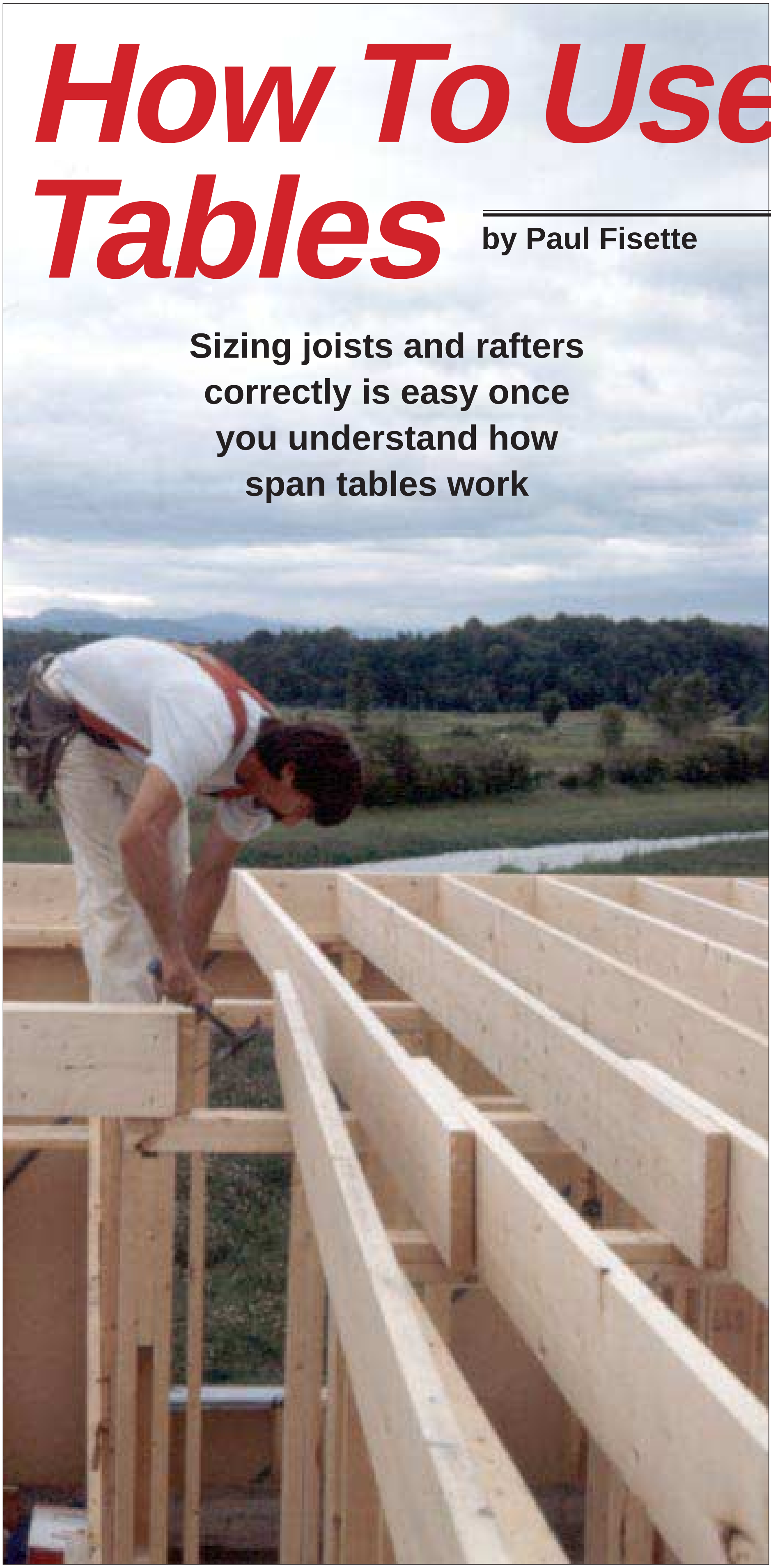
How To Use Span Tables

by Paul Fisette

Sizing joists and rafters correctly is easy once you understand how span tables work



Wood is naturally engineered to serve as a structural material. The tree is fastened to the earth with its roots, the foundation; the trunk supports the weight of the branches, as a column; and it bends when loaded by the wind, as a cantilever beam. Wood's mechanical properties are complex, but if you understand a few basics of lumber strength you can easily size uniformly loaded joists and rafters with span tables.

Stiffness and Strength

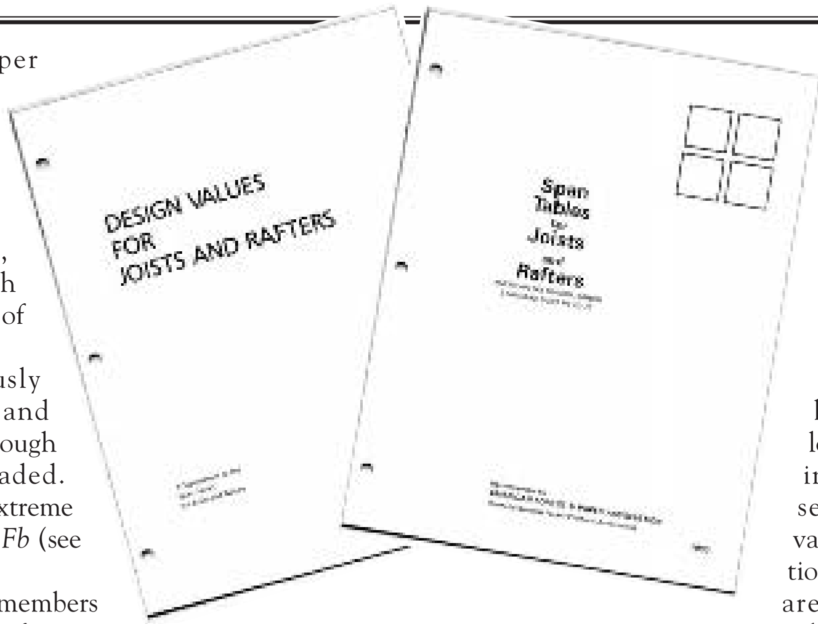
A good set of tables includes a number of variables, the most basic of which are *stiffness* and *strength*. A house frame has to resist dead loads (the weight of materials), live loads (the weights imposed by use and occupancy), snow loads, and wind loads. Beams, studs, joists, and rafters must be strong enough *and* stiff enough to resist these loads.

Stiffness. A set of second-story floor joists can be strong enough to support all dead and live loads yet still be too bouncy. The joists won't break, but the first-story ceiling plaster may crack as the occupants walk across the second floor.

Stiffness requirements for joists or rafters are limited by their maximum allowable *deflection*, which is set by code. Deflection limits vary for different parts of the house and are based on the live loads experienced in each room. They're expressed as a fraction: the clear span in inches (*L*) over a specified number.

Typical code-prescribed deflection limits are L/360 for all floors and any rafters with plaster on their underside, L/240 for rafters with drywall attached, and L/180 for rafters with no plaster or drywall. A floor joist that's appropriately selected to span 10 feet with an L/360 limit will deflect no more than 1/3 inch (120 inches ÷ 360) under its maximum design load.

The measure of a material's stiffness is "modulus of elasticity," or *E*. It's

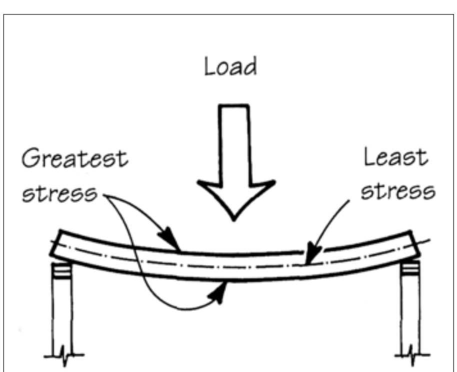


expressed in pounds per square inch, or psi. A material with a higher E value is stiffer. For example, No. 2 eastern white pine has an E value of 1,100,000 psi, while No. 2 hem-fir, which is stiffer, has an E value of 1,300,000 psi.

Strength is obviously important, too: Joists and rafters must be strong enough not to break when loaded. Strength is expressed as "extreme fiber stress in bending," or *Fb* (see illustration, below).

Loads cause structural members like beams, joists, and rafters to bend. As a structural member bends, the wood fibers on its top and bottom edges are stressed more than the fibers along its centerline. The fibers along the top edge are squeezed in compression, while those along the bottom edge are stretched in tension. Fb is the design strength of those "extreme," or outermost, fibers; the higher the Fb, the stronger the wood.

How strong a structural member must be depends on the load it will carry. You can calculate the minimum design values required of a structural member by adding the live loads and dead loads carried by that member. The individual weights of drywall, strapping, floor joists, plywood, and carpet are listed in *Architectural Graphic Standards* and other reference books. But adding the weights of materials is rarely necessary except for in unusual designs. The tables list a variety of average live and dead load combinations for floors, ceilings, and rafters. These combinations are more than adequate for most residential designs.



As a structural member bends, the fibers along its upper and lower edges are highly stressed, while those near the center are not stressed at all. Fb ("extreme fiber stress in bending") is a measure of the stress that can be placed on these outermost (or "extreme") fibers; the higher the Fb, the stronger the wood.

Other Considerations

Of course, stiffness and strength aren't the only factors that determine how a structural member responds to loading. That's why the tables also include several other variables. The ability to balance these lets you fine-tune a structure's cost and performance.

Depth of structural members. The deeper the joist or rafter, the more weight it can support. For example, 2x10 joists spaced 24 inches on-center often provide a stronger and stiffer floor assembly than 2x8s of the same grade and species spaced 16 inches on-center.

Lumber grade. A higher grade of a given species usually has a higher strength rating (Fb) and often a higher stiffness value (E), too.

Wood species. All species are not created equal. Southern pine, for example, is generally stronger and stiffer (higher Fb and E values) than spruce.

Duration of load. How long will the members be loaded? Full-time live loading (as with floor joists) serves as the benchmark value, so-called normal duration. Normal duration values are multiplied by 1.15 to yield snow-load values and by 1.25 for 7-day loading.

Over time, the load on a joist or rafter can cause it to bend permanently. This happens whether or not the load is continuous; the effect is cumulative. The *normal duration* Fb value assumes that, during its lifetime, a joist will be subjected to its *full design load* for a cumulative total of ten years. Using the normal duration Fb value for a given wood species ensures that the joist will not fail. In reality, actual loads on the joist are much less than the design loads. The cumulative effect of lighter loads drops off sharply as the load decreases, meaning that rarely are joists in danger of failure.

Likewise, the *snow loading* Fb value assumes that a roof will have to support the *design* snow load for a total of only two months during its lifetime. Snow load Fb values are increased 15% over normal duration values because shorter loading periods have less effect than loads of longer duration. This means, for example, that a 2x10 of a given species may have a higher assigned Fb value when used as a rafter than when used as a joist.

Seven-day loading assumes an even shorter loading period, and is applied in some code districts where there are no wind or snow loads on roofs. The "seven days" assumes that over the lifetime of the roof, construction workers may place full design loads on the roof for a cumulative total of a week — roofers storing shingles on the roof, for instance.

Calculations for normal duration, snow loading, and 7-day loading are automatically factored into the tables. You can apply them according to your local code.

What You Need

To use this information, you'll need three publications. The first is a building code book, which includes information about required grades, spans, bearing, lateral support, notching, etc. The *One and Two Family Dwelling Code* from the Council of American Building Officials (5203 Leesburg Pike, Suite 708, Falls Church, VA 22041; 703/931-4533) is a good choice. It has one appendix with span tables for joists and rafters and another appendix with design values for joists and rafters. Many local codes reference the CABO code as an acceptable option.

The other two publications are available from the American Forest & Paper Association (AF&PA, 1111 19th St. NW, Suite 800, Washington, DC 20036; 202/463-2700). They are *Design Values for Joists and Rafters*, which lists Fb and E values for various species, sizes, and grades of dimensional lumber, and *Span Tables for Joists and Rafters*, which assigns allowable spans to various combinations of E and Fb. I find the AF&PA documents easy to follow. And if you get stuck, the association's technical staff can help you.

Western Wood Products Association (WWPA, Yeon Bldg., 522 S.W. 5th Ave., Portland, OR 97204; 503/224-3930) also publishes span tables. WWPA's tables are more flexible than AF&PA's, so some designers and engineers prefer them for calculating loads on complex structures. However, they're also harder to use, because they require the correct use of numerical multipliers. The AF&PA publications, by contrast, use a simplified approach that's suitable for most wood-frame homes. This makes them a better tool for most architects and builders.

Table No. R–201.4
MINIMUM UNIFORMLY DISTRIBUTED LIVE LOADS

Use	Live Load
Balconies (exterior)	60
Decks	40
Fire escapes	40
Garages (passenger cars only)	50
Attics (no storage with roof slope not steeper than 3 in 12)	10
Attics (limited attic storage)	20
Dwelling units (except sleeping rooms)	40
Sleeping rooms	30
Stairs	40

Table No. R–201.6
ALLOWABLE DEFLECTION OF STRUCTURAL MEMBERS

Structural Member	Allowable Deflection
Rafters having slopes > 3/12 with no ceiling load	L/180
Interior Walls and Partitions	L**/180
Floors and Plastered Ceilings	L/360
All Other Structural Members	L/240

Notes:
L = span length   L** = vertical span

THESE TABLES ARE REPRINTED FROM THE *ONE AND TWO FAMILY DWELLING CODE*, COUNCIL OF AMERICAN BUILDING OFFICIALS, FALLS CHURCH, VA.

Figure 1. *Live loads and deflection limits are set by code. These tables are from the CABO One and Two Family Dwelling Code.*

Table F–2
FLOOR JOISTS WITH L/360 DEFLECTION LIMITS

DESIGN CRITERIA:
Deflection – For 40 psf live load.
Limited to span in inches divided by 360.
Strength – Live load of 40 psf plus dead load of 10 psf determines the required bending design value.

Joist Size (in.)	Spacing (in.)	Modulus of Elasticity, E, in 1,000,000 psi								
		0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6
2x6	12.0	8–6	8–10	9–2	9–6	9–9	10–0	10–3	10–6	10–9
	16.0	7–9	8–0	8–4	8–7	8–10	9–1	9–4	9–6	9–9
	19.2	7–3	7–7	7–10	8–1	8–4	8–7	8–9	9–0	9–2
	24.0	6–9	7–0	7–3	7–6	7–9	7–11	8–2	8–4	8–6
2x8	12.0	11–3	11–8	12–1	12–6	12–10	13–2	13–6	13–10	14–2
	16.0	10–2	10–7	11–0	11–4	11–8	12–0	12–3	12–7	12–10
	19.2	9–7	10–0	10–4	10–8	11–0	11–3	11–7	11–10	12–1
	24.0	8–11	9–3	9–7	9–11	10–2	10–6	10–9	11–0	11–3
2x10	12.0	14–4	14–11	15–5	15–11	16–5	16–10	17–3	17–8	18–0
	16.0	13–0	13–6	14–0	14–6	14–11	15–3	15–8	16–0	16–5
	19.2	12–3	12–9	13–2	13–7	14–0	14–5	14–9	15–1	15–5
	24.0	11–4	11–10	12–3	12–8	13–0	13–4	13–8	14–0	14–4
2x12	12.0	17–5	18–1	18–9	19–4	19–11	20–6	21–0	21–6	21–11
	16.0	15–10	16–5	17–0	17–7	18–1	18–7	19–1	19–6	19–11
	19.2	14–11	15–6	16–0	16–7	17–0	17–6	17–11	18–4	18–9
	24.0	13–10	14–4	14–11	15–4	15–10	16–3	16–8	17–0	17–5
F_b	12.0	718	777	833	888	941	993	1043	1092	1140
F_b	16.0	790	855	917	977	1036	1093	1148	1202	1255
F_b	19.2	840	909	975	1039	1101	1161	1220	1277	1333
F_b	24.0	905	979	1050	1119	1186	1251	1314	1376	1436

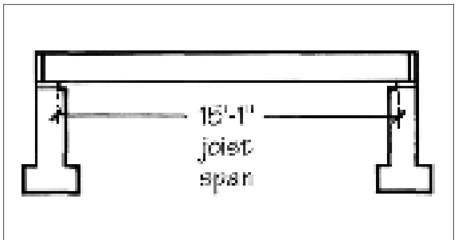
Note: The required bending design value, F_b, in pounds per square inch is shown at the bottom of each table and is applicable to all lumber sizes shown. Spans are shown in feet–inches and are limited to 26' and less. Check sources of supply for availability of lumber in lengths greater than 20'.

EXCERPTED FROM *SPAN TABLES FOR JOISTS AND RAFTERS*, AMERICAN FOREST & PAPER ASSN., WASHINGTON, D.C. ACTUAL TABLE GIVES E VALUES UP TO 2,400,000 PSI.

Figure 2. *Given a design span of 15 feet 1 inch and a 16-inch joist spacing, first determine which size lumber will work. Then find the required Fb value at the bottom of the column.*

Sizing Floor Joists

Let's work through an example that illustrates the steps involved in using the tables. Let's say you're building a 16-foot addition and have to select the correct size and species of lumber for the floor joists. The joists will be 16 inches on-center. Their design span — the exact length from face to face of the supports — is 15 feet 1 inch (see illustration, below).



When sizing joists, use the clear span — the length from support to support — not the full length of the joist.

Step 1: Check the Code

First, check the local code for allowable live load, dead load, and deflection (see Figure 1). For this example I'll use the CABO *One and Two Family Dwelling Code*, which serves as the model for many state and local codes. This sets an allowable first-floor live load of 40 psf, a dead load of 10 psf, and a deflection of L/360.

Step 2: Span Table

Select the appropriate table in *Span Tables for Joists and Rafters*. The table of contents indicates that Table F-2 watches these loading conditions. Using Table F-2 (Figure 2), check each lumber size to see if a 16-inch spacing will permit a span of 15 feet 1 inch. Start with the "16.0" line in the "Spacing" column at the left of the table, then go to the right until you reach an appropriate span (at least 15 feet 1 inch in this case). Then drop down to find the appropriate Fb value for that span.

As the table shows, no 2x8s meet the span and spacing requirements, but a 2x10 with an E of 1,300,000 psi and an Fb of 1093 psi can span 15 feet 3 inches — more than enough. A 2x12 with an E of 800,000 psi and Fb of 790 psi also works, since it can span 15 feet 10 inches.

Step 3: Wood Design Values

Now you must select a wood species and grade that meets the required Fb and E values, and that's available in your area. For this, use the tables in *Design Values for Joists and Rafters*. For this example, I've excerpted the relevant sections from tables for hem-fir, Douglas fir-larch, and spruce-pine-fir (Figure 3).

In hem-fir, either a No. 1 2x10 or a No. 2 2x12 would work. In Douglas fir-larch, either a No. 2 2x10 or a No. 2 2x12 works. In spruce-pine-fir, a No. 1 & 2 2x10 or 2x12 would do the job.

Step 4: Compression Check

The final step is to make sure the lumber you've chosen meets the required design value for *compression perpendicular to the grain*. The loads carried by floor joists, ceiling joists, and rafters are transferred through their end points to supporting walls and beams. The ends of these members must be able to resist these loads without crushing.

Table 9.1 in *Span Tables for Joists and Rafters* (Figure 4, next page) gives a required compression value of 237 psi for a span of 16 feet and a bearing length of 1.5 inches. (The tables permit a bearing length of up to 3.5 inches, but

Table W–1
DESIGN VALUES FOR JOISTS AND RAFTERS
VISUALLY GRADED LUMBER

These "F_b" values are for use where repetitive members are spaced not more than 24 inches. For wider spacing, the "F_b" values shall be reduced 13%.

Values for surfaced dry or surfaced green lumber apply at 19% maximum moisture content in use.

Species and Grade	Size	Design Value In Bending ("F_b") Normal Duration	Snow Loading	7 Day Loading	Modulus of Elasticity ("E")
HEM-FIR					
Select Structural	2x10	1770	2035	2215	1,600,000
No.1 & Btr	2x10	1330	1525	1660	1,500,000
No.1	2x10	1200	1380	1500	1,500,000
No.2	2x10	1075	1235	1345	1,300,000
No.3	2x10	635	725	790	1,200,000
Select Structural	2x12	1610	1850	2015	1,600,000
No.1 & Btr	2x12	1210	1390	1510	1,500,000
No.1	2x12	1095	1255	1365	1,500,000
No.2	2x12	980	1125	1220	1,300,000
No.3	2x12	575	660	720	1,200,000
DOUGLAS FIR-LARCH					
Select Structural	2x10	1835	2110	2295	1,900,000
No.1 & Btr	2x10	1455	1675	1820	1,800,000
No.1	2x10	1265	1455	1580	1,700,000
No.2	2x10	1105	1275	1385	1,600,000
No.3	2x10	635	725	790	1,400,000
Select Structural	2x12	1670	1920	2085	1,900,000
No.1 & Btr	2x12	1325	1520	1655	1,800,000
No.1	2x12	1150	1325	1440	1,700,000
No.2	2x12	1005	1155	1260	1,600,000
No.3	2x12	575	660	720	1,400,000
SPRUCE-PINE-FIR					
Select Structural	2x10	1580	1820	1975	1,500,000
No.1/No.2	2x10	1105	1275	1385	1,400,000
No.3	2x10	635	725	790	1,200,000
Select Structural	2x12	1440	1655	1795	1,500,000
No.1/No.2	2x12	1005	1155	1260	1,400,000
No.3	2x12	575	660	720	1,200,000

EXCERPTED FROM *DESIGN VALUES FOR JOISTS AND RAFTERS*, AMERICAN FOREST & PAPER ASSN., WASHINGTON, D.C. ACTUAL TABLES LIST DESIGN VALUES FOR 2x4s, 2x6s, AND 2x8s.

Figure 3. *After determining what size lumber to use, turn to the tables in Design Values For Joists and Rafters to select a species and grade that meets the required Fb and E values. The tables shown here are excerpts from the hem-fir, Douglas fir-larch, and spruce-pine-fir tables.*

Table 9.1, *Span Tables for Joists and Rafters*

Required compression perpendicular to grain design values ($F_{c\perp}$) in pounds per square inch for simple span joists and rafters with uniform load.

	Bearing Length, in				
Span, ft	**1.5**	**2.0**	**2.5**	**3.0**	**3.5**
8	119	89	71	59	51
10	148	111	89	74	63
12	178	133	107	89	76
14	207	156	124	104	89
16	237	178	142	119	102
18	267	200	160	133	114
20	296	222	178	148	127
22	326	244	196	163	140
24	356	267	213	178	152

Notes: 1) Bearing width is assumed to be 1.5".
2) Total uniform load is assumed to be 66.67 plf.
3) Alternate $F_{c\perp}$ values are possible by adjusting the tabulated values in direct proportion to the desired load. Adjustment factors are tabulated in Table 9.2.
4) See A.1.3 for 2 span floor joist requirements.

EXCERPTED BY PERMISSION OF AF&PA.

Addendum to *Design Values for Joists and Rafters*

Species[1]	Compression design value perpendicular to grain, psi "$F_{c\perp}$"
Douglas Fir-Larch	625
Eastern White Pine	350
Hem-Fir	405
Southern Pine	
Dense	660
Select Structural No. 1, No. 2, No. 3, Stud, Construction, Standard, Utility	565
Non-Dense	480
Spruce-Pine-Fir	425
Spruce-Pine-Fir (South)	335

1. Design values apply to all grades for the species listed unless otherwise indicated in the table above.

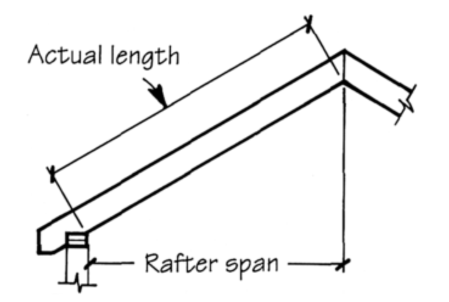
EXCERPTED BY PERMISSION OF AF&PA.

Figure 4. *Check to see that the lumber species selected has the necessary compression strength perpendicular to the grain. Table 9.1 (left) in Span Tables for Joists and Rafters gives the required values for various design conditions; an addendum that comes with Design Values for Joists and Rafters (below, left) gives the values for specific species.*

since 1.5 is probably the worst case that you'll encounter for joist or rafter bearing, it's a safe value.) You can get the compression design value for various species selected from the addendum that comes with *Design Values for Joists and Rafters*. For instance, hem-fir has an acceptable value of 405 psi, spruce-pine-fir of 425.

Ceiling Joists and Rafters

Ceiling joists are sized like floor joists except that deflection limits vary depending on whether the joists will be used for attic storage or will have a plaster or drywall finish. Check your code and follow the AF&PA tables accordingly.



Use the horizontal projection of a rafter, not its actual length, when figuring rafter span.

When using the tables to size rafters, there are two points to keep in mind. First, remember that the rafter's span is not its actual length but its total horizontal projection (see illustration, below, left). Second, use the snow load value for your region in determining which rafter table to use. If your code book says your snow load is 40 psf, then you must use the 40 psf live load rafter table. The fact that snow loads only act part of the year has been taken into account in the rafter tables, but don't forget to use the "Snow Loading" column to get the Fb design value. ■

Paul Fisette is a wood technologist and director of the Building Materials Technology and Management program at the University of Massachusetts in Amherst.