Framing an Open-Plan Saltbox

Structural stability can be a problem when the load-bearing partition is removed

by Pat and Patsy Hennin

Many houses built with energy efficiency and contemporary design in mind just don't look very homelike to lots of people, so builders are taking a second look at the ability of traditional styles to accommodate alternative technology and a modern, open interior while maintaining the dignity befitting a house. The saltbox is inherently efficient, with its high heat-collecting south face and its low north wall, often backed by wind-buffering closets. In some modern incarnations, though, it is also inherently unstable, with structural characteristics that place dangerous outward thrust on bearing walls. Appropriate framing can solve this problem, and result in the best of both worlds—open space within, and the traditional saltbox silhouette outside.

A modern saltbox under construction in upper New York state. Framing is basically traditional, but the common partition between Cape and shed has been replaced by posts and beams to open up the interior. Photo: Patsy Hennin

Development—The saltbox style evolved from the center-chimney Cape Cod, $1\frac{1}{2}$ stories with a peaked roof, which was both simple and symmetrical (drawing, facing page, top). The side walls of the traditional Cape are built to equal heights and tied to each other with joists at floor and ceiling levels. Rafters are locked into compression at the roof peak, and the ceiling-level joists neutralize the tendency of the roof load to push the walls out. Above the walls the rafters and joists form triangles, the most solid of shapes, while corner braces (more triangles) give the walls rigidity. A Cape is very stable.

In its pure form, a saltbox is a Cape with a shed addition, which often continues the roof line at its original slope. The original rear wall (A in the drawing) becomes a shared load-bearing partition, and the new roof exerts no outward thrust because shed roofs place their loads equally on both bearing walls (A and B). An old-fashioned saltbox is as stable as the Cape it evolved from.

Today's saltboxes, though, are usually erected from scratch by builders who want a traditional look outside, but large, open spaces inside—and this can be the source of many structural problems. The saltbox's exterior walls and rafters by no means form a free-standing arch, and dispensing with the common partition or the joists that tie the rafters together destroys its structural integrity. Under heavy loads, such a building will collapse. If you want a sound, open-plan saltbox, you have to compensate for these missing structural elements.

Framing a new saltbox—One way to deal with the outward thrust of the roof is to eliminate rafters and build the entire structure in bents of progressive heights conforming to the shape of the saltbox roofline (drawing, facing page, bottom). No rafter ties are necessary, so the house can be open vertically as well as horizontally—great if you want a cathedral ceiling. Each bent is made up of a purlin (a timber running parallel to the ridge) resting on posts that help form the end walls, which also become the bearing walls. (In a conventional Cape, the front and rear walls are the bearing walls.)

Purlins up to 18 ft. long are cost-effective, so assuming the tall wall is to the south, this method can provide clear spans from east to west of up to 18 ft. You can add sections of up to 18 ft. to the east or west. If you have special needs, you can replace one or two common posts with a beam that will support the weight of purlins. If you need to span more than about 12 ft. under loading conditions similar to Maine's, look into using a steel beam. Steel companies will size them for you, and they probably won't ruin your budget.

There are probably as many ways to frame up a new saltbox as there are housebuilders, but let's run quickly through one way you could proceed, taking as our example a house that is, in effect, two saltboxes of different heights slightly offset. This is probably the hardest case, and if you can frame it, you'll be able to frame any similar design.

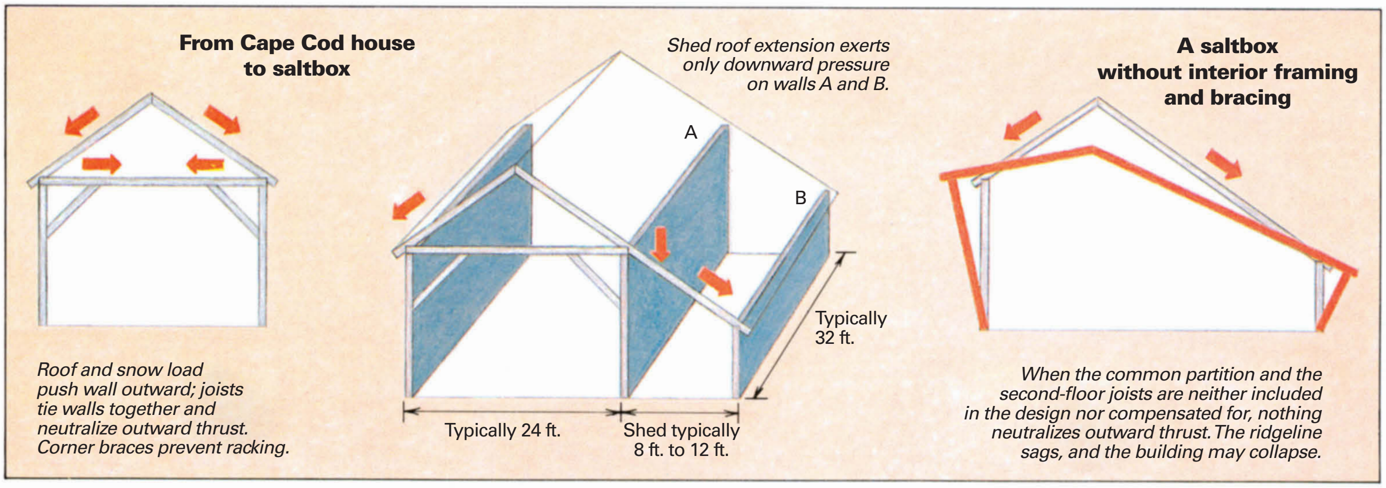
The foundation must support the weight of the loaded building in the soil of the site and against heavy wind loads. For example, we can use pressure-treated 6-in. to 9-in. diameter utility poles anchored to concrete pads below frost level, attaching heavy 6x10 sills to them with steel strapping, as shown in detail C. In this case, we would space the posts 8 ft. o.c. from north to south and 9 ft. o.c. from east to west, so that a row of them would run front to back under the center of each part of the structure. You could, of course, pour a perimeter wall or a slab, and make the sill connection with bolts set right into the concrete.

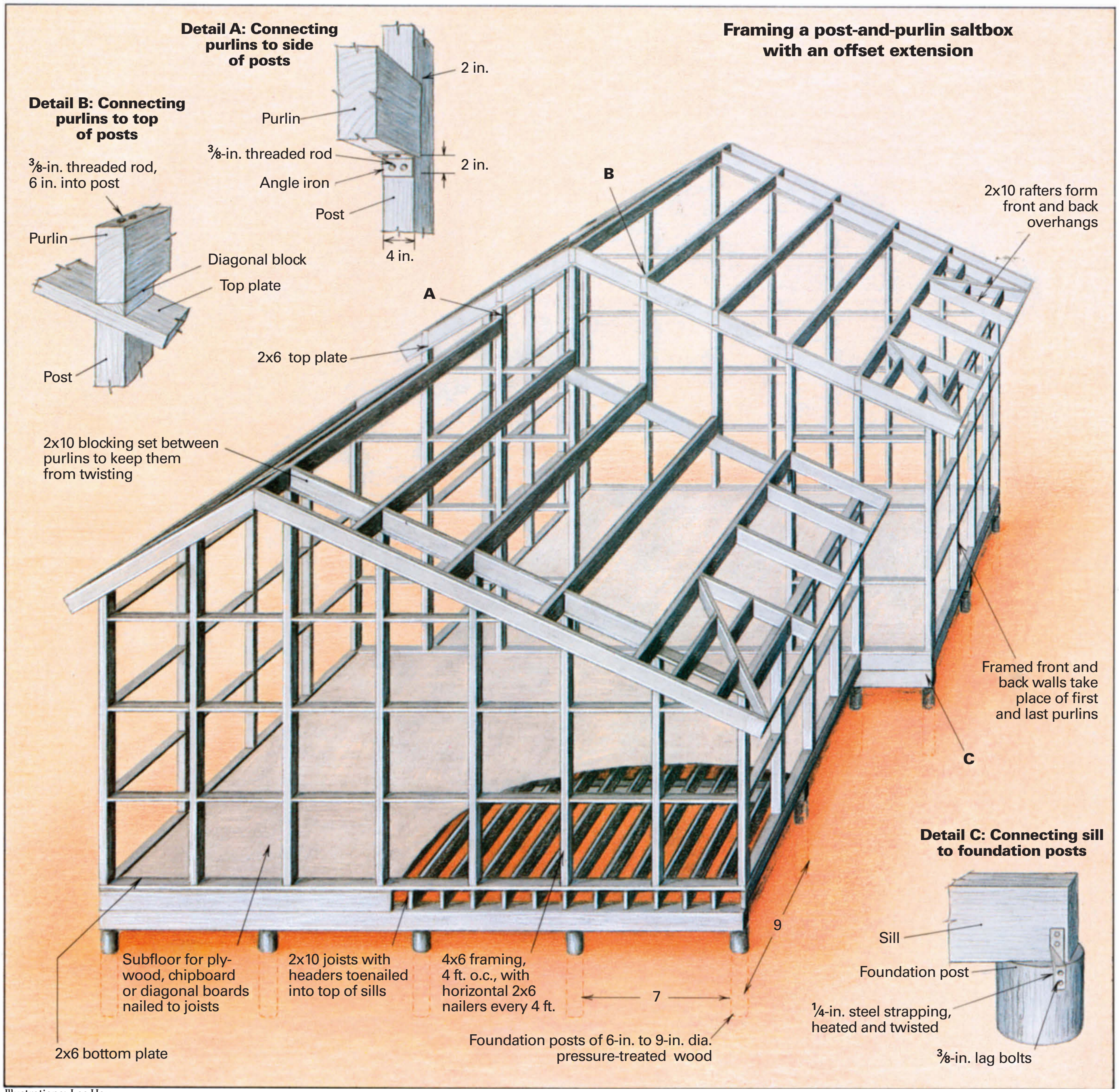
Joist hangers are the simplest way to connect joists to sills, but they are expensive and aren't sized to accept roughsawn lumber. We usually set the joists 16 in. o.c. on top of the sills. We use 16d nails to attach 2x10 headers to the joists' ends, take careful measurements corner to corner, and use a sledge to persuade the whole shebang into square. Then we toenail the joists into the sills with 10d nails. Subflooring (plywood, diagonal boards or flakeboard) is fastened to the joists with 8d nails, and we've got a platform to work on.

The post-and-purlin bents can go up as units, but putting up the side walls first makes it easier to keep the roofline straight. The walls are framed right on the deck. We usually use 4x6s, 4 ft. o.c., with 2x6 top and bottom plates and install horizontal blocking every 4 ft. up the height of the walls to act as a nailing surface for asphalt-impregnated sheathing, which breathes better, prevents infiltration better and is cheaper than plywood. Bracing against wind racking can be achieved with either plywood in the corners or diagonal steel or wood bracing. If you are framing with roughsawn lumber, 20d galvanized box nails are standard fasteners. Use 16d common nails with milled wood. Tilt the side walls up, nail the bottom plates through the deck into the joists with 20d nails, and brace the walls with 2x4s or the like while you get the 4x10 purlins up and in place.

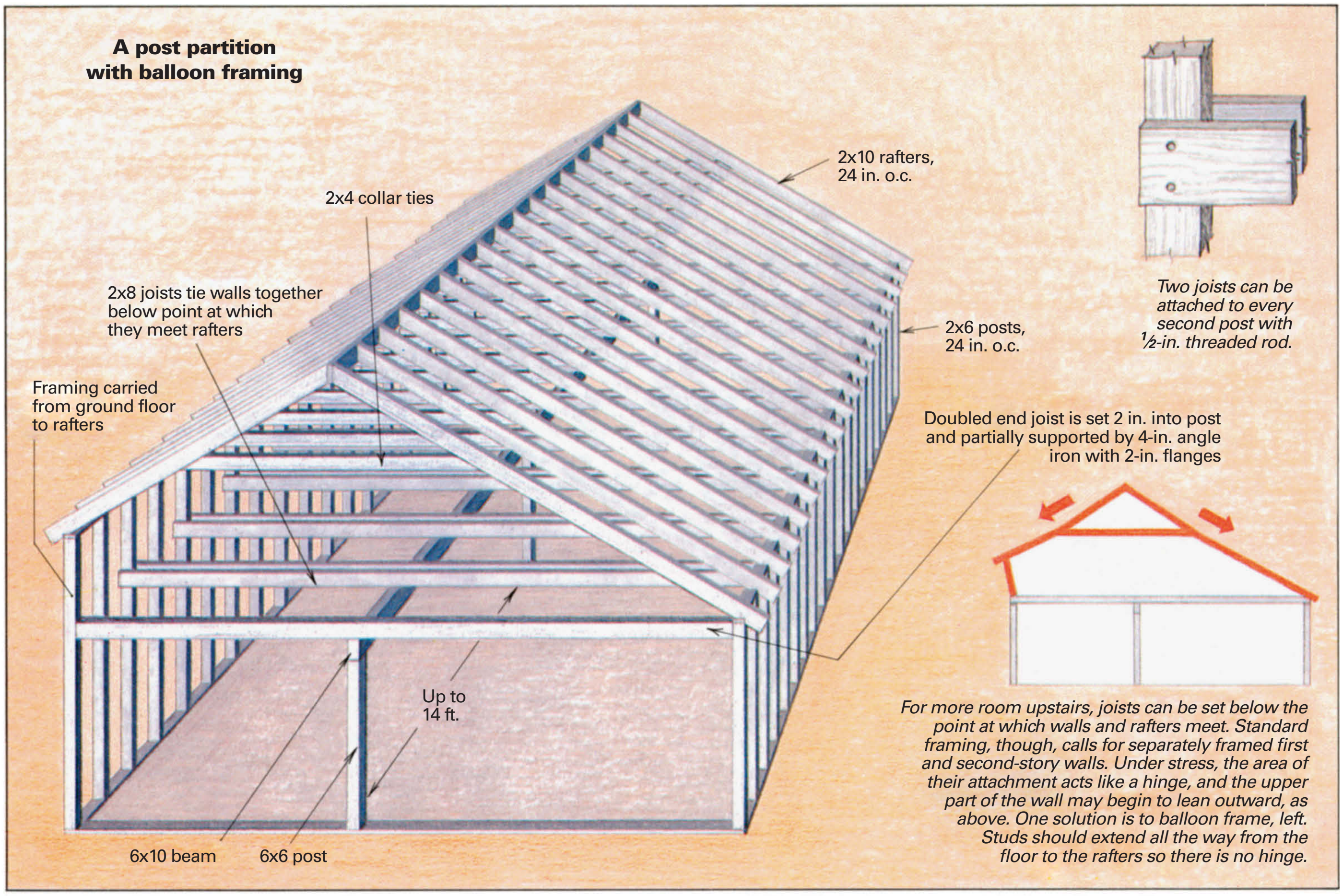
Small diagonal blocks under each purlin will keep them all sitting perpendicular to the floor, the attitude in which they're strongest. One of the best ways to secure the purlins is to use a $\frac{3}{8}$-in. self-feeding 18-in. carbide bit to drill two holes through purlin, block, top plate, and 6 in. into each post. Use a sledge to drive $\frac{3}{8}$-in. rebar into each hole to anchor the purlins solidly in place (detail B). Toenail 2x10 blocking to the top plate between purlins, trimming it to the proper height. This blocking helps keep the purlins from twisting. Extending the purlins 18 in. or so beyond the posts allows for overhangs at east and west.

Where the purlins of the lower house section lie against rather than on top of posts, we notch the posts out 2 in. deep (detail A), and also bolt





Illustrations: Lee Hov



Sizing a beam

A beam must be large enough to support the "dead" load of the structure above it and the "live" load (of snow or activity) that is imposed on it. Calculating the size of a beam is a two-step process: First, add up the various loads on the structure and decide how they are bearing on the beams. The weight is either spread evenly (a uniform load) or concentrated (a point load). A point load typically requires a beam twice as large as the same uniform load would. Second, choose a beam of the right shape and species to resist the load.

The first load calculation is a bending moment problem in engineering terms. More than 40 formulae analyze the ways a load tends to break a beam, depending on the type of load (uniform or point), and on the beam and how it is supported (at both ends, cantilevered, with ends overhanging and so on). *Architectural Graphic Standards* is a useful reference for typical beam placement formulae; your local library probably has a copy.

As an example, let's size a purlin like one shown in the drawing on the previous page. This purlin is supported at both ends, with a roof load and a snow load spread evenly along its clear span (unsupported length)—a simple beam with a uniform load. The bending moment (M), or load that will break it, is calculated by:

$$M = \frac{WL}{8},$$

where W is the weight carried by the beam (the load per square foot multiplied by the top surface area of the beam in square feet) and L is the unsupported length of the beam in inches. Assuming that the posts are spaced 4 ft. on center, this beam will carry a rectangle of roof area above it 4 ft. (halfway to its neighboring purlins) by 18 ft. (the length of the clear span), or 72 sq. ft. On each square foot is the weight of the snow plus the weight of the roof structure itself. Check your local building code's snow-load estimate; in Maine it is 40 lb./sq. ft. The weight of the structure varies, but a typical figure is 10 lb./sq. ft. Hence the total weight on this purlin is 50 lb./sq. ft. Returning to the formula,

$$W = 50 \text{ lb./ft.}^2 \times 72 \text{ ft.}^2 = 3{,}600 \text{ lb.}$$

$$L = 18 \text{ ft.} \times 12 \text{ in./ft.} = 216 \text{ in.}$$

$$M = \frac{WL}{8} = \frac{3{,}600 \text{ lb.} \times 216 \text{ in.}}{8} = 97{,}200 \text{ in.-lb.}$$

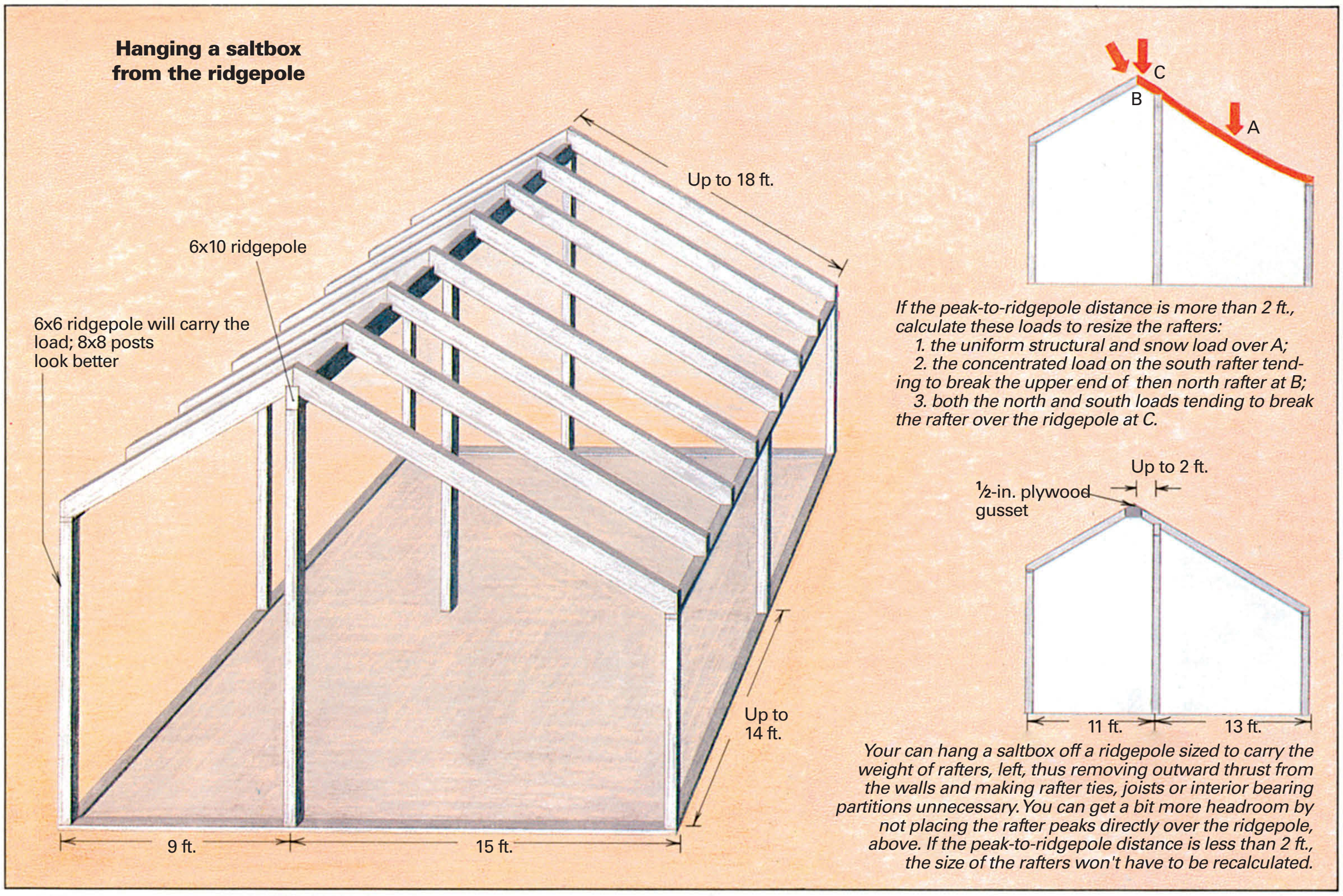
The amount of wood needed to resist this load is the section modulus (S), found by dividing the bending moment M by the fiber stress value (f) on the species of wood, or the pounds per square inch that the species can carry. *Architectural Graphic Standards* and many wood and building guidebooks list allowable stress values for structural timber of commonly used species. Eastern hemlock, our usual choice, can carry 1,200 lb./sq. in. This section modulus is calculated as follows:

$$S = \frac{M}{f} = \frac{97{,}200 \text{ in.-lb.}}{1{,}200 \text{ lb./in.}^2} = 81 \text{ in.}^3.$$

The section modulus is just a theoretical shape. The actual concrete dimensions of the lumber are calculated by the formula

$$S = \frac{bd^2}{6},$$

where b is the breadth in inches and d the depth in inches of the beam. We usually use roughsawn lumber, where a 2x4 is really 2 in. by 4 in.; for milled lumber, use the planed-down dimensions. To find the right size beam, substitute various sizes for b and solve for d. The strength of the concrete dimensions must be equal to or greater than the theoretical shape, in this case 81 in.^{3}. For example, if b is 4 in., d is 11 in. If b is 6 in., d is 9 in. Since lumber is sawn in 2-in. increments, order a 4x12 or a 6x10. Either will do. There are tables that will size joists and beams, but rarely can you find one that will size a timber as large as these purlins. Also, most tables aren't written for roughsawn lumber. —*Patsy Hennin*



If the peak-to-ridgepole distance is more than 2 ft., calculate these loads to resize the rafters:
1. the uniform structural and snow load over A;
2. the concentrated load on the south rafter tending to break the upper end of then north rafter at B;
3. both the north and south loads tending to break the rafter over the ridgepole at C.

Your can hang a saltbox off a ridgepole sized to carry the weight of rafters, left, thus removing outward thrust from the walls and making rafter ties, joists or interior bearing partitions unnecessary. You can get a bit more headroom by not placing the rafter peaks directly over the ridgepole, above. If the peak-to-ridgepole distance is less than 2 ft., the size of the rafters won't have to be recalculated.

angle iron with 2-in. flanges onto the posts with ⅜-in. threaded rod at the bottom of the notch, creating the 4-in. bearing surface required by most building codes.

We don't set purlins on top of the first and last posts. Instead, we frame the 4x6 front and rear walls up to the proper height. We set 4x6s 4 ft. o.c. with 2x6 top and bottom plates and blocking, just as in the side walls. The asphalt-impregnated sheathing goes on with 1½-in. roofing nails. We also extend rafters from the front and back purlins to create overhangs at the north and the south.

On the roof, 1-in. boards over the purlins do double duty as both sheathing and ceiling. They are nailed to each purlin with three 8d nails. This ties all the purlins together and further reduces the likelihood of their twisting. At the peak, we fasten boards from both sides of the roof together with 1⁄16-in. or 22-ga. metal secured with 5d nails. Our post-and-purlin saltbox is now framed and sheathed.

Modifications to traditional framing—There are techniques other than post and purlin that can result in a structurally stable open-plan saltbox. One is simply to modify traditional framing by replacing the common wall with a series of structural posts topped by a beam sized to support the rafters above (drawing, facing page). Here in Maine, we can use reasonably sized beams to span up to 14 ft. In areas where a smaller snow load can be expected, you could span greater distances. This technique results in an open horizontal space, but the joists tying the walls together block vertical openness.

If you want an open first floor and also more room on the second, set the joists below the level at which the rafters meet the top plate. Then install collar ties near the peak of the roof. You'll still need the common partition or a row of posts, but this technique increases the headroom at the south wall, and will give you more space for upstairs rooms. It imposes great point loads on the south studs, though, and snow loads could make the south wall bend at the plate between the first and second floor framing. The best solution is to balloon frame—use studs long enough to carry in one piece all the way from the first floor through the second floor to the rafters, and use enough of them to divide the loads down to a minimum per stud and rafter. In Maine we often use 2x6s, 24 in. o.c. as studs, and set our rafters 24 in. o.c. also.

Hanging from the ridgepole—Another way to eliminate outward thrust is by using a ridgepole sized as a beam to carry the weight of the rafters (drawing, above). Sizing a beam is explained in the box on the facing page. If you attach the rafters to the ridgepole with angle iron or rebars, or gusset them to each other over the ridgepole, the building will hang like a tent from the ridge. You no longer need second-floor joists or rafter ties, because there is no outward thrust. As with the purlin method, the house can be open vertically as well as horizontally. Rafters up to 18 ft. long make economic sense, and in Maine ridgepoles can span up to 14 ft., so clear interior spans in a saltbox could reach 24 ft. by 14 ft., and the only obstruction in a 24-ft. by 28-ft. room would be a single post in the middle.

If you need more space north or south of the obstruction caused by the rafters and ridgepole, you can set the peak several feet away from the ridge, as in the drawing, above right. The southern rafters are in compression against the northern rafters, and are exerting a downward pull on their high ends. Technically, this is a point load on cantilever, and the ridgepole can be as much as 2 ft. from the peak without affecting the size of the rafter. If you want the peak even farther from the ridge, you have to consider three types of load when you calculate the size of the rafter, as shown in the drawing, top right.

You can build a safe, open-plan saltbox using any of these methods, or a combination of several. Draw the floor plan first and think about which technique would obstruct your pattern least. If necessary, fiddle with your floor plan a little so that you can use a method that will guarantee a stable house. If changing your floor plan is too traumatic, consider using steel beams to allow longer safe spans. Remember that you always have to account for the outward thrusts created by disturbing the original simplicity and balance of the Cape/shed combination that we now call the saltbox. □

At time of writing, the Hennins were directors of the Shelter Institute in Bath, Maine, an owner-builder school which they founded in 1973.