Office of Education and Data Management

Spring 2018 Career Development

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Demystifying the Structural Requirements of the International Residential Code

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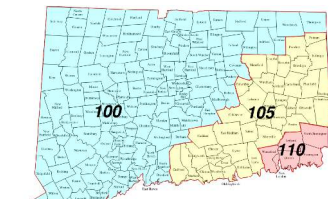
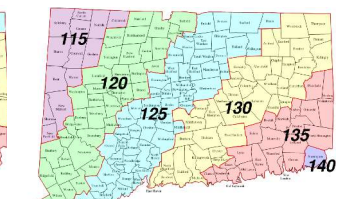
Topics of Discussion

- Ultimate vs. Nominal Wind Speeds
- Windborne Debris Regions
- Wind Exposure Categories
- Component and Cladding Wind Loads
- Attic Live Loads
- Basement Wall Nomenclature
- Basement Wall Reinforcing
- Non-Tabulated Loading Conditions for Joists & Rafters
- Hurricane Anchor Requirements
- Tied Rafters with Raised Ceilings
- I-Joists
- Prefabricated Wood Truss Bracing

Ultimate vs. Nominal Wind Speeds



2012 IRC
Basic Wind Speeds
Nominal Wind Speeds (V_{asd})



2015 IRC
Ultimate Wind Speeds
(V_{ult})

Ultimate vs. Nominal Wind Speeds

Why the Change?

- *Bring into alignment with IBC*
  - *Inconsistencies with recurrence intervals*
  - *Ultimate loads were used for seismic design*

	2012 IRC		2015 IRC
LRFD:	$1.2D + f_1L + 1.6W$	LRFD:	$1.2D + f_1L + 1.0W$
	$0.9D + 1.6W$		$0.9D + 1.0W$
ASD:	$D + 0.75(L + 1.0W)$	ASD:	$D + 0.75(L + 0.6W)$
	$0.6D + 1.0W$		$0.6D + 0.6W$

Ultimate vs. Nominal Wind Speeds

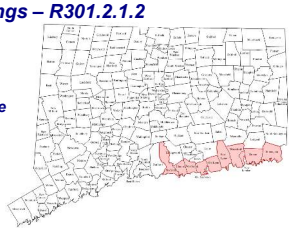
What is the impact?

Location	IRC 2015		IBC 2012
	V_{ult}	V_{asd}	V
Stonington	140	108	105
New Haven	125	97	100
Greenwich	120	93	100
Salisbury	115	89	90
Enfield	125	97	100
Thompson	130	101	100

Windborne Debris Regions

- *Per CT Supplement: Limited to areas south of I-95 from Madison to Stonington*
- *Protection of Openings – R301.2.1.2*

➢ *Areas more than one mile from coastal mean high-water line as certified by a Registered Design Professional are exempt.*



Windborne Debris Regions

- *Protection of Openings – R301.2.1.2*
  - *Glazed Openings: Must meet requirements of Large Missile Test of ASTM E 1996 and ASTM E1886*
  - *Glazing in garage doors must meet approved impact-resisting standard or ANSI/DASMA 115.*
  - *In lieu of impact-rated glazing, wood structural panels may be used for opening protection.*
    - *Panels must be pre-cut*
    - *Panels must be pre-drilled*
    - *Anchors must be corrosion-resistant*
    - *Anchors must be permanently attached to building*
    - *For h ≤ 45', fastening per Table R301.2.1.2 is permissible*

TABLE R301.2.1.2
WINDBORNE DEBRIS PROTECTION FASTENING SCHEDULE FOR WOOD STRUCTURAL PANELS[a, b, c, d]

FASTENER TYPE	FASTENER SPACING (inches)[e, f]		
	Panel span ≤ 4 feet	4 feet < panel span ≤ 6 feet	6 feet < panel span ≤ 8 feet
No. 8 wood screw based anchor with 2-inch embedment length	16	10	8
No. 10 wood screw based anchor with 2-inch embedment length	16	12	9
$^{5}/_{16}$-inch lag screw based anchor with 2-inch embedment length	16	16	16

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Wind Exposure Categories

- *Why are they important?*
  - *Significant impact on wind pressure and suction loads*

Example:

Dwelling with 30' mean roof height

- *Exposure Category C loads are 40% higher than Exposure Category B*
- *Exposure Category D loads are 66% higher than Exposure Category B and 19% higher than Exposure Category C*

  - *Impact wide array of elements including component and cladding loads, braced walls, rafter anchorage, etc.*
- *Change in IRC definitions for 2018 CSBC*
  - *Will now align with IBC*

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Wind Exposure Categories

Surface Roughness B

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

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Wind Exposure Categories

Surface Roughness C

Open terrain with scattered obstructions generally less than 30 feet. This category includes flat, open country, and grasslands.

Wind Exposure Categories

Surface Roughness D

Flat, unobstructed areas and water surfaces. This category includes smooth mud flats, slat flats and unbroken ice.

Wind Exposure Categories

Exposure B

- ***For buildings with mean roof height up to 30', Surface Roughness B prevails in the upwind direction for a distance of at least 1,500' (2,600' for mean roof height > 30').***

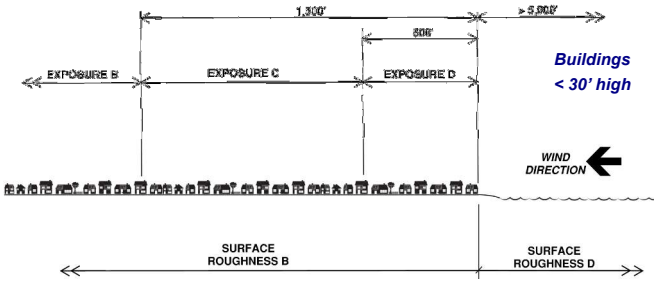
Exposure C

- ***Applies where Exposures B and D do not apply***

Exposure D

- ***For buildings where Surface Roughness D prevails in the upwind direction for a distance of at least 5,000'. Also applies upwind of the site a distance of 600' or 20 times the building height from the Exposure D condition.***

Wind Exposure Categories

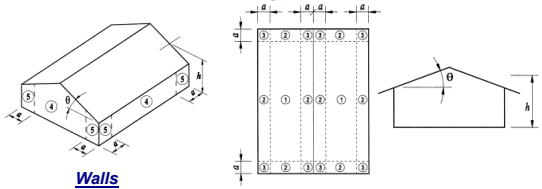


Component & Cladding Wind Loads

- Load Performance Requirements for wall coverings, curtain walls, roof coverings, windows, skylights, doors, garage doors, etc. (§R301.2.1)
- Function of:
  - Wind speed
  - Exposure
  - Mean roof height
  - Effective wind area
  - Roof pitch
  - Location on dwelling

Component & Cladding Wind Loads

Pressure Zone Locations [Figure R301.2(7)]:



Walls

Gable Roofs ($7^o < \Theta \leq 45^o$)

- Also diagrams for hip roofs and lower pitch gable roofs
- a = 4'

Component & Cladding Wind Loads

Effective Wind Area:

- *The smaller the area, the greater the potential for exposure to a higher, localized wind pressure/suction*
- *Effective wind area is often but not always the same as tributary area.*
- *Table R301.2(2) – Footnote a*

  The effective wind area shall be equal to the span length multiplied by an effective width. This width is permitted to be not less than one-third the span length.

  - *3' x 5' window: A_{TRIB} = 15 s.f. = A_{EFF}*
  - *3' x 6'-8" door: A_{TRIB} = 20 s.f. = A_{EFF}*
  - *9' high wall stud spaced @ 16"o.c.: A_{TRIB} = 12 s.f.; A_{EFF} = 9' x 9'/3 = 27 s.f.*
  - *Fasteners: effective wind area not greater than area tributary to an indidual fastener (footnote a)*

Component & Cladding Wind Loads

- *Pressure and suction load tabulations [Table R301.2(2)]*
  - *30' High – Exposure B*

TABLE R301.2(2)
COMPONENT AND CLADDING LOADS FOR A BUILDING WITH A MEAN ROOF HEIGHT OF 30 FEET LOCATED IN EXPOSURE B (ASD) (psf)[a, b, c, d, e]

	ZONE	EFFECTIVE WIND AREA (feet²)	ULTIMATE DESIGN WIND SPEED, V_{ult} (mph)													
			110		115		120		130		140		150		160	
Roof 0 to 7 degrees	1	10	10.0	-13.0	10.0	-14.0	10.0	-15.0	10.0	-18.0	10.0	-21.0	9.9	-24.0	11.2	-27.0
	1	20	10.0	-12.0	10.0	-13.0	10.0	-15.0	10.0	-17.0	10.0	-20.0	9.2	-23.0	10.6	-26.0
	1	50	10.0	-12.0	10.0	-13.0	10.0	-14.0	10.0	-17.0	10.0	-19.0	8.5	-22.0	10.0	-26.0
	1	100	10.0	-11.0	10.0	-13.0	10.0	-14.0	10.0	-16.0	10.0	-19.0	7.8	-22.0	10.0	-25.0
	2	10	10.0	-21.0	10.0	-25.0	10.0	-26.0	10.0	-30.0	10.0	-35.0	9.9	-40.0	11.2	-46.0
	2	20	10.0	-19.0	10.0	-21.0	10.0	-23.0	10.0	-27.0	10.0	-31.0	9.2	-36.0	10.6	-41.0
	2	50	10.0	-16.0	10.0	-18.0	10.0	-19.0	10.0	-23.0	10.0	-26.0	8.5	-30.0	10.0	-34.0
	2	100	10.0	-14.0	10.0	-15.0	10.0	-16.0	10.0	-19.0	10.0	-22.0	7.8	-26.0	10.0	-30.0
	3	10	10.0	-33.0	10.0	-36.0	10.0	-39.0	10.0	-46.0	10.0	-53.0	9.9	-61.0	11.2	-69.0
	3	20	10.0	-27.0	10.0	-29.0	10.0	-32.0	10.0	-38.0	10.0	-44.0	9.2	-50.0	10.6	-57.0
	3	50	10.0	-19.0	10.0	-21.0	10.0	-23.0	10.0	-27.0	10.0	-32.0	8.5	-36.0	10.0	-41.0
	3	100	10.0	-14.0	10.0	-15.0	10.0	-16.0	10.0	-19.0	10.0	-22.0	7.8	-26.0	10.0	-30.0

Component & Cladding Wind Loads

- *Pressure and suction load tabulations [Table R301.2(2)]*
  - *30' High – Exposure B*
  - *V_{ULT} = 130 mph*
  - *Roof with Slope: 0° to 7°*

Effective Wind Area	Zone 1		Zone 2		Zone 3		Zone 4		Zone 5	
10 s.f.	10.0	-18.0	10.0	-30.0	10.0	-46.0	18.2	-19.0	18.2	-24.0
20 s.f.	10.0	-17.0	10.0	-27.0	10.0	-38.0	17.4	-19.0	17.4	-22.0
50 s.f.	10.0	-17.0	10.0	-23.0	10.0	-27.0	16.3	-17.0	16.3	-20.0
100 s.f.	10.0	-16.0	10.0	-19.0	10.0	-19.0	15.5	-17.0	15.5	-19.0

Component & Cladding Wind Loads

- *Pressure and suction load adjustment factors for height and exposure [Table R301.2(3)]*

MEAN ROOF HEIGHT	EXPOSURE		
	B	C	D
15	1.00	1.21	1.47
20	1.00	1.29	1.55
25	1.00	1.35	1.61
30	1.00	1.40	1.66
35	1.05	1.45	1.70
40	1.09	1.49	1.74
45	1.12	1.53	1.78

Component & Cladding Wind Loads

Example: 8' wide x 7' high garage door in Haddam – 18" high door panels

- *Wind speed = 130 mph*
- *Exposure: C (adjacent to open terrain)*
- *Mean roof height: 30'*
- *Pressure Zone Location: 4 (more than 4' from corner)*
- *Effective Wind Area – Panelized Door Spanning Horizontally: Tributary Area of Panel = 1.5' x 8' = 12 s.f. Per footnote 'a', the effective width shall be permitted to be not less than 1/3 the span length. Effective Wind Area = 8' x 8'/3 = 21 s.f.*

Table R310.2(2):
- *For 20 s.f. Effective Wind Area, C&C Pressure = 17.4 psf; C&C Suction = 19.0 psf*

From Table R301.2(3):
- *Height and Exposure Adjustment = 1.40*

Design Pressure = 1.40 x 17.4 psf = 24.4 psf
Design Suction = 1.40 x 19.0 psf = 26.6 psf

Attic Live Loads

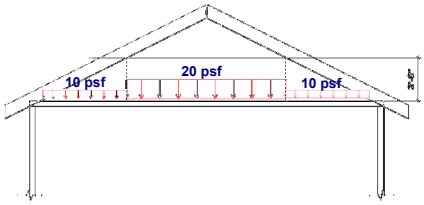
Table R301.5
- *Habitable Attics and Attics with Fixed Stairs: 30 psf*
- *Uninhabitable Attics with Limited Storage: 20 psf*
- *Uninhabitable Attics with No Storage: 10 psf*
  (not concurrent with other live loads)

What differentiates Uninhabitable Attics with Limited Storage from those with No Storage? For Limited Storage:
- *20"x30" access opening at point of minimum 30" clear height required*
- *Slope of joists or truss bottom chords ≤ 2V:12H*
- *Required insulation depth < joist or truss bottom chord depth*
- *Height/opening limitations*

Attic Live Loads

Limited Storage: Joist Construction

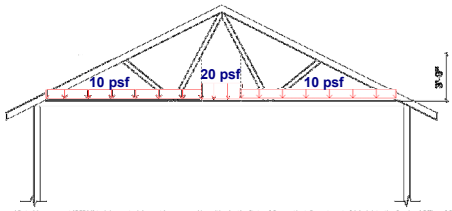
- *Clear Height Between Joists and Rafters ≥ 42"*



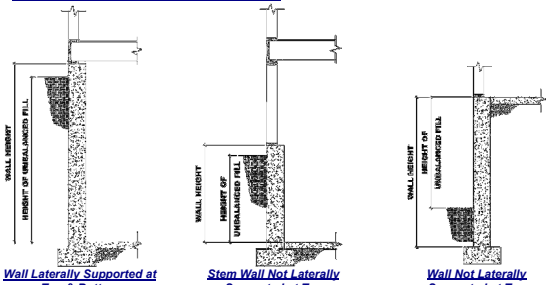
Attic Live Loads

Limited Storage - Truss Construction

- *Clear Height Between Truss Bottom and Top Chords ≥ 42"*
- *Web Configuration Can Accommodate 42"H x 24"W Rectangle Between 2 or More Trusses*



Basement Walls: *Nomenclature*



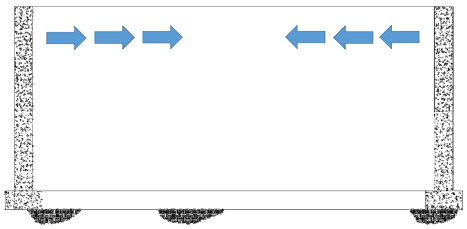
Wall Laterally Supported at Top & Bottom | *Stem Wall Not Laterally Supported at Top* | *Wall Not Laterally Supported at Top*

Basement Walls

- When is reinforcing required?
  - Horizontal Reinforcing: Required in all basement walls
  - Vertical Reinforcing: Function of:
    - Unsupported Wall Height
    - Unbalanced Backfill Height
    - Soil Type
    - Wall Thickness

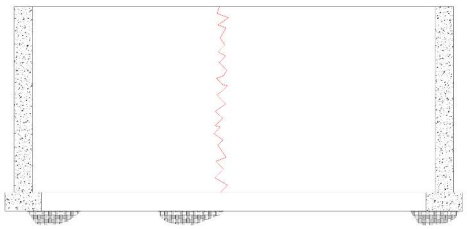
Basement Walls

- Why horizontal reinforcing?
  - Concrete shrinkage cracking



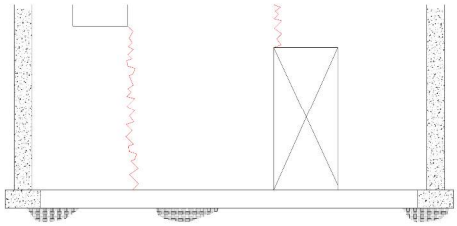
Basement Walls

- Why horizontal reinforcing?
  - Concrete shrinkage cracking



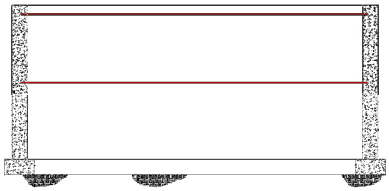
Basement Walls

- *Why horizontal reinforcing?*
  - *Concrete shrinkage cracking*



Basement Walls

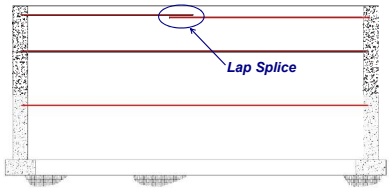
- *Horizontal Reinforcing [Table R404.1.2(1)]*
  - *Unsupported wall height ≤ 8'*



- *One #4 bar within 12" of top of wall*
- *One #4 bar near mid-height of wall*

Basement Walls

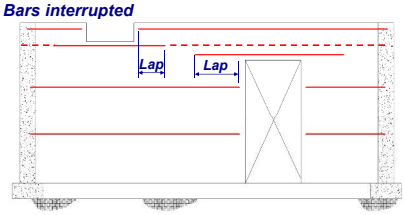
- *Horizontal Reinforcing [Table R404.1.2(1)]*
  - *Unsupported wall height > 8'*



- *One #4 bar within 12" of top of wall*
- *One #4 bar near third points of wall height*

Basement Walls

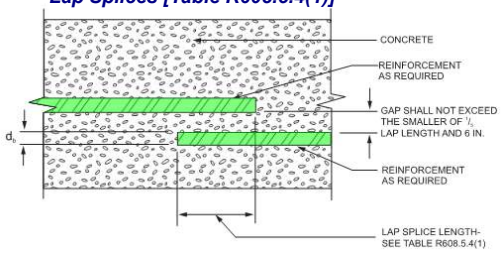
- Horizontal Reinforcing [Table R404.1.2(1)]
  - Bars interrupted



Basement Walls

- Lap Splices [Table R608.5.4(1)]

Lap Splice Lengths
(f_y = 60,000 psi)
- #4: 30"
- #5: 38"
- #6: 45"



Basement Walls

- Vertical Reinforcing
  - Soil Types – USCS – Table R405.1

TABLE R405.1
PROPERTIES OF SOILS CLASSIFIED ACCORDING TO THE UNIFIED SOIL CLASSIFICATION SYSTEM

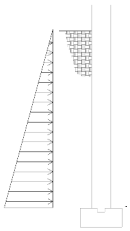
SOIL GROUP	UNIFIED SOIL CLASSIFICATION SYSTEM SYMBOL	SOIL DESCRIPTION	DRAINAGE CHARACTERISTICS[a]	FROST HEAVE POTENTIAL	VOLUME CHANGE POTENTIAL EXPANSION[b]
Group I	GW	Well-graded gravels, gravel sand mixtures, little or no fines	Good	Low	Low
	GP	Poorly graded gravels or gravel sand mixtures, little or no fines	Good	Low	Low
	SW	Well-graded sands, gravelly sands, little or no fines	Good	Low	Low
	SP	Poorly graded sands or gravelly sands, little or no fines	Good	Low	Low
	GM	Silty gravels, gravel-sand-silt mixtures	Good	Medium	Low
	SM	Silty sand, sand-silt mixtures	Good	Medium	Low
Group II	GC	Clayey gravels, gravel-sand-clay mixtures	Medium	Medium	Low
	SC	Clayey sands, sand-clay mixture	Medium	Medium	Low
	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity	Medium	High	Low
	CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays	Medium	Medium	Medium to Low

Basement Walls

- *Vertical Reinforcing*
  - *Soil Types – USCS*

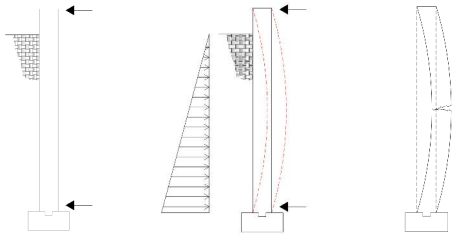
DESIGN LATERAL SOIL PRESSURES BASED ON SOIL CLASS

Soil Class	Lateral Soil Pressure
GW, GP, SW, SP	30 psf/foot of depth
GM, GC, SM SM-SC, ML	45 psf/foot of depth
SC, ML-CL Inorganic CL	60 psf/foot of depth



Basement Walls

- *Vertical Reinforcing – Why do we need it?*



Braced Basement Wall ***Lateral Earth Pressure*** ***Stresses in Concrete Wall***

Basement Walls

- *Vertical Reinforcing – Why do we need it?*

Reinforcing Inhibits Cracking

TABLE R404.1.2(3)
MINIMUM VERTICAL REINFORCEMENT FOR 8-INCH (203 mm) NOMINAL FLAT CONCRETE BASEMENT WALLS[b, c, d, e, f, h, i, j]

MAXIMUM UNSUPPORTED WALL HEIGHT (feet)	MAXIMUM UNBALANCED BACKFILL HEIGHT[a] (feet)	MINIMUM VERTICAL REINFORCEMENT-BAR SIZE AND SPACING (inches)		
		Soil classes[g] and design lateral soil (psf per foot of depth)		
		GW, GP, SW, SP 30	GM, GC, SM, SM-SC and ML 45	SC, ML-CL and inorganic CL 60
9	4	NR	NR	NR
	5	NR	NR	NR
	6	NR	NR	6 @ 35
	7	NR	6 @ 35	6 @ 32
	8	6 @ 36	6 @ 32	6 @ 23
	9	6 @ 35	6 @ 25	6 @ 18

8" wall – 9' high – 8' unbalanced fill height – 45 pcf soil

- *From Table R404.1.2(3), use #6 @ 32"o.c.*

READ THE FOOTNOTES !!!

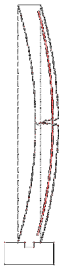
- *Footnote b: vertical bars located at center of the wall*

Basement Walls

- *Vertical Reinforcing*
  - *Flat Basement Walls 6" to 12" Thick*
    - *Tables R404.1.2(2) to R404.1.2(5) – Bars in center of wall (per footnote b): #6 @ 32" required per previous example*

TABLE R404.1.2(8)
MINIMUM VERTICAL REINFORCEMENT FOR 6-, 8-, 10- AND 12-INCH NOMINAL FLAT BASEMENT WALLS[a, b, c, d, e, f, g, h, i, j, k, l, m, n]

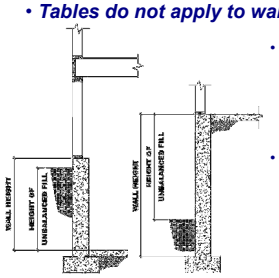
MAXIMUM WALL HEIGHT (feet)	MAXIMUM UNBALANCED BACKFILL HEIGHT[h] (feet)	MINIMUM VERTICAL REINFORCEMENT-BAR SIZE AND SPACING (inches)											
		Soil classes[a] and design lateral soil (psf per foot of depth)											
		GW, GP, SW, SP 30				GM, GC, SM, SM-SC and ML 45				SC, ML-CL and inorganic CL 60			
		Minimum nominal wall thickness (inches)											
		6	8	10	12	6	8	10	12	6	8	10	12
9	4	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
	5	NR	NR	NR	NR	4 @ 35	NR[i]	NR	NR	5 @ 40	NR	NR	NR
	6	4 @ 34	NR[i]	NR	NR	6 @ 48	NR	NR	NR	6 @ 36	6 @ 39	NR[i]	NR
	7	5 @ 36	NR	NR	NR	6 @ 34	5 @ 37	NR	NR	6 @ 33	6 @ 38	5 @ 37	NR
	8	6 @ 38	5 @ 41	NR	NR	6 @ 43	6 @ 38	5 @ 37	NR[i]	6 @ 24	6 @ 29	6 @ 39	4 @ 48"
	9	6 @ 34	6 @ 46	NR	NR	6 @ 38	6 @ 40	6 @ 41	NR	6 @ 19	6 @ 23	6 @ 30	6 @ 39



- *Table R404.1.2(8) – Bars located 1¼" clear from inside face of wall (per footnote h): #6 @ 38"o.c. required for same wall*

Basement Walls

- *Tables do not apply to walls <u>not</u> laterally supported at top!*

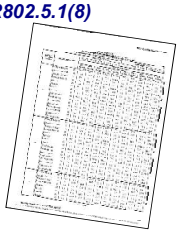


- *§R404.1.1: Design in accordance with accepted engineering practice is required for walls supporting more than 48" of unbalanced backfill that do not have permanent lateral support at the top or bottom.*
- *§R404.1.3.2.2: Stem walls not laterally supported at top with more than 48" of unbalanced fill – references to §R404.1.1* above and §R404.4 (retaining walls; design in accordance with accepted engineering practice)*

Joist and Rafter Spans

- *Floor Joist Span Tables R502.3.1(1) to R502.3.1(2)*
- *Ceiling Joist Span Tables R802.4(1) to R802.4(2)*
- *Rafter Span Tables R802.5.1(1) to R802.5.1(8)*

Variety of:
- *Lumber Species*
- *Lumber Grades*
- *Joist/Rafter Spacings*
- *Dead Loads*
- *Live/Snow Loads*
- *Deflection Criteria*



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Joist and Rafter Spans

- *How to deal with non-tabulated loading conditions*
  - *For Rafters with Ground Snow Loads Between 30-50 psf:*
    - *Use linear interpolation in the span charts (permitted by R802.5 – 2018 CT Amendments*
    - *Use AWC STJR, "Span Tables for Joists and Rafters," as permitted by R802.5*

      (http://awc.org/codes-standards/publications/stjr-2015)
    - *Use rafter span handout from OSBI (limited to No. 2 DF, HF, SoP, SPF – 35 & 40 psf snow)*
    - *Use AWC Maximum Span Calculator for Wood Joists & Rafters*

      (http://awc.org/codes-standards/calculators-software/spancalc)

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Joist and Rafter Spans

- *How to deal with non-tabulated loading conditions*
  - *For Floor Joists with Higher Live Loads or Different Dead Loads:*
    - *Use AWC STJR as permitted by R502.3*
    - *Use AWC Maximum Span Calculator for Wood Joists & Rafters*

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Joist and Rafter Spans

- *How to deal with non-tabulated loading conditions*
  - *AWC Maximum Span Calculator Example:*

Species	Douglas Fir-Larch
Size	2x8
Grade	No. 2
Member Type	Rafters (Snow Load)
Deflection Limit	L/240
Spacing (in)	16
Exterior Exposure	Wet service conditions? No
	Incised lumber? No
Snow Load (psf)	35
Dead Load (psf)	15

Calculate Maximum Horizontal Span

The Maximum Horizontal Span is:

13 ft. 8 in.

with a minimum bearing length of **0.49 in.** required at each end of the member.

Property	Value
Species	Douglas Fir-Larch
Grade	No. 2
Size	2x8
Modulus of Elasticity (E)	1600000 psi
Bending Strength (F_b)	1428.3 psi
Bearing Strength (F_{cp})	625 psi
Shear Strength (F_v)	207 psi

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Roof Tie-Down Anchorage

- When are tie-down anchors necessary?
  - §R802.11: Fastening per Table R602.3(1) (toe nails) is permitted when uplift force is less than 200 pounds

Table R802.11

Uplift Connx. Forces

TABLE R802.11—continued
RAFTER OR TRUSS UPLIFT CONNECTION FORCES FROM WIND (POUNDS PER CONNECTION)[a, b, c, e, f, g, h]

RAFTER OR TRUSS SPACING	ROOF SPAN (feet)	EXPOSURE C									
		Ultimate Design Wind Speed V_{ult} (mph)									
		110		115		120		130		140	
		Roof Pitch		Roof Pitch		Roof Pitch		Roof Pitch		Roof Pitch	
		< 5:12	≥ 5:12	< 5:12	≥ 5:12	< 5:12	≥ 5:12	< 5:12	≥ 5:12	< 5:12	≥ 5:12
16" o.c.	12	126	117	146	136	168	157	214	201	263	247
	18	161	148	188	174	217	201	277	259	342	322
	24	197	181	230	213	266	246	340	318	422	396
	28	221	202	259	238	299	277	384	358	476	446
	32	245	223	287	265	331	307	427	398	529	496
	36	269	246	315	291	364	338	469	438	583	547
	42	305	279	358	330	415	384	535	499	664	622
	48	340	311	402	370	464	430	599	559	745	697

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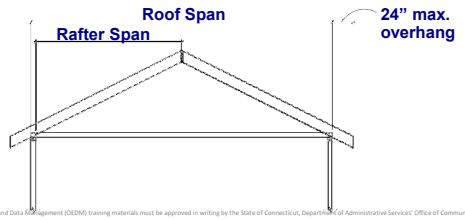
Roof Tie-Down Anchorage

- When are tie-down anchors necessary?
  - Note: Table is based on Roof Span, not Rafter Span!



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Roof Tie-Down Anchorage

- Table R802.11 – Read the Footnotes!!!
  - Tables are based on Exposures B & C. For Exposure D, use next highest tabulated value in Exposure C (e.g. for 130 mph Exposure D, use values from 140 mph Exposure C)
  - Table not valid for roof overhangs greater than 24"
  - Table not valid for mean roof height > 33'
  - For connections more than 8' from building corners, uplift forces can be reduced by multiplying by 0.75
  - For connections at hip roofs with pitch ≥ 5:12, uplift forces can be reduced by multiplying by 0.70

Roof Tie-Down Anchorage

- *Example*
  - *Given: Trusses/Rafters spaced @ 24"o.c.; overhang ≤ 24"*
  - *Find: The allowable roof span for which standard toe-nailed connections are permissible?*

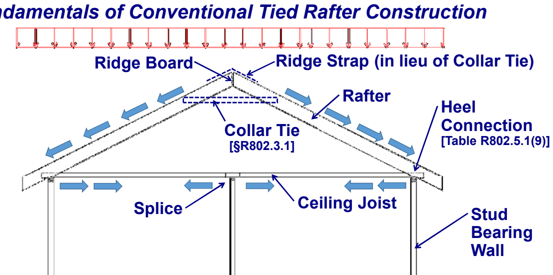
Wind Speed	Roof Pitch	Allowable Roof Span		
		Exposure B	Exposure C	Exposure D
115 mph	< [illegible]	[illegible]	*	*
	≥ [illegible]	[illegible]	*	*
[illegible] mph	< [illegible]	[illegible]	*	*
	≥ [illegible]	[illegible]	*	*
[illegible] mph	< [illegible]	[illegible]	*	*
	≥ [illegible]	[illegible]	*	*
[illegible] mph	< [illegible]	[illegible]	*	*
	≥ [illegible]	15'-6"	*	*
[illegible] mph	< [illegible]	*	*	*
	≥ [illegible]	*	*	*
[illegible] mph	< [illegible]	*	*	*
	≥ [illegible]	*	*	*

* [illegible]

Demystifying the Structural Provisions of the IRC

Tied Rafters with Raised Ceilings

- *Fundamentals of Conventional Tied Rafter Construction*



Demystifying the Structural Provisions of the IRC

Tied Rafters with Raised Ceilings

- *Heel connection requirements – Table R802.5.1(9)*

TABLE R802.5.1(9)
RAFTER/CEILING JOIST HEEL JOINT CONNECTIONS[a, b, c, d, e, f, h]

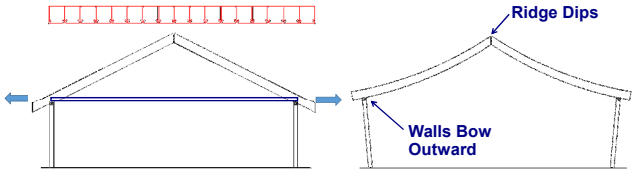
RAFTER SLOPE	RAFTER SPACING (inches)	GROUND SNOW LOAD (psf) 20[g]				30				50				70			
		Roof span (feet) 12	20	28	36	12	20	28	36	12	20	28	36	12	20	28	36
		Required number of 16d common nails[a, b] per heel joint splices[c, d, e, f]															
3:12	12	4	6	8	10	4	6	8	11	5	8	12	15	6	11	15	20
	16	5	8	10	13	5	8	11	14	6	11	15	20	8	14	20	26
	24	7	11	15	19	7	11	16	21	9	16	23	30	12	21	30	39
4:12	12	3	5	6	8	3	5	6	8	4	6	9	11	5	8	12	15
	16	4	6	8	10	4	6	8	11	5	8	12	15	6	11	15	20
	24	5	8	12	15	5	9	12	16	7	12	17	22	9	16	23	29
5:12	12	3	4	5	6	3	4	5	7	3	5	7	9	4	7	9	12
	16	3	5	6	8	3	5	7	9	4	7	9	12	5	9	12	16
	24	4	7	9	12	4	7	10	13	6	10	14	18	7	13	18	23
7:12	12	3	4	4	5	3	3	4	5	3	4	5	7	3	5	7	9
	16	3	4	5	6	3	4	5	6	3	5	7	9	4	6	9	11
	24	3	5	7	9	3	5	7	9	4	7	10	13	5	9	13	17

Tied Rafters with Raised Ceilings

- *Heel connection requirements – Table R802.5.1(9)*
  - *30 psf Ground Snow Load*
  - *28' Roof Span*
  - *24" Rafter Spacing*

Rafter Slope	16d Nails Required
3:12	16
4:12	12
5:12	10
7:12	7
9:12	6
12:12	4

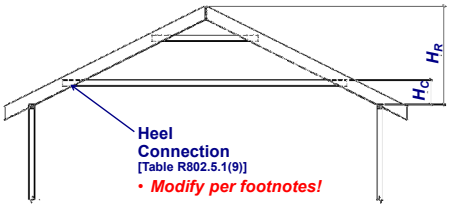
Tied Rafters with Raised Ceilings



When are the options?
- *Add a structural ridge beam*
- *Add rafter ties*

Tied Rafters with Raised Ceilings

- *Rafter span reductions – Tables R802.5.1(1) to (8)*



- *Modify per footnotes!*

H_C/H_R	Rafter Span Adjustment Factor	
	IRC 2012 IRC 2015	IRC 2003
2/3 or greater	Not Allowed	0.50
1/2	Not Allowed	0.58
1/3	0.67	0.67
1/4	0.76	0.76
1/5	0.83	0.83
1/6	0.90	0.90
1/7.5 and less	1.00	1.00

Tied Rafters with Raised Ceilings

- *Rafter/Ceiling Joist Heel Connections – Table R802.5.1(9)*

Footnotes

f. *Where rafter ties are substituted for ceiling joists, the heel joint connection requirements shall be taken from the tabulated heel joint connection requirements for two-thirds of the actual rafter slope.*

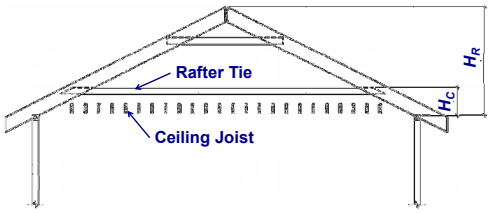
DELETED IN 2018 IRC

h. *Tabulated heel joint connections assume that ceiling joists or rafter ties are located at the bottom of the attic space. Where ceiling joists or rafter ties are located higher in the attic, heel joint connection requirements shall be increased by the following factors.*

H_C/H_R	Heel Joist Connection Adjustment Factor
1/3	1.5
1/4	1.33
1/5	1.25
1/6	1.2
1/10 or less	1.11

Tied Rafters with Raised Ceilings

- *Rafter span reductions – Tables R802.5.1(1) to (8)*
  - *Ceiling joists not parallel to rafters*



Tied Rafters with Raised Ceilings

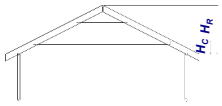
Given:

- *Gable Roof*
- *28' roof span w/ 2' overhang*
- *7:12 pitch*
- *No. 2 S-P-F*
- *8' Plate Height*
- *9'-9" Ceiling Height*
- *2x6 Stud Walls*
- *130 mph Wind Zone – Exp. B*
- *30 psf Ground Snow Load (Ceiling Attached to Rafters)*
- *Uninhabitable Attic with No Storage*
- *10 psf Roof Dead Load*
- *2"x10 @ 16"o.c. Rafters*
- *2"x6" @ 16" Ceiling Joists*

Find:

1. *Are rafters adequate?*
2. *Are ceiling joists adequate?*
3. *What is the required connection between the ceiling joists and rafters?*
4. *Are hurricane ties required between the rafter and stud wall?*

Tied Rafters with Raised Ceilings



Basic Geometry

- Roof Span = 28'
- Rafter Span = 28'/2 – 6" (wall) = 13'-6"
- H_C ≈ 9'-9" (clg. ht.) – 8'-0" (plate ht.) + 6" (clg. joist depth) = 2'-3"
- H_R ≈ 28'/2 x 7/12 (pitch) + 8" (rafter ht. above plate at outside of wall) = 8'-10"
- H_C / H_R = 2.25'/8.83' = 0.254 ≈ ¼
- Ceiling Joist Span = [13'-6" – (1'-9" x 12/7)] x 2 = 21'-0"

Tied Rafters with Raised Ceilings

1. Are Rafters Adequate?
   - Table R802.5.1(5): Allowable span for 2"x10" @ 16"o.c. rafters (No. 2 S-P-F) with 30 psf snow load, 10 psf dead load and attached ceiling = 18'-5".
   - From footnote "a", Rafter Span Adjustment Factor for H_C/H_R of ¼ = 0.76.
   - Modified Allowable Rafter Span = 0.76 x 18'-5" = 14'-0" > 13'-6" actual rafter span
     - ➢ Rafters are O.K.
2. Are Ceiling Joists Adequate?
   - Table R802.4(1): Allowable span for 2"x6" @ 16"o.c. ceiling joists (No. 2 S-P-F) with 10 psf live load (no storage) = 16'-11" < 21'-0" actual ceiling joist span.
     - ➢ 2"x6" ceiling joists are N.G.
     - ➢ Use 2"x8" ceiling joists instead – allowable span = 22'-4"

Tied Rafters with Raised Ceilings

3. What is the Required Connection Between the Ceiling Joists and the Rafters?
   - Table R802.5.1(9): For a roof span of 28', ground snow load of 30 psf, rafter slope of 7:12 and rafter spacing of 16"o.c., five (5) 16d nails are required at the rafter/ceiling heel joint connection.
   - From footnote "h", a Heel Joint Connection Adjustment Factor is to be applied when the ceiling joists are located above the wall plate. For H_C/H_R = 1/4, this adjustment factor is 1.33.
   - Number of nails required = 1.33 x 5 = 6.7
     - ➢ Use seven (7) 16d nails at the rafter/ceiling heel joint connection

Tied Rafters with Raised Ceilings

4. *Are Hurricane Anchors Required Between the Rafter and Stud Wall?*
   - *Table R802.11: For a 130 wind speed in Exposure B with rafters spaced @ 16"o.c., a roof span of 28' with a 24" overhang and a 7:12 roof pitch, the rafter uplift connection force = 203#.*
     - *As the connection force exceeds 200#, the standard toe-nailed connections in the Fastening Schedule are not permissible and a hurricane anchor (or acceptable alternative connection) would be required.*
     - *Per footnote "d", the tabulated connection forces at locations more than 8'-0" from the building corners may be multiplied by 0.70. The design connection force in these areas would be 0.70 x 203# = 142#; toe-nailed connections in accordance with Table R602.3(1) would be permissible in these locations.*

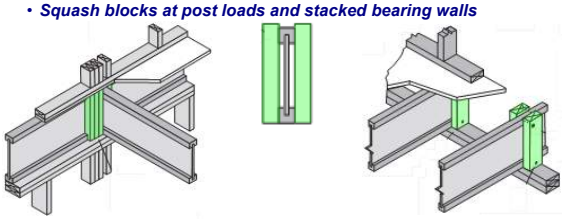
Special Considerations for I-Joists

- *Benefits*
  - *Dimensionally stable*
  - *Longer spans*
  - *Larger openings*
- *Challenges*
  - *More complicated installation*
  - *Plethora of details to follow*
  - *Footnotes galore*
  - *Specific design criteria not contained within IRC*

Evaluation Service Reports

Special Considerations for I-Joists

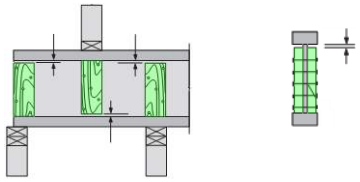
- *Concentrated Loads*
  - *Squash blocks at post loads and stacked bearing walls*



At exterior bearing walls, rim joists can often eliminate need for squash blocks below bearing walls above; squash blocks are generally still required at posts

Special Considerations for I-Joists

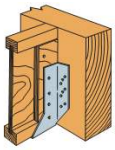
- *Web stiffeners*
  - *Sometimes required at points of bearing and when supporting concentrated loads – required locations identified on drawings*



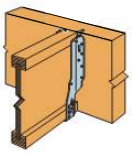
Stiffener thickness and nailing requirements per manufacturer

Special Considerations for I-Joists

- *Joist Hangers*
  - *Hangers must provide lateral restraint of top flange; otherwise web stiffeners required*



Hanger Does Not Restrain Top Flange
- *Web Stiffener Required*



Hanger Restrains Top Flange

Special Considerations for I-Joists

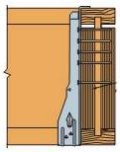
- *Joist Hangers*

Hanger Does Not Restrain Top Flange
- *Web Stiffener Required*

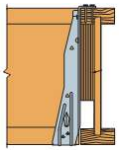
Hanger Restrains Top Flange

Special Considerations for I-Joists

- *Joist Hangers*
  - *When I-Joists are used as headers, backer blocks are required at hanger connections.*



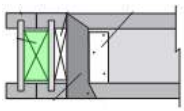
Backer Blocks on Both Sides at Face-Mount Hangers (to bear flush with bottom flange)

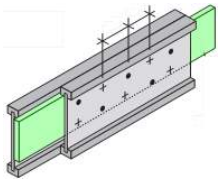


Backer Blocks on Hanger Side at Top-Flange Hangers (to bear flush with top flange)

Special Considerations for I-Joists

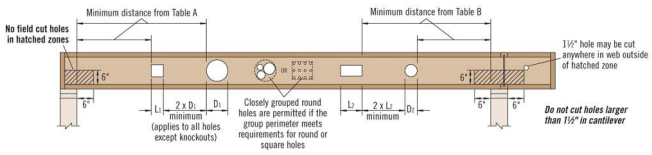
- *Double I-Joists*
  - *When double I-Joists are used as headers or to support concentrated loads, they must be interconnected with filler blocks to act as a unit.*





Special Considerations for I-Joists

- *Joist Penetrations*
  - *I-Joists can accommodate considerably larger penetrations that than sawn lumber*
  - *Read the footnotes!!!*



Special Considerations for I-Joists

- *Joist Penetrations*
  - *Example Based on LPI 42Plus Joists*

CLOSEST DISTANCE TO SUPPORT

Joist Depth	Circular Hole Diameter						
	2″	3″	4″	5″	6″	7″	8″
9½″	1′-3″	2′-3″	3′-4″	4′-4″	5′-5″	-	-
11⅞″	3′-2″	3′-10″	4′-7″	5′-3″	6′-0″	6′-9″	7′-8″
14″	4′-5″	5′-0″	5′-7″	6′-1″	6′-8″	7′-3″	8′-0″
16″	5′-4″	5′-10″	6′-4″	6′-10″	7′-4″	7′-10″	8′-6″

CLOSEST DISTANCE TO SUPPORT

Joist Depth	Rectangular Hole Maximum Dimension						
	2″	3″	4″	5″	6″	7″	8″
9½″	5′-8″	6′-6″	7′-4″	8′-2″	9′-3″	9′-7″	9′-11″
11⅞″	7′-2″	8′-0″	9′-0″	10′-0″	10′-11″	12′-1″	13′-8″
14″	4′-4″	4′-2″	6′-0″	6′-10″	7′-10″	9′-1″	10′-10″
16″	5′-3″	6′-0″	6′-9″	7′-7″	8′-6″	9′-8″	11′-2″

Special Considerations for I-Joists

- *Joist Penetrations*
  - *These web hole tables are valid for simple and continuous spans with uniform loads only, as sized from tables contained in LP's current I-Joist product guides. Larger holes and non-uniform loading conditions and/or closer proximity to supports may be possible, but require further analysis using LP's design software.*

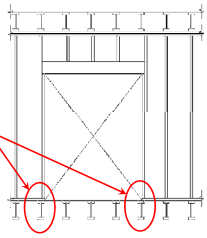
Special Considerations for I-Joists

- *Joist Penetrations*

Multiple penetrations near support | *Openings too close together* | *Penetration through flange*

Special Considerations for I-Joists

- *Load Path Issues*



Concentrated Loads in Offset Bearing Wall

Special Considerations for I-Joists

- *Issues with Other Trades – Ductwork Conflicts*

Special Considerations for I-Joists

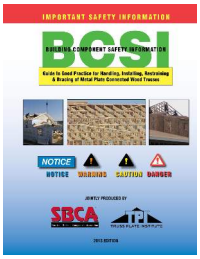
- *Issues with Other Trades – Ductwork Conflicts*

Joists cut – increases load on adjacent joists

Metal-Plate-Connected Wood Trusses

- *Permanent Bracing Requirements*

R802.10.3 Bracing. *Trusses shall be braced to prevent rotation and provide lateral stability in accordance with the requirements specified in the construction documents and on the individual truss design drawings. In the absence of specific bracing requirements, trusses shall be braced in accordance with accepted industry practices, such as, the SCBA "Building Component Safety Information (BCSI) Guide to Good Practice for Handling, Installing & Bracing of Metal-Plate-Connected Wood Trusses."*



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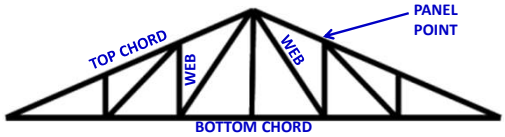
Metal-Plate-Connected Wood Trusses

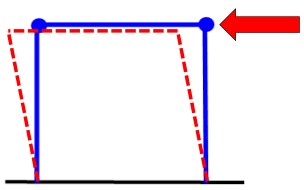
- *Permanent Bracing Requirements – Truss Basics*



- *Primary stresses in truss members:*
  - *Top Chord: compression*
  - *Bottom Chord: tension*
  - *Webs: some compression, some tension*
- *Permanent bracing inhibits buckling of compression members*

Metal-Plate-Connected Wood Trusses

- *Permanent Bracing Requirements – Truss Basics*



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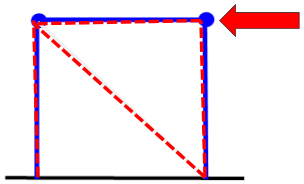
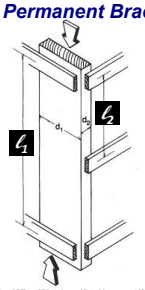
- *Permanent Bracing Requirements – Truss Basics*



Triangulation

Metal-Plate-Connected Wood Trusses

- *Permanent Bracing Requirements*



Slenderness Ratio

ℓ_e/d

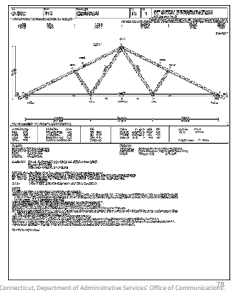
How does the slenderness ratio affect the allowable compression strength?

- *2"x4" - No. 1/No. 2 Spruce-Pine-Fir -Snow Load Condition*

ℓ_e/d	P_{allow}
10	7,270#
26	2,924#
50	861#

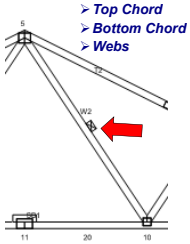
Metal-Plate-Connected Wood Trusses

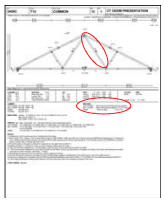
- *Permanent Bracing Requirements*
  - *Truss Design Drawings*
    - *Truss IDs*
    - *Geometry*
    - *Truss Bearing*
    - *Lumber*
    - *Plates*
    - *Permanent Restraint/Bracing*
    - *Forces*
    - *Deflections*
    - *Design Loads*
    - *Design Criteria*
    - *Multi-Ply Girder Fastening*



Metal-Plate-Connected Wood Trusses

- *Permanent Bracing Requirements*
  - *Truss Design Drawings*
    - *Top Chord*
    - *Bottom Chord*
    - *Webs*



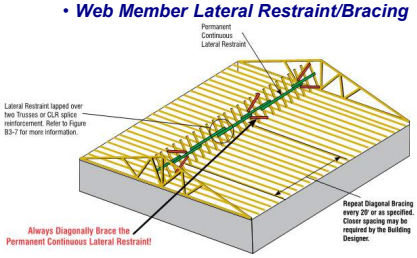


BRACING-

TOP CHORD	Structural wood sheathing directly applied.
BOT CHORD	Rigid ceiling directly applied or 2-2-0 oc bracing.
WEBS	1 Row at midpt 5-12, 5-10

Metal-Plate-Connected Wood Trusses

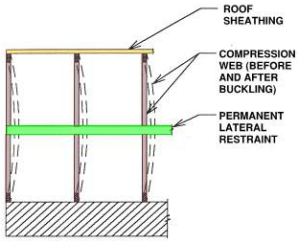
- *Permanent Bracing Requirements*
  - *Web Member Lateral Restraint/Bracing*



Requires continuous lateral restraint and intermittent diagonal bracing.

Metal-Plate-Connected Wood Trusses

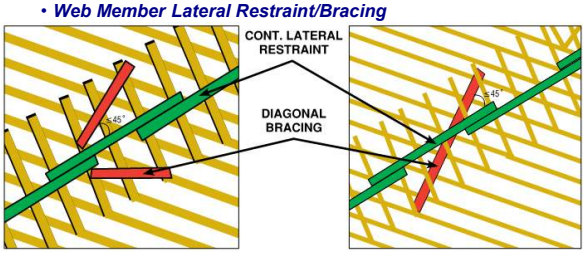
- *Permanent Bracing Requirements*
  - *Web Member Lateral Restraint/Bracing*



Continuous lateral restraint alone will not prevent buckling of the compression web.

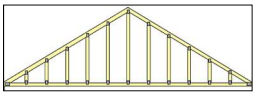
Metal-Plate-Connected Wood Trusses

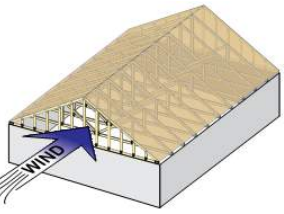
- *Permanent Bracing Requirements*
  - *Web Member Lateral Restraint/Bracing*



Metal-Plate-Connected Wood Trusses

- *Permanent Bracing Requirements*
  - *Gable End Trusses*
    - *Prefabricated stud walls*

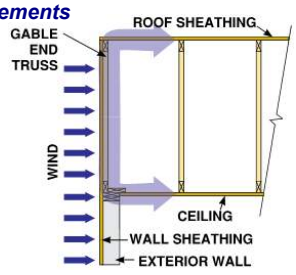




- *Deliver loads to walls below*
- *Must resist wind!*

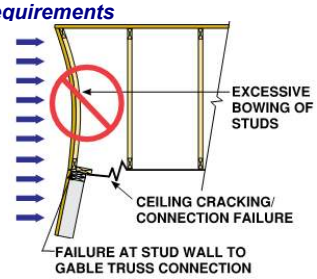
Metal-Plate-Connected Wood Trusses

- *Permanent Bracing Requirements*
  - *Gable End Trusses*
    - *Need to establish load path by which to transfer lateral wind loads (pressure or suction) from the exterior wall surface into the structure so that they can ultimately be delivered down to the foundation.*



Metal-Plate-Connected Wood Trusses

- *Permanent Bracing Requirements*
  - *Gable End Trusses*
  - *Potential Points of Failure*

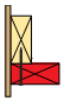


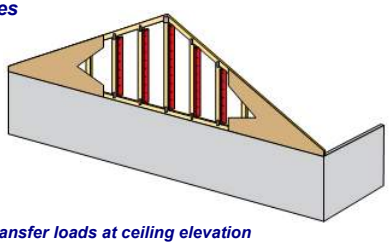
Metal-Plate-Connected Wood Trusses

- *Permanent Bracing Requirements*
  - *Gable End Trusses*

Metal-Plate-Connected Wood Trusses

- *Permanent Bracing Requirements*
  - *Gable End Trusses*
    - ➢ *Add L-Reinforcement to Strengthen Studs*

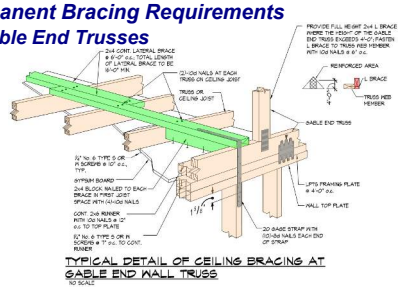




Still need to transfer loads at ceiling elevation

Metal-Plate-Connected Wood Trusses

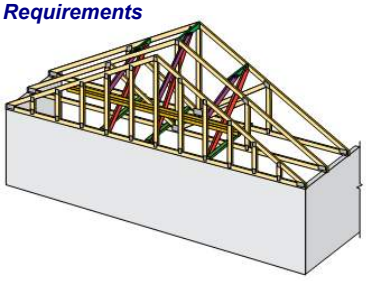
- *Permanent Bracing Requirements*
  - *Gable End Trusses*



TYPICAL DETAIL OF CEILING BRACING AT GABLE END WALL TRUSS
NO SCALE

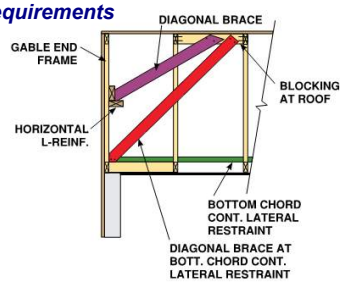
Metal-Plate-Connected Wood Trusses

- *Permanent Bracing Requirements*
  - *Gable End Trusses*
    - ➢ *Add Bracing*



Metal-Plate-Connected Wood Trusses

- *Permanent Bracing Requirements*
  - *Gable End Trusses*
    - ➢ *Add Bracing*



Demystifying the Structural Provisions of the IRC

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