PART II ENGINEERED BASIS OF RIDGE AND EAVE VENT DETAILS

A - INTRODUCTION

This report addresses engineered design for unblocked wood structural panel (plywood or OSB) roof diaphragms with either continuous or intermittent openings for ridge vents and with intermittent openings for eave vents. The objective of this report is to present rational design approaches to accommodating ridge and eave vents. This report is intended for use by engineers for design of diaphragms with ridge and eave vent openings, and by plan reviewers for checking of designs with ridge and eave vent openings.

Design provisions for engineered unblocked diaphragms are found in International Building Code[1] (IBC) Sections 2305.2 and 2306.3, and ASD shear values in Table 2306.3.1. IBC provisions apply to fully sheathed roof diaphragms, with wood structural panel sheets spaced at approximately 1/8-inch clear to prevent buckling with moisture variation. Examples of diaphragm design can be found in publications including APA's *Diaphragms and Shear Walls Design/Construction Guide*[2] and *Design of Wood Structures*[3]. It is common for engineers to design diaphragms to accommodate openings for a variety of purposes, including skylights and ventilation. Design to accommodate a ridge vent is just one specific application of design for diaphragm openings.

Engineered design for openings is commonly based on calculations using "principles of mechanics," as permitted by IBC Section 2305.1.1. To date testing of roof diaphragms has not provided alternate tools for evaluating diaphragm openings. Using "principles of mechanics," the engineer develops a rational analysis model with which strength and deflection can be evaluated. The following discussion will address strength and defection considerations, additional considerations, limitations, and available resources. Example calculations are provided in accordance with the provisions of the 2003 IBC and 2001 *National Design Specification for Wood Construction*[4] (NDS) in Part III of this report.

B - STRENGTH CONSIDERATIONS

Design of a roof diaphragm in accordance with the IBC requires design for wind and earthquake loading in two perpendicular horizontal directions. Similarly loading in both directions must be addressed in design for ridge and eave vent openings. Figures 1 and 2 provide diagrams of roof diaphragms with ridge vents. Roof diaphragms, however are seldom as simple as those illustrated in Figures 1 and 2. Figure 3 shows what might be a more realistic configuration.

Application of a rational "mechanics of materials" approach requires that the discontinuity in strength caused by the ridge vent opening be addressed. Analysis models first determine forces that would occur if the opening did not exist. Next, unit stresses are adjusted to account for the opening. Finally a load path is created to transfer the forces around or across the opening. In this final step it is necessary to either determine unit shears at the opening boundary and provide a load path for the unit shears, or provide detailing to develop the allowable ASD unit shear. The latter approach is recommended when practical, however both are acceptable.

At most diaphragm openings, neither the sheathing nor framing continues across the opening. As a result, boundary chords and collectors must be provided at each side of the opening, as shown in Figure 4. An example of design for this type of opening can be found in APA Research Report 138[5]. The continuous ridge vent is a special case because the framing members are continued across the opening. With the framing continuous, the unit shears along the long continuous side of the opening are transferred into the framing members (rafters or trusses) at one side of the opening, across the roof ridge, and back into the diaphragm at the other side of the opening, as shown in Figure 5. The following details illustrate approaches to transferring shear forces across the ridge.

Detail 1A. Continuous ridge board or ridge beam and solid-sawn rafters – Toenail.
An ASD shear force equal to the unit shear times the rafter member spacing is assumed to be in the rafter due to sheathing nailing. The rafter force is transferred through toenails to the ridge board or beam, and again transferred through toenails to the rafter on the far side, and into the diaphragm. Toenails for each rafter to ridge member connection are shown in Table 1. The toenails are calculated to transfer diaphragm forces only; Connection for vertical gravity forces must be provided in addition. Although blocking between rafters at the edge of the sheathing is strictly speaking not required for an unblocked diaphragm, some engineers believe that this is good practice and require blocking. Toenails must be installed per the NDS. Care must be taken to avoid splitting of framing at toenails. Toenails at split framing may not be counted towards the required number.

Detail 1B. Low ridge beam and solid-sawn rafters - Toenail.
Detail 1B shows an alternate to Detail 1A with the ridge beam low. Detail 1B shows a continuous 2x ridge board member at the rafter level rather than blocking between rafters. This is because it would be very difficult to install adequate toenailing of the rafter to blocking. See also Detail 2B. Toenails must be installed per the NDS. Care must be taken to avoid splitting of framing at toenails. Toenails at split framing may not be counted towards the required number.

Detail 1C. Continuous ridge beam or ridge board and solid-sawn rafters - Blocking.

Detail 1C shows an alternate to Detail 1A with face nailed blocking substituted for toenails. This detail should be used where there is concern regarding adequate installation of toenails. It is important that the blocking between joists be located near the joist top and have a tight fit against the joist hanger at each end.

An ASD shear force equal to the unit shear times the rafter member spacing is assumed to be in the rafter due to sheathing nailing. The rafter force is transferred from the rafter to the blocking due to bearing. From the blocking the force is transferred to the ridge board or beam through face nailing. From the ridge board or beam the force is transferred to blocking and to the rafter on the far side, and finally back into the diaphragm.

Three 16 penny face nails, common, box or sinker, are adequate to transfer force between blocking and ridge member for the maximum unblocked diaphragm forces tabulated by the IBC.

Detail 2A. Continuous ridge board or ridge beam and solid-sawn rafters - Angle Clip.
An ASD shear force equal to the unit shear times the rafter member spacing is assumed to be in the rafter due to sheathing nailing. The rafter force is transferred through an angle clip to the ridge board or beam, and again transferred through an angle clip to the rafter on the far side, and into the diaphragm. Angle clips for each rafter to ridge member

connection are shown in Table 2. The angles are calculated to transfer diaphragm forces only; connection for vertical gravity forces must be provided in addition. Although blocking between rafters at the edge of the sheathing is strictly speaking not required for an unblocked diaphragm, some engineers believe that this is good practice and require blocking.

Detail 2B. Low ridge beam and solid-sawn rafters – Angle Clip.
Detail 2B shows an alternate to Detail 2A with the ridge beam low. Detail 2B shows blocking between rafters rather than a continuous 2x member because fastening of the rafter to blocking can be made with angle clips. The angle clips might be visible if this detail is used for an open-beam ceiling.

Where ridge blocking can be provided every other bay, transfer through the framing member is not required. For the level of load in unblocked diaphragms per the IBC tables, the shear capacity of the sheathing far exceeds the capacity of the nailing. As a result the diaphragm continuity across the ridge can be completed for alternate framing bays up to 24 inches wide. The number of roof sheathing fasteners for two bays are installed in the bays that are blocked, dropping the nail spacing from six inches to three inches as shown in the following details. This detail could be used for solid sawn framing as well as metal plate connected (prefabricated) trusses.

Detail 3. Roof trusses with ventilation provided every alternate bay.
Where metal plate roof trusses are to be used as shown in Detail 3, it is recommended that ridge blocking with edge nailing be provided in every alternate truss bay. Roof sheathing edge nailing at three inches on center is required at blocked bays. While this detail illustrates use with metal plate connected trusses, this approach can also be applied to solid sawn framing. Although blocking between rafters at the edge of the sheathing is strictly speaking not required for an unblocked diaphragm, some engineers believe that this is good practice and require blocking.

Where framing uses metal plate connected trusses and ridge blocking at alternate bays per Detail 3 cannot be provided, diaphragm shear is transmitted through the truss top chord, through the truss ridge plates, and into the top chord member on the other side. Truss Plate Institute design procedures[6] do not specifically address design for this type of force. Testing that has been conducted for out of plane wind on gable-end truss members[7] and for diaphragm capacity of manufactured home roofs[8] suggests that moderate forces can be transferred through the ridge plates. Because diaphragm force transfer across the ridge plate may be the weakest link in the diaphragm, and because loss of truss vertical load capacity could result from failure of the ridge plates, ridge blocking at alternate truss bays, per Detail 3 is recommended. Detail 4 is provided as an unblocked alternative that should only be considered when 1) diaphragm loads are very low, 2) the diaphragm configuration is simple enough that design forces can be considered reasonably representative, unlike the diaphragm in Figure 3, and 3) an appropriately large factor of safety is used. A factor of safety of not less than six is recommended to compensate for a number of factors including expected earthquake loads being larger than used for design, testing without reverse cyclic loading, testing used a plate on one face however matching plates on both faces are specified in Detail 4, testing was of a two-member connection where ridge connections usually have at least three members reducing the amount of connection into each member. Table 4A provides plate capacity information from testing conducted by Alpine Engineered Products, Inc.[7], and Table 4B provides suggested ASD capacities using a factor of safety of six and based on the 3x6 plate size tested by Alpine. Included in the Table 4B values is a density adjustment factor of 0.80 suggested by Alpine as an adjustment from the tested SPF average specific gravity of 0.48 to the NDS tabulated minimum density for SPF of 0.42. Because the metal connector plates are proprietary and vary with manufacturer, discussion of acceptable design loads with the truss manufacturer is suggested.

> **Detail 4. Roof trusses with ventilation provided every bay – Low Diaphragm Loads.**
> Where metal plate roof trusses are to be used as shown in Detail 4, it is recommended that ridge blocking be provided, even though not nailed to the sheathing. Use of Detail 4 is recommended only for very low load and simple diaphragms. It is suggested that the designer specify a minimum plate size of 3 x 6 inches (each face) for the ridge plate, matching the available testing. Although blocking between rafters at the edge of the sheathing is strictly speaking not required for an unblocked diaphragm, some engineers believe that this is good practice and require blocking.

The width of the sheathing opening for the roof ridge vent is extremely narrow (normally less than six inches). Where the vent runs continuous for the full length, there are no unit shears at the short side of the opening to provide a load path for. Where a vent is stopped short, there is a very small force due to the unit shear times the vent opening width, however the force is usually negligible, Although this force could be calculated and accommodated with additional sheathing fastening, it is not common for any special detailing to occur.

The fastening described in Details 1, 2 and 3 is intended to develop the tabulated ASD capacity of the diaphragm. This approach is recommended because 1) it is the simplest approach to providing adequate capacity, 2) with the complexity of most diaphragms (Figure 3) the load and load distribution could vary from the simplified analysis models, and 3) because seismic loads in excess of ASD design loads are anticipated to occur. Fastening to develop the diaphragm capacity will help keep the ridge connection from being the weakest link in the diaphragm. Where further refinement of the fastening is desirable, the engineer can calculate fastening, capable of transferring only the calculated design loads.

Ridge vents are most often used in combination with eave vents. Similar to the ridge, the eave is a location where diaphragm connection needs are in possible conflict with ventilation needs. The approach used in Detail 3, with blocking at alternate bays, is easily adapted for use at the eave. Detail 5 shows an eave condition where every alternate block is stopped below the top of framing to allow installation of a vent. While installation instructions may call for nailing of the sheathing through the vent to the blocking below in this bay (Detail 5b), the structural capacity of this nailing can not be verified, so structural nailing of the sheathing will be provided with increased nailing at full height blocks (Detail 5a). Similar to Detail 3, the sheathing nail spacing is reduced from six inches to three inches.

> **Detail 5. Eave with ventilation provided every alternate bay.**
> Where eave venting is needed, as shown in Detail 5, it is recommended that eave blocking with edge nailing be provided in every alternate roof framing bay. Roof sheathing edge nailing at three inches on center is required at blocked bays. This approach can also be applied to solid sawn framing and truss framing. Nailing required at the vented bays (Detail 5b) should not be used to reduce nailing in the blocked bays (Detail 5a).

C - Deflection Considerations

IBC Section 2305.2 limits diaphragm permissible deflection to that for which the diaphragm and any attached distributing or resisting element maintain structural integrity under design load conditions such that the resisting elements will continue to support design loads without danger to occupants of the structure. In addition to this diaphragm deflections are sometimes calculated to determine the type of force distribution to be used. Within the range of permitted loads for unblocked wood structural panel diaphragms, the width of opening required to accommodate a ridge vent will result in minimal change in calculated diaphragm deflection. If deflection of a diaphragm is close to being critical without the ridge opening, a rational estimate of the increase in deflection should be made. For normal use, the deflection implications of the opening can be ignored.

D - Additional Considerations

The following related items should be considered by the design engineer:

Rafter connection for vertical gravity loads. The connections provided in Tables 1 and 2 are calculated to transfer diaphragm forces only. Connection for vertical gravity forces must be provided in addition.

Vertical support of sheathing. Panel edge support is required for some combinations of roof sheathing and span. Where panel edge support is required, support of the wood structural panel sheathing edge at the ridge vent should also be given consideration. Because panel clips cannot be used at this location, lumber blocking is recommended. Alternately, the sheathing nominal thickness may be increased. See NDS Panel Supplement, Section 6.3.

High wind design. Increased nailing of wood structural panel roof sheathing is required for high wind loads. An example of this can be found in 1997 UBC Table 23-II-B-2. The additional nailing does not appear to affect the use of ridge vents.

Chord and collector continuity. Diaphragm chords and collectors must be provided for all diaphragms. Continuity of chords and collectors where ridge vent openings meet exterior walls should be given particular attention.

E - Limitations

The presented approaches are consistent with the standard of practice currently used in the Western US, and particularly in California. It is the responsibility of the engineer of record to determine whether these approaches are acceptable for a particular building and application. It is also the responsibility of the engineer of record to determine acceptability of the example calculation method and the tabulated values. This report addresses unblocked wood structural panel diaphragms designed in accordance with the provisions of IBC Sections 2305.2 and 2306.3, and limited to the ASD shear values for unblocked diaphragms provided in IBC Table 2306.3.1. ASD unit shears and connection capacities are used. Applicable duration of load factors are included. See example calculations for details.

Some applications of ridge vents require additional consideration. Included are roof configurations where the engineered design requires that the ridge member (ridge board, ridge beam, etc.) serve as a boundary member for the roof diaphragm, and where the ceiling finish is applied to the underside of roof rafters (cathedral ceiling) and ventilation of each rafter bay is required at both the ridge and eave. In these cases the engineer of record may determine that ridge vents are acceptable with additional detailing, or may decide that the ridge vent opening cannot be accommodated.

F - RESOURCES

[1]International Building Code (IBC), 2003 edition, International Code Council, Inc., Country Club Hills, Inc., 2002.
[2]Diaphragms and Shear Walls Design/Construction Guide (Form L350G), APA The Engineered Wood Association, Tacoma, WA, Revised 2001.
[3]Design of Wood Structures – ASD, 5th edition, Breyer, D, K. Fridley, D. Pollock Jr., and K. Cobeen, McGraw-Hill, New York, New York, 2003.
[4]National Design Specification for Wood Construction (NDS), 2001 edition, American Forest and Paper Association, Washington D.C., 2001.
[5]Research Report 138 Plywood Diaphragms, APA The Engineered Wood Association, Tacoma, WA, Revised 2000.
[6]National Design Standard for Metal Plate Connected Wood Truss Construction (ANSI/TPI 1-2002), Truss Plate Institute, Madison, WI, 2002.
[7]"Report of Joint Tests, Tooth Holding Out-of-Plane (Withdrawal) Tests," Alpine Engineered Products, Inc, Research & Development Department, January 29, 1993.
[8]Roof Diaphragms for Manufactured Homes (Research Report 146), APA The Engineered Wood Association, Tacoma, WA, Revised September 1993.

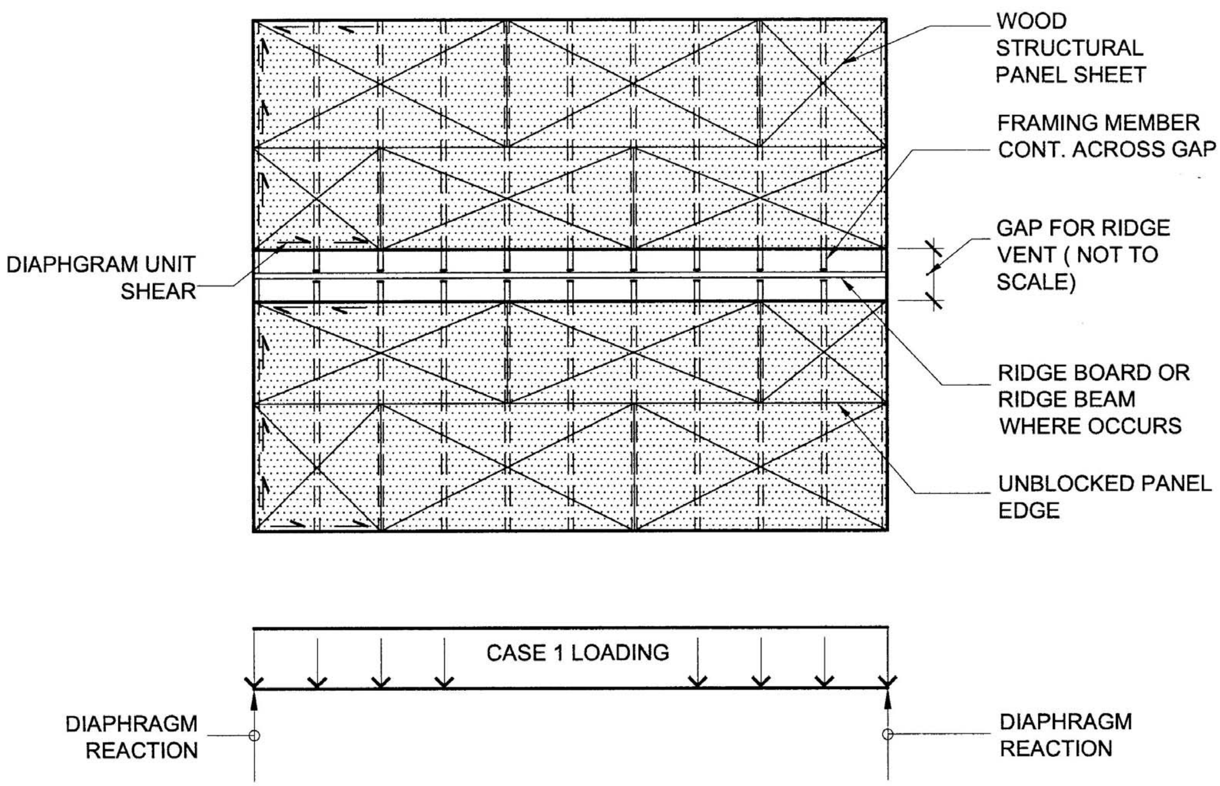

FIG 1. DIAPHRAGM PLAN VIEW - LOAD DIRECTION 1

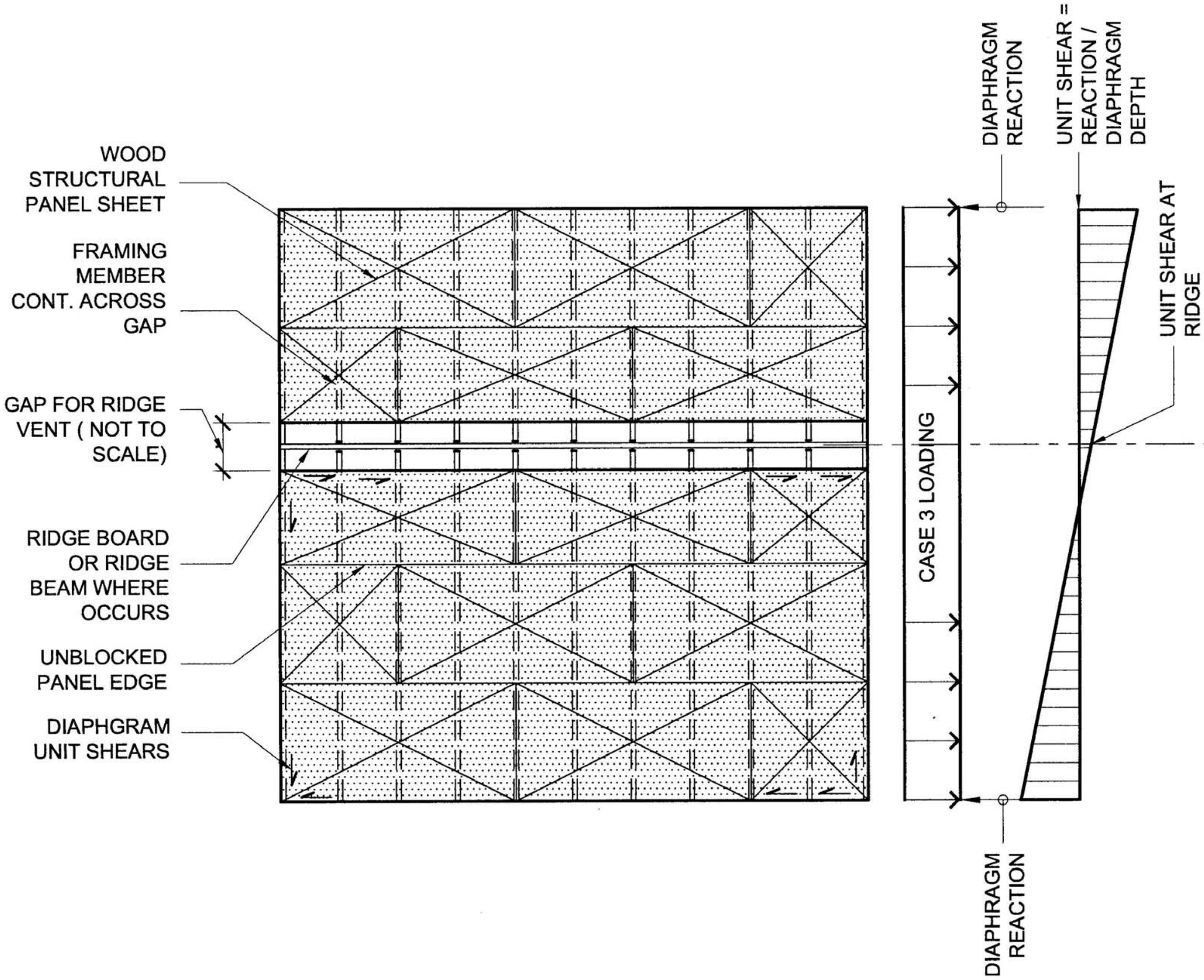

FIG 2. DIAPHRAGM PLAN VIEW - LOAD DIRECTION 2

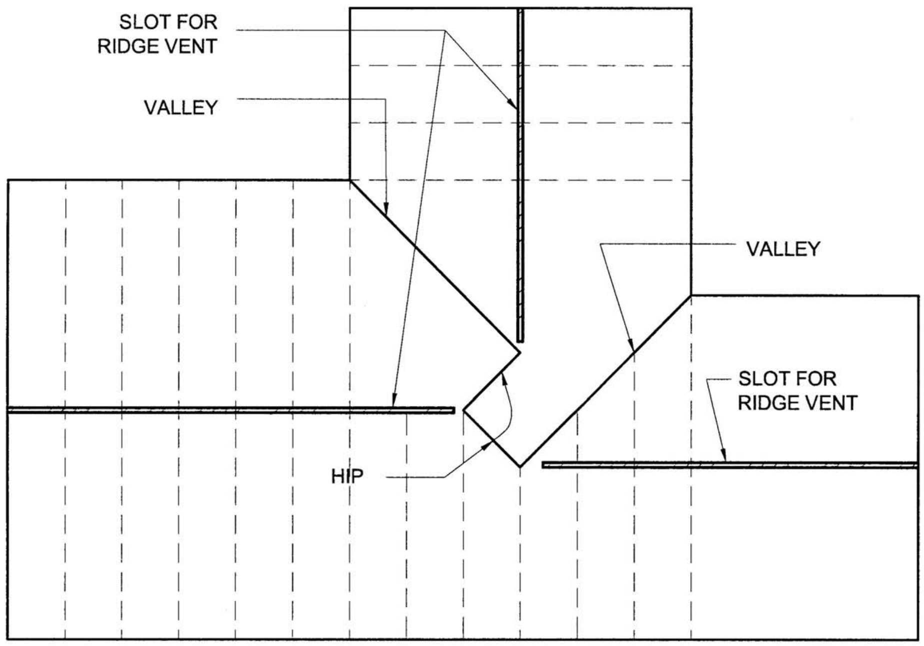

FIG 3. ROOF DIAPHRAGM PLAN VIEW - REALISTIC COMPLEXITY

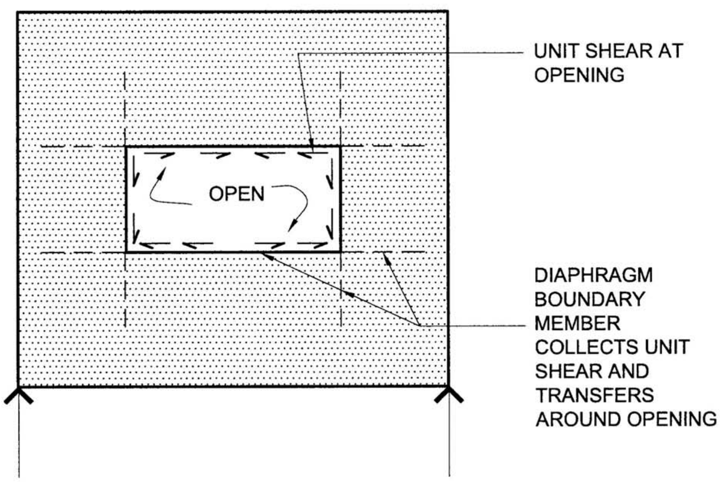

FIG 4. SHEATHING AND FRAMING DISCONTINUED AT OPENING

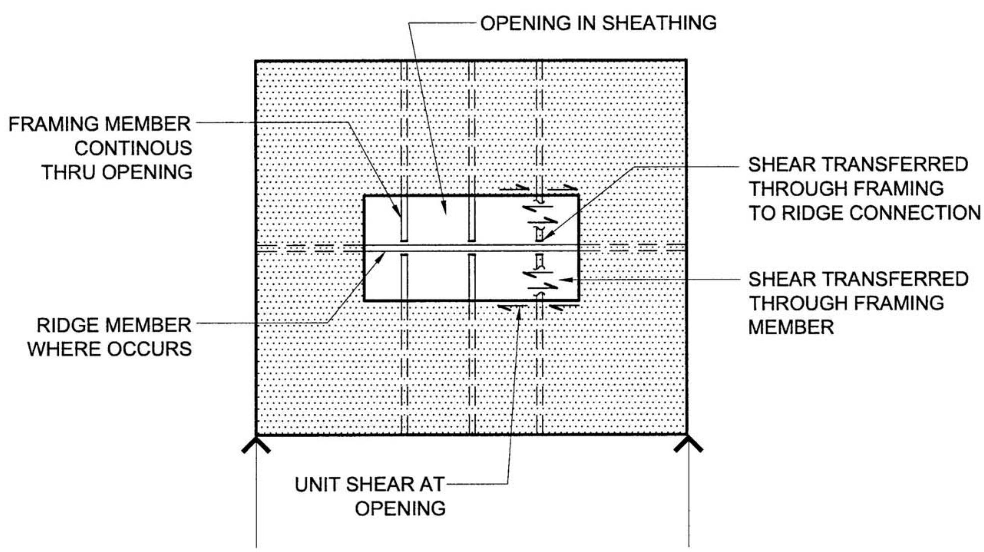

FIG 5. FRAMING MEMBERS CONTINUOUS ACROSS OPENING

PART III – EXAMPLE CALCULATIONS

Table 1 – 16-penny sinker toenail, installed dry, connecting 2x to 2x SPF:

$Z' = Z \times C_D \times C_M \times C_t \times C_g \times C_\Delta \times C_{eg} \times C_{di} \times C_{tn}$

Z	= 100 lb.	NDS Table 11N
C_D	= 1.6	NDS Table 2.3.3 – Note: Because fastener allowable load is controlled by Mode IV, C_D of 1.6 is also permitted by 1997 UBC, 2001 CBC.
C_M	= 1.0	NDS Table 10.3.3
C_t	= 1.0	NDS Table 10.3.4 – Note: Need for adjustment for elevated temperature needs to be determined by engineer of record.
C_g	= 1.0	NDS Section 10.3.6.1, based on diameter less than ¼”
C_Δ	= 1.0	NDS Section 11.5.1, based on diameter less than ¼”
C_{eg}	=	Not applicable
C_{di}	=	Not Applicable
C_{tn}	= 0.83	NDS Section 11.5.4.2

Z = 100 x 1.6 x 0.83 = 133 lb
For rafter spacing = 24 inches, 3 toenails per rafter, ASD allowable = 133 lb*3/2 ft = 200 plf

Table 1 – 16-penny sinker toenail, installed wet, connecting 2x to 2x SPF:

$Z' = Z \times C_D \times C_M \times C_t \times C_g \times C_\Delta \times C_{eg} \times C_{di} \times C_{tn}$

Z	= 100 lb.	NDS Table 11N
C_D	= 1.6	NDS Table 2.3.3 – Note: Because fastener allowable load is controlled by Mode IV, C_D of 1.6 is also permitted by 1997 UBC, 2001 CBC.
C_M	= 0.7	NDS Table 10.3.3, footnote 3
C_t	= 1.0	NDS Table 10.3.4 – Note: Need for adjustment for elevated temperature needs to be determined by engineer of record.
C_g	= 1.0	NDS Section 10.3.6.1, based on diameter less than ¼”
C_Δ	= 1.0	NDS Section 11.5.1, based on diameter less than ¼”
C_{eg}	=	Not applicable
C_{di}	=	Not Applicable
C_{tn}	= 0.83	NDS Section 11.5.4.2

Z = 100 x 1.6 x 0.7 x 0.83 = 93 lb
For rafter spacing = 24 inches, 3 toenails per rafter, ASD allowable = 93 lb*3/2 ft = 140 plf

Table 2 – L30, installed dry, connecting 2x to 2x SPF:

$Z' = Z \times C_D \times C_M \times C_t \times C_g \times C_\Delta \times C_{eg} \times C_{di} \times C_{tn}$

Z	= 205 lb./clip	2004 Simpson Strong-Tie catalog, P. 143, adjusted for CD
C_D	= 1.0	Already adjusted
C_M	= 1.0	NDS Table 10.3.3
C_t	= 1.0	NDS Table 10.3.4 – Note: Need for adjustment for elevated temperature needs to be determined by engineer of record.
C_g	= 1.0	NDS Section 10.3.6.1, based on diameter less than ¼"
C_Δ	= 1.0	NDS Section 11.5.1, based on diameter less than ¼"
C_{eg}	=	Not applicable
C_{di}	=	Not Applicable
C_{tn}	= 1.0	Not Applicable
Penetration	= 0.81	Simpson footnote 4

Z = 205 x 1.0 x 0.81 = 166 lb
For rafter spacing = 24 inches, L30, ASD allowable = 166 lb/2 ft = 83 plf

Table 2 – L30, installed wet, connecting 2x to 2x SPF:

$Z' = Z \times C_D \times C_M \times C_t \times C_g \times C_\Delta \times C_{eg} \times C_{di} \times C_{tn}$

Z	= 205 lb./clip	2004 Simpson Strong-Tie catalog, P. 143, adjusted for CD
C_D	= 1.0	Already adjusted
C_M	= 0.7	NDS Table 10.3.3 footnote 3
C_t	= 1.0	NDS Table 10.3.4 – Note: Need for adjustment for elevated temperature needs to be determined by engineer of record.
C_g	= 1.0	NDS Section 10.3.6.1, based on diameter less than ¼"
C_Δ	= 1.0	NDS Section 11.5.1, based on diameter less than ¼"
C_{eg}	=	Not applicable
C_{di}	=	Not Applicable
C_{tn}	= 1.0	Not Applicable
Penetration	= 0.81	Simpson footnote 4

Z = 205 x 0.7 x 0.81 = 116 lb
For rafter spacing = 24 inches, L30, ASD allowable = 116 lb/2 ft = 58 plf