vapor Control
  - Window installation
  - Cladding installation
- Addresses
  - Performance criteria (design)
  - Evaluation/testing criteria by application
  - Prescriptive criteria (“cook-book” design and installation)
- Exclusions
  - Refer to locally applicable code for fire safety requirements (e.g., IBC Chapter 14 and 26; IRC Section R316)
  - Use FPIS manufacturer data to demonstrate compliance (ASTM E84, ASTM E119, NFPA 285, etc. – as applicable)

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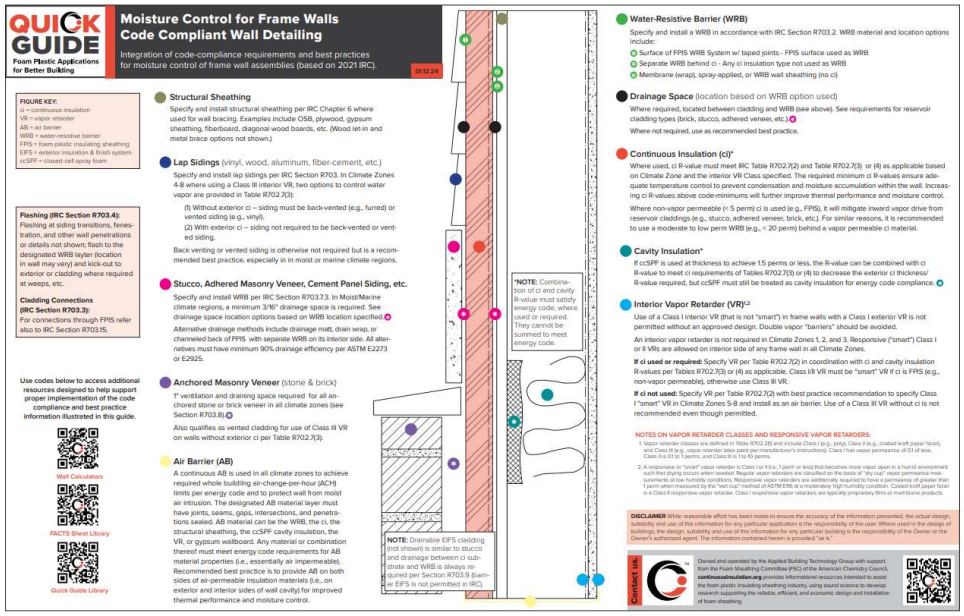
ANSI/ABTG FS200.1 – 2022

Standard for Use of Foam Plastic Insulating Sheathing (FPIS) in Building Envelopes: Above-grade Walls

https://www.appliedbuildingtech.com/standards



https://www.continuousinsulation.org/resources/quick-guides

“Cheat Sheet”

Integrated, Code-Compliant Moisture Control

D. IBC/IRC Fenestration Installation Compliance

- IBC/IRC Code Requirements
- Field Installation Experience
- Installed Performance Testing
- Recommended installation instructions

For more information, refer to:
https://www.continuousinsulation.org/window-installation


ABTG

Research Report

Installation and Performance of Flanged Fenestration Units Mounted on Walls with Foam Plastic Insulating Sheathing

ABTG Research Report No. 2104-01

Conducted for the Foam Sheathing Committee (FSC) of the American Chemistry Council

Report Written by:

Applied Building Technology Group, LLC
appliedbuildingtech.com

Final Report: April 7, 2021

https://www.appliedbuildingtech.com/rr/2104-01

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IBC Code Requirements – Fenestration Install

- 2024 IBC Sections 1404.4 & 1404.13.1
  - Flashing

1404.4.1 Fenestration flashing.

Flashing of the fenestration to the wall assembly shall comply with the fenestration manufacturer's instructions or, for conditions not addressed by the fenestration manufacturer's instructions, shall comply with one of the following:

1. The *water-resistive barrier* manufacturer's flashing instructions.
2. The flashing manufacturer's flashing instructions.
3. A flashing design or method of a *registered design professional*.
4. Other *approved* methods.

  - Structural Support

1404.13.1 Installation. Windows and doors shall be installed in accordance with *approved* manufacturer's instructions. Fastener size and spacing shall be provided in such instructions and shall be calculated based on maximum *loads* and spacing used in the tests.

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IRC Code Requirements – Fenestration Install

- 2024 IRC Sections R609.1 & R703.4.1
  - Flashing & Structural Support

R609.1 General. This section prescribes performance and construction requirements for exterior windows and doors installed in walls. Windows and doors shall be installed in accordance with the fenestration manufacturer's written instructions. Window and door openings shall be flashed in accordance with Section R703.4. Written installation instructions shall be provided by the fenestration manufacturer for each window or door.

R703.4.1 Flashing installation at exterior window and door openings. Flashing at exterior window and door openings shall extend to the surface of the exterior wall finish or to a *water-resistive barrier* complying with Section 703.2 for subsequent drainage. Air sealing shall be installed around all window and door openings on the interior side of the rough opening gap. Mechanically attached flexible flashings shall comply with AAMA 712.

Flashing at exterior window and door openings shall be installed in accordance with one or more of the following:

1. The fenestration manufacturer's installation and flashing instructions, or for applications not addressed in the fenestration manufacturer's instructions, in accordance with the flashing or *water-resistive barrier* manufacturer's instructions. Where flashing instructions or details are not provided, *pan flashing* shall be installed at the sill of exterior window and door openings. *Pan flashing* shall be sealed or sloped in such a manner as to direct water to the surface of the exterior wall finish or to the water-resistive barrier for subsequent drainage. Openings using *pan flashing* shall incorporate flashing or protection at the head and sides.
2. In accordance with the flashing design or method of a *registered design professional.*
3. In accordance with other *approved* methods.

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Field Installation Experience with FPIS ci

- Historically accepted practice (survey actual experience)
  - Dating to the 1970's (~50 years)
- Typical builder experienced with FPIS ci:

  "We have been installing vinyl double pane windows over 1½" XPS foam with no OSB for over six years and before that over 1" foam for almost 30 years and have seen no issues with window movement."
- Other sources indicate similar experience
- Experience from Canada also imported to U.S.

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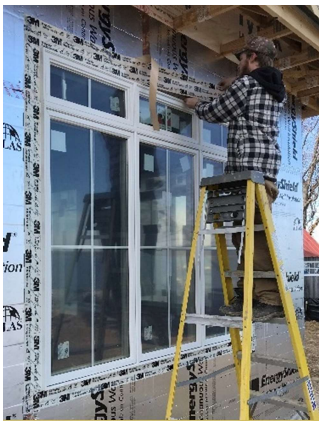
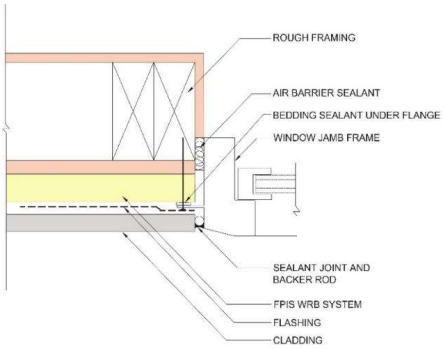
Examples of Historically Accepted Practice (≤ 1.5“ thick FPIS ci)

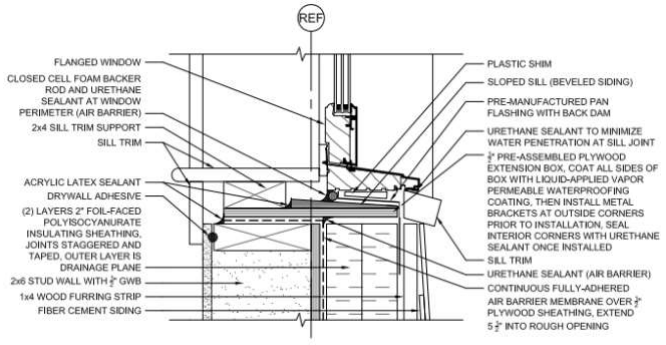




111

Examples of Historically Accepted Practice (> 1.5” thick FPIS ci)

- Plywood window buck with 4"-thick FPIS ci
- 2x wood bucks also used (especially for masonry/concrete construction)
- NOTE: For Type I-IV construction (IBC), the window-wall interface also must comply with NFPA 285 tested assembly and engineering analysis.
  - Applies regardless of FPIS thickness.
  - See examples next two slides.



Source: www.nist.gov/system/files/nzertf-architectural-plans3-june2011.pdf

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Example NFPA 285 Fenestration Rough Opening Details

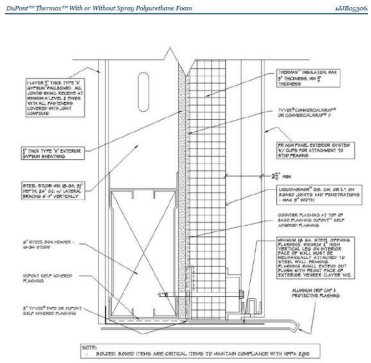


Figure 7. Use of Tyvek® CommercialWrap® or CommercialWrap® D WRB behind Thermax™ insulation

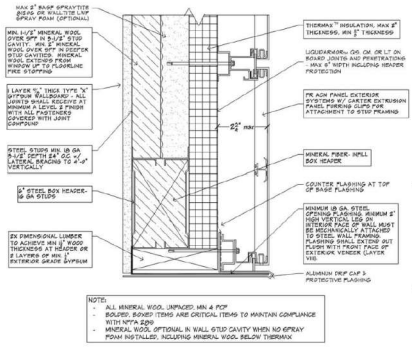
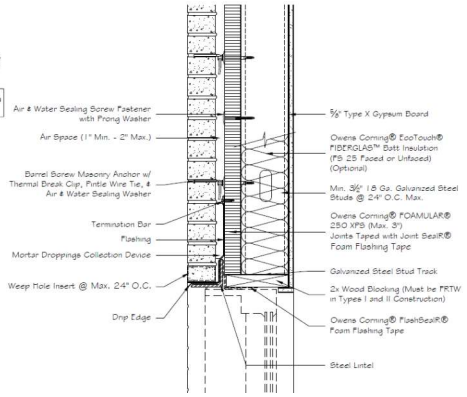


Figure 4 – Required Opening Head Protection When BASF SPRAYTITE® 81206 or Walltite LWP Spray Foam Is Used in the Cavity – OPTION 2

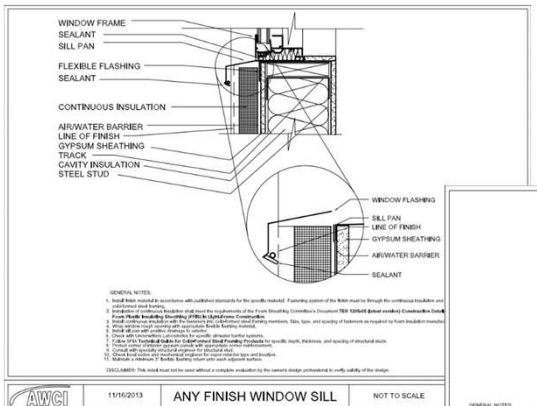
Source: DuPont Building Performance Solutions, Jensen Hughes Engineering Analysis, February 4, 2022

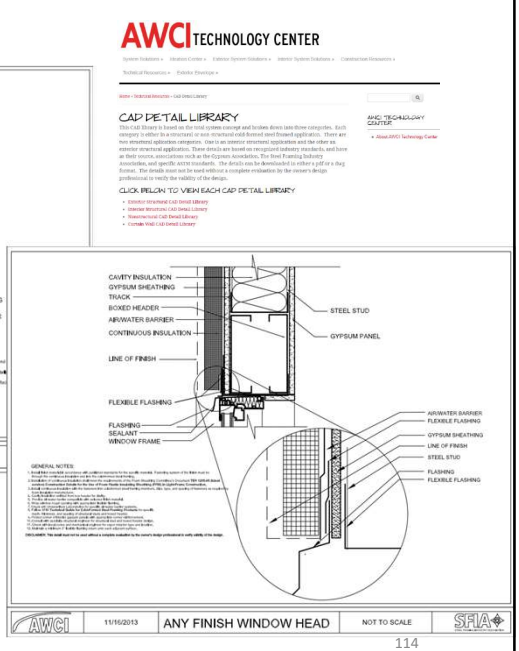


Source: Owens Corning, Enclosure Solutions NFPA 285 Guide, May 2019

Example Details from AWCI/SFIA

- Various CAD details for ci on steel frame wall assemblies





http://www.awcitechnologycenter.org/content/cad-detail-library

Example of “Inny” Window Install

- For any thickness of FPIS
- For block frame and finned windows
- Can be used for new or retrofit (re-siding with added ci)
- Requires use of separate WRB behind FPIS ci flashed to window trim extension (or window fin)

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Installed Performance Testing

- ~150 tests on ~30 wall assembly specimens by two independent sources (HIRL & CBI) funded by DOE and ACC/FSC
- Integrally-flanged window types (SH, DH, C, and HS; vinyl and wood frames; single and mulled; openings up to 6-ft wide; 30 to 400 lb window unit weight)
- Three FPIS types (XPS, EPS, and PIR), 1” and 2" thick, and 15 and 25 psi compressive resistance
- FPIS WRB systems installed and flashed per manufacturers’ specifications
- FGIA/AAMA TIR-504-2020 fenestration installation evaluation method: air leakage ➔ water resistance ➔ thermal cycling ➔ design pressure ➔ repeat water test ➔ structural pressure
- 6-month sustained load/creep tests also conducted

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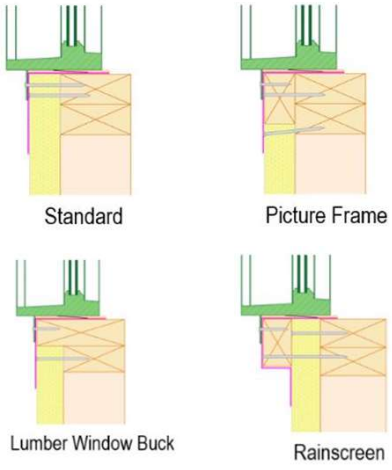
Installed Performance Testing

For more information, refer to:
https://www.continuousinsulation.org/window-installation




ABTG

Research Report

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ABTG Research Report No. 2104-01

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Report Written by:

Applied Building Technology Group, LLC
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Final Report: April 7, 2021

https://www.appliedbuildingtech.com/rr/2104-01

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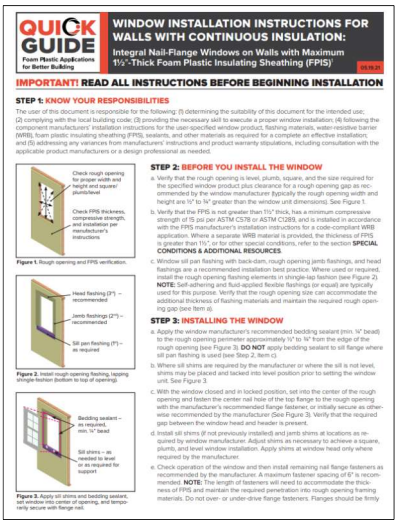
Recommended Installation Instructions

- For FPIS of minimum 15 psi compression resistance and maximum 1.5" thickness:
  - Use fenestration manufacturer shim and fastener schedule
    - Adjust fastener length to maintain embedment in framing
  - Use WRB or window manufacturer flashing instructions
- For FPIS > 1.5" thick:
  - Use window buck or similar support method
    - Some manufacturers offer specialty support brackets
  - Otherwise, same as above for remaining installation details
- For any type and thickness of FPIS: Option to use an "inny" window install
- If window manufacturer instructions address the specific application with FPIS, use those instructions.
- NOTE: If NFPA 285 applies (Type I-IV construction), the window-wall interface must comply with the FPIS manufacturer's tested assembly and engineering analysis, regardless of FPIS thickness.
  - Refer to the manufacturer data and standard details


QUICK GUIDE
Foam Plastic Applications for Better Building

WINDOW INSTALLATION INSTRUCTIONS FOR WALLS WITH CONTINUOUS INSULATION:
Integral Nail-Flange Windows on Walls with Maximum 1½"-Thick Foam Plastic Insulating Sheathing (FPIS)

IMPORTANT! READ ALL INSTRUCTIONS BEFORE BEGINNING INSTALLATION

STEP 1: KNOW YOUR RESPONSIBILITIES

STEP 2: BEFORE YOU INSTALL THE WINDOW

STEP 3: INSTALLING THE WINDOW

For additional information, refer to:
https://www.continuousinsulation.org/applications/window-installation

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ANSI FS200.1 Standard for FPIS ci Applications

- Scope
  - Above-grade frame walls
  - Labeling & Quality Assurance
  - Wind resistance
  - WRB (water resistance)
  - Vapor Control
  - Window installation
  - Cladding installation
- Addresses
  - Performance criteria (design)
  - Evaluation/testing criteria by application
  - Prescriptive criteria ("cook-book" design and installation)
- Exclusions
  - Refer to locally applicable code for fire safety requirements (e.g., IBC Chapter 14 and 26; IRC Section R303)
  - Use FPIS manufacturer data to demonstrate compliance (ASTM E84, ASTM E119, NFPA 285, etc. – as applicable)

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6300 Enterprise Lane
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ANSI/ABTG FS200.1 – 2022

Standard for Use of Foam Plastic Insulating Sheathing (FPIS) in Building Envelopes: Above-grade Walls

https://www.appliedbuildingtech.com/standards

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E. IBC/IRC – FPIS Wind Pressure Compliance

- IBC/IRC Wind pressure requirements for exterior walls and wall coverings
- IBC/IRC wind resistance requirements for FPIS
- FPIS wind pressure testing
- FPIS wind pressure design values & application

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IBC/IRC Wind Resistance Requirements

R703.1.2 Wind resistance. Wall coverings, backing materials and their attachments shall be capable of resisting wind loads in accordance with Tables R301.2.1(1) and R301.2.1(2). Wind-pressure resistance of the siding, soffit and backing materials shall be determined by ASTM E330 or other applicable standard test methods. Where wind-pressure resistance is determined by design analysis, data from *approved* design standards and analysis conforming to generally accepted engineering practice shall be used to evaluate the siding, soffit and backing material and its fastening. All applicable failure modes including bending rupture of siding, fastener withdrawal and fastener head pull-through shall be considered in the testing or design analysis. Where the wall covering, soffit and backing material resist wind load as an assembly, use of the design capacity of the assembly shall be permitted.

1402.3 Structural. *Exterior walls*, and the associated openings, shall be designed and constructed to resist safely the superimposed *loads* required by Chapter 16.

NOTE: This IRC code provision was added to ensure all sheathing materials, claddings, and exterior wall covering products and assemblies have added wind resistance.

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Why is this important?

All wall coverings or sheathings are subject to wind damage if not properly qualified, designed, specified, and installed.

Wood structural panels

Fiber board

Foam sheathing

Etc….

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IBC/IRC Wind Resistance Requirements for FPIS

R303.8* Wind resistance. Foam plastic insulation complying with ASTM C578 and ASTM C1289 and used as exterior wall sheathing on framed wall assemblies **shall comply with SBCA FS 100** for wind pressure resistance unless installed directly over a sheathing material that is separately capable of resisting the wind load or otherwise exempted from the scope of SBCA FS 100.

2603.10 Wind resistance. Foam plastic insulation complying with ASTM C578 and ASTM C1289 and used as *exterior wall* sheathing on framed wall assemblies **shall comply with ANSI/FS 100** for wind pressure resistance.

*R316.8 in 2021 and earlier editions of IRC

https://www.appliedbuildingtech.com/standards

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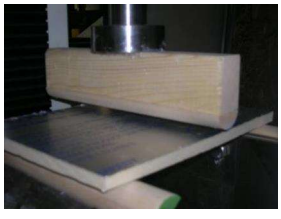
FPIS Wind Pressure & Bending Tests

- Test Program:
  - 6 manufacturers
  - Three foam types
  - Multiple thicknesses
  - 16” and 24” stud spacing
- Also confirmed in full-scale whole building wind tunnel tests
- Data served as basis for developing the FS100 standard referenced in IBC/IRC (similar to DOC PS2 standard for OSB)
- Manufacturer’s individually test to FS100 standard by *approved agency* and report design wind pressure data for code-compliance



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Results – siding removed, only FPIS on exterior

IBHS wind tunnel test
(Photo courtesy of Dave Johnston)

Foam sheathing and taped WRB joints survived exposure to hurricane force winds with no damage (even with siding removed)

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Application of FPIS Design Wind Pressure

- Applies only when foam sheathing is applied as the sole exterior sheathing layer spanning open wall cavities between framing.
  - It must resist out-of-plane components & cladding wind load in this application like any other exterior sheathing
- Not applicable when FPIS is used as under- or over-sheathing with another structural sheathing material separately attached to resist wind load.
- Typically, cladding attachments secure and supplement FPIS installation fasteners
  - FPIS fasteners can be designed to resist wind load independently (using large structural plastic cap washers, metal wind-lock washers, or furring/battens)
- Must refer to manufacturer-specific code compliance data/report.

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Example FPIS Wind Pressure Design Values

- Example *approved agency* data for an FPIS product tested and evaluated in accordance with the FS100 standard.

Specimen	Lot #	Load Values				
		Max Load (psf)	Yield Load (psf)	Allowable Design Wind Pressure Resistance (psf)	*ASCE 7-05* Basic Wind Speed (mph)	*ASCE 7-10* Basic Wind Speed (mph)
1" Greenguard Insulated Board	W320G16	65.8	38.7	38.7	125	160
		68.7	N/A	45.8		
		108.9	59.6	59.6		
		66.7	38.4	38.4		

Specimen	Lot #	Load Values				
		Max Load (psf)	Yield Load (psf)	Allowable Design Wind Pressure Resistance (psf)	*ASCE 7-05* Basic Wind Speed (mph)	*ASCE 7-10* Basic Wind Speed (mph)
2" Greenguard Insulated Board	W214C20	109.0	69.7	69.7	145	180
		109.2	53.7	53.7		
		106.1	67.7	67.7		

Source: https://www.drjengineering.org/resources

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F. IBC/IRC Cladding Attachment Compliance

- Performance Research & Testing
- IBC/IRC Prescriptive Solutions
- Design Procedure for cladding and structural connections through FPIS

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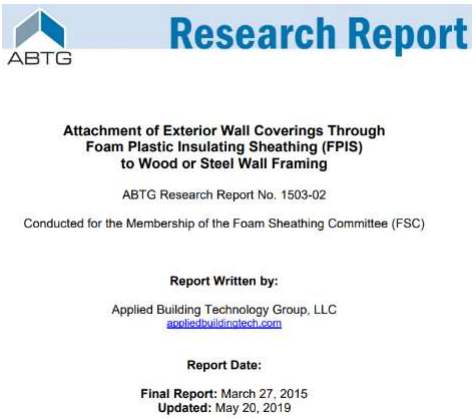
Performance Research & Testing

- Basis for prescriptive requirements in:
  - Section 2603, International Building Code (IBC) – 2012 through 2024 editions
    - **Moved into Chapter 14 Section 1404.5 in 2024 IBC**
  - Section R703.15/.16/.17, International Residential Code (IRC) – 2012 through 2024 editions
- Provides the engineering design procedure supporting the above code provisions



ABTG

Research Report

Attachment of Exterior Wall Coverings Through Foam Plastic Insulating Sheathing (FPIS) to Wood or Steel Wall Framing

ABTG Research Report No. 1503-02

Conducted for the Membership of the Foam Sheathing Committee (FSC)

Report Written by:

Applied Building Technology Group, LLC
appliedbuildingtech.com

Report Date:

Final Report: March 27, 2015
Updated: May 20, 2019

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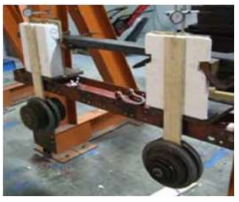
Performance Research & Testing

- Collaborative research
  - FSC, NYSERDA, SFA, BSC for DOE/BA, Newport Partners, ARES/ABTG, etc.
- Extensive testing effort
  - Siding and furring connections
  - FPIS (up to 4” thick)
  - Wood and steel framing
  - Commodity nails, screws, & lags
- Developed design method consistent with NDS and AISI standards
  - DESIGN GOAL: Limit short-term deflection to 0.015" maximum and stabilized creep
- Support:
  - Solutions added to 2015 IBC/IRC
  - Proprietary fastener innovations
  - Used in various cladding and fastener manufacturer installation instructions

Typical Test Set-up



Long term Tests – in Lab & Exposed

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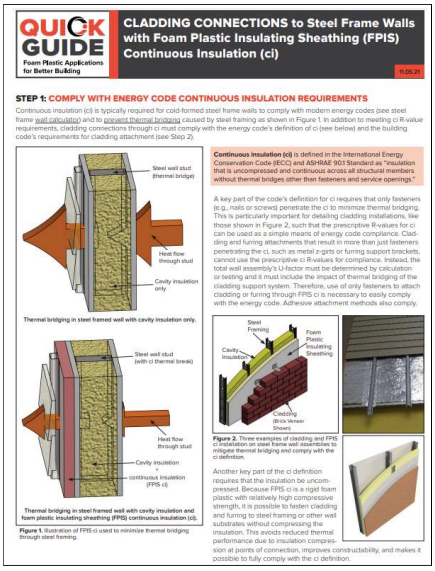
IBC/IRC Prescriptive Solutions

- Prescriptive "Quick Guide" for code compliance
- Applications for wood and steel framed walls:
  1. Direct Cladding Attachment through FPIS ci
  2. Furring Attachment through FPIS ci
  3. Cladding Attachment through FPIS ci to a Wood Structural Panel Substrate
- Not required for separately supported cladding (e.g., anchored masonry veneer)
  - Best practice: use thermally efficient brick ties



QUICK GUIDE
Foam Plastic Applications for Better Building

CLADDING CONNECTIONS to Steel Frame Walls with Foam Plastic Insulating Sheathing (FPIS) Continuous Insulation (ci)

11.05.21

STEP 1: COMPLY WITH ENERGY CODE CONTINUOUS INSULATION REQUIREMENTS

Continuous insulation (ci) is typically required for cold-formed steel frame walls to comply with modern energy codes (see steel frame wall calculator) and to prevent thermal bridging caused by steel framing as shown in Figure 1. In addition to meeting ci R-value requirements, cladding connections through ci must comply with the energy code's definition of ci (see below) and the building code's requirements for cladding attachment (see Step 2).

Steel wall stud (thermal bridge)
Heat flow through stud
Cavity insulation only

Thermal bridging in steel framed wall with cavity insulation only.

Steel wall stud (with ci thermal break)
Heat flow through stud
Cavity insulation + continuous insulation (FPIS ci)

Thermal bridging in steel framed wall with cavity insulation and foam plastic insulating sheathing (FPIS) continuous insulation (ci).

Figure 1. Illustration of FPIS ci used to minimize thermal bridging through steel framing

Continuous insulation (ci) is defined in the International Energy Conservation Code (IECC) and ASHRAE 90.1 Standard as "insulation that is uncompressed and continuous across all structural members without thermal bridges other than fasteners and service openings."

A key part of the code's definition for ci requires that only fasteners (e.g., nails or screws) penetrate the ci to minimize thermal bridging. This is particularly important for detailing cladding installations, like those shown in Figure 2, such that the prescriptive R-values for ci can be used as a simple means of energy code compliance. Cladding and furring attachments that result in more than just fasteners penetrating the ci, such as metal z-girts or furring support brackets, cannot use the prescriptive ci R-values for compliance. Instead, the total wall assembly's U-factor must be determined by calculation or testing and it must include the impact of thermal bridging of the cladding support system. Therefore, use of only fasteners to attach cladding or furring through FPIS ci is necessary to easily comply with the energy code. Adhesive attachment methods also comply.

Steel Framing
Foam Plastic Insulating Sheathing
Cavity Insulation
Cladding (Brick Veneer Shown)

Figure 2. Three examples of cladding and FPIS ci installation on steel frame wall assemblies to mitigate thermal bridging and comply with the ci definition.

Another key part of the ci definition requires that the insulation be uncompressed. Because FPIS ci is a rigid foam plastic with relatively high compressive strength, it is possible to fasten cladding and furring to steel framing or other wall substrates without compressing the insulation. This avoids reduced thermal performance due to insulation compression at points of connection, improves constructability, and makes it possible to fully comply with the ci definition.

https://www.continuousinsulation.org/cladding-connections

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Code Prescriptive Solutions

- General Requirements
  - FPIS minimum 15 psi compressive strength; compliant with ASTM C578 or C1289
  - Also check cladding attachment requirements for wind load, etc. (the more stringent fastening schedule will control)
  - Fastener length must be long enough to accommodate FPIS thickness and maintain required fastener embedment in wood/steel
  - Fastener tightened to draw connected materials together but not distort/compress
  - Connections to masonry/concrete must be approved by alternate means (often proprietary fasteners are used)

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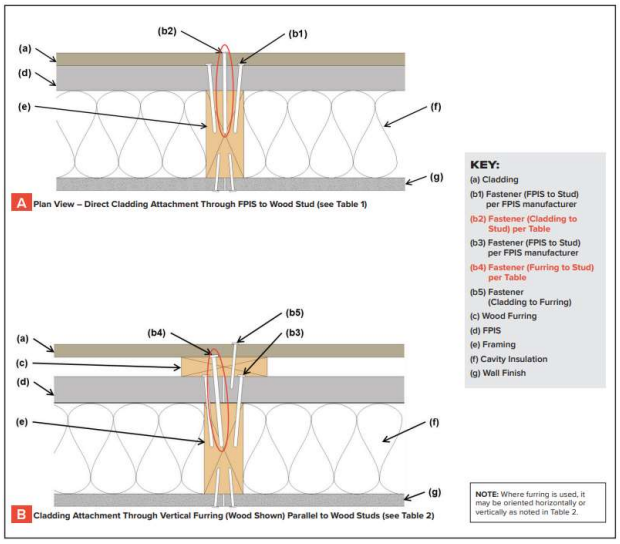
Code Prescriptive Solutions (wood wall framing)

- Applications 1 and 2:
  - Direct cladding attachment
  - Wood furring attachment
- Requirements vary by cladding weight

Typical cladding materials included in the weight classes listed in Tables 1, 2, and 3 are as follows (verify with cladding manufacturer data):[1]

- 3 psf – e.g., wood lap and panel siding, vinyl siding, and most fiber-cement sidings
- 11 psf – e.g., 3-coat Portland cement stucco
- 18 psf – e.g., medium weight adhered stone veneer
- 25 psf – e.g., heavy weight adhered stone veneer



Code Prescriptive Solutions

Table 1. Siding Minimum Fastening Requirements to Wood Framing for Direct Cladding Attachment Over FPIS to Support Cladding System Weight [1,2,3,4]

CLADDING FASTENER THROUGH FPIS INTO:	Siding Fastener Type & Minimum Size	Siding Fastener Vertical Spacing (in.)	MAXIMUM THICKNESS OF FPIS (IN.)							
			16" o.c. Fastener Horizontal Spacing				24" o.c. Fastener Horizontal Spacing			
			CLADDING SYSTEM WEIGHT				CLADDING SYSTEM WEIGHT			
			3 psf	11 psf	18 psf	25 psf	3 psf	11 psf	18 psf	25 psf
Wood Framing (minimum 1¼" penetration)	Nail (0.113" shank; 0.226" head)	6	2.00	1.45	0.75	DR	2.00	0.85	DR	DR
		8	2.00	1.00	DR	DR	2.00	0.55	DR	DR
		12	2.00	0.55	DR	DR	1.85	DR	DR	DR
	Nail (0.120" shank; 0.281" head)	6	3.00	1.70	0.90	0.55	3.00	1.05	0.50	DR
		8	3.00	1.20	0.60	DR	3.00	0.70	DR	DR
		12	3.00	0.70	DR	DR	2.15	DR	DR	DR
	Nail (0.131" shank; 0.281" head)	6	4.00	2.15	1.20	0.75	4.00	1.35	0.70	DR
		8	4.00	1.55	0.80	DR	4.00	0.90	DR	DR
		12	4.00	0.90	DR	DR	2.70	0.50	DR	DR
	16d Nail (0.162" shank; 0.344" head)	6	4.00	3.55	2.05	1.40	4.00	2.25	1.25	0.80
		8	4.00	2.55	1.45	0.95	4.00	1.60	0.85	0.50
		12	4.00	1.60	0.85	0.50	4.00	0.95	DR	DR

For SI: 1" = 25.4 mm; 1 pound per square foot [psf] = 0.0479 kPa

1. Table values are based on wood framing of Spruce-Pine-Fir or any wood species with a specific gravity of 0.42 or greater in accordance with NDS. *Required fastener minimum penetration shall be permitted to include thickness of wood structural panel sheathing materials.*
2. Nail fasteners shall comply with ASTM F1667, except nail l ength shall be permitted to exceed ASTM F1667 standard lengths. Fasteners of equivalent or greater diameter and bending strength shall be permitted.
3. FPIS shall have a minimum compressive strength of 15 psi in accordance with ASTM C578 or ASTM C1289.
4. DR = Design Required

- Application 1 – Direct Cladding Attachment
- Foam sheathing thickness limit based on:
  - Nail size & spacing
  - Cladding weight
- Same as cladding connection table in IBC/IRC for attachment to wood framing

Code Prescriptive Solutions

Table 2. Furring Minimum Fastening Requirements to Wood Framing for Application Over FPIS to Support Cladding System Weight [1,2,3,4,5,6]

FURRING MATERIAL	Framing Member	Fastener Type & Min. Size	Minimum Penetration into Wall Framing (in.)	Fastener Spacing in Furring (in.)	MAXIMUM THICKNESS OF FPIS (IN.)							
					16" o.c. Furring				24" o.c. Furring			
					CLADDING SYSTEM WEIGHT				CLADDING SYSTEM WEIGHT			
					3 psf	11 psf	18 psf	25 psf	3 psf	11 psf	18 psf	25 psf
Min. 1x3 Wood Furring	Min. 2x Wood Stud	Nail (0.120" shank; 0.271" head)	1¼"	8	3.00	1.85	1.05	0.65	3.00	1.20	0.60	DR
				12	3.00	1.20	0.60	DR	3.00	0.70	DR	DR
				16	3.00	0.80	DR	DR	2.30	DR	DR	DR
		Nail (0.131" shank; 0.281" head)	1¼"	8	4.00	2.45	1.45	0.95	4.00	1.60	0.85	DR
				12	4.00	1.60	0.85	DR	4.00	0.95	DR	DR
				16	4.00	1.10	DR	DR	3.05	0.60	DR	DR
		16d Nail (0.162" shank; 0.344" head)	1¼"	8	4.00	4.00	2.45	1.60	4.00	2.75	1.45	0.85
				12	4.00	2.75	1.45	0.85	4.00	1.65	0.75	DR
				16	4.00	1.90	0.95	DR	4.00	1.05	DR	DR
		#10 wood screw (0.363" head)	1"	12	4.00	2.30	1.20	0.70	4.00	1.40	0.60	DR
				16	4.00	1.65	0.75	DR	4.00	0.90	DR	DR
				24	4.00	0.90	DR	DR	2.85	DR	DR	DR
		¼" hex lag screw	1½"	12	4.00	2.65	1.50	0.90	4.00	1.65	0.80	DR
				16	4.00	1.95	0.95	0.50	4.00	1.10	DR	DR
				24	4.00	1.10	DR	DR	3.25	0.50	DR	DR

For SI: 1" = 25.4 mm; 1 pound per square foot [psf] = 0.0479 kPa

1. Table values are based on wood framing and furring of Spruce-Pine-Fir or any wood species with a specific gravity of 0.42 or greater in accordance with *NDS*.
2. Nail fasteners shall comply with ASTM F1667, except nail length shall be permitted to exceed ASTM F1667 standard lengths. Wood screws and lag screws shall comply with NDS Appendix L and ANSI/ASME B18.6.1. Other approved fasteners of equivalent or greater diameter and bending strength shall be permitted. *Required fastener minimum penetration shall be permitted to include thickness of wood structural panel sheathing materials.*
3. A minimum 2x wood furring shall be used where the required siding fastener penetration into wood material exceeds ¾" (19.1 mm) and is not more than 11/2" (38.1 mm), unless approved deformed shank siding nails or siding screws are used to provide equivalent withdrawal strength, allowing the siding connection to be made to a 1x wood furring.
4. Furring shall be spaced a maximum of 24" o.c. in a vertical or horizontal orientation.
   a. In a vertic al orientation, furring shall be located over wall studs and attached with the required fastener spacing.
   b. In a horizontal orientation, furring shall be fastened at each stud with a number of fasteners equivalent to that required by the fastener spacing. If the required nail spacing is 12" o.c. and the studs are 24" o.c., then two (2) nails would be required at each stud (24/12=2). In no case shall fasteners be spaced more than 24" (0.6 m) apart.
5. FPIS shall have a minimum compressive strength of 15 psi, in accordance with ASTM C578 or ASTM C1289.
6. DR = Design Required

- Application 2 – Wood furring attachment
- Wood screws and lag screws also included
- Same as furring connection table in IBC/IRC for attachment to wood framing

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Code Prescriptive Solutions

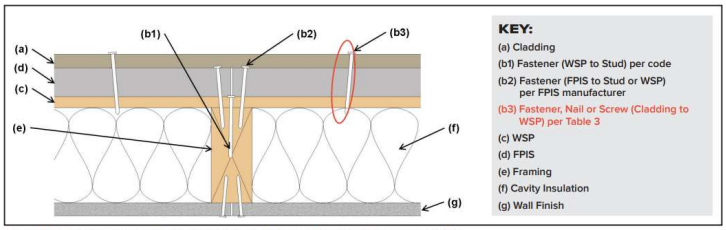

Figure 4. Illustration of light-weight cladding (≤3 psf) attachment through maximum 2"-thick FPIS to minimum 7/16"-thick wood structural panel (WSP) sheathing.

Table 3. Light-weight Cladding (≤3 psf) Minimum Fastening Requirements for Attachment Through Maximum 2"-thick FPIS to Minimum 7/16"-thick Wood Structural Panel [1,2,3]

TYPE AND SIZE OF FASTENER	HORIZONTAL SPACING OF FASTENERS ALONG SIDING
Roof sheathing ring shank nail (0.120" min. shank; 0.281" head)	12" oc
Post frame ring shank nail (0.148" min. shank; 5/16" head)	15" oc
No. 6 screw (0.138" min. shank; 0.262" head)	12" oc
No. 8 screw (0.164" min. shank; 0.312" head)	16" oc

For SI: 1" = 25.4 mm

1. Horizontal spacing of fasteners along siding is based on a siding width (distance between horizontal rows of fasteners) of 12 inches. For other siding widths, multiply required horizontal spacing by 12/w where w is the siding width in inches.
2. This table is based on IRC Table R703.3.3. Use of this table is limited to the wind load scope limits for cladding attachments in accordance with Section R703.3.2 of the IRC (i.e., maximum 30 psf negative design wind pressure).
3. The cladding fastener must be of sufficient length to penetrate a minimum of ¼" beyond the back side of the wood structural panel sheathing.

- Application 3 – Attachment to wood structural panel sheathing (not to studs)
  - Limited to light-weight cladding (3psf or less)
  - Limited to max. 2" thick FPIS (min. 15 psi)
  - Limited to max -30 psf wind load (per scope of IRC)
- Same as Table R703.3.3 in IRC for cladding connection to WSP

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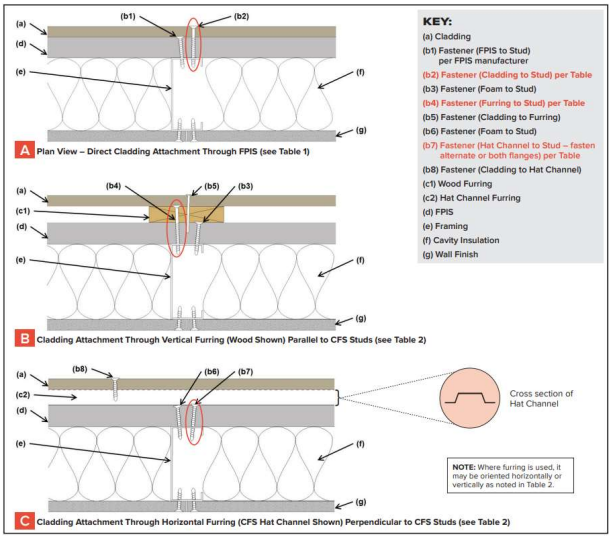
Prescriptive Solutions (CFS wall framing)

- Applications 1 and 2:
  - Direct cladding attachment
  - Wood or steel furring attachment
- Requirements vary by cladding weight:

Typical cladding materials included in the weight classes listed in Tables 1, 2, and 3 are as follows (verify with cladding manufacturer data):[1]

- 3 psf – e.g., wood lap and panel siding, vinyl siding, and most fiber-cement sidings
- 11 psf – e.g., 3-coat Portland cement stucco
- 18 psf – e.g., medium weight adhered stone veneer
- 25 psf – e.g., heavy weight adhered stone veneer



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Prescriptive Solutions

Table 1. Siding Minimum Fastening Requirements to Cold-formed Steel Framing for Direct Cladding Attachment Over FPIS to Support Cladding System Weight [1,2,3,4]

CLADDING FASTENER THROUGH FPIS INTO:	Siding Fastener Type & Minimum Size	Siding Fastener Vertical Spacing (in.)	MAXIMUM THICKNESS OF FPIS (IN.)							
			16" o.c. Fastener Horizontal Spacing				24" o.c. Fastener Horizontal Spacing			
			CLADDING SYSTEM WEIGHT				CLADDING SYSTEM WEIGHT			
			3 psf	11 psf	18 psf	25 psf	3 psf	11 psf	18 psf	25 psf
Steel Framing (minimum penetration of steel thickness + 3 threads)	#8 screw (0.285" head) into 33 mil steel or thicker	6	3.00	2.95	2.20	1.45	3.00	2.35	1.25	DR
		8	3.00	2.55	1.60	0.60	3.00	1.80	DR	DR
		12	3.00	1.80	DR	DR	3.00	0.65	DR	DR
	#10 screw (0.333" head) into 33 mil steel	6	4.00	3.50	2.70	1.95	4.00	2.90	1.70	0.55
		8	4.00	3.10	2.05	1.00	4.00	2.25	0.70	DR
		12	4.00	2.25	0.70	DR	3.70	1.05	DR	DR
	#10 screw (0.333" head) into 43 mil steel or thicker	6	4.00	4.00	4.00	3.60	4.00	4.00	3.45	2.70
		8	4.00	4.00	3.70	3.00	4.00	3.85	2.80	1.80
		12	4.00	3.85	2.80	1.80	4.00	3.05	1.50	DR

For SI: 1" = 25.4 mm; 1 pound per square foot [psf] = 0.0479 kPa

1. Tabulated values are based on minimum 33 ksi steel for 33 mil and 43 mil steel and 50 ksi steel for 54 mil steel or thicker.
2. Screws shall comply with the requirements of ASTM C1513.
3. FPIS shall have a minimum compressive strength of 15 psi in accordance with ASTM C578 or ASTM C1289.
4. DR = Design Required

- Application 1 – Direct Cladding Attachment
- Foam sheathing thickness limit based on:
  - Framing thickness
  - Screw size
  - Screw spacing
  - Cladding weight
- Same as cladding connection table to steel framing in IBC/IRC

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Prescriptive Solutions

Table 2. Furring Minimum Fastening Requirements to Cold-formed Steel Framing for Application Over FPIS to Support Cladding System Weight [1,2,3,4,5]

FURRING MATERIAL	Framing Member	Fastener Type & Min. Size	Minimum Penetration into Wall Framing (in.)	Fastener Spacing in Furring (in.)	MAXIMUM THICKNESS OF FPIS (IN.)							
					16" o.c. Furring				24" o.c. Furring			
					CLADDING SYSTEM WEIGHT				CLADDING SYSTEM WEIGHT			
					3 psf	11 psf	18 psf	25 psf	3 psf	11 psf	18 psf	25 psf
Minimum 33mil Steel Hat Channel or Minimum 1x3 Wood Furring	33 mil Cold-formed Steel Stud	#8 screw (0.285" head)	Steel thickness +3 threads	12	3.00	1.80	DR	DR	3.00	0.65	DR	DR
				16	3.00	1.00	DR	DR	2.85	DR	DR	DR
				24	2.85	DR	DR	DR	2.20	DR	DR	DR
		#10 screw (0.333" head)	Steel thickness +3 threads	12	4.00	2.25	0.70	DR	3.70	1.05	DR	DR
				16	3.85	1.45	DR	DR	3.40	DR	DR	DR
				24	3.40	DR	DR	DR	2.70	DR	DR	DR
	43 mil or thicker Cold-formed Steel Stud	#8 screw (0.285" head)	Steel thickness +3 threads	12	3.00	1.80	DR	DR	3.00	0.65	DR	DR
				16	3.00	1.00	DR	DR	2.85	DR	DR	DR
				24	2.85	DR	DR	DR	2.20	DR	DR	DR
		#10 screw (0.333" head)	Steel thickness +3 threads	12	4.00	3.85	2.80	1.80	4.00	3.05	1.50	DR
				16	4.00	3.30	1.95	0.60	4.00	2.25	DR	DR
				24	4.00	2.25	DR	DR	4.00	0.65	DR	DR

For SI: 1" = 25.4 mm; 1 pound per square foot [psf] = 0.0479 kPa

1. Table values are based on:
   a. Wood furring of Spruce-Pine-Fir or any softwood species with a specific gravity of 0.42 or greater per NDS.
   b. Minimum 33 mil steel hat channel furring of 33 ksi steel. Steel hat channel shall have a minimum 7/8" (22.2 mm) depth, 1¼" (32 mm) web width, and ½" (12.7 mm) wide flanges with web or flanges bearing on FPIS surface.
   c. Cold-formed steel framing of indicated nominal steel thickness and minimum 33 ksi steel for 33 mil and 43 mil steel and 50 ksi steel for 54 mil steel or thicker.
2. Screws shall comply with the requirements of ASTM C1513.
3. Furring shall be spaced a maximum of 24" o.c. in a vertical or horizontal orientation.
   a. In a vertical orientation, furring shall be located over wall studs and attached with the required fastener spacing.
   b. In a horizontal orientation, furring shall fastened at each stud with a number of fasteners equivalent to that required by the fastener spacing. If the required fastener spacing is 12" o.c. and the studs are 24" o.c., then two (2) fasteners would be required at each stud (24/12=2). In no case shall fasteners be spaced more than 24" (0.6 m) apart.
4. FPIS shall have a minimum compressive strength of 15 psi, in accordance with ASTM C578 or ASTM C1289.
5. DR = Design Required

- Application 2 – Wood or steel furring attachment
- Same as furring connection table in IBC/IRC for steel framing

Prescriptive Solutions

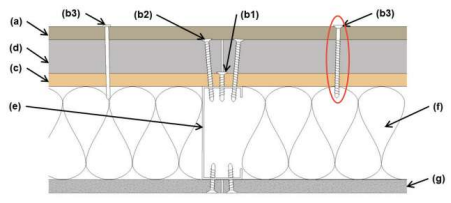

Figure 4. Illustration of light-weight cladding (≤3 psf) attachment through maximum 2"-thick FPIS to minimum 7/16"-thick wood structural panel (WSP) sheathing.

Table 3. Light-weight Cladding (≤3 psf) Minimum Fastening Requirements for Attachment Through Maximum 2"-thick FPIS to Minimum 7/16"-thick Wood Structural Panel [1,2,3]

TYPE AND SIZE OF FASTENER	HORIZONTAL SPACING OF FASTENERS ALONG SIDING
Roof sheathing ring shank nail (0.120" min. shank; 0.281" head)	12" oc
Post frame ring shank nail (0.148" min. shank; 5/16" head)	15" oc
No. 6 screw (0.138" min. shank; 0.262" head)	12" oc
No. 8 screw (0.164" min. shank; 0.312" head)	16" oc

For SI: 1" = 25.4 mm

1. Horizontal spacing of fasteners along siding is based on a siding width (distance between horizontal rows of fasteners) of 12 inches. For other siding widths, multiply required horizontal spacing by 12/w where w is the siding width in inches.
2. This table is based on IRC Table R703.3.3. Use of this table is limited to the wind load scope limits for cladding attachments in accordance with Section R703.3.2 of the IRC (i.e., maximum 30 psf negative design wind pressure).
3. The cladding fastener must be of sufficient length to penetrate a minimum of ¼" beyond the back side of the wood

- Application 3 – Attachment to wood structural panel sheathing (not to studs)
  - Limited to light-weight cladding (3psf or less)
  - Limited to max. 2" thick FPIS (min. 15 psi)
  - Limited to max -30 psf wind load (per scope of IRC)
- Same as cladding connection table in IRC for attachment to WSP

Design Procedure (CFS wall framing)

- Design of connections through FPIS to cold-formed Steel
  - Tension allowable design values: Follows same procedure in AISI S100 for screw withdrawal capacity (just use longer screws to accommodate FPIS thickness)
  - Shear allowable design values: Follows the same procedure in AISI S100, Section J4.3.1, but modifies Eq. J4.3.1.-1 by a gap reduction factor, Gr, as follows:
    - For #10 screw in 54mil and 50 ksi steel: $G_r = 0.17 - 0.0048\,r$
    - For #10 screw in 43mil and 33 ksi steel: $G_r = 0.19 - 0.0066\,r$
    - For #8 or #10 screw in 33mil and 33 ksi steel: $G_r = 0.16 - 0.0064\,r$
      - Where,
        - r = d_sep/d
        - d_sep = thickness of FPIS separating connected steel parts
        - d = nominal screw diameter (0.164" for #8, 0.190" for #10)
      - Value of r shall not exceed 21.
      - For $0<r<2$, Gr need not be less than $(1 - r/2)$
      - Material against screw head shall be minimum 33mil and 33ksi steel or minimum 3/8" thick wood or wood-based material with specific gravity of 0.42 or greater.
      - Material in the gap must be minimum 15psi FPIS

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Design Procedure (wood wall framing)

- Design of connections through FPIS to wood framing
  - Tension allowable design values: Follows same procedure in NDS Section 12.2 for nail/screw fastener withdrawal capacity (just use longer fasteners to accommodate FPIS thickness)
  - Shear allowable design values: Follows the same procedure in NDS Section 12.3, but modifies as follows based on test program:
    - Shear reduction term, Rd, shall not be less than 3.0.
    - Use yield limit equations with "gap" parameter per AWC/TR12 Table 1-1 with g = thickness of FPIS
    - Minimum fastener penetration in wood of 1-inch for screws and 1-1/4 inches for nails.
    - Minimum wood specific gravity (density) of 0.42
    - Material in the gap must be minimum 15psi FPIS

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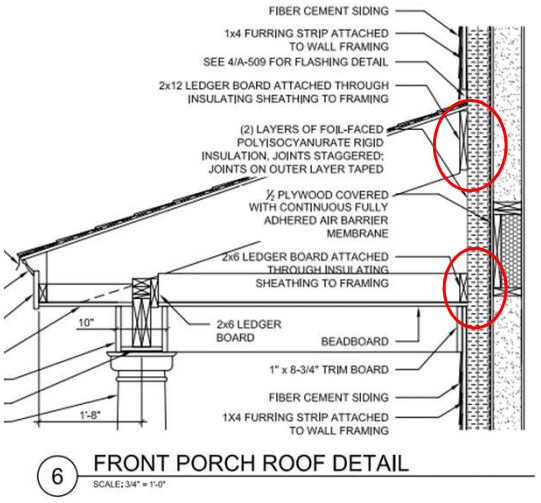
Connection Design Procedure Applications

- Example Applications:
  - Cladding and furring connections using alternative fasteners through FPIS ci
  - Load bearing structural component connections through FPIS (e.g., deck and roof ledgers attached to wall surface)
  - Architectural component connections through FPIS (e.g., awning frames, shading devices, etc.)
  - Structural sheathing connections through FPIS (under sheathing rather than over sheathing)
  - Window and door frame anchorages where passing through a rough opening gap or through a layer of foam sheathing (e.g., conditions not addressed in fenestration manufacturer instructions)



https://www.nist.gov/el/net-zero-energy-residential-test-facility/project-details

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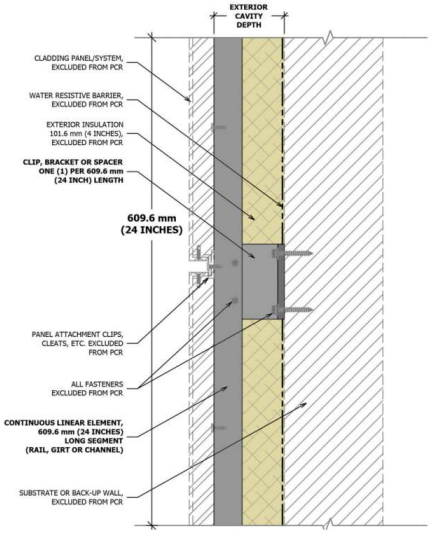
Other Designed or Manufacturer-Provided Details

- Clip and rail systems for rainscreen cladding and ci
  - Much better thermal performance than metal furring thermal bridge completely through ci
  - But, still does not comply with ci definition
  - Must account for thermal bridge effect of furring and clip
  - Refer to manufacturer specifications, shop drawings, or design details on approved plans
- Remember to check NFPA 285 compliance if used on Type I-IV buildings!



Source:
http://www.sustainableminds.com/files/transparency/pgds/Part_B_Product_Group_Definition_Cladding_Support_Components_and_Systems_10312022.pdf

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ANSI FS200.1 Standard for FPIS ci Applications

- Scope
  - Above-grade frame walls
  - Labeling & Quality Assurance
  - Wind resistance
  - WRB (water resistance)
  - Vapor Control
  - Window installation
  - Cladding installation
- Addresses
  - Performance criteria (design)
  - Evaluation/testing criteria by application
  - Prescriptive criteria (“cook-book” design and installation)
- Exclusions
  - Refer to locally applicable code for fire safety requirements (e.g., IBC Chapter 14 and 26; IRC Section R303)
  - Use FPIS manufacturer data to demonstrate compliance (ASTM E84, ASTM E119, NFPA 285, etc. – as applicable)

6300 Enterprise Lane
Madison, Wisconsin 53719
608-310-6710

ABTG
Applied Building Technology Group, LLC

ANSI/ABTG FS200.1 – 2022

Standard for Use of Foam Plastic Insulating Sheathing (FPIS) in Building Envelopes: Above-grade Walls

https://www.appliedbuildingtech.com/standards

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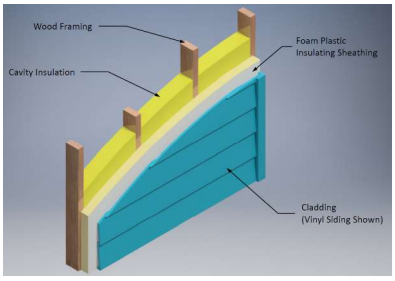
G. IBC/IRC – Vinyl siding installation over FPIS

- Performance Testing & Research
- IBC/IRC Code Requirements
- QuickGuide



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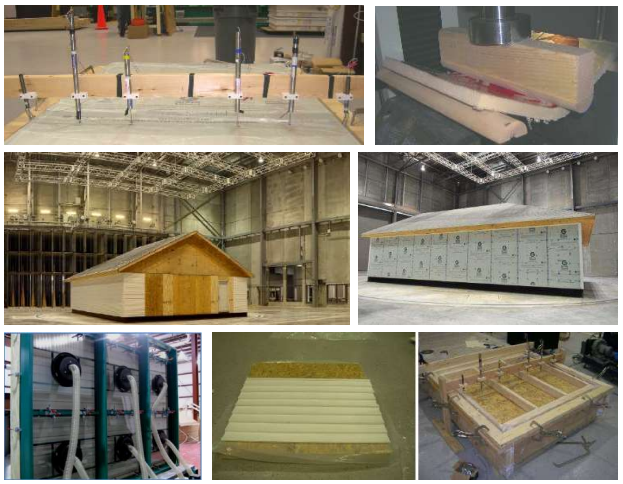
Performance Testing & Research

- State-of-art testing program
- Worked with FSC/ACC, IBHS, NAHB, VSI, DOE, HIRL, and AWC
- Informed development of ANSI/ABTG FS100 Standard for wind resistance of foam sheathing
- Also resulted new code requirements for vinyl siding wind pressure rating when installed on walls with foam sheathing as the sole exterior sheathing, and not separately fastened to resist full design wind load per FS100 standard
- Addresses the case where vinyl and foam sheathing acts as an exterior wall covering assembly in resisting wind load per IRC R703.1.2



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IRC Code Requirements

- Use vinyl siding wind load design pressure rating per Table R703.11.2
- Exceptions!
  - Where FPIS is not the sole exterior sheathing (separate sheathing applied as over- or under-sheathing)
  - Where vinyl siding manufacturer data is specific for application over FPIS
- Proposal to add similar provisions to 2027 IBC

R703.11.2 Installation over foam plastic sheathing. Where vinyl siding or *insulated vinyl siding* is installed over foam plastic sheathing, the vinyl siding shall comply with Section R703.11 and shall have a wind load design pressure rating in accordance with Table R703.11.2.

Exceptions:

1. Where the foam plastic sheathing is applied directly over *wood structural panels*, fiberboard, gypsum sheathing or other *approved* backing capable of independently resisting the design wind pressure, the vinyl siding shall be installed in accordance with Sections R703.3.3 and R703.11.1.
2. Where the vinyl siding manufacturer's product specifications provide an *approved* wind load design pressure rating for installation over foam plastic sheathing, use of this wind load

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IRC Code Requirements

TABLE R703.11.2
REQUIRED MINIMUM WIND LOAD DESIGN PRESSURE RATING FOR VINYL SIDING INSTALLED OVER FOAM PLASTIC SHEATHING ALONE

ULTIMATE DESIGN WIND SPEED (MPH)	ADJUSTED MINIMUM DESIGN WIND PRESSURE (ASD) (PSF)[a, b]					
	Case 1: With interior gypsum wallboard[c]			Case 2: Without interior gypsum wallboard[c]		
	Exposure			Exposure		
	B	C	D	B	C	D
≤ 95	-30.0	-33.2	-39.4	-33.9	-47.4	-56.2
100	-30.0	-36.8	-43.6	-37.2	-52.5	-62.2
105	-30.0	-40.5	-48.1	-41.4	-57.9	-68.6
110	-31.8	-44.5	-52.8	-45.4	-63.5	-75.3
115	-35.5	-49.7	-59.0	-50.7	-71.0	-84.2
120	-37.4	-52.4	-62.1	-53.4	-74.8	-88.6
130	-44.9	-62.8	-74.5	-64.1	-89.7	-106
> 130	See Note d					

For SI: 1 inch = 25.4 mm, 1 foot = 304.8 mm, 1 square foot = 0.0929 m², 1 mile per hour = 0.447 m/s, 1 pound per square foot = 0.0479 kPa.

a. Linear interpolation is permitted.

b. The table values are based on a maximum 30-foot mean roof height, and effective wind area of 10 square feet Wall Zone 5 (corner), and the ASD design component and cladding wind pressure from Table R301.2.1(1), adjusted for exposure in accordance with Table R301.2.1(2), multiplied by the following adjustment factors: 1.87 (Case 1) and 2.67 (Case 2).

c. Gypsum wallboard, gypsum panel product or equivalent.

d. For the indicated wind speed condition and where foam sheathing is the only sheathing on the exterior of a frame wall with vinyl siding, the wall assembly shall be capable of resisting an impact without puncture at least equivalent to that of a wood frame wall with minimum $^{7}/_{16}$-inch OSB sheathing as tested in accordance with ASTM E1886. The vinyl siding shall comply with an adjusted design wind pressure requirement in accordance with Note b, using an adjustment factor of 2.67.

Source: 2024 International Residential Code, https://codes.iccsafe.org/content/IRC2024P1

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Quick Guide for Vinyl Siding Over FPIS ci

- No difference in install except longer siding fastener
  - Where foam sheathing installed under or over a separate wind resistant sheathing layer
- Where foam sheathing is the sole exterior sheathing:
  - Requires foam sheathing wind pressure rated per code (FS100 standard) – see manufacturer
  - Requires vinyl siding wind pressure rating enhancement (IRC R703.11.2)
    - Not needed where foam is separately attached to resist wind load per FS 100 standard (e.g., structural cap fasteners)

https://www.continuousinsulation.org/resources/quick-guides

QUICK GUIDE
Foam Plastic Applications for Better Building

CODE-COMPLIANT VINYL SIDING APPLICATIONS over Foam Plastic Insulating Sheathing (FPIS) Continuous Insulation (ci)

12.02.21

IMPORTANT! READ ALL INSTRUCTIONS BEFORE BEGINNING INSTALLATION

INTRODUCTION

Vinyl siding is a popular siding material and is commonly applied over foam plastic insulating sheathing (FPIS) continuous insulation (ci) used for building code and energy code compliant walls. Like other siding products, it must be specified and installed to resist design wind load pressures as required by code. Design wind load pressure ratings of standard vinyl siding products rely on ASTM D3679.[1] This standard uniquely incorporates wind pressure equalization effects that account for reduced wind load on the siding material. This load-reducing effect varies depending on construction of the wall assembly to which the vinyl siding is installed.

This Quick Guide outlines a step-by-step process to ensure vinyl siding is properly specified and installed when applied over FPIS ci for a durable and code-compliant installation.

STEP 1: VERIFY MATERIAL COMPLIANCE.

Ensure that the specified vinyl siding product complies with ASTM D3679 in accordance with 2021 IRC Section R703.11 and identify the product's design wind pressure rating as required for any vinyl siding application (see Photo 1).

Design Pressure Rating: 77.2 psf

Photo 1. Example of typical vinyl siding product label with a design wind load pressure rating of 77.2 psf.

STEP 2: CONSIDER ADDITIONAL REQUIREMENTS FOR INSTALLATION OVER FPIS.

Determine if any additional specification and installation requirements are applicable for vinyl siding installed over FPIS in accordance with 2021 IRC Section R703.11.2, including the listed exceptions. The following three installation conditions govern the design wind pressure rating and installation of the vinyl siding and the FPIS material:

CONDITION 1	CONDITION 2	CONDITION 3
2021 IRC Section R703.11.2, Exception 1	2021 IRC Section R703.11.2	2021 IRC Section R703.11.2, Exception 2
FPIS installed as "Over-sheathing" (see Figure 1)	**FPIS installed directly over Open Stud Cavities (see Figure 2)** OPTION A: FPIS material and siding fastened as an assembly to resist wind load OPTION B: FPIS material fastened to resist design wind load independent of siding	**Vinyl siding installed over FPIS in accordance with siding manufacturer's installation instructions**

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H. IBC/IRC Wall bracing code compliance

- Foam plastics are not structural wall bracing materials (in general)
  - Exceptions:
    - Spray foams can supplement bracing (proprietary, if considered at all)
    - Structural composite insulating sheathing (proprietary)
- Foam plastics can be integrated with all bracing methods and structural systems for lateral force resistance.

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IBC requirements (Ch16,19,21,22, 23)

- Generally engineered wall bracing & varies by building construction
  - CFS framing – metal X-bracing, WSP, Gypsum Sheathing, etc.
  - Wood framing – WSP, Gypsum Board, Structural Insulated Panels, etc.
  - Concrete/Masonry – Reinforced shear walls
  - Structural steel – brace frames, moment frames, etc. (with various types of curtain walls that provide the thermal envelope)

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IRC Wall Bracing (Prescriptive)

- GOAL: Right-size wall bracing and select bracing method to optimize cost and performance of overall wall assembly (integrate with FPIS ci)
- CHALLENGES TO OPTIMIZATION:
  - IRC Section R602.10 is complex – 36 pages of text, tables, details, adjustment factors, and math
  - There are no "simple" solutions – all bracing methods must be shown to comply with the code for a given building configuration and design condition
  - Large buildings, high wind/seismic, large open spaces, and lots of window/door openings
  - Layout of interior walls/spaces can help economize bracing strategy (or be necessary to make it work)
- BENEFITS: Code provides a lot of flexibility to optimize use of any given bracing method (or alternative bracing methods)

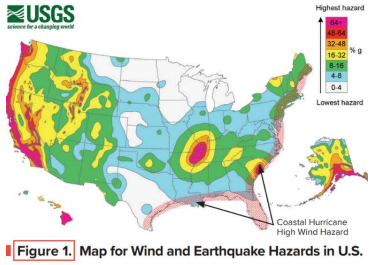
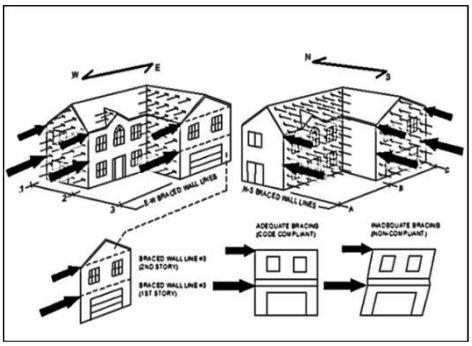


Figure 1. Map for Wind and Earthquake Hazards in U.S.



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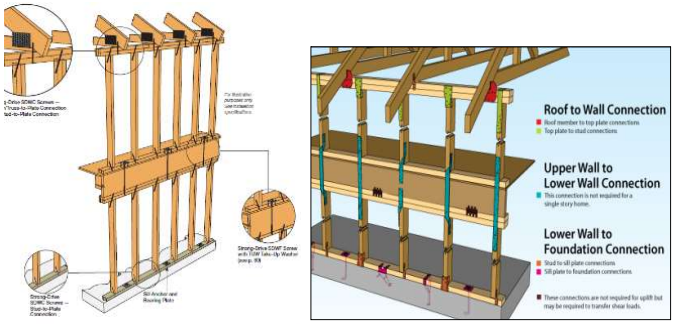
Wind Uplift Load Path is Critical!

- Many building collapses related to wind may look like bracing failures, but are actually initiated by failures of wind-uplift load path.
- IRC addresses this by requiring a continuous wind-uplift load path in coordination with wall bracing (see Sections R602.3.5 and R802.11).
  - Consider labor and material cost savings of using long self-drilling wood screws (see image).

Image Sources: Institute for Business and Home Safety (as published in HUD *Durability by Design, 2nd Edition* and also HUD *Safer, Stronger Homes)* and Simpson Strong-Tie.



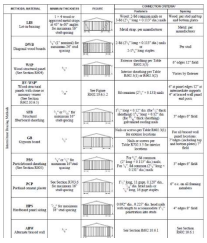
Long wood screws, metal straps & brackets, etc.

Stepwise Accounting Process

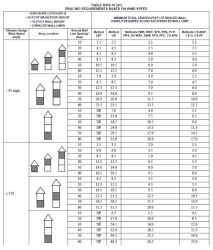
(think IRS 1040 form without TurboTax or instructions)

Steps 1&2 – ID BWLs per story

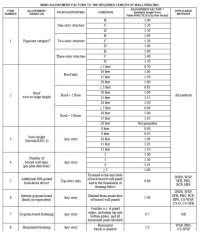
Step 3 – Select from 16 BMs for each BWL



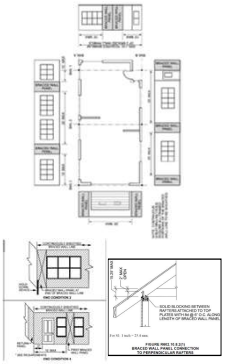
Step 4 – Bracing Length Req'd



Steps 5&6 – Adjustment Factors and Check vs. Bracing Length Provided



Steps 7&8 – Check BWP layout and connection/anchorage details



Repeat for each Brace Wall Line (BWL) on each story

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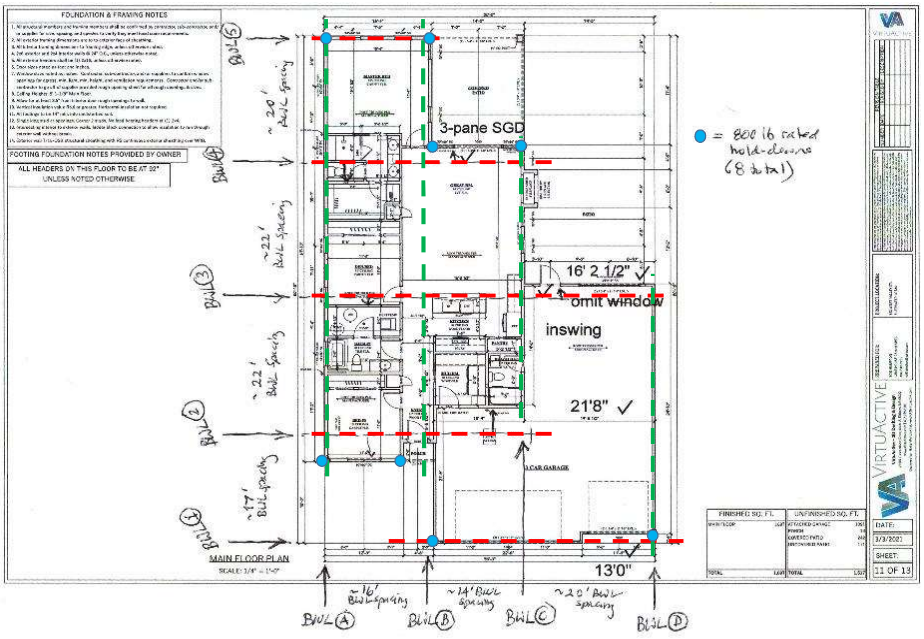

Example House Plan & BWL Layout

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Code Compliance Accounting Sheet (partial copy)

STEP 1 Braced Wall Line ID	STEP 1 Maximum BWP Offset from BWL ≤ 4'? (Yes or No)	STEP 2 BWL Support Condition Roof only Roof+1 floor Roof+2 floors	STEP 2 BWL Spacing (feet)	Length of Braced Wall Line (feet)	STEP 3 Selected Bracing Method (s)	STEP 4 Tabulated Bracing Length Table R602.10.3 (1) (feet)	STEP 4 Adjusted Bracing Length per Table R602.10.3(2) (inches)	STEP 5 Bracing Length Provided by BWPs (inches)	STEP 6 Is Value in Column G ≥ Value in Column F? (Yes or No)	STEP 7 Is BWP distance from ends of BWL ≤ 10'? (Yes or No)	STEP 7 Do BWPs comply with maximum 20'oc spacing btwn BWPs? (Yes or No)	Comments
Braced Wall Lines												
C (Int. right side of Kitch./ Bath at Garage)	OK	Roof only	17' (avg)	41'	GB (2-sided)	5.6'	5.6' x adj = 9.2'	16.6' provided	OK	OK	OK	Almost 200% extra capacity
D (right side of garage)	OK	Roof only	20'	39.8'	GB (1-sided)	6.5'	6.5' x adj = 10.7'	39.8' provided	OK	OK	OK	Can use GB fastening of Int. GWB for 4' at ends and in middle
1 (garage front)	OK	Roof only	17'	35'	CS-WSP + CS-G	3.0'	3.0'x1.2x0 .94x1.6=5. 4'	6.8' CS-WSP	OK	OK	OK	3.4' WSP-CS panels at ends of larger garage opening and minimum 30" CS-G panel or 20" CS-PF at small garage door outside corner with 800 lb hold-downs at outside corners of garage front (no corner returns)

- Used wood structural panels where needed (e.g., street facing & garage opening walls)
- Used interior gypsum walls where needed to optimize exterior wall bracing
- Used FPIS ci on exterior and enhanced fastening for Gypsum Bracing of exterior walls on interior side
- Wind uplift wind load path per code w/ long self-drilling screws
- Saved several thousand on above-grade framing cost
- Saved couple thousand on slab foundation using FPIS ci for FPSF foundation (addressed later)
- Improved energy efficiency above minimum energy code
- Reduced carbon footprint of building by about 2,500 kg CO2e (mainly reduced concrete in foundation)

Source: IRC Wall Bracing: A guide for builders, designers, and plan reviewers
https://www.appliedbuildingtech.com/rr/1601-01

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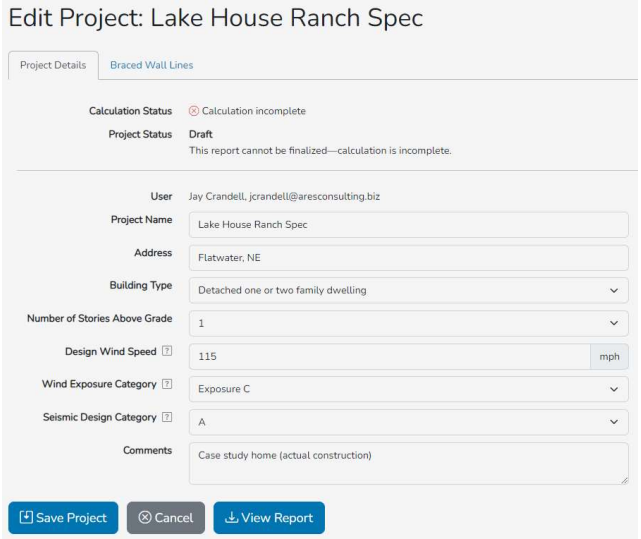
Help is here!

(Turbotax for wall bracing)

- IRC wall bracing free on-line calculator
- Aid to complying with the IRC wall bracing provisions and documentation of compliance.
- Also helps optimize design for building and energy code compliance.



https://www.continuousinsulation.org/calculators

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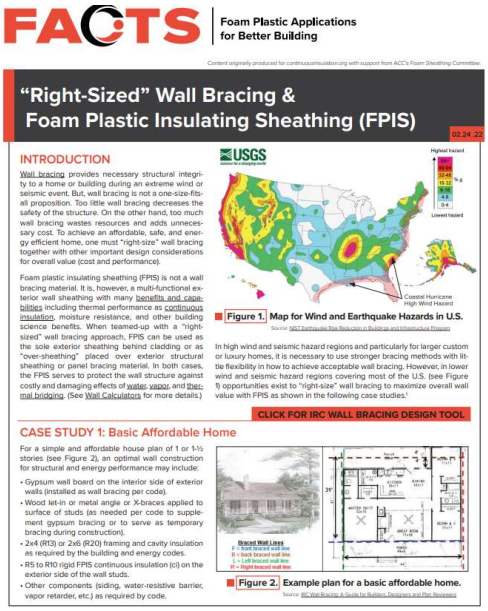
Additional Resources:

- **IRC Wall Bracing: A Guide for Builders, Designers and Plan Reviewers**
  https://www.appliedbuildingtech.com/rr/1601-01
- **Residential Structural Design Guide – 2000 Edition**
  https://www.huduser.gov/publications/pdf/res2000_1.pdf
- **"Right-Sized" Wall Bracing (FACTs sheet)**
  https://www.continuousinsulation.org/resources/facts
- **SIMPSON Strong-Tie, Wall-Bracing-Length Calculator**
  https://www2.strongtie.com/products/strongwall/wallbracing/intro.asp
- **Wood Frame Wall Calculator** (energy + building code integrated thermal & moisture control)
  https://www.continuousinsulation.org/wood-wall-calculator



FACTS | Foam Plastic Applications for Better Building

"Right-Sized" Wall Bracing & Foam Plastic Insulating Sheathing (FPIS)

INTRODUCTION

Wall bracing provides necessary structural integrity to a home or building during an extreme wind or seismic event. But, wall bracing is not a one-size-fits-all proposition. Too little wall bracing decreases the safety of the structure. On the other hand, too much wall bracing wastes resources and adds unnecessary cost. To achieve an affordable, safe, and energy efficient home, one must "right-size" wall bracing together with other important design considerations for overall value (cost and performance).

Foam plastic insulating sheathing (FPIS) is not a wall bracing material. It is, however, a multi-functional exterior wall sheathing with many benefits and capabilities including thermal performance as continuous insulation, moisture resistance, and other building science benefits. When teamed-up with a "right-sized" wall bracing approach, FPIS can be used as the sole exterior sheathing behind cladding or as "over-sheathing" placed over exterior structural sheathing or panel bracing material. In both cases, the FPIS serves to protect the wall structure against costly and damaging effects of water, vapor, and thermal bridging. (See Wall Calculators for more details.)

USGS

Figure 1. Map for Wind and Earthquake Hazards in U.S.

In high wind and seismic hazard regions and particularly for larger custom or luxury homes, it is necessary to use stronger bracing methods with little flexibility in how to achieve acceptable wall bracing. However, in lower wind and seismic hazard regions covering most of the U.S. (see Figure 1) opportunities exist to "right-size" wall bracing to maximize overall wall value with FPIS as shown in the following case studies.

CLICK FOR IRC WALL BRACING DESIGN TOOL

CASE STUDY 1: Basic Affordable Home

For a simple and affordable house plan of 1 or 1½ stories (see Figure 2), an optimal wall construction for structural and energy performance may include:

- Gypsum wall board on the interior side of exterior walls (installed as wall bracing per code).
- Wood let-in or metal angle or X-braces applied to surface of studs (as needed per code to supplement gypsum bracing or to serve as temporary bracing during construction).
- 2x4 (R13) or 2x6 (R20) framing and cavity insulation as required by the building and energy codes.
- R5 to R10 rigid FPIS continuous insulation (ci) on the exterior side of the wall studs.
- Other components (siding, water-resistive barrier, vapor retarder, etc.) as required by code.

Figure 2. Example plan for a basic affordable home.

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IV. Residential & Commercial Foundation Insulation

A. IECC – Thermal compliance
B. IBC/IRC – Frost-protected shallow foundations (FPSF)
C. IBC/IRC – Unvented crawlspaces
D. IBC/IRC – Termite protection

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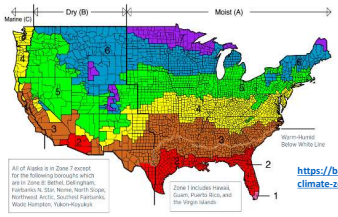
A. IECC – Thermal Compliance

2024 IECC Commercial Provisions – Tables C402.1.2 & C402.1.3

Climate Zone	Building Use	Below-Grade Wall	Slabs	
			Unheated	Heated
0 and 1	All other	NR (C-1.140)	NR (F-0.73)	R-7.5 for 12" + R-5 full slab (F-0.69)
	Group R			
2	All other			
	Group R			
3	All other			R-10 for 24" + R-5 full slab (F-0.66)
	Group R		R-10 for 24" (F-0.54)	
4 Except Marine	All other	R-7.5ci (C-0.119)	R-15 for 24" (F-0.52)	R-15 for 24" + R-5 full slab (F-0.62)**
	Group R	R-10ci (C-0.092)		
5 and Marine 4	All other	R-7.5ci (C-0.119)		R-15 for 36" + R-5 full slab (F-0.62)**
	Group R	R-10ci (C-0.092)	R-20 for 24" (F-0.51)	
6	All other		R-20 for 48" (F-0.434)	R-20 for 48" + R-5 full slab (F-0.602)
	Group R	R-15ci (C-0.063)		
7	All other		R-20 for 24" (F-0.51)	
	Group R		R-20 for 48" (F-0.434)	
8	All other			
	Group R		R-25 for 48" (F-0.424)	



https://basc.pnnl.gov/images/iecc-climate-zone-map

2024 IECC Residential Provisions – Tables R402.1.2 & 402.1.3

Climate Zone	Basement Wall	Slab		Crawlspace
		Unheated	Heated	
0, 1 and 2	0 (U-0.360)	0 (F-0.73)	R-5ci edge + R-5 full slab (F-0.74)	0 (U-0.477)
3	R5ci or R13 (U-0.091)	R10ci, 2ft (F-0.54)	R-10ci, 2 ft + R-5 full slab (F-0..66)	R5ci or R13 (U-0.136)
4 except Marine	R10ci or R13 (U-0.059)	R10ci, 3ft (F-0.51)	R10ci, 3ft + R-5 full slab (F-0.66)	R10ci or R13 (U-0.065)
5 and Marine 4	R15ci or R19 or R13+5ci (U-0.050)			R15ci or R19 or R13+5ci (U-0.055)
6		R10ci, 4ft (F-0.48)	R10ci, 4ft + R-5 full slab (F-0.66)	
7 and 8				

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U-factor, C-factor, and F-factor Equivalents

- Refer to ASHRAE 90.1 (2022) Appendix A for alternative C-factors for below grade walls (basement and crawlspace) and F-factors for slabs-on-grade.
- 2024 IECC-R has NEW appendix RF that provides similar data specific to application in the IECC (with improvements).
- Example: IECC-C requires unheated slab to be insulated to R-20 for 24" below grade (vertical perimeter of slab foundation).
  - The equivalent F-factor is F-0.51
  - ASHRAE 90.1 Table A6.3.1-1 provides alternate R-value options with F-0.51 or better (lower): R-10 for 48" (F-0.51) or R-5 full slab and edge (F-0.46)

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IECC Specific BTE Insulation Requirements

• IECC-C

C402.2.5 Below-grade walls.

- Insulation must be installed between framing members, be integral to wall assembly, be continuous on wall assembly, or be any combination of these methods.
- Installation complying with **Section C401.2.1**, installation must extend not less than 10 ft deep below outside finished ground level or to level of lowest floor of *conditioned space enclosed* by *below-grade wall*, whichever is less.

Below grade walls (crawlspace or basement) are not required to be insulated if the below grade space is not conditioned (e.g., unconditioned basement or ventilated crawlspace). In this case the floor above must be insulated.

• IECC-R

R402.2.9.1 Basement wall insulation installation.

- Insulation must extend from top of *basement wall* 10ft below grade or to basement floor (whichever is less), or in accordance with *proposed design* or *rated design*

R402.2.11.1 Crawl space insulation installations.

- Insulation secured to wall and extend down from sill plate to not less than top of foundation wall footing.
- Exposed earth in unvented crawl space covered with Class I vapor retarder (VR) per IRC/IBC. Joints sealed/taped and overlay 6 inch. Edges of VR attached and extend not less than 6 inches up stem wall.

  Exception: Insulation installed on the interior side of wall of crawl space floor more than 24 inches below exterior grade, insulation shall be permitted to extend from sill plate to not less than interior floor of crawl space.

R402.2.11.2 Alternative crawl space insulation configurations.

- *Buildings* complying with Section R405 or 406, *crawl space wall* insulation must be installed with *proposed design or rated design.*

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IECC Specific BTE Insulation Requirements

• IECC-C

C402.2.4 Slab-on-grade.

- Perimeter insulation:
  - Placed outside or inside of foundation wall.
  - If installed per **Table C402.1.3**, must extend downward from top of the slab for the minimum distance or to top of footing (whichever is less), or downward to not less than bottom of slab and horizontally to interior or exterior for total distance shown.
- Full slab insulation must be continuous under entire area of slab-on-grade floor, except at structural column locations and service penetrations.
- At heated slab perimeter insulation is not required to extend below bottom of heated slab but must be continuous with the full slab insulation.

  Exception: For perimeter insulation where slab-on-grade floor is greater than 24 inches below finished exterior grade.

• IECC-R

R402.2.10 Slab-on-grade floors.

- Floor surface within 24 inches above/below grade must be insulated per **Section R402.2.10.1 or R402.2.10.2.**

  Exception: Slab-edge insulation not required in jurisdictions designated a very heavy termite infestation probability.

R402.2.10.1 Slab-on-grade floor insulation installation.

- *Buildings* complying with **Section R401.2.1**, slab edge ci must extend downward from the top of slab on the outside or inside of foundation wall.
- Insulation below grade must extend vertical distance in **Table R402.1.3** but not exceed footing depth per **Section R403.1.4** of IRC.
- Insulation extending away from the *building*, must be protected by pavement or 10 inches of soil.
- Full-slab and perimeter slab insulation similar to IECC-C.

R402.2.10.2 Alternative slab-on-grade insulation configurations.

- *Buildings* complying with **Section R405** or **R406**, slab-on-grade insulation shall be installed in accordance with *proposed design* or *rated design.*

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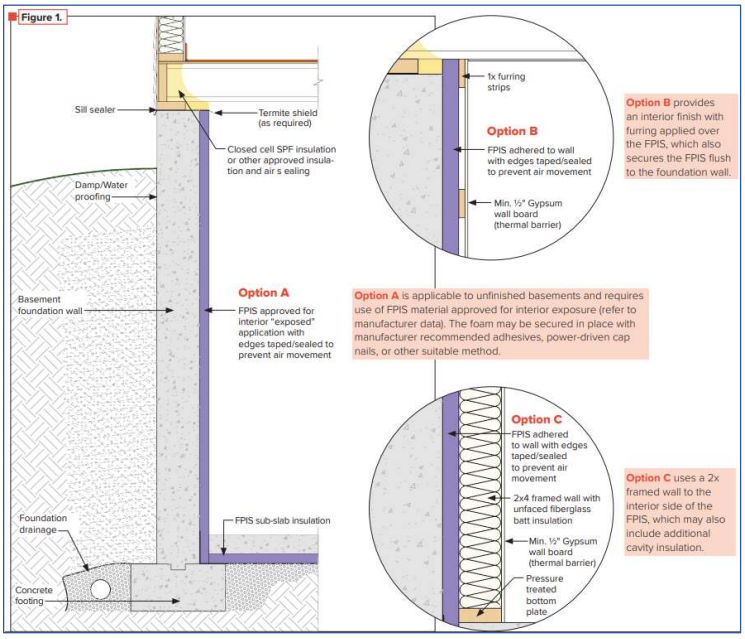
Basement Walls

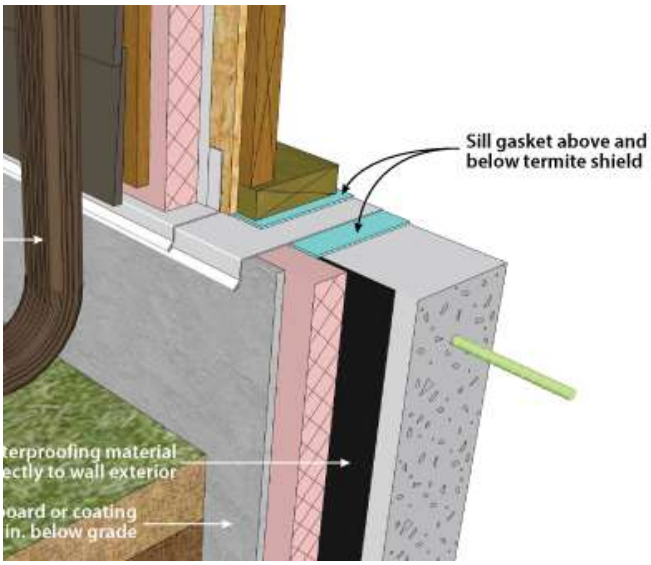
- Interior FPIS ci application
- Most common
- If FPIS exposed to interior, then must be approved for that application
  - Refer to manufacturer fire test data/approvals
- FPIS ci is considered a “hall of fame” insulation method for basement walls by DOE Building America Program
  - Improved energy efficiency and moisture resistance
  - Vapor retarder should be avoided to interior side of FPIS



https://www.continuousinsulation.org

Basement Walls

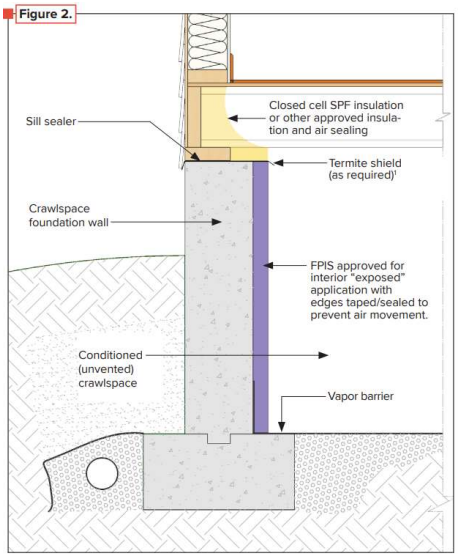
- Exterior FPIS ci application
- Requires protection of insulation above-grade
- Allows continuity with FPIS ci on above-grade wall
- Connects thermal mass of basement wall with interior space
- Wall also can be insulated on both sides (e.g., insulating concrete form or ICF – usually of EPS foam)

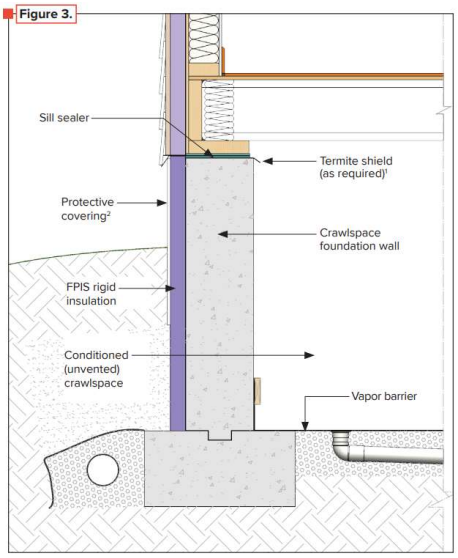


https://foundationhandbook.ornl.gov/handbook/

Crawlspace Walls

- Interior and exterior FPIS ci applications
- Similar to basement walls
- Unvented (conditioned) crawlspace per **Section R408.3**
  - No need to insulate entire floor area & improved moisture control

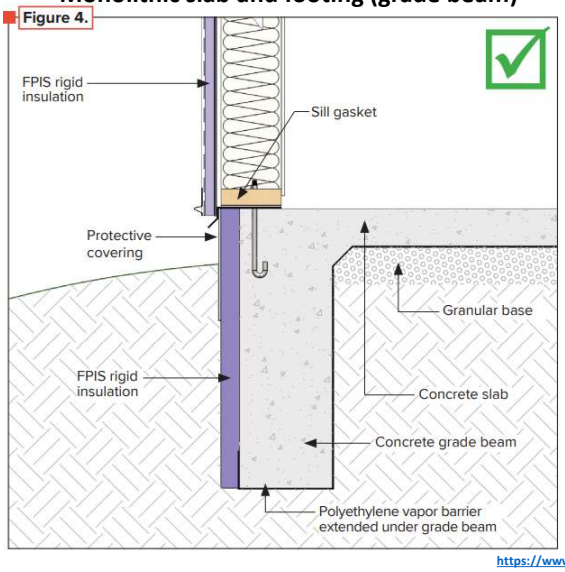




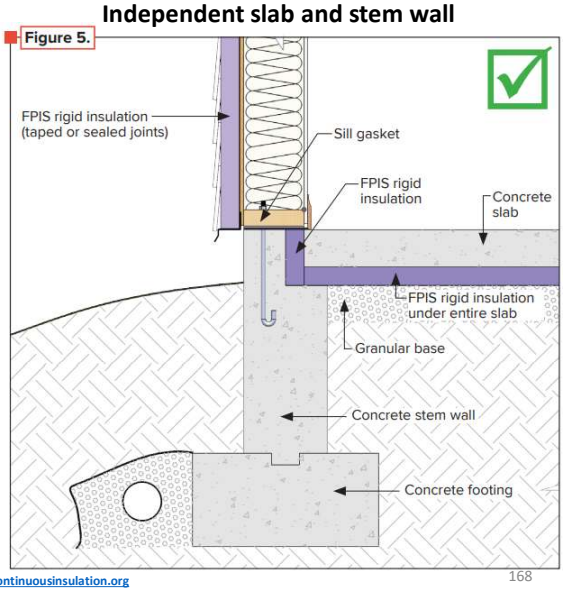
https://www.continuousinsulation.org 167

Slab-on-Grade

Monolithic slab and footing (grade beam)



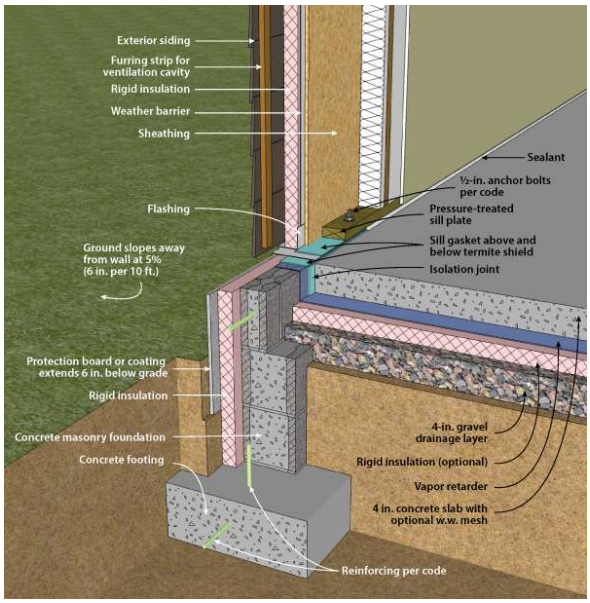
Independent slab and stem wall



https://www.continuousinsulation.org 168

Slab-on-Grade

- Alternate insulation configuration for independent slab and stem wall



https://foundationhandbook.ornl.gov/handbook/

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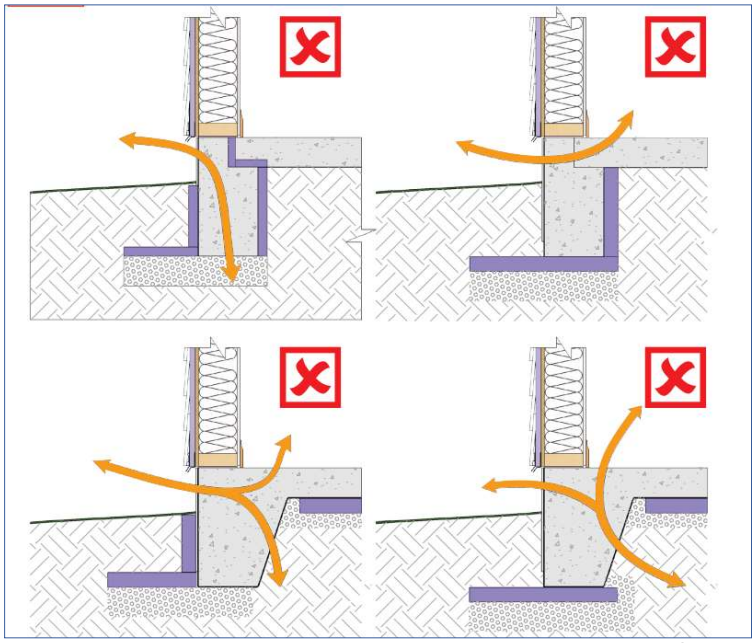
Avoid Thermal Bridges

- Proper insulation placement at slab edge prevents major thermal bridging
- Required for compliance with code R-values and F-factor alternatives



https://www.continuousinsulation.org

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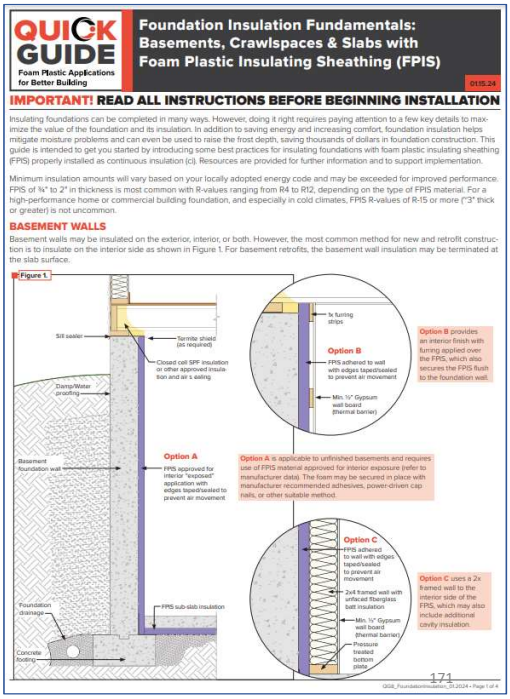
Quick Guide for FPIS Foundation Application

- https://www.continuousinsulation.org/resources/quick-guides


QUICK GUIDE
Foam Plastic Applications for Better Building

Foundation Insulation Fundamentals: Basements, Crawlspaces & Slabs with Foam Plastic Insulating Sheathing (FPIS)

0115.24

IMPORTANT! READ ALL INSTRUCTIONS BEFORE BEGINNING INSTALLATION

Insulating foundations can be completed in many ways. However, doing it right requires paying attention to a few key details to maximize the value of the foundation and its insulation. In addition to saving energy and increasing comfort, foundation insulation helps mitigate moisture problems and can even be used to raise the frost depth, saving thousands of dollars in foundation construction. This guide is intended to get you started by introducing some best practices for insulating foundations with foam plastic insulating sheathing (FPIS) properly installed as continuous insulation (ci). Resources are provided for further information and to support implementation.

Minimum insulation amounts will vary based on your locally adopted energy code and may be exceeded for improved performance. FPIS of ¾" to 2" in thickness is most common with R-values ranging from R4 to R12, depending on the type of FPIS material. For a high-performance home or commercial building foundation, and especially in cold climates, FPIS R-values of R-15 or more ("3" thick or greater) is not uncommon.

BASEMENT WALLS

Basement walls may be insulated on the exterior, interior, or both. However, the most common method for new and retrofit construction is to insulate on the interior side as shown in Figure 1. For basement retrofits, the basement wall insulation may be terminated at the slab surface.

Figure 1

Option A
FPIS approved for interior "exposed" application with edges taped/sealed to prevent air movement

Option A is applicable to unfinished basements and requires use of FPIS material approved for interior exposure (refer to manufacturer data). The foam may be secured in place with manufacturer recommended adhesives, power-driven cap nails, or other suitable method.

Option B
FPIS adhered to wall with edges taped/sealed to prevent air movement

Option B provides an interior finish with furring applied over the FPIS, which also secures the FPIS flush to the foundation wall.

Option C
FPIS adhered to wall with edges taped/sealed to prevent air movement

Option C uses a 2x framed wall to the interior side of the FPIS, which may also include additional cavity insulation.

Sill sealer
Termite shield (as required)
Closed cell SPF insulation or other approved insulation and air s ealing
Damp/Water proofing
Basement foundation wall
FPIS sub-slab insulation
Foundation drainage
Concrete footing
2x furring strips
Min. ½" Gypsum wall board (thermal barrier)
2x4 framed wall with unfaced fiberglass batt insulation
Pressure treated bottom plate

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B. Frost-Protected Shallow Foundations (FPSF)

- Brief History
- IRC/IBC provisions & ASCE 32 standard
- FPSF applications

NOTE: You use FPIS to build FPSF

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History of FPSFs

- 1930s – Frank Lloyd Wright designed and built the first FPSFs in the Chicago area
- 1950s – 1970s In rebuilding after WWII, Scandinavian countries studied U.S. construction and then became leaders in FPSF technology
- 1980s – U.S. Plastics Industry and NAHB/RC begin technology transfer back to U.S.
- 1992 – 1994 U.S. HUD sponsors a 5-home verification study in the northern U.S. climates; Air-freezing Index map is created; U.S. design guide developed
- 1995 CABO OTFDC – first model code recognition of FPSF in U.S.
- 2001 – ASCE standard 32 is completed (based on HUD guides for FPSFs)
- More than 1,000,000 FPSF foundations built in Europe and US

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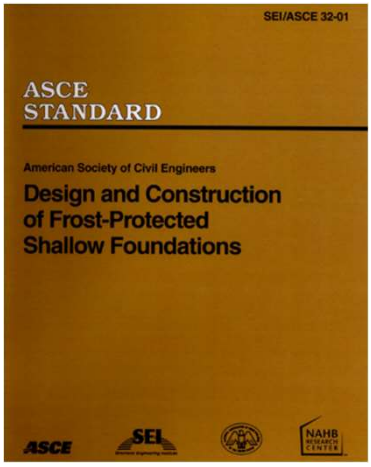
IBC on Frost Protection

Section 1809.5 Frost protection

- Foundation walls, piers and building permanent supports shall be protected by one or more of the following methods:
  1. Extended below the frost line of the locality
  2. Constructed in accordance with ASCE 32
  3. Erected on solid rock
- Shallow foundations shall not bear on frozen soil unless the frozen condition is permanent

Section 1809.5.1 Frost protection at required exits

- Provided at exterior landings for all required exits with outward-swinging doors
- Only required to ensure unobstructed opening of exit doors



https://www.asce.org

Note: Exceptions to Section 1809.5 for Risk Category I buildings, building area/type , and eave height.

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IRC on Frost Protection

Section R403.1.4.1 Frost protection

- Foundation walls, piers and building permanent supports shall be protected by one or more of the following methods:
  1. Extended below the frost line (Table R301.2)
  2. Constructed per Section R403.3*
  3. Constructed in accordance with ASCE 32
  4. Erected on solid rock
- Footings shall not bear on frozen soil unless the frozen condition is permanent

* Prescriptive approach based on simplified method in ASCE 32
Note: Exceptions similar to IBC

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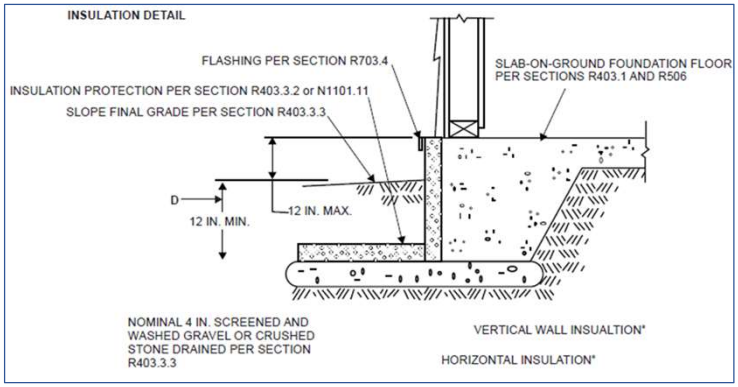
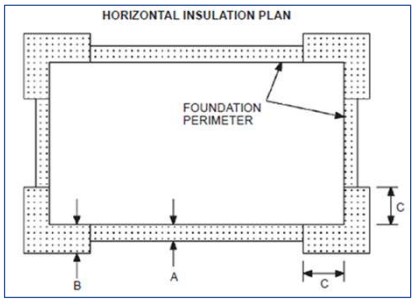
IRC on FPSF

Section R403.3 Frost-protected shallow foundations

- Footings not required to extend below frost line if building is maintained at monthly mean temperature not less than 64˚F (18˚C) and is protected by insulation per **Figure R403.3.1** and **Table R403.3(1)**
- Foundations protected per **Figure R403.3.1** and **Table R403.3(1)** shall not be used for unheated spaces (e.g., porches, garages, utility rooms) and shall not be attached to basements or crawlspaces not maintained at minimum monthly mean temperature of 64˚F (18˚C)





Source: IRC Figure R403.3.1

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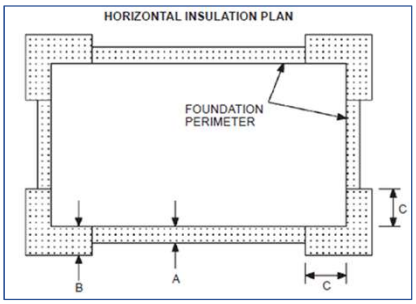
IRC on FPSF



Source: IRC Figure 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

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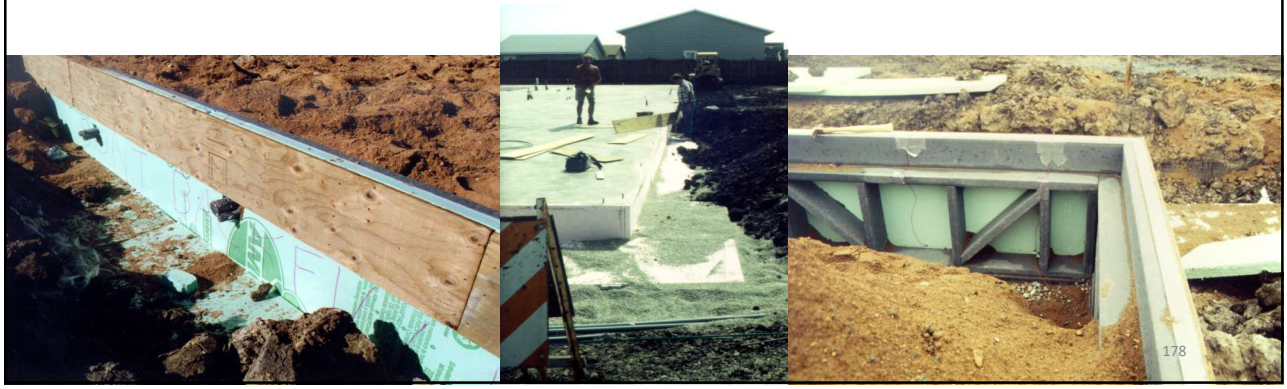
FPSF Applications

- Heated buildings
  - Slab on grade
  - Crawlspace
  - Walk out basement
- Unheated buildings
- Unheated cold foundations
- Others: Exterior stairways, retaining walls, utility trenches



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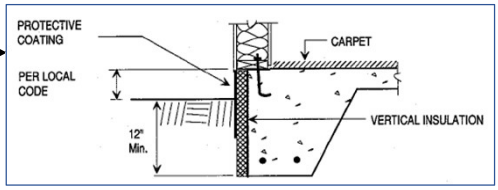
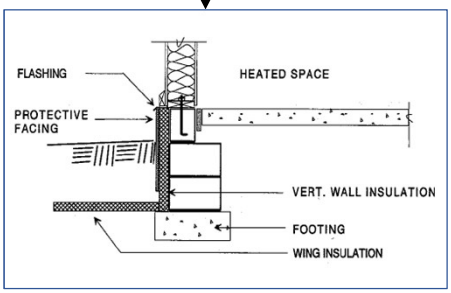
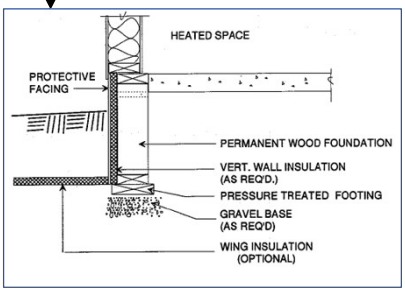
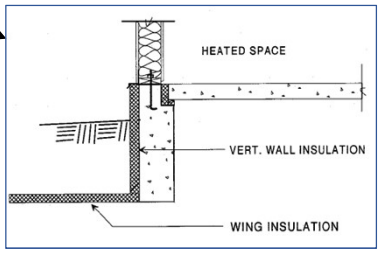
FPSF Application: Slab on Grade (Heated Building)

- Monolithic thickened edge
- Concrete stem wall
- Permanent wood stem wall
- CMU stem wall









Source: https://www.huduser.gov/publications/pdf/fpsfguide.pdf

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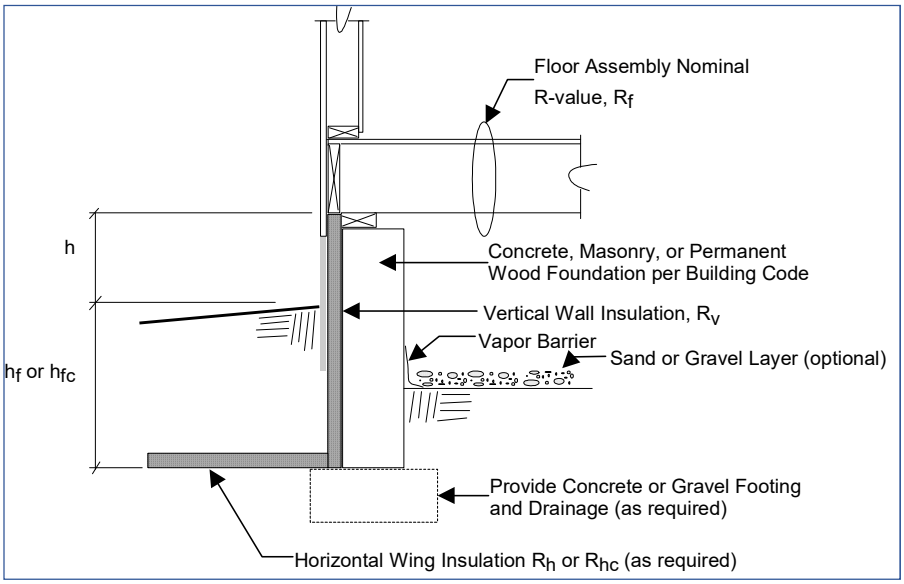
FPSF Application: Unvented Crawlspace (Heated Building)*



*** Unvented (conditioned) crawlspaces recognized in IRC Section R408.3. But FPSF insulation must be determined in accordance with ASCE 32 (referenced in IRC/IBC) and the IECC (more stringent applies at least for the vertical insulation)**

Source: SEI/ASCE 32-01

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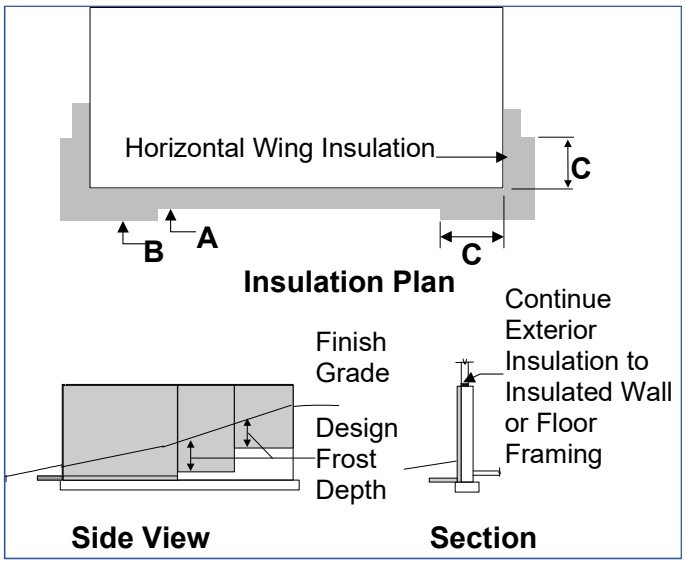
FPSF Application: Walk out Basement (Heated Building)*

- Apply FPSF insulation to exterior of basement wall, or
- Use Permanent wood walls (insulation in wall)
- Avoids need for stepped footings to frost depth at walk-out side.



*** Refer to ASCE 32 (not addressed in IRC)**

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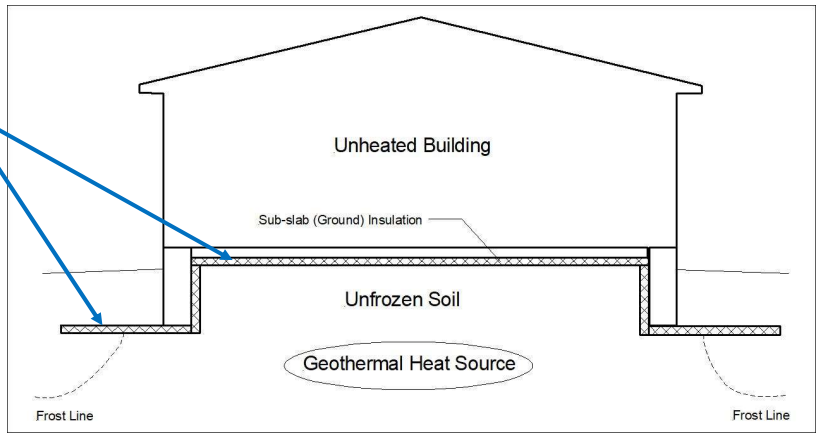
FPSF Application: Unheated Building*

- Ground insulation must "blanket" entire footprint of foundation
- Also used for unheated portions of heated buildings (e.g., garages, porches, etc.)



https://erdc-library.erdc.dren.mil/items/81b728f7-5e2f-4ef8-e053-411ac80adeb3

*** Must refer to ASCE 32 to specify insulation type and compressive resistance to support structural foundation loads**

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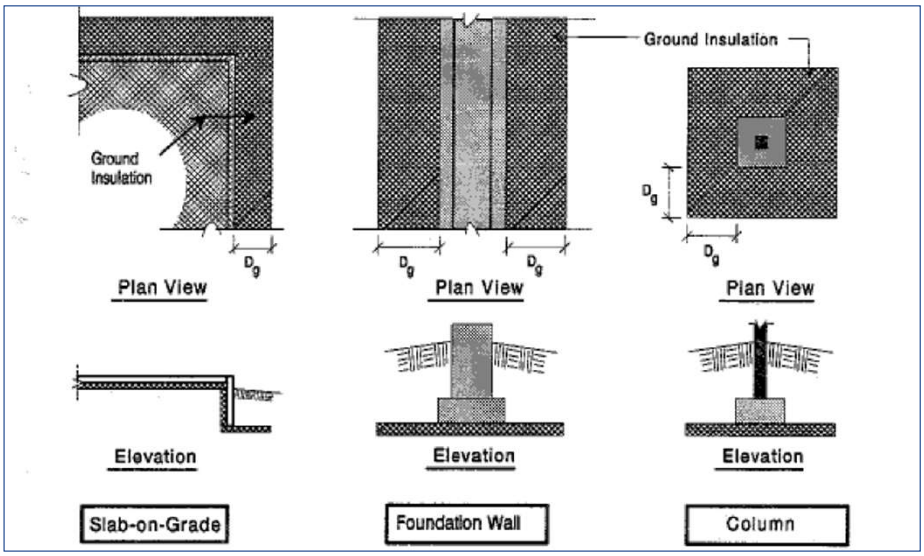
FPSF Applications: Unheated "Cold" Foundations*



*** Refer to ASCE 32 (not addressed in IRC)**

Source: https://www.huduser.gov/publications/pdf/fpsfguide.pdf

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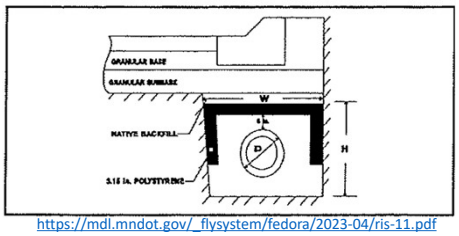
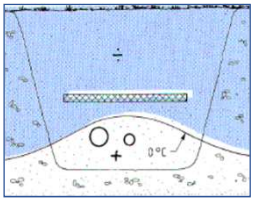
FPSF Applications: Exterior Slabs/Stairs, Retaining Walls, U/G Wet Utilities*

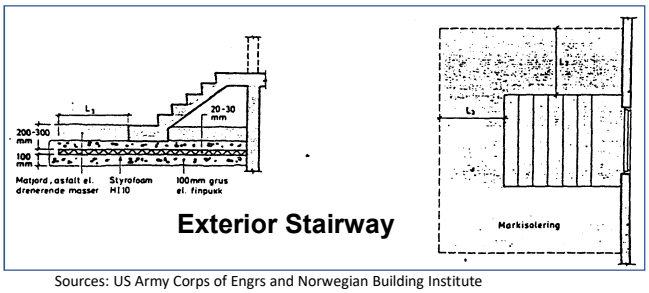
Utility Trench



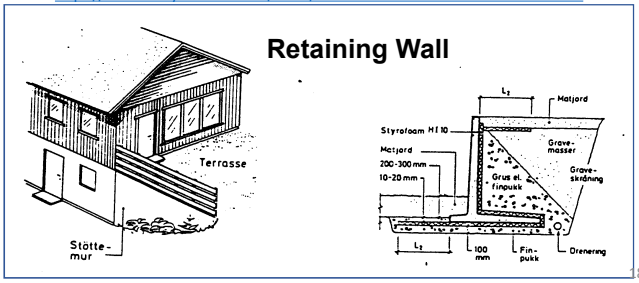
https://mdl.mndot.gov/_flysystem/fedora/2023-04/ris-11.pdf
https://apps.dtic.mil/sti/tr/pdf/ADA350992.pdf



***Not addressed in IRC or ASCE 32 – refer to guides or manufacturer recommendations for geotechnical applications**



Sources: US Army Corps of Engrs and Norwegian Building Institute
https://erdc-library.erdc.dren.mil/items/81b728f7-5e2f-4ef8-e053-411ac80adeb3



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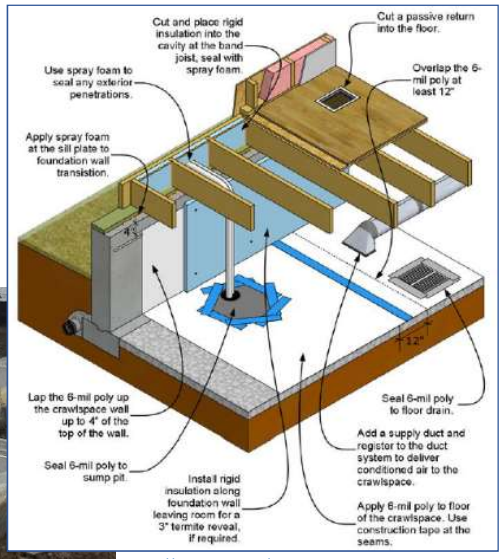
C. IBC/IRC – Unvented Crawlspaces

- **IRC R408.3**
- Allows ductwork in conditioned space; warm floor; no moist air foundation vents; storage space
- Insulation only at crawlspace perimeter, not between joists
- Requires conditioned air supply



https://basc.pnnl.gov/resource-guides/unvented-insulated-crawlspaces

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D. Termite Protection Compliance

- **IBC 2603.8/IRC R305.4 – Foam Plastic Protection**
- Areas with "very heavy" probability of termite infestation (**see Figure 2603.8/R305.4**), foam plastics shall not be installed on the exterior face or under interior or exterior foundation walls or slab foundations located below *grade*.
- Foam plastics installed above *grade* and exposed earth shall have clearance not less than 6 inches (152 mm).
- **Exceptions:**
  - 1. Buildings with structural members (walls, floors, ceilings and roofs) are entirely of *noncombustible materials* or pressure-preservative-treated wood.
  - 2. Where in addition to the requirements of **R305.1**, an *approved* method of protecting the foam plastic and structure from subterranean termite damage is used.
  - 3. On the interior side of basement *walls*.

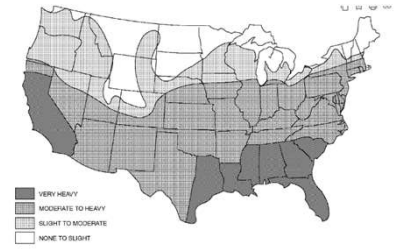
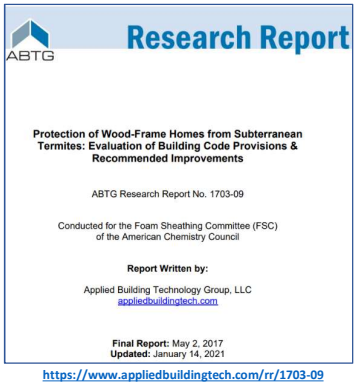


FIGURE 2603.8 TERMITE INFESTATION PROBABILITY MAP



https://www.appliedbuildingtech.com/rr/1703-09

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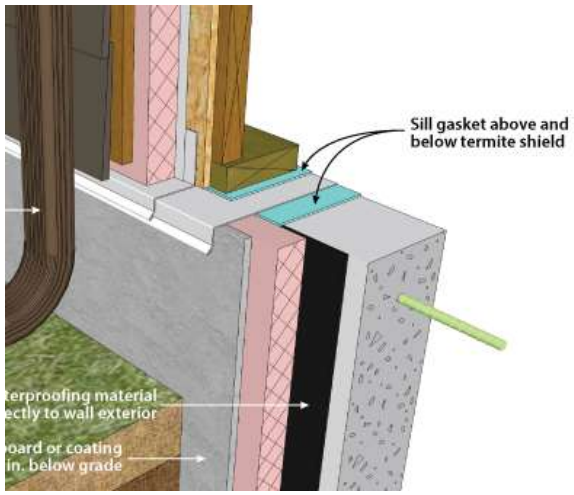
Termite Protection Solutions

- **Recommended practice:**
  - Termite shield for shelter tube inspection (installed during construction)
  - Ground termite treatment (maintained periodically by pest control operator)
  - Code requires one of the above (both are recommended in areas of "very heavy" termite infestation probability).
- **Termite treatment certificate (required for home sales/loans)**
  - Consult with local pest control operators
  - Consult local code requirements
  - Some local/state codes require an inspection strip in "very heavy" termite regions
  - Termite shield may or may not be accepted as an alternative even though a proven technology since at least the 1950s (old FHA building codes) and a recognized method in **IRC Section R305**



https://foundationhandbook.ornl.gov/handbook/

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V. Residential & Commercial Roof & Floor Insulation (Horizontal Assemblies)

A. IECC/IRC – Thermal compliance
B. Applications

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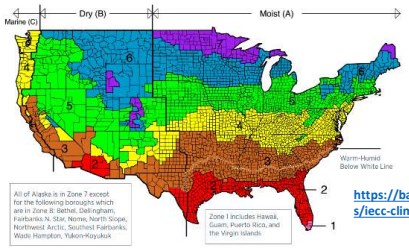
A. IECC – Thermal Compliance

2024 IECC Commercial Provisions – Tables C402.1.2 & C402.1.3

Climate Zone	Building Use	Insulation Entirely Above Roof Deck	Attic & other
0, 1	All other	R-20ci (U-0.048)	R-38 (U-0.027)
	Group R	R-25ci (U-0.039)	
2	All other		
	Group R		
3	All other		
	Group R		
4 Except Marine	All other	R-30ci (U-0.032)	R-49 (U-0.021)
	Group R		
5 and Marine 4	All other		
	Group R		
6	All other		
	Group R		
7	All other	R-35ci (U-0.028)	R-60 (U-0.017)
	Group R		
8	All other		
	Group R		



https://basc.pnnl.gov/images/iecc-climate-zone-map

2024 IECC Residential Provisions – Tables R402.1.2 & 402.1.3

Climate Zone	Ceiling	Insulation Entirely Above Roof Deck	Floor
0, 1	R-30 (U-0.035)	R-25ci (U-0.039)	R-13 or 7+5ci or 10ci (U-0.064)
2	R-38 (U-0.030)		
3			R-19 or 13+5ci or 15ci (U-0.047)
4 except Marine	R-49 (U-0.026)	R-30ci (U-0.032)	
5 and Marine 4			R-30 or 19+7.5ci or 20ci (U-0.033)
6			
7 and 8		R-35ci (U-0.028)	R-38 or 19+10ci or 25ci (U-0.028)

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Specific BTE Insulation Requirements

- **IECC-C**

  C402.1.2 Assembly U-factor, C-factor or F-factor-based method
  - C402.1.2.1.1 Tapered above-deck insulation based on thickness
  - C402.1.2.1.2 Suspended ceilings

  C402.1.3 Insulation component R-value method
  - C402.1.3.1 R-value of multi-layered insulation components
  - C402.1.3.2 Area-weighted averaging of R-values
  - C402.1.3.3 Suspended ceilings

  C402.2 Specific insulation and installation requirements
  - C402.2.1 Roof-ceiling construction
  - C402.2.1.1 Joints staggered
  - C402.2.1.2 Skylight curbs
  - C402.2.1.3 Minimum thickness of tapered insulation

- **IECC-R**

  R402.2 Specific insulation requirements
  - R402.2.1 Ceilings with attics*
  - R402.2.2 Ceilings without attics *
  - R402.2.8 Floors**

* exceptions for framing depth can be overcome by SPF

** specifically addresses “hybrid” cavity + ci floor systems (now included in 2024 IECC R-value options)

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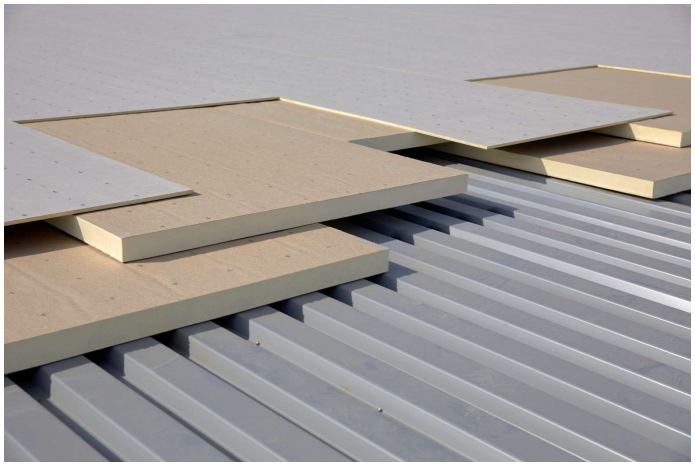
B. Applications: Insulation Entirely Above Roof Deck

- FPIS ci commonly used in low-slope roofs as "above deck" continuous insulation
  - Below roof membrane (most common)
  - Over roof membrane (Protected Membrane Roof System) – New provisions in 2024 IBC
- Also, used in steep slope roof applications



Source: PIMA

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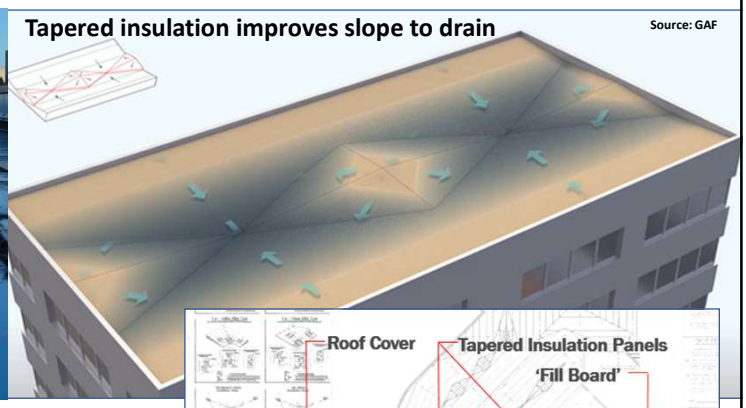
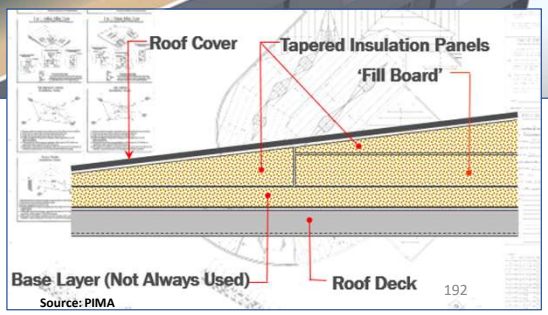
Applications: Insulation Entirely Above Roof Deck





- IBC, Chapter 15 Roof Assemblies and Rooftop Structures covers other requirements for roofs including roof replacement provisions (Section 1512, Reroofing)
- Requirements in IRC, Chapter 9 Roof Assemblies (Section R908, Reroofing)

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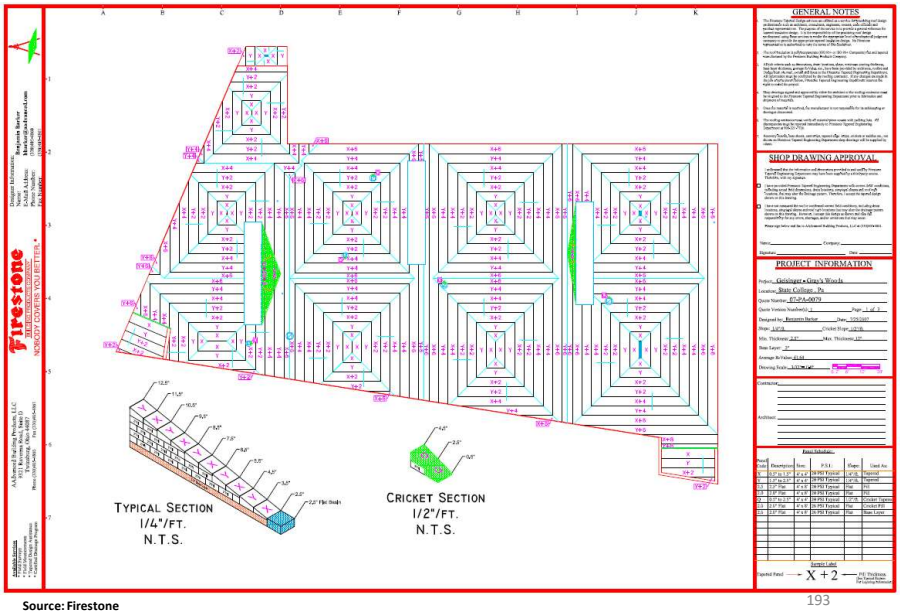
Applications: Insulation Entirely Above Roof Deck

- Often, tapered roof insulation systems are addressed by manufacturer “shop drawings” for drainage, insulation layout, and overall roof R-value compliance.



Source: Firestone

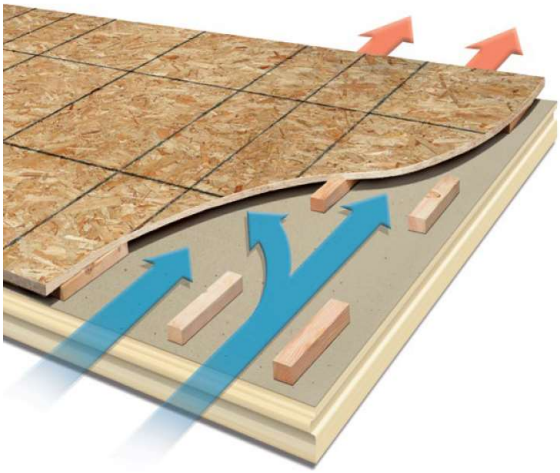
Applications: Insulation Entirely Above Roof Deck

- SPF used as above-deck roof insulation and roofing
- Requires added coating for UV protection

Source: BASF

Applications: Vented, Nailbase with FPIS ci

- Used for steep slope roofs
  - Cathedral and attic roofs
  - Allows direct attachment of roof covering and other materials
  - Offers vented roof deck where required by roofing manufacturer (e.g., asphalt shingles)
  - Can be used to convert attic into conditioned space or conditioned attic (improved HVAC performance and energy savings)



Vented nail-base roof deck panel

Source: GAF

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Applications: Cathedral Roofs / Unvented Conditioned Attics

- SPF used to insulate conditioned attic & cathedral ceiling on interior side of roof deck
  - Alternate to above-deck roof insulation which is more appropriate for metal roof framing
- Refer to insulation requirements in **IRC Section R806.5** and **IBC Section 1202.3** for insulation details to control moisture in unvented roof.

https://www.americanchemistry.com/industry-groups/spray-foam-coalition-sfc

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Applications: Raised Floors/Elevated Buildings

- Floor over Unconditioned Space (e.g., vented crawlspace or raised coastal foundation, etc.)
  - FPIS provide continuous insulation and air-barrier
    - Must be approved for interior exposure if no thermal barrier (e.g., gypsum panels)
  - Also useful for floor overhangs, particularly if adjoining walls have FPIS ci
- Can also use SPF for floor cavities and perimeter (band/rim joist insulation and air sealing)
  - SPF has R-values as much as R-7 and can achieve high R-values in shallow floor cavities (especially useful for retro-fit)

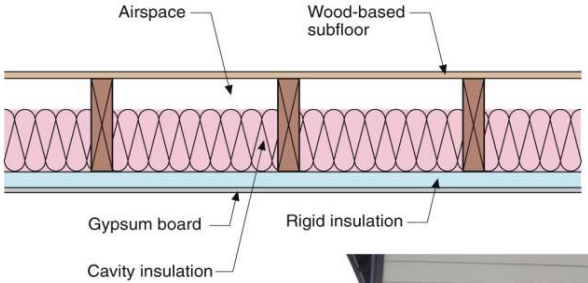

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Photo by Shaunna Mozingo

VI. Residential & Commercial – Existing Buildings/ Alterations

- **2024 IECC Section C503/R503 Alterations**
  - **Section C503.2/R503.1.1 Building Thermal Envelope**
  - Reorganized and triggers added for improving or bringing insulation up to current code based on type of alteration occurring to:
    - C503.2.1/R503.1.1.2 Roof, ceiling and attic alterations
    - C503.2.2/R503.1.1.1 Vertical fenestration
    - C503.2.3 Skylight area
    - C503.2.4/R503.1.1.3 Above-grade wall alterations
    - C503.2.5/R503.1.1.4 Floor alterations
    - C503.2.6/R503.1.1.5 Below-grade wall alterations
    - C503.2.7/R503.1.1.6 Air barrier
    - C503.3.6 Replacement or added roof mounted mechanical equipment

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Alterations – General

C503.1/R503.1.1 General. *Alterations* to any *building* or structure:

- Must comply with requirements of **Section C503**.
- Must not be less conforming than prior to the alteration.
- Must conform to the provisions of this code as those provisions relate to new construction without requiring the unaltered portions to comply with this code.
- Must not create unsafe or hazardous conditions or overload existing building systems.

Exceptions: Following *alterations* need not comply with requirements for new construction, provided that energy use of *building* is not increased:

1. Storm windows installed over existing fenestration
2. Surface-applied window film installed on existing single-pane fenestration assemblies reducing solar heat gain, provided that the code does not require the glazing or *fenestration* to be replaced
3. *Roof* recover
4. *Roof replacement* where roof assembly insulation is integral to or located below structural roof deck (NEW)
5. *Air barriers* shall not be required for *roof recover* and *roof replacement* where *alterations* or renovations to *building* do not include *alterations*, renovations or *repairs* to remainder of *building thermal envelope* *(CE only)*
6. Existing building undergoing alterations that complies with **Section C407** (NEW)

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Roof, Ceiling, and Attic Alterations

C503.2.1/R503.1.1.2 Roof, ceiling, and attic alterations. Insulation complying with **Section C402.1** and **Section C402.2.1**, or an *approved* design that minimizes deviation from the insulation requirements, shall be provided for the following alterations:

1. An *alteration* of roof-ceiling construction other than *reroofing* where existing insulation located below the roof deck or on an attic floor above *conditioned space* does not comply with Table **C402.1.2**.

2. *Roof replacement* or a roof *alteration* that includes removing and replacing the *roof covering*, where the *roof assembly* includes insulation entirely above the *roof* deck.

Exceptions: Where compliance with Section C402.1 cannot be met due to limiting conditions on an existing roof, an *approved* design shall be submitted with the following:

1. *Construction documents* that include a report by a *registered design professional* or an *approved* third-party documenting details of the limiting conditions affecting compliance with the insulation requirements.
2. *Construction documents* that include a roof design by a *registered design professional* or *approved* third party that minimizes deviation from the insulation requirements.

3. Conversion of unconditioned attic space into *conditioned space*.

4. Replacement of ceiling finishes exposing cavities or surfaces of the roof-ceiling construction.

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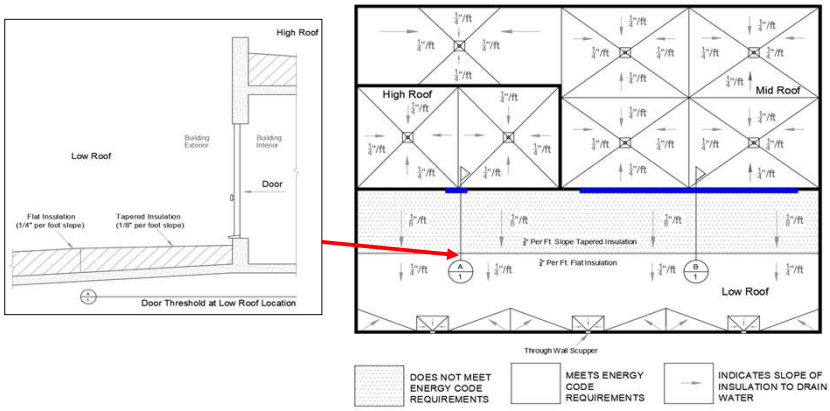
Roof, Ceiling, and Attic Alterations

- **(IECC) Roof Replacement.** An *alteration* that includes the removal of all existing layers of *roof assembly* materials down to the roof deck and installing replacement materials above the existing roof deck.
- **(IBC) 1512.2 Roof replacement.** *Roof replacement* shall include the removal of all existing layers of *roof assembly* materials down to the *roof deck*.



Example roof replacement plan (above deck roof insulation) by RDP or *approved* third party to "minimize deviation" from insulation requirements (exception to meeting full insulation amount when limiting conditions cannot be otherwise reasonably addressed).

Images courtesy of PIMA: https://www.polyiso.org/

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Roof Mounted Mechanical Equipment (NEW)

C503.3.6 Replacement or added roof-mounted mechanical equipment. For roofs with insulation entirely above the roof deck and where existing roof-mounted mechanical equipment is replaced or new equipment is added, and existing roof does not comply with insulation requirements for new construction in accordance with **Sections C402.1** and **C402.2.1**, curbs for added or replaced equipment shall be of height necessary to accommodate future addition of above-deck roof insulation to be installed in accordance with **Section C503.2.1**, Item 2. Alternatively, curb height shall comply with **Table C503.3.6**. Curb height shall be distance measured from top of curb to top of roof deck.

TABLE C503.3.6
ROOF-MOUNTED MECHANICAL EQUIPMENT CURB HEIGHTS

CLIMATE ZONE	CURB HEIGHT, MINIMUM
0, 1, 2 and 3	16 inches
4, 5 and 6	17 inches
7 and 8	18 inches

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Metal Building Retrofit with FPIS ci (Rated for Interior Exposure)

Before

After

Source: Dow / DuPont Building Performance Solutions

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Above-Grade Wall Alterations

C503.2.4 Above-grade wall alterations. *Above-grade wall* alterations shall comply with the following:

1. Where wall cavities are exposed, the cavity shall be filled with *cavity insulation* complying with Section C303.1.4. New cavities created shall be insulated in accordance with Section C402.1 or an *approved* design that minimizes deviation from the insulation requirements.

2. Where *exterior wall* coverings and *fenestration* are added or replaced for the full extent of any *exterior wall* assembly on one or more elevations of the *building* , insulation shall be provided where required in accordance with one of the following:

2.1 An R-value of continuous insulation not less than that designated in Table C402.1.3 for the applicable *above-grade wall* type and existing *cavity insulation* R-value, if any;

2.2 An R-value of not less than that required to bring the *above-grade wall* into compliance with Table C402.1.2; or,

2.3 An *approved* design that minimizes deviation from the insulation requirements of Section C402.1.

3. Where Items 1 and 2 apply, the insulation shall be provided in accordance with Section C402.1.

Where any of the above requirements are applicable, the *above-grade wall alteration* shall comply with Sections 1402.2 and 1404.3 of the *International Building Code*.

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Retrofit of Above Grade Walls with FPIS ci

- Best if siding and window replacements done at same time
- Can be done with just siding replacement
  - Need to properly integrated wall WRB and flashing with windows and doors if they are not replaced.
  - https://www.pnnl.gov/projects/re-siding-ext-insulation
- For additional information on existing building retrofits, refer to: https://www.continuousinsulation.org/remodeling-energy-efficiency

https://basc.pnnl.gov/resource-guides/rigid-foam-insulation-existing-exterior-walls

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THANK YOU!

Questions?

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