A Hard-Dollar Approach Design & Build In-Demand, Entry-Level Homes

NAHB IBS™

IBS Education

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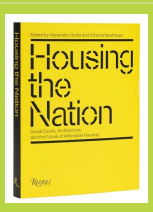
The Issues and Opportunity

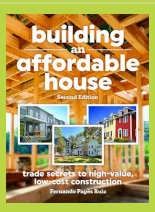
URBAN INSTITUTE

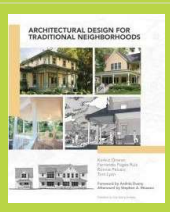
- Homeowners facing cost burdens increased by 2.3 million to 19.0 million.
- With population growth slowing, domestic migration becomes a key driver of household growth. In 2022, it was the primary source of population growth in 20 states and most growing counties.
- **Solution: Address the national housing shortage**: Explore alternative construction techniques, such as off-site and modular construction; encourage the adoption of accessory dwelling units in areas with limited land; and address local zoning policies and regulatory barriers to diversify housing types.

Why Fernando?

- Research, practice, practice, practice.





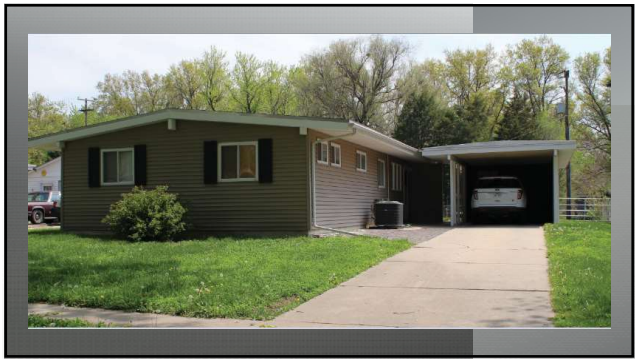


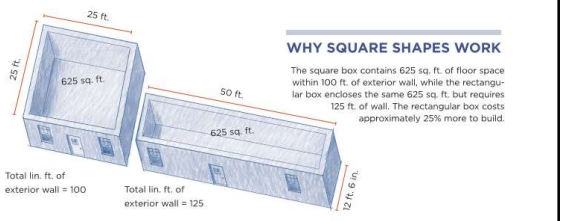
First Principles: Cheap Washing

- If affordability is your goal, make it so.
- You cannot meet all the goals at once.
- List your values in order of importance (value engineering):
  - Affordability (Lowest-cost)
  - Marketability (Pretty enough)
  - Durability (Quality control)

Steps to Achieving Affordability

1. Design for affordability
2. Collaborate toward affordability
3. Build affordably
4. And… shoot: Land strategies





WHY SQUARE SHAPES WORK

The square box contains 625 sq. ft. of floor space within 100 ft. of exterior wall, while the rectangular box encloses the same 625 sq. ft. but requires 125 ft. of wall. The rectangular box costs approximately 25% more to build.

Rational Ratio

÷ ft^2 of floor by ft^2 of exterior wall

My example of the square 625 ft^2 ÷ (25 ft X 4) X 8 = 800 ft^2 wall = .78

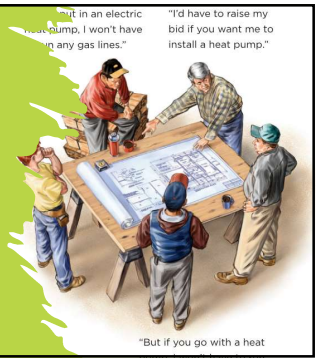
And the rectangle 625 ft^2 ÷ 1,000 ft^2 wall = .62

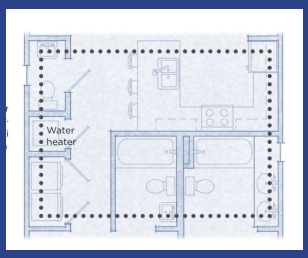
My favorite shape = 24 x 34

816 ft^2 floor ÷ 928 ft^2 wall = .88

Mechanical & Electrical Most Expensive Elements

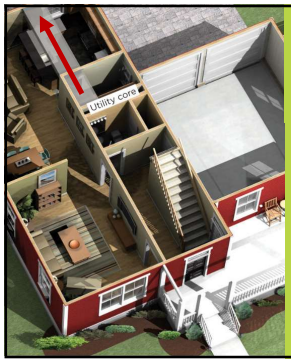
- Skill Level & Hourly Wage
- Make the work easy
- Make the utility runs as short as possible



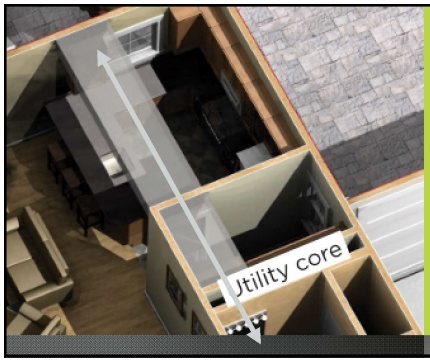


Cost-effective Plumbing: More than Bathrooms back-to-back

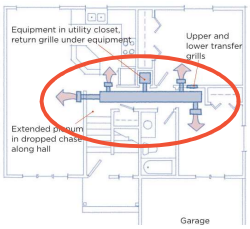
- Wet-room rectangle
- Gary Klein
- Ratio of rectangle relative to the total area of the house.
- The smaller, the better, and the larger percentage the less efficient.
- 67% was the sweet spot. $2,000 average savings.



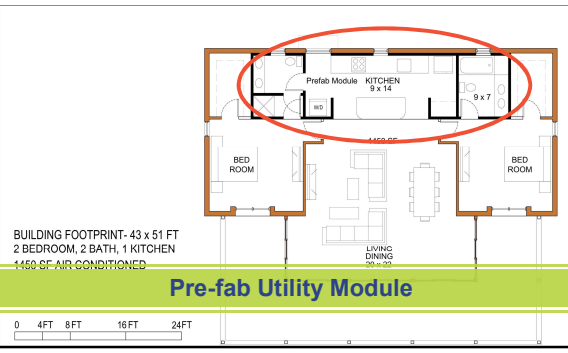
Central MEP: The utility core



The Plenum Air Distribution



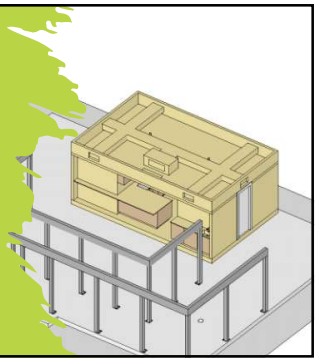
Plenum and Registers



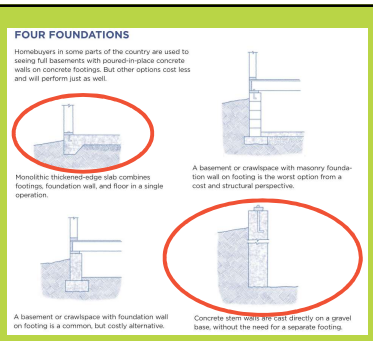
Pre-fab Utility Module

Plenum over the kitchen

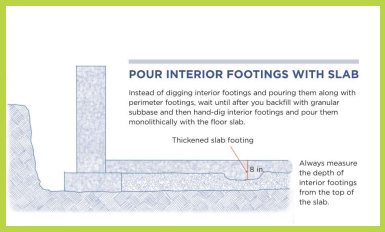
- Seven-foot ceiling.
- Equipment and ducts in conditioned space over the kitchen.
- Ducts feed living, baths and bedrooms

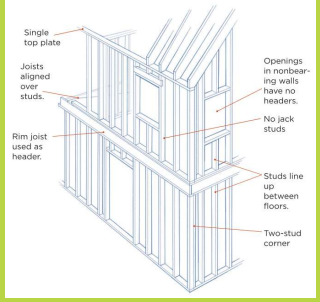


Foundations



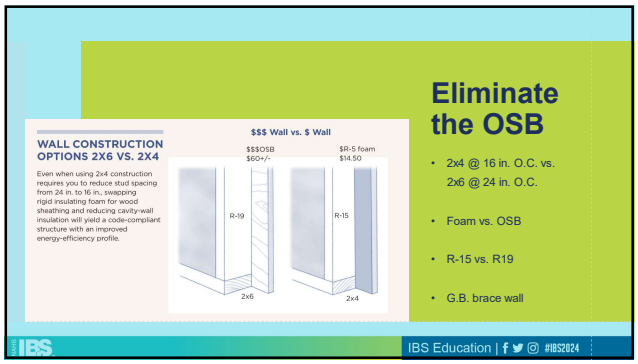
Don't discount the slab





Framing it Not Just 24 in O.C. or only 24 in O.C.

- Headers sizes
- Opening framing
- Stairwell framing
- Joist layouts
- Braced wall schemes
- New hardware options (screws)


WALL CONSTRUCTION OPTIONS 2X6 VS. 2X4
Even when using 2x4 construction requires you to reduce stud spacing from 24 in. to 16 in., swapping rigid insulating foam for wood sheathing and reducing cavity-wall insulation will yield a code-compliant structure with an improved energy-efficiency profile.
$$$ Wall vs. $ Wall
$$$OSB
$60+/-
$R-5 foam
$14.50
R-19
R-15
2x6
2x4
Eliminate the OSB
2x4 @ 16 in. O.C. vs. 2x6 @ 24 in. O.C.
Foam vs. OSB
R-15 vs. R19
G.B. brace wall
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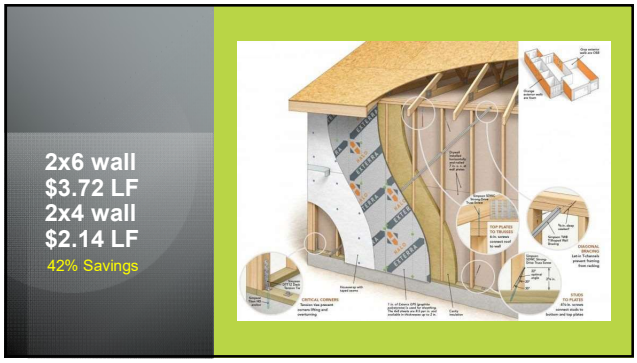
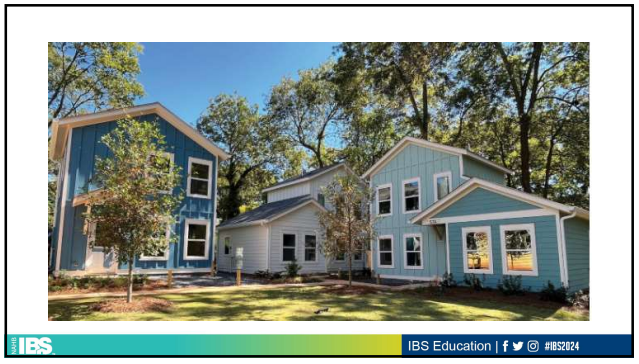
Look at section
R602.10


2x6 wall
$3.72 LF
2x4 wall
$2.14 LF
42% Savings


Land Strategy
"HOMEnibus" bill (NH) and "Yes in my back yard" (MA).
There are 18 legislative bills in eight states that aim to incentivize the construction of
ADUs to solve the housing shortage and affordability crisis.


ADU
ADU
GUEST HOUSE
DUPLEX
GUEST HOUSE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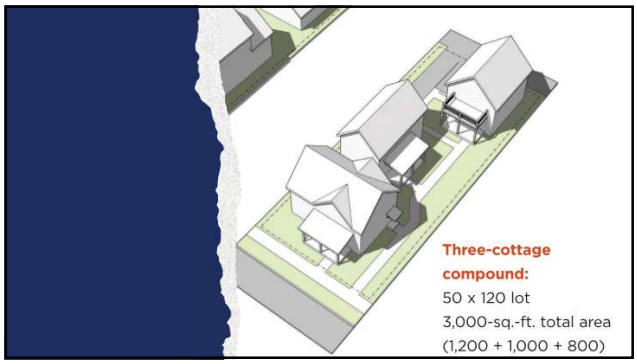
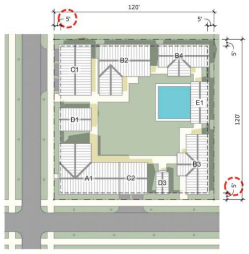
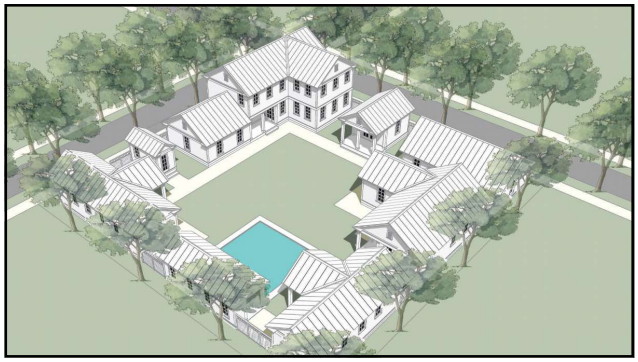
Lots are 21-ft. x 26-ft.
Tealight Series


Use Easement
• Both yards have a five-foot setback.
• The RH neighbor has an exclusive use easement on the LH neighbor's side yard.
• Each house has a useful outdoor area.

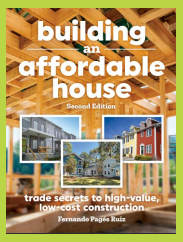


Six kitchens





My Contact Information



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Now for the Main Attraction: Jay Crandell, PE

PART 2 – "Hard Dollar" Design & Construction (ideas from and engineer's perspective)

- "Hard Dollar" Foundations
- "Hard Dollar" Above-grade Walls
- "Hard Dollar" Parting Thoughts

Jay Crandell, P.E.
ABTG/ARES Consulting

A. “Hard-Dollar” Foundations

i. Foundation Construction Methods (footings, basement, crawlspace, slab-on-grade)
ii. Leveraging Foundation Insulation Strategies for Optimum Value
iii. Frost-Protected Shallow Foundations

Right-sized Footings

IRC Section 403 – Footings

Section 403.1 General – concrete footings, crush stone footings, wood foundations, or other approved based on loads and soil bearing.

3 Big tables for sizing concrete footings ranging from 24x8 to 12x6 (minimum) w/many limiting assumptions

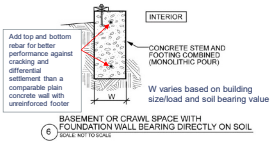
For soils with ≥ 2,500 psf soil bearing, a footing may not be required (direct bearing) or can be downsized to the minimum 12x6.

Requires analysis of building design load at base of foundation and soil test

- Example: 3000 psf soil can support 2000 plf of foundation load from direct bearing 8" thick concrete wall (no footer)

Soil tests to determine bearing can use a dynamic cone penetrometer for a portable, simple, and accurate test at footing depth

https://www.humboldtmfg.com/penetrometer-dynamic-cone.html



2021 IRC Figure R403.1(1)

Precast Concrete Foundation

IRC Section R403.4

Oddly limits footing sizing table to minimum 8" thick wall (Table R403.4)

In many cases a 6" thick wall and crush stone or gravel footing will work

Crush stone footing width in code appears off? (too wide as load spread from base of wall to ground is at best ~30° angle)

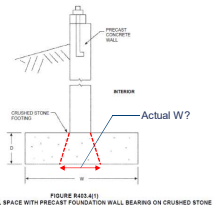
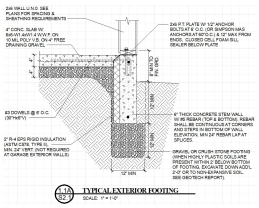


FIGURE R403.4(1)
BASEMENT OR CRAWL SPACE WITH PRECAST FOUNDATION WALL BEARING ON CRUSHED STONE

6” Concrete Stem Wall w/ Gravel Footing

- 6” foundation stem wall and independent floor slab
- Designed for military housing at Ft. Belvoir, VA
- Savings in concrete, excavation, labor, and minimized site disturbance
- Uses gravel footing to distribute load from 6” foundation wall to 12” width on soil (may not be needed on many sites)
- Grave footing also used as needed to reach suitable bearing soil
- Similar design to precast foundations in IRC Section R403.4 (but with right-sized aggregate footing)
- Must verify reaction of wind uplift load with weight (D) of foundation (i.e., 0.6D + 0.6W = allowable stress with “safety factor on dead load and ASD load factor on ultimate wind load W)
- Concerned? Try it with a detached garage first.



Permanent Wood Foundations (PWF)

Gravel footing

Trt’d Wood “mud sill” (e.g., 2x8 to 2x10)

Treated wood framing (e.g. No.1 SYP 2x6 or 2x8 studs @ 12” or 16”oc)

5/8” to ¾” Treated plywood

SS sheathing nails

Poly water barrier on exterior

Aggregate (gravel or crush stone) for drainage

Can also be used as independent stem wall and slab on grade

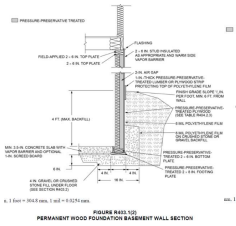


FIGURE R403.1(2)
PERMANENT WOOD FOUNDATION BASEMENT WALL SECTION

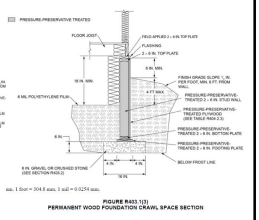


FIGURE R403.1(3)
PERMANENT WOOD FOUNDATION CRAWL SPACE SECTION

Permanent Wood Foundations

Resources

Designers:

Permanent Wood Foundation Design Specification

American Wood Council

https://awc.org/publications/2015-pwf/

Builders:

Permanent Wood Foundations Design & Construction Guide

Southern Forest Products Association

https://www.southernpine.com/applications/permanent-wood-foundations/

Leveraging Foundation Insulation for Optimum Value

Basements

Crawlspaces

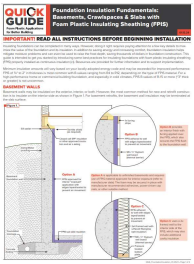
Slabs on grade

Frost-protected Shallow Foundations

GOAL: Take advantage of multi-functional capabilities of insulation to provide two or more functions at once.

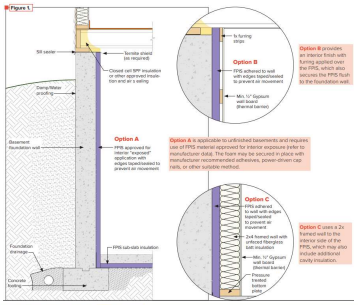
RESOURCE:

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



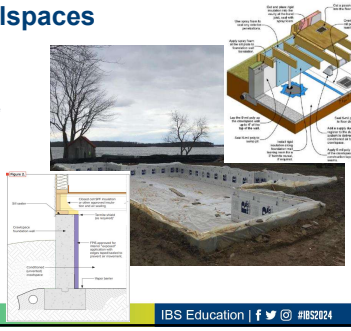
Basement Walls

- Foam plastic insulating sheathing (FPIS) insulation application
- Ready-to-finish space
- If FPIS exposed to interior, then must be approved for that application
  - Refer to manufacturer fire test data and evaluation report
- FPIS continuous insulation is considered a "hall of fame" insulation for basement walls by DOE Building America Program
  - Improved energy efficiency, moisture control, and comfort
  - No vapor retarder to interior of FPIS (drying inward)



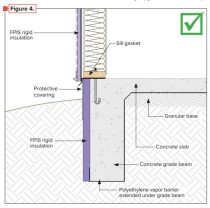
Unvented Crawlspaces

- **IRC Section R408.3**
- Place insulation only at crawlspace perimeter, not between every joist (less insulation with higher performance and less interference with trades)
- Moves ductwork into conditioned space (better energy savings)
- Warm floor above (better comfort)
- No moist air foundation vents (better moisture control)
- Potential for added dry storage space (particularly if 2-1/2" mud slab used over poly vapor barrier)
- Similar benefits for unvented (conditioned) attic spaces, but often not with first cost savings (see IRC Section R806.5) unless valued as "bonus" living space or storage area.

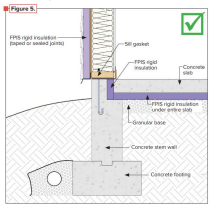


Slab on Grade

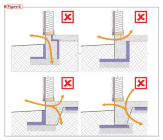
Monolithic slab and footing (grade beam)



Independent slab and stem wall



Avoid Thermal Bridges!



Frost protected shallow foundations (FPSF)

- **IRC R403.3 Frost-protected shallow foundations**
- Leverage foundation insulation required for energy code to also deliver significant foundation cost savings:
  - Typically save $1,000 to $4,000 per home
  - ~$300,000 for 100-home development in 1994
- Also applicable to light commercial buildings
- Greater savings in areas with greater frost depth (>24")
- Not applicable in areas of permafrost (artic)
- Used on millions of buildings in Europe and US
- Concept first used by FLW in 1930s affordable housing
- Been in US codes since 1995 CABO
- Based on HUD and NAHB Research Center research, technology transfer, code development, and standardization

4-unit townhouse slab
Fargo, ND

IRC on Frost Protection

- IRC Section 403.3 for prescriptive FPSF design
- IRC references ASCE 32 for more design options:

R403.1.4.1 Frost protection. Except where otherwise protected from frost, foundation walls, piers and other permanent supports of buildings and structures shall be protected from frost by one or more of the following methods:

1. Extended below the frost line specified in Table R301.2.
2. Constructed in accordance with 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.

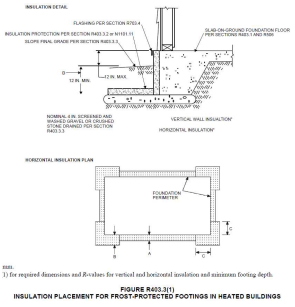
Exceptions:

Exceptions are similar to IBC

IRC on FPSF

R403.3 Frost-protected shallow foundations. For buildings where the monthly mean temperature of the building is maintained at not less than 64°F (18°C), footings are not required to extend below the frost line where protected from frost by insulation in accordance with Figure R403.3(1) and Table R403.3(1). Foundations protected from frost in accordance with Figure R403.3(1) and Table R403.3(1) shall not be used for unheated spaces such as porches, utility rooms, garages and carports, and shall not be attached to *basements* or *crawl spaces* that are not maintained at a minimum monthly mean temperature of 64°F (18°C).

Materials used below *grade* for the purpose of insulating footings against frost shall be *labeled* as complying with ASTM C578.



1) for required dimensions and *R*-values for vertical and horizontal insulation and minimum footing depth.

FIGURE R403.3(1)
INSULATION PLACEMENT FOR FROST-PROTECTED FOOTINGS IN HEATED BUILDINGS

IRC on FPSF

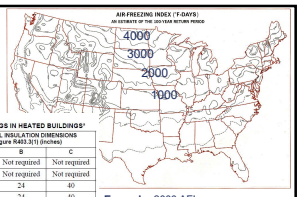


TABLE R403.3(1)
MINIMUM FOOTING DEPTH AND INSULATION REQUIREMENTS FOR FROST-PROTECTED FOOTINGS IN HEATED BUILDINGS[a]

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

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

a. Insulation requirements are for protection against frost damage in heated buildings. Greater values could be required to meet energy conservation standards.

b. See Figure R403.3(2) or Table R403.3(2) for Air-Freezing Index values.

c. Insulation materials shall provide the stated minimum *R*-values under long-term exposure to moist, below-ground conditions in freezing climates. The following *R*-values shall be used to determine insulation thicknesses required for this application: Type II expanded polystyrene (EPS)-3.2 R per inch for vertical insulation and 2.6 R per inch for horizontal insulation; Type IX expanded polystyrene (EPS)-3.4 R per inch for vertical insulation and 2.8 R per inch for horizontal insulation; Types IV, V, VI, VII, and X extruded polystyrene (XPS)-4.5 R per inch for vertical insulation and 4.0 R per inch for horizontal insulation.

d. Vertical insulation shall be expanded polystyrene insulation or extruded polystyrene insulation.

e. Horizontal insulation shall be expanded polystyrene insulation or extruded polystyrene insulation.

Example: 2000 AFI,
Vertical insulation only
R5.6 required (see Table)
Type IX EPS (R3.4/in) – note 'c'
Use R5.6/R3.4/in = 1.65" thick (1-3/4")
Energy code requires min. R10
Use R10/R4.2/in = 2.4" thick (2-1/2")
for 4' (vertical down then horizontal)
NOTE: R per inch differs for FPSF vs. energy code application

FPSF Applications

Home or multi-unit town house slabs

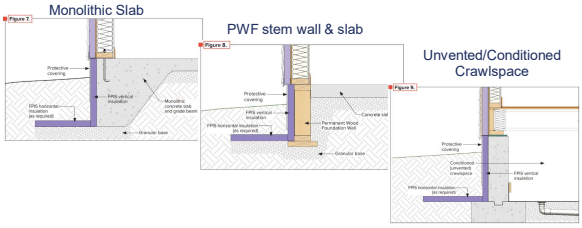
Permanent Recycled Plastic Lumber Stem Wall & Slab

FPSF Applications

Monolithic Slab

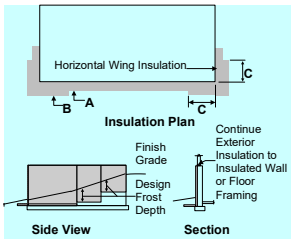
PWF stem wall & slab

Unvented/Conditioned Crawlspace



FPSF Application: Walk-out Basement (Heated Building)*

- Apply FPSF insulation to exterior of walk-out basement wall
- Avoids need for stepped footings to frost depth at walk-out side.
- Leverages optimum insulation location with foundation cost savings



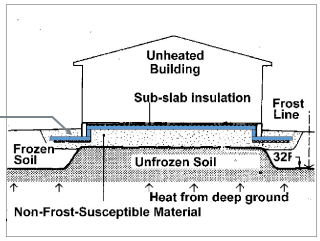
* Not addressed in IRC; must refer to ASCE 32

FPSF Application: Unheated Buildings*

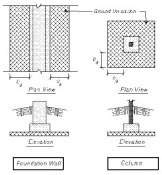
* Must refer to ASCE 32 to specify insulation type and compressive resistance to support structural foundation loads (40psi to 100psi FPIS = 2,000 to 4,500 psf design bearing load w/ Safety Factor of 3)

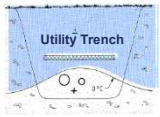
Ground insulation must "blanket" entire footprint of foundation under unheated building portions

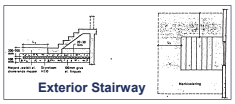
Also used for unheated portions of heated buildings, garages, porches, etc.

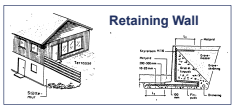


FPSF Applications: Cold Footings, Retaining Walls, & Utilities*









* Refer to ASCE 32 (not addressed in IRC)

B. “Hard Dollar” Above-grade Walls

i. Wall framing & headers
ii. Wall bracing
iii. Leveraging wall insulation for optimum value

Rule of Thumb: Avoid High Framing Factors

- Material and labor cost increase
- Energy use increase
- Resource efficiency impact (wasteful)
- Efficient framing can save:
  - Up to 30% in framing material and labor
  - Up to 5% in heating/cooling cost
- Better framing includes:
  - more efficient use of conventional framing (e.g. 16”oc studs)
  - varying degrees of advance framing techniques (where applicable).
- Thermal bridging impact is reduced or even negated depending on how wall is insulated (cavity vs. exterior insulation)

Framing factor = % of solid wall area occupied by framing

IRC on Efficient Wall Framing (Studs)

R602.3 Stud Options:

2x4@24"oc – supporting roof only

2x6@24"oc - supporting roof + 1 floor

2x3@16" – interior non-bearing partitions ?

2x5@24"oc – perhaps optimal for many exterior walls (but not in common use – may require volume purchase from mill) ?

Goal – use only what is required for the building condition & coordinate decision with other factors (e.g., some sheathing and sidings may be limited to 16"oc or require "up-sizing" to work with 24"oc studs, etc.)

TABLE R602.3(5)
SIZE, HEIGHT AND SPACING OF WOOD STUDS[a]

STUD SIZE (inches)	BEARING WALLS						NONBEARING WALLS	
	Laterally unsupported stud height[a] (feet)	Maximum spacing where supporting a roof-ceiling assembly or a habitable attic assembly, only (inches)	Maximum spacing where supporting one floor, plus a roof-ceiling assembly or a habitable attic assembly (inches)	Maximum spacing where supporting two floors, plus a roof-ceiling assembly or a habitable attic assembly (inches)	Maximum spacing where supporting one floor height[c] (inches)		Laterally unsupported stud height[a] (feet)	Maximum spacing (inches)
2 × 3[b]	—	—	—	—	—		10	16
2 × 4	10	24[c]	16[c]	—	24		14	24
3 × 4	10	24	24	16	24		14	24
2 × 5	10	24	24	—	24		16	24
2 × 6	10	24	24	16	24		20	24

For SI: 1 inch = 25.4 mm, 1 foot = 304.8 mm.

a. Listed heights are distances between points of lateral support placed perpendicular to the plane of the wall. Bearing walls shall be sheathed on not less than one side or bridging shall be installed not greater than 4 feet apart measured vertically from either end of the stud. Increases in unsupported height are permitted where in compliance with Exception 2 of Section R602.3.1 or designed in accordance with accepted engineering practice.

b. Shall not be used in exterior walls.

c. A habitable attic assembly supported by 2 × 4 studs is limited to a roof span of 32 feet. Where the roof span exceeds 32 feet, the wall studs shall be increased to 2 × 6 or the studs shall be designed in accordance with accepted engineering practice.

Notes:

1. *Single top plate is permitted, but with limitations (floor/roof and wall framing must be aligned and use of metal splice plates) – Not worth the hassle?*
2. *2-stud corners w/clips or wood cleats also permitted; may not be worth it if exterior insulation used. It's also an important area for cladding and trim attachment (highest wind load at corners) and interior GWB attachment for bracing.*

IRC on Efficient Wall Framing (Headers)

- **R602.7 Headers**
  - R602.7.1 Single member headers
  - R602.7.2 Rim board headers
  - Double 2x flatwise (non-bearing walls)
- Cost savings plus more energy efficient insulated headers

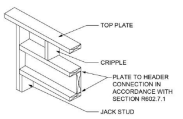


FIGURE R602.7.1(1)
SINGLE-MEMBER HEADER IN EXTERIOR BEARING WALL

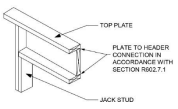


FIGURE R602.7.1(2)
ALTERNATIVE SINGLE-MEMBER HEADER WITHOUT CRIPPLE

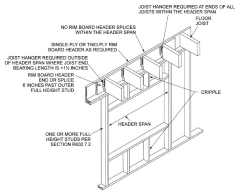


FIGURE R602.7.2
RIM BOARD HEADER

IRC on Efficient Wall Bracing

- GOAL: Right-size wall bracing and select bracing method to optimize cost and performance of overall wall assembly
- 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)

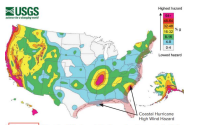
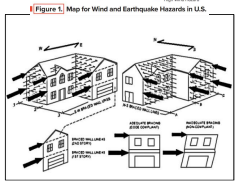


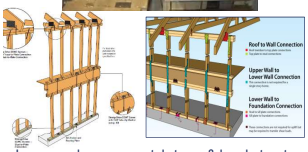
Figure 1. Map for Wind and Earthquake Hazards in U.S.



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.
- 2021 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.



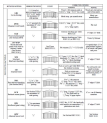
Long wood screws, metal straps & brackets, etc.

Stepwise Accounting Process

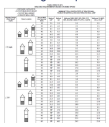
(think IRS 1040 form without TurboTax or instructions)

Steps 1&2 – ID BWLs per story

Step 3 – Select BMs for each BWL

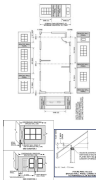


Step 4 – Bracing Length Req'd

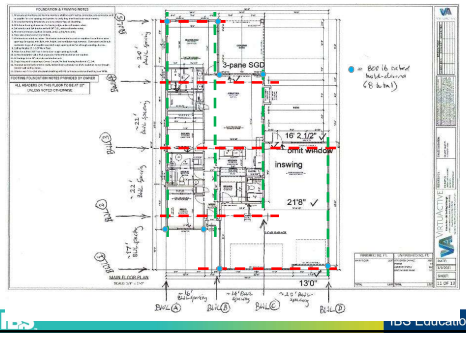


Steps 5&6 – Adjustment Factors and Check vs. Bracing Length Provided

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



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



Example House Plan & BWL Layout

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)

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

- May need to iterate to find optimal design
- May need to engineer some portions
- May need to shift some windows/doors or interior wall lines
- May need to consider a proprietary brace
- May need to get help!

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Different views of the world of walls?

Sources:
(1) http://www.greenbuildingadvisor.com/blogs/dept/musings/osb-airtight
(2) http://buildingscience.com/documents/digests/bsd-139-deep-energy-retrofit...
(3) Baby It's Cold Outside – Nazareth College, Rochester, NY (Wikimedia commons)

- Minimum bracing requirements rule the wall area!
- But, everybody seems to want their product continuous…
    - Continuous structural sheathing
    - Continuous insulation
    - What next?...Continuous windows?
- Balance is achieved in smart, code-compliant designs.

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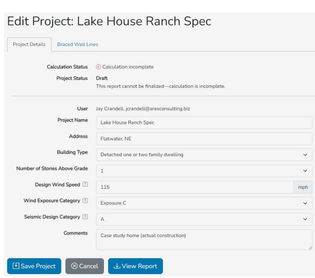
Help is here!
(Turbotax for wall bracing)

- A new IRC bracing free on-line calculator as just been released to aid in complying with the IRC wall bracing provisions and documentation for code compliance.
- Also helps optimize design for building and energy code compliance.



https://www.continuousinsulation.org/calculators

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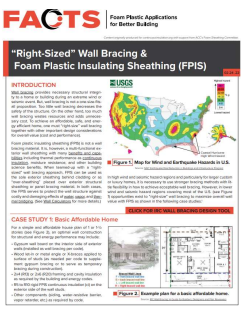
Additional Resources:

- **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
CASE STUDY 1: Basic Affordable Home
CLICK FOR IRC WALL BRACING DESIGN TOOL

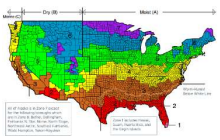
Leveraging Wall Insulation for Optimum Value

It is important to understand the nexus of structural efficiency, moisture control, and energy efficiency – there are opportunities to leverage and optimize interactions for cost savings and robust performance.

Insulation for Energy Code Compliance

IECC Residential Provisions Tables R402.1.2 & 402.1.3

Climate Zone	Wood Frame Walls	
	2018 IECC	2021 IECC[a]
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		
5 and Marine 4		R30 or R20+5ci or R13+10cior R20ci (U-0.045)
6	R20+5ci or R13+10ci (U-0.045)	
7 and 8		



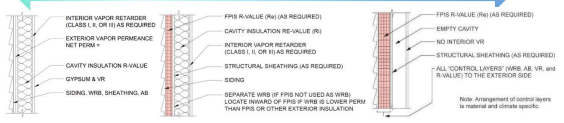
- Prescriptive cavity only, Ci only, and Hybrid options available for all climate zones in 2021 IECC.
- Can also consider UA trade-off or other performance paths (ERI, whole building modeling)
- Need to consider impact on moisture control whether making insulation trade-offs or not

Three Basic Methods for Insulating Light-Frame *Exterior Walls*

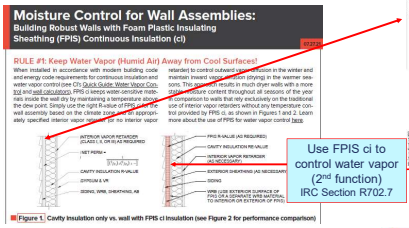
1. ***Cavity insulation only*** (traditional method)
2. ***Cavity insulation + continuous insulation*** (common choice for high-performance frame walls)
3. ***Continuous insulation (ci) only*** (provides the "perfect wall" approach for maximum thermal and moisture control performance)

Use FPIS as continuous insulation (1st function)

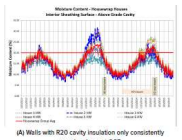
CAVITY INSULATION ONLY → CAVITY + CONTINUOUS HYBRID → CONTINUOUS ONLY



RULE #1 of 3 (Vapor Control)



Use FPIS ci to control water vapor (2nd function) IRC Section R702.7



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

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

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

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

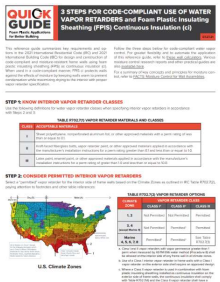
https://www.continuousinsulation.org/resources/facts-ci

3-Step Guide for Water Vapor Control Code Compliance

(based on 2021 IBC/IRC)

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

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



Rule #2 of 3 – Air Control

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

FPIS ci as air barrier (3rd function) or use GWB as air-barrier and also as wall bracing (3 functions)

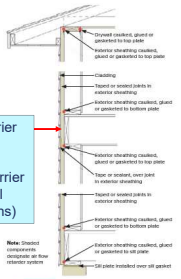


Figure 3. FPIS ci installed as an air barrier exterior sheathing.

Rule #3 of 3 – Rain Water Control

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 FPS 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.

Use FPIS ci as WRB (4th function)

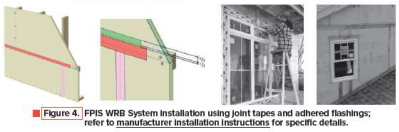
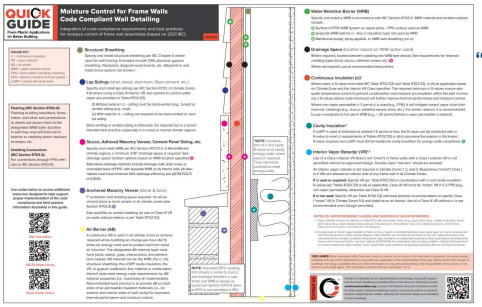


Figure 4. FPIS WRB System installation using joint tapes and adhered flashings; refer to manufacturer installation instructions for specific details.

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



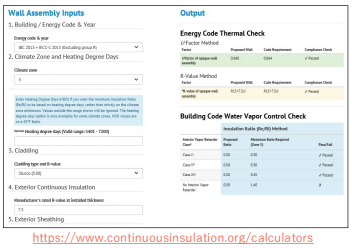
"Cheat Sheet"

Integrated, Code-Compliant Moisture Control

https://www.continuousinsulation.org/moisture-control-frame-walls

Help is here!

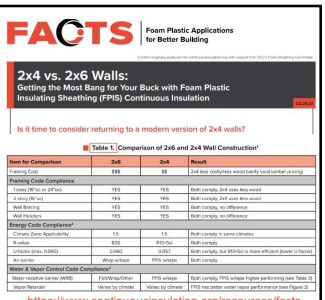
- Simplified energy & water vapor code compliance
- Implements R-value and U-factor checks per IECC & ASHRAE 90.1
- Vapor control check per IBC/IRC (including insulation ratio and permeance ratio checks)
- Flexible, More Solutions than Code, More Precise
- Wood and Steel framing
- 3-minute wall design and optimization (or compliance check)



https://www.continuousinsulation.org/calculators

Optimize framing and energy code compliance

- Continuous insulation enables use of 2x4 construction in cold climates (conventional 16"oc or 24"oc)
- Could be considered a 5th function of FPIS ci
- **CONCLUSION:** A "hard dollar" approach must consider and optimize interaction of structure, moisture, and energy efficiency functions of walls and specified materials while complying with both the building code and energy code
- This is a challenging task, but once done it can yield cost-saving with at least equivalent if not better performance than minimum code.


FACTS Foam Plastic Applications for Better Building

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

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" o.c. or 24" o.c.)	YES	YES	Both comply, 2x4 uses less wood
2-story (16" o.c.)	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

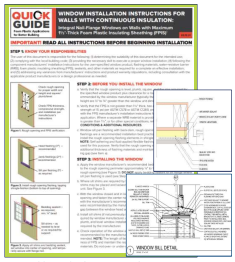
C. "Hard Dollar" Parting Thoughts

- Window & Door Installation Coordination
- Cladding Specification and Installation Coordination
- Maximize Multi-functional Material Capabilities
- Rediscover some of the good ol' ways of building?

Optimize Integration of Wall with Windows & Doors

"Inny" (recessed) window & trim/flashing extension

"Outty" (flush) window (simplest detailing)

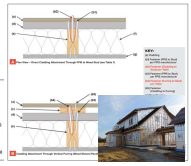


For additional information, refer to:
https://www.continuousinsulation.org/applications/window-installation

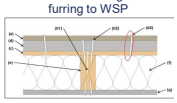
Optimize Cladding Installation

Refer to attachment schedules in IRC Section R703.15 and Quick Guide

Attach cladding or furring to studs



Attach cladding or furring to WSP



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

Quick Guide for Vinyl Siding Over FPIS ci

- Based on IRC Section R703.11.2
- 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
  - 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

Consider Multifunctional Materials

- Multi-functional material application is an important part of optimizing performance and construction costs (labor vs. materials)
  - If using gypsum interior finish, why not put it to work for other functions?
  - If using cavity insulation, why not put it to work for other functions?
  - If using continuous insulation, why not put it to work as wall bracing?
  - If using vinyl siding, why not put it to work as continuous insulation?
- This is particularly cost-effective if the material is being used anyway for its primary (or commonly understood) function.

Multi-functional use Gypsum Panels

- Interior finish
- Interior thermal (fire) barrier
- Wall bracing (see IRC table)
- Sound deadening
- Air barrier
- Class III vapor retarder (with appropriate paint specification)

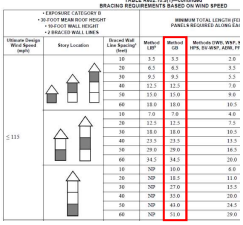


TABLE R602.10.3(1)—continued
BRACING REQUIREMENTS BASED ON WIND SPEED

Ultimate Design Wind Speed (mph)	Story Location	Braced Wall Line Spacing[1] (feet)	Method LIB[2]	Method GB	Methods DWB, WSP, SFB, PBS, SW-WSP, ABW, PF
≤ 115		10	3.5	3.5	2.0
		20	6.5	6.5	3.5
		30	9.5	9.5	5.5
		40	12.5	12.5	7.0
		10	15.0	15.0	8.0
		60	18.0	18.0	10.5
		10	7.0	7.0	4.0
		20	12.5	12.5	7.5
		30	18.0	18.0	10.5
		40	23.5	23.5	13.5
		50	29.0	29.0	16.5
		60	34.5	34.5	20.0
		10	NP	10.0	6.0
		20	NP	18.5	11.0
		30	NP	27.0	15.5
		40	NP	35.0	20.0
		50	NP	43.0	24.5
		60	NP	51.0	29.0

Multi-functional Use of SPF

Jay's home ☺

Masonry & Brick Cavity Wall

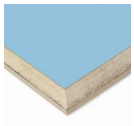
www.energyefficientsolutions.com

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

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

FPIS structural insulating sheathings

- Multi-functional Sheathing (Structural sheathing + FPIS ci + WRB + AB + Vapor Control)
- 5 in 1 products
- Several code-approved products



Multi-functional Panelized Construction

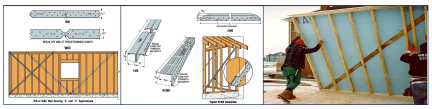
Multi-functional Insulated Cladding Applications

www.progressivefoam.com

www.kingspanpanels.us

LIB - Rediscover the way our grandfathers built?

- Use conventional 3-coat stucco as siding and bracing?
- Use T1-11 (grooved or brd&batten) as siding and bracing?
- Use 1x4 wood Let-in brace (LIB) – or approved metal brace?
  - Metal strap braces commonly used on engineered steel frame commercial buildings
  - Metal Brace Manufacturers: USP, *Simpson, Tamlyn, etc.* (install per manufacturer) – verify equivalency to 1x4 LIB
  - Simple to use, but limited (≤ 2 stories, wall ht ≤ 10'; low wind/seismic)
  - Great option for small to moderate sized affordable homes
- Don't forget the wind uplift load path!



Post-frame Construction

- Efficient foundation and framing/bracing system
- Adaptable (and used) for homes and businesses
- Commonly thought of as "pole barn" ag building
- But, these are highly engineered buildings

https://www.youtube.com/watch?v=__X0kPQdWNs

https://www.hansenpolebuildings.com/

THE END

- Questions?
  - THANK YOU