UDC BRACED WALL DESIGN

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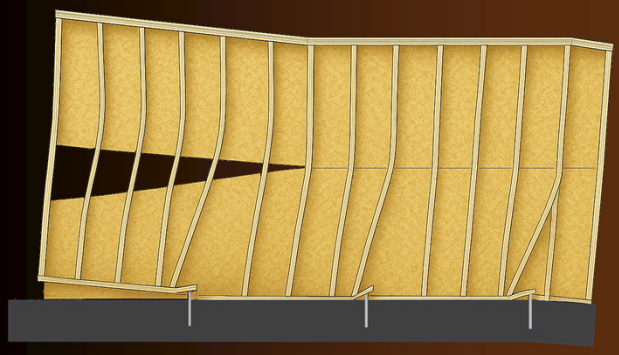
- DSPS Course Id Number 962482
  Four Hours of Credit for
  Dwelling Contractor Qualifier
  UDC Construction Inspector



COURSE OUTLINE

- FUNDAMENTALS OF WIND FORCES ON BUILDINGS
- FACTORS THAT INFLUENCE THE MAGNITUDE OF THE WIND FORCE
- WIND DISTRIBUTION ON AN ENCLOSED STRUCTURE
- SHEAR WALLS
- BASICS: METHODS OF RESISTANCE
- UDC CODE METHODOLOGY
- UDC APPROVED METHODS FOR RESISTING LATERAL LOADS
- UDC DESIGN PROCESS
- INTERMITTENT WALL BRACING
- EXAMPLE
- CONTINUOUS WALL BRACING
- EXAMPLE
- CLASS PROBLEM:
- ADDITIONAL TOPICS FOR WALL BRACING

FUNDAMENTALS OF WIND FORCES ON BUILDINGS

Wind creates forces on buildings in all directions.

- Windward Wall
  Wind produces lateral force on the walls that can be an inward positive pressure,
- Leeward Wall
  On the opposite side of the structure this wind force is often a negative (suction) pressure.
- Roof
  The wind can act as a downward or upward force depending upon the direction of the wind and slope of the roof.

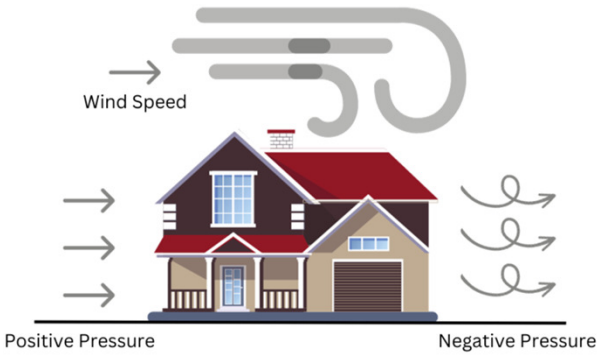


Figure reference:
https://southernstarwindows.com.au/windows-in-heavy-winds/

FACTORS THAT INFLUENCE THE MAGNITUDE OF THE WIND FORCE

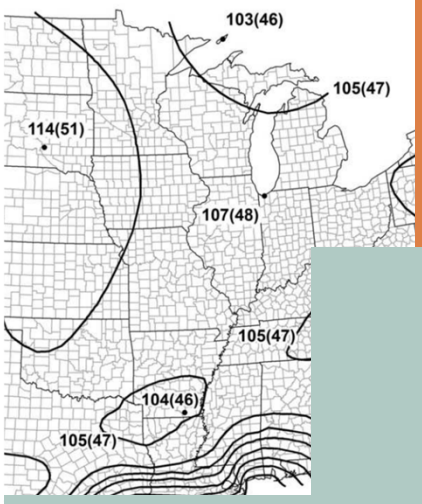
The magnitude of the wind force on a structure is influenced by multiple factors.

- Location – Basic Wind Speed
- Exposure
- Topography
- Enclosed / Open / Partially Open
- Building Geometry



LOCATION: BASIC WIND SPEED

- Basic Wind Speeds (Velocities) from ASCE 7-16 for category II buildings (most buildings)
- Lower speed for low-risk buildings (storage and agriculture)
- Higher speed for essential facilities, hazardous facilities and large assembly occupancies



EXPOSURE MODIFICATIONS

Exposure category (also Surface Roughness) characterizes terrain and obstructions affecting wind pressure on structures.

Wind exposure category B:

- Urban and suburban areas, wooded areas, or other terrain with numerous closely spaced obstructions having the size of single-family dwellings or larger.



EXPOSURE MODIFICATIONS

Wind exposure category C

- Flat, open country and grasslands with scattered obstructions, including surface undulations or other irregularities, having heights generally less than 30 feet extending more than 1,500 feet from the building site in any quadrant.
- This exposure also applies to any building located within Exposure B type terrain where the building is directly adjacent to open areas of Exposure C type terrain in any quadrant for a distance greater than 600 feet.



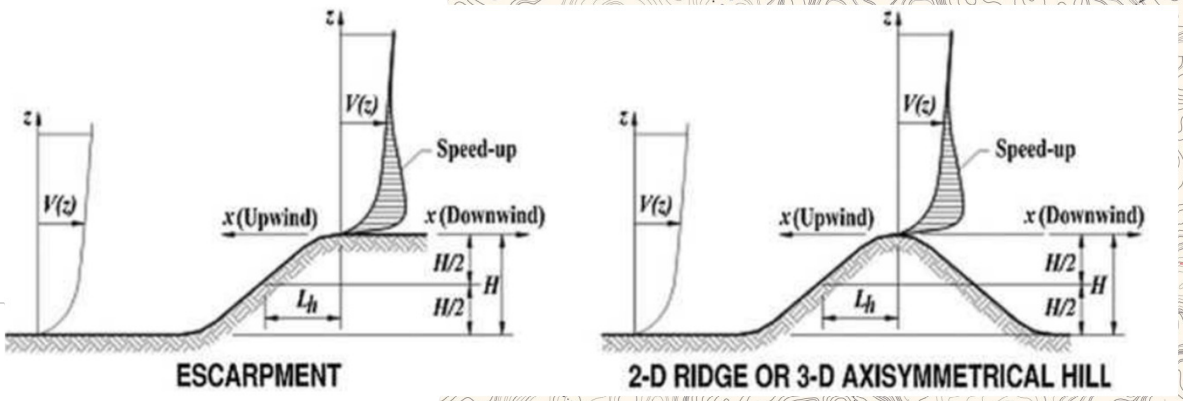
EXPOSURE MODIFICATIONS

Wind exposure category D

- Flat, unobstructed areas exposed to wind flowing over open water for a distance of at least 1 mile. This exposure applies only to those buildings and other structures exposed to the wind coming from over the water.
- Exposure D extends inland from the shoreline a distance of 1,500 feet or 10 times the height of the building or structure, whichever is greater.



TOPOGRAPHY



BUILDING ENCLOSURE

- Enclosed
- Partially Enclosed
- Partially Open
- Open

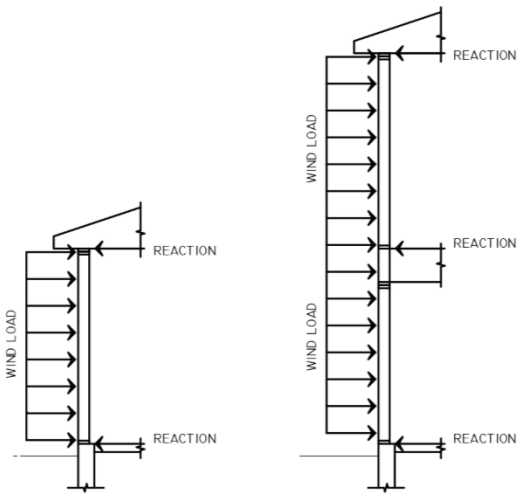


Table 26.13-1 Main Wind Force Resisting System and Components and Cladding (All Heights): Internal Pressure Coefficient, (GC_{pi}), for Enclosed, Partially Enclosed, Partially Open, and Open Buildings (Walls and Roof)

Enclosure Classification	Criteria for Enclosure Classification	Internal Pressure	Internal Pressure Coefficient, (GC_{pi})
Enclosed buildings	A_o is less than the smaller of $0.01A_g$ or 4 sq ft (0.37 m) and $A_{oi}/A_{gi} \le 0.2$	Moderate	+0.18 −0.18
Partially enclosed buildings	$A_o > 1.1A_{oi}$ and $A_o >$ the lesser of $0.01A_g$ or 4 sq ft (0.37 m) and $A_{oi}/A_{gi} \le 0.2$	High	+0.55 −0.55
Partially open buildings	A building that does not comply with Enclosed, Partially Enclosed, or Open classifications	Moderate	+0.18 −0.18
Open buildings	Each wall is at least 80% open	Negligible	0.00

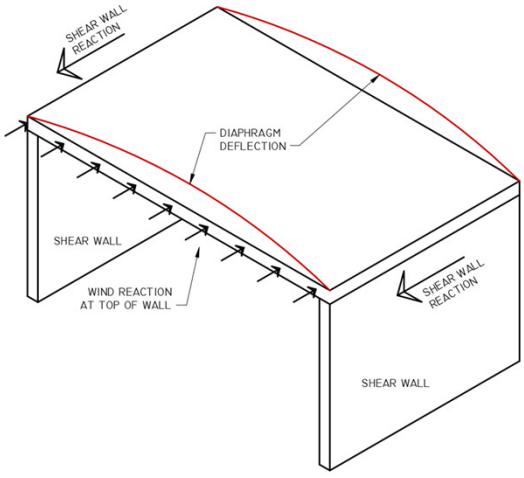
WIND DISTRIBUTION ON AN ENCLOSED STRUCTURE

- Wind forces on the wall of a building. There is a reaction at the top of the wall and the bottom of the wall.
- For a single-story building, half of the load goes into the roof diaphragm and half to the foundation. The entire wind load from the roof enters the diaphragm.
- For a two-story building, half of the load from the second floor to the roof goes into the roof diaphragm. The entire wind load from the roof enters the diaphragm. The second-floor diaphragm receives half the load from the story above and half from the story below. Half the load from the grade to the second floor goes directly into the foundation.



LOAD FROM DIAPHRAGM TO SHEAR WALLS

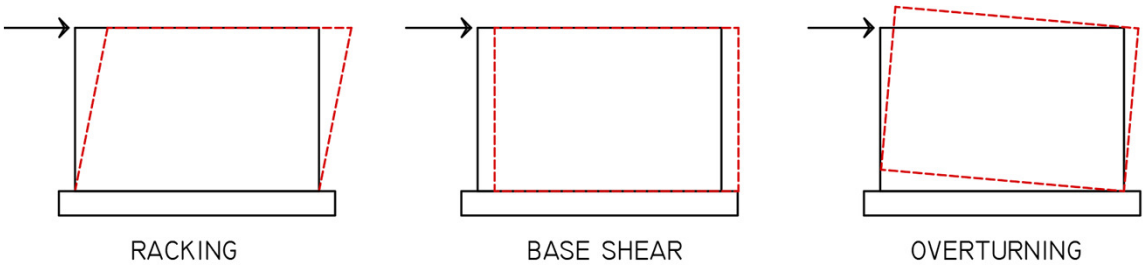
The load is resisted by the lateral load resisting system perpendicular to the walls with the wind load applied normal to the wall.



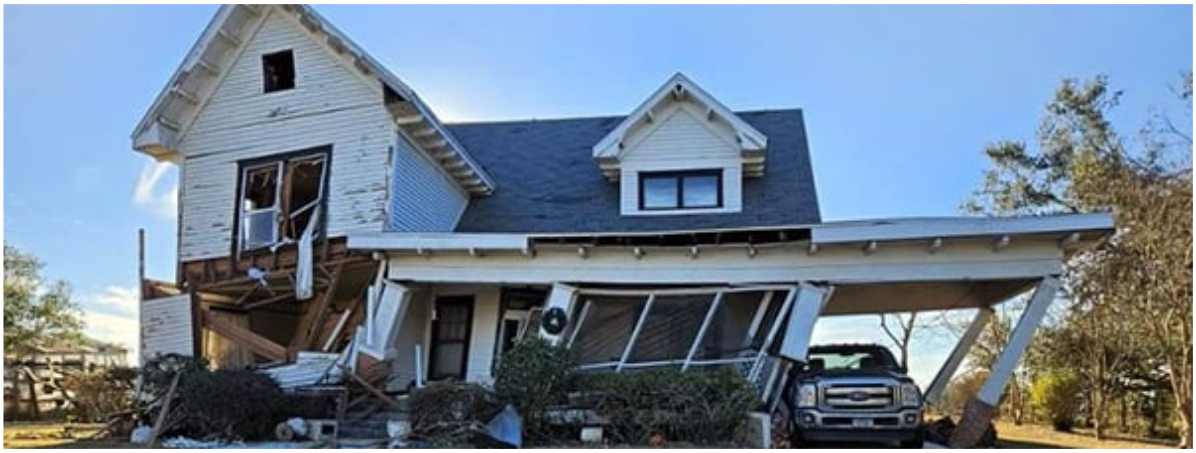
SHEAR WALLS

BASICS: METHODS OF FAILURE

- Racking
- Base Shear
- Overturning



RACKING



BASE SHEAR

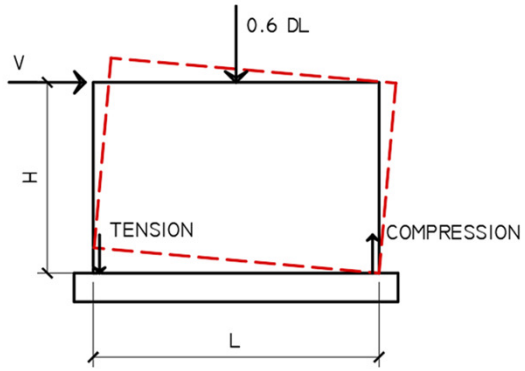


OVERTURNING



BASICS: METHODS OF RESISTANCE

- Racking – Sheathing or Diagonal Bracing
- Base Shear – Anchors to foundation
- Overturning – Dead Load and Hold-downs
  - Overturning force (Mot) = VxH (ft-lbs)
  - Resisting force from weight of structure (M res) = 0.6D x L/2
  - If Mres>Mot, no overturning.



UDC CODE METHODOLOGY

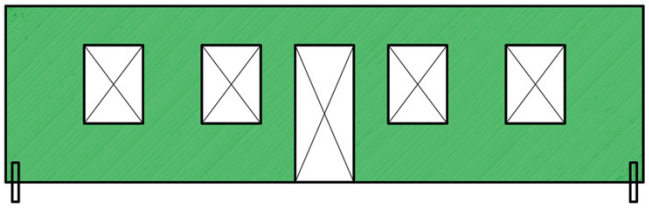
METHODS ALLOWED FOR LATERAL LOAD DESIGN

- In accordance with the UDC Code, section 321.25(8)
- IRC 2012 Code Methodology R602.10 or 602.12: Similar to UDC
- Design in accordance with the engineering basis of the 2012 IRC bracing provisions, such as
  - *The Story Behind the 2009 IRC Wall Bracing Provisions* (Part 2: New Wind Bracing Requirements)
  - *Wood Design Focus, Forest Products Society*
- Installation instructions from the manufacturer of the bracing product that are compliant with s. SPS 321.02.

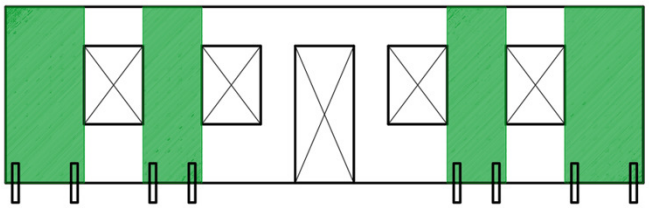
UDC APPROVED METHODS FOR RESISTING LATERAL LOADS

Shear walls

- Continuous (Perforated)
- Intermittent (Segmented)



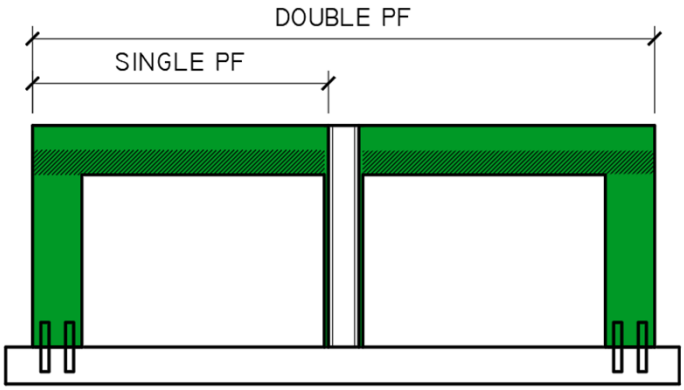
CONTINUOUS (PERFORATED) SHEAR WALL



INTERMITTENT (SEGMENTED) SHEAR WALL

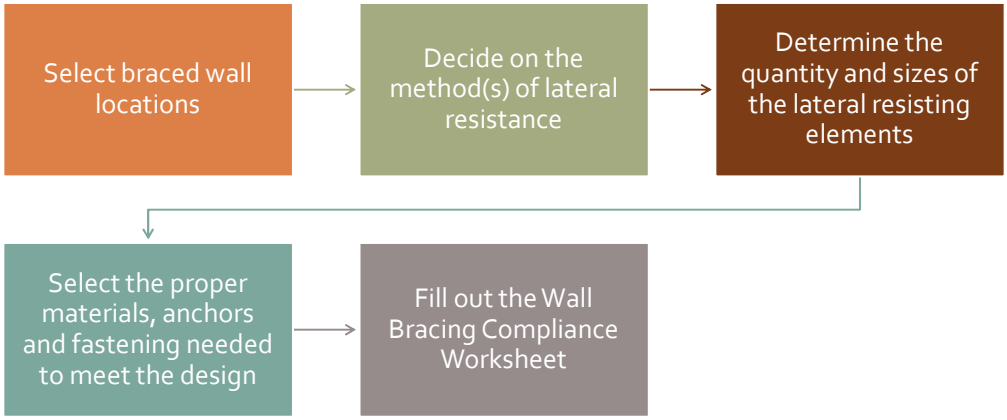
UDC APPROVED METHODS FOR RESISTING LATERAL LOADS

- Portal Frames
- Figure 321.25-1, & IRC R602.10.6.2



UDC DESIGN PROCESS

THE UDC BRACED WALL DESIGN PROCESS

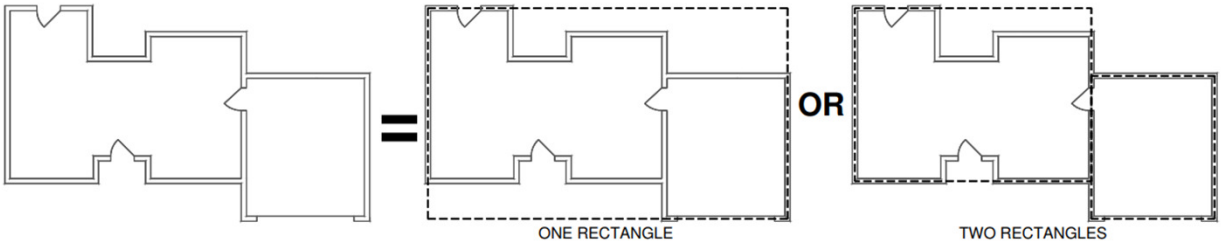


STEP 1: LOCATE BRACED WALL LINES

- Max length-to-width ratio is 3:1
- Max spacing between braced wall locations
  - Intermittent braced walls 75'
  - Continuous braced walls 80'
  - IRC restricts all to 60'
- Minimum braced wall panel length 4' with 2 panels minimum (8' total)

UDC – Braced Wall Lines

FIGURE 321.25-B
DEFINING BUILDING SIDES AND LENGTHS WITH ONE OR MORE CIRCUMSCRIBED RECTANGLES[a,b,c]

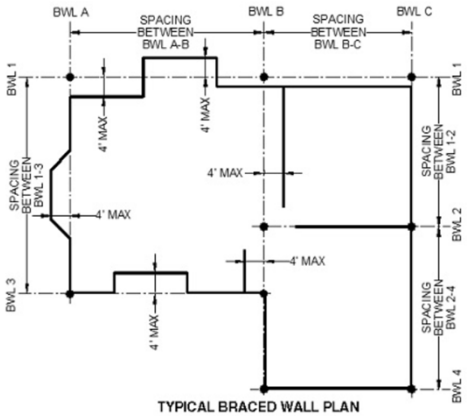


(1) Basic floor plan

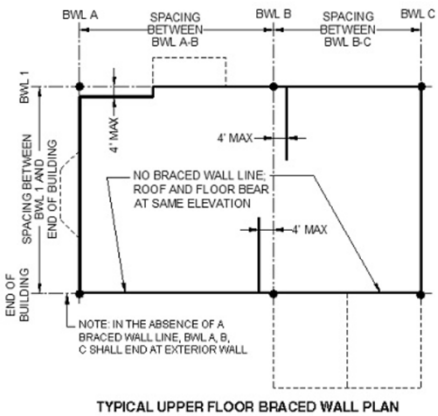
LOCATE BRACED WALL LINES

FROM THE IRC

The application of the 4' offset is unique to the IRC and not specified in the UDC. It is a helpful guideline for use in the UDC although it is not specifically required.



TYPICAL BRACED WALL PLAN



TYPICAL UPPER FLOOR BRACED WALL PLAN

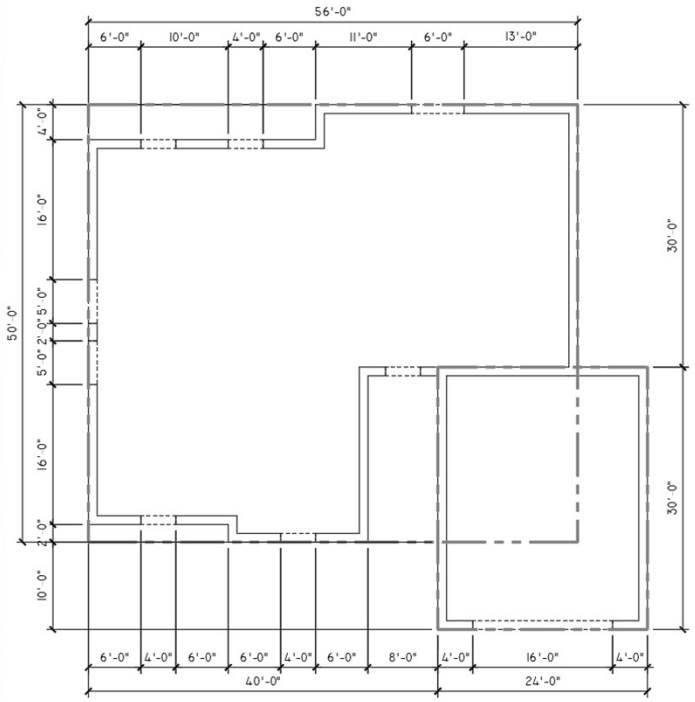
LOCATE BRACED WALL LINES

STEP 1: LOCATE BRACED WALL LINES:

This building is shown with two separate braced wall outlines (phantom line type).

This meets the criteria of the max 3:1 ratio as well as the maximum wall braced wall spacing of 75' or 80'.

Before we dig deeper into the example, we will discuss the differences between the processes of using intermittent and continuous braced wall design.



INTERMITTENT WALL BRACING

BRACING METHODS

See also Table 321.25-G

ABBV	Description	Min Panel Width
LIB	LET-IN BRACING	45° (1)
DWB	DIAGONAL WOOD BOARDS	4'
WSP	WOOD STRUCTURAL PANEL (Plywood & OSB)	4'
SFB	STRUCTURAL FIBERBOARD SHEATHING (MDF)	4'
GB	GYPSUM BOARD	8'

(1) Example: 8' tall wall would have 8' min width

RESTRICTIONS

- Max wall height = 10'… sort of. Wall height can be increased to 12' if the adjustments in the wall design sections are made. Discussed in next slides
  Actual height may be the stud height plus top and bottom plates (10'- 4 ½")
- Inside face is GB. All edges attached to sheathing or blocking.
- Each braced panel may contain only a single hole. Width is no more than 10% of panel width and located in middle ¾ of panel width. This is 4.75" in a 4' wide panel.
- LIB (Let in bracing)
  - Not allowed for 2 stories plus roof
  - Two 60° braces may be used in lieu of one 45° brace

BRACING TYPES

Method of Bracing	Minimum Thickness	Figure	Fasteners	Spacing
LIB Let-in-bracing	1 × 4 wood or approved metal straps at 45° to 60° angles for maximum 16" stud spacing		Wood: 2-8d common nails or 3-8d ($2^1/_2$" long x 0.113" dia.) nails	Wood: per stud and top and bottom plates
			Metal strap: per manufacturer	Metal: per manufacturer
DWB Diagonal wood boards	$^3/_4$"(1" nominal) for maximum 24" stud spacing		2-8d ($2^1/_2$" long × 0.113" dia.) nails or 2 - $1^3/_4$" long staples	Per stud
WSP Wood structural panel (See Section R604)	$^3/_8$"		Exterior sheathing per Table R602.3(3)	6" edges 12" field
			Interior sheathing per Table R602.3(1)or R602.3(2)	Varies by fastener

Table from IRC, See also UDC Table 321.25-G

BRACING TYPES

Method of Bracing	Minimum Thickness	Figure	Fasteners	Spacing
SFB Structural fiberboard sheathing	$^1/_2$" or $^{25}/_{32}$" for maximum 16" stud spacing		$1^1/_2$" long × 0.12" dia. (for $^1/_2$" thick sheathing) $1^3/_4$" long × 0.12" dia. (for $^{25}/_{32}$" thick sheathing) galvanized roofing nails or 8d common ($2^1/_2$" long × 0.131" dia.) nails	3" edges 6" field
GB Gypsum board	$^1/_2$"		Nails or screws per TableR602.3(1) for exterior locations	For all braced wall panel locations: 7"edges (including top and bottom plates) 7"field
			Nails or screws per TableR702.3.5 for interior locations	

Table from IRC, See also UDC Table 321.25-G

TABLE 321.25–I
REQUIRED NUMBER OF INTERMITTENT BRACED WALL PANELS ON WALLS PARALLEL TO EACH RECTANGLE SIDE AT EACH FLOOR LEVEL[a,b,c,d,e,f, h, j]

Wall Supporting:	Required Number of Brace Panels on a Building Side, Length of Perpendicular Side (feet)[g] ≤25	≤50	≤75
Roof and ceiling only	1[i]	2	3
One floor, roof and ceiling	2	4	6
Two floors, roof and ceiling	3	6	9

Note, 2 panels are the minimum even though (1) is shown for a roof and ceiling with 25' spacing

DETERMINE THE NUMBER OF INTERMITTENT BRACED PANELS REQUIRED FOR EACH BRACED WALL

INTERMITTENT BRACED WALL ADJUSTMENTS

Table 321.25-I is based on Exposure Category B

- Increase by 30% for Category C (x 1.30)
- Increase by 60% for Category D (x 1.60)

Table is based on 10' tall walls. Adjustments for other heights

Height	Adjustment
8'	0.90
9'	0.95
11'	1.15
12'	1.30

Roof Peak/Ridge Adjustment: If the vertical distance from the top of the wall to the top of the roof is a height other than 10', there are the following adjustments

Structure Type		Height Adjustment Factor for Peak Height 5 ft	15 ft	20 ft
Single Story	Roof only	0.70	1.30	1.60
Two Story	Roof + 1 floor	0.85	1.15	1.30
Three Story	Roof + 2 floors	0.90	1.10	

Interior finish – Drywall/Gyp
LIB – 1.70 increase if there is no gyp
All others – 1.40 increase if there is no gyp.

Adjustments are cumulative –

Round up to nearest number of required panels.

INTERMITTENT BRACED WALLS EXAMPLE 1

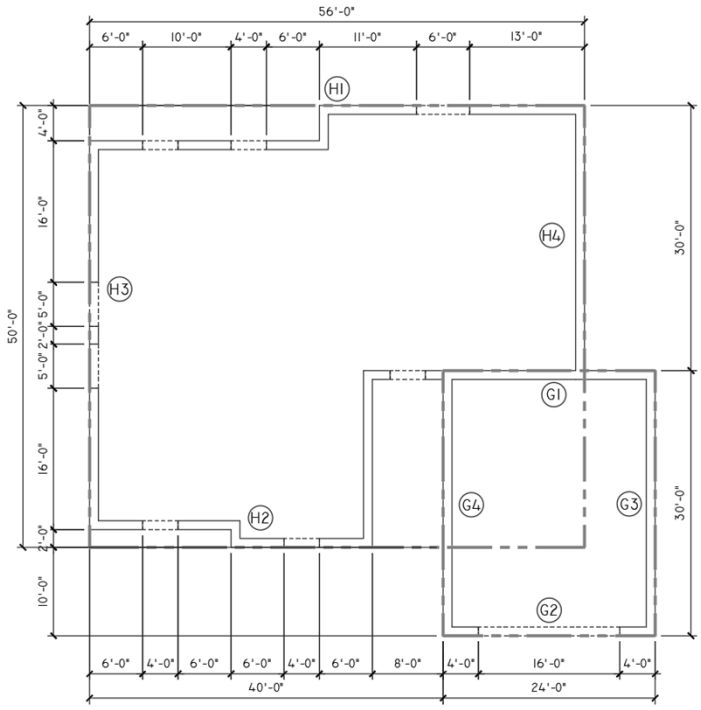
- Building criteria:
  - Single Story house
  - Wall bracing material - WSP
  - Wind Exposure C
  - Roof
    - Roof type - Gable
    - Roof Pitch = 3/12
    - Heel = 1'
    - Max roof truss spans
      - Garage = 24'
      - House = 32'
  - Wall Height = 9'
  - Interior drywall
    - House – yes
    - Garage – no

INTERMITTENT BRACED WALLS EXAMPLE 1

- Step 1 – locate braced wall lines (already completed)
- Step 2: Calculate adjustments
  - House:
    - Exposure = 1.30
    - Wall height = 0.95
    - Peak height; h= 4' + 1' = 5' = 0.70
    - Interior drywall = 1.00
    - Multiply all adjustments **= 0.86**
  - Garage
    - Exposure = 1.30
    - Wall height = 0.95
    - Peak height; h= 3' + 1' = 4' = 0.70
    - No Interior drywall = 1.40
    - Multiply all adjustments **= 1.21**

INTERMITTENT BRACED WALLS EXAMPLE 1

BRACED WALL LINES INDICATED



INTERMITTENT BRACED WALLS EXAMPLE 1

Step 3: Determine the number of panels required for each braced wall

- House
  - Walls H1 and H2
    - Distance between these brace lines is 50'
    - Table 321.25 – 2 Panels required
    - Adjustment - = 2*.86 = 1.72
    - Since (2) panels are the minimum, use (2)
  - Walls H3 & H4
    - Distance between these brace lines is 56'
    - Table 321.25 – 2.25 Panels required (interpolation)
    - Adjustment - = 2.25*.86 = 1.94
    - Since (2) panels are the minimum, use (2)

INTERMITTENT BRACED WALLS EXAMPLE 1

Step 3 - Continued

- : Determine the number of panels required for each braced wall
  - Walls G1 and G2
  - Distance between these brace lines is 30'
  - Table 321.25 – 1.2 Panels required
  - Adjustment - = 1.2*1.21 = 1.45
  - Since (2) panels are the minimum, use (2)
- Walls G3 & G4
  - Distance between these brace lines is 24'
  - Table 321.25 – 1 Panel required
  - Adjustment - = 1.0 * 1.21 = 1.21Since (2) panels are the minimum, use (2)

CONTINUOUS WALL BRACING

BRACING METHODS

- See also Table 321.25-G

ABBV	Description
CS-WSP	WOOD STRUCTURAL PANEL (Plywood & OSB)
CS- SFB	STRUCTURAL FIBERBOARD SHEATHING (MDF)

RESTRICTIONS

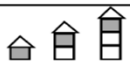
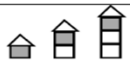
- Max wall height = 12'
- Inside face is GB.
- All edges attached to sheathing or blocking

Table 321.25–J
REQUIRED LENGTH OF CONTINUOUS BRACING ON WALLS PARALLEL TO EACH RECTANGLE SIDE AT EACH FLOOR LEVEL[a,b,c,d,e,g,h, j]

Top-of-Wall-to-Ridge Height (feet)	Wall Supporting:		Total Required Length (feet) of Full-Height Bracing on Any Side of Rectangle							
			Length of Perpendicular Side (feet)[f]							
			10	20	30	40	50	60	70	80
10	Roof and ceiling only		2.0[i]	3.5[i]	5.0	6.0	7.5	9.0	10.5	12.0
	One floor, roof and ceiling		3.5[i]	6.5	9.0	12.0	14.5	17.0	19.8	22.6
	Two floors, roof and ceiling		5.0	9.5	13.5	17.5	21.5	25.5	29.2	33.4

DETERMINE THE REQUIRED LENGTH OF CONTINUOUS BRACING FOR EACH BRACED WALL

Table 321.25–J
REQUIRED LENGTH OF CONTINUOUS BRACING ON WALLS PARALLEL TO EACH RECTANGLE SIDE AT EACH FLOOR LEVEL[a,b,c,d,e,g,h, j] (Continued)

Top-of-Wall-to-Ridge Height (feet)	Wall Supporting:		Total Required Length (feet) of Full-Height Bracing on Any Side of Rectangle							
			Length of Perpendicular Side (feet)[f]							
15	Roof and ceiling only		2.6[i]	4.6	6.5	7.8	9.8	11.7	13.7	15.7
	One floor, roof and ceiling		4.0	7.5	10.4	13.8	16.7	19.6	22.9	26.2
	Two floors, roof and ceiling		5.5	10.5	14.9	19.3	23.7	27.5	32.1	36.7
20	Roof and ceiling only		2.9[i]	5.2	7.3	8.8	11.1	13.2	15.4	17.6
	One floor, roof and ceiling		4.5	8.5	11.8	15.6	18.9	22.1	25.8	29.5
	Two floors, roof and ceiling		6.2	11.9	16.8	21.8	27.3	31.1	36.3	41.5

DETERMINE THE REQUIRED LENGTH OF CONTINUOUS BRACING FOR EACH BRACED WALL

CONTINUOUS BRACED WALL ADJUSTMENTS

Table 321.25-J is based on Exposure Category B

- Increase by 30% for Category C (x 1.30)
- Increase by 60% for Category D (x 1.60)

Table is based on 10′ tall walls. Adjustments for other heights

Height	Adjustment
8′	0.90
9′	0.95
11′	1.05
12′	1.10

Interior finish – Drywall/Gyp
All others – 1.40 increase if there is no gyp.

Adjustments are cumulative –

Round up to nearest number of required panels.

CONTINUOUS BRACED WALLS EXAMPLE 2

- Project criteria:
  - Single Story house
  - Wall bracing material - WSP
  - Wind Exposure C
  - Roof
    - Roof type - Gable
    - Roof Pitch = 3/12
    - Heel = 1′
    - Max roof truss spans
      - Garage = 24′
      - House = 32′
  - Wall Height = 9′
  - Interior drywall
    - House – yes
    - Garage – no

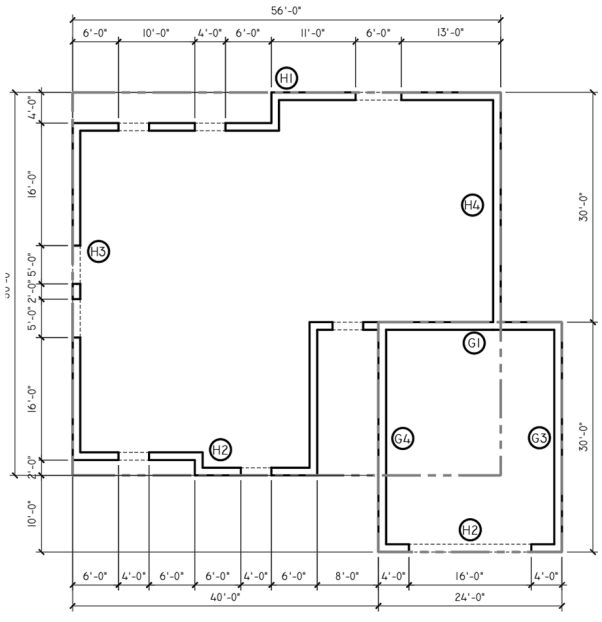
CONTINUOUS BRACED WALLS EXAMPLE 2

Step 1 – locate braced wall lines (already completed)

Step 2: Calculate adjustments

- House:
  - Exposure = 1.30
  - Wall height = 0.95
  - Interior drywall = 1.00
  - Multiply all adjustments **= 1.24**
- Garage
  - Exposure = 1.30
  - Wall height = 0.95
  - No Interior drywall = 1.40
  - Multiply all adjustments **= 1.73**

CONTINUOUS BRACED WALLS – EXAMPLE 2



CONTINUOUS BRACED WALLS EXAMPLE 2

Step 3: Determine the lengths of the braced walls required.

- House
  - Walls H1 and H2
    - Distance between these brace lines is 50'
    - Table 321.25J – wall length is 7.5'
    - Adjustment = 7.5*1.24 = 9.3'
  - Walls H3 & H4
    - Distance between these brace lines is 56'
    - Table 321.25J – 8.1' (interpolation)
    - Adjustment = 8.1*1.24=10.0'

CONTINUOUS BRACED WALLS EXAMPLE 2

Step 3 (cont):

Determine the lengths of the braced walls required.

- Garage
  - Walls G1 and G2
    - Distance between these brace lines is 30'
    - Table 321.25J – 5'
    - Adjustment = 5*1.73 = 8.65'
  - Walls G3 & G4
    - Distance between these brace lines is 24'
    - Table 321.25J – 4.1' (interpolation)
    - Adjustment = 4.1 * 1.73 = 7.1'

ANALYSIS NOTES:

Continuous wall bracing does not provide any adjustments with low peak heights.

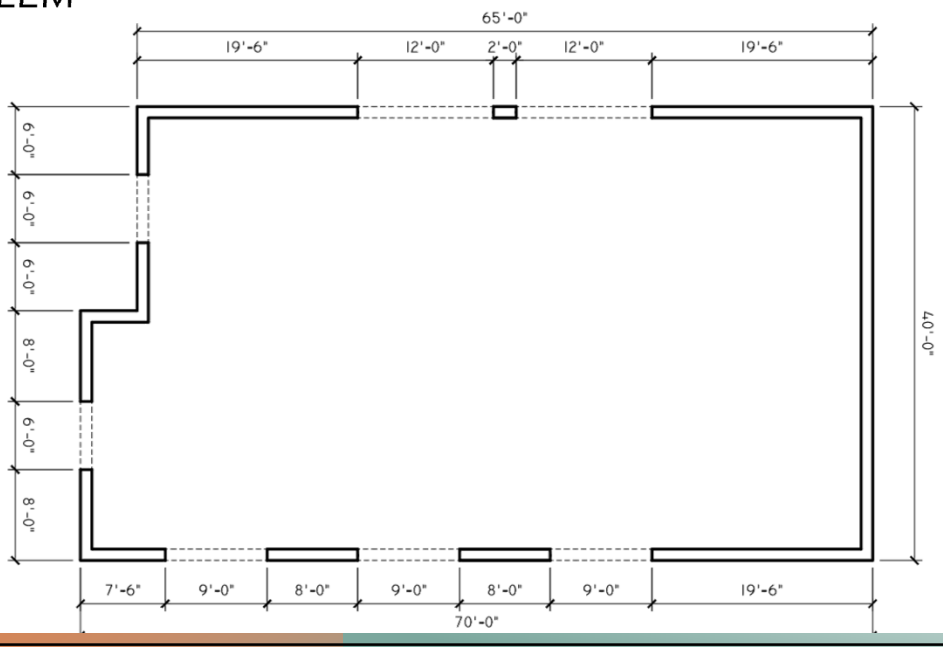
If the amount of bracing cannot be obtained on a given length of wall, changing geometry or materials may be needed.

CLASS PROBLEM

Determine the wall bracing required using both intermittent and continuous methods for the following structure:

- Two Story house
- Wall bracing material - WSP
- Wind Exposure C
- Roof
  - Roof type - Gable
  - Roof Pitch = 5/12
  - Heel = 1.5'
  - Roof Span = 40'
- Wall Height = 9'
- Interior drywall – yes

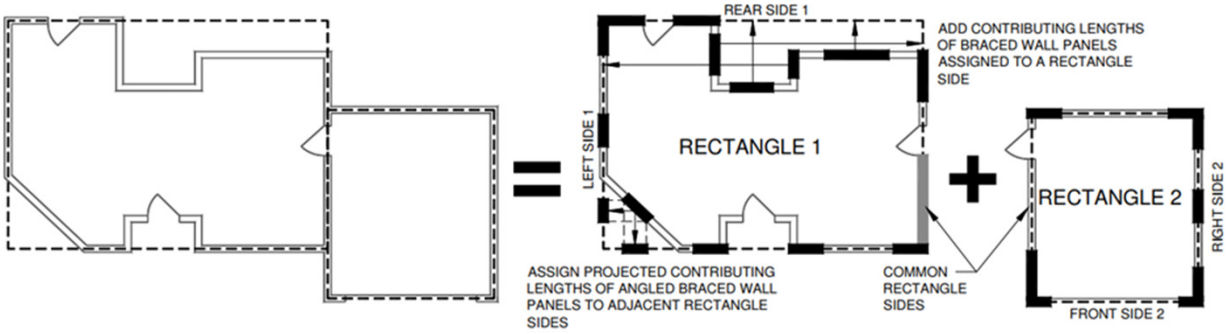
CLASS PROBLEM



ADDITIONAL TOPICS FOR WALL BRACING

SHARED WALLS AND ANGLED WALLS

- The shared wall must provide the summed total of the shear resistance for Rectangle 1 and Rectangle 2
- The shear resistance of the angled wall can be applied to the "projected" available wall length
  - Example: 12' long wall at 45 degree angle
  - 12 * sin 45 = 8.48' feet
  - Length can be used for both the north-south and east-west walls (wind theoretically blows one direction at a time)



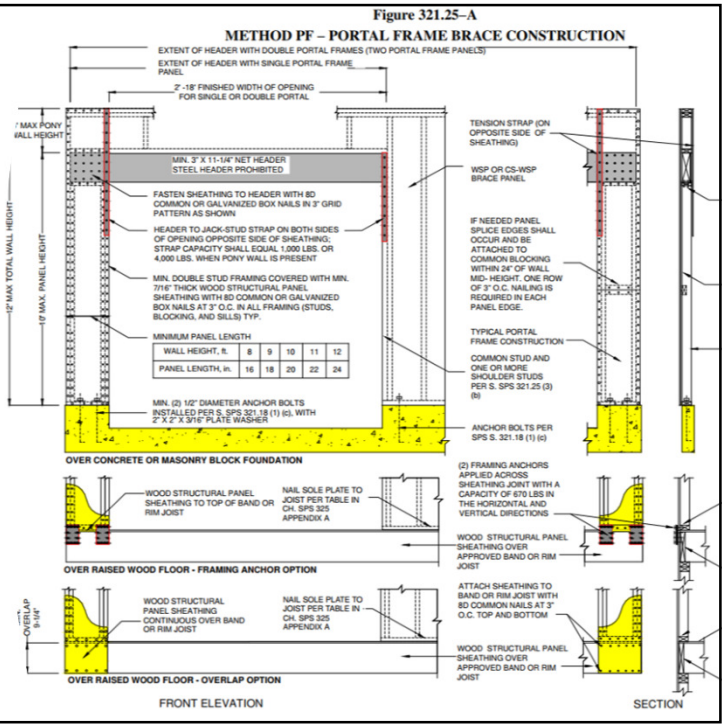
(2) Angled-building-side plan[d]

PORTAL FRAMES

- Bracing methods
- See also Table 321.25-G

ABBV	Description	Min Panel Width
PF	PORTAL FRAME	SEE FIGURE 321.25-1

- RESTRICTIONS
  - Max wall height = 12'
  - All edges attached to sheathing or blocking



HOW TO USE PORTAL FRAMES

Can be used in conjunction with continuous or intermittent bracing

INTERMITTENT BRACING – TABLE 321.25-I

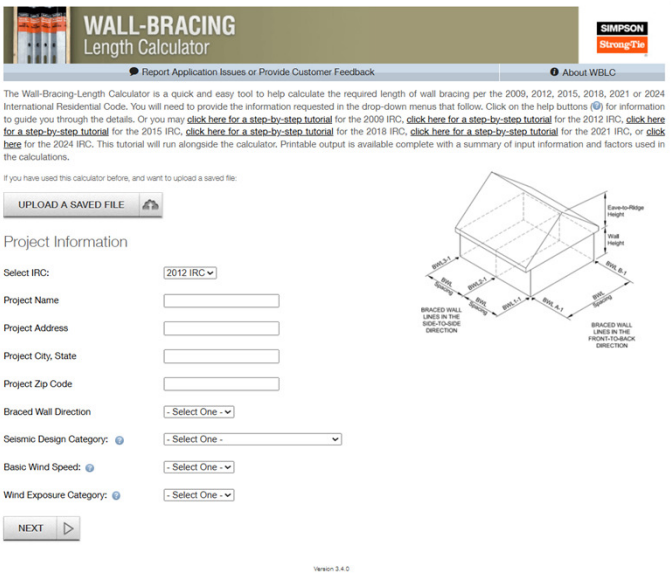
- Footnote "h": The following braced wall panel conditions shall be permitted to be counted as one-half a braced wall panel toward meeting the required number of panels one PF brace panel complying with Figure 321.25A.
- Therefore, **two** PFs are required to equal the resistance of a **single** panel.
- No designs are allowed to have a single panel, so there will be at least one additional panel conforming to minimum panels lengths in 321.25-G

CONTINUOUS BRACING – TABLE 321.25-J

- Footnote "h": When used on a wall line with continuous sheathing, each portal frame panel is counted for its actual length in contributing toward the length of continuous sheathing used on other portions of the same wall line, such as the building side at a given story level.

WALL BRACING CALCULATORS

- APA Wall Bracing Calculator
  - https://www.apawood.org/guides-tools-training/calculators/apa-wall-bracing-calculator/
- Simpson
  - https://www2.strongtie.com/webapps/BracedWall/



MANUFACTURED PRODUCT OPTIONS: SHEAR WALLS

- Simpson Strong-Wall Shearwalls
  - Intermittent shear walls
  - Wood or steel
  - Minimum Width = 12”
  - Maximum Height = 12.75’
  - Special base detailing, hold-downs and foundation requirements



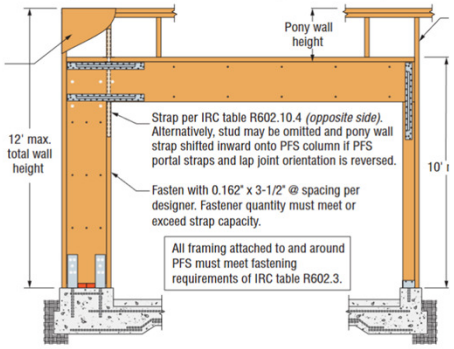


MANUFACTURED PRODUCT OPTIONS: WOOD PORTAL FRAMES

Portal Frame System Bracing Equivalents for Wind and Seismic

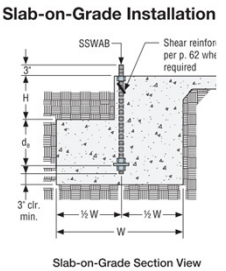
Framing Material[7,8]	Concurrent Vertical Load on Column (lb.)[4]	Equivalent Wall-Bracing Length (ft.)				Maximum Allowable Beam End Reaction (lb.)[5,6]		
		10 in. Nominal Column Size		12 in. Nominal Column Size		Number Of Additional Trimmer Studs		
		Single-Wall Portal	Double-Wall Portal	Single-Wall Portal	Double-Wall Portal	No Studs	1 Stud	2 Studs
LVL	7,500	4.00	8.00	4.00	8.00	5,200	7,500	8,000
DF/SP	4,000[9]	3.00	6.00	4.00	8.00	3,600	4,700	—
SPF/HF	4,000[9]	2.75	5.50	3.50	7.00	3,100	3,800	—

- Simpson Garage Portal Frames
  - Portal frame with wood end columns
  - Opening width = 2′-18′
  - Wall height – 12′ max
  - Special base detailing, hold-downs and foundation requirements
  - Will not work properly on standard thickened slab

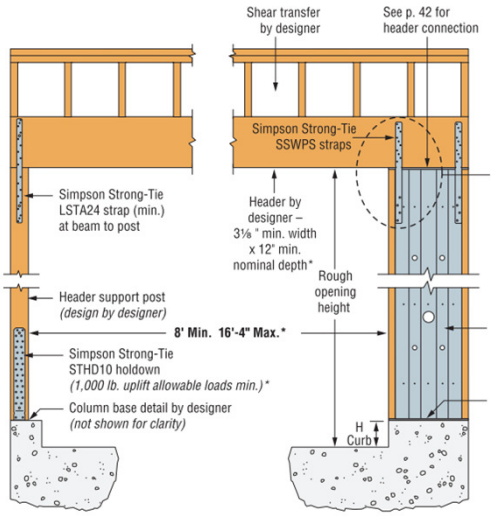


MANUFACTURED PRODUCT OPTIONS: PORTAL FRAMES

- Simpson Garage Portal Frames
  - Portal frame with steel shear wall
  - Width = 12″, 15″, 18″
  - Door height = 7′ or 8′
  - Special base detailing, hold-downs and foundation requirements
  - Will not work properly on standard thickened slab



Slab-on-Grade Section View



Q&A

Thank you for attending!
If you have any questions, please feel free to ask.

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