Wood Design FOCUS

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In This Issue:

Designs and Details for Deck Construction



In The Next Issue:

2016 World Conference on Timber Engineering Update

# Editorial

The current issue of Wood Design Focus elaborates on some of the challenges of deck building as part of our current series. Last issue, the articles focused on inspection of in-place decks. This issue is focused on some of the technical challenges of complying with current deck regulations through the 2015 International Residential Code and DCA 6 - *Prescriptive Residential Wood Deck Construction Guide*.

The Wood Design Focus editorial board believes that the issues of deck safety and deck construction are essential for protecting the safety of homeowners. This is the second issue devoted to the topic of deck construction, and we hope to bring you a third issue next time focused on exterior moisture detailing, which is a misunderstood and often overlooked area of the building.

In this issue, we feature three articles about wood construction. First, David Finkenbinder discusses deck design provisions in the 2015 IRC, providing an update to a previous Wood Design Focus article from 2006. Next, Buddy Showalter and Loren Ross discuss the updates to the DCA 6 construction guide for decks. Finally, Erik Farrington discusses loading of guarding systems (posts, rails, pickets) and discusses the distribution of forces placed on the guard on focused on the principal directions of loading.

We hope you find this issue helpful in improving the design and construction of residential deck systems.

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# 2015 International Residential Code Requirements for Wood-Framed Decks

*David Finkenbinder, P.E.*

**Introduction**

A previous Wood Design Focus article by Lewis (2006) summarized the 2003 International Residential Code (IRC) provisions for wood-framed decks, along with helpful commentary. The article provided an essential resource to design professionals, as the building code at the time did not have a wealth of prescriptive information specific to decks, and the information that would apply to decks was widely dispersed throughout the code. In subsequent code development cycles much effort has been devoted to establish prescriptive deck code provisions that best meet the code intent of providing safety, affordability, and structural strength. This effort has been spearheaded by the Deck Code Coalition (DCC), a group comprised of building officials, builders, engineers, product manufacturers, and trade organizations with a common concern of wood-framed decks.

This article presents the provisions for wood-frame decks found in the 2015 IRC (ICC 2015). Substantial progress has been made from previous IRC editions and deck-related information is organized more now in a common location, section R507. Similar to the format of Lewis (2006), 2015 IRC sections are referenced herein and commentary is added based-upon the engineering background of the author. For any project, the authority having jurisdiction should be contacted to verify their interpretation of the code and any local building code amendments.

**Alternate Means and Methods**

> **R104.11 Alternative materials, design and methods of construction and equipment.** *The provisions of this code are not intended to prevent the installation of any material or to prohibit any design or method of construction not specifically prescribed by this code, provided that any such alternative has been approved. An alternative material, design or method of construction shall be approved where the building official finds that the proposed design is satisfactory and complies with the intent of the provisions of this code, and that the material, method, or work offered is, for the purpose intended, not less than the equivalent of that prescribed in this code…*

The importance of the "alternate means and methods" provision merits emphasis to the design professional, as the IRC prescriptive information is not meant to limit or prohibit an alternate detail or material. ICC Evaluation Service (ICC-ES) Acceptance Criteria (AC) are a resource as well when considering proprietary options, as the criteria are developed to meet the building code provisions and referenced standards, and provide a consistent standard of testing and evaluation across the industry. Product evaluation reports will list the submitted AC data that supports that report. Related AC are cited in this article.

**Loads**

> **R301.5 Live Load.** *The minimum uniformly distributed live load shall be as provided in Table R301.5.*

Decks, exterior balconies, and stairs shall support a 40 psf live load. Guards and handrails shall support a single concentrated load applied in any direction at any point along the top. Guard infill components shall be designed to support a horizontally applied normal load of 50 pounds applied on an area equal to 1 square foot (non-concurrent with any other live load requirement). Individual stair treads shall support the worst case of the uniformly distributed live load or a 300 pound concentrated load acting over an area of 4 square inches.

*Keywords: Wood-framed decks, residential, 2015 International Residential Code, IRC, prescriptive*

**Lateral loads.**

Lateral loads are not specifically outlined for decks, however design for lateral loads is required by Section R507.1 in the context of supporting a deck from an adjacent structure. In addition to standard wind and seismic loads, the subject of occupant-generated lateral loads is an ongoing subject of interest for the deck design and building community. Researchers from Washington State University have studied what forces are generated on a simple deck by wind and seismic cases (Lyman and Bender, 2013; Lyman et al., 2013). Their research has also investigated occupant-generated lateral loads by having groups of people perform a variety of movement on a deck floor configuration (Parsons et al., 2013). Formal conclusions from this research are pending.

**Resistance to Decay, Corrosion, and Termites**

IRC Sections R317 should be referenced for requirements relating to protection of wood and wood based products from decay, and also requirements for fasteners in contact with treated wood. Attention is directed to several sections herein to add commentary. IRC Section R318 should be referenced for requirements relating to protection against subterranean termites.

> **R317.1.1 Field treatment.** *Field-cut ends, notches and drilled holes of preservative-treated wood shall be treated in the field in accordance with AWPA M4.*

> **R317.1.2 Ground contact.** *All wood in contact with the ground, embedded in concrete in direct contact with the ground, or embedded in concrete exposed to the weather that supports permanent structures intended for human occupancy shall be approved pressure-preservative-treated wood suitable for ground contact use…*

> **R317.1.3 Geographic areas.** *In geographical areas where experience has demonstrated a specific need, approved naturally durable or pressure-preservative-treated wood shall be used for those portions of wood members that form the structural supports of buildings, balconies, porches or similar permanent building appurtenances when those members are exposed to the weather without adequate protection from a roof, eave, overhang or other covering that would prevent moisture or water accumulation on the surface or at joints between members. Depending on local experience, such members may include: 1. Horizontal members such as girders, joists and decking. 2. Vertical members such as posts, poles and columns. 3. Both horizontal and vertical members.*

> **R317.1.4 Wood columns.** *Wood columns shall be approved wood of natural decay resistance or approved pressure-preservative-treated wood.* **Exceptions:** *3. Deck posts supported by concrete piers or metal pedestals projecting not less than 1 inch above a concrete floor or 6 inches above exposed earth.*

Naturally durable wood for decay resistance is defined in Chapter 2 of the IRC as redwood, cedar, black locust, and black walnut, where heartwood comprises 90% or more of the width of each side. For preservative-treated wood, Section R317.1 states that treatment should be in accordance with AWPA U1 for the wood species, product, preservative and end use. Proprietary wood treatments can be evaluated per *ICC-ES AC326 – Acceptance Criteria for Proprietary Wood Preservative Systems*.

Section R317.1 states that preservative-treated wood should be in accordance with AWPA U1. The requirement for field treatment of cuts and holes in preservative-treated wood is an important part of the construction phase, as wood can rapidly bring in moisture through exposed end grain. Due to the difficulty in repairing or replacing a wood post in service it is recommended to use a naturally decay resist or treated column, even if the criteria for the exception is met.

> **R317.3.1 Fasteners for preservative-treated wood.** *Fasteners, including nuts and washers, for preservative-tread wood shall be of hot-dipped galvanized steel, stainless steel, silicon bronze or copper. Coating types and weights for connectors in contact with preservative-treated wood shall be in accordance with the manufacturer's recommendations. In the absence of manufacturer's recommendations, a minimum of ASTM A 653 type G185 zinc-coated galvanized steel, or equivalent, shall be used.* **Exceptions:** *1. ½-inch-diameter or greater steel bolts.; 2. Fasteners other than nails or timber rivets shall be permitted to be of mechanically deposited zinc-coated steel with coating weights in accordance with ASTM B 695, Class 55 minimum…*

Fasteners and connectors are typically either hot-dipped galvanized or stainless steel (Type 304, 305, or 316), with connector manufacturer recommendations offering greater detail than the code in terms of which finish/ material is appropriate for a given service environment and preservative-treatment type. Fasteners installed into connectors should be the same finish/material as the connector, to prohibit galvanic corrosion potential from otherwise using dissimilar metals. Joist hangers and other steel connectors are evaluated per *ICC-ES AC13 – Joist Hangers and Similar Devices*.

A number of proprietary fastener options exist, which typically include features that do not require the pre-drilling necessary when installing bolts or lag screws. Screw-type proprietary fasteners are evaluated per *ICC-ES AC233 – Alternate Dowel-type Threaded Fasteners*. These fasteners also typically have proprietary coatings which are evaluated per *ICC-ES AC257 – Corrosion-resistant Fasteners and Evaluation of Corrosion Effects of Wood Treatment Chemicals*, to demonstrate equivalence to hot-dip galvanization.

**Flashing**

> **R703.4 Flashing.** *Approved corrosion-resistant flashing shall be applied shingle-fashion in a manner to prevent entry of water into the wall cavity or penetration of water to the building structural framing components. Self-adhered membranes used as flashing shall comply with AAMA 711. Fluid-applied membranes shall comply with AAMA 714. The flashing shall extend to the surface of the exterior wall finish. Approved corrosion-resistant flashings shall be installed at the following locations… 5. Where exterior porches, decks or stairs attach to a wall or floor assembly of wood-frame construction.*

This section is relatively open to the design professional in terms of not prescribing certain materials or methods. The type of preservative-treatment present in the framing lumber will be a consideration as to the types of flashing materials that are corrosion resistant. Proprietary flashing products can be evaluated per *ICC-ES AC148 – Flexible Flashing Materials*, with copper and PVC flashing materials being potential options depending on the lumber treatment. Aluminum flashing is not corrosion -resistant for preservatives containing copper.

**Decking**

**R507.4 Decking.** *Maximum allowable spacing for joists supporting decking shall be in accordance with Table R507.4. Wood decking shall be attached to each supporting member with not less than (2) 8d threaded nails or (2) No. 8 wood screws.*

Table R507.4 provides joist spacing requirements that will satisfy the span ratings for common thicknesses of wood decking. For plastic composite decking the joist spacing will be limited by the maximum allowable span for the specific product, as noted by Section R507.3. *ICC -ES AC174 – Deck Board Span Ratings and Guardrail Systems*, is a criteria for the evaluation of deck board span ratings.

Establishing a minimum requirement for diaphragm capacity was not specifically an intention when Section R507.4 was added to the IRC, however this consideration is important to a design professional. The *2015 Special Design Provisions for Wind & Seismic* standard (AWC 2015) provides some pertinent information in Chapter 4 in regards to diaphragm aspect ratios and shear capacities for diaphragms with horizontal or diagonal lumber sheathing. Common alternative decking material types and methods of attachment (such as concealed clip connections) may have limited information in terms of diaphragm performance – a designer may consider cross bracing on the underside of the deck joists as a separate means in developing diaphragm capacity.

**Joists and Beams**

> **R507.5 Deck joists.** *Maximum allowable spans for wood deck joists, as shown in Figure R507.5, shall be in accordance with Table R507.5. Deck joists shall be permitted to cantilever not greater than one-fourth of the actual, adjacent joist span.*
>
> **R507.5.1 Lateral restraint at supports.** *Joist ends and bearing locations shall be provided with lateral restraint to prevent rotation. Where lateral restraint is provided by joist hanger or blocking between joists, their depth shall equal not less than 60 percent of the joist depth. Where lateral restraint is provided by rim joists, they shall be secured to the end of each joist with not less than (3) 10d (3-inch x 0.128-inch) nails or (3) No. 10 x 3-inch long wood screws.*
>
> **R507.6 Deck Beams.** *Maximum allowable spans for wood deck beams, as shown in Figure R507.6, shall be in accordance with Table R507.6. Beam plies shall be fastened with two rows of 10d (3-inch x 0.128-inch) nails minimum at 16 inches on center along each edge. Beams shall be permitted to cantilever at each end up to*

*one-fourth of the actual beam span. Splices of multi-span beams shall be located at interior post locations.*

**R507.7 Deck joist and deck beam bearing.** *The ends of each joist and beam shall have not less than 1½ inches of bearing on wood or metal and not less than 3 inches on concrete or masonry for the entire width of the beam. Joist framing into the side of a ledger board or beam shall be supported by approved joist hangers. Joists bearing on a beam shall be connected to the beam to resists lateral displacement.*

The joist and beam span tables were constructed using a standard 40 psf ground snow or live load, and a 10psf dead load. A secondary loading case was evaluated of a 220 lb point load, the typical point load evaluated for the span rating of a wood deck board, applied at the end of the cantilever. Significant concentrated loads, such as a hot tub, would be outside the scope of these tables. The beam span table assumes joists are framing in from one side only. Deflection limits for both the joist and beam tables were L/360 for the simple span or main span of the case with cantilever, and L/180 for the cantilever.

**Ledgers**

**R507.1 Decks.** *Wood-framed decks shall be in accordance with this section and Section R301 for materials and conditions not prescribed herein. Where supported by attachment to an exterior wall, deck shall be positively anchored to the primary structure and designed for both vertical and lateral loads.*

*Such attachment shall not be accomplished by the use of toenails or nails subject to withdrawal. Where positive connections to the primary building structure cannot be verified during inspection, decks shall be self-supporting. For decks with cantilevered framing members connections to exterior walls or other framing members shall be designed and constructed to resist uplift resulting from the full live load specified in Table R301.5 acting on the cantilevered portion of the deck.*

**R507.2 Deck ledger connection to band joist.** *Deck ledger connections to band joists shall be in accordance with this section, Tables R507.2 and R507.2.1, and Figures R507.2.1(1) and R507.2.1(2). For other grades, species, connection details, and loading conditions, deck ledger connections shall be designed in accordance with Section R301.*

These sections lay the groundwork for provisions governing a ledger-supported deck. It identifies the need to design for both vertical and lateral loads at the point where the deck is supported by the primary structure – subsequent sections address these loads separately. The prohibition of toenails or nails subject to withdrawal, and the paramount requirement of verification of the connections being made to the primary structure, underscores the critical importance of the deck ledger connection.

Section R507.2 addresses a common case of a deck ledger overlapping in elevation with the floor system of the primary structure, so that fasteners can attach the ledger to a band or rim joist through the wall sheathing. Common cases where the ledger sits beneath the elevation of the floor system (likely due to the deck floor being a step down from the primary structure floor) would require design in accordance with the loads of Section R301 and accepted engineering practice.

**R507.2.1 Ledger details.** *Deck ledgers installed in accordance with Section R507.2 shall be a minimum 2-inch by 8-inch nominal, pressure-preservative-treated southern pine, incised pressure-preservative treated Hem-fir, or approved, naturally durable, No. 2 grade or better lumber. Deck ledgers installed in accordance with Section R507.2 shall not support concentrated loads from beams or girders. Deck ledgers shall not be supported on stone or masonry veneer.*

**R507.2.2 Band joist details.** *Band joists attached by a ledger in accordance with Section R507.2 shall be a minimum 2-inch-nominal, solid saw, spruce-pine-fir lumber or a minimum 1-inch by 9½-inch dimensional, Douglas fir, laminated veneer lumber. Band joists attached by a ledger in accordance with Section R507.2 shall be fully supported by a wall or sill plate below.*

**R507.2.3 Ledger to band joist fastener details.** *Fasteners used in deck ledger connections in accordance with Table R507.2 shall be hot-dipped galvanized or stainless steel and shall be installed in accordance with Table R507.2.1 and Figures R507.2.1(1) and R507.2.1 (2).*

The on-center fastener spacings for ½" diameter lag screws and ½" diameter bolts are derived from laboratory testing of ledger assemblies conducted by Carradine et al. (2006). Limitations to fastener types, member sizes, wood species, and sheathing thickness, are based upon the scope of the test program. Fastener allowable loads were established from a factor of safety of 4.8. Bolts for the ledger connection are specifically required to be hot-dipped galvanized or stainless steel for a degree of corrosion protection to the critical connection, which overrides the general Section R317.3.1 exception waiving ½" bolts to be hot-dipped galvanized or stainless steel.

The prohibition of the deck ledger to be supported on stone or masonry veneer is another significant portion of Section R507.2.1.

> **R507.2.4 Deck lateral load connection.** *The lateral load connection required by Section R507.1 shall be permitted to be in accordance with Figure R507.2.3(1) or R507.2.3(2). Where the lateral load connection is provided in accordance with Figure R507.2.3(1), hold-down tension devices shall be installed in not less than two locations per deck, within 24 inches of each end of the deck. Where the lateral load connections are provided in accordance with Figure R507.2.3(2), the hold-down tension devices shall be installed in not less than four locations per deck, and each device shall have an allowable stress design capacity of not less than 750 pounds.*

This section essentially presents two options, or "permitted" details, for meeting the lateral load design required for a deck supported by a primary structure. The details are focused solely at transferring lateral loads beyond the ledger support, and do not address other lateral load concerns such as the deck diaphragm, transfer of lateral loads through other deck supports and into the foundation, and lateral bracing that may be required between posts and the deck floor joists/beams. If considering an alternate method it is important to note that both permitted details were developed to deliberately bypass the joist hanger and ledger in the lateral load path – both of which are designed to resist gravity loads primarily.

**Posts**

> **R507.7.1 Deck post to deck beam.** *Deck beams shall be attached to deck posts in accordance with Figure R507.7.1 or by other equivalent means capable to resist lateral displacement. Manufactured post-to-beam connectors shall be sized for the post and beam sizes. All bolts shall have washers under the head and nut.* ***Exception:*** *Where deck beams bear directly on footings in accordance with Section R507.8.1.*

> **R507.8 Deck posts.** *For single-level wood-framed decks with beams sized in accordance with Table R507.6, deck post size shall be in accordance with Table R507.8.*

Deck post height limits are based upon the axial capacity of each post size, supporting the maximum tributary area of floor framing. Notching a post is only permitted for the case shown in Figure R507.7.1. An alternate detail of bolting a beam to the face of the post, does not meet IRC requirements for providing bearing to the beam.

**Footings**

> **R507.8.1 Deck post to deck footing.** *Posts shall bear on footings in accordance with Section R403 and Figure R507.8.1. Posts shall be restrained to prevent lateral displacement at the bottom support. Such lateral restraint shall be provided by manufactured connectors installed in accordance with Section R507 and the manufacturers' instructions or a minimum post embedment of 12 inches in surrounding soils or concrete piers.*

*IRC* Section R403 should be referenced for the design of concrete footings, or alternately be designed in accordance with ACI 332. Minimum size, minimum depth, and frost protection, are amongst the provisions.

**Guards**

> **R312.1.1 Where required.** *Guards shall be located along open-sided walking surfaces, including stairs, ramps, and landings, that are located more than 30 inches measured vertically to the floor or grade below and point within 36 inches horizontally to the edge of the open side. Insect screening shall not be considered as a guard.*

> **R312.1.2 Height.** *Required guards at open-sided walking surfaces, including stairs, porches, balconies or landings, shall be not less than 36 inches in height as measured vertically above the adjacent walking surfaces or the line connection the leading edges of the treads.* **Exceptions:** *1. Guards on the open sides of stairs shall have a height not less than 34*

*inches measured vertically from a line connecting the leading edges of the treads. 2. Where the top of the guard serves as a handrail on the open sides of stairs, the top of the guard shall be not less than 34 inches as measured vertically from a line connecting the leading edges of the treads.*

**R312.1.3 Opening limitations.** *Required guards shall not have openings from the walking surface to the required guard height that allow passage of a sphere 4 inches in diameter.* **Exceptions:** *1. The triangular openings at the open side of stair, formed by the riser, tread and bottom rail of a guard, shall not allow passage of a sphere 6 inches in diameter. 2. Guards on the open side of stairs shall not have openings that allow passage of a sphere 4-3/8 inches in diameter.*

These sections establish a degree of safety for guards, in terms of required heights and limits for opening in the guard system, to safeguard against occupants falling from the deck surface or small children fitting through openings. Strength requirements are as listed in table R301.5; the IRC does not provide a prescriptive detail or details for a guard that meets the strength requirements.

Laboratory-tested guards typically have a target load to reach a factor of safety of 2.5. Research by Loferski et al. (2006) has shown that the leverage created by the live load at the top of a 4x4 guard post requires reinforcement of the connection between the post and the deck, beyond traditional fastening details. A number of proprietary guard options are available, with *ICC-ES AC273 – Handrails and Guards* guiding testing and evaluation for wood or steel systems, *ICC-ES AC174 – Deck Board Span Ratings and Guardrail Systems* for alternate materials such as wood plastic composites and PVC, and *ICC-ES AC439 – Glass Railing and Balustrade Systems* for glass.

**Stairs**

IRC Sections R311.7 should be reviewed in its entirety by the design professional, as the section covers the vast range of general stairway requirements, requirements for individual stair components, handrails, and requirement for illumination. Several provisions, such as limits to the variability of riser height and tread depth within a flight of stairs, serve to provide regularity to the user of the stair. Limitations for openings in risers and guards serve to protect small children. Requirements for handrails are important to provide the stair user with the option to hold onto a graspable object for the full length of the stair. A standard 2x4 or 2x6 rail cap does not meet the geometric requirements for a handrail to ensure graspability. The IRC appears to incorrectly refer to Section R303.7 for the important safety requirement of illumination, where Section R303.8 refers to illumination for an exterior stair.

**Summary and Future Direction**

The effort to establish and improve the code provisions for wood-framed decks is ongoing. Topics of interest include lateral loads, freestanding decks, ledger details, bracing between posts beams or joists, guard details, and any clarifications or simplifications to the existing code to aid in use and interpretation of the code. Development for the 2018 IRC is in progress and the DCC has several proposals that are being considered for adoption.

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*Acceptance Criteria for Joist Hangers and Similar Devices (AC13), ICC Evaluation Service.*

*Acceptance Criteria for Alternate Dowel-type Threaded Fasteners (AC233), ICC Evaluation Service.*

*Acceptance Criteria for Corrosion-resistant Fasteners and Evaluation of Corrosion Effects of Wood Treatment Chemicals (AC257), ICC Evaluation Service.*

*Acceptance Criteria for Flexible Flashing Materials (AC148), ICC Evaluation Service.*

*Acceptance Criteria for Deck Board Span Ratings and Guardrail Systems (AC174), ICC Evaluation Service.*

*Acceptance Criteria for Handrails and Guards (AC273), ICC Evaluation Service.*

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# Select Engineering Topics Related to the Prescriptive Residential Wood Deck Construction Guide DCA 6 - 2012 IRC Version International Residential Code Requirements for Wood-Framed Decks

*Buddy Showalter P.E., Loren Ross P.E.*

**Introduction**

According to recent industry reports, 6,500 people have been injured from collapsing balconies and decks in the United States since 2003. Complicating matters for existing homes, the North American Deck and Rail Association (NADRA) estimates there are 40 million decks in America that are more than 20 years old. This means these decks were installed prior to today's building codes.

To encourage compliant deck design and construction, the American Wood Council published *Design for Code Acceptance No. 6 – Prescriptive Residential Wood Deck Construction Guide* (DCA 6). The latest version reflects new requirements in the International Code Council's (ICC) *2012 International Residential Code (IRC)* and other new provisions pertaining to single-level residential wood deck construction. DCA-6 can be found at http://www.awc.org/codes-standards/publications/dca6.

The DCA 6 Commentary follows the same organization as DCA 6. The DCA 6 Commentary provides background information intended to give the reader an understanding of the data and/or experience upon which the provision is based. One or more examples of the calculation procedures used to produce several of the tables are given to illustrate the scope of conditions covered by the table.

Engineers may be called upon to design decks or certain portions of them. They may also be involved in inspection and retrofit activities related to residential wood decks. The purpose of this article is to highlight certain engineering topics related to DCA 6 and provide some of the background for those issues. Much of the information is taken from the DCA 6 Commentary. Sections of this article are keyed to similar sections of DCA 6 for ease of use.

**Minimum Requirements and Limitations**

DCA 6 applies to single level residential wood decks only. Multi-level decks create additional variables such as concentrated loads due to stairs. Structural members and connections shown in DCA 6 have been sized based primarily on a uniformly distributed floor live load of 40 psf and a dead load of 10 psf (table footnotes specify where other point loads have been considered). If a deck is not prone to sliding or drifting snow, the criteria in DCA 6 can be conservatively applied to a deck with a uniformly distributed snow load of 40 psf and a 10 psf dead load. Concentrated loads such as those created by hot tubs are beyond the scope of DCA 6 and require a design professional or other approved installation approach. All decks prescribed in DCA 6 assume the primary structure resists lateral forces per Section R507.2.3 of the IRC.

Smooth shank nails are prone to "backing out" of wood due to moisture cycling. Deformed-shank nails, which are specified in DCA6, include helical (spiral) and annular (ring-shank) nails as defined in ASTM F 547. Reference design values for post-frame ring shank nails in accordance with ASTM F1667 are provided in the *2012 National Design Specification® (NDS®) for Wood Construction*.

When subjected to standardized laboratory tests that accelerate the corrosion process, metal connectors and fasteners exposed to the chemicals used in certain preservative treatments exhibit high rates of corrosion. Users should rigorously apply recommendations of the chemical manufacturers and the treating industry – to use corrosion resistant fasteners and connectors or zinc coated (galvanized) fasteners and connectors with corrosion protection at least equivalent to that of hot-dip galvanized products. Additional information is available from various sources including: http://awc.org/faqs/materials/connections/where-can-i-find-information-about-corrosion-of-fasteners

FEMA TB8-96, *Technical Bulletin 8, Corrosion Protection of Metal Connectors in Coastal Areas*, recommends that stainless steel fasteners be used in areas exposed to salt water.

**Decking Requirements**

Alternate decking materials or alternate methods of fastening decking to joists can have a critical impact on the resistance of lateral loads. Equivalent strength and stiffness developed by alternative materials and fastening methods is important to ensure adequate lateral capacity. An example is the use of "hidden" fasteners for edge-grooved decking material. As shown in the product overview of one such fastening system: "These fasteners create a fast and simple way to install your deck and create a smooth deck surface, uninterrupted by visible screws or nails." The potential problem with this type of fastener system is that the deck boards would provide very little to no diaphragm capacity or stiffness for the deck with respect to lateral loads. As discussed in the Deck Lateral Loads section below, decking can provide diaphragm capacity and stiffness, but those strength and stiffness values assume face nailing of the decking into framing.

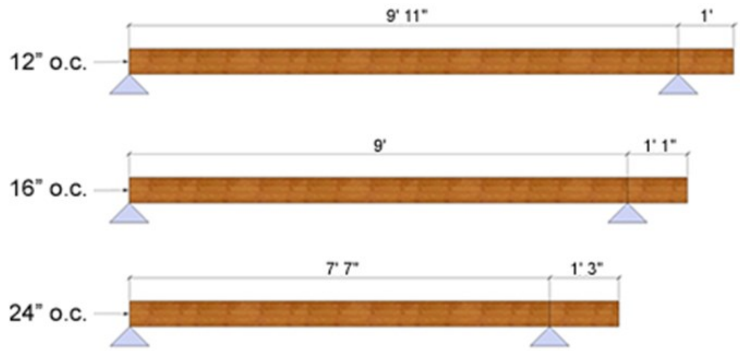


**Figure 1. Comparison of Overhang Lengths For Southern Pine 2x6 Joists With Different Joist Spacings**

**Joist Size**

Span calculations in Table 1 (a reprint of Table C2 from DCA-6) assume a 40 psf live load, 10 psf dead load, *L*/360 deflection limit for simple spans, No. 2 grade lumber, and wet service conditions. Overhang (cantilevers) calculations assume *L*/180 cantilever deflection with a 220 lb point load (same as used for span rated decking), No. 2 grade lumber, and wet service conditions. IRC Table R301.7 states that *L* is taken as twice the length of the cantilever, so the *L*/360 limit becomes L/180 with L being the cantilever length.

The format of Table 2 changed in the 2012 version. An allowable simple span is given, and then an allowable overhang for that span is calculated. The calculated allowable overhang is limited by the governing bending moment, deflection caused by the 220 lb point load, or by

**Table 1. Reprint of Table C2 from DCA-6.**

**Table C2. Conditions Where Deflection Controls Overhang Length*.**

| | | Joist Spacing (o.c.) | | |
|---|---|---|---|---|
| | | 12" | 16" | 24" |
| Species | Size | Allowable Overhang[3] ($L_O$) | | |
| Southern Pine | 2x6[6] | 1' - 0" | 1' - 1" | 1' - 3" |
| | 2x8 | 1' - 10" | 2' - 0" | 2' - 4" |
| | 2x10 | 3' - 1" | 3' - 5" | 2' - 10" |
| | 2x12 | 4' - 6" | 4' - 2" | 3' - 4" |
| Douglas Fir-Larch, Hem-Fir, Spruce-Pine-Fir[4] | 2x6[6] | 0' - 11" | 1' - 0" | 1' - 2" |
| | 2x8 | 1' - 8" | 1' - 10" | 2' - 2" |
| | 2x10 | 2' - 10" | 3' - 2" | 2' - 9" |
| | 2x12 | 4' - 4" | 3' - 11" | 3' - 3" |
| Redwood, Western Cedars, Ponderosa Pine[5], Red Pine[5] | 2x6[6] | 0' - 9" | 0' - 10" | 0' - 11" |
| | 2x8 | 1' - 5" | 1' - 7" | 1' - 9" |
| | 2x10 | 2' - 5" | 2' - 7" | 2' - 8" |
| | 2x12 | 3' - 7" | 3' - 9" | 3' - 1" |

* Shading indicates overhand is deflection controlled. See Table 2 for footnotes.

a maximum cantilever span of one fourth of the back span ($L/4$). The 220 lb point load always produces a larger moment and deflection than the uniform load. The shaded cells in Table C2 indicate where deflection controls overhang length. Unshaded cells indicate that the overhang length is controlled by the $L/4$ maximum.

Note that for a given joist size, the overhang span sometimes increases as joist spacing increases. As noted previously, a uniform load on the joist never determines the allowable span of the overhang. In DCA 6, deflection due to the point load or ¼ the length of the main span (whichever controls) limit the length of the overhang. Under a single point load, deflection at the overhang decreases as the main span decreases. Thus for many cases in the table, allowable overhang spans decrease because the allowable main spans increase. Where it appears that the overhang spans are inconsistent with the joist spacing, the increased deflection of the overhang is controlling. Where the overhang deflection does not control, the overhang spans are limited to 1/4 the main span and appear consistent with the joist spacing. For example, the three joists below are the maximum allowable spans for Southern Pine 2x6 joists, which are all deflection controlled. While the allowable overhang span increases as joist spacing increases (widens), the main span decreases in length, which adds to the stiffness of the overhang. Overall deck length is increased by closer joist spacing.

**Beam Size And Assembly Requirements**

Deck beam spans can extend past the post up to LB/4. Beams are sized based on tributary load from joists framing in from one side only within the span limits shown. With appropriate assumptions, DCA 6 can be used to size beams with joists spanning from both sides. Since tabulated values for beams assume ½ of the joist span to calculate tributary area, using 2 times the joist span for cases where joists span symmetrically (equal joist spans) from opposite sides is acceptable. For example, assume there are 8'-0" joists spanning from opposite sides of the same beam. The column in DCA 6 Table 3 labeled for 16'-0" joist spans can be used to size a beam in this case. A similar procedure is required for footing sizes.

Glued-laminated timber beams are required to be treated with oil-based preservatives in accordance with AWPA U1. When these preservatives are used, the glued-laminated timber industry recommends that the NDS wet service factor ($C_M$) not be used in this specific outdoor application; therefore, all glued-laminated timber beams have been designed using design values based on dry service conditions.

**Deck Framing Plan**

For resistance of lateral loads, the deck is assumed to act as a diaphragm in an open-front structure. The decking, when nailed to the joists and rim joist, acts as sheathing in this diaphragm. Larger aspect ratios may be permitted where calculations show that larger diaphragm deflections can be tolerated.

**Joist Hangers**

Research has shown that joist hanger to ledger connections resist lateral loads. When permitted by the hanger manufacturer, the use of screws instead of nails to attach hangers to the ledger can decrease the potential for the joist to pull away from the ledger.

**Post Requirements**

IRC section R407.3 specifies a minimum 4x4 (nominal) wood column size; however, it would often be overstressed in applications covered in DCA 6. Table C4A shows allowable 4x4 post heights for the loading conditions of DCA 6. Further, this simplification provides adequate bearing for beams. Note that notching the post to accommodate a nominal 3x, 4x, or 2-ply 2x beam exceeds notching limits for bending members, so if posts are embedded and designed to resist lateral load conditions, the post would need to be designed per the NDS. An option of 8x8 nominal posts allows for a deck height of up to 14' in all cases.

Prohibiting attachment of the beam to the sides of the post with fasteners only ensures wood-to-wood bearing. Design of fasteners for wet-service conditions requires significant capacity reductions and should be evaluated by a design professional.

For 3-ply 2 inch nominal beams, a post cap is required since the remaining cross section at the post notch would not be sufficient to provide adequate bearing of the beam on the column.

Provisions for Alternative Methods and Materials allow for other post sizes and post-to-beam connections if approved by the building official. For example, in order to use a 4x4 post, a post cap connection would be required. There is not enough cross sectional area in a 4x4 to permit the let-in notch detail. Connector hardware for a 4x4 post is generally limited to support of 2-ply 2 inch nominal or 4 inch nominal beams. Certain post caps may be adjusted to fit a 3-ply 2 inch nominal member onto a 4x4 post, but must be special ordered. Contact a connector manufacturer to determine if there are solutions for connecting a single 3 inch nominal member onto a 4x4 post.

Diagonal bracing can contribute to the stiffness of the deck and, therefore, cause additional lateral loads on the posts. Since center posts receive more vertical load than corner posts, additional lateral load can cause overstress. For this reason, DCA 6 does not show the use of diagonal bracing on center posts.

The lateral force applied to corner posts is based on the capacity of the connection at the brace. Therefore, the full capacity of the brace connection is assumed to be developed and applied 2 feet below the beam.

**Footings**

Footing sizes are based on the assumptions of 1,500 psf soil bearing capacity and 2,500 psi compressive strength of concrete which are the minimum values based on IRC Tables R401.4.1 and R402.2. See Table C4B for footing sizes with higher soil bearing capacities. A concrete weight of 150 pcf is also assumed, which makes solving for the footing size an iterative process. The following equations may be used to size footings for other assumptions (see Figure C12):

Post load (lbs):

$$R = 50\left(\frac{L_{Joist}}{2} + L_{Joist\ Overhang}\right)\left(L_{Beam}\right) + 150\frac{B*D*T}{1728}$$

where: L units are in feet and *B*, *D*, and *T* are in inches.

Square footing (in.): $$B = 12\sqrt{\frac{R}{(\text{soil capacity})}}$$

**Figure C12. Footing Dimensions and Variables.**

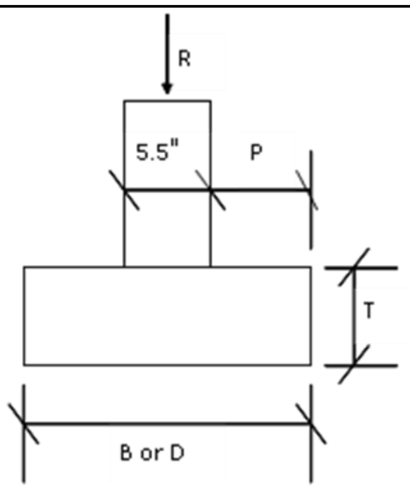


**Figure 3. Reprint of Figure C12 From DCA-6.**

**Table 2. Reprint of Table C4A from DCA-6**

**Table C4A. 4x4 Post Heights.**

| Beam Span, $L_B$ | Joist Span $L_J$ | Post Heights[1] Southern | Douglas Fir-Larch[3] | Hem-Fir[3], Western Cedars | Redwood | Ponderosa Pine, Red Pine, SPF[3] |
|---|---|---|---|---|---|---|
| 6' | <10' | 4' | 2' | 3' | 4' | 3' |
| | <14' | 3' | 2' | 2' | 3' | 2' |
| | <18' | 2' | 2' | 2' | 2' | 2' |
| 8' | <10' | 3' | 2' | 2' | 4' | 2' |
| | <14' | 2' | 2' | 2' | 3' | 2' |
| | <18' | 2' | 2' | 2' | 2' | 2' |
| 10' | <10' | 3' | 2' | 2' | 3' | 2' |
| | <14' | 2' | 2' | 2' | 2' | 2' |
| | <18' | 2' | 2' | 2' | 2' | 2' |
| 12' | <10' | 2' | 2' | 2' | 2' | 2' |
| | <14' | 2' | 2' | 2' | 2' | 2' |
| | <18' | 2' | 2' | 2' | 2' | 2' |
| 14' | <10' | 2' | 2' | 2' | 2' | 2' |
| | <14' | 2' | 2' | 2' | 2' | 2' |
| | <18' | 2' | 2' | 2' | 2' | NP |
| 16' | <10' | 2' | 2' | 2' | 2' | 2' |
| | <14' | 2' | 2' | 2' | 2' | 2' |
| | <18' | 2' | 2' | 2' | 2' | NP |
| 18' | <10' | 2' | 2' | 2' | 2' | 2' |
| | <14' | 2' | 2' | 2' | 2' | NP |
| | <18' | 2' | 2' | NP | 2' | NP |

**Table 3. Reprint of Table C4B from DCA-6**

**Table C4B. Footing Sizes for Higher Soil Bearing Capacities.**

| Beam Span, $L_B$ | Joist Span $L_J$ | 2000 psf Round Footing Diameter | 2000 psf Square Footing | 2000 psf Footing Thickness[4] | 2500 psf Round Footing Diameter | 2500 psf Square Footing | 2500 psf Footing Thickness[4] | 3000 psf Round Footing Diameter | 3000 psf Square Footing | 3000 psf Footing Thickness[4] |
|---|---|---|---|---|---|---|---|---|---|---|
| 6' | ≤10' | 15" | 13"x13" | 6" | 14" | 12"x12" | 6" | 12" | 11"x11" | 6" |
| | ≤14' | 18" | 16"x16" | 7" | 16" | 14"x14" | 6" | 15" | 13"x13" | 6" |
| | ≤18' | 20" | 18"x18" | 8" | 18" | 16"x16" | 7" | 16" | 15"x15" | 6" |
| 8' | ≤10' | 17" | 15"x15" | 6" | 16" | 14"x14" | 6" | 14" | 13"x13" | 6" |
| | ≤14' | 21" | 18"x18" | 8" | 18" | 16"x16" | 7" | 17" | 15"x15" | 6" |
| | ≤18' | 23" | 21"x21" | 9" | 21" | 18"x18" | 8" | 19" | 17"x17" | 7" |
| 10' | ≤10' | 19" | 17"x17" | 7" | 17" | 15"x15" | 6" | 16" | 14"x14" | 6" |
| | ≤14' | 22" | 21"x21" | 9" | 20" | 18"x18" | 8" | 19" | 17"x17" | 7" |
| | ≤18' | 26" | 23"x23" | 11" | 23" | 21"x21" | 9" | 21" | 19"x19" | 8" |
| 12' | ≤10' | 21" | 19"x19" | 8" | 19" | 17"x17" | 7" | 17" | 15"x15" | 6" |
| | ≤14' | 25" | 22"x22" | 10" | 22" | 20"x20" | 9" | 20" | 18"x18" | 8" |
| | ≤18' | 29" | 26"x26" | 12" | 26" | 23"x23" | 11" | 23" | 21"x21" | 9" |
| 14' | ≤10' | 23" | 21"x21" | 9" | 20" | 18"x18" | 8" | 19" | 17"x17" | 7" |
| | ≤14' | 27" | 24"x24" | 11" | 24" | 22"x22" | 10" | 22" | 20"x20" | 9" |
| | ≤18' | 31" | 28"x28" | 13" | 28" | 24"x24" | 12" | 25" | 22"x22" | 10" |
| 16' | ≤10' | 25" | 22"x22" | 10" | 22" | 19"x19" | 9" | 20" | 18"x18" | 8" |
| | ≤14' | 29" | 26"x26" | 12" | 26" | 23"x23" | 11" | 24" | 21"x21" | 10" |
| | ≤18' | 33" | 30"x30" | 14" | 30" | 26"x26" | 13" | 27" | 24"x24" | 11" |
| 18' | ≤10' | 26" | 23"x23" | 11" | 23" | 21"x21" | 9" | 21" | 19"x19" | 8" |
| | ≤14' | 31" | 28"x28" | 13" | 28" | 24"x24" | 12" | 25" | 22"x22" | 10" |
| | ≤18' | 36" | 32"x32" | 16" | 31" | 28"x28" | 13" | 28" | 25"x25" | 12" |

Round footing (in.): $$D = 12\sqrt{\frac{4R}{(\text{soil capacity})\pi}}$$

Footing thickness (in.): $T \geq P$ $$T \geq \frac{D-5.5}{2}$$

DCA 6 Table 4 Footnote 2 allows for the footing thickness and size to be reduced for corner posts since the tabulated values assume center posts, which resist more vertical load. The factor is 0.9 instead of 0.5 because of additional load applied from the diagonal (knee) brace.

Additional footing options were added to the 2012 version of DCA 6 Figure 12. One allows for a 12" diameter concrete stem to reduce the amount of concrete required. The second provides an option for a fully embedded post in concrete with a gravel base to allow for water drainage.

**Ledger Attachment Requirements**

Fastener spacing requirements in DCA 6 are based on 2012 IRC R507.2.1, which is based on testing at Virginia Tech and Washington State University (Carradine et al., 2006). Designers should note that this empirical approach allows for greater fastener spacing than can be calculated per the NDS. It also allows for the use of lag screws that don't meet the minimum fastener penetration requirements into the main member for lag screws.

According to IRC R311.3.1, the distance from the top of the threshold to the top of deck boards cannot exceed 1½". If a door does not swing over the landing or deck, the step-down can be up to 7¾". The ledger can be lowered for improved drainage, subject to meeting maximum step-down heights for accessibility and means of egress, edge distance and spacing requirements, and shear design at connection requirements of NDS 3.4.3.3 (a).

The basis for edge distances and spacing between rows is NDS Tables 11.5.1C and 11.5.1D, respectively, for perpendicular to grain conditions. Per NDS Table 11.5.1C, edge distance is 4*D* (where *D* is fastener diameter) for the loaded edge. For ½" diameter bolts, 4*D* = 2" edge distance.

Per NDS Table 11.5.1D, spacing between rows is based on the $\ell$ / *d* ratio of the fastener. For a 1½" ledger and rim board, $\ell$ / *d* = 1½" / ½" = 3 and the minimum spacing is (5$\ell$ + 10*D*) / 8 = 1-9/16" – this is rounded up to 1-5/8". Per 11.5.1.3 of the NDS, the maximum spacing between fasteners is 5". This requirement is based on potential shrinkage of the ledger which could create tension perpendicular to grain stresses if the outer edges of the ledger are constrained by bolts.

The requirement for minimum distance between the top of the ledger and the bottom row of fasteners is based on NDS 3.4.3.3(a) for shear design at connections. When the connection is less than five times the depth, *5d*, of the bending member from its end, the adjusted design shear is calculated as follows:

$$V_r' = \left[\frac{2}{3}F_v' b d_e\right]\left[\frac{d_e}{d}\right]^2$$

Solving for $d_e$ yields the following:

$$d_e^3 = 3\ V_r\ d^2\ /\ (2\ F'_v\ b)$$

Assuming a Hem-Fir No. 2 ledger, the reference horizontal shear design value, $F_v$ = 150 psi. The adjusted shear design value, $F'_v$, is based on a wet service factor, $C_M$ = 0.97, and incising factor, $C_i$ = 0.80. The maximum allowable lateral design value of 725 lbs for ½" bolts and 385 lbs for ½" lag screws - is based on testing at Virginia Tech and Washington State University (Carradine et al., 2006). Spacing calculations assume that bolts or lag screws at the end of the ledger have half the tributary area of interior bolts or lag screws and that the shear at interior bolts or lag screws is half of the interior bolt or lag screw reaction. Therefore, the minimum value of de is calculated assuming $V_r$ equals one-half of the allowable lateral design value for the ½" bolts (725/2 lbs) or ½" lag screws (385/2 lbs). Resulting values of de are as follows:

| | ½" bolts | ½" lags |
|---|---|---|
| 2x8 | $d_e$ = 5.47" | $d_e$ = 4.43" |
| 2x10 | $d_e$ = 6.43" | $d_e$ = 5.21" |
| 2x12 | $d_e$ = 7.33" | $d_e$ = 5.9" |

The problem with these effective depths is that a 2x8 ledger connected to a 2x8 band joist with bolts will not work (see Figure C19).

Possible solutions for the 2x8 band joist include:

1) Non-ledger deck.
2) Require lag screws for 2x8 band joist and revise required $d_e$ = 4½".
3) Allow bolted connections for 2x8 band joist if bolt spacing is reduced to the same as that for lag screws (only applies to ½" bolts without stacked washers as shown in Table C5).

**Figure C19. Edge Distance and Spacing Requirements for 2x8 Band Joist and 2x8 Ledger.**

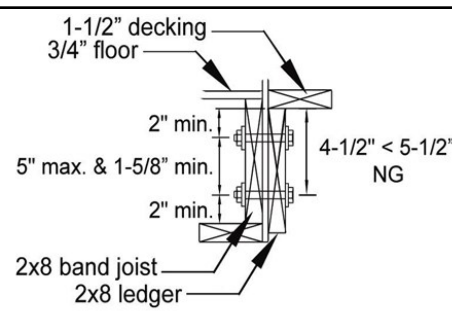


**Figure 3. Reprint of Figure C19 From DCA-6.**

4) Reduce bolt spacing requirements for 2x8 ledger to 2x8 band joist. When $d_e$ = 4.5", $V_r$ = 202 lbs, and the back-calculated adjustment factor is 0.56. Based on DCA 6 Table 2, the maximum joist span for a 2x8 is 10'-6". This results in revised spacing for ½" bolts as shown in Table C5.

**Table 4. Reprint of Table C5 From DCA-6**

**Table C5. Revised Bolt Spacing Requirements for 2x8 Ledgers to 2x8 Band Joists.**

| | Joist Span | | | |
|---|---|---|---|---|
| | **6'-0" & less** | **6'-1" to 8'-0"** | **8'-1" to 10'-0"** | **10'-1" to 12'-0"** |
| ½" bolt | 32" | 24" | 19" | 16" |
| ½" bolt with ½" stacked washers | 27" | 20" | 16" | 13" |

To achieve the minimum spacing requirements noted above, a nominal 2x8 ledger is required even if the deck joists are 2x6's.

Connection of ledgers to existing empty or hollow masonry cell blocks is generally not practical because most manufacturers of concrete block anchors do not publish allowable shear values for a ledger connected to empty hollow masonry block of unknown compression and breakout strength. Due to the uncertainty and lack of test data for this application, use of a non-ledger deck is recommended for this application.

### Non-Ledger Decks — For Resisting Vertical Loads

The provisions of DCA 6 assume that the primary structure is used for lateral stability. A non-ledger deck, as defined in DCA 6, is vertically independent of the primary structure but still relies on the primary structure to resist lateral loads; whereas, a free-standing deck is both vertically and laterally independent.

### Deck Lateral Loads

The IRC currently does not state the design lateral loads for decks, but it does provide an approved design, which DCA 6 incorporates. DCA 6 states that the document does not address lateral stability issues beyond those addressed in Section R507.2.3 of the IRC. IRC R507.1 requires anchorage of the deck to the primary structure to resist lateral loads. Further, the IRC includes hold-down tension devices as a prescriptive means to achieve compliance with the lateral load connection requirements without requiring engineering (see IRC Section R507.2.3). In lieu of the prescriptive 1,500 lb hold-down tension device specified, an alternate engineered connection detail would be required. To ensure transfer of tension device loads into the floor diaphragm, DCA 6 shows nailing from above through floor sheathing and into floor joists or blocking between floor joists of the house. An equivalent connection from underneath is permissible using framing angles and short fasteners to penetrate into the floor sheathing.

Decks are assumed to be similar to open-front structures defined in the *Special Design Provisions for Wind and Seismic (SDPWS).* Decks covered in DCA 6 are assumed to be diaphragms that cantilever from the house and are limited to a deck length-to-width ratio of 1:1. Larger aspect ratios may be permitted where calculations show that larger diaphragm deflections can be tolerated. Designers should also note that diagonal sheathing (deck boards at 45 degrees to the joists) provide a much stronger and stiffer diaphragm. A comparison of diagonal lumber sheathing versus horizontal sheathing (boards perpendicular to joists) in SDPWS Table 4.2D reveals a four-fold stiffness increase for diagonal sheathing.

For non-ledger decks, DCA 6 prescribes three methods of transferring lateral loads from deck joists to the rim board: joist hangers, blocking, or use of framing angles. This connection is to transfer forces acting parallel to the house. A connection equal to the diaphragm capacity of single layer diagonal boards, or approximately 300 plf, is required.

Diagonal (knee) bracing is commonly used on decks to help resist lateral forces and provide increased stiffness; however, the IRC does not prescribe diagonal bracing.

### Guard Post Attachments for Required Guards

Both the IRC and International Building Code (IBC) specify that guardrails and handrails be capable of resisting a minimum concentrated live load of 200 lbs applied in any direction for required guard rails (See IRC R312.1). Commonly used residential guardrail post connections were laboratory tested at the required load level for a code-conforming assembly per the IBC (Loferski et al., 2006). A commercially available connector, typically used in shear wall construction, was tested in a post-to-deck residential guardrail assembly. The connection passed a load test based on code provisions for a "tested assembly." Connection details in DCA 6 reflect these test results.

A minimum requirement of 1,800 lbs for the hold-down connector ensures adequate capacity (Loferski et al., 2005) for a 36" maximum rail height. A higher rail height requires design of a higher capacity connector. Manufacturers' tabulated values for hold-down connectors typically include a load duration ($C_D$) increase of 60% since connectors for shear walls are used to resist wind and seismic loads. The 200 lbs concentrated load requirement for guard rails is assumed to be a 10 minute load duration (e.g. it would not see a maximum 200 lbs outward load for more than 10 minutes cumulatively in its lifetime). Therefore, $C_D$=1.6 is used for hold-downs in this application.

This section requires deck guard posts to be at least 4x4 nominal with a reference bending design value not less than 1,100 psi to ensure sufficient bending stress in the post. Assuming the lever arm is 39.5" (36" + 1½" deck board + 2" edge distance), the bending moment is 39.5" x 200 lbs = 7,900 in-lbs. Bending stress, $f_b$, is calculated as follows:

M/S(4x4) = 7,900 in-lbs / 7.146 in$^3$ = 1,106 psi.

No. 2 grades of all DCA 6 species meet this requirement with the following assumptions. The adjusted bending design value, $F'_b$, is based on a wet service factor, $C_M$ = 0.85, and incising factor, $C_i$ = 0.80 (Douglas Fir-Larch, Hem-Fir, Spruce-Pine-Fir). A load duration factor, $C_D$ = 1.6, is assumed for consistency with the hold-down device used to connect the guard to the joist.

DCA 6 shows minimum and maximum spacing requirements for bolts in deck joists and deck rim boards. The 5" maximum spacing is per NDS 11.5.1.3. This requirement is based on potential shrinkage of the joist or rim board which could create tension perpendicular to grain stresses if the outer edges of the deck joist or rim are constrained by bolts. To achieve the minimum spacing requirements, a nominal 2x8 or wider (deeper) outside joist or rim board is required.

**Stair Requirements**

DCA 6 shows 5/4 boards spanning 18" or less. Specific products classified by size as decking are usually assigned a recommended span of 16" or 24". Additionally, IRC Table R301.5 footnote(c) requires a 300 lb concentrated load check on stair treads. Analysis revealed that 2x8 No. 2 Southern Pine works for a 34½" span (36" minus ¾" bearing at each end) when the 300 lbs is distributed across 2 inches (e.g. 150 pli), based on L/288 deflection criteria (ICC ES Acceptance Criteria 174 requires 1/8" deflection limit: 36" / 1/8" = 288). No species referenced in DCA 6 will calculate for that span using 2x6 No. 2 grade.

Solid stringers were analyzed as simple span beams using the horizontal span not the actual stringer length. Cut stringers were analyzed with 5.1" depth which is based on 7.75:10 rise to run ratio. A size factor, $C_F$, of 1.0 is used since 2x12 is the size basis.

**Stair Footing Requirements**

Stair stringers should be supported by bearing at the end where the stairway meets grade. The detail shown assumes a 40 psf live load and 10 psf dead load over a tributary area of 18" and one-half of the maximum span of 13'-3" permitted for solid stringers. This calculates to 500 lbs. For Southern Pine, seven #8 wood screws would be required. Northern Species would require eleven #8 wood screws (16d box or common threaded nails would be comparable).

While bolts are sometimes used for this detail, proximity to the end of the stringer could lead to splitting of the stringer – especially cut stringers. The 2x4 bearing block alleviates this situation. However, in addition to the bearing block, bolts would also be required to provide lateral support if a guard post is used.

**Table 5. Reprint of Table C7a From DCA-6**

**Table C7a. Maximum Distance "a" from Trimmer Joist End to a Point where a 6' Header Frames into a 2-ply Trimmer Joist.**

| Species | Trimmer Size | $a_{max}$ |
|---|---|---|
| **Southern Pine** | 2-2x6 | 15" |
| | 2-2x8 | 17" |
| | 2-2x10 | 19" |
| | 2-2x12 | 25" |
| **Douglas Fir-Larch, Hem-Fir, SPF[1]** | 2-2x6 | 11" |
| | 2-2x8 | 14" |
| | 2-2x10 | 16" |
| | 2-2x12 | 19" |
| **Redwood, Western Cedars, Ponderosa Pine[2], Red Pine[2]** | 2-2x6 | 10" |
| | 2-2x8 | 13" |
| | 2-2x10 | 16" |
| | 2-2x12 | 18" |

1. Incising assumed for Douglas Fir-Larch, Hem-Fir, and Spruce-Pine-Fir.
2. Design values based on Northern Species with no incising assumed.

**Table 6. Reprint of Table C7b From DCA-6**

**Table C7b. Maximum Trimmer Joist Span ($L_J$) Based on Distance "a" from the Trimmer Joist End to the Point where the Header Frames Into the Trimmer[1,4]**

| Ledger Species | Size | a = 1' | a = 2' | a = 3' |
|---|---|---|---|---|
| **Southern Pine** | 2x8[5] | 5' - 9" | 7' - 5" | 8' - 11" |
| | 2x10 | 9' - 2" | 10' - 11" | 12' - 7" |
| | 2x12 | 9' - 5" | 11' - 2" | 12' - 10" |
| **Douglas Fir-Larch, Hem-Fir, Spruce-Pine-Fir[2]** | 2x8[5] | 4' - 6" | 6' - 0" | 7' - 6" |
| | 2x10 | 6' - 10" | 8' - 6" | 10' - 1" |
| | 2x12 | 7' - 0" | 8' - 9" | 10' - 4" |
| **Ponderosa Pine[3], Red Pine[3], Redwood, Western Cedar** | 2x8[5] | 4' - 3" | 5' - 9" | 7' - 3" |
| | 2x10 | 6' - 5" | 8' - 1" | 9' - 8" |
| | 2x12 | 6' - 7" | 8' - 3" | 9' - 10" |

1. Assumes 6' header span. See Figure 35 for header, trimmer, and ledger framing details.
2. Incising assumed for Douglas Fir-Larch, Hem-Fir, and Spruce-Pine-Fir.
3. Design values based on Northern Species with no incising assumed.
4. Shading indicates where triple trimmers are required. See text for alternate 2-ply trimmer conditions.
5. Applies to 2x6 trimmer joist spans as well.

## Framing At Chimney or Bay Window

Where the header frames into the trimmer joist, a concentrated load is created. This condition was evaluated assuming one ply of a double trimmer joist carries the uniform load and one ply carries the point load from a 6' header. The analysis revealed that the distance from the end of the trimmer joist to the point where the header frames into it – designated as dimension "*a*" – must be limited. The maximum distance was calculated based on joist spans given in Table 2. A maximum distance of *a* = 3' was chosen to cover common framing conditions. Triple trimmer joists are required on each side of the header if joist spacing is 12" or 16" o.c., or if the trimmer joist span exceeds 8'-6"; otherwise a double trimmer joist is permitted. If "*a*" is less than that shown in Table C7a, a double trimmer joist is also permitted.

Bending and shear were checked to determine the reduction in a double trimmer joist span when carrying a 6' header. For a simple span beam, with a concentrated load offset from the center, maximum moment is calculated as $Pab/L$ and maximum shear is calculated as $Pb/L$, where $P$ is the concentrated load based on the tributary area carried by the header, $b = L - a$, and $L$ is the trimmer joist span.

Moment controlled for this analysis in determining $a_{max}$. While shear was evaluated, the NDS permits the shear load to be reduced within a distance "*d*" (equal to the joist depth) from the end of the joist. With that reduction, shear did not control any of the spans evaluated.

**Table 7. Reprint of Table C7c from DCA 6.**

**Table C7c. Trimmer Joist Hanger Vertical Capacity Based on Trimmer Span.**

| Trimmer Span | Minimum Capacity, lbs |
|---|---|
| 8' | 660 |
| 10' | 860 |
| 12' | 1060 |
| 14' | 1260 |
| 16' | 1325 |
| 18' | 1430 |

The trimmer hanger capacities listed in Table 7 are based on Southern Pine joist spans at 12" o.c. or 16" o.c. spacing (whichever controls). The reaction is a combination of the concentrated header load $Pb/L_J$ and the tributary uniform load between the trimmer and the next adjacent joist. Another way of tabulating trimmer hanger capacities is shown in Table C7c based on trimmer spans. Table C7c is based on the header framing into the trimmer at 1' ($a$=1', see Figure 35). Table C7c will be conservative for larger protrusions (larger "$a$" values.) Linear interpolation of tabulated values is permitted.

### *Trimmer Joist Span Limited by Concentrated Load on the Ledger*

Bolts or lag screws used to attach the trimmer hanger to the ledger are required to fully extend through the ledger into the band joist or rim board. If a typical face mounted hanger is installed where only nails are used to attach the hanger to the ledger, the ledger would carry a large portion of the load. Since a concentrated load would be created on the ledger, it would be resisted by the bolts at the end of the ledger. As discussed under Ledger Attachment Requirements, the provisions for minimum distance, $d_e$, between the top of the ledger and the bottom row of fasteners is based on NDS 3.4.3.3(a) for shear design at connections. Based on this analysis, trimmer joist lengths would need to be limited to the maximum trimmer joist spans shown in Table C7b, regardless of the trimmer joist species or number of plies. Since this analysis is based on a simple span trimmer joist, a trimmer joist with an overhang of up to $L_J/4$ would be conservative. The load on the end of the cantilever would reduce the reaction at the ledger.

### Examples

1) Assume a 2x10 Redwood joist spanning 12'-0" at 16" o.c. (per Table 2) framing around a 5' wide by 2'-6" deep chimney. Set a 6' header 3' from the end of the trimmer joist. A triple trimmer joist is required since the span exceeds 8'-6". If the trimmer hanger does not attach through the ledger to the rim board or band joist, the trimmer joist span is limited to 9'-8" per Table C7b. Several solutions exist:

- Reduce all joist spans to 9'-8".
- $L_J/4$ = 2'-5" so $L_J + L_J/4$ = 12'-1" total joist length, which would provide the same square footage.
- Place a post under the center of the header to reduce the header span.

2) Assume a 2x8 western cedar joist spanning 8'-0" at 24" o.c. (per Table 2) framing around a 5' wide by 1.5' deep bay window. Set a 6' header 2' from the end of the trimmer joist. A double trimmer joist is permitted since the spacing is 24" o.c. If the trimmer hanger does not attach through the ledger to the rim board or band joist, the trimmer joist span is limited to 5'-9" per Table C7b. Several solutions exist:

- Reduce all joist spans to 5'-9".
- Place a post under the center of the header to reduce the header span.
- Increase joist size to 2x10 which will span 8'-1" per Table C7b.

3) Assume a 2x12 southern pine joist spanning 18'-0" at 12" o.c. (per Table 2) framing around a 5' wide by 1'-6" deep bay window. Set a 6' header 2' from the end of the trimmer joist. A double trimmer joist is permitted since $a$ = 24" which is less than $a_{max}$ = 25" in Table C7a. However, if the trimmer hanger does not attach through the ledger to the rim board or band joist, the trimmer joist span is limited to 11'-2" per Table C7b. Several solutions exist:

- Reduce all joist spans to 11'-2".
- Place a post under the center of the header to reduce the header span.

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# Guard Loads for Wood Deck Design

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**Introduction**

The design and construction of guards in wood deck construction is a polarizing topic. There are wildly varying "solutions" to guard construction, ranging from manufactured guard assemblies, to those published by the American Wood Council in their Prescriptive Residential Wood Deck Construction Guide (DCA 6), to the variety of questionable suggestions found across the internet. The constructability of these various solutions is typically at odds with their ability to meet the requirements of the governing building code. This article focuses on the loads associated with guards in both the *2015 International Residential Code (IRC)* and the *2015 International Building Code (IBC)* and how guards do, or do not, resist those loads. While this article will focus on guards associated with deck construction, the requirements and arguments below apply to all guards in wood construction.

The Deck Code Coalition (DCC) was formed in 2013 to provide prescriptive deck specifications that are not provided in the IRC. The DCC is formed of building officials, representatives of industry associations and product manufacturers, design professionals, and academia. The most significant code change proposals were submitted to ICC in January 2016 for inclusion in the 2018 IRC and were reviewed at the ICC committee hearings in April of 2016. These code change proposals include several prescriptive details for connection of guard posts to wood deck framing. While the code change proposals regarding guards were recommended for disapproval by the IRC Building Committee in April 2016, the DCC has been hard at work revising the guard details through public comment for review again later this year. The author has worked with the DCC since 2015 developing prescriptive guard post connection details for the DCC code change proposals.

The 2015 IBC defines a guard as "a building component or a system of components located at or near the open sides of elevated walking surfaces that minimizes the possibility of a fall from the walking surface to a lower level." The definition of a guard in the 2015 IRC is very similar.

There are many types and configurations of guards. For clarity, this article will focus on guards comprised of guard assemblies that consist of top and bottom rails supporting balusters or infill panels and that transfer guard loads to the deck structure by way of guard posts. An important distinction is that, while both the IBC and IRC lump guards and handrails together in terms of their load criteria, not all guards include a handrail. The top rail of a guard assembly may be considered a handrail when the details allow it, however, a handrail is a "rail intended for grasping by the hand for guidance or support," and is not required in all locations where a guard may be required.

The IBC defines the loads associated with guards under Section 1607.7 Live Loads.

- Guards shall be designed to resist a linear load of 50 pounds per linear foot. As this load is defined as a Live Load, it must be included in all load combinations, such as those combinations that include both Live Load and Wind Load. There is an exception listed in the IBC, which requires only the concentrated load described below to be applied in the case of one- and two-family dwelling units.
- Guards shall be designed to resist a concentrated load of 200 pounds. While this load is defined in the Live Load section of the code, the Commentary in the 2015 IBC indicates that it is not to be combined with any other loads.

- Guards shall be designed to resist a concentrated load of 50 pounds applied over an area not to exceed one foot square on the intermediate rails or infill panel.

According to the IBC, all of the loads listed above are to be applied in accordance with Section 4.5.1 of ASCE 7-10. The first two loads are defined in ASCE 7 to be applied "in any direction at any point along the top." The third load is defined in ASCE 7 to be applied horizontally, over an area not to exceed one foot square.

Chapter 3 of the 2015 IRC defines the loads associated with guards as a single 200 pound concentrated load. As the IRC does not reference ASCE 7 with respect to the guard load, it defines the application as "a single concentrated load applied in any direction at any point along the top." Thus, for one- and two-family dwellings the load requirements for guards are the same in both the IBC and the IRC. While the IRC is a prescriptive code, there are currently no prescriptive details for guard assemblies available, therefore guard assemblies must be designed to meet the loads defined in Chapter 3.

**Comparison of IBC and IRC Provisions**

The important difference between the loads defined in IBC and IRC loads is the 50 plf uniform load (first bullet above). Because this load is applied uniformly along the top rail, the spacing of the guard posts determines the magnitude of the force that needs to be delivered from the guard posts to the deck framing. Where wood framed decks are constructed under the provisions of the IBC, the uniform load controls for posts spacing greater than 4ft on center.

**Application of Loads To Guards**

An important, and often misinterpreted, aspect of these guard loads is the application of the loads (uniform or concentrated) at the top of the guard, as defined in both ASCE 7 and the IRC. Regardless of whether evaluating the 200 pound concentrated load or the 50 plf uniform load, these loads are intended to be applied "in any direction." The "load in any direction" can be broken down to five cardinal load directions; outward, inward, upward, downward, and in-line.

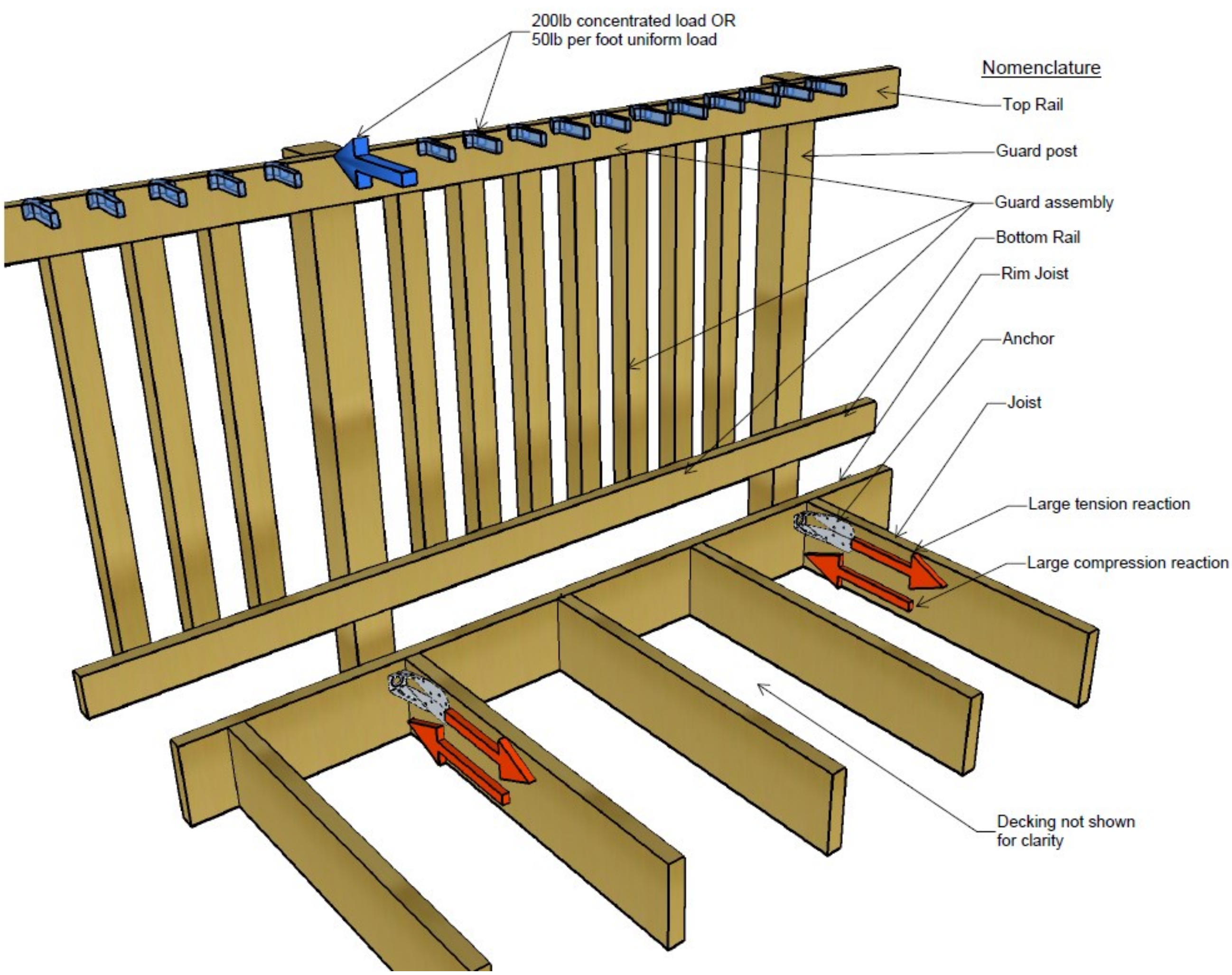


**Figure 1. Outward Load on Guard**

*Outward*

This is the most obvious load direction associated with guards and, in the author's experience, is the load that many people believe is the intent of the code. Outward load at the top of the guard creates a large force couple at the guard post base (Figure 1). In the case where a guard post is connected to a rim joist, the only way to successfully resist these forces is to deliver the load through the rim joist to the deck joists.

Manufactured guard assemblies are typically tested for this load condition. However, the connection of the guard post to the deck framing is not always included in the testing requirements, nor is the configuration of the deck framing that supports the guard known when the guard assemblies are being tested. If the guard assembly relies on a wood post fastened to the deck framing, it is rare that the connection of the post to the deck framing is defined by the guard assembly manufacturer.

The guard post details described in DCA 6 are adequate for this load direction for one- and two-family dwellings. Note that the post is mounted on the exterior of the deck framing. If the post were to be mounted on the interior of the joist/rim, this detail is no longer adequate for this load direction. Also note that DCA 6 is specifically for one- and two-family dwellings, where only the concentrated load is required and the top rail heights are limited to 36 inches above the walking surface.

*Inward*

An inward load is an obvious load when considering a handrail. It seems less obvious when considering a guard alone. In the author's experience, this load direction is typically not considered a load direction that is required for guards, unless a handrail is present. While this load direction would not appear to "minimize the possibility of a fall from the walking surface to a lower level," several testimonies during the ICC code

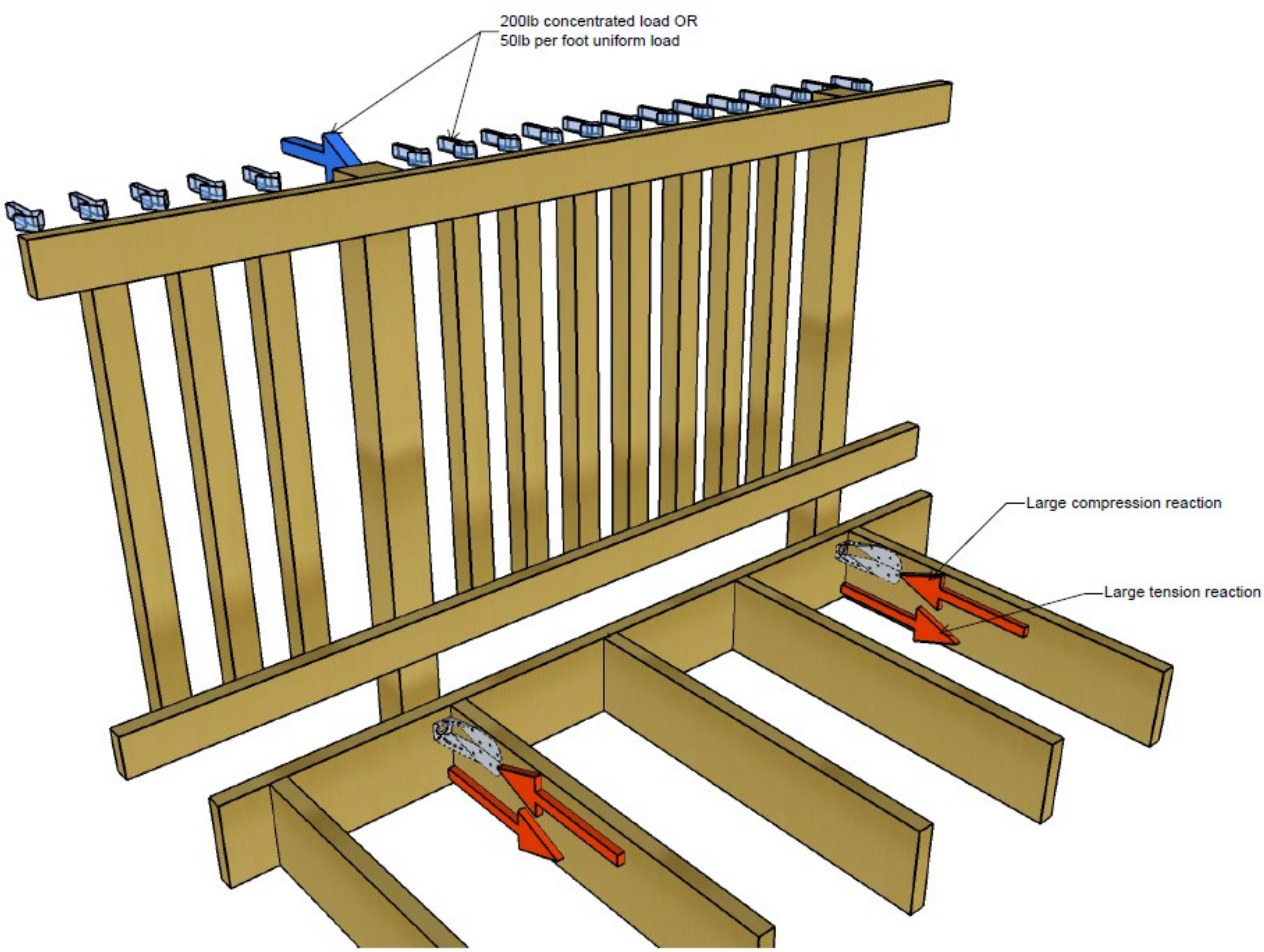


**Figure 2. Inward Load on Guard**

hearings in April 2016 stated that this load direction is as important as the outward load direction for preventing a fall. Inward load at the top of the guard creates a large force couple at the base, similar to the Outward load direction described above, but in the opposite direction (Figure 2).

Manufactured guard assemblies generally meet this load condition by virtue of the fact that their specimens and test set-ups are typically symmetrical. However, the framing of the deck structure supporting the guard is not included in the testing requirements. Therefore, if the connection of the guard post to the deck structure has an inherent directionality to its capacity, there is the potential that the detail would not be able to resist the loads in this direction. The guard post details described in DCA 6 have this directionality and are not adequate for the inward loads defined in either the IRC or the IBC. When using hardware to resist the force couple at the base of the guard post, there must be hardware associated with both the top and the bottom forces.

***Downward***

This is another obvious load direction associated with guards and, in the author's experience, this load is typically considered by designers and builders. Manufactured guard assemblies are typically tested for this load direction.

Downward forces applied at the top of the guard are transferred to the posts through various methods, but typically rely on both the infill panel, or balusters, and the bottom rail to aid in the load transfer. Many guard assemblies increase their maximum guard post spacing by adding foot blocks under the bottom rail between guard posts to achieve the required load resistance in this direction (Figure 3). The loads at the base of the guard posts, or at the foot blocks, are generally small and the connection of the guard to the deck framing is easy to accomplish.

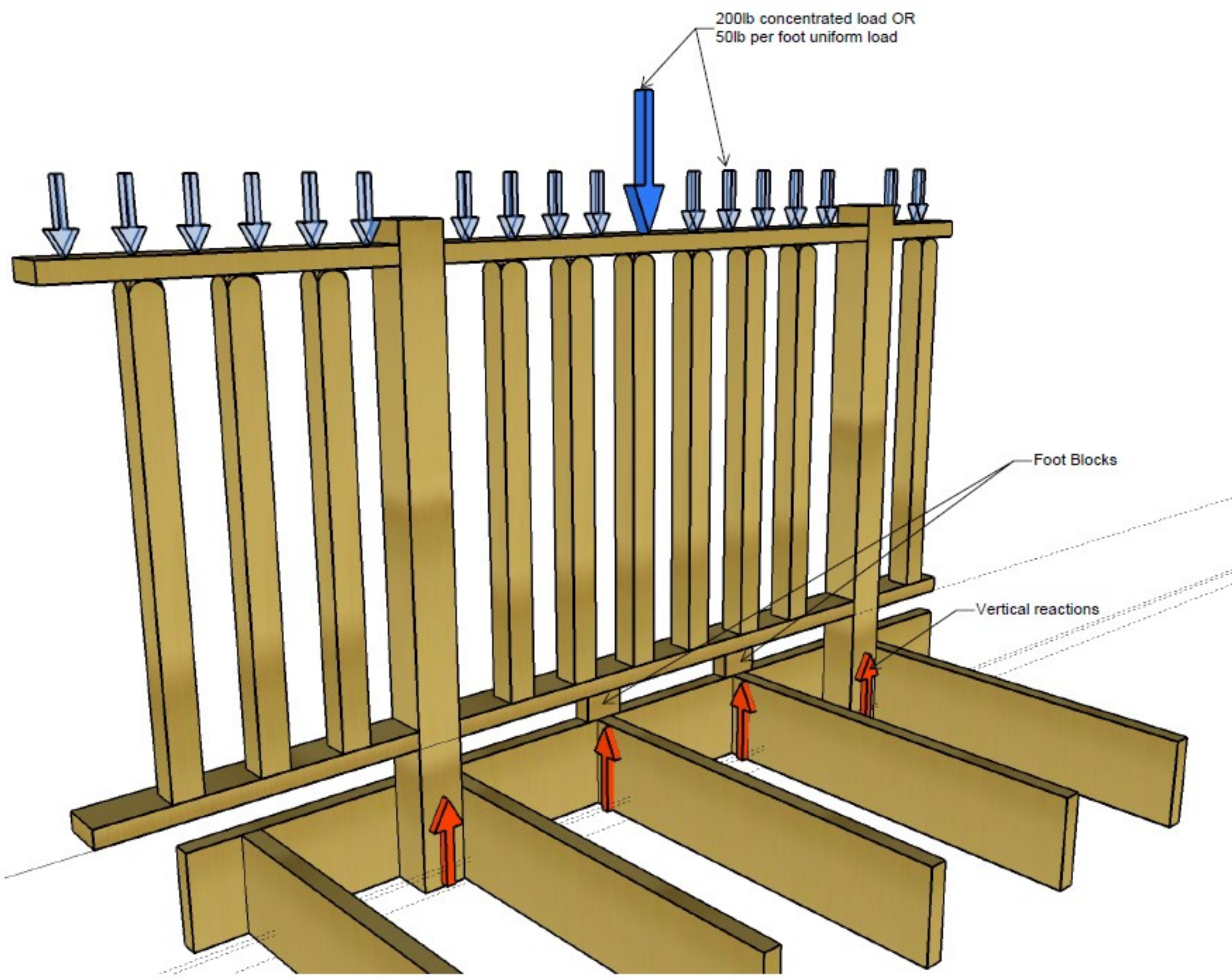


**Figure 3. Downward Load on Guard**

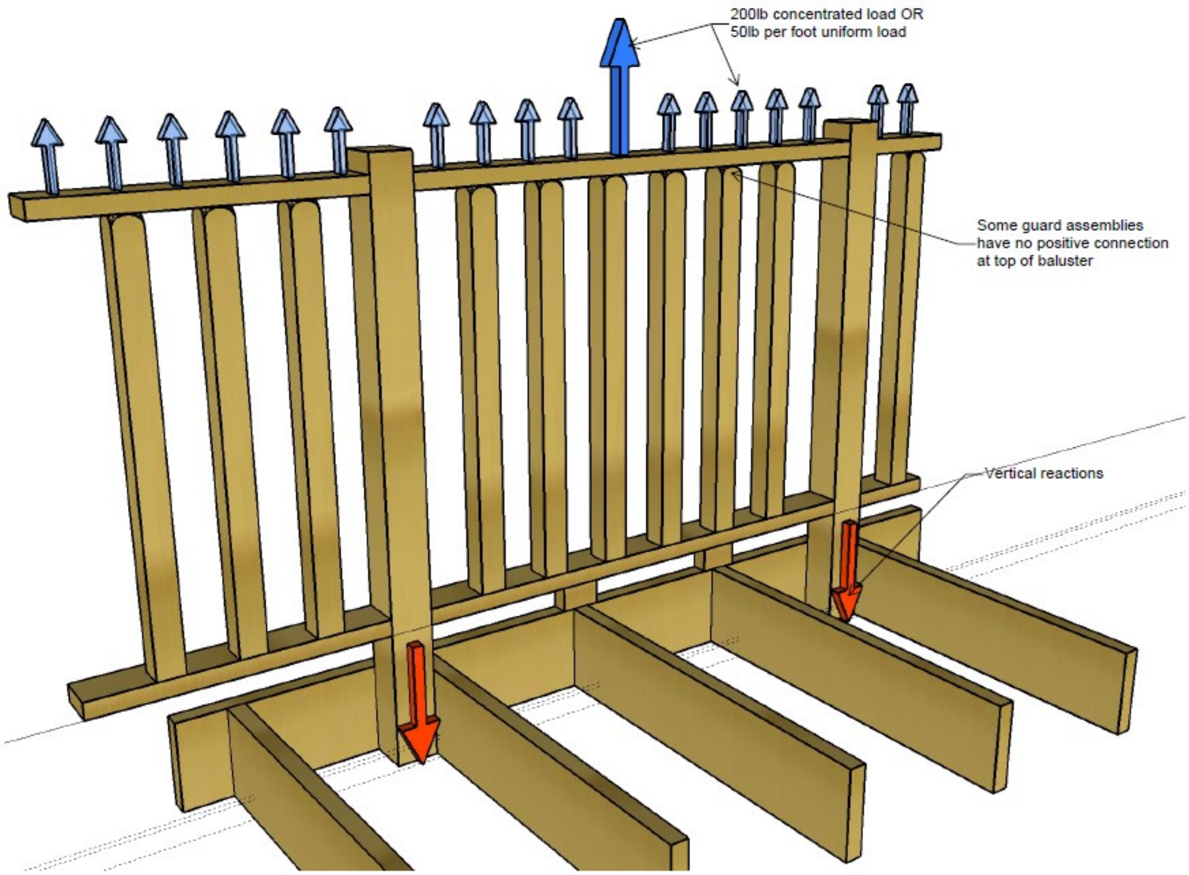


**Figure 4. Upward Load on Guard**

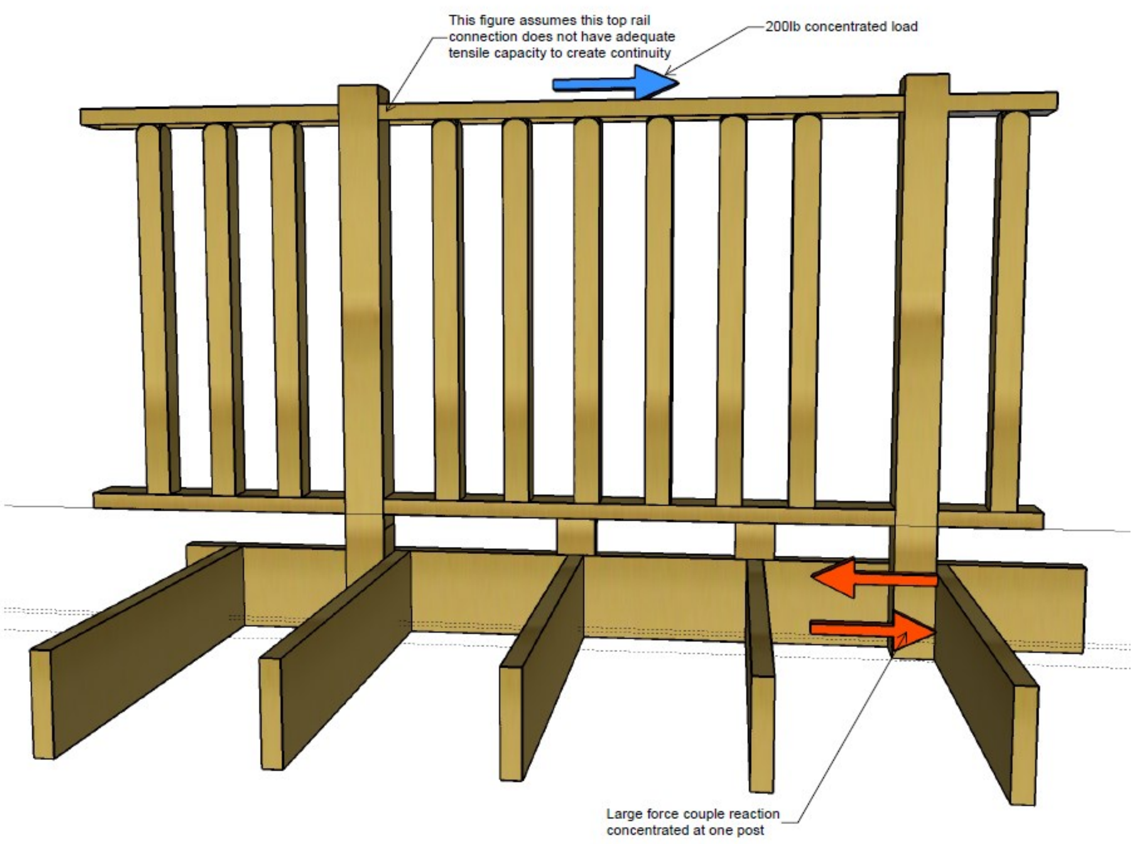


**Figure 5. In-line Load on Guard—No Continuity of Top Rail**

***Upward***

This load direction is not obvious and, in the author's experience, is not considered by many designers or builders as a load direction that is required under intent of the code. Manufactured guard assemblies are not typically tested for this load direction. While this load direction would not appear to "minimize the possibility of a fall from the walking surface to a lower level," several testimonies during the ICC code hearings in April 2016 stated that this load direction is as important as the outward load direction for preventing a fall.

Upward forces applied at the top of the guard are transferred to the guard posts through various methods, but typically rely on both the infill panel, or balusters, and the bottom rail to aid in the load transfer (Figure 4). The loads at the base of the guard posts are generally small and the connection of the guard post to the deck framing is easy to accomplish. However, guard assemblies that require blocking below the bottom rail in order to meet the downward load direction may not meet the upward load requirement. In addition, guard assemblies that do not have a positive connection between the balusters and the top rail will rely solely on the top rail to transfer this upward load to the guard posts.

***In-Line***

This load direction is not obvious and in the author's experience is the most controversial load direction, as it is rarely considered in design. However, it is an important load direction when a guard either supports a handrail, or acts as a handrail, particularly at a stair. Forces applied along the top rail are transferred to the guard posts, and then to the base structure (Figure 5). It is difficult to make the connection of the guard posts to the deck framing work for this load direction under the IRC unless the guard assembly provides continuity between guard posts. If the top rail of the guard assembly provides continuity between posts, then the in-line load can be distributed over multiple posts (Figure 6). It is even more difficult to make the connection of the guard posts to the deck framing work for this load direction under the IBC unless the guard assembly can act as a shear panel. The uniform load is applied over the entire length of the guard, therefore there is no sharing between posts, each post must resist the in-line load tributary applied to it. If the

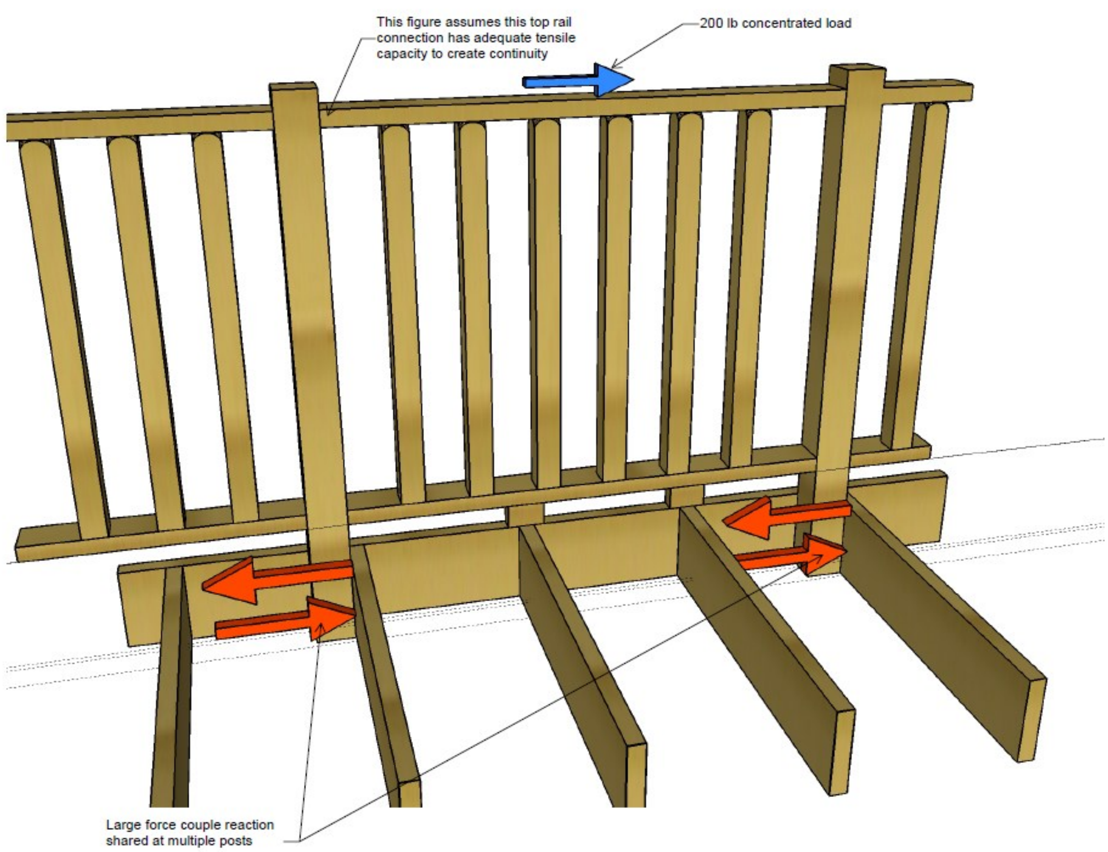


**Figure 6. In-Line Load on Guard—Continuity of Top Rail**

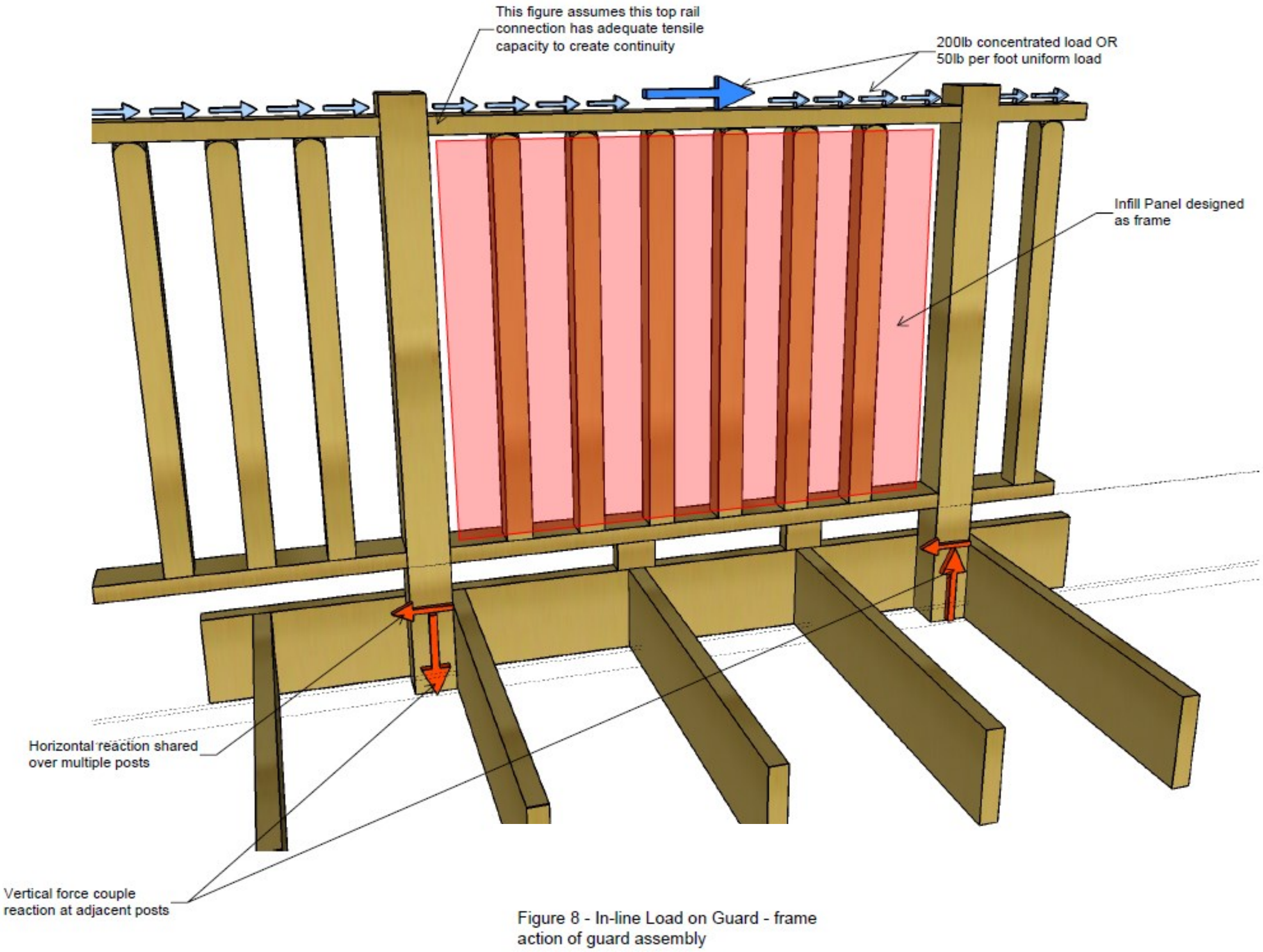


**Figure 7. In-Line Load on Guard—Frame Action of Guard Assembly**

guard assembly is designed to have the strength to act as a shear panel, the in-line forces can be resisted by the entire guard assembly between posts (Figure 7).

**Conclusions**

There appears to be a significant disconnect between the load requirements for guards, as defined by the IRC and IBC, the loads associated with the construction industry's understanding of the intent of the code, and the industry standards for testing and constructing guard assemblies.  The design and construction of guards must consider them as a system that includes not only the guard assembly, but the framing that supports the guard assembly and the connections between the two.

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