Cold-Formed Steel Provides the Strength Needed to Take Sustainable Building to a New Level

Green Terraces Present Design Challenges in a 10-Story Senior Housing Complex

By John Matsen, P.E.

Figure 1. The terraces, totaling 12,000 square feet, are each support entirely by cold-formed steel.

Around 1900, the School Sisters of Notre Dame settled on a wooded hill in Milwaukee. According to the Milwaukee Journal Sentinel, the nuns built "a little pioneer home hidden under mighty trees." More than a century later, greenery crowns another home built on the same hill: Convent Hill, a $9.9 million, 10-story senior residence with roof terraces filled with day lilies, spirea, phlox, shrubs and grass. The terraces are extensive. They hold lightweight soil filled to a depth of three inches, ground cover plants and wild flowers, and irrigation systems (*Figure 1*).

The street level is retail, the second floor houses the offices for the facility, and the 3rd through 10th floors are senior residential apartments. The upper eight stories are cold-formed steel framed bearing walls and C-joists with Levelrock gypsum concrete fill on metal deck. The second story and below are hot-rolled steel framed with post-and-beam construction. However, the joists are cold-formed steel C-joists (*Figure 2*).

Figure 2. Hot-rolled steel with cold-formed steel joists were used strategically for only the first two floors.

The foundation walls, lower slab and footings are cast-in-place concrete. The main lateral resisting systems are cast-in-place reinforced concrete stairs and elevator cores. The cast-in-place concrete cores served to resist the lateral loads resulting from both wind load and seismic load. The concrete core was chosen over discrete bracing or cold-formed steel shear walls due to building height restrictions. The concrete core also aided in detailing and fire rating of the shafts.

The City of Milwaukee had the Convent Hill complex built in 1959. For the present redevelopment, the city wanted to take advantage of the latest environmentally friendly building designs. The structure, which features 12,000 square feet of green roofs, represents "a new level of sustainable and green technology," states the Milwaukee Journal Sentinel.

But how could the structure support the green roofs without a large and significant use of structural steel? Matsen Ford Design Associates, Waukesha, Wisconsin, engineered the project's cold-formed steel system, which comprises the majority of the structure's support system.

Design Solution and Special Considerations

Cold-formed steel framing is the primary load-carrying structure for the upper residential stories. Cast-in-place concrete was used for the foundation walls, lower slab and shallow footings. The main lateral resisting system is cast-in-place reinforced concrete stairs and elevator cores. The combination of concrete and some structural steel with cold-formed steel supports 120 senior apartments and five rooftop garden terraces. From the second floor upward, the structure features cold-formed steel joists that were prefabricated into panels to shorten construction times and eliminate on-site labor. These joists leverage the strength and formability of cold-formed steel with punched web holes to accommodate HVAC, mechanical, plumbing and sprinkler runs. The perimeter of the web holes had rolled edge stiffeners to add web strength and stiffness over the entire span of the joist.

Figure 3. The design features pre-fabricated cold-formed steel joists, rim track and structural blocking.

Figure 4. The 10-story Convent Hill senior housing complex features a new level of sustainable and green technology.

The roof joists are cold-formed steel C-sections, 10-inch deep x 2-inch wide flange x 54 mil thickness, spaced at 24 inches on center for the 15-foot spans. Joist bridging was typically at 6 to 7 feet on center. Double C-sections 12-inch deep x 2-inch flange x 97 mil thickness where used for the longer 24-foot spans and 8-inch deep x 1⅝-inch wide flanges x 43 mil thickness were used to span the corridors. The roof membrane is a screw fastened 1½-inch B deck with tapered insulation and ballasted EPDM roofing. The cold-formed steel joist roof structure at Convent Hill has the strength and stiffness to support five terraces each filled with a variety of greenery.

The floor joists are cold-formed steel C-sections, 10-inch deep x 2-inch wide flanges x 54 mil thickness spaced at 16 inches on center. The joists were fastened into pre-punched tabs on ClarkDietrich Building System's "Trade-ready" rim track (*Figure 3*), which facilitated maintaining the 16-inch center-to-center joist spacing. The rim track was also used in many locations to eliminate the need for load bearing headers. The rim track was fastened to the wall stud flange with either screws or welds. The floor framing supported a 0.6 C-deck with Levelrock gypsum concrete fill cover which served as the horizontal diaphragm to transfer lateral loads to the concrete cores.

The wall framing, 6-inch deep C-sections with thicknesses from 97 to 43 mil having either 1⅝-inch or 2-inch wide flanges, were used at interior locations; at the exterior wall locations the 6-inch deep C-section thicknesses varied from 68 to 43 mils. The wall stud bridging was strap and blocking or channel with clip angle.

To expedite the construction process, the walls were prefabricated on site. To ensure proper seating of the stud into the track, the stud panels were compressed to achieve tight seating of the wall stud. Typically, fabrication was done with welding because screw fastening of the thicker steel members proved too difficult.

Development of a load path proved to be a design challenge. First, for vertical wall loads, the floor deck did not have sufficient web crippling strength; thus, deck crushing at the inter-story load transfer was a design concern. To resolve the inter-story load path, a steel-to-steel stud connection was used. However, this steel-to-steel connection resulted in a discontinuity for the diaphragm. The diaphragms had to be broken and additional perimeter fasteners used to ensure diaphragm continuity. Also, angles as drag struts were required at some locations to accomplish the diaphragm load path. Second, the marriage of the two systems, the concrete towers and the cold-formed steel framing, was necessary. Floor diaphragm forces were provided for inclusion in the design of the towers.

The School Sisters of Notre Dame would be proud. The little hill in Milwaukee where they had built their home remains verdant and filled with life. The owner, too, is proud of the green contribution Convent Hill makes to Milwaukee's Park East corridor (*Figure 4*).▪

Figure 5. Exterior cold-formed steel framing the primary load-bearing system for the top eight floors.

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Project Team

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Developer: Housing Authority of the City of Milwaukee
Architect: Zimmerman Architectural Studios
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Cold-Formed Framing Contractor: Worthington Building Systems