Building a High-Performance Shell

by David Joyce

Advanced framing and exterior foam reduce conductive heat loss and provide good air-sealing opportunities

Editor's note: This is the first part of a two-part article. Part I will describe framing and exterior sheathing; Part II will cover window and siding installation, air sealing and insulation, mechanical systems, and finishes.

In a previous article, I described an exterior insulation upgrade that our energy-oriented company performed on an older home (see "Retrofitting Exterior Insulation," 11/09). Early in the fall of '09, we started work on a new home using many of the same concepts that had allowed us to dramatically improve the older home's energy performance.

Architect Betsy Pettit of Building Science Corp., who'd consulted on the retrofit job, designed this new building from the ground up. Among her performance-boosting strategies was the use of "advanced framing" — which eliminates redundant and structurally unnecessary lumber — and an exterior skin of insulating foam. Although not an essential ingredient of advanced framing, foam sheathing is a natural fit. On this job, we installed a double layer of 2-inch foil-faced Tuff-R polyiso board directly over the studs. The foam serves triple duty as a thermal break, a drainage plane for any water that gets past the siding, and an air barrier, with no need for supplemental housewrap. All seams and any tears in the foil facing are taped to provide an airtight, waterproof surface. To provide lateral strength to the frame, we installed vertical $\frac{1}{2}$-inch plywood shear panels at specified intervals, covering the plywood with $1\frac{1}{2}$-inch foam to match the thickness of the first foam layer.

Figure 1. In an advanced frame, headers are minimized in favor of insulation cavities. All framing is vertically aligned and point loads are distributed directly through to the foundation. In this sloped ceiling section, squash blocks carry the rafters' load path over the second-floor rim joist (A). Where interior partitions intersect exterior walls, horizontal ladder blocking will secure the end stud, keeping the wall bay fully open and accessible for insulation (B). Structural headers are packed with foam board to create a thermal break (C). Openings in nonbearing walls are minimally framed, with single-member headers installed on the flat (D). The 1/2-inch plywood lining the rough opening extends out to cap the edge of the 4-inch-thick foam sheathing.

Figure 2. For the 24-foot lengths required to frame the main roof, the author used LSL (laminated strand lumber) rafters and collar ties in place of old-growth dimensional lumber (top). The floors are framed with 14-inch I-joists on 2-foot centers. TimberLok structural screws replace metal ties for faster, code-approved rafter hold-downs (above).

Advanced Framing In the Field

The NAHB developed the advanced framing concept — originally known as "optimal value engineered," or OVE, framing — back in the '70s, with the intention of making more efficient use of building materials. In a nutshell, all framing is strictly aligned from the first-floor deck up to the rafters on 24-inch centers. Walls have single top plates, corners are built with two studs instead of three or more, and structural headers are reduced to single members or insulated cores; in non-load-bearing walls, headers are eliminated.

Tying top plates together. Single-member top plates serve only to position and secure the studs, not to support or redistribute offset point loads. When butting plates together, it isn't necessary to land the joint on a stud. Instead, we use a Simpson TP49 metal splice plate or a piece of wood blocking. Blocking is cheaper and faster to install; where it just won't fit, as in corners, we use the metal plates. To prevent joint stress and separation, we install the metal plates after standing the walls. Before nailing them off, we throw a strap around a few studs on either side of the joint and pull it tight.

Because a single plate is more flexible than double top plates, it takes a little more time and a few more braces to straighten walls. When we brace the walls, we pull them slightly inward, about 1/4 inch from plumb. Throughout construction, the top plates tend to get forced outward, mostly by rafter thrust before the collar ties are installed. Later, it's a lot easier to push a wall outward to plumb it than it is to haul it back in, so I like to start with that advantage.

Wall layout modifications. When laying out the front walls, we had to keep in mind how to support the second floor and roof. Although the general framing was consistently aligned from bottom to top, five rough openings didn't coincide with the 24-inch on-center layout. The situation was further complicated by two doghouse dormers, each with doubled rafters on both sides, that landed off-layout. To transfer these loads, we had to add studs on both floors and squash blocks at the rim joists (**see Figure 1, page 2**). Generally, we found that the simplest approach was to lay out the wall according to the plan and install the supplemental framing as needed later.

When framing the gables, we adjusted the layout to accommodate the foam sheathing. The first layer of 4-by-8-foot foam sheathing is installed with its edges aligned on stud centers, but because it's also overlapped at the building corners, it falls off standard layout by its 2-inch thickness. To compensate, we centered the first stud in from the corner at 22 inches and established the 24-inch layout from that point. We used simple two-stud "L" configurations at corners, which allows for slightly better insulation.

Rough openings on nonbearing walls don't typically require structural headers

Figure 3. Intermittent vertical 4-by-10-foot sheets of 1/2-inch CDX plywood applied directly to the frame brace it against wind racking (top). Hold-down rods — required with intermittent bracing — are installed at building corners and at regular intervals around the perimeter. They're anchored in the foundation and continue up the walls (above) through the topmost wall plate (left).

or jack studs, so there we installed king studs only, with single 2x6 head and sill members installed on the flat. If sheathing the frame with plywood, you'd cut the headers and sills to the exact rough opening width. But in this case, we lined the openings with 1/2-inch plywood bucks that projected out 4 inches to cap the edges of the foam sheathing. To accommodate the bucks, we added an inch to the height and width of each rough opening.

Partition backers. Instead of standard partition backers, we used single studs at wall intersections and installed ladder blocking to attach them. Again, this eliminates an interruption in the insulation layer typically created in conventional framing.

Floor and roof framing. There was nothing unusual about the floors or the roof. We used wood I-joists aligned with the 24-inch on-center wall layout. At the gable ends, we substituted OSB rim-joist material for the I-joists and installed vertical 2x4 squash blocks directly below the studs. We took the blocks from the scrap pile and saved the cost of a few I-joists. On top of the plates, we nailed 2x4 cleats on the flat. Stopped by the squash blocks, this provided a 1 1/2-inch attachment surface for the ceiling drywall while still leaving the end bays accessible for insulation — in this case, closed-cell spray foam at all rims.

Standard dimensional lumber in the 24-foot lengths we needed for the rafters has to come from old-growth trees, which we prefer not to use (**Figure 2, page 3**). And for the 4-pitch roof in the rear, solid lumber joists on 24-inch centers wouldn't have had the capacity we needed to handle the area's snow load plus the weight of the solar panels we'd be installing. So we used 2x12 laminated strand lumber, or LSL, which cuts just like solid dimensional lumber and doesn't require additional reinforcement at the plates. It's

Framing, Insulation, and Air-Sealing Details

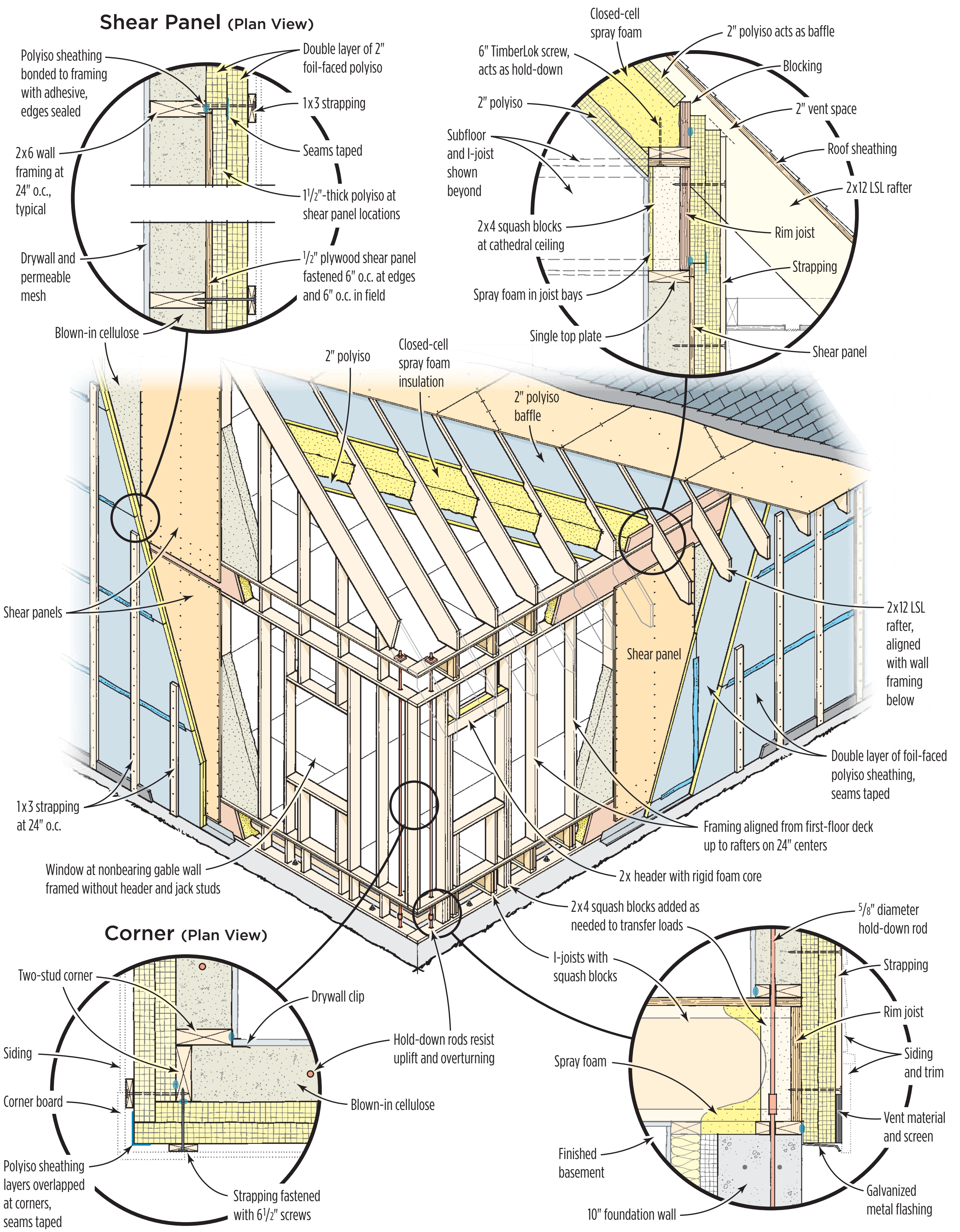

Figure 4. A galvanized metal flashing, air-sealed to the rim and foundation with adhesive, provides a starter strip for the foam sheathing and protects the bottom edge from burrowing bugs, rodents, and flying sparks (A). The attached insect screen was later folded up over the ends of the vertical vent strips behind the siding. Expanding foam seals random cutouts in the rim joist. The first layer of 2-inch foam is installed vertically and sealed and bonded to the frame with adhesive (B). The second layer installs horizontally (C), overlapping in an alternating weave at building corners. Note the air-sealing tape on the first layer where it intersects the projecting window bucks (D).

much harder than solid lumber, though — our standard pneumatic nails bent when we were nailing off the collar ties. We switched to the heaviest-gauge nail the guns would handle and still had to hammer the last 3/4 inch home.

We saved a little time by eliminating conventional metal rafter ties. Instead, we drove 6-inch-long TimberLok (800/518-3569, fastenmaster.com) screws up through the top plate into the rafters. Where they can't be driven directly up through the plate underside, they can be sent into the rafter from the front corner of the plate at a 22-degree angle. According to a technical bulletin on the company's Web site, these screws are code-approved replacements for straps or ties, which is nice because they're also faster and less obtrusive.

Shear Panels

Because foam sheathing doesn't provide racking resistance, we applied vertical 4-by-10-foot sheets of 1/2-inch CDX plywood at intervals specified by code. Nailed every 6 inches around the edges and in the field, the plywood spans from the first- to the second-floor rim joists; on gable walls it's continued up to the second-floor ceiling rim (**Figure 3, page 4**). According to the IRC, intermittent shear panels must be installed at no more than 25 feet on-center, and a 40-foot-long wall must have a minimum of three shear panels over its run. Here in the Boston area, wind-speed provisions are moderate, so these are fairly basic standards. In high-wind and seismic zones, these specs are unlikely to be adequate.

We installed the shear panels after completing the framing, when everything was straightened, plumbed, and braced. It was a lot easier to make the necessary final adjustments to the frame without the panels providing resistance. There was a total of 16 panels, most of which required no cutting or fitting; it took two workers

Figure 5. Before framing the unheated attached garage, the author applied foam sheathing to the common wall, establishing a thermal break between the two structures (above). Structural screws driven through the foam tie the isolated frames together. Here, the author anchors a walk-out bay rafter to the wall framing (left).

about three hours to install them all.

In addition to the shear panels, the plans called for continuous $^{5}/_{8}$-inch hold-down rods from the foundation up through the uppermost top plates, at all corners and most shear-panel locations. These rods resist building uplift and overturning. They required accurate placement when pouring the foundation, which was a bit of a pain, but running the 10-foot links up through the walls was easy. To install and tension 16 rods required six man-hours.

Foam Sheathing

We started the first layer of sheathing on top of a galvanized metal flashing strip set an inch lower than the top of the foundation (**Figure 4, page 6**). To help with air-sealing and to keep out bugs, we set the strip in GreenSeries high-performance adhesive (800/624-7767, osipro.com) applied to the pressure-treated sill and foundation. The flashing projects out $4^{1}/_{2}$ inches, then bends down in a drip edge. It protects the bottom of the foam from insects, rodents, and flying sparks. We nailed a 10-inch-wide strip of insect screen over the flashing, to be folded up later over the sheathing.

We installed the first layer of 2-inch-thick 4-by-8-foot sheets vertically, with their long edges centered on the studs. To aid in air-sealing, we bedded all edges in a heavy bead of GreenSeries adhesive against the framing. The adhesive bonds and seals the sheathing to the framing; we used only a single screw and a 3-inch washer — the kind used to fasten rubber membrane roof underlayment — near the center of the sheet to hold it until the glue set. To match up with adjacent 2-inch-thick material, we applied a $1^{1}/_{2}$-inch layer of foam board over the shear panels. We taped every seam in both layers of foam with Dow Weathermate tape, which sticks well in both wet and cold conditions.

Figure 6. With the foam sheathing serving as a drainage plane, 1x3 vertical strapping creates a venting and drying space behind the siding. Additional strips around windows and doors provide separate backing for trim and siding.

Around window openings, we taped the first layer of foam to the plywood bucks.

We installed the second layer of 2-inch foam horizontally, starting with a 2-foot-wide panel to ensure that few if any seams would align between layers. At building corners, we also made sure to overlap the edges. There's no adhesive between the layers; instead, we temporarily held the outer layer in place with FastenMaster HeadLok screws driven through plywood scraps. Ultimately, the vertical strapping for the siding would secure it.

The project included an attached two-car garage that isn't conditioned or insulated. Before framing it, we applied the foam sheathing to the common gable wall (**Figure 5, page 7**). Later, we tied the two structures together using 8-inch HeadLok screws through the foam. We used the same approach when framing the roofs over an ell and a walk-out bay window, first sheathing the main structure and then overlaying the rafters.

Strapping for siding. To provide an attachment point for the fiber-cement siding, we applied vertical 1x3 strapping, screwed through the foam into the framing with $6^{1}/_{2}$-inch HeadLok screws (**Figure 6**). The strapping creates a drainage cavity for any water that may penetrate the siding and allows drying air to circulate behind it. At the base, we cut strips of Cougar (800/346-7655, benjaminobdyke.com) nylon-matrix ridge-vent material to fit between the strapping, to help pin the insect screen against the back of the siding. Around window openings, we installed strapping to back the exterior trim, and adjacent pieces to catch the siding. To provide attachment points for some of these screws, we had to add 2x4 blocking to the framing around the rough openings.

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