Sizing Joists for a Hot Tub

by Christopher DeBlois, P.E., & Don Jackson

This month's column is in answer to a reader's letter. He writes:

I am building a deck that will hold a five-person hot tub. According to the manufacturer, the weight of the filled tub with five people in it will add about 94 pounds per square foot of weight to the deck over a 45-square-foot area. I am concerned about the loads. Even without occupants, the filled tub will weigh almost 3,000 pounds — a constant load on the deck, as opposed to a standard occupant live load, which comes and goes. How can I correctly size the pressure-treated pine joists? Should I use a standard span table?

The question is a good one, and it points up the difference between a *permanent* load and a *live* load. The answer is that, with care, you can use standard joist span tables to size joists for this unusually high load. It's a two-step process: First, we have to adjust the loads to account for the permanent loading condition, and also the fact that the deck joists will be outdoors, where they may be wet much of the time. Both of these factors affect the design strength of the lumber. Second, we have to manipulate the typical span tables to address the unusually high load.

Duration of Load

The *National Design Specification for Wood Construction (NDS)*, which is used in the creation of most span tables, includes a concept called the Load Duration Factor. (In case you want to get into the calculations, in the *NDS* the symbol for the Load Duration Factor is C_D.) The Load Duration Factor is used to modify the allowable stresses in wood based on how long the load will be applied. This is because wood can carry substantially higher loads for short periods of time. Load duration factors are applied to all design values except modulus of elasticity (E) and compression perpendicular to grain ($F_{C\perp}$).

"Normal" loading is defined as an occupancy live load having a ten-year duration. Depending on whether live loads last longer or shorter than normal loading, you may need to decrease or may get to increase the design capacity of the wood. The allowable stresses due to wind forces, for example, which are short and intermittent, can be increased by 60% over normal loading conditions (see Table 1, below).

For permanent loads, such as the hot tub and its water, $C_D = 0.9$. That means you are only allowed to use 90% of the normal capacity of the joists.

Applying the Load Factor

Another way to apply the load factor is to use the normal allowable stresses (which are used to create most span tables) but to increase the load by 11% (1 divided by 0.9 is equal to 1.11). That's a good approach when working with joist tables. Add 10 psf of dead load for the weight of the deck itself to the 94 psf for the hot tub and people, and increase the total load by 11% to 115 psf.

Note that this approach is somewhat conservative, since not all of the loads involved are permanent dead loads (the people come and go).

Wet Use Adjustment Factor

There's another adjustment we have to make when sizing joists for an outdoor deck. Typical lumber design values are based on the assumption that the wood will be used in a protected location and will have a moisture content no greater than 19%. For lumber that will be wetter than that for extended periods, such as the joists in an unsheltered deck, you have to apply the *wet service factor* (C_M in the *NDS*) to the lumber design values. The wet service factors for Southern Pine are listed in Table 2, next page. Two of these are important for deck design: the factor for F_b, the allowable bending strength, and the factor for $F_{C\perp}$, compression perpendicular to grain. Bending strength is multiplied by 0.85, or reduced 15%, while compressive strength goes down 33%.

Table 1: Load Duration Factors (C_D)

Load Duration	C_D	Design Loads
Permanent	0.9	Dead Load
Ten Years	1.0	Occupancy Live Load
Two Months	1.15	Snow Load
Seven Days	1.25	Construction Load
Ten Minutes	1.6	Wind/Earthquake Load
Impact	2.0	Impact Load

Note: Duration factors do not apply to modulus of elasticity (E) or compression perpendicular to grain ($F_{C\perp}$). Factors greater than 1.6 do not apply to pressure-treated or fire-retardant-treated lumber. For more information, see the 1997 *NDS*.

To account for the reduction in bending strength, we can increase the loading, as we did when adjusting for permanent loading. In this case, we bump up the load by another 18% (1 divided by .85 equals 1.18), and the design load for bending goes from 115 psf to 136 psf.

The reduction in compressive strength means that you need to make sure you have enough bearing area at the joist ends to prevent the bottoms of the joists from crushing. We'll look at that later.

To the Span Tables

For now, let's go to the span tables to choose a joist size. If you happen to have span tables that include heavy loadings, you may need no further information. But what if you're using a standard joist table that address a total load of 50 psf (10 psf dead weight plus 40 psf live load)?

The key concept is that for the same span, two joists are exactly twice as strong and twice as stiff as one, and therefore can carry exactly twice as much load as the single joist. Three joists have three times the strength, and so forth. If you understand this, you can manipulate the information in the span table to solve for the joist size and spacing that will work for a load heavier than those the table covers.

Let's assume your deck joists need to span 12 feet, and that you're using #2 pressure-treated Southern Pine. The American Forest & Paper Association span table for 50 psf loading (AF&PA Table F-2; similar tables are found in the model codes) indicates that 2x8s 16 inches on-center can span 12 feet 10 inches. (See end of article for sources for span tables). Since the design load in this case is 2.7 times as high as the 50 psf from the table, (136 psf ÷ 50 psf = 2.7), you will need 2.7 2x8s every 16 inches to carry the 136-psf load. Since there's no such thing as .7 of a joist, you can reduce the spacing to 6 inches (16 inches ÷ 2.7 = 5.9 inches).

Since 6 inches is a little close, you could also double the 2x8s. Instead of 2.7 2x8s, you could use 1.35 double 2x8s every 16 inches, or one double 2x8 every 12 inches (16 inches ÷ 1.35 = 11.8 inches).

What you'd probably do is consider a deeper joist. The same table indicates that a #2 Southern Pine 2x10 24 inches on-center will span 13 feet. For our 136-pound load, that means 2.7 2x10s every 24 inches, or a 2x10 every 9 inches (24 inches ÷ 2.7 = 8.88 inches).

Again, note that this approach is conservative, because the hot tub does not extend the full 12-foot length of the joists.

Another Trick

What if you want to consider 2x12s? The smallest span the 50-psf table gives for 2x12s on 24-inch centers is 13 feet 10 inches, and that's for a weaker lumber than #2 Southern Pine. (Remember, when using the code-style span tables, you first find the span and spacing, then use the minimum required F_b and E values to choose the lumber species.)

Using the same procedure that you used for the 2x10s, you'll get the same answer: a 2x12 every 9 inches. At this point, rather than waste the 2x12's extra spanning capability (1 foot 10 inches, or 15% more than you need), you might be tempted to somehow increase the joist spacing by the same percentage. In fact, this will work, and will give you a conservative answer — as long as you're going from a longer to a shorter span, as in this case (13 feet 10 inches to 12 feet). A 2x12 every 10^3/8 inches — or 15% fewer joists — will work.

You'll get yourself in trouble, however, if you try to manipulate the tables so that the span for a given joist size gets *longer* than the maximum allowed. That's because bending stresses in a joist — which limit joist span — do not increase in direct proportion to an increase in span, but as a function of the *square* of the span. A 15% *increase* in span results in a 32% increase in maximum bending moment in the joist.

Fine Tuning: Try Another Table

You can probably do better than 2x12s on 10-inch centers. Another table in the AF&PA book (Table F-7) gives joist sizes for 60-psf live plus 20-psf dead load — a total load of 80 psf. For this load, 2x12s 24 inches on-center will span 12 feet 1 inch. There's little wasted span here. Doing the same math as above, the 136-psf load is 1.7 times larger than the 80-psf load (136 ÷ 80 = 1.7). So we need 1.7 2x12s every 24 inches, or one 2x12 every 14 inches.

Check for Adequate Bearing

There's one possible hitch to this procedure that we need to check out. Span tables always make some assumption about how much bearing area is required at the joist ends. The AF&PA tables assume a minimum bearing length of 1^1/2 inches, or a bearing area of 2^1/4 square inches for a 2-by joist (1.5 x 1.5 = 2.25). This is typically enough bearing area for ordinary loads in dry conditions. But apply the wet service factor for compression perpen-

Table 2: Wet Service Factors (C_M)

Lumber Design Values (psi)		C_M
F_b	allowable bending stress	0.85
F_t	allowable tension parallel to grain	1.0
F_v	allowable shear parallel to grain	0.97
$F_{c\perp}$	allowable compression perpendicular to grain	0.67
F_c	allowable compression parallel to grain	0.8
E	allowable modulus of elasticity	0.9

Note: Lumber used in wet conditions (moisture content above 19%) is subject to reduction of design strength. For instance, bending design values for wet lumber are 85% of the dry lumber values. For more information, see the 1997 *NDS*.

dicular to grain (C_M = 0.67) and things might change.

The design value for $F_{C\perp}$ for #2 Southern Pine is 565 pounds per square inch. Apply the wet service factor and this reduces to 379 psi. That's the maximum pressure that the deck joist end bearing area can take before the wood crushes.

Take the 2x12s 14 inches on-center. Each 2x12 carries 1.17 square feet of deck load for every linear foot of run (14 inches ÷ 12 inches = 1.17). So each joist carries a total load of 1615 pounds (115 psf x 12 ft. x 1.17 sq. ft./ft.). Each end gets half this load, or 807.5 lb. Distributed over the bearing area, this gives 359 psi (807.5 ÷ 2.25). This is less than the allowable compressive strength of 379 psi, so we're okay.

Bearing is almost never a problem with joists, as long as you have the code minimum 1$^1/_2$ inches of bearing length. If you needed more bearing area, you could always use a joist hanger with a 2-inch-long seat.

Final Precautions

Properly sizing the joists for the hot tub is important, but you can't ignore the rest of the structure. The deck posts and girders must also be able to handle the loads. If the deck joists are hanging from a ledger attached to the house, you'll have to make sure you use enough bolts to transfer the loads to the rim joist. You'll also have to choose your hangers more carefully than usual, to make sure they have the needed capacity (top flange hangers are a good idea). In short, every member and every connection must be thought out with the heavy loads in mind.

For second-story decks or decks that are high off the ground, it's probably a good idea to run your plan by an engineer to spot check member sizes, connections, and lateral bracing of supports.

__Chris DeBlois__ is a structural engineer with Palmer Engineering in Tucker, Ga. __Don Jackson__ is managing editor of JLC.

For More Information

Span Tables for Joists and Rafters is available from the American Forest & Paper Assoc. by calling 800/890-7732. The cost is $15 plus $5 shipping.

Also available from AF&PA is the 1997 ***National Design Specification for Wood Construction***, the standard document used by engineers practicing wood structural design. The cost is $25 plus $5 shipping.

Maximum Spans for Southern Pine Joists & Rafters is available from the Southern Pine Council (P.O. Box 641700, Kenner, LA 70064; 504/443-4464; www.southernpine.com) for $2 plus $1 shipping. This booklet gives 47 joist and rafter tables specifically for Southern Pine lumber, including tables for heavy loads. The tables are also available at the Southern Pine Council's Web site.