Structural Specifications

updates and discussions on structural specifications

Residential Wood Deck Design

By John "Buddy" Showalter, P.E. and Loren Ross, P.E.

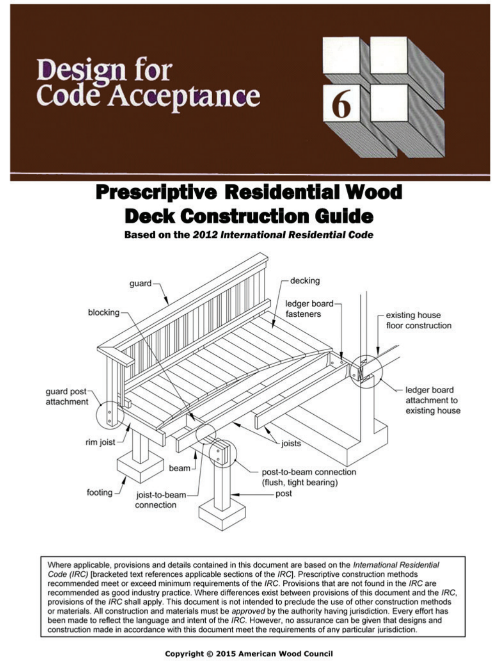
John "Buddy" Showalter is Vice President of Technology Transfer for the American Wood Council and serves as a member of the STRUCTURE magazine Editorial Board. He may be reached at ***bshowalter@awc.org***.

Loren Ross is Manager of Engineering Research with the American Wood Council. He can be reached at ***lross@awc.org***.

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 requirements in the International Code Council's (ICC) 2012 *International Residential Code* (IRC) and other provisions pertaining to single-level residential wood deck construction. DCA 6 can be found at **www.awc.org/codes-standards/publications/dca6**.

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*.



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.

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 are necessary to ensure adequate lateral capacity. An example is a use of "hidden" fasteners for edge-grooved decking material. The potential problem with this type of fastener system is that the deck boards 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 the framing.

Joists and Beams

Joist span calculations 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-pound point load (same as used for span rated decking), No. 2 grade lumber, and wet service conditions. Joist spans are limited to a maximum of 18 feet, with beams and footings sized accordingly. If longer joist spans are designed, joist hangers, beams, posts, and footings will have to be analyzed to ensure appropriate load path. Joist spans can cantilever past the beam, or the joists may attach to one side of the beam with joist hangers. Deck beam spans can extend past the post up to $L_B/4$. Beams are sized based on tributary load from joists framing in from one side only within the span limits.

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

A minimum 6x6 nominal post is specified in DCA 6. IRC section R407.3 specifies a minimum 4x4 (nominal) wood column size; however, it would often be overstressed in applications covered in 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. Therefore, if posts are embedded and designed to resist lateral load conditions, the post would need to be designed per the *National Design Specification® (NDS®) for Wood Construction*. An option of 8x8 nominal posts allows for a deck height of up to 14 feet in all cases.

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

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. A concrete weight of 150 pcf is also assumed, making solving for the footing size an iterative process.

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 spacings than can be calculated per the NDS. It also permits the use of lag screws that don't meet the minimum fastener penetration requirements into the main member for lag screws.

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 4D (where D is fastener diameter) for the loaded edge. Per NDS Table 11.5.1D, the spacing between rows is based on the l/d ratio of the fastener. Per 11.5.1.3 of the NDS, the maximum spacing between fasteners is 5 inches. 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, an adjusted design shear must be calculated.

The connection of ledgers to existing empty or hollow masonry cell blocks is not practical. 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

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 mandating engineering (see IRC Section R507.2.3). Instead of the prescriptive 1,500-pound 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 American Wood Council (AWC) *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 pounds applied in any direction for required guardrails (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 pounds for the hold-down connector ensures adequate capacity (Loferski et al., 2005) for a 36-inch maximum rail height. A higher rail height requires the 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-pound concentrated load requirement for guardrails is assumed to be a 10-minute load duration (e.g. it would not see a maximum 200 pounds outward load for more than 10 minutes cumulatively in its lifetime). Therefore, C_D=1.6 is used for hold-downs in this application.

DCA 6 shows minimum and maximum spacing requirements for bolts in deck joists and deck rim boards. The 5-inch 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 inches or less. Specific products classified by size as decking are usually assigned a recommended span of 16 or 24 inches. Additionally, IRC Table R301.5 footnote (c) requires a 300-pound concentrated load check on stair treads. Analysis revealed that 2x8 No. 2 Southern Pine works for a 34½-inch span (36 inches minus ¾-inch bearing at each end) when the 300 pounds is distributed across 2 inches (e.g. 150 pli), based on L/288 deflection criteria (ICC-ES Acceptance Criteria 174 requires ⅛-inch deflection limit: 36-inch/⅛-inch = 288).

Solid stringers were analyzed as simple span beams using the horizontal span, not the actual stringer length. Cut stringers were analyzed with 5.1-inch 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 default footing assumes a 40 psf live load and 10 psf dead load over a tributary area of 18 inches and one-half of the maximum span of 13 feet–3 inches permitted for solid stringers. This calculates to 500 pounds.

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

Where the header frames into the trimmer joist, a concentrated load is created. This condition was evaluated and 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. Bending and shear were checked to determine the reduction in a double trimmer joist span when carrying a 6-foot header.

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 significant 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. 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.

Conclusion

Engineers may be called upon to design residential decks or inspect existing decks. While prescriptive provisions for deck construction are readily available, an understanding of the basis for those provisions will help engineers with the design process.▪

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