Verifying the Load Capacity of Railing Posts

Q I understand the 200-pound load requirement for guardrail posts. But all the testing seems to have been done with 2x8 joists, southern pine components, and a 36-inch-high 4x4 railing post. Does changing the size or wood species of the joists or posts affect code compliance if you're using the new post reinforcing hardware?

A Andy Engel, editor of *PDB,* replies: This is a complicated question with no short answer (see "Code-Compliant Guardrail Posts," page 42). The concept of requiring hardware to reinforce the railing post attachment springs from research done at Virginia Tech by Joseph Loferski and Frank Woeste. They tested common post connections using 2x8 joists and a 36-inch-high 4x4 post, both of southern pine ("Strong Rail-Post Connections for Wooden Decks," *JLC,* February 2005; jlconline.com). All the lag-screwed and bolted connections failed to meet even half the 200-pound load requirement once the standard safety factor of 250 percent for preconstruction load testing was applied. (Safety factors account for variations between laboratory and in-service conditions.) Eventually the researchers developed a detail that passed their test: making the connection with a Simpson Strong-Tie HD2 hold down.

Because posts can act like levers when a force is applied to them, the biggest problem (but not the only one — more on that later) is resisting the moment (engineering jargon for torque, or a twisting force) that the post imposes on the connection between the deck's rim joist and its joists. Since the Virginia Tech test results were published, three manufacturers (DeckLok Bracket Systems, deck-lok.com; Simpson Strong-Tie Co., 800/999-5099, strongtie.com; USP Structural Connectors, 800/328-5934, uspconnectors.com) have come out with post connection hardware that's capable of resisting this moment in the Virginia Tech test. All the hardware has been tested to at least 250 percent of the values the manufacturers publish. Because the hardware testing accounts for it, I'll ignore the safety factor from now on.

Calculating the Forces

When a deck has nominal 2x8 joists and 2-by decking, and the top bolt attaching a 36-inch-high 4x4 post to the framing is located 2 inches down from the top of the joist, the math to figure the force at the top bolt is as follows (the illustration and calculations below are republished from the *JLC* article):

Moment = force x distance

Applied moment = resisting moment

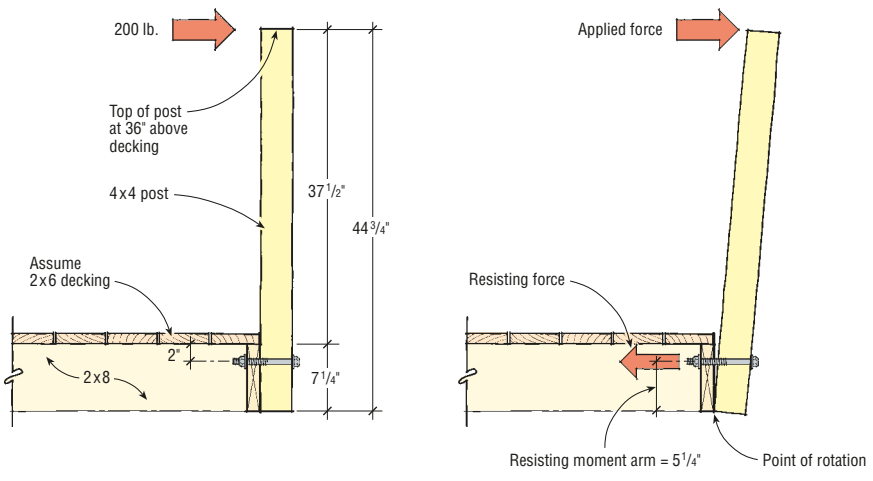
Applied moment = 200 lb. x 44.75 in. = 8,950 inch-pounds at base of post

Resisting moment = ? lb. x 5.25 in. (distance from the bottom of the joist to the bolt centerline)

Resisting force = 8,950 inch-pounds / 5.25 in. = 1,705 lb.

Round 1,705 up for safety, and the hardware and its connection to the deck framing must be able to resist 1,800 pounds of force. In the Virginia Tech configuration, and also with Douglas fir joists, all the manufacturers' published hardware values just exceed this number.

Forces in a Typical Guardrail Post



When the strength of the connection between a post and the deck frame is calculated, many factors come into play. The length of the post interacts with the location of the bolted connection to determine the leverage the post imposes. Deeper joists can reduce the leverage of the post, while shallower joists increase it. Wood species also plays a role.

Other Factors Affecting Post Connections

Different wood species have different characteristics, however, and when used with single hem-fir or SPF joists, hardware is rated at only 1,400 to 1,500 pounds, depending on the manufacturer. To address that, Simpson publishes a detail in which blocking is used to thicken the joist the hardware is attached to, allowing the use of longer screws. In that configuration, Simpson's hardware is rated at 2,105 pounds with hem-fir and SPF joists (2,145 pounds with southern pine or Douglas fir joists), which should satisfy most building officials. To use another manufacturer's hardware in that configuration, you'd have to seek that manufacturer's approval.

The wood species of the joists isn't the only factor that affects the strength of the connection. Change joist size or post height and the moment changes, sometimes exceeding the capacity of the hardware. Unfortunately, the IRC doesn't offer any prescriptive solutions, even for the Virginia Tech design. The DCA6-09, an alternative deck construction guide published by the American Wood Council (AWC) and available for free at its website (awc.org) offers some designs, but these mirror the Virginia Tech tests.

Still, since the IRC, as well as DCA6-09, is based on the AWC's National Design Standard for Wood Construction, many building departments accept DCA6-09 as an alternative code for deck building. I asked David Finkenbinder, an engineer with Simpson Strong-Tie, for ways these sources could be used to design post-to-deck connections when one or more construction details differ from the Virginia Tech example. Here's what he told me: "The guard post details shown in the DCA6 are based on the Virginia Tech research. The DCA6 Commentary states that 'a higher rail height requires design of a higher capacity connector.' Additional background is also given on the calculation of post bending strength. If approved by the authority having jurisdiction, a deck designer could potentially use the engineering mechanics outlined in the *JLC* article and DCA6 Commentary to calculate the required hold-down force. The post itself could be designed for bending as outlined in the DCA6 Commentary."

I'm going to show you how to do that here, but remember, I'm not an engineer. Verify my numbers before using them, and know that your building department may require an engineer's stamp anyway.

The first question that comes to mind is whether there's a way to achieve the required values when attaching a post to 2x6 joists. Using 2x6s instead of 2x8s reduces the distance in the equation from 44.75 inches to 43 inches and the divisor from 5.25 inches to 3.5 inches ($5^1/2$-inch actual joist depth less the 2 inches from the top for the bolt location):

200 lb. x 43 in. = 8,600 inch-pounds

8,600 inch-pounds / 3.5 in. = 2,457 lb.

MIKE GUERTIN

Several manufacturers produce hardware designed to withstand the loads imposed by railing posts. Shown here is a Simpson Strong-Tie DTT2.

That number (2,457 lb.) exceeds the published values for all currently manufactured post connection hardware in any configuration. As far as I can tell, 2x6 joists aren't an option if there's a railing system, unless the post is somehow further braced below those joists. For example, it might tie into a lower-level deck frame or anchor to a footing.

Another possible variation on the Virginia Tech design would be using a taller railing post. Say you wanted a 42-inch-high rail. That would increase the distance in the equation to 50.75 inches. With 2x8 joists, you get:

200 lb. x 50.75 in. = 10,150 inch-pounds

10,150 inch-pounds / 5.25 in. = 1,933 lb.

That means with any common deck-framing species, you would have to use the Simpson detail with the blocking and the longer screws for a 42-inch-high rail to have enough capacity to resist a 200-pound force.

Alternatively, you could build a 42-inch-high rail without the extra blocking if you used 2x10 southern pine or Douglas fir joists. In that case, the distance would be 52.75 inches, and the divisor would be 7.25 inches.

200 lb. x 52.75 in. = 10,550 inch-pounds

10,550 inch-pounds / 7.25 in. = 1,455 lb.

For 2x12 joists, you'll have to do the math yourself, but it's likely that a single thickness of joist of any common species would accommodate a 42-inch-high post.

Wood Species and Posts

The final issue is that the posts themselves have to be rigid enough to withstand the force. DCA6-09 assumes unnotched 4x4 posts, and all the previous calculations assume posts that are able to withstand a certain amount of bending stress. According to the DCA6-09 Commentary, 36-inch-high posts must have a "reference bending design value not less than 1,100 psi to ensure sufficient bending stress in the post." Bending stress (F_b) is a measure of the internal stress a certain size and length of wood beam or post endures under

a perpendicular load. The design values found in handbooks are based on a standard test and provide the maximum bending stress allowable for various species of wood.

If you look at published F_b values, several common species don't seem to make the grade. However, it's not that simple. The DCA6-09 Commentary references "adjusted bending design value," which includes other factors. These are reductions for "wet service" and "incising" (when treated, western species are incised to improve preservative penetration). There are also positive adjustments for load duration and member size. In short, 4x4s in number 2 and better grades of common deck-building wood species all meet the 1,100-psi requirement.

It can be even more complicated than I've laid out. With softer woods, pushing outward on the post can compress the fibers under the upper bolt and washer. That can allow movement between the post and the rim joist, which changes the fulcrum point of the post from the top bolt to the bottom of the post. That loads the top bolt even more, leading to more crushed fibers, and so on.

Do You Really Need to Do All This?

Not all jurisdictions will look this deeply at the code. Some old-school building inspectors will be impressed you're using connectors. Others will require an engineer's stamp for anything that falls outside the prescriptive solutions in the IRC or DCA6-09. The bottom line is that no matter what other factors come into play, adding post connection hardware to your deck posts is going to make them stronger and safer than ever. ❖