Is Roof Eave Blocking Required To Transmit Wind/Seismic Forces?

By Felix Martin, S.E.

Blocking between wood rafters or trusses at roof eaves (commonly known as eave blocking) has been standard framing practice in residential construction, particularly at open eaves. Blocking typically consists of nominal 2-inch wide material, normally of a depth matching the height from the bottom of the roof sheathing to the top plate of the wall.

The installation of edge blocking serves several purposes. The blocking enclosed the attic space, preventing birds and vermin from entering, and it was a means to assure accurate dimensional spacing between the rafters or roof trusses. It also provided a load path from the roof diaphragm to the exterior walls to transfer wind or seismic forces. However, as fire requirements and aesthetic considerations have resulted in the increased use of enclosed eaves, the installation of eave blocking has been abandoned in many places.

Whether or not the installation of eave blocking is required depends on a number of factors. These may be prescriptive, required by building code statute; or, as an integral part of the lateral load-resisting system, a means to maintain a complete load path from the roof diaphragm to the shear walls. A need exists to clarify all requirements and establish a reasonable basis for determining when eave blocking is required and when it may not be.

Building Code Requirements

The *International Residential Code* (IRC) did not specifically require eave blocking under the 2006 edition. Some conditions are provided in the 2009 IRC under which eave Section R602.10.6.2 requires blocking for lateral support against rotation, but only at top plate sections above braced wall panels. Low wind/seismic regions require partial height (to allow attic venting per R806) eave blocking, but only at rafter/truss heel heights above 9.25 inches. High wind/seismic regions require eave blocking per Figures R602.10.6.2(1), R602.10.6.2(2) or R602.10.6.2(3) for all heel heights.

That the required blocking is only partial height for attic ventilation seems unnecessary in that the blocking is only required over braced wall panels and not elsewhere along the wall line. IRC Figures R602.10.6.2(1), R602.10.6.2(2) and R602.10.6.2(3) do not provide a load path, and serve solely to prevent rotation of the rafter/truss. The IRC therefore does not require the use of eave blocking for the transfer of wind or seismic forces.

Similarly, the 2009 *International Building Code* (IBC) under *Conventional Light-Frame Construction* Section 2308.10.6 requires the use of blocking per Section 2308.8.5, which uses heel height limits to require lateral support against rotation of the roof framing. The heel depth-to-thickness ratio for roof framing is held to a maximum unblocked ratio of 5:1. This requirement again exists only to resist rotation of the roof framing and does not address the transfer of wind or seismic forces.

The 2006 IBC's *General Design Requirements for Lateral Force Resisting Systems* section prescribed the use of "boundary members" to transmit tension and compression forces (Section 2305.1.2). This was generally taken by engineers to indicate a requirement for eave blocking. Since wind/seismic chord forces are typically resisted by the wall top plates, an obvious load path would be from the roof diaphragm to the top plates through the eave blocking. Under that configuration, eave blocking meets the IBC requirement for boundary members to transmit tension and compression forces.

However, the 2009 IBC deleted Section 2305.1.2 and under newly revised Section 2306.2.1 (*Wood Structural Panel diaphragms*) defaults the design and construction of horizontal wood diaphragms to as in accordance with the American Forest & Paper Association's *Special Design Provisions for Wind and Seismic*.

AF&PA's 2005 *Special Design Provisions for Wind and Seismic* Section 4.2.6 (Construction Requirements) requires diaphragm "boundary elements" to transmit tension, compression and shear forces, but does not specifically require those to be eave blocking. In the design to resist chord tension and compression forces, the boundary members are normally assumed to be the wall double top plates.

Eave blocking can transfer forces to the top plates, but that transfer may instead be arguably accomplished without it, using metal connectors attaching the rafter/truss to the top plate. The load path would then be from the wood diaphragm to the connector through the roof rafter/truss,

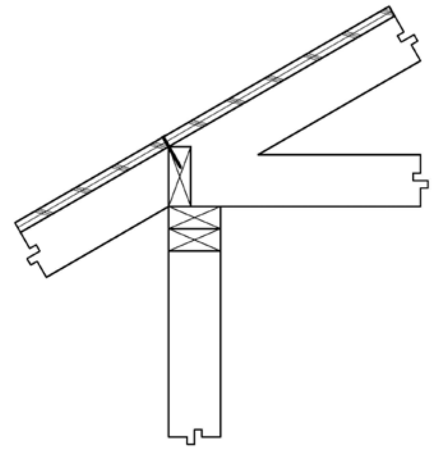

Figure 1a: Wood Framed Eave with Eave Blocking.

and from the connector to the wall top plates. This load path will be further discussed in the following sections.

Analysis Requirements

Diaphragm

Figure 1a shows a standard roof framing detail for a wood framed eave, with eave blocking. *Figure 1b* shows the same detail, without the eave blocking but substituting standard connection hardware.

Figure 1c shows again the same detail, without the eave blocking, at a masonry wall condition with standard connection hardware.

In considering the need to transfer wind/seismic forces at roof eaves, two issues need to be addressed. First would be the resolution of resistant forces parallel to the direction of applied wind/seismic forces (the reaction shear forces). Second would be the resolution of resistant forces perpendicular to the direction of applied wind/seismic forces (the chord forces).

The reactive shear forces resisting wind/seismic forces for a flexible, unblocked diaphragm are typically determined from a tributary span length and a tributary wind/seismic load. *Table 1* tabulates reactive shear values for different combinations of wind/seismic loadings (w) and different diaphragm length-to-depth ratios (L/d). Because we are only considering the analysis of eaves perpendicular to the roof framing and the roof trusses are assumed to span across the shorter dimension, the wind/seismic forces would act across the short direction of the diaphragm and we would only investigate the reactive shear forces from wind/seismic forces perpendicular to the roof framing (IBC Table 2306.3.1, Case 3 unblocked diaphragm).

The results show the reactive shear forces fall within most popular sheathing

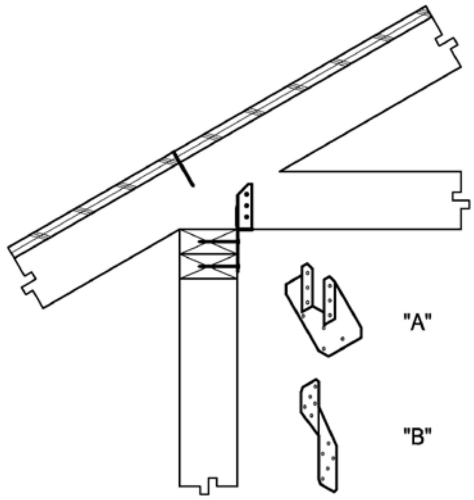

Figure 1b: Wood Framed Eave, No Eave Blocking.

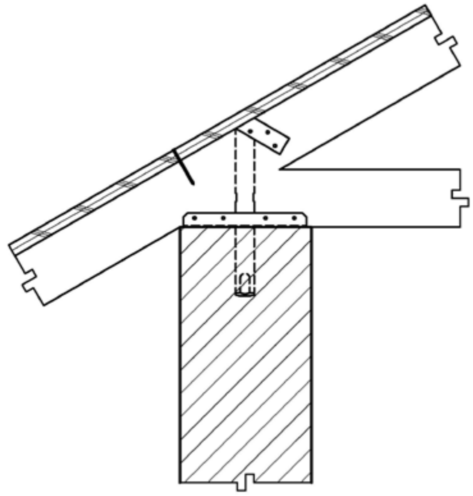

Figure 1c: Masonry Wall Wood Framed Eave, No Eave Blocking.

thickness/nail size combinations for unblocked diaphragms. Diaphragm shear capacity would thus not seem to be a concern in eliminating eave blocking when considering reactive shear forces.

Chord forces for flexible, unblocked diaphragms are typically calculated as simple span moments between diaphragm supports, divided by the depth of the diaphragm. *Table 2* tabulates chord forces for different combinations of wind/seismic loadings (w) and different diaphragm length-to-depth ratios (L/d), divided by the length of the diaphragm. Again considering chord forces perpendicular to framing but due this time to wind/seismic forces parallel to framing, we look at chord flow forces along the diaphragm edge corresponding to an IBC Table 2306.3.1, Case 3 loading.

The tabulated results show that the chord flow shear forces fall within most popular sheathing thickness/nailing combinations for unblocked diaphragms. In considering chord forces at diaphragms without eave blocking, diaphragm shear capacity does not appear to be a concern.

Mechanical Connectors

Typical roof wood rafter/truss to wood wall construction uses metal connectors such as those shown in *Figure 1b*, while typical roof wood rafter/truss to masonry wall construction uses connectors such as the one shown in *Figure 1c*. Available from a number of manufacturers, these connectors have load capacities (depending on the model used) of up to several hundred pounds per connector.

The values tabulated in either *Table 1* or *Table 2* compare well with the allowable loads for these metal connectors. Provided the proper connector is selected and standard spacings used, shear force demands from the diaphragm to the exterior walls can be met. These connectors would thus meet the IBC Section 2305.1.2 requirement for the use of "boundary members" to transmit tension and compression forces.

However, where eave blocking is not used, the rafter/truss would receive the wind/seismic load from the diaphragm at the top of the rafter/truss and transfer it to the wall top plates at the base of the rafter/truss. This creates a rotational moment across the rafter/truss. Disregarding that this rotational moment induces cross-grain bending on the rafter/truss, in order for the wind/seismic load to successfully transfer into the top plates there needs to be a free-body resolution of the rotational moment.

The moment may be resisted by the metal connectors tying the rafter/truss to the top plates. In the case of connector "A" shown in *Figure 1b*, nailed flanges on either side of the rafter/truss may develop a resistive couple. Similarly, a connector "B" could be installed each side of the rafter/truss to resist the rotational couple. However, the rated load values for these connectors were developed through testing that restrained the wood members from rotation. The rated load values represent capacities for straight shear transfer, and do not assume a combination of shear and rotational loads. Manufacturers typically include catalogue warnings that the connectors are not intended to prevent cross grain bending.

Engineers could bypass the manufacturer's warnings and apply engineering design concepts to analyze the connector. Such a study should include a complete free-body analysis and a unity equation check. Those intending to install "B" connectors should also consider manufacturers' recommendation to use a minimum 2½-inch thick rafter/truss when installing "B" connectors opposite each other.

In order to use mechanical connectors to replace edge blocking as the load path transfer elements, a disregard of cross-grain bending across the rafter/truss is necessary. In addition, an engineering analysis of the connector, including a free-body analysis and a unity equation check, would be required before determining the adequacy of the connection.

Empirical Test Data

The U.S. Department of Housing and Urban Development (HUD) sponsored tests on roof truss to wall connections and reported the results in 2004. The tests involved four different attachment configurations, none using eave blocking. Two of the configurations used toe nails as the sole means of attachment.

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Table 1: Reactive Shear Forces.

	Shear Flow (plf)				
L/d w (plf)	0.25	0.33	0.50	0.67	1.00
100	13	17	25	34	50
150	19	3	38	50	75
200	25	33	50	67	100
250	31	41	63	84	125
300	38	50	75	101	150

Table 2: Chord Forces.

	Chord Flow (plf)				
L/d w (plf)	4.00	3.00	2.00	1.50	1.00
100	50	38	25	19	13
150	75	56	38	28	19
200	100	75	50	38	25
250	125	94	63	47	31
300	150	113	75	56	38
350	175	131	88	66	44

The third configuration used a combination of twenty-two toe nails and nine metal connectors. The fourth configuration used only four toe nails and nine metal connectors. The metal connectors were installed on only one side of the truss.

Test results showed a noticeable difference between toe-nail failure and metal connector failure modes. Toe-nail failure was defined by lower load capacities, splitting of the wood and lateral sliding of the truss along the top plate, with little out-of-plane truss rotation. Metal connector failures occurred at higher load capacities. In some cases the truss rotated out-of-plane, resulting in truss plate separations. In others, the connectors failed, either by failing in tension or by excessive deformation due to localized buckling of the connector.

Metal connectors are typically load-rated based on joint slip limits, rather than on failure load capacity. The HUD tests were based on failure load capacity and as such reports excessively high failure-load-to-rated-load safety factors. One of recommendations in the report is the abandonment of metal connectors' allowable loads based on joint slip limits because of the higher loads made possible by failure load analysis. However, in the configurations tested, load failure occurred at deformations of over an inch, excessive by any measure and surely a condition that would benefit from the installation of eave blocking.

Conclusions

Roof eave blocking is not prescriptively required by either the IRC or the IBC to transfer wind/seismic forces. Eave blocking is only code-required to resist lateral rotation of the rafter/truss assemblies when prescribed height-to-width heel ratios are exceeded.

Wood roof diaphragms do not appear able to develop large enough shear or chord forces in standard configurations to require the installation of eave blocking. Similarly, metal truss connector load capacities appear sufficient to not require the additional installation of eave blocking to resist standard configuration shear or chord forces. However, the use of only truss connectors in lieu of eave blocking requires a disregard of cross-grain bending across the rafter/truss assembly, and should include a complete free-body analysis and a unity equation check.

Although the splitting failure of toe-nailed connections indicated safety factors for toe nails may not be low enough to use without eave blocking, test data seems to indicate that the omission of eave blocking is possible in some low-load, low heel-height conditions. Toe nail shear capacities are so low, cross-grain bending in low-heel conditions does not appear to have an opportunity to develop as a concern. In other words, for low heel-height load cases requiring only toe-nailing, cross-bending concerns could be disregarded. With some limits, low-load conditions might be possible without eave blocking.

However, at higher loads and particularly as the heel height increases, cross-grain bending should not be ignored. Test results indicate the use of connector hardware greatly increases the load capacity over that of just toe-nailed assemblies. This increased load capacity, however, also brings about a rise in the incidence of cross-grain rotational failure. For gang-nailed roof trusses, that rotational failure may take place through truss plate separation.

Where demand loads are sufficiently large to require the installation of metal connector hardware, in assemblies without eave blocking cross-grain bending becomes the primary failure mechanism. Higher loads and higher heel heights may also result in assembly deformations too excessive to be acceptable, and well beyond the joint slip limits of the metal hardware. In designing higher-load assemblies (such as those in high wind and earthquake zones), the decision to omit eave blocking should be considered thoroughly and carefully.▪

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References

International Code Council, 2009, *International Residential Code*, Country Club Hills, IL.

International Code Council, 2009, *International Building Code*, Country Club Hills, IL.

Crandell, J., Rice, R., Foley, B, and Woeste, F., Spring 2009, "When is Roof Eave Blocking Required?", *Wood Design Focus*, Forest Products Society, Vol. 19, No. 1, pp. 10:12.

U.S. Department of Housing and Urban Development, Office of Policy Development and Research, by NAHB Research Center, February 2002, *Roof Framing Connections in Residential Construction*, Washington, DC.

Yaxley, Wilbur T., December 2004, "Forensic Engineering Analysis & Testing of Wood Truss/Wall Connections", *Journal of the National Academy of Forensic Engineers*, National Academy of Forensic Engineers, Vol. XXI, No. 2, pp. 7:18.

Simpson Strong-Tie Company, 2009-2010, *Wood Construction Connectors*, Pleasanton, CA.