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Photos by Mark Pollard/Thompson Johnson Woodworks

Roof Framing Challenge

BY TED CUSHMAN

Last fall, *JLC* went to the jobsite on Peaks Island where lead carpenter Mark Pollard and the crew of Thompson Johnson Woodworks were building the foundation for one of the company's most challenging jobs to date: an architect-designed custom home with enough odd angles to puzzle Pythagorus (see "Customizing an ICF Foundation," Nov/16).

Unique as it was, that foundation has not been the toughest problem this custom project has thrown at the Thompson Johnson team. Wall framing, involving a wood I-joist buildout for superinsulation as well as a two-story corner window, brought its own head-scratchers. And then came the roof (the topic of this story).

To make the most of a gently sloping clearing that borders on woods, Portland architects Kaplan and Thompson devised a highly original form. The largest element in the house (shown during framing) is a long, parallelogram-shaped main room with a two-story vaulted space at the downhill end **(1)**. This long room has a monopitch shed roof, with one major wrinkle: Rising up at one corner of the roof is the upper portion of a tall, two-story corner window wall, which, for lack of a better term, the construction crew is calling "a dormer." But this is no ordinary doghouse dormer. It's really more of a boxy shaft that thrusts through the main shed roof, and it's topped with its own shed roof that pitches on two axes, forming a shallow valley with the main roof **(2)**.

Visualizing the shape. The custom-designed windows specified for this end of the house aren't square at the top, but instead have one corner higher than the other. And at the wall-to-ceiling joint, says Pollard, the plans call for no window casing: "The drywall on the ceiling just dies right into the top of that window, without any step-down." So Pollard took his layout for the roof assembly from the shop drawings for the upper corner windows. "I just drew a full-scale drawing on the subfloor," he says. Then he framed a skeleton shape with 2x4s **(3)** to guide

The crew set pie-shaped pieces of Zip System sheathing in place on the skeleton outline of the window-wall structure **(4)**. The valley rafter, downsized to a 12-inch height to allow for insulation above it, had to be shaved at the ends to allow for its out-of-square and out-of-level orientation with respect to the common rafter supporting it at the uphill end, and the wall header supporting it at the downhill end **(5, 6, 7)**.

the placement of massive LVL headers to support the roof frame. This skeleton outline would also determine the plane of the vaulted room's ceiling.

BEAMS AND A FLUSH CEILING

This custom home is aiming for Passive House energy performance, and for health reasons, the clients also need indoor relative humidity maintained at 50% year-round. For airtightness and calibrated vapor control, the designers opted to sheathe the underside of the ceiling with Huber Zip System sheathing (with the membrane side facing down) and tape the seams with Zip tape. So once the 2x4 skeleton of the room was in place, Pollard went ahead and installed Zip System panels around the perimeter of the shape (see photos, above). The panels defined the plane of the ceiling, even before the perimeter beams and low-slope I-joist roof rafters were installed.

If the pie shapes of the panels and the zig-zag pattern they form look peculiar, it's because the crew laid out and cut the panel shapes in anticipation of the roof framing that would follow. Says Pollard: "Those pieces of Zip panel were cut that way so that they would be square to the rafters, so that eventually when we were all done framing the roof, we could go back, and we would not have to cut weird polygon shapes to infill the rest of the Zip on the ceiling. The edges are cut to fall out at the midline of the rafters when the rafters are placed."

Next the crew had to set structural beams around the perimeter of the room, forming a sort of hybrid between a window header and a structural rim joist—but intended to support not floor joists but low-slope I-joist rafters. They also needed to set a structural valley rafter at the intersection between the main building's shed roof and the counter-sloping roof of the window-wall room. For




The LVL rafters for the low-slope roof system were set out of square to the beams that they tied into, requiring the use of “slopeable, skewable” structural connectors **(8, 9)**. The bottom shoe of these hangers can pivot up and down, while the ears on the sides can be bent from side to side. Where the I-joist rafters meet the doubled-up LVL valley rafter, the I-joists stand about 4 inches proud, leaving space for insulation above the valley member to reduce the risk of melting snow and formation of ice in winter **(10, 11)**.

this valley rafter, Pollard explains, Portland engineers Casco Bay Engineering originally specified a single 16-inch-deep LVL. At the uphill end of the valley, the original plan was to tie the valley rafter into a doubled-up 16-inch LVL common rafter.

“But we were concerned about thermal bridging at the valley,” says Pollard, “and the potential for ice to form there in the wintertime when there’s a lot of snow on the roof. So we asked the engineer to downsize the valley rafter, as well as the common rafter that it ties into at the uphill end.” The revised solution was a double 12-inch LVL valley rafter and a double 14-inch common rafter. The 16-inch I-joist jack rafters would sit proud of the valley beam by 4 inches, leaving room for blown cellulose insulation between the beam and the skin of the roof.

Connecting the valley rafter to its support beams at either end, and connecting the I-joist jack rafters to the wall header beams and the valley beam, posed a hardware problem: None of the connections were at right angles. For the I-joist rafters, however, there turned out to be an off-the-shelf solution. “It’s a Simpson Strong-Tie product called the LSSUH310—a ‘slopeable, skewable’ hanger,” says Pollard. “It has a bottom shoe that can pivot up and down for your roof slope, and two big wings on either side, where it gets nailed to the carrying beam, that you can bend in order to skew the rafter from side to side.” To connect the hangers to the beams, the crew used positive-placement gun nails—$1\frac{1}{2}$-inch nails for fastening to single LVL timbers, and 3-inch nails where doubled-up LVLs provided enough meat for the longer nails.

There was no comparable piece of hardware for the valley rafter, however—and it, too, had to connect at out-of-square angles to the LVLs supporting its ends. So the crew had to shave and bevel the rafter’s ends (see photos, page 24) to fit into a conventional hanger.

With the roof framing complete, the crew constructed a vented roof assembly. Vapor-open, water-resistive VaproShield SlopeShield roof membrane was attached to the rafters **(12)**, and 2x4 furring laid on top of that. Then the crew sheathed over the furring with Zip System roof sheathing **(13)**, sealing the seams with Zip tape and protecting the valley with Grace Ice & Water Shield **(14)**. The 16-inch I-joist rafter cavities would later be filled with dense-blown cellulose insulation.

CONSTRUCTING THE VENTED ROOF

A unique, low-pitch cathedralized roof wouldn't be complete without an extra building-science challenge thrown in, and this building supplies one: As we mentioned, the home's mechanical systems are designed to maintain interior relative humidity at a constant 50% because of the owners' health requirements. So the superinsulated walls and ceilings have to be able to handle this condition, year round.

The team got a thumbs-up from Portland mechanical engineer and Passive House consultant Sonia Barrantes for a cold-roof assembly with plywood sheathing on the rafters, 2x4 sleepers to create an air channel, and another layer of plywood for the roof deck. But in the end, they opted for a more vapor-open solution. They stretched VaproShield's SlopeShield membrane (vaproshield.com) over the rafters, and nailed 2x4s through the membrane to create a venting space. Then they installed Zip System roof sheathing over the furring, sealing the seams with Zip tape and protecting the valley with Grace Ice & Water Shield.

Like other high-performance weather-barrier products on the market, VaproShield membranes are highly vapor-open. "But my big reason to prefer VaproShield was its Integrated Tape system," says Pollard. "At the bottom of each roll of fabric, there's tape on the back, and at the top, the tape is on the face. So as you shingle-lap the courses, you pull off the cellophane on the strips of tape, and the two faces bond together tenaciously—as opposed to other systems where you have to face-tape over the laps. I mean, those other systems have worked forever, and you know they're going to work, but to me it just seems wrong to reverse-lap tape."

Ted Cushman is a senior editor at JLC.

Decorative Beams for a Craftsman-Style Arbor

BY CREGG SWEENEY

Our crew was recently asked to build an arbor for a Craftsman-style house we were building on Cape Cod. The arbor created a covered connection between a greenhouse and a garage in a T-layout **(1)**. The framework for the arbor was pretty simple: Horizontal 4x10 (actual) red-cedar beams notched into pressure-treated posts to form the "T." (The posts later received a cedar veneer.) On top of the beams, we built 16 cross beams, also made from 4-inch-wide red cedar. Each cross beam had a gently sloped top surface and an arch below. Horizontal "wings" extended from the ends of each beam to overhang the support beams by about 18 inches at each end. Angled notches at the ends of the wings completed the detail.

The two sections of the T were different widths, so the cross beams had to be two different sizes to span between the horizontal members. Our challenge was to come up with a way to cut multiple beams so that all the beams within each section would be exactly the same. In the name of production, the cutting process had to go fairly quickly while leaving as smooth a surface as possible to minimize sanding.

GLUE-UP MAKES DEEPER STOCK

For the longer cross beams, the total vertical height was just under 20 inches. Because stock that size is hard to get, as well as being expensive, and because we would end up removing a fair amount of wood to make each cross beam, we opted to create stock for each beam by laminating a small section of 4x4 and two short sections of 4x6 to a longer piece of 4x10 **(2)**.

The 4x4 piece was centered on the top of the 4x10 to give us stock for the peak of the beam. For the extra stock needed at the ends of the beam for the bottom part of the arch and the horizontal wings, we placed the 4x6 pieces about 18 inches from the center, one on each side. When the cross beams were installed, the lower faces of the 4x6s would rest on the horizontal arbor beams.

To align the pieces and help strengthen the cross section, we pinned the laminations with strategically placed dominoes. We laid out and marked the positions of the dominoes so they wouldn't be exposed when we cut out the beam. We used waterproof Gorilla glue for the glue-up, and with the dominoes aligning the faces of the boards, we only needed to clamp them in one direction.

DUAL-PURPOSE TEMPLATES

After letting the glue cure properly, one of the crew removed the excess dried glue and sanded the faces of the blanks. When they were ready, we set them on blocks on a large worktable.

We'd made two MDO templates—one for each size of cross beam—working directly from the dimensions on the architect's

Photos by Roe Osborn

On a Craftsman-style home on Cape Cod, arched, red-cedar cross beams support a glass covering for this arbor **(1)**. To make the arbor beams, the crew laminates multiple layers of 4-inch-thick cedar together. Two pieces of 4-by-6-inch cedar glue to the bottom side of a 4x10, while a short 4x4 clamps to the top **(2)**. Dominoes align the pieces during the glue-up.

A crew member traces a line 1/4 inch outside the template with a spacer **(3)** and then cuts along the line with a circular saw. A jigsaw finishes the cut and rough-cuts the arch **(4)**. A router with a top-bearing flush-trim bit follows the template for the first finish cut **(5)**. The beam is flipped over and an up-cut spiral bit rides on the first surface to finish the cut **(6)**.

blueprints. The templates served two purposes: First we used them to lay out for the rough cutting, and then later they became router-bit guides for our initial finished cut.

To lay out for the rough cut, we centered the template on the blank with the bottom edge of the template lined up with the bottom edge of the blank and clamped them together. We indexed the template to the blank so that we could reposition it after the rough cut. To mark out for the rough cut, we placed a small, 1/4-inch-thick block of wood against the template and drew a pencil line outside the block **(3)**. When we'd marked the edges of the beam that needed to be cut, we removed the template and set it aside.

We rough-cut the straight lines of each beam with a 10 1/4-inch wormdrive saw. Unfortunately, the blade did not cut all the way through the true 4-inch-thick lumber, so we finished the cut with a jigsaw equipped with an aggressive 6-inch blade. We used the same jigsaw to cut the arch **(4)**. Admittedly, a jigsaw does not leave a precision cut, but for this step, our cuts were still 1/4 inch outside the finished surface of the beam.

TWO-STEP ROUTING

With the rough-cutting done, we re-clamped the template to the beam and worktable, taking care to position the template on the beam exactly where it had been before. For the first router pass, we mounted a top-bearing flush-trim bit in a fixed-base router. With the router-bit bearing riding against the template, we cut back the edges of the beam, moving the clamps as necessary to complete the pass **(5)**. Whenever you're routing in this manner, it's always important to push the router against the rotation of the bit so that it cuts into the work without tearing out.

The 3/4-inch-diameter bit was removing only about 1/4 inch of material, so it wasn't over-taxed and stayed sharp for a longer period of time. As soon as we noticed the bit cutting more slowly than normal, we stopped and changed it, usually after cutting three or four beams. The result was a glass-smooth surface that would be easy to sand. But more importantly, we needed that smooth surface to guide our second pass with the router.

We removed the template and flipped the beam over before making the second pass with the router. This time, we used an industrial-grade up-cutting spiral bit with a double bearing on the *bottom* of the bit. With the bearings following the surface from the first pass, the bit cut perfectly flush with that surface **(6)**. The up-cutting action of the bit minimized the chances of tear-out, and again we carefully monitored the sharpness of the bit, changing it before it could start burning the wood. When the routing was finished, each beam received a thorough sanding.

To locate the holes for the attachment screws, a crew member places a small template on the bottom of the beam **(7)** before carefully drilling the holes **(8)**. Crew members center each cross beam on the horizontal beams **(9)**, and then drive the structural screws while keeping the beams square to the top surface of the carrying beams below **(10)**.


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ATTACHMENT STRATEGIES

As nice as these beams looked, they also had to be functional, tying together the arbor structure. The cross beams attached to the linear support beams (that formed the T) in two different ways. At all four ends of the T, as well as at the intersection points of the T and at intermediate points along the longer, narrower section, we bolted the cross beams to galvanized threaded rod epoxied into the posts. Structural screws secured all of the other beams in place. Both strategies required accurate placement of the holes to keep the cross beams aligned properly and fastened securely to the support beams below.

To locate the holes for the through-bolts, we set each beam in place, centered it, and scribed the bolt positions onto the beam. To drill the holes, we started with a Forstner bit that made a large, flat-bottom hole for the nut and washer on the top side of the beam, and a clearance hole on the bottom of the beam for the nut already threaded onto the bolt. We connected the top and bottom holes with a spade bit slightly larger than the bolt diameter to give us a little wiggle room for positioning the beams. After slipping the beam into place, it was just a matter of measuring the overhangs for an exact placement before tightening the nuts.

We used a different approach for the structural screws that attached the other beams. On the bottom edges of each beam, we measured in the distance from the beginning of the arch to the horizontal beam (about 2 inches), and then set a small template in place that located the screw positions **(7)**.

We drilled guide holes at every screw position, then drilled a hole through from the bottom of the beam to the top while keeping the bit as square to the beam as possible **(8)**. As with the through-bolts, the bit we used was slightly larger than the thread diameter of the structural screws. After drilling all the way through, we flipped the beam over and chased the holes with a 1-inch Forstner bit, for a flat-bottomed hole for the screw heads to bear on.

After setting the beams in place, we again centered them side to side over the horizontal beams **(9)**. Because the screws fell on the sides, not in the center, of the cross beams, we took special care to keep the beams vertically square to the beams below as we torqued the screws with impact drivers **(10)**.

To complete the installation, we cut wooden plugs and glued them into the holes above each fastener. After cutting the plugs flush, the beams were ready to support the glass covering that would provide protection for people walking below.

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