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DESIGN OF RIM BOARDS FOR USE WITH I-JOIST FRAMING SYSTEMS

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Design of Rim Boards for Use with I-Joist Framing Systems

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Abstract

The fastest growing glued engineered wood composite in North America is pre-fabricated wood I-joists. I-joists now represent approximately 45% of the residential raised floor construction market in North America. This translates to over 300 million lineal meters (1 billion lineal feet) of I-joists being used annually in North America. A key structural component for the I-joist floor system is the rim board, which serves as a closure panel, as an element to transfer vertical loads, and as a lateral load resisting element. In traditional sawn lumber construction, the rim board is typically a sawn lumber joist. However, sawn lumber joists are not satisfactory for use with I-joist framing due to differential shrinkage and other considerations. As such, rim boards used with I-joist framing are other engineered wood composites including primarily oriented strand board (OSB), laminated veneer lumber (LVL), plywood, oriented strand lumber (OSL), and laminated strand lumber (LSL).

Since rim boards represent an essentially unregulated building component in North America, APA - The Engineered Wood Association determined there was a need to develop qualification and acceptance criteria for rim boards given the wide range of products that could be used as rim boards. This paper describes the development of the *Performance Standard for APA EWS Rim Boards*, PRR-401, and the test procedures that have evolved as industry standards. Also discussed are design recommendations developed by APA for transmitting lateral forces between floors and between floors and foundations using rim boards. Fire-rated rim board assemblies are also presented. Lastly, this paper describes the limitations on holes in rim boards as is common in residential construction.

1. Introduction

Prefabricated wood I-joists have been used in North American residential construction for more than 35 years. The total production volume for I-joists grew phenomenally from 39.6 million lineal meters (130 million lineal feet) in 1989 to 326 million lineal meters (1.07 billion lineal feet) in 2003. A vast majority of these I-joists, approximately 80%, have been used in new residential floor construction. This represents a market share of approximately 45% in 2003 [1], which exceeds the market share of solid-sawn lumber floor joists.

A key structural component of the I-joist floor system is the rim board, which is a wood component that fills the space between the sill plate and bottom plate of a wall or, in second floor construction, between the top plate and bottom plate of two wall sections. The rim board matches the depth of the framing members between floors or between the floor and foundation to perform one or a combination of the following functions:

- To transfer all vertical loads from above to below at the rim board location
- To provide diaphragm attachment for floor sheathing to the top edge of rim board
- To transfer lateral loads from the diaphragm to the wall plate below
- To provide lateral support for the floor joists through the attachment to the joists
- To provide closure for ends of floor joists
- To provide attachment base for siding and/or exterior deck ledger

While lumber has been traditionally used as rim boards with sawn lumber floor systems, its depth dimension is not compatible with typical I-joist depths. Additionally, since the sawn lumber rim boards have different shrinkage or swelling characteristics than I-joists when exposed to moisture changes, it is always problematic to maintain dimensional compatibility when an I-joist floor system is mixed with sawn lumber rim boards. With the increasing use of wood I-joists, a demand for compatible engineered wood rim boards has resulted. After years of research and development, APA published the *Performance Standard for APA EWS Rim Boards*, PRR-401 [2], in 1997. Most of the product evaluation methods given in PRR-401 were subsequently incorporated into the *Acceptance Criteria for Wood-Based Rim Board Products*, AC124 [3], by the then ICBO Evaluation Service (ICBO-ES). Since then, the total production volume for rim boards, mostly oriented strand board (OSB) and laminated strand lumber (LSL), has grown from approximately 3.2 million square meters (35 million square feet) in 1997 to 5.4 million square meters (59 million square feet) on a 25-mm (1-inch) thickness basis [4]. The standard sizes for rim board products certified by APA is 25 to 32 mm (1 to 1-1/4 inches) in thickness, 241 to 610 mm (9-1/2 to 24 inches) in depth, and 2.4 to 7.3 m (8 to 24 feet) in length.

2. Evaluation Methods

As an engineered wood product, the rim board should be manufactured in accordance with a recognized product standard, such as the *Voluntary Product Standards PS1* [5] or *PS2* [6] in the U.S., or *Construction Sheathing CSA-0325* [7] in Canada, for wood structural panel products. Since the rim board functionalities, as mentioned above, are beyond typical sheathing applications, additional product evaluation is required per APA PRR-401 and ICBO-ES AC124. This includes horizontal load transfer capacity, uniform vertical load capacity, concentrated vertical load capacity, and lag screw lateral resistance (for attachment of deck ledgers). The durability of rim boards is addressed by the lateral nail durability and thickness swell tests. In addition, edgewise-bending properties for rim boards are required to be evaluated in PRR-401 so that the rim board products may be used to span over an opening of 1.2 m (4 feet) or less as a bending member. Due to the space limitation in this paper, the following paragraphs briefly describe these test methods.

The horizontal load transfer capacity is evaluated using ten replicates of 91-cm (3-ft) long and 30-cm (1-ft) wide rim board assemblies, as shown in Figure 1. Each assembly represents a section of floor where the lateral loads are transferred through the rim board and floor joists using the minimum nailing schedule prescribed in the International Building Code [8]. As several nail types, including toe nails (rim board to sill plate), face nails (rim board to joist and sheathing to joist flange), slanted nails (joist to sill plate), and edge nails (sheathing to rim board), are part of the lateral load transfer mechanism, the only rational option for evaluating the lateral load transfer capacity is through the assembly test. It should be noted that due to the difficulty in nailing the sheathing into the edge of rim board when the rim board thickness is too small, the industry has adopted a minimum rim board thickness of 25 mm (1 inch) to reduce the likelihood of missing edge-nail connections. Overall, due to the fact that the core density of OSB is generally lower than the face, the predominant failure mode for OSB rim boards is the edge nailing between sheathing and rim board.

Figure 1. Test setup for horizontal load transfer capacity

The uniform vertical load capacity of rim board is evaluated using the rim board as a stand-alone column. The uniform vertical load capacity determined from these column tests is compared with the theoretical column buckling capacity. The uniform vertical load capacity is published based on the lower of the empirical and theoretical values. The concentrated vertical load capacity is tested in a similar manner and the mean test value from 10 tests is required to be at least 46.7 kN (10,500 lbf), which is equivalent to an allowable load of 15.6 kN (3,500 lbf), based on the provisions of the conventional construction practices prescribed in the International Building Code [8].

The lag screw tests are intended to provide a design value for the attachment of deck ledger to siding and rim board. In the U.S., the attachment typically consists of lag screws of 12.7 mm (1/2 inch) in diameter. However, due to the lag screw penetration being limited to the rim board thickness, which is below the minimum penetration of 4 times the fastener diameter, performance tests are required, as shown in Figure 2. The predominant failure mode for OSB rim boards is the fastener rotation and crushing of wood (referenced to as a Mode II failure).

Since rim boards are limited to dry service conditions, such as with most protected framing members where the average equilibrium maximum moisture content for solid-sawn lumber is less than 16%, the durability of rim boards is addressed by conducting lateral nail durability and thickness swell tests. The lateral nail durability tests are performed in the same manner as the lateral load transfer capacity tests (see Figure 1) with the exception that the rim board used in the assembly is pre-conditioned by a 24-hour water soak in accordance with Method B of ASTM D1037 [9] and the assembly is assembled while the rim board is still wet. The whole assembly is then re-dried to room conditions before the mechanical test is conducted. This is intended to simulate the conditions when the rim board is installed wet due to a rain delay in construction and

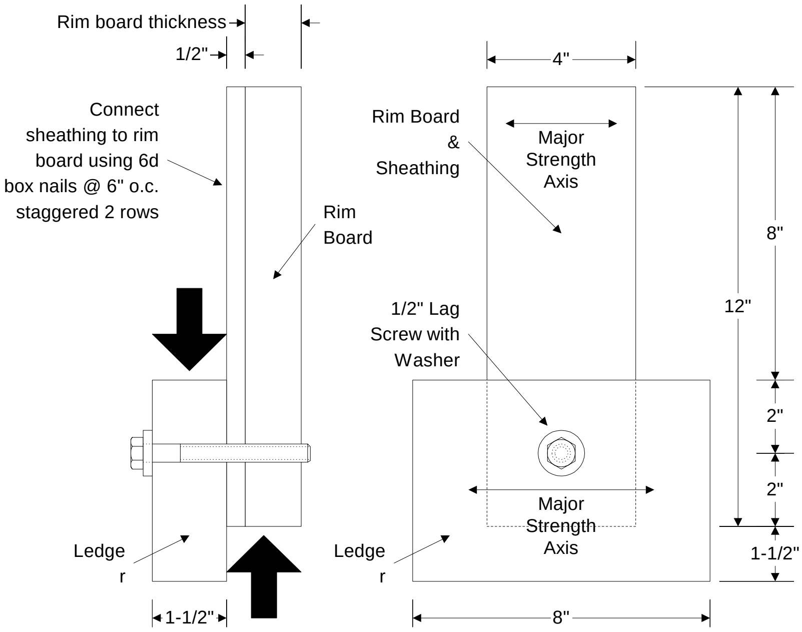


Figure 2. Test setup for lag screw lateral resistance

subsequently re-dried after the building is closed in. The mean lateral load transfer capacity obtained from the lateral nail durability tests cannot be less than 75% of the mean capacity determined from the control (dry). In addition, the mean thickness swell of rim boards based on the 24-hour water soak cannot exceed 10% and no individual value shall exceed 12%.

The edgewise-bending properties of rim boards are evaluated in accordance with the principles of ASTM D5456 [10]. For quality assurance purposes, PRR-401 requires rim board products to meet the process control requirements in accordance with typical structural panel production. In addition, thickness swell, internal bond, and density of rim boards are required to meet the control values established during qualification.

3. Design Values

Tables 1 and 2 show the characteristic properties for 2 generic rim board products certified by APA. These 2 classes of rim boards have been widely used and accepted in North America since 1997. It should be noted that there are some additional proprietary rim board products that reflect different design values evaluated in accordance with AC124 and recognized in a code-compliance report.

4. Design Considerations

4.1 Connection requirements

The design values given in Tables 1 and 2 are based on the results of performance tests. As a result, the rim board design and installation must be based on the following connection requirements, which are part of the performance tests:

Table 1. Required Mean Test Values[a] for *APA EWS* Rim Boards

Grade	t_{min}[b] (mm)	H[c] (kN/m)	V[d] (kN/m)		Z[e] (kN)	P[f] (kN)
		Depth (d) Limitation (cm)				
		d ≤ 61	d ≤ 41	41 < d ≤ 61	d ≤ 61	41 < d ≤ 61
Rim Board	25	7.4	144	72	5.3	47
	29	7.4	193	131	6.2	47
Rim Board Plus	25	N/A[g]				
	29	8.2	212	140	6.2	47

[a] The tabulated values are the average test values.
[b] Minimum thickness.
[c] Mean test value for the horizontal load transfer capacity.
[d] Mean test value for the vertical load capacity.
[e] Mean test value for the lateral resistance of a 12.7-mm diameter lag screw.
[f] Mean test value for the concentrated load capacity, which is required only when the rim board exceeds 41 cm in depth.
[g] The minimum thickness for *APA EWS* Rim Board Plus is 29 mm.

Table 2. Required Edgewise Bending Values for *APA EWS* Rim Boards [a]

Grade	f_{be}[b] (MPa)	E_e[c] (MPa)	f_{ve}[d] (Mpa)	$f_{c\perp e}$[e] (MPa)
Rim Board or Rim Board Plus	14.3	3,999	5.9	6.3

[a] The tabulated values are test values.
[b] Characteristic (5th percentile with 75% confidence) edgewise bending strength.
[c] Characteristic (mean) edgewise apparent modulus of elasticity.
[d] Characteristic (5th percentile with 75% confidence) edgewise shear strength.
[e] Characteristic (mean) edgewise compressive strength perpendicular to grain at 0.04-in. deformation.

a) Floor sheathing to Rim Board – Use 64-mm (2-1/2-inch) long common nails at 150 mm (6 inches) o.c. It should be noted that the horizontal load transfer capacity is not necessarily increased with decreased nail spacing. This is because the tendency to split at the edge-nailed joint is greater with decreasing nail spacing, which will offset the increased joint strength due to the increased number of nails for a given rim board length. To avoid excessive splitting, the nail spacing shall not be less than 75 mm (3 inches). For the same reason, the 89-mm (3-1/2-inch) long common nails used to connect the bottom plate of a wall to the rim board through the sheathing do not increase nor reduce the horizontal load transfer capacity of the rim board provided that the 64-mm (2-1/2-inch) long common nail spacing (sheathing-rim board) is 150 mm (6 inches) o.c. and the 89-mm (3-1/2-inch) long common nail spacing (bottom plate-sheathing-rim board) is in accordance with the prescriptive requirements of the International Building Code [8].

b) Rim Board to I-Joist – Use two 64-mm (2-1/2-inch) long common nails, one each into the top and bottom flanges. This is typical for rim board having a thickness up to 29 mm (1-1/8 inches). A larger nail size may be required by the I-joist manufacturer or for thicker rim board products.

c) Rim Board to Sill Plate – Toenail using 64-mm (2-1/2-inch) long common nails at 150 mm (6 inches) o.c.

d) Attachment of Lumber Ledgers to Rim Board – Use 12.7-mm (1/2-inch) diameter lag screws with a minimum nominal length of 100 mm (4 inches) or use 12.7-mm (1/2-inch) diameter through-bolts with washers and nuts. Note that the lag screw should be inserted in a lead hole by turning with a wrench, not by driving with a hammer. Over-torquing can significantly reduce the lateral resistance of the lag screw and should therefore be avoided.

e) Lateral Resistance of Nails Applied to The Faces of Rim Board – Calculate the lateral nail resistance based on the procedures given in the applicable code using an equivalent specific gravity of 0.50 for OSB rim boards. If the rim boards are made of structural composite lumber (SCL), refer to the equivalent specific gravity published by the SCL manufacturer.

4.2 Rim boards spanning over opening

Rim boards may be used to span openings up to 1.2 m (4 feet) in length, depending on the applied loads at the opening. In some instances, the rim board may not have sufficient edgewise-bending capacity to resist the applied loads to the same level as the uniform vertical load capacity given in Table 2, which is based on a fully supported rim board. If there is not sufficient edgewise-bending capacity, a built-up (multiple pieces of) rim board may be considered for providing adequate edgewise-bending capacity. When spanning openings, rim board end (butt) joints shall not occur over the opening.

4.3 Holes in rim board

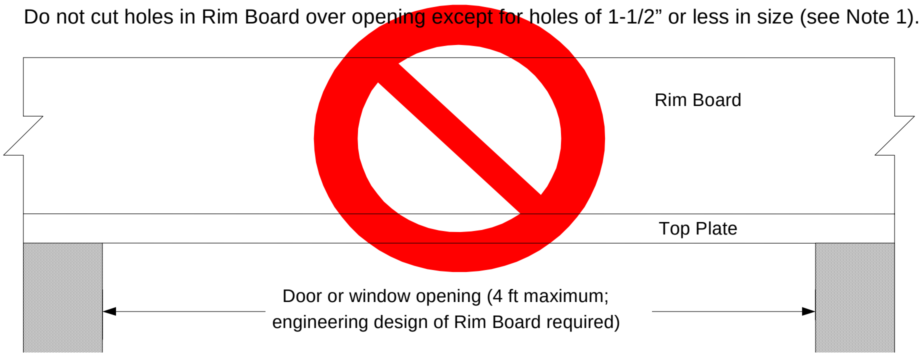
Based on experience with similar products, the maximum allowable hole size for rim boards is limited to 2/3 of the rim board depth as shown below. Based on the test results of an APA research study [11], the length of any rim board segment containing a hole is required to be at least 8 times the hole size to allow for stress re-distribution around the hole, while maintaining an adequate factor of safety.

Table 3. Maximum allowable hole size and minimum rim board length

Rim board depth (cm)	Maximum allowable hole size[(a)(b)] (cm)	Minimum Rim Board length[(c)] (cm) for the maximum allowable hole size
24	16	127
30	20	157
36	24	188
41	27	213

(a) These hole provisions do not apply to rim board installed over openings, such as doors or windows.
(b) The diameter of a round hole or the longer dimension of a rectangular hole.
(c) The length of rim board per wall line. For multiple holes, the minimum rim board length shall be 8 times the sum of all hole sizes.

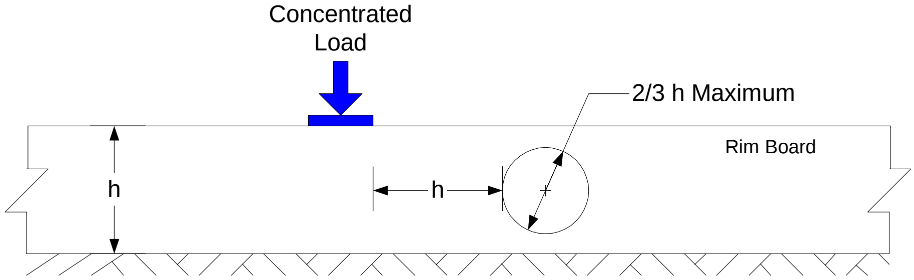
a) Holes should not occur in rim board installed over openings, such as doors or windows, where the rim board is not fully supported, except that holes of 38 mm (1-1/2 inches) or less in size are permitted provided they are positioned at the mid-depth and in the middle 1/3 of the span.



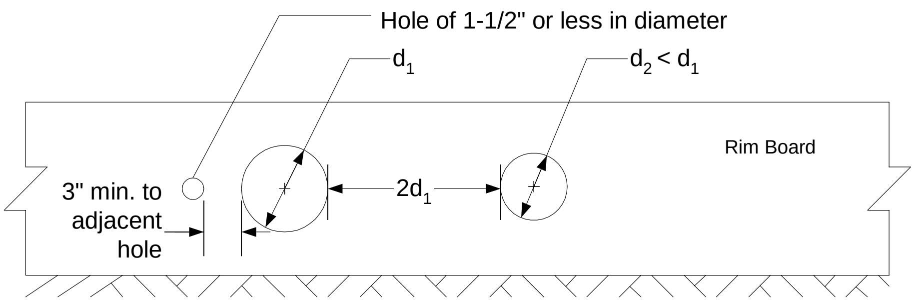
b) Field-cut holes should be vertically centered in the rim board and at least one hole diameter or 15 cm (6 inches), whichever is less, clear distance away from the end of the wall line. Holes should never be placed such that they interfere with the attachment of the rim board to the ends of the floor joist, or any other code-required nailing.

c) While round holes are preferred, rectangular holes may be used, provided that the corners are not over-cut. Slightly rounding corners or pre-drilling corners with a 25-mm (1-inch) diameter bit are recommended.

d) When concentrated loads are present on the rim board (loads not supported by other vertical-load-carrying members such as squash blocks), holes should not be placed in the rim board within a distance equal to the depth of the rim board from the area of loading.



e) For multiple holes, the clear spacing between holes should be at least two times the diameter of the larger hole, or twice the length of the longest side of the longest rectangular hole. This minimum hole spacing does not apply to holes of 38 mm (1-1/2 inches) or less in diameter, which can be placed anywhere in the rim board except that the clear distance to the adjacent hole should be 76 mm (3 inches) minimum.



4.4 Fire-rated rim board assemblies

In the U.S. building codes, fire resistant or fire-rated assemblies are required in certain locations, occupancies, and types of buildings to slow or prevent the spread of fire. When fire-rated walls and/or floor/ceiling assemblies are required, a fire barrier over the walls is typically required to prevent flames from escaping the confinement provided by the wall or ceiling assembly. Rim boards in continuous length can be used as an effective fire barrier. Based on a study commissioned by APA and conducted by the Forest Products Laboratory, U.S. Department of Agriculture [12], several 1-hour and 2-hour fire-rated assemblies, both with load transfer (the load carried by the fire-exposed rim board is assumed to transfer to the adjacent rim board when the fire-exposed rim board fails) and without load transfer. Figure 3 shows the 1-hour fire-rated rim board assemblies with load transfer. For a complete list of fire-rated rim board assemblies, please refer to APA Data File D350, *APA Rim Board in Fire Rated Assemblies* [13], at the APA web site (http://www.apawood.org).

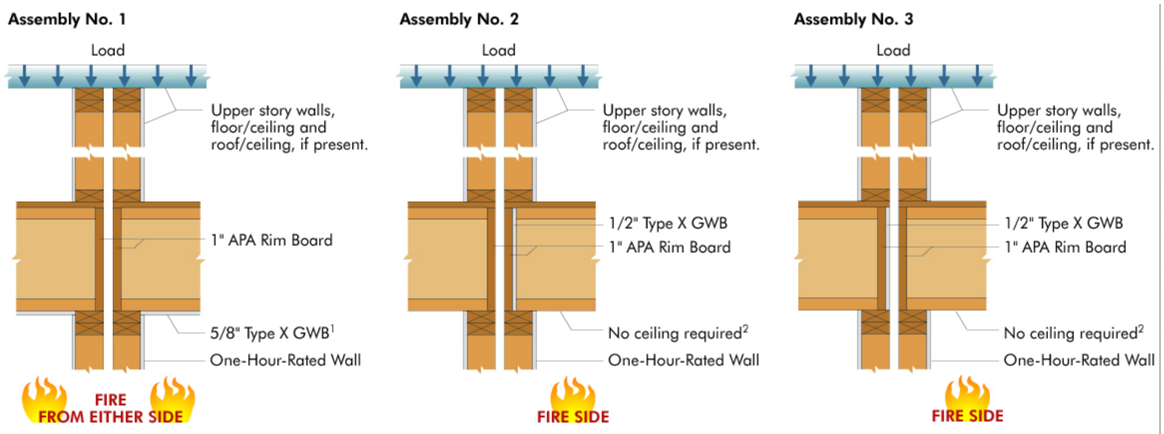


Figure 3. One-hour fire-rated rim board assemblies with load transfer

4.5 High lateral load transfer

When rim boards are used in applications where a high lateral load transfer capacity is required, the following options are available. For additional design information, please refer to APA Data File EWS Y250, *Shear Transfer at Engineered Wood Floors* [14], at the APA web site (http://www.apawood.org).

a) Use commercially available specialty metal connectors made by connector manufacturers between the rim board and framing or sole plate, as shown in Figure 4. These types of connectors are installed using face nailing into the rim board, thereby increasing the lateral load transfer capacity of the rim board assembly.

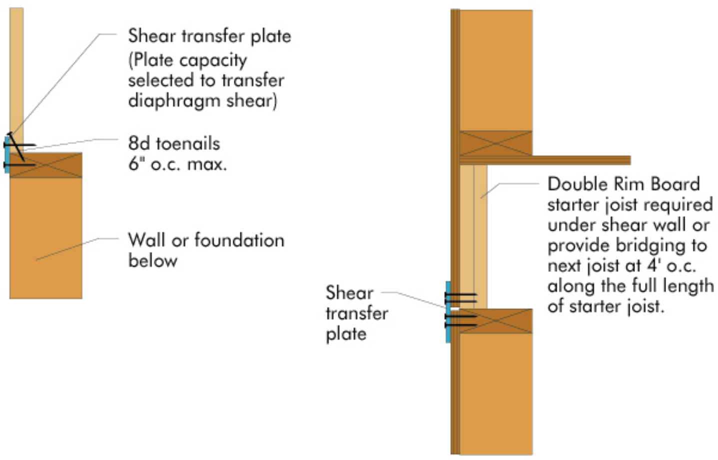


Figure 4. High lateral load transfer using metal connectors

b) Use nailed connections with face nailing into the rim board or additional lumber blocking, as shown in Figure 5.

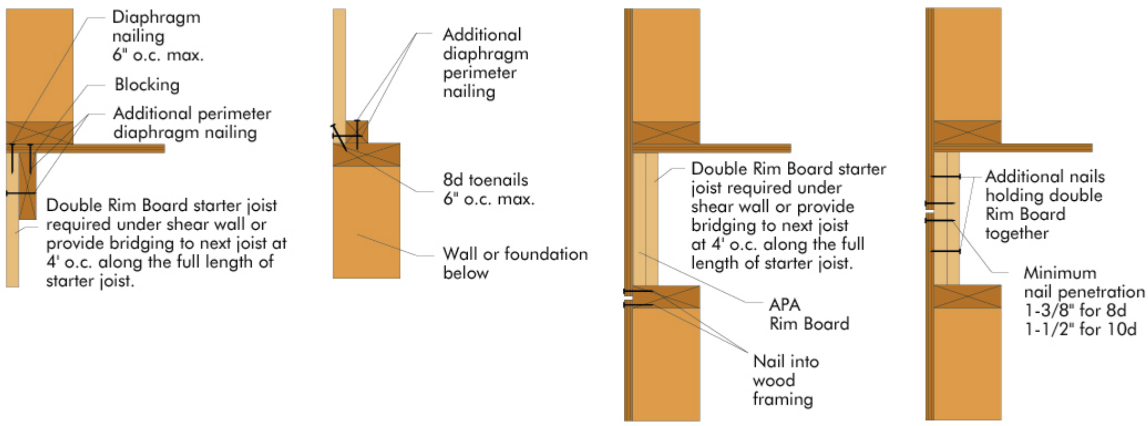


Figure 5. High lateral load transfer using metal connectors

5. Conclusions

Rim boards are an integral part of engineered wood systems because they transfer both lateral and vertical forces, and provides lateral support for the floor joists. Due to their multiple functionalities, rim boards should be properly manufactured, evaluated, designed, and constructed to ensure that the design loads are successfully transferred through rim boards. With the increasing demand for I-joist floor systems, it is expected that engineered rim boards will play a critical role in future building construction. This paper provides some information for proper design and construction of rim boards.

6. References

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