Commentary to *Prescriptive Residential Wood Deck Construction Guide* *DCA 6 – 2012 IRC Version*

Design for Code Acceptance 6

Foreword

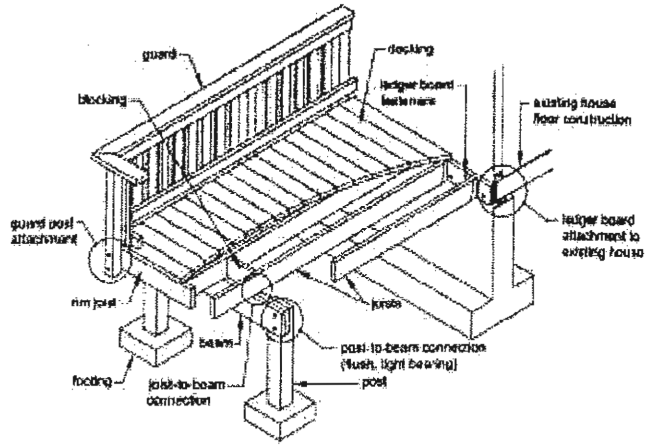
This *Commentary* to *DCA 6 – Prescriptive Residential Wood Deck Construction Guide* has been requested by builders, building officials, and others, to provide background information and example calculations for various sections and tables of *DCA 6*.

The *DCA 6 Commentary* follows the same organization as *DCA 6*. Discussion of a particular provision in *DCA 6* is found in the *DCA 6 Commentary* by locating the same section or subsection found in *DCA 6*. Not every section of *DCA 6* has a corresponding commentary section. 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.

The provisions of *DCA 6* come primarily from the International Code Council's (ICC) *International Residential Code (IRC)*. In developing the *DCA 6 Commentary*, data available from laboratory tests and experience with structures in-service was analyzed and evaluated for the purpose of providing a consistent explanation. It is intended that this document be used in conjunction with competent design, accurate fabrication, and adequate supervision of construction. Therefore, the American Wood Council (AWC) does not assume any responsibility for errors or omissions in the *DCA 6 Commentary*, nor for designs or plans prepared from it.

Inquiries, comments, and suggestions from readers of this document are invited.

American Wood Council



Background

In August 2006, AWC, then part of the American Forest & Paper Association, formed an ad-hoc task group to address prescriptive provisions for residential wood deck construction. Representatives of the wood products industry, home builders, connector manufacturers, building officials, and truss industry were represented on the task group.

The task group was assigned to review existing information to determine if there was something on which to build. One resource reviewed was a document developed by the Fairfax County, Virginia Department of Public Works and Environmental Services titled *Typical Deck Details*. With Fairfax County's permission, this became the basis for *DCA 6*.

Since Fairfax County's *Typical Deck Details* was developed for a specific geographic location, *DCA 6* was expanded to apply on a national basis (e.g. addition of western lumber species). The first version of *DCA 6* was posted to the AWC website in October 2007.

At the end of 2013 and into 2014, the task group was formed again to update *DCA 6* to be in compliance with the 2012 IRC. The *DCA6 – 2012 IRC Version* was posted on the AWC website in June 2014.

Basis

As stated in the boxed text on the cover of *DCA 6*, provisions and details are based on the International Code Council's *International Residential Code*. The original version of *DCA 6* was based on the *2006 IRC*. The current version of *DCA 6* is based on the *2012 IRC*.

Alternative Methods and Materials

A key point for users is the statement: "This document is not intended to preclude the use of alternative methods and materials." Further, *IRC* R104.11 states: "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, at least the equivalent of that prescribed in this code." While AWC develops design tools and guidelines for wood construction, it is recognized that decks are built with materials other than wood. Many of these materials undergo scrutiny through a code evaluation process such as that promulgated by ICC's Evaluation Services. Typically, the result is an Evaluation Service Report (ESR) for the product. The building official is usually the authority having jurisdiction and makes the final decision regarding all construction methods and materials.

<u>**MINIMUM REQUIREMENTS and LIMITATIONS**</u>

1. This document applies to single level residential wood decks only. Multiple level decks will likely have stairs that create additional concentrated loads that are not considered in the joist and beam span tables for *DCA 6*. Non-residential decks or balconies typically require design by a licensed professional. All decks prescribed in *DCA 6* use the primary structure to resist lateral forces per Section R507.2.3 of the IRC.

2. This ratio is limited to 1:1, similar to open-front structures defined in *Special Design Provisions for Wind and Seismic* (SDPWS). Decks covered in this document 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. See Deck Framing Plan.

3. *DCA 6* provides 6x6 nominal posts as the primary prescriptive solution with the alternative to substitute 8x8 posts. In some instances, this commentary provides a 4x4 nominal post alternative. See commentary regarding Table 4.

4. Table 1 does not provide an exhaustive list of preservative treatments for ground contact lumber. The American Wood Protection Association (AWPA) promulgates voluntary wood preservation standards. AWPA Standards are developed by its technical committees under an ANSI accredited consensus-based process. Note also that many preservative treatments undergo scrutiny through a code evaluation process such as that promulgated by ICC's Evaluation Services. Typically, the result is an Evaluation Service Report (ESR) for the product.

5. Smooth shank nails are prone to "backing out" of wood due to moisture cycling. Deformed-shank nails include helical (spiral) and annular (ring-shank) nails as defined in *ASTM F 547*. Including the common terms "spiral" and "ring-shank" is important to ensure availability from lumber yards. 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*.

6. *NDS* Chapter 11 contains spacing, end, and edge distance requirements for various fasteners, including bolts and lag screws.

7. 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:
<u>http://awc.org/helpoutreach/faq/faqFiles/Corrosion.php</u>

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.

8. Concentrated loads, such as those created by hot tubs, stairs, and planters, are beyond the scope of *DCA 6*.

9. 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.

10. Section R507.1 of the *IRC* states that decks shall be designed to resist lateral loads and that the design is permitted to be per IRC Section 507.2.3. The *IRC* currently does not state the design lateral loads for decks, but it does provide an approved design, which *DCA 6* incorporates.

11. *IRC* R703.8(5) requires attachment of flashing "...Where exterior porches, decks, or stairs attach to a wall or floor assembly of wood-frame construction." Aluminum flashing should not be used if it will be in contact with treated lumber. Lumber treated with certain preservatives contain copper and will corrode aluminum flashing as well as ferrous metals.

12. *IRC* R110.1 Use and occupancy states: "No building or structure shall be used or occupied...until the building official has issued a certificate of occupancy..."

13. See Commentary for **Alternative Methods and Materials**.

DECKING REQUIREMENTS

The American Lumber Standard Committee (ALSC) *Policy for Evaluation of Recommended Spans for Span Rated Decking Products* (ALSC Decking Policy) provides a uniform method for assessing span-rated decking products which are produced from many different species of wood, and graded under several different grading standards. This ALSC policy covers specific products classified by size of decking and are assigned a recommended span of usually 16" or 24". This policy is not intended to be used for the assessment or approval of decking spans in excess of 24". The range of current grading rule specifications and species requires the establishment of a uniform common analytical procedure for assessing the appropriateness of these products relative to the recommended spans. This ALSC policy establishes this uniform analytical procedure.

The analysis for maximum span rating assumes the following design conditions:

1. Span – Two-span continuous with load applied to only one span.
2. Seasoning – Green use condition assumed to be 23% MC or greater.
3. Deflection Limit – Deflection under design loads using calculated average allowable modulus of elasticity shall not exceed L/180.

Load Conditions – Allowable span analysis includes the following two load conditions with load applied on one span of a two-span continuous beam:

a. Uniform Load – the calculated maximum allowable fiber stress in bending derived from *ASTM D2555* and *D245*, or the In-grade test procedures of ALSC Decking Policy, Annex 1 equals or exceeds the stress induced by a 70 psf uniform load on the recommended span. The analysis assumes normal load duration.

b. Point Load – the calculated maximum allowable fiber stress in bending derived from *ASTM D2555* and *D245*, or the In-grade test procedures of ALSC Decking Policy, Annex 1 equals or exceeds the stress induced by a 220 pound point load applied at the midpoint of one span. The analysis assumes 7-day load duration.

See Commentary for **Alternative Methods and Materials** for decking materials not covered by the ALSC policy. In addition, alternate decking materials and/or use of alternate methods of fastening decking to joists has 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.

JOIST SIZE

Span calculations in Table 2 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.

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 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. See

Table C2 which indicates where deflection controls overhang length.

Joist spans are based on lumber size and joist spacing. The span of a joist is measured from the face of bearing at one end of the joist to the face of bearing at the other end of the joist and does not include the length of the overhangs. This method of measuring the "clear" span is for ease of construction and is commonly used by builders; however, it differs from standard engineering practice, where span is defined as the distance between centers of required bearing, as in the *2012 NDS.* To align the two differing definitions, 3" was subtracted from each allowable span in Table 2 to account for the difference between tabulating clear span and engineered span.

Joist spans are limited to a maximum of 18'-0" to ensure appropriate design of beams and footings. If longer joist spans are designed, joist hangers, beams, posts, and footings will have to be analyzed to ensure appropriate load path. See the span calculator at www.awc.org for simple span conditions without overhangs, however spans shall not exceed 18'-0" when used in conjunction with *DCA 6*.

Joist spans can cantilever past the beam up to L_O or L/4 as shown in Figure 1A and Figure 2, or the joists may attach to only one side of the beam with joist hangers as shown in Figure 1B (however, joists shall not be attached to opposite sides of the same beam). Allowing joists to span from opposite sides of the beam without appropriate consideration could potentially lead to a condition where beam capacity is exceeded.

Incising factors are used for refractory species including Douglas Fir-Larch, Hem-Fir, and Spruce-Pine-Fir. Hem-Fir spans control for these three species combinations. Ponderosa Pine and Red Pine were sized using Northern Species design values except that the incising factor was not applied since Ponderosa Pine and Red Pine are not incised when treated. Since incising is not necessary for naturally durable wood (heartwood of the following species: decay-resistant Redwood and Cedars - corner sapwood is permitted if 90 percent or more of the width of each side on which it occurs is heartwood), Redwood and Western Cedar are also not incised. Since Ponderosa Pine, Red Pine, Redwood, and Western Cedar have comparable design values, Northern Species design values are used to calculate the controlling spans for these four species combinations.

Table C2. Conditions Where Deflection Controls Overhang Length*.

Species	Size	Joist Spacing (o.c.) 12"	16"	24"
		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 overhang is deflection controlled. See Table 2 for footnotes.

BEAM SIZE & ASSEMBLY REQUIREMENTS

Deck beam spans are in accordance with Table 3 and can extend past the post up to $L_B/4$ as shown in Figure 3. Beams are sized based on tributary load from joists within the span limits shown in Table 2. Joists are assumed to span from one side only. Allowing joists to span from opposite sides of the beam without appropriate consideration could potentially lead to a condition where beam capacity is exceeded.

With appropriate assumptions, Table 3 could 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 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.

Douglas Fir-Larch, Hem-Fir and Spruce-Pine-Fir (refractory species) are combined with Redwood and Western Cedars (naturally durable species). Even though design values for these naturally durable species are lower than design values for these refractory species, the incising factors applied to strength and stiffness values of refractory species offset the differences. Therefore, span differences are minimal. Additionally, Ponderosa Pine and Red Pine were sized using Northern Species design values except that the incising factor was not applied since Ponderosa Pine and Red Pine are not incised when treated. Therefore, design values for the Northern Species combination (includes Ponderosa Pine and Red Pine) are used to calculate spans for all of these species.

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.

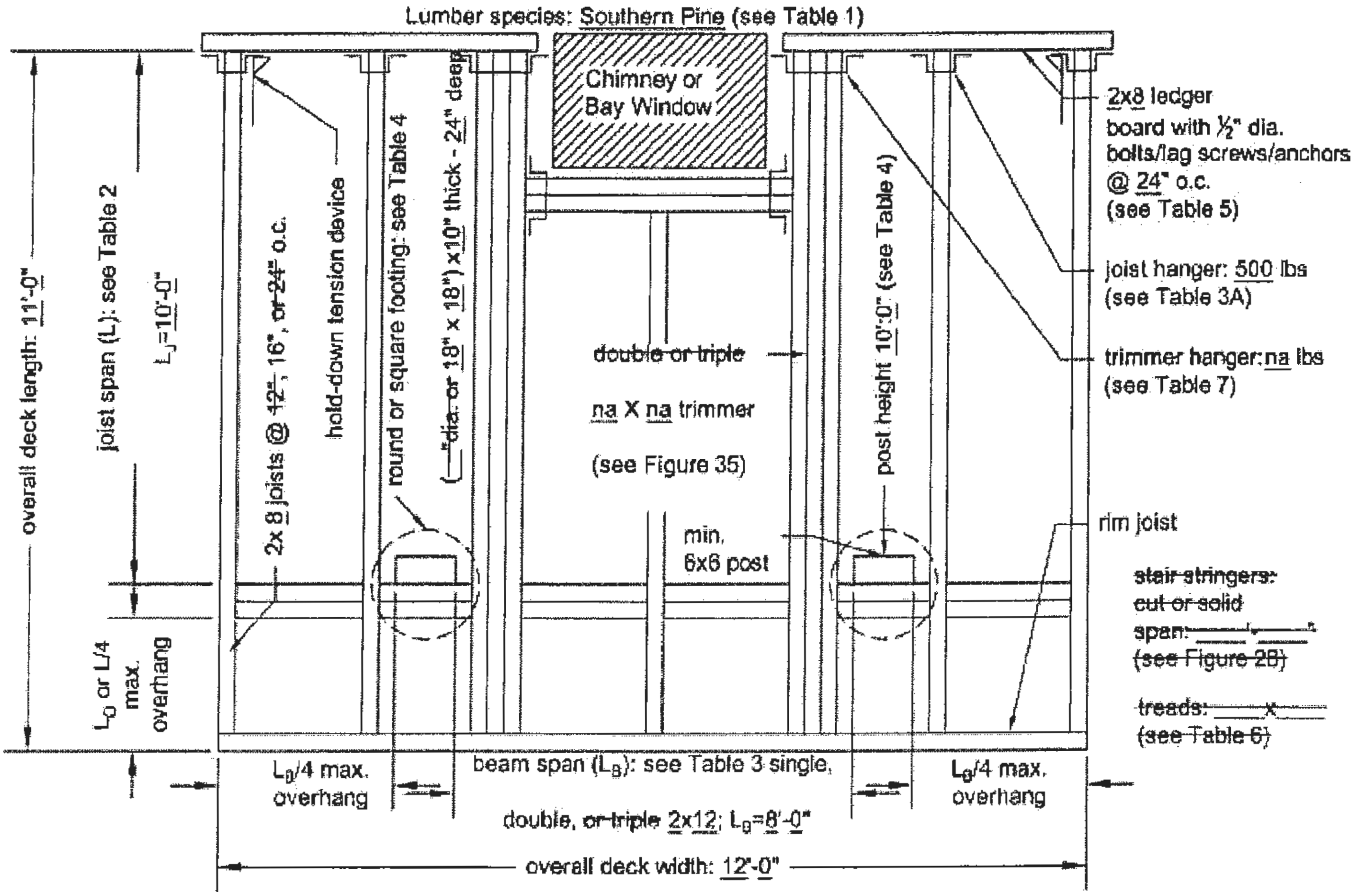
DECK FRAMING PLAN

A framing plan shows the layout of the primary structural system. Examples of structural elements include: joists, beams, ledger board, posts, footings, stringers, treads, and the type, size, and spacing of ledger board fasteners. Figure C5 shows an example of a typical 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.

Figure C5. Example of a Typical Deck Framing Plan.



JOIST-TO-BEAM CONNECTION

Joist-to-beam connections must be installed to handle forces in several directions. Options 1 and 2 handle gravity loads through bearing of the joist to the beam, while Option 3 requires nails to resist these downward loads. All three options have been evaluated to ensure that an uplift load created by a 220 lb point load at the end of a cantilevered joist will be resisted.

Connector manufacturers regard connectors with missing fasteners as improper installations and only support the product to be used with the type and number of fasteners specified in the product literature.

JOIST HANGERS

The loads listed in the Table 3A are derived from the worst case condition for each joist size based on Table 2 (379 lb, 483 lb, 571 lb, and 675 lb for Southern Pine joists spaced at 24" o.c. for 2x6, 2x8, 2x10, and 2x12, respectively).

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 this document. Requiring a minimum 6x6 post in *DCA 6* is slightly conservative for most deck applications. 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 shown in Table 4 footnote 5.

Prohibiting attachment of the beam to the sides of the post with fasteners only (Figure 9) 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 connection of the beam to the column. The connector shown in Figure 8B is readily available with extra corrosion protection and offers uplift and lateral load resistance.

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 as shown in Figure 8B would be required. There is not enough cross sectional area in a 4x4 to permit the let-in notch detail as shown in Figure 8A. 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. See Table C4A: 4x4 Post Heights.

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, Figure 10 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.

Table C4A. 4x4 Post Heights.

Beam Span, L_B	Joist Span L_J	Post Heights[1]				
		Southern Pine	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

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):

$$R = 50\left(\frac{L_{Joist}}{2} + L_{JoistOverhang}\right)\left(L_{Beam}\right) + 150\frac{BDT}{1728}$$

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

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

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

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

Figure C12. Footing Dimensions and Variables.

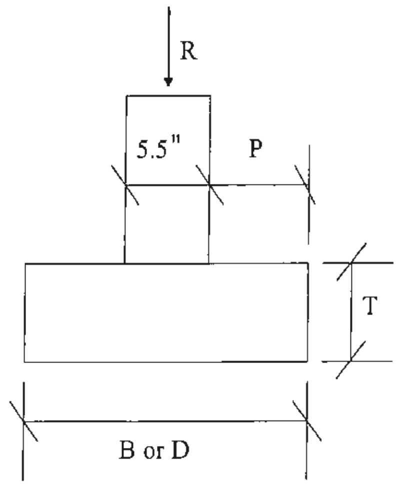


Table C4B. Footing Sizes for Higher Soil Bearing Capacities.

Beam Span, L_B	Joist Span L_J	2000 psf			2500 psf			3000 psf		
		Round Footing Diameter	Square Footing	Footing Thickness[4]	Round Footing Diameter	Square Footing	Footing Thickness[4]	Round Footing Diameter	Square Footing	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"

Footnote 2 of Table 4 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.

Coordinating the footing thickness with post base and anchor requirements means ensuring that post anchor length does not exceed the thickness of the footing.

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 Table 5 are based on *2012 IRC* R507.2.1, which is based on testing at Virginia Tech and Washington State University (Carradine et al., 2006). Testing was conducted for three common deck ledger constructions using ½" diameter lag screws and bolts. In the tests, two types of band joist materials were used: 2x10 Spruce-Pine-Fir (SPF) lumber and 1-inch-thick Douglas-Fir (DF) laminated veneer lumber (LVL) rim board. SPF has a relatively low specific gravity of G = 0.42, so other denser species groupings (e.g., Hem-Fir, Douglas-Fir-Larch, and Southern Pine) can be conservatively substituted. Similarly, the 1"-thick rim board is the minimum thickness that is currently sold in the marketplace. Thicker composite rim board products with equivalent specific gravities of 0.50 or greater (such as Southern Pine) can be conservatively substituted for the LVL band joist material tested.

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 (Figure 19) 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 4D (where D is fastener diameter) for the loaded edge. For ½" diameter bolts, 4D = 2" edge distance.

Per *NDS* Table 11.5.1D, spacing between rows is based on the ℓ/d ratio of the fastener. For a 1½" ledger and rim board, ℓ/d = 1½" / ½" = 3 and the minimum spacing is $(5\ell + 10D)/8 = 1^9/_{16}$" – 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 (Figure 19) 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 d_e 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 d_e 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" as shown in Figure 19.
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) as shown in Figure 19.
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 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.

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

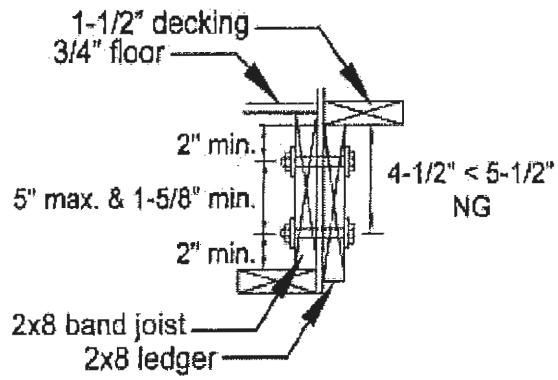
Continuous flashing is required as shown in Figure 14 to prevent water intrusion behind tbe ledger. One alternative to this detail would be continuous flashing with a drip edge, however, this would be labor intensive because the flashing would require notching at every deck joist location.

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"

Connection of ledgers to existing empty or hollow masonry cell blocks (Figure 15) 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 (see Figure 21).

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



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 this document, 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

Item 10 of *DCA 6* Minimum Requirements & Limitations 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 hold-down tension device specified, an alternate engineered connection detail would be required.

Where deck joists are perpendicular to the house floor joists, blocking between house joists and boundary nailing of the house floor diaphragm to the blocking is required for the installation of hold-down tension devices.

For connecting the hold down tension devices to I-joists, a detail recommended by the Wood I-Joist Manufactures Association and similar to Figure R507.2.1(2) of the IRC, is provided.

For non-ledger decks, Figures 22 and 23 prescribe three methods of transferring lateral loads from deck joists to the rim board: joist hangers (as shown), 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. See Post Requirements for more on the implications of diagonal bracing.

Figures 22 and 23 show 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.

GUARD REQUIREMENTS

Figure 24 requires that openings not allow the passage of a 4" diameter sphere. However, it does not address openings underneath a fixed deck bench used in place of guards. All openings, including those underneath benches used in place of guards, shall not allow the passage of a 4" diameter sphere.

Additionally, if fixed seating is adjacent to guards, the guard height should be measured from the seat rather than the deck surface. This will help minimize exposure to falls over the top of the guard due to individuals standing on deck seats.

IRC Table R301.5 requires guard in-fill components (all those except the handrail), balusters, and panel fillers to be designed to withstand a horizontally applied normal load of 50 pounds on an area equal to 1 square foot. This load need not be assumed to act concurrently with any other live load requirement. Baluster connection requirements shown in Figure 24 have been designed to resist that load.

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 Figures 25 and 26 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 Table 2 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.

Figures 25 and 26 show 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

Figure 29 shows 5/4 boards spanning 18" or less. As noted under DECKING REQUIREMENTS commentary, 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 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.

FRAMING AT CHIMNEY OR BAY WINDOW

IRC R502.10 on framing of openings states: "Openings in floor framing shall be framed with a header and trimmer joists. When the header joist span does not exceed 4', the header joist may be a single member the same size as the floor joist. Single trimmer joists may be used to carry a single header joist that is located within 3' of the trimmer joist bearing. When the header joist span exceeds 4', the trimmer joists and the header joist shall be doubled and of sufficient cross section to support the floor joists framing into the header. Approved hangers shall be used for the header joist to trimmer joist connections when the header joist span exceeds 6'..."

Trimmer Joist Size and Span Limited by Concentrated Load from the Header

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 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.

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.

<u>Trimmer Joist Span Limited by Concentrated Load on the Ledger</u>

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 (Figure 19) 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.

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.

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

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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