Simply Serene

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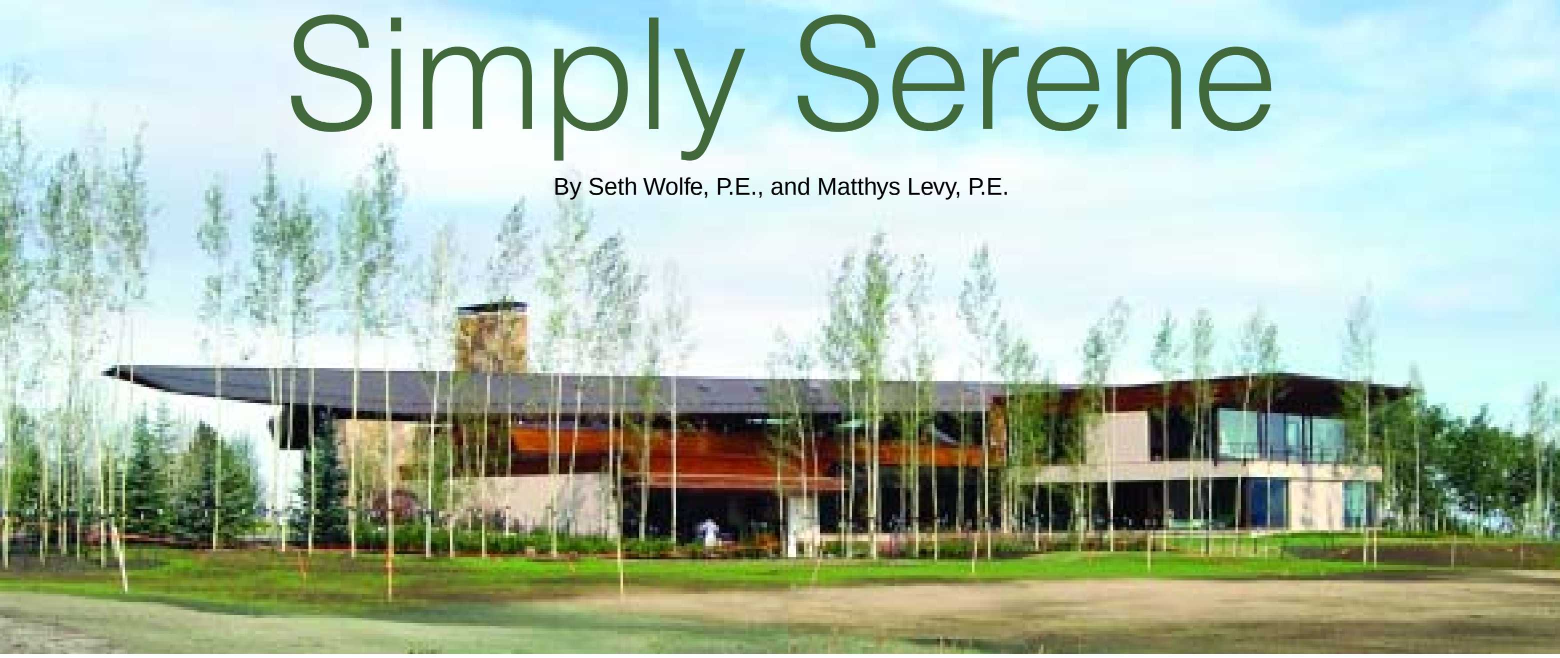

Structural steel creates a clean-lined folded plate roof for an idyllic residence in beautiful Aspen, CO.

Above: The master suite is located at the northern end of the house, seen completed in this view.

Inset: In this construction photo, the steel-framed folded-plate roof that runs along the axis of the house is clearly evident.

Maximizing views while minimizing site impact may seem like mutually exclusive goals in the design of a 14,300-sq.-ft residence, but the clever use of steel, glass, and moss rock helped the designers of this amazing Aspen residence meet these requirements. A dramatic folded plate roof, which cantilevers out 40 ft, is the structure's defining architectural element. But rather than creating a visual distraction, the thin roof appears to float above the west wing of the structure—an illusion achieved through the use of low partitions and clerestory windows.

The primary architectural goal was to create the most transparent building possible in a setting of extreme natural beauty. Due to the length of the roof spans and the heavy snow loads in Aspen, creating a light, transparent structure maximizing views of the surrounding mountains proved to be a significant challenge for the design team—but the end result was worth it.

The folded plate roof was originally designed as a cast-in-place concrete folded plate. Ultimately, it was redesigned using structural steel because, as noted by the contractor, Aspen's harsh climate limited the time available for placing concrete, and delays in the schedule would have translated into significant cost increases. Therefore, structural steel was the more economical material, because its use ensured a shorter erection and construction time. In addition, the non-repetitive geometry of the roof could be completely detailed and checked during the shop-drawing phase, thereby minimizing the need for on-site coordination.

The main wide-flange roof girders span along the ridge and valley lines to transverse steel trusses that form visible ribs inside the house and extend outside to the edge of the cantilevered valley on the west side. In the original concrete folded plate scheme, the ribs served as stiffening elements and were an integral part of the architect's design. The ribs also acted visually to break down the longitudinal lines of the roof and ceiling.

A moss rock wall divides the residence into a living space in the west wing and services and children's bedrooms in the east wing. The wall conceals the mechanical ducts and structural columns that support both the folded plate roof and the flat roof above the east wing. This solution eliminated the need for air ducts within the ceiling cavity and enabled the design team to create the thin roof envisioned by the client.

Clearly Unique

In the steel scheme, the trusses replicate the ribs of the concrete scheme and carry the loads of the main girders to the perimeter HSS steel columns. Each unique steel truss was shop-fabricated of welded steel angles. The top and bottom chords of the trusses were then welded to the columns on site to create a series of transverse rigid frames.

Rigid frames, in conjunction with braced frames in each direction, act as the lateral load resisting system for the folded plate roof. Secondary wide-flange beams spanning in the direction of the slope of the roof to the main girders support the metal roof deck. A clerestory above the west side valley of the roof interrupts the roof framing and allows sunlight to penetrate the upper area of the 24′-high interior rooms.

The roof's edges cantilever beyond the house's exterior walls. At the folded plate roof, a repetitive pair of angles forms a triangular cantilever to the edge of the roof. Refining this design allowed the contractor to adjust the geometry of the roof eaves in the field. An angle placed above the top of the cantilever supports the outer edge of the metal roof deck and is concealed within the depth of the roofing insulation.

Above: Steel trusses (in the east-west direction) are the principal roof framing elements. They cantilever over columns on the west facade (at right in this photo) to provide a roof overhang.

Below: The entrance canopy on the south end of the house is a 40' cantilever extension of the steel-framed folded-plate roof. The cantilever is framed with W shapes (*inset*).

Hidden Strengths

At the entrance of the house, the roof cantilevers 40′ over the driveway to offer much-needed shade in the summer. A triangulated beam structure follows the folds of the cantilever and provides the stiffness and strength needed to support the design roof snow load of 100 psf as determined by the local building official.

The cantilever consists of one ridge beam and two edge beams sloping down and out from the tip of the cantilever to the main support truss at the exterior wall. The triangulated beam structure of the cantilever is mirrored for the back span. The moment in the cantilever is resisted as a vertical compression reaction at the exterior truss and a vertical tension reaction at the end of the back span. Therefore, the cantilever is stable without introducing a horizontal reaction at the end of the back span.

Horizontal slotted holes were used to ensure that a horizontal reaction would not develop at the shear connection between the back span members and their supporting beam near the chimney. Resisting the moment as a coupling of vertical tension and compression eliminated the need to use the roof's lateral load resisting system to resist the moment. The ridge and valley beams of the cantilever are W18s that develop a maximum axial force of nearly 400 kips under the 100 psf design snow load.

The tip of the cantilever was erected to a position 1¾″ above its final elevation. Weidlinger estimated that when the scaffolding temporarily supporting the cantilever was removed, the tip of the cantilever would deflect ⅝″ due to the self-weight of the structure. The actual measured deflection was ¾″. The additional dead load from the roofing and finishes moved the tip of the cantilever to its final elevation.

Flooring in the house is constructed of normal weight concrete on metal deck, and the house is founded on drilled caissons. The concrete basement walls not only retain earth but span between the caissons in place of grade beams. Void forms placed beneath the walls allow the soil to heave without applying pressure to the structure.

Simply Successful

Although originally conceived as a concrete folded plate, the dramatic roof was successfully redesigned in structural steel to meet the construction schedule by taking full advantage of off-site fabrication. In the end, the use of structural steel enabled the design team to achieve the architect's intent and respect the client's wishes while staying within budget and on schedule. ★

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