Calculating Loads on Overhanging Floors

by Harris Hyman, P.E.

The Garrison is an early New England house style that continues to be popular with builders all over the country. Its principal feature is an overhanging second floor under the front eaves of the house, which allows for more generous bedrooms upstairs (see Figure 1).

The style presents an interesting structural problem, because the second-floor joists overhang the outside wall. Like any joists, these joists carry floor loads — for the upstairs bedrooms and bathrooms in this case. The wrinkle here is that the overhanging ends of the joists also support the second-story exterior wall. The exterior wall in turn supports the roof above, so depending on snow loads, roof coverings, and the span of the building, the concentrated load on the overhang can be quite large.

We have to design the second-story joists for *both* loads: the continuous floor load inside the house and the concentrated load from the roof that is carried to the joist through the wall.

Beam Design

A typical floor joist is a beam — a uniformly loaded "simple" beam. We looked at how to design simple beams a few years back (*Practical Engineering,* 8/94 & 9/94). But because uniformly loaded simple beams are so common in houses, it's not really necessary to individually design most joists, headers, and girders: You can just look up the sizes in available span tables — as long as you know the loads.

The second-story joists along the front of a Garrison are a little more complicated than that, and there are no tables that I know of that will size them for you (in dimensional lumber, that is — there are tables for wood I-joists available from the manufacturers). The floor loads inside the house are no big deal — any correctly sized joist could easily handle the overhang in Figure 1 if uniform floor loads were all we were concerned with (see "Overhanging Decks: How Far Can You Go?" *Practical Engineering,* 9/95). The problem is the concentrated load coming down from the roof (Figure 2).

To get some idea of the problems, let's suffer through the design process. Here's what we'll do. First, in this month's article, we'll figure out the loads on the joist from the roof and the floor. Then stay tuned, and in a future issue we'll calculate the effects of these loads and select a plausible piece of wood for the joist. Then, as in any beam design, we'll back-check the selected joist for bending strength, shear strength, crushing where it's supported on the wall, and deflection under load. In this case, we'll also want to look at the lifting effect created by the point load at the outboard end, to make sure the inboard end of the joist is held down.

Adding Up the Loads

Figure 3 shows the two examples we'll work with. On top (A) is a typical truss-roofed Garrison with shingle roofing, wood siding, and wood flooring inside. To make things more interesting, the bottom example (B) shows a style you might find on the West Coast, built with heavier materials — clay tile roofing, stucco cladding, and a tile floor inside. This roof is rafters, not trusses.

In both examples, the joists are placed 16 inches on-center, with 2 feet overhanging the first floor wall. A good technique is to look at a 16-inch-wide slice of the building, so that we're working with the loads on a single joist.

There are two types of loads to account for: the dead load from the structure itself and the live load from furniture and people in the room and snow on the roof. Live loads are spelled out in the codes, with 40 psf being the standard residential floor load. This is hardly realistic, of course, with furniture randomly scattered around the room and varying numbers of people moving about, but over the years it has proven a

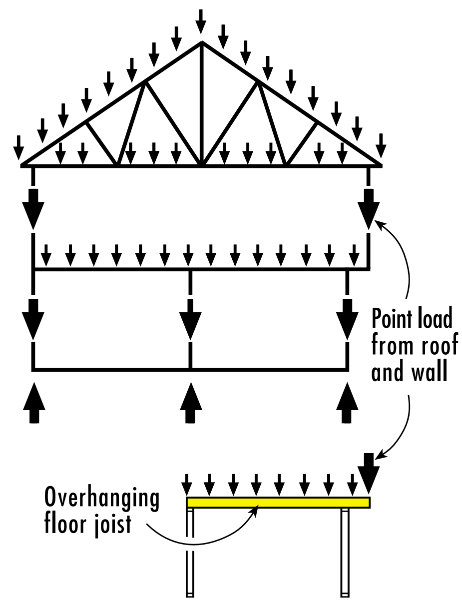


Figure 1. The outstanding feature of a Garrison Colonial is the overhanging second floor. As the overhang gets longer and roof loads get heavier, the second-floor joists must be carefully sized to handle the point load from the roof.

Forces in an Overhanging Joist

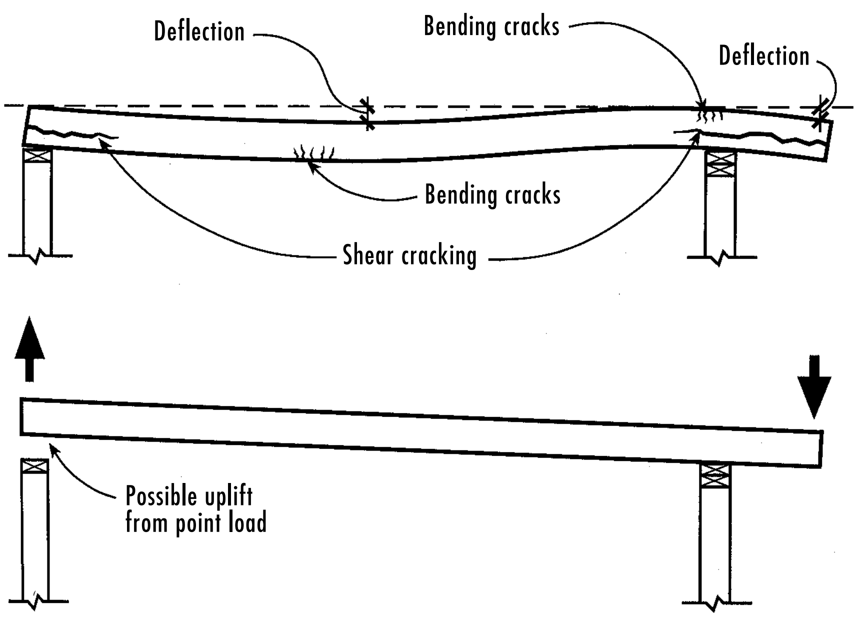


Figure 2. The overhanging joists must be designed to handle shear forces, bending forces, and deflection imposed by both the uniform floor loads and the point load from the roof. At the outboard support, the tension face and thus the maximum bending moment are on top of the joist. Shear cracking and crushing at the outer support are also intensified by the point load. Finally, the point load may exert a lifting force on the inboard end of the joist, which has to be calculated to ensure that the joists are adequately anchored.

useful number for designing. It should be modified for special situations, like grand pianos and such. Snow loads vary by region, running from 15 psf in the South to over 100 psf in the northern Rockies. For these examples, we'll use 40 and 25 psf for snow loading.

Dead loads require a closer look, since they depend on the weight of the construction materials. Most span tables take a shortcut of assuming a wood-framed floor or roof weight of 10 pounds per square foot — higher if heavy roofing materials or ceramic tile are involved. Some tables use 15 psf, some 20 psf, for truss roofs. For this exercise, we'll calculate the dead loads to see how they compare with the conventional wisdom. Figure 4 lists the weight of materials in pounds per square foot, making it easier to add things up.

Start at the Top

Gravity loads originate at the top of the house and accumulate as they work their way down through the structure. A good way to account for everything is to work from the top down. Here are some other tips for adding up loads.

Study the roof configuration carefully. With most truss roofs, the roof load is equally distributed to the exterior walls — each wall gets half. The same is often true for stick-framed roofs, unless there's a structural ridge or a bearing wall under the ridge. In that case, the exterior walls might get only one-fourth the roof load, with half the load running down to a center girder in the basement.

Adjust for roof slope where necessary. When adding up the weight of roofing materials, the load per square foot must be taken along the slant of the rafter. In the examples in Figure 3, we started with half the span of the roof, then multiplied by slope adjustment factors (1.12 for 6/12, 1.2 for 8/12) to allow for the increased distance along the slant. Live loads and snow loads, which are code driven, are calculated along the horizontal distance; no adjustment is necessary.

Don't forget the eaves overhang when calculating the roof load. In these examples, I've added in a foot for the overhang.

Remember the weight of ceilings. The drywall in the bottom of joists and rafters adds a lot of dead weight to the structure. Even ceiling insulation, which seems practically weightless, can add half a pound per square foot or more.

Note in example B in Figure 3 that only half of the attic floor-ceiling transfers its load to the outside wall. The other half is picked up by a center bearing wall.

Don't be confused by a truss roof. Even though there may be a center partition, it is almost always nonbearing (that's why you use truss clips to attach it to the bottom chord). Trusses are typically designed to carry their loads to the exterior walls.

Allow for attic storage where appropriate — codes specify 20 psf. Many truss roofs do not provide for any storage.

Don't forget the weight of the wall itself. Window units are heavy, so remember to average in their weight.

Account for unusually heavy materials and assemblies — tile roofs, masonry veneers, ceramic tile — that may place extra weight on wood framing.

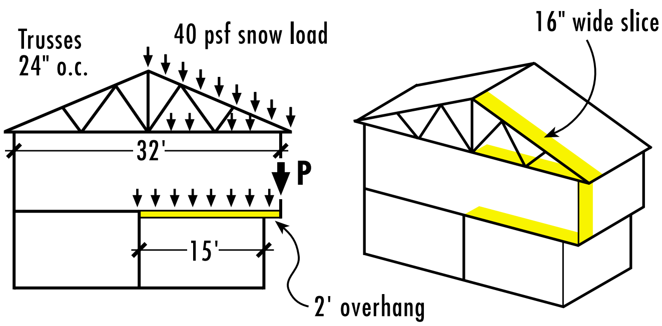
Be conservative when calculating dead loads. The conventional 10 psf for floor, wall, and roof assemblies is often not enough. Use at least 15 pounds for roof dead loads for asphalt shingle roofs. Using 20 pounds will account for additional layers of shingles that might be added over the years.

Selecting a Joist Size

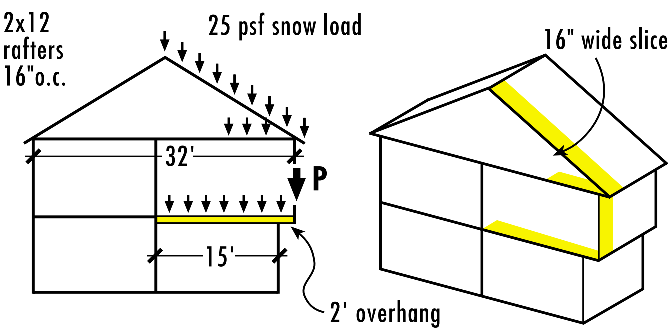
The floor loads on the overhanging joists in our two examples are pretty standard. But those 1,200-pound and 1,400-pound point loads coming down

Adding Up the Loads on Each Floor Joist

A



B



Example A: Truss-Roofed Garrison

Concentrated load (P) from roof & wall onto each joist

Roof dead load:	Shingle roofing	2.5 psf
	1/2-inch plywood sheathing	+1.5 psf
		4.0 psf
	4 psf x1.12 (factor for 6/12 pitch) =	4.5 psf
	Weight of truss @24" o.c.	+4.0 psf
	Insulation	+0.5 psf
	5/8-inch drywall ceiling	+2.5 psf
		11.5 psf
Roof uniform live load (snow load)		+40.0 psf
Total roof uniform load		51.5 psf
Total roof load per joist	51.5 psf x17 ft. x1.33 sq. ft/ft.	**1165 lb.**
Dead weight of wall:	2x6 studs @ 16"o.c.	1.4 psf
	1/2-inch sheathing	1.5 psf
	Wood siding @ window unit, avg.	4.8 psf
	Fiberglass insulation	0.3 psf
	1/2-inch drywall	+2.0 psf
		10.0 psf
Load from wall onto each joist	10.0 psf x 8 ft. x1.33 sq.ft./ft. =	**107 lb.**
Point load P onto each joist	1165 lb. +107 lb =	**1272 lb**

Floor load on each joist

Floor uniform dead load	2x12 joists @ 16" o.c.	2.9 psf
	3/4-inch plywood subfloor	2.3 psf
	Hardwood flooring	4.0 psf
	1/2-inch drywall ceiling	+2.0 psf
		11.2 psf
Floor uniform live load		+40.0 psf
		51.2 psf
Total floor load per joist on 15-ft. inboard span		
	51.2 psf x15 ft. x1.33 sq.ft./ft. =	**1022 lb.**
Total uniform floor load per joist on 2-ft. overhang		
	51.2 psf x 2 ft. x 1.33 sq.ft./ft. =	**137 lb.**

Figure 3. Example A is a wood-sided Garrison with a truss roof covered with asphalt shingles. Inside are hardwood floors. Example B is stucco-clad, with a stick-framed tile roof and ceramic tile floor inside. The calculations show the total dead and live loads from a 16-inch (1.33 ft.) slice of the building coming down on each overhanging joist.

Example B: Tile-Roofed Garrison

Concentrated load (P) from roof, attic & wall onto each joist

Roof uniform dead load:	Clay tile roofing	12.0 psf
	2x12 rafters @ 16" o.c.	2.9 psf
	1/2-inch plywood sheathing	+1.5 psf
		16.4 psf
	16.4 psf x 1.2 (factor for 8/12 pitch) =	19.7 psf
Roof uniform live (snow) load		+25.0 psf
Total uniform roof load		44.7 psf
Total roof load onto each joist	44.7 psf x17 ft. x1.33 sq.ft./ft. =	**1011 lb.**
Attic load (from half of 17-ft. attic joist span)		
	2x8 joists @ 16" o.c.	1.9 psf
	Insulation	0.4 psf
	5/8-inch drywall ceiling	2.5 psf
	1/2-inch plywood floor	+1.5 psf
Attic uniform dead load		6.3 psf
Attic storage (uniform live load)		+20 psf
Total attic uniform load		26.3 psf
Load from attic onto each joist		
	26.3 psf x8.5 ft. (half span of attic joist) x1.33 sq. ft./ft.=	**298 lb.**
Dead weight of wall:	2x4 studs @ 16" o.c.	0.9 psf
	1/2-inch sheathing	1.5 psf
	Stucco cladding	10.0 psf
	Fiberglass insulation	0.2 psf
	5/8-inch drywall	+2.5 psf
		15.1 psf
Load from wall onto each joist	15.1 psf x8 ft. x1.33 sq.ft./ft. =	**161 lb.**
Point load P onto each joist	1011 lb. + 298 lb. + 161 lb. =	**1470 lb.**

Floor load on each joist

Floor uniform dead load on 15-ft. inboard span		
	2x12 joists @ 16" o.c.	2.9 psf
	3/4-inch plywood subfloor	2.3 psf
	Ceramic tile over mortar bed	14.5 psf
	5/8-inch drywall ceiling	+2.5 psf
		22.2 psf
Floor uniform live load		+40.0 psf
Floor total uniform load		62.2 psf
Total floor load per joist on 15-ft. inboard span		
	62.2 psf x 15 ft. x1.33 sq.ft./ft. =	**1241 lb.**
Total floor load per joist on 2-ft. overhang		
	62.2 psf x 2 ft. x 1.33 sq.ft./ft. =	**166 lb.**

Weights of Common Building Materials (lb. per sq. ft.)

Studs, Joists & Rafters

2x4s, 16" o.c.	.9
2x6s, 16" o.c.	1.4
2x6s, 24"o.c.	1
2x8s, 16" o.c.	1.9
2x8s, 24" o.c.	1.3
2x10s, 16" o.c.	2.4
2x10s, 24"o.c.	1.6
2x12s, 16" o.c.	2.9
2x12s, 24" o.c.	2
Residential roof truss, 24" o.c.	4

Sheet Goods

1/2-inch plywood	1.5
3/4-inch plywood	2.3
1/2-inch drywall	2
5/8-inch drywall	2.5

Flooring

3/4-inch hardwood strip flooring	4
3/8-inch ceramic tile	2.5
1/2-inch quarry tile	6
1-inch mortar bed	12
Cement backerboard	3.5
Carpet & pad	3

Exterior Wall Cladding

Wood siding	1.5
Three-coat stucco	10
Window unit	8

Roofing

Asphalt shingles	2.5- 4.5
Clay tiles	9-12
Spanish tile	19
Mortar bed for roof tile	10

Insulation (per inch thickness)

Fiberglass batt insulation	.05
Rigid foam	.2

Figure 4. This chart was compiled from a variety of sources and provides guidelines only. For the exact weight of specific materials, it's best to check with the manufacturer.

on the end are worrisome. Framer's instinct tells us we're looking at 2x12s at the least, but how can we be sure?

You may not care to do your own beam design — that's what engineers are paid for, and their stamp reduces your liability. (In many jurisdictions, of course, you have no choice.) But if you can run through a procedure like the examples in Figure 3, then you can confidently provide the loading to your neighborhood engineer, and let him or her do the rest. If you want to try your hand at designing, make sure your subscription is up to date, and we'll get into it in an upcoming issue.

Harris Hyman *is a civil engineer in Portland, Ore. He lives at hh@spiritone.com.*