Steel helps a single-family home and pool house project go swimmingly.

# Diving In

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Images courtesy of Dominick R. Pilla Associates

**WHEN CONSIDERING** the structural composition of a "wood" building, the demands of the architectural and structural requirements often exceed the capabilities of an exclusively wood structural design.

That's where steel comes in.

Steel can be incorporated into wood construction when the limits of wood are reached—i.e. strength, stiffness or limiting dimensions based on architectural constraints. It provides the ability to "push" design limits well beyond an all-wood adaptation while respecting the architectural vernacular. Modern wood construction incorporates the use of structural steel in a variety of ways ranging from straps and anchors used to create connections—which provide continuity of internal forces between wood members and between wood members and foundations—to the use of steel framing members or assemblies.

With one such project, a single-family residence and contiguous pool house in Greenwich, Conn., the structural engineer for the project, Dominick R. Pilla Associates (DRPILLA), considered the many influencing architectural constraints—wall thicknesses, window and door locations, slope of the roofs, floor and roof spans, routing of ducts and placement of equipment—and realized that steel would be needed to do the heavy lifting where wood's structural limits are reached.

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Because the basement of the building extends under the garage, a composite steel construction floor system was needed to support vehicles. For the body of the main house, structural steel ridges and transfer beams and systems support the upper floor chimney masses, which do not extend to the foundations. Steel is also used in the main house to support gravity loading. The lateral strength and stability of the building is achieved by wood shear walls and floor diaphragms. The garage floor uses W14 beams with 2-in.-thick 20-gauge metal deck and 3 ½-in. concrete topping. The beam spacing in the garage is approximately 7 ft. The main house uses lateral frames (bents) made from steel beams (W10×68), supported by HSS columns and spanning approximately 25½ ft, to support "fake" chimneys. Slotted connections were provided at column-beam intersections to allow for horizontal movement of about $\frac{5}{16}$ in. during installation of chimneys.

## Bigger Role

While the pool house was designed to match the main house and garage from a design point, it incorporates a much more aggressive steel solution due to its more challenging geometry. Wood framing was used as infill between structural steel members.

The building is approximately 110 ft long by 23.5 ft wide with a main roof height of 19 ft. It houses a 73-ft × 17-ft pool that varies in depth from 3.75 ft to 9.75 ft with a fireplace at grade level and a mechanical room, pool equipment room and access tunnel at subgrade level. The pool house connects to the main residence via a gallery hallway that extends from the rear of the garage. The perimeter consists largely of glass, allowing maximum natural light to enter the space, and the building is oriented with the long sides of building facing east and west.

As the architecture of the building evolved from initial design, so did the structure. The original structural design called for a total of eight steel moment frames, consisting of HSS columns and W10 beams spaced approximately 17 ft on center, oriented in the short direction to resist gravity and lateral loads, and wood shear walls employed in the long direction. However, the architectural plans were revised and this framing system became unusable due to deflection. The original design also didn't allow adequate space for additional mechanical equipment that was to be located between ceiling finish and steel structure.

DRPILLA's answer was to use steel plate girders, reinforced with angles and plates that would allow large openings to be cut for mechanical systems. From an engineering standpoint the reinforced plate girders, due to their deep sections, provided a large section modulus and moment of inertia, which in turn created a strong member that had minimum deflection under gravity loading. The deep end of each truss, connected with field welds at each column, minimized the un-braced height of the column, which in turn mini-

◄ The steel framing system for the pool house.

▼ Steel transfer framing supporting the masonry chimney mass.

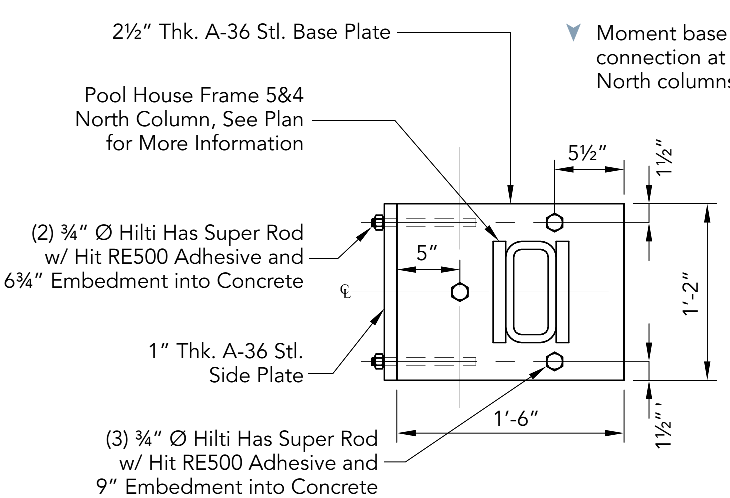
Steel transfer system at a gable end of the building.

mized the total deflection of the frame under lateral (wind) loading. The truss depth varies between approximately 2 ft at the narrowest point to around 4½ ft at the widest point. The plate girder web is ⅜ in. thick and the top and bottom chords consist of (2) 4½-in. continuous steel plates. The web is additionally reinforced with L4×4×¼ steel angles, and a total of eight frames oriented in the short direction resist the gravity and lateral loads. From an architectural point of view this design allowed for a maximum ceiling height. And from a constructability standpoint, the plate girders could be entirely fabricated off-site in the shop and assembled on-site.

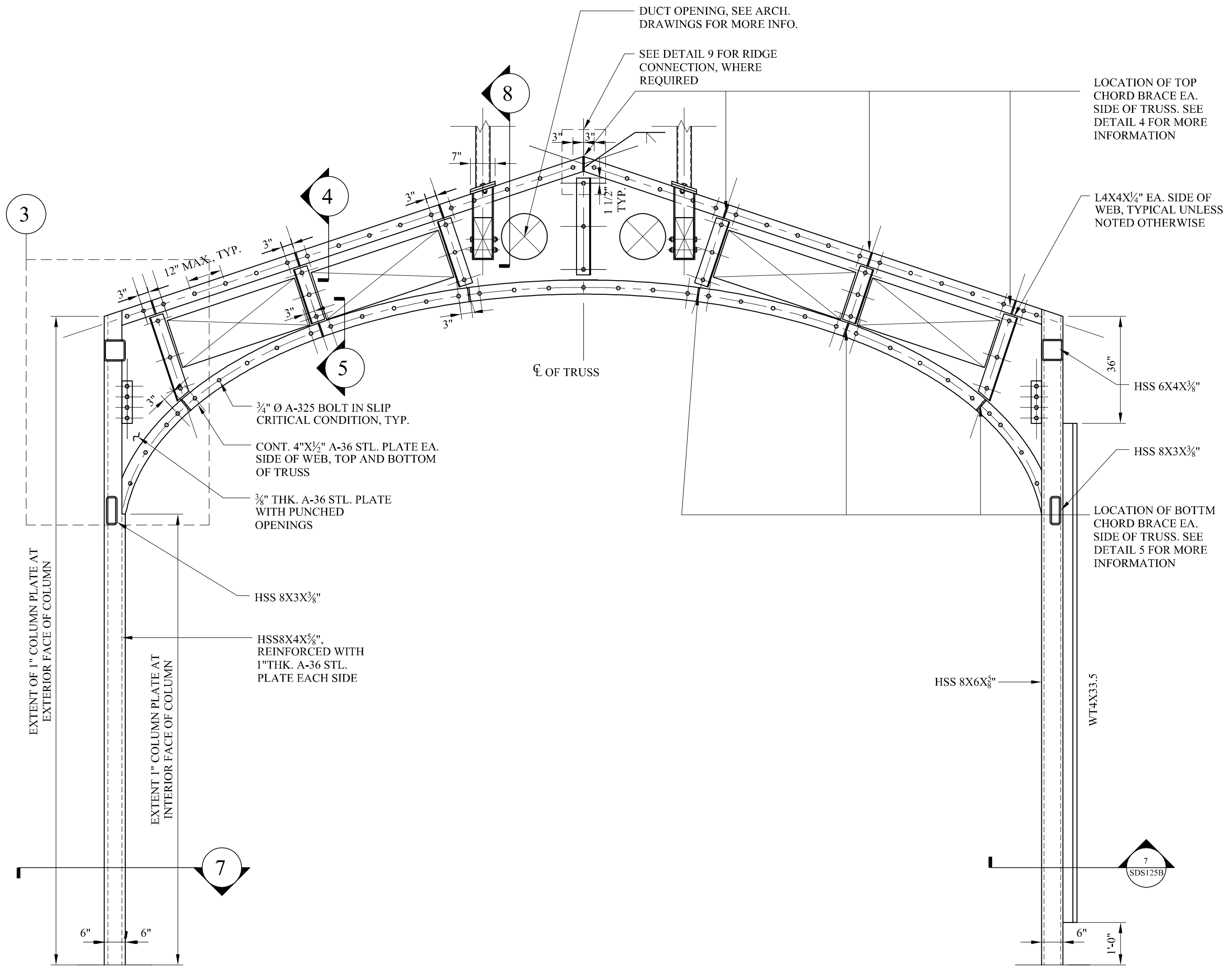
STAAD Pro Structural engineering analysis software was used to analyze the building frames. As STAAD Pro Structural doesn't include a database for custom members, such as the built-up plate girder used for the pool house, members with equivalent properties were used for analysis. Due to the varying depth of the plate girder, the properties change along the length of the beam. Therefore the modeled girder in the analysis was divided into 10 equal segments with varying properties. Member forces, reactions and deflections were obtained from the analysis. Due to the use of a custom member for the plate girder, engineering could only be done "by hand," and the factors that drove the design of the plate girder frame were: the buckling of both the top and bottom chord under axial load, which was reinforced by angles and solid blocking; buckling of the plate girder, especially between the cut openings where it was reinforced by the angles; and the connection of the plate girder to the columns where it was fixed to provide resistance for lateral movement.

## Negating Wind

As the architectural development neared completion, it became clear that minimizing deflection due to wind loading would be critical to ensure that cracks wouldn't form in the plaster finishes on the ceilings and walls. In an effort to maximize stiffness of the frame, the columns located on the south end of the pool house were reinforced with WT4×33.5 sections, and the columns on the north side of the pool house were reinforced with 1-in. steel




Moment base plate connection at pool house North columns (Plan).




▲ Pool house steel frame section.

▼ Garage floor composite steel construction.

plates at each side. These adjustments to the structure reduced the overall deflection of the building from ⅝ in. to ⅜ in. To minimize deflection even further, a fixed base plate connection was developed. The existing brick shelf needed to be cut down to an 18-in.-wide wall to allow for installation of an 18 in. × 14 in. × 2½-in. thick base plate. Fixing of the moment frame columns further reduced the overall deflection of the frame from ⅜ in. to ¼ in.

All of these elements are included in a total of 30 tons of structural steel. Wood members alone would not have permitted the desired architecture to be realized without substantially altering the design, and the addition of this tonnage prevented that from happening. MSC

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