

Heel Blocking Requirements and Capacity Analysis

Overview

Revised 3/22/2017

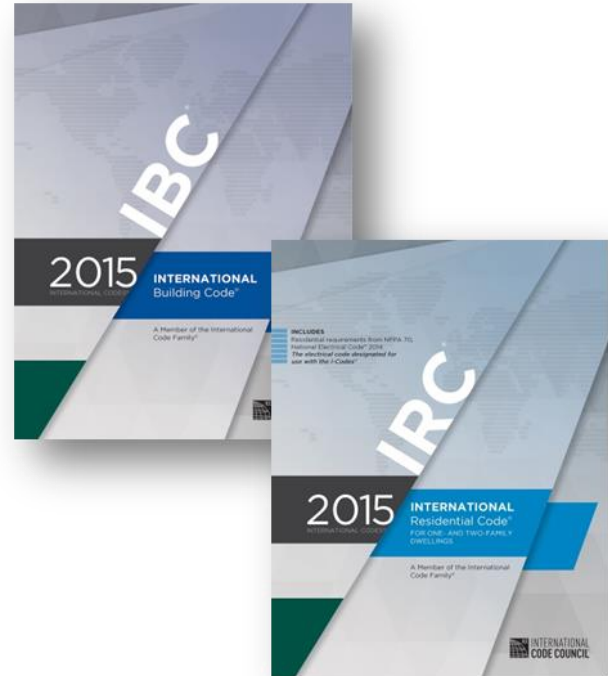
SBCA

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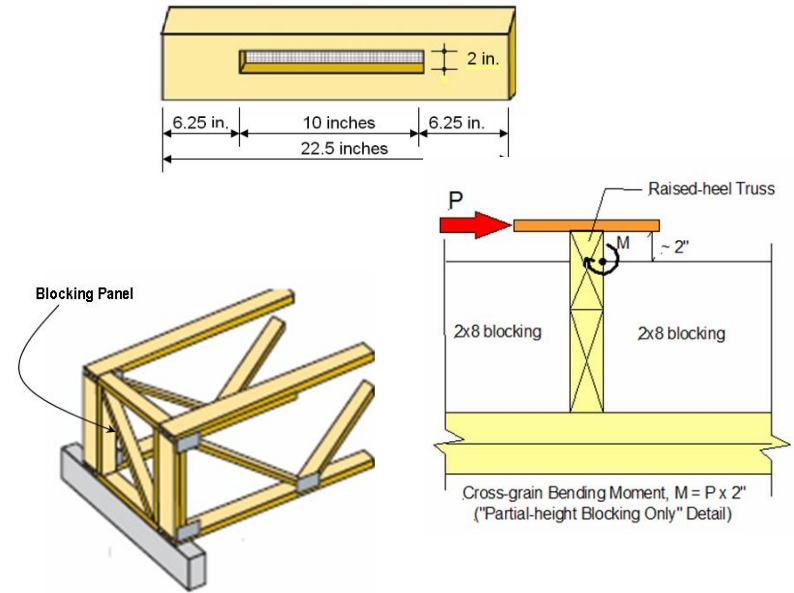
Introduction

- Both the International Residential Code (*IRC*) and the International Building Code (*IBC*) require that the top plates of exterior braced wall panels be attached to the rafters or roof trusses above.
- This connection is only required for designated exterior braced wall panels, not all exterior walls.



Introduction

- This presentation covers code requirements (IRC, IBC) and alternate engineered designs and capacities, including:
 - Heel/bird blocking
 - Partial height blocking
 - Panel blocking



Introduction

- Heel blocking is a commonly used method to transfer in-plane lateral loads from the braced wall panel to the roof diaphragm.
- Structural engineers may have questions regarding the prescriptive code requirements or the capacity of commonly used heel blocking to achieve a desired load transfer.
- In addition there may be questions as to who is responsible for the determining the required strength.

Key Definitions

- **Braced Wall Line:** A straight line through the building plan that represents the location of the lateral resistance provided by the wall bracing.
- **Braced Wall Panel:** A full-height section of wall constructed to resist in-plane shear loads through interaction of framing members, sheathing material and anchors. The panel's length meets the requirements of its particular bracing method and contributes toward the total amount of bracing required along its braced wall line.
- **Building Designer:** Owner of the building or the person that contracts with the Owner for the design of the Framing Structural System and/or who is responsible for the preparation of the Construction Documents. When mandated by the Legal Requirements, the Building Designer shall be a Registered Design Professional.

Key Definitions

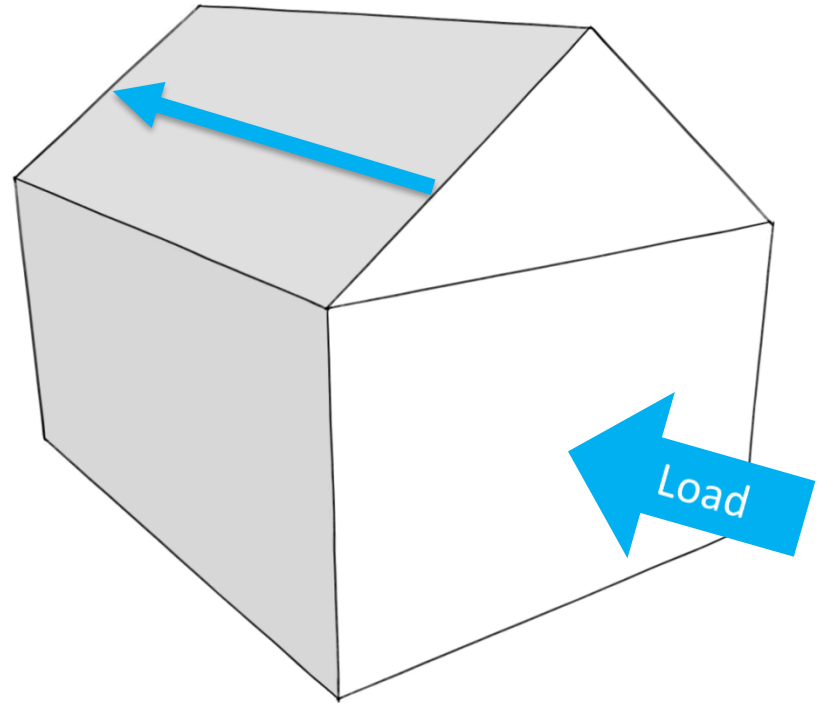
- **Cross-grain Bending:** When a wood member is loaded such that it tends to bend in a direction against or across the grain, it is said to be in cross-grain bending. Wood is weak in bending about this axis.
- **Diaphragm:** A horizontal or nearly horizontal system acting to transmit lateral forces to the vertical resisting elements. Where the term “diaphragm” is used, it includes horizontal bracing systems.
- **Heel Block/ Bird Block/ E Block:** Is a term used for the block installed between roof truss heels at the top of the exterior wall.

Key Definitions

- **Partial Height Blocking:** A heel block that is not the full height of the truss heel is called Partial Height Blocking. The shear transfer capacity of this kind of blocking is less than that of full height blocking, but it provides room for ventilation, insulation, ducts, etc.
- **Perimeter Blocking:** Blocking along the perimeter of the roof diaphragm that has the ability to transfer loads into the side walls or end walls.
- **Truss Designer:** Person responsible for the preparation of the Truss Design Drawings.
- **Weak-axis Bending:** When a structural member is loaded such that it tends to bend about the axis of lower moment of inertia, it is said to be in weak-axis bending. Wood members are especially weak in bending about this axis.

Background

- Structures can be designed to take a considerable amount of lateral load from wind or earthquake loading.
- These lateral loads in the roof system are transferred through the roof diaphragm, which is the structural plane created by the roof sheathing.



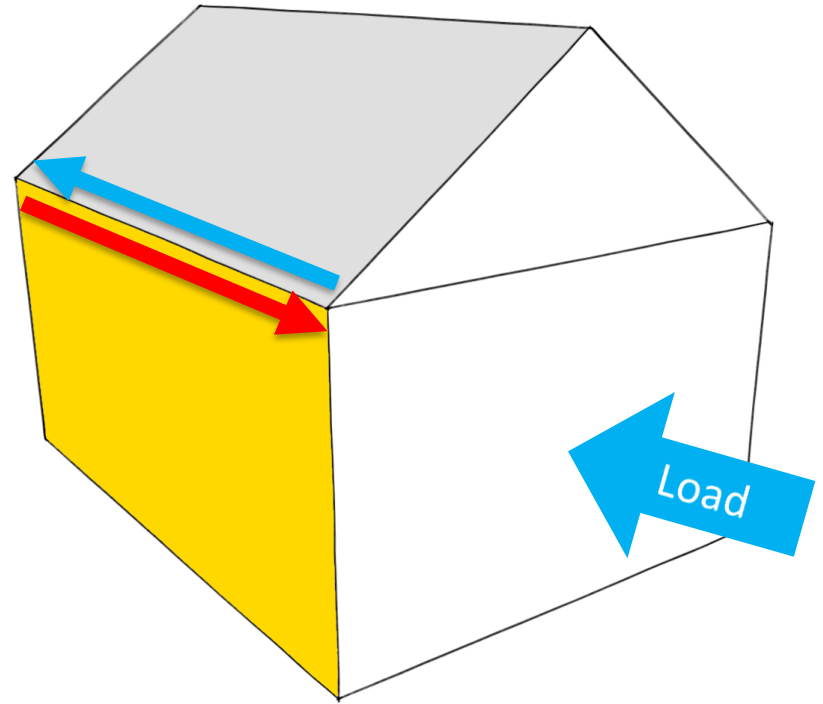
Background

- To design the roof diaphragm, building designers determine:
 - The thickness and grade of the roof sheathing
 - The nail size and frequency
 - The size of the supporting framing members
 - The amount of blocking required



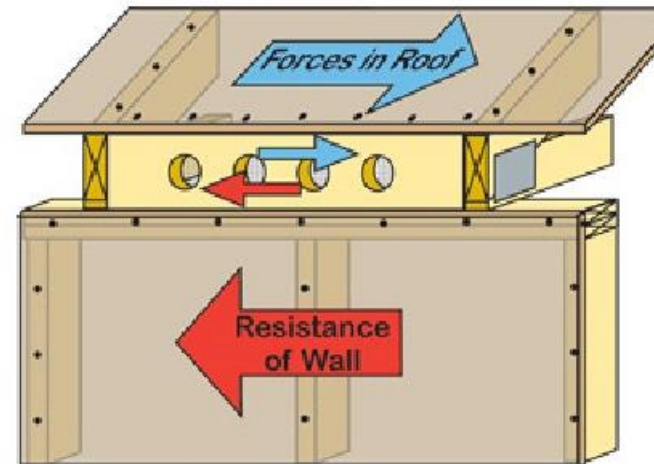
Background

- The perimeter of the diaphragm then must have the ability to transfer loads into the side walls, or shear walls.
- Shear walls act like a roof diaphragm, only there are installed vertically.



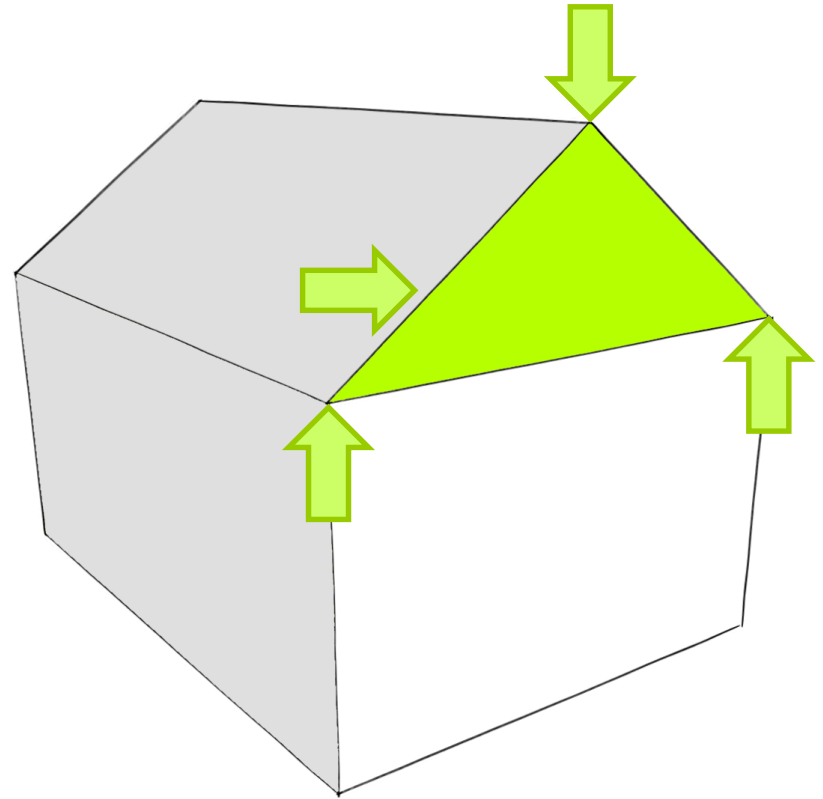
Background

- Truss heel blocking can function as perimeter blocking of the roof diaphragm
- However, the adequacy of this connection depends on multiple factors
- The Building Designer may not assume that prescriptive heel blocking will perform adequately as perimeter blocking for the roof diaphragm



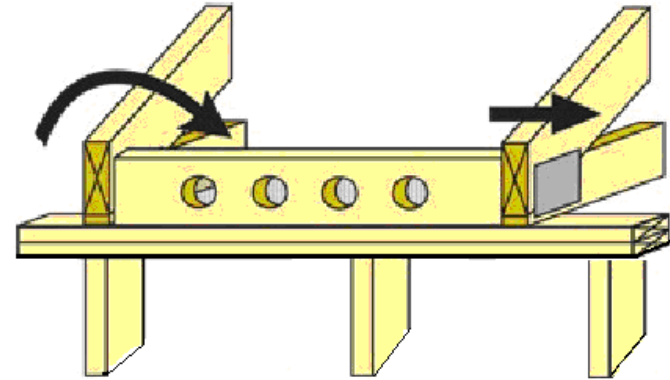
Designer Responsibility

- The Truss Designer assumes that the truss will carry only in-plane loads and designs the truss accordingly
- The Building Designer is responsible for designing the system as a whole to resist loads not in-plane with the truss, including lateral loads and rotation



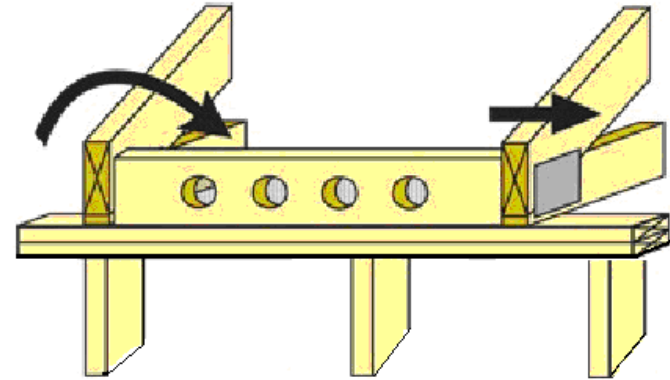
Designer Responsibility

- The *IRC* requires blocking at the truss heels where there is a greater expectation of lateral loads causing rotation and displacement.
- Blocking is not typically installed in most interior parts of the country because the truss-to-bearing connections and the relatively close roof sheathing attachment is assumed to be sufficient to prevent any movement.



Designer Responsibility

- A few other considerations:
 - Blocks may not have to go the full height of the truss heel to effectively block it and keep it from rotating
 - A block may not be required in every space between trusses.
 - Ventilation requirements may need more area than a partial height block can supply.



Building Code Requirements – IRC 2015

- IRC 2015 contains general code requirements for bracing (lateral support) of trusses
- These requirements are specifically to resist rotation and do not address the transfer of wind or seismic forces.
- [R802.10.3 Bracing](#) (Roof)
- [R502.11.2 Bracing](#) (Floor)

Building Code Requirements – IRC 2015

- IRC 2015 also provides prescriptive guidance for the roof diaphragm to shear wall connections
- Connections are primarily determined by:
 - Seismic zone
 - Distance from the roof sheathing to the top of the braced wall panel plate
- [R602.10.8.2 Connections to roof framing.](#)

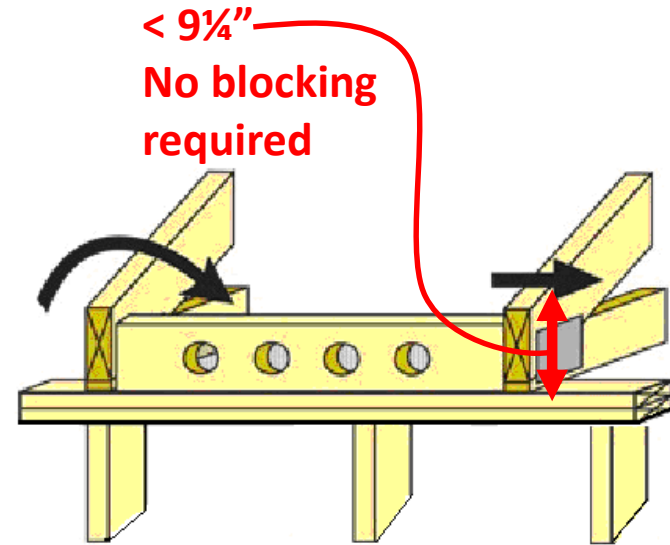
Building Code Requirements - IRC

- Fastening of blocking to the top plate is to be in accordance with Table R602.3(1) [item 1]

ITEM	DESCRIPTION OF BUILDING ELEMENTS	NUMBER AND TYPE OF FASTENER ^{a, b, c}	SPACING AND LOCATION
Roof			
1	Blocking between ceiling joists or rafters to top plate	4-8d box (2 ¹ / ₂ " × 0.113") or 3-8d common (2 ¹ / ₂ " × 0.131"); or 3-10d box (3" × 0.128"); or 3-3" × 0.131" nails	Toe nail

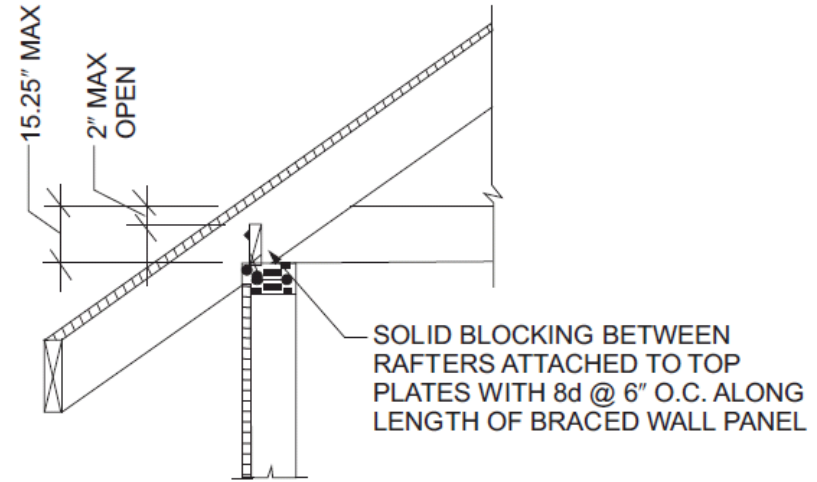
Building Code Requirements - IRC

- For Seismic Design Categories A, B, and C:
 - Braced Wall to Roof Truss Distance $9\frac{1}{4}$ " or less
 - Blocking is not required



Building Code Requirements - IRC

- For Seismic Design Categories A, B, and C:
 - Braced Wall to Roof Truss Distance between $9\frac{1}{4}$ " and $15\frac{1}{4}$ "
 - Blocking according to Figure R602.10.8.2(1) is required.

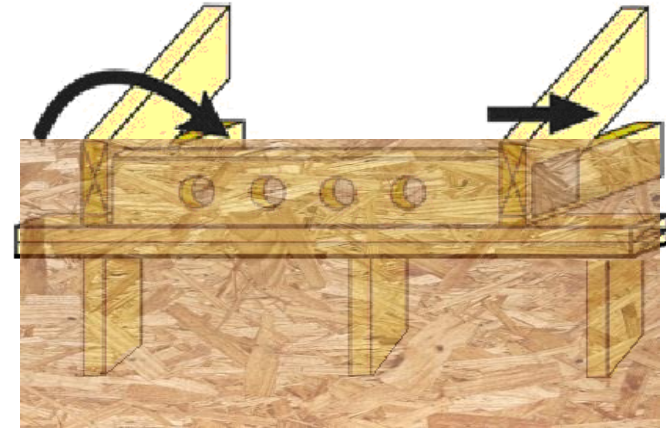


For SI: 1 inch = 25.4 mm.

FIGURE R602.10.8.2(1)
BRACED WALL PANEL CONNECTION
TO PERPENDICULAR RAFTERS

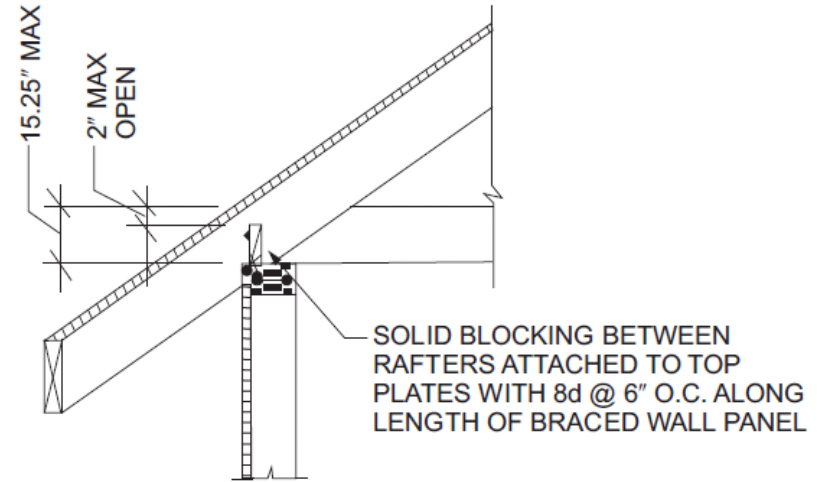
Building Code Requirements - IRC

- For Seismic Design Categories A, B, and C:
 - An exception allows wood structural panels to extend above the top plate where the outside edge of the truss aligns with the outside face of the wall .



Building Code Requirements - IRC

- For Seismic Design Categories D_0 , D_1
 - Braced Wall to Roof Truss Distance $15\frac{1}{4}$ " or less
 - Blocking according to Figure R602.10.8.2(1) is required.

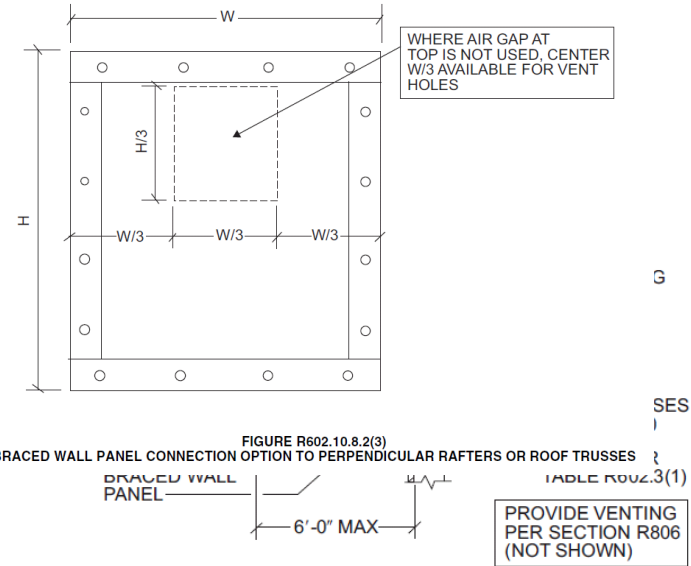


For SI: 1 inch = 25.4 mm.

FIGURE R602.10.8.2(1)
BRACED WALL PANEL CONNECTION
TO PERPENDICULAR RAFTERS

Building Code Requirements - IRC

- For all Seismic Design Categories:
 - Braced Wall to Roof Truss Distance greater than $15\frac{1}{4}$ "
 - Blocking according to Figure R602.10.8.2(2) or R602.10.8.2(3) is required



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

a. Methods of bracing shall be as described in Section R602.10.4.

FIGURE R602.10.8.2(2)
BRACED WALL PANEL CONNECTION OPTION TO PERPENDICULAR RAFTERS OR ROOF TRUSSES

Building Code Requirements - IRC

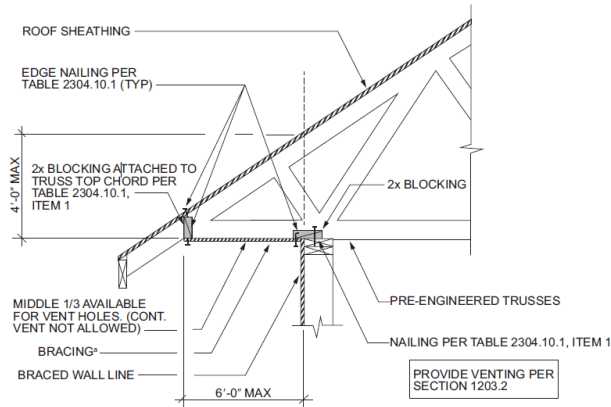
Seismic Design Category	Braced Wall to Roof Truss Distance			Engineered Design Allowed
	$\leq 9\frac{1}{4}"$	$> 9\frac{1}{4}"$ & $\leq 15\frac{1}{4}"$	$> 15\frac{1}{4}"$	
A, B, C	None	R602.10.8.2(1)	R602.10.8.2(2) or (3)	Yes
D ₀ , D ₁	R602.10.8.2(1)	R602.10.8.2(1)	R602.10.8.2(2) or (3)	Yes

Building Code Requirements - IBC

- For design of wood-frame diaphragms, the *IBC* directs one to AWC SDPWS (Section 2306.2).
- 2308.6.7 Connections of braced wall panels.
- 2308.6.7.2 Top plate connection.

Building Code Requirements - IBC

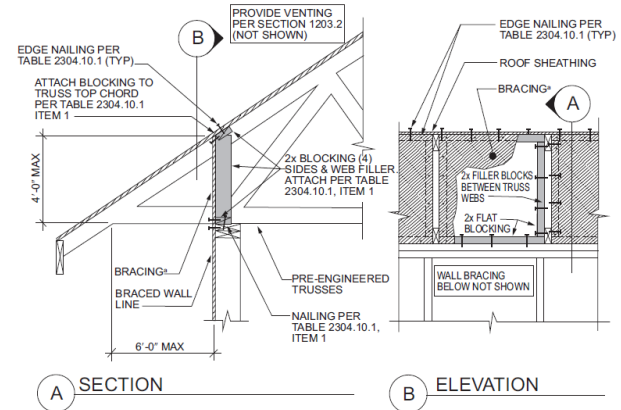
- For conventional light-frame construction the *IBC* includes different requirements than in the *IRC*



a. Methods of bracing shall be as described in Table 2308.6.3(1) DWB, WSP, SFB, GB, PBS, PCP or HPS.

For SI: 1 foot = 304.8 mm.

FIGURE 2308.6.7.2(1)
BRACED WALL LINE TOP PLATE CONNECTION



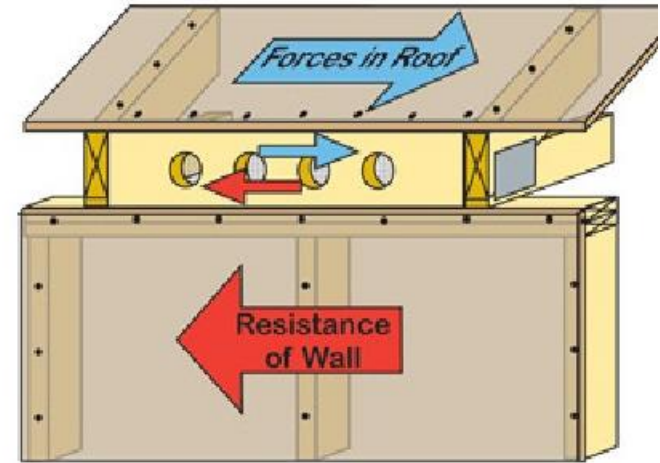
a. Methods of bracing shall be as described in Table 2308.6.3(1) DWB, WSP, SFB, GB, PBS, PCP or HPS.

For SI: 1 foot = 304.8 mm.

FIGURE 2308.6.7.2(2)
BRACED WALL PANEL TOP PLATE CONNECTION

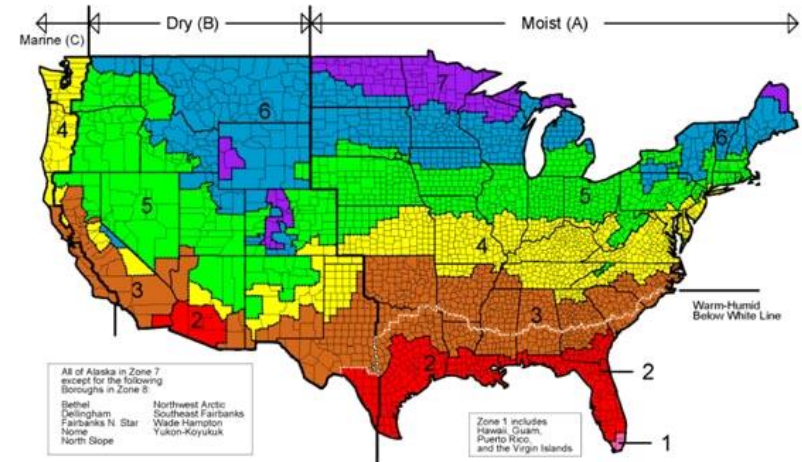
Engineered Design – Bird Blocking

- Bird blocking is another method of transferring lateral loads from the roof diaphragm to the shear walls.
- The block is installed between roof truss heels at the top of the exterior wall to carry and transfer lateral forces from the roof diaphragm to the braced wall.
- Blocks with ventilation holes typically have wire mesh on one side to prevent animals from entering the attic space.



Engineered Design – Bird Blocking Example

- Note that *IRC* energy/ventilation requirements in [IRC R806.2](#) and [R806.3](#) need to be met.
- Attics or roofs can be designed and constructed to be either vented or un-vented in any hygro-thermal zone
- The choice of venting or not venting is a design and construction choice and not a requirement determined by the physics or by the building codes.

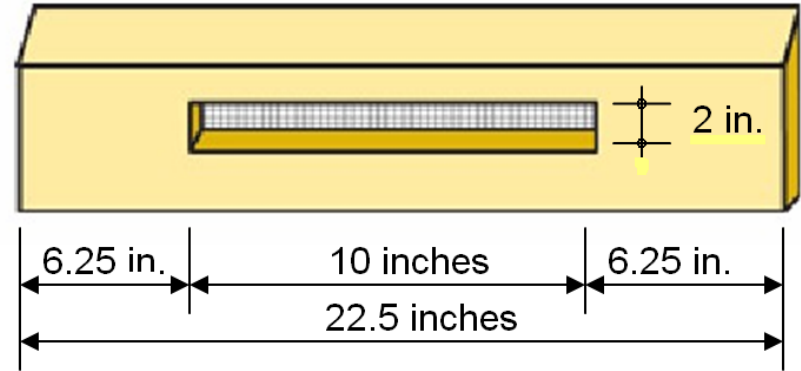


Engineered Design – Bird Blocking

- Even a block with holes or slots cut into it can provide significant capacity for resisting these loads
- The capacity of a bird block depends on:
 - The adjusted shear design value parallel to grain (horizontal shear) of the lumber
 - The amount of material removed to create the ventilation holes

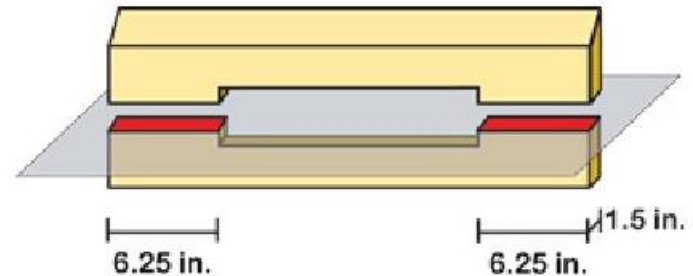
Engineered Design – Bird Blocking Example

- Given:
 - The truss manufacturer uses 2"x6" beveled blocks with a 2x10 letterbox type ventilation hole as shown



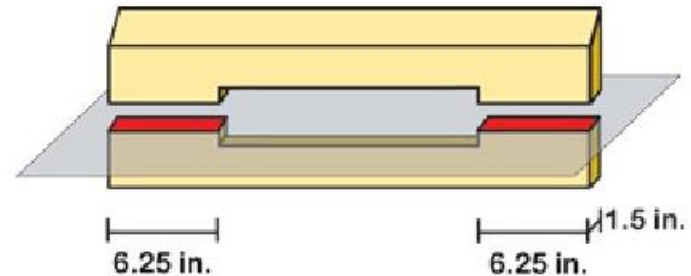
Engineered Design – Bird Blocking Example

- Imagine a horizontal plane cutting through the block at the location with the least material.
- In this case it's a total of 18.75 sq. in.



Engineered Design – Bird Blocking Example

- This is the area of block left to resist the shear forces being transferred from the roof diaphragm to the wall below.
- To be conservative, we will use a value of $F_v = 110$ psi which is for “Northern Species”



Engineered Design – Bird Blocking Example

- The only adjustment factor to consider is load duration factor (Table 2.3.2 of the *NDS*).
- We will use 1.6, since these forces are either caused by wind or seismic events.

Table 2.3.2 Frequently Used Load Duration Factors, C_D ¹

Load Duration	C_D	Typical Design Loads
Permanent	0.9	Dead Load
Ten years	1.0	Occupancy Live Load
Two months	1.15	Snow Load
Seven days	1.25	Construction Load
Ten minutes	1.6	Wind/Earthquake Load
Impact ²	2.0	Impact Load

1. Load duration factors shall not apply to modulus of elasticity, E , nor to compression perpendicular to grain design values, $F_{c\perp}$, based on a deformation limit.
2. Load duration factors greater than 1.6 shall not apply to structural members pressure-treated with water-borne preservatives (see Reference 30), or fire retardant chemicals. The impact load duration factor shall not apply to connections.

Engineered Design – Bird Blocking Example

- Shear Capacity of the block = $F_v' \times \text{Area}$

$$= 110 \text{ psi} * 1.6 * 18.75 \text{ sq. in.} = 3300 \text{ lb}$$

- A 22.5" block with 3300 lb of shear capacity would have the following shear load in pounds per linear foot (plf)

$$3300 \text{ lbs} / (22.5 \text{ in} * \frac{1 \text{ ft}}{12 \text{ in}}) = 1760 \text{ plf}$$

Engineered Design – Bird Blocking Example

- According to the APA’s *Introduction to Lateral Design*, the highest recommended load listed is 820 plf for roof diaphragms and 870 plf for shear walls.
- Therefore, even a low grade “bird block” with a large horizontal ventilation opening is adequate, provided the building designer properly details the roof-to-block and the block-to-wall connections.

SHEAR WALLS: RECOMMENDED SHEAR (POUNDS PER FOOT) FOR APA PANEL SHEAR WALLS WITH FRAMING OF DOUGLAS-FIR, LARCH, OR SOUTHERN PINE^(a) FOR WIND OR SEISMIC LOADING^(b)

Panel Grade	Minimum Nominal Panel Thickness (in.)	Minimum Nail Penetration in Framing ^(b) (in.)	Nail Size (common or galvanized box)	Panels Applied Direct to Framing				Panels Applied Over 1/2" or 5/8" Gypsum Sheathing				
				Nail Spacing at Panel Edges (in.)				Nail Size (common or galvanized box)	Nail Spacing at Panel Edges (in.)			
				6	4	3	2 ^(e)		6	4	3	2 ^(e)
APA STRUCTURAL I grades	5/16	1-1/4	6d	200	300	390	510	8d	200	300	390	510
	3/8			230 ^(d)	360 ^(d)	460 ^(d)	610 ^(d)					
	7/16	1-1/2	8d	255 ^(d)	395 ^(d)	505 ^(d)	670 ^(d)	10d ^(f)	280	430	550	730
	15/32			280	430	550	730					
	15/32	1-5/8	10d ^(f)	340	510	665	870	—	—	—	—	—
APA RATED SHEATHING; APA RATED SIDING ^(e) and other APA grades except species Group 5	5/16 or 1/4 ^(c)	1-1/4	6d	180	270	350	450	8d	180	270	350	450
	3/8			200	300	390	510		200	300	390	510
	3/8			220 ^(d)	320 ^(d)	410 ^(d)	530 ^(d)					
	7/16	1-1/2	8d	240 ^(d)	350 ^(d)	450 ^(d)	585 ^(d)	10d ^(f)	260	380	490	640
	15/32			260	380	490	640					
APA RATED SIDING 303 ^(e) and other APA grades except species Group 5	15/32	1-5/8	10d ^(f)	310	460	600	770	—	—	—	—	—
	19/32			340	510	665	870	—	—	—	—	—
APA RATED SIDING 303 ^(e) and other APA grades except species Group 5			Nail Size (galvanized casing)	Nail Spacing at Panel Edges (in.)				Nail Size (galvanized casing)	Nail Spacing at Panel Edges (in.)			
	5/16 ^(c)	1-1/4	6d	140	210	275	360	8d	140	210	275	360
	3/8	1-1/2	8d	160	240	310	410	10d ^(f)	160	240	310	410

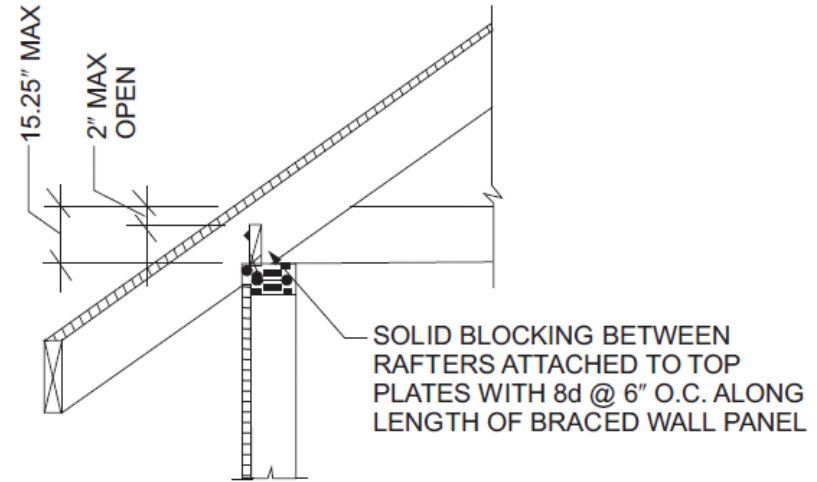
Engineered Design – Bird Blocking Example

- Bird blocks can also be designed with holes instead of a slot.
- The effective area is given by:
 - $Area = (L * B) - (n * d * B)$
where:
 - L = Length of block
 - B = Breadth of the block
 - d = Diameter of the hole
 - n = Number of holes
- Higher effective area = higher shear transfer capacity



Engineered Design – Partial Height Blocking

- Partial Height blocking is illustrated in the IRC.
- In some cases it may be used to leave room for insulation baffles.
- Per [IRC R806.3](#), a minimum of 1" space must be provided between insulation and the roof sheathing at the location of the vent.

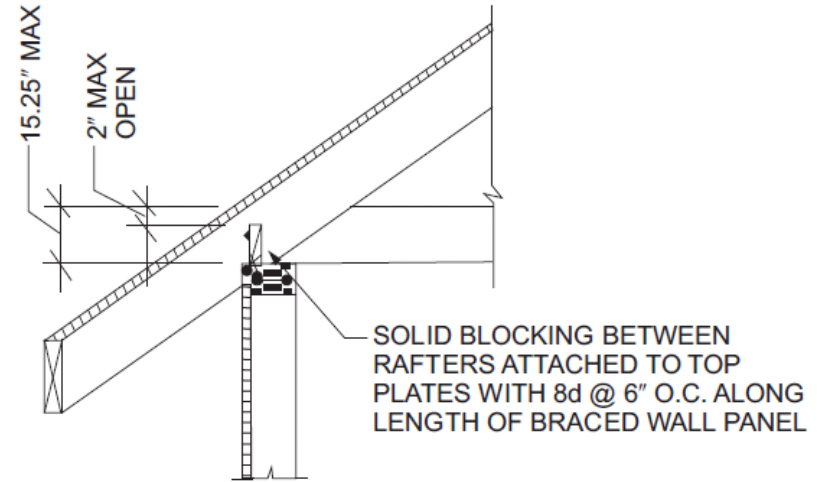


For SI: 1 inch = 25.4 mm.

FIGURE R602.10.8.2(1)
BRACED WALL PANEL CONNECTION
TO PERPENDICULAR RAFTERS

Engineered Design – Partial Height Blocking

- The use of Partial Height Blocking relies on both weak-axis bending and cross-grain bending of the top chord member of trusses to transfer lateral forces from the roof diaphragm to the wall below.
- Section 3.8.2 of the NDS recommends avoiding “designs that induce stress perpendicular to grain”.

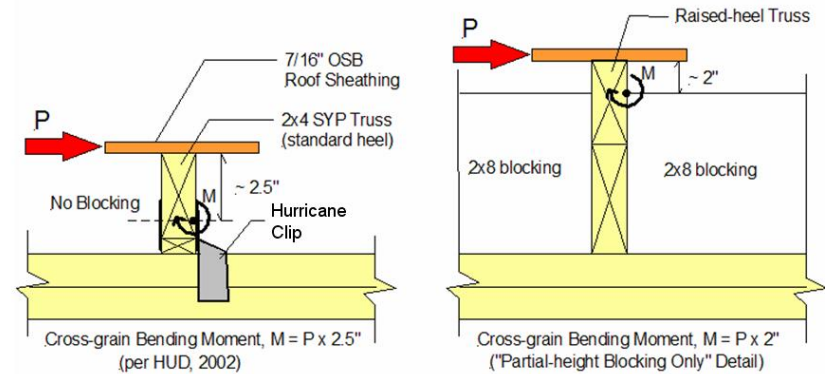


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FIGURE R602.10.8.2(1)
BRACED WALL PANEL CONNECTION
TO PERPENDICULAR RAFTERS

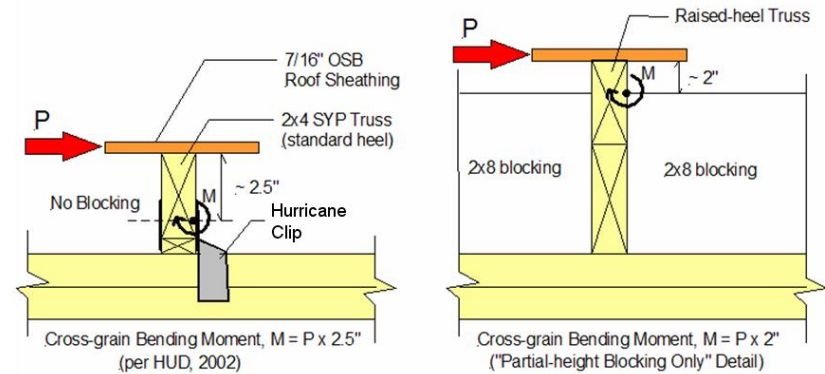
Engineered Design – Partial Height Blocking

- HUD tested lateral force transfer from roof diaphragm system to braced walls.
- The absence of failure of the top chord due to cross-grain bending indicated yielding and ductile overall response.
- The tests used no blocking, and are therefore conservative compared with a raised-heel truss with Partial Height Blocking.



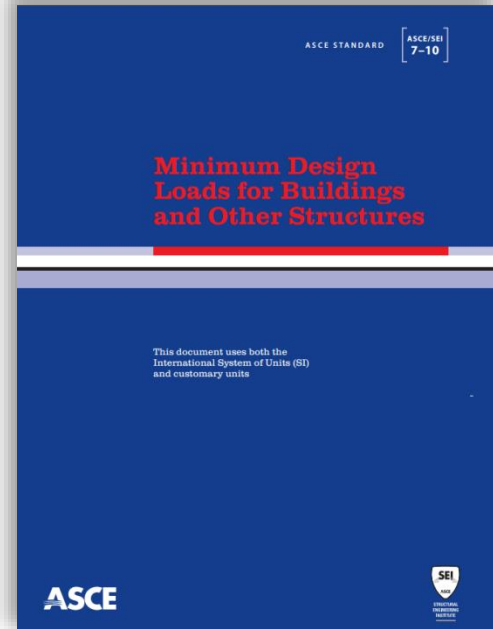
Engineered Design – Partial Height Blocking

- Testing yielded a maximum lateral force transfer of about 570 lb/truss.
- Applying a safety factor of 2.5 results in a design value of 228 lb/truss for in-plane shear transfer for the “Partial Height Blocking only” detail.
- With trusses spaced 24” o.c., the design unit shear in the roof diaphragm will be 114 plf.



Engineered Design – Partial Height Blocking

- A span limit for roof diaphragm systems with partial-height blocking only can be determined per *IBC* Simplified Method / ASCE 7-10 Section 12.14 Simplified Method



Engineered Design – Partial Height Blocking

- Take the following equation and substitute to solve for Roof Span:

$$V = 1.2 \left(\frac{S_{DS}}{R} \right) * W * \frac{1}{1.4} * \Omega_o$$

where:

- V = shear force per unit length at the roof diaphragm connection to the wall
- W = $\frac{1}{2}$ x (Roof Span) x (1-ft unit length along wall) x (D_r of 15 psf dead load of roof-ceiling assembly) = D_r x (Roof Span)
- R = seismic response modifier = 6.5
- Ω_o = over-strength factor = 3.0
- $S_{DS} = 1.17$, Assume $S_s = 1.25$, Soil Site F= 1.4 , $S_{DS} = 2/3 * F_a * S_s$
- $1/1.4$ = factor to convert from strength design force to ASD design force level.

Engineered Design – Partial Height Blocking

- Given a design unit shear, V , of 114 plf, the span limit will be:

$$\text{Roof Span} = \frac{2 * 1.4 * V * R}{[(1.2 * S_{DS} * D_r) * \Omega_0]}$$

$$\text{Roof Span} = \frac{2 * 1.4 * 114 \text{ plf} * 6.5}{[(1.2 * 1.17 * 15 \text{ psf}) * 3]} = \mathbf{33 \text{ ft}}$$

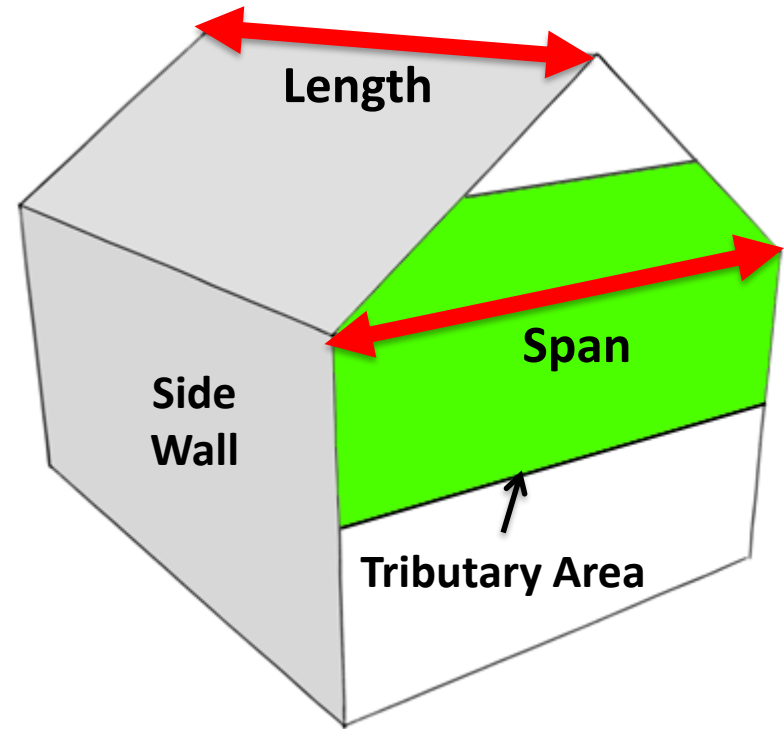
- Thus, for the stated design conditions, the “partial-height blocking only” detail provides adequate seismic shear force transfer for roof clear spans up to 33 feet.

Engineered Design – Partial Height Blocking

- A similar equation can be developed for transfer of shear forces due to wind acting on the gable end of a roof.
 - Analysis indicates that for a 120 mph Exposure B condition, the roof span should be limited to **28 feet** for 12:12 gable roof pitch or **52 feet** for a 6:12 gable roof pitch or less
 - For gable roof pitches in between 12:12 and 6:12, the roof span limit can be scaled by interpolation (e.g., span limit of 40 feet for 9:12 gable roof pitch).
- For hipped roofs, the span limits for wind should not control over seismic.

Engineered Design – Partial Height Blocking

- This analysis is based on ASCE 7-10 wind loads with the assumption that the length of the roof is at least equal to the span of the roof
- Gable end tributary area is equal to one-half the story height of 8 feet plus one-half the gable end area above the supporting end walls.

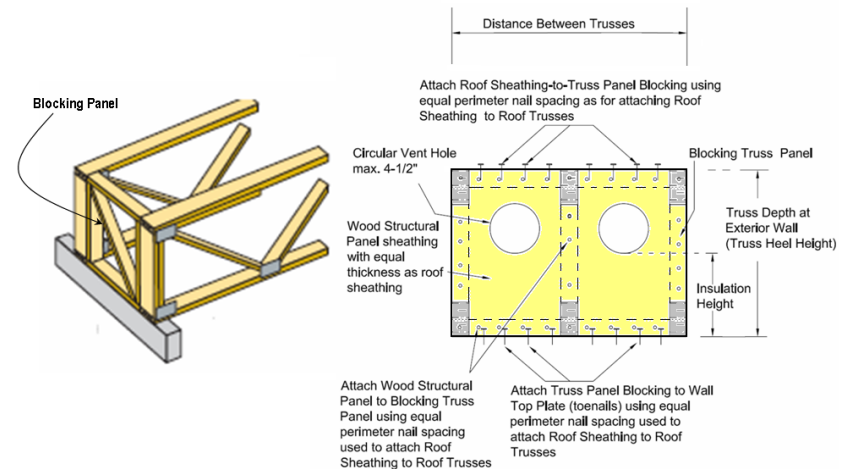


Engineered Design – Partial Height Blocking

- For special conditions requiring an even greater amount of force transfer than can be provided by the “partial-height blocking only” detail (114 plf) the following options should be considered:
 1. Provide additional full-height blocking in the eave overhang.
 2. Use approved proprietary connection hardware in place of or in addition to Partial Height Blocking.

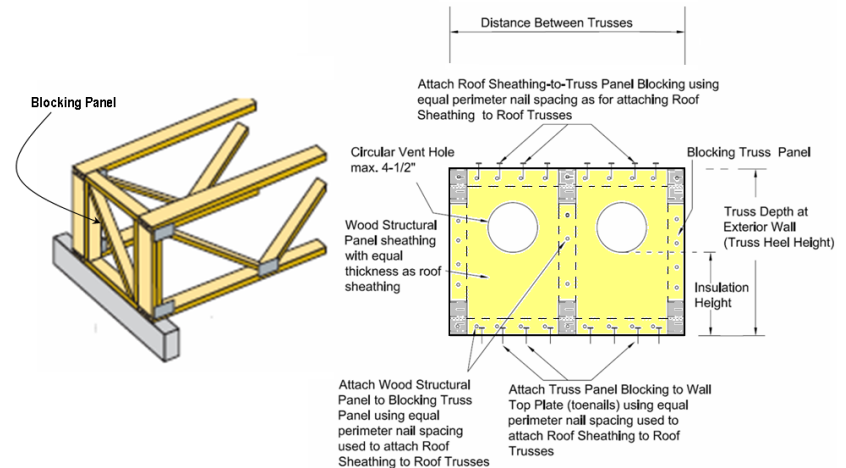
Engineered Design – Engineered Panel Blocking

- Another option Building Designers may specify for high heel or flat truss applications is a blocking panel.
- Truss manufacturers can provide these as long as they have enough information to complete the design (the shear load).



Engineered Design – Engineered Panel Blocking

- Benefits of panel blocking:
 - Lateral loads are easily resisted
 - Structural component that has solid design values
 - The component manufacturer can reuse material that might otherwise go to waste



Conclusion

- A heel block or “bird block” with a large horizontal ventilation opening can more than suffice as perimeter blocking, provided the building designer properly details the roof-to-block and the block-to-wall connections.
- Partial Height Blocking can be used as long as it is able to achieve sufficient shear transfer.
 - If insufficient, either full height blocking at the wall or full height blocking in the eave overhang should be considered.
 - Alternatively, approved proprietary connection hardware in place of or in addition to Partial Height Blocking should be used.
- The Building Designer must be aware that the lateral load capacity will also be limited by the capacity of the roof sheathing (diaphragm).
- Lateral load capacity of the roof sheathing will be reduced due to insufficient perimeter nailing caused by the absence of blocking as a nailing surface.

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