Hybrid Wood/Steel Framing

Story poles and templates make it easier to integrate steel with wood framing

BY RICK MILLS

Not every job requires it, but steel has become increasingly common on our projects as engineers continue to raise the bar on their tolerances for deflection and shear strength. For anyone not familiar with the details of steel construction, it can be intimidating at first to unroll a set of structural plans with a lot of steel called out, and I remember well our first few projects that included more than just a steel beam inside a floor system. Looking at all the unfamiliar beam and post sizes and shapes, it was hard for me to transform the two-dimensional plans into a three-dimensional mental picture.

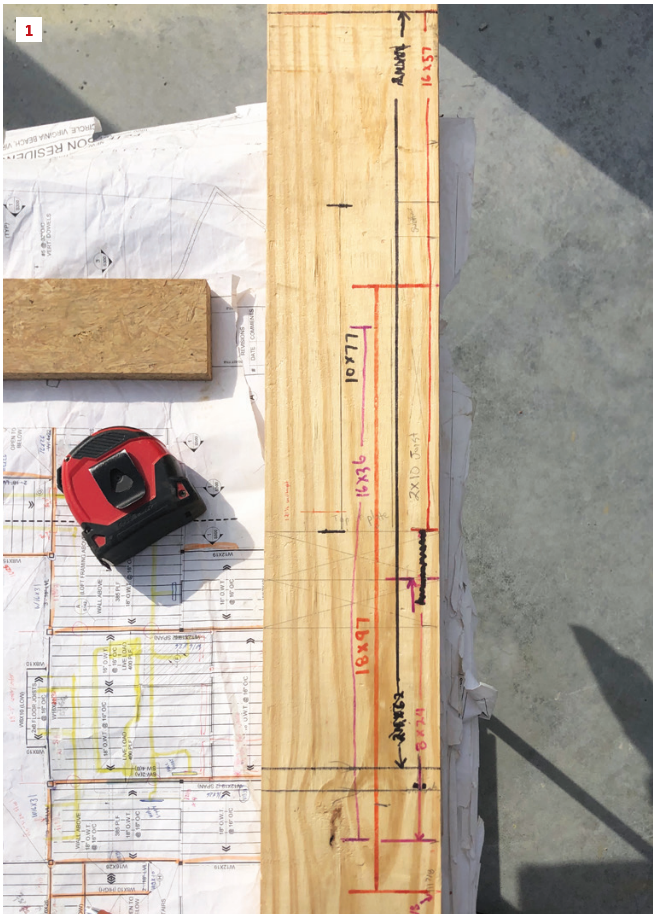
At Jackson Andrews Building + Design, where I'm a project manager, I've seen the complexity of steel and wood construction increase in recent years. Over several projects, I've deliberately familiarized myself with the different types of steel profiles and sizes so that now when I look at structural plans with both wood-framed and steel-framed details, I am able to focus on how everything will fit together.

WORKING WITH A STEEL FABRICATOR

Because a small, local shop supplied us with the steel for the large project featured in this article, we were able to assemble the steel as we installed the wood framing. This helped with scheduling, as we didn't have to wait for all the steel to be ready at once. Another benefit was that this gave us an opportunity to make adjustments to ensure better alignment with the framing members. By framing and installing steel simultaneously, we were able to complete the framing in one area while measuring for the next round of steel.

Photos by Rick Mills

1



2

WIDE FLANGE BEAM

W-SHAPES
ASTM A-36

DESIGNATION DEPTH in Inches x WEIGHT Per Ft. Lbs.(Nominal Size)	WEIGHT Per Foot Lbs.	DEPTH Section in Inches	WIDTH Flange in Inches	FLANGE Thickness (Average) in Inches	WEB Thickness in Inches	Area of Section In.²	Section Modulus Sx In.³	**Surface Area Foot of Length.²
W4 x (4x4)	13	*4-1/8	4	3/8	1/4	3.83	5.46	1.96
W5 x	16	5	5	3/8	1/4	4.68	8.51	2.42
(5x5)	19	5-1/8	5	7/16	1/4	5.54	10.20	2.45
W6 x	9	5-7/8	4	3/16	3/16	2.68	5.56	2.23
(6x4)	12	6	4	1/4	1/4	3.55	7.31	2.26
	16	6-1/4	4	3/8	1/4	4.74	10.20	2.31
W6 x	15	6	6	1/4	1/4	4.43	9.72	2.92
(6x6)	20	6-1/4	6	3/8	1/4	5.87	13.40	2.96
	25	6-3/8	6-1/8	7/16	5/16	7.34	16.70	3.00
W8 x	10	7-7/8	4	3/16	3/16	2.96	7.81	2.56
(8x4)	13	8	4	1/4	1/4	3.84	9.91	2.58
	15	8-1/8	4	5/16	1/4	4.44	11.80	2.61
W8 x	18	8-1/8	5-1/4	5/16	1/4	5.26	15.20	3.03
(8x5-1/4)	21	8-1/4	5-1/4	3/8	1/4	6.16	18.20	3.05
W8 x	24	7-7/8	6-1/2	3/8	1/4	7.08	20.90	3.39
(8x6-1/2)	28	8	6-1/2	7/16	5/16	8.25	24.30	3.42
W8 x	31	8	8	7/16	5/16	9.13	27.50	3.89
(8x8)	35	8-1/8	8	1/2	5/16	10.30	31.20	3.92
	40	8-1/4	8-1/8	9/16	3/8	11.70	35.50	3.95
	48	8-1/2	8-1/8	11/16	3/8	14.10	43.30	4.00
	58	8-3/4	8-1/4	13/16	1/2	17.10	52.00	4.06
	67	9	8-1/4	15/16	9/16	19.70	60.40	4.11
W10 x	12	9-7/8	4	3/16	3/16	3.54	10.90	2.89
(10x4)	15	10	4	1/4	1/4	4.41	13.80	2.92
	17	10-1/8	4	5/16	1/4	4.99	16.20	2.94
	19	10-1/4	4	3/8	1/4	5.62	18.80	2.96
W10 x	22	10-1/8	5-3/4	3/8	1/4	6.49	23.20	3.53
(10x5-3/4)	26	10-3/8	5-3/4	7/16	1/4	7.61	27.90	3.56
	30	10-1/2	5-3/4	1/2	5/16	8.84	32.40	3.59
W10 x	33	9-3/4	8	7/16	5/16	9.71	35.00	4.16
(10x8)	39	9-7/8	8	1/2	5/16	11.50	42.10	4.19

Working from his marked-up plans, the author lays out the steel work for each location in full scale on a story pole **(1)**. The author refers to a printed list of steel sizes with actual dimensions when working with steel framing; the one above (from Coyote Steel) is a particularly useful resource **(2)**.

Depending on the steel fabricator and the scale of the project, you can elect to have the fabricator erect all the steel for the job at once. If you choose this approach, you need to have confidence in your layout and be willing to possibly make adjustments in the field later. Our approach is probably slower, because we rely on templates to communicate tricky details to the fabricator, but the back-and-forth process ultimately allows us to avoid making costly mistakes.

LABELS AND STORY POLES

To keep track of all the details and ultimately ensure a successful execution, we make extensive use of story poles in the layout process. Everything from elevations to the sizes of posts and beams and how they connect with the wood framing can be accurately tracked on a story pole.

Labeling system. When I first receive a set of plans, I like to go through each page with a highlighter and mark all the vertical and horizontal steel. This kick-starts the process of visualizing where things are located and where foundation and framing members intersect with beams and columns.

Once everything has been located and marked on the plans, I use a labeling system to differentiate between the various steel members, if one is not already included in the plans. I label all verticals with the letter C followed by a number, and all horizontals with an H and their corresponding number. For example, a W12x26 beam, which has a 12-inch-deep section and weighs 26 pounds per foot, might be identified with the label H23.

Next, I make a note next to the call numbers on the plans with the actual dimensions of the steel. This way, we know what size beam or column we're dealing with when we look at the plans and can transfer the actual steel sizes to our story poles or layout locations in the field. This step is necessary because there are sometimes slight variations in beam sizes from manufacturer to manufacturer and—because of the nature of the casting process—sometimes even from the same manufacturer, though most of the time those variations are less than 1/8 inch. When the steel arrives on-site, I always confirm dimensions and adjust as necessary.

Story poles. In the field, the marked-up plans make it easier to accurately lay out where everything goes, whether I'm marking up the foundation or the top of a framed wall. The project shown in this article included a poured concrete slab in a crawlspace foundation

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The steel columns were shimmed to final elevation with steel shims and grouted later with non-shrinking grout **(3)** and locked in place with 2-by braces fastened to 2-by collars clamped around each column **(4, 5)**. Then framers began installing the sawn-lumber floor system in the first location, notching the framing as needed around the steel **(6, 7)**.

(see "High-Performance Crawlspace Foundation," Sept/20) and numerous steel columns located on either the foundation wall or the slab floor, with several columns extending to the roofline.

Rather than attach the steel columns directly to the footings and bury them between block work, or attach them to footing pads below the concrete slab, we decided to elevate the steel attachment points. We did this by reinforcing the CMU walls with additional rebar and grout wherever there was an attachment point and by forming a reinforced concrete "pedestal" above slab height on the interior of the foundation for each interior column. This way, if any of the steel columns needed adjustment later for plumb, they wouldn't be buried under the concrete.

Knowing how critical it was to have all the steel placements work out with the framing, we brought our framer on-site shortly after footings were poured and the CMU work was just underway. Working together on the layout gave us confidence that our steel column locations were accurate.

Using the top of the CMU wall as our benchmark elevation, I created story poles for each location with all the framing elements laid out to scale. On this project, we started with the house's main steel columns, which were located in the great room. To match the overall height of the house, which was about 30 feet, we scabbed together several long 2x8s to create the story poles.

While we waited for the first batch of steel columns to be fabricated and delivered, our team set the rebar and formed and poured the interior pedestals. Meanwhile, I began working on the vertical layout for the steel. There were enough details to keep track of in specific areas that we didn't want to lay out more than one area on a single pole if they didn't coordinate with each other.

For example, the two-story great room would have three layers of windows with steel between each window unit and a "U" shaped steel beam welded to the top of the columns to support a large roof overhang. Starting from the top of the CMU wall, our benchmark elevation, we laid out all the wood framing elements it would take to determine the top of the rafter bearing height at the roof. Then we shot grades with a transit across the top of our foundation wall and measured down to the top of each concrete pedestal location. This was the best way to ensure that each column would be level with the others. We took this measurement and added it to the story pole.

With all the wood framing elements marked on the story pole, the next step was to incorporate the steel into the layout. The first horizontal beams were in the first-floor ceiling joist system, which was being framed with 18-inch open web truss joists. All the steel that was called out in this area was +/-16 inches, depending on the exact callout; with a 2-by plate added to the top of the beam, the height works out to just under 18 inches, which is the height we would set all the second-floor steel to. The steel being slightly higher than the bottoms of the joists is actually good, because if anything deflected with load later, it would not drop into the ceiling plane.

The plans called for the second-floor ceiling to be framed with dimensional 2x10 joists, and all the steel we'd be using was around 8 inches—typically W8x24 wide-flange beams, which have a 7 1/8-inch depth and 6 1/2-inch flange width—so the same concept applied. As we added the steel locations to our story pole, we followed the same approach anywhere it would work, so that all the horizontal steel beams would be set 1 1/2 inches below the tops of the joists.

Topping off the great room was a pair of large W18x40 steel beams that spanned the entire space. As we worked through the details, it became clear that at one end of the room, the W18x40 beams would bear on HSS8x8 columns, while at the other end, each beam would need to be welded to the back of the corresponding 8x8 column, because those columns needed to be slightly taller to receive the steel for a large roof overhang. Laying out all of these details on the story pole was necessary to make it extremely clear how all the different elements would come together and to get the steel height right on the first shot.

STEEL COLUMNS

We had provided the steel fabricator with plywood templates for each column location that indicated the exact positions of the threaded bolts that hold the columns in place, so there were no surprises when erecting the steel. But we still needed to fine-tune their height and make sure they were plumb. One way to do this is by using a pair of nuts on each bolt with the flange sandwiched between them and tightening or loosening the lower nuts at each corner of the mounting flange to adjust the position of the column. In our case, the fabricator supplied us with bars of steel stock in different thicknesses to be used as shims as needed between the flange and the pier. In both methods, after the column is locked into place, the gap between the flange and the pier is filled with non-shrinking grout.

Once the first round of columns was erected, our framer devised a simple solution for bracing the free-standing steel. While the fabricator assured us that the base plate bolts would hold the 30-foot-tall columns in place while we worked on the framing, we didn't want to end up with a bunch of fallen steel if a coastal storm swooped through. To connect the tall columns to each other with simple 2-by bracing, he assembled slightly undersized sawn-lumber "clamps" that snugged up tightly around the steel when the screws holding them together were tightened. Then the braces could be fastened to the wood clamps with structural screws, tying the assembly together.

In the main part of the house, we commenced with framing the traditional "box" floor system, though at each column location, the mudsill and rim joists were interrupted. After setting all the sawn-lumber joists and laying down the subfloor, we were able to mark out the first-floor walls, which confirmed that our meticulous foundation layout was correct.

The framing crew erected an extensive temporary scaffolding system over a future outdoor living pavilion to install the complex steel framing for the master suite **(8)**.

BEAMS

The next step was to take the measurements for the horizontal beams that were part of the second-floor joist system. We took all the measurements at floor level because that was the most accurate place to measure from. Despite popular belief, steel is not always straight, and any measurements taken higher up on the columns had the potential to be off.

Scaffolding. In some parts of the house, we would be installing horizontal steel more than 16 feet above ground level. To safely and efficiently install the beams for the master suite, which was located partly over a future crawlspace for the outdoor living area, we assembled extensive temporary scaffolding. Where we had a level first-floor system in place, we assembled staging, with wheels on the lowest sections so we could move the staging around as needed. Not only did this allow us to be at the proper height to take accurate measurements and make templates for some of the more complicated steel intersections, it also allowed us to install all the steel and truss joists comfortably and safely from the same scaffold.

Openings for mechanicals. While putting together the order for our steel beams, I was also working on the order for truss joists. Complicating matters, duct work for the HVAC system was going to be located within the joist system, which meant that the openings in the trusses and beams had to be coordinated. This may have been the most challenging part of the entire job.

The good news was that the client saw the value in a set of plans

Rather than attempting to cut and fit complex beam connections in the field, the framing crew mocked up plywood templates that recorded lengths, notch sizes, and other critical dimensions **(9, 10)**. These templates were supplied to the steel fabricator, which could then accurately prefabricate beams that could be welded into place with few modifications **(11)**.

for a well-designed HVAC system. For this, we partnered with Positive Energy, of Austin, Texas, which provided detailed plans for every element of the HVAC system, including all the duct paths. This facilitated determining where ducts would need to pass through the steel beams.

I provided the duct path locations to our open web truss designer, which then incorporated appropriate duct chases inside the trusses. Then I sent the designer's detailed schematic of the trusses with dimensions to our structural engineer, who calculated the opening sizes that we could put in the steel. In some areas, a round hole worked fine, but in several other locations, the round hole was too large, and we had to make equivalent size holes in rectangular form to make it through the steel beams. We were now ready to order and install the first round of horizontal beams that connected the columns.

Templates. As this area came together, there were several locations where we needed to make templates for the steel fabricator because of how certain beams intersected with other beams. Some had flanges notched into webs, while others had some 45 degree angles notching over other beams. Some of these adjustments could be made in the field, but some of the beam intersections were so complex that our framer carefully assembled plywood templates for the fabricator's reference.

As we progressed to the rooflines, we needed to keep several more beams at the top of this space under rafter-bearing height and above soffit height. The clearances were tight, but our careful planning paid off and everything came together nicely.

Packing out. Almost all the beams needed to be packed out with sawn lumber to connect to the wood-framed joist systems. The process of packing out a steel beam is—not surprisingly—time consuming. On this job, the structural plans called for using 5/8-inch-diameter carriage bolts 16 inches on-center at staggered locations to fasten the sawn lumber to the steel. While the steel fabricator had drilled the necessary 11/16-inch-diameter holes in the beams, it's still challenging to hold a 2x10 or 2x12 in place against the web of a beam while someone else safely drills the holes out for the bolts from the other side.

To quickly clamp the 2-by material to a beam for safe, hands-free drilling, our framers cut some 3-inch-square scraps of plywood to make what they called screw blocks. They drove wood screws through these screw blocks and through three or four holes in the steel beam into the back of the 2-by to hold it in place, then the remaining holes were drilled out with an 11/16-inch-diameter bit to match the holes in the steel. Once the holes are drilled, we can then push a few bolts through some of them and thread on nuts to hold the 2-by in place while the screw blocks are removed and the remaining holes drilled out.

Most of the time, both sides of a beam needed to be packed out, and the process is basically the same—run screw blocks through to hold the new 2-by in place, then drill it out. After both sides are prepped, the through bolts can be installed and tightened as the screw blocks are removed.

Sometimes, we were able to pack out the beam with only one 2-by member on each side of the web, because the sawn or engineered joists were narrower than the distance between the upper and lower flanges. However, any time we were attaching truss joists, the beam had to be packed out flush, which required some creativity to achieve the desired thickness. We realized quickly we would need numerous sizes of CDX plywood on-site and made sure to have four or five sheets each of 1/4-inch through 3/4-inch plywood to be able to rip up what we needed.

Where the beams needed plates, we drove 1 1/2-inch-long by 1/2-inch-diameter lag screws through holes that the steel fabricator had made in the flanges into the bottom of 2-by stock sized to match the width of the flange. On vertical posts, we fastened wood members

To pack out the beams to adapt them to conventional wood framing, the framing crew drove screws through 3-inch-square blocks **(12)** and through bolt holes in the web into the back of 2-by stock sized to fit the flange **(13)**. With the beam held in place, holes for bolts and other penetrations could accurately be drilled out **(14)**, so that the wood members could be fastened to the beam **(15, 16)**. After fastening 2-by plates to the tops of the beams with structural screws driven up through holes in the flange provided by the fabricator, workers wrapped the assembly with Zip tape **(17)**.

to the steel using Reamer Tek self-tapping wood-to-steel screws.

Because this job would be exposed to weather for a long time before dry-in, we opted to wrap the tops of the packed-out beams with Zip tape to help keep water out of the assembly and prevent the lumber from swelling and thus shifting any joists around.

DETAILING THE BUILDING ENVELOPE

Because of the size of the project, we worked in sections, erecting the steel and framing in one location while ordering the materials for the next. Once the steel framing was packed out, framing and sheathing the structure was straightforward.

Going into this project, we knew getting the air-sealing right and meeting the performance standards that we like to build to was going to be a challenge. In Virginia Beach, where we work, a blower door score is not yet required for code but is in the process of being adopted. Once that's in place, we will need to hit a blower door score of 3.0 ACH50 to pass code. So from day one, even though we realized that we would not reach passive house standards, we have taken as many steps as possible to ensure good air-sealing details, with a goal of scoring below 2.0 ACH50 (as of the writing of this article, we have not tested the house.)

Starting at the sill-plate connection to the CMU foundation wall, we used two heavy beads of ProClima's Contega HF, a highly elastic adhesive caulk, below a foam sill sealer, and another two heavy beads between the sill sealer and our 2x8 mud sill (we borrowed these details from Jake Bruton, a Missouri builder who has written about air-sealing for *JLC*; see "Air Sealing That Works," Apr/18).

After our floor system box was framed, we sealed the gaps

Large gaps between the wood framing were filled with fluid-applied flashing membrane **(18)**. After the steel was packed out, the structure was framed **(19)** and sheathed conventionally. To air-seal the joint at the wall-to-roof connection, workers cut blocks of sheathing to fit snugly between the rafter tails **(20)**, installed blocking in the rafter bays, and sealed the roof sheathing to the blocking with Contega sealant **(21)**. All joints and penetrations through the sheathing of the large home were sealed with either Zip tape or liquid flashing **(22)**.

between the framing and steel columns with Zip System liquid-applied flashing. While this step is probably redundant, since the Zip R6 sheathing that we used to sheathe the house is the air-sealing layer, we figured the gaps were big enough that it couldn't hurt to take care of them while we had access to these locations.

We like to use Zip System sheathing on our projects because it offers a straightforward air-sealing approach that's easy for our trades to execute. We followed standard Zip System installation practices until we got to the roofline, where in a perfect world we would have connected the wall plywood to the roof plywood in a continuous layer. But this project featured a large overhang and built-in gutters hanging on the ends of the rafters, so it wasn't feasible or cost-effective to frame the overhang after boxing in the building envelope with sheathing. Our solution was to cut pieces of the Zip-R sheathing and a 2-by to go between each rafter bay to continue the Zip layer up to the roofline. From there we laid a bead of the Contega sealant on top of the blocking prior to the roof sheathing being installed to air-seal the wall-to-roof connection.

Once the roof sheathing was completed, our painting crew came in and sealed all the blocking between the rafters with Zip liquid-applied flashing. Later, they'll seal around every pipe and wire that passes through the air barrier as well. We're confident that the methods we've used will result in blower door scores that meet our goals when we are ready to test later this year.

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