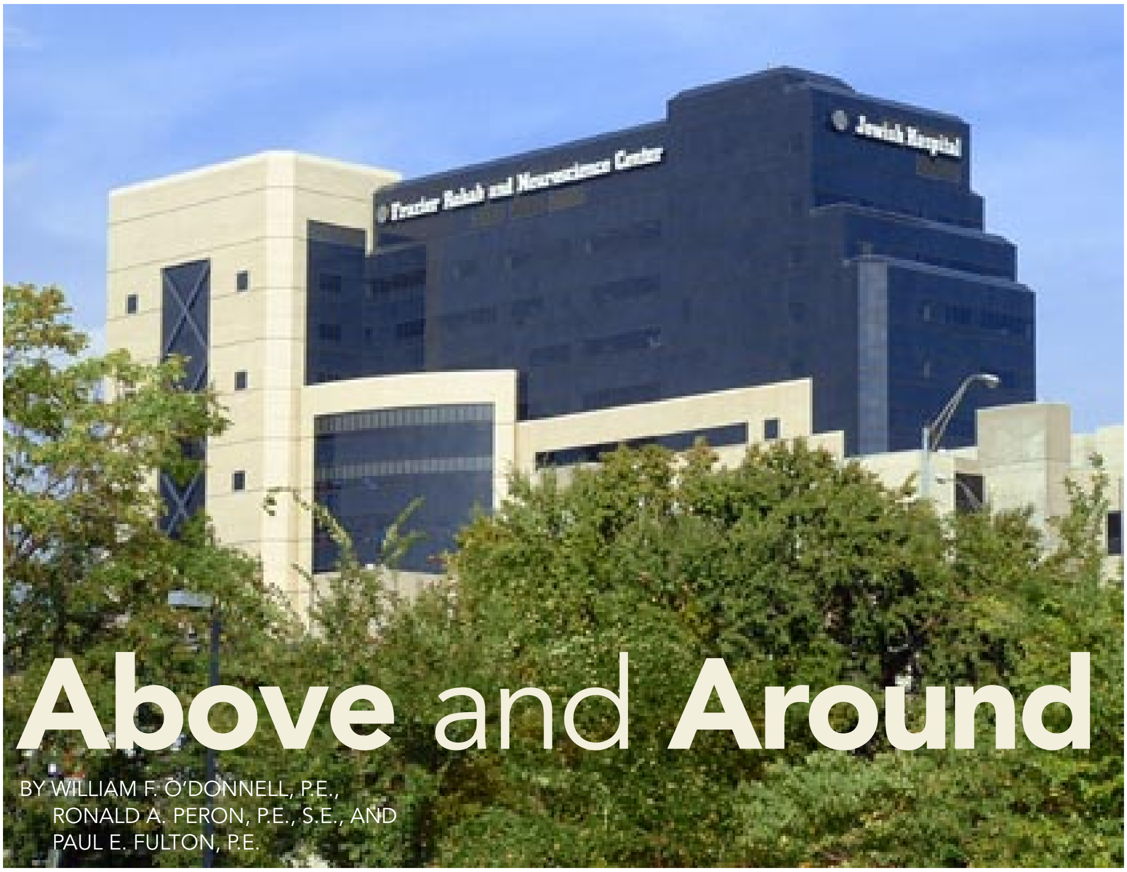

Above and Around

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Jewish Hospital in downtown Louisville overcame expansion challenges by building above and around its existing rehabilitation facility.

EXPANSION AT MAJOR HEALTH-CARE FACILITIES IS COMMON THESE DAYS, BUT WHAT TO DO WHEN YOU RUN OUT OF ROOM TO GROW?

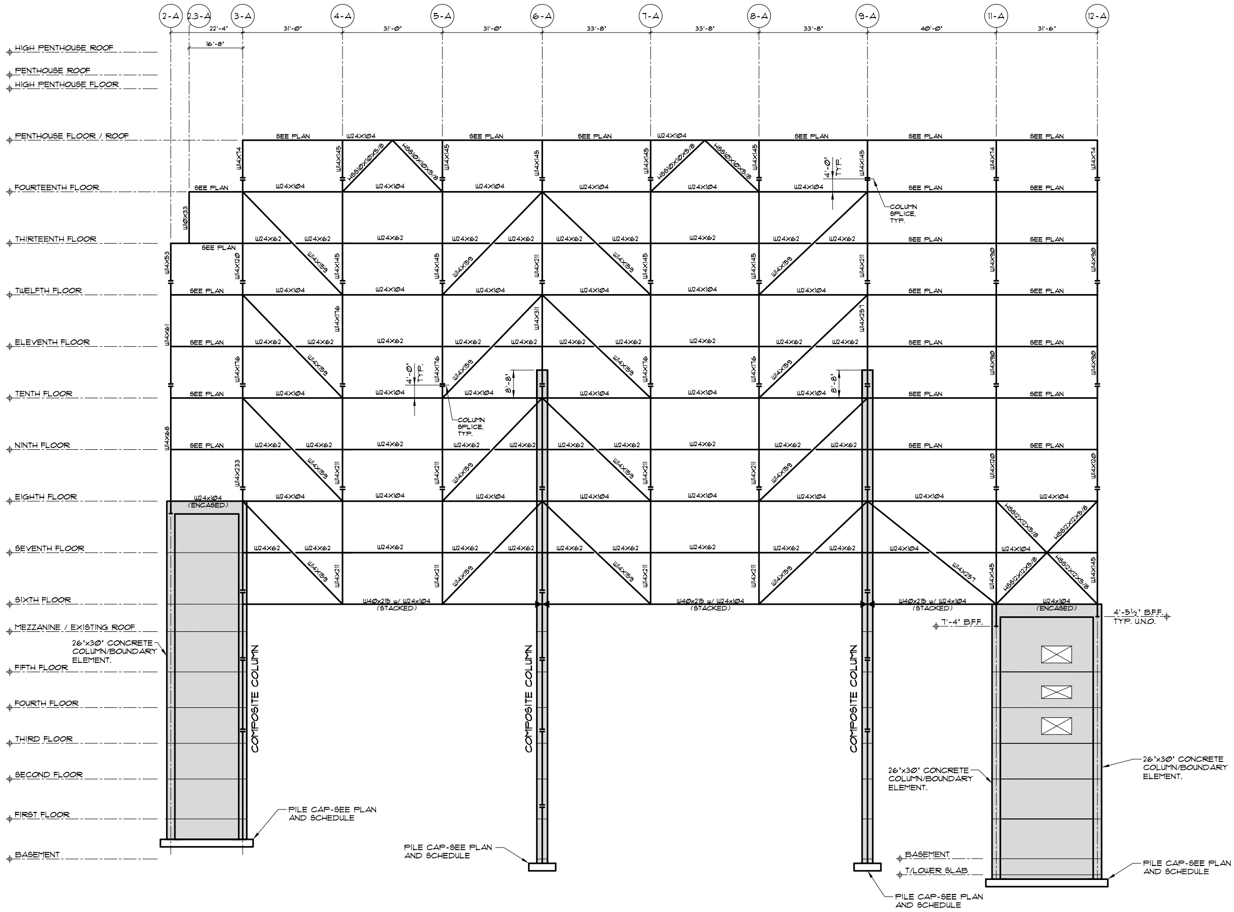
Jewish Hospital faced such a dilemma when it was looking to replace its aging Frazier Rehabilitation Center in downtown Louisville, Ky. Horizontal expansion on the main hospital campus was not a possibility, and the existing facility was not designed for any significant vertical expansion. Furthermore, the temporary relocation of the facility to a leased-off campus site, followed by demolition of the existing structure and construction of a new facility on the existing site, was explored but not feasible due to the cost and inconvenience of multiple moves.

As such, the project team decided to construct a new facility over and around the existing five-story building. Adding to the challenge was the fact that the rehab center had to remain in operation throughout construction.

The result is the new Frazier Rehab and Neuroscience Center at Jewish Hospital, a 14-story structure plus a mechanical penthouse and a basement. The total new floor area is approximately 370,000 sq. ft and the total gross area, including the existing building, is approximately 447,000 sq ft. New additions along the north, northwest and south ends enclose the existing structure. The new building footprint extends approximately 350 ft in the north-south direction and is typically 74 ft wide in the east-west direction, expanding to approximately 110 ft in width at the northwest addition.

The complexity and unique nature of this structure was driven by numerous constraints that had to be closely coordinated and evaluated by members of the design team, construction manager, steel fabricator and erector, and owner. The project was located in a congested downtown area, with limited material storage and working space, so the design evolution required creative solutions to address function, economy, safety, and project phasing. Additionally, each structural option had to consider member weights and lengths based on the lifting capacity and reach limitations of the tower cranes, as well as shipping and handling limitations both to and at the site. Due to the project complexity and required steel delivery dates, the steel fabrication and erection were negotiated based on unit prices early in the design process.

The new facility has five inpatient floors (seven through 11) holding 135 beds. These floors specialize in neurological, orthopedic, cardiopulmonary, and pediatric care. Each inpatient floor is provided with a complete therapy gym and other needed treatment spaces, allowing patients to remain on their respective floor for all of their therapy. An outpatient floor was constructed on the sixth floor, which is the first complete floor above the existing building. This level has a complete therapy gym, neuropsych lab, gait lab, and locomotor clinic, as well as two hydrotherapy pools with built-in treadmills. The remaining upper floors include space for administration, research, and physician suites. Patient rooms, four new elevators and an exit stairwell are included in the south addition, and the northwest addition includes mechanical and electrical rooms, six new elevators and a featured glass-enclosed exit stairwell. The north addition consists primarily of patient rooms except for the hydrotherapy pools on the sixth floor.



EAST EXTERIOR WALL/TRUSS FRAMING ELEVATION

A combination wall and truss, framed in structural steel, spans the existing structure. Support is provided by composite steel and concrete super-columns embedded in the existing structure's facade.

Superstructure Framing

Built in 1962, the original three-story facility included plans for an additional two floors. In 1980, the two floors were completed and a three-story addition (also designed for an additional two floors) was constructed to the south of the original building. As part of the first phase of the latest expansion, completed in August 2003, the two floors were constructed above the 1980 south addition using structural steel. At the same time, the new south addition was erected up to the eighth floor and a temporary roof was installed over the sixth floor. The third and fourth floors of the south addition were built out and tied into the existing third and fourth floors to provide expansion space to address the hospital's immediate needs.

Architectural considerations and site constraints, including adjacent buildings and property lines, did not permit the addition of new columns outside of the existing building envelope along the east and west sides. Adding new interior columns through the existing building wasn't feasible either, since the hospital had to remain in operation throughout construction.

As a result, the preliminary design concept involved clear-spanning 240 ft over the existing five-story facility using an eight-story exterior wall/truss framing system supported by four "super-columns" located beyond the north and south ends of the building. However, this concept was problematic since there was no practical means to provide temporary shoring to erect the exterior wall/trusses. Site and tower crane constraints prevented pre-assembling the wall/truss elements on the ground and lifting them into place. For safety reasons, it was determined that lifting and erection operations would only be performed over the existing building when the top floor of the building could be evacuated or until the new sixth-floor concrete slab over the existing roof was completed. Also, clear-spanning the existing structure would have required the erection of six or more floors of framing prior to placing any of the concrete slabs. With these restrictions for erecting over the existing building, the construction schedule would have been significantly impacted. Another solution would have to be found.

Three unique elements were combined to solve these safety, erection, schedule, and hospital operation concerns. First, the team determined that four composite columns could be added, two each through both the east and west existing exterior walls and spandrel beams, with minimal disruption to the existing facility. Adding columns at these locations reduced the maximum span of the exterior wall/trusses from 240 ft to 101 ft. Secondly, built-up "stacked" beams were designed to span between the new composite columns. These beams were designed to allow the sixth-floor framing to be erected and the sixth-floor slab placed prior to erecting the exterior wall/trusses, and also to provide a much-needed work-staging platform. Finally, 60-in. deep castellated girders were used to span over the shorter direction of the existing building between the exterior wall/trusses. The final design solution resulted in 240-ft by 72-ft column-free interior floor areas from the sixth floor up through the mechanical penthouse.

Composite Columns

The maximum loads on the four new columns through the existing exterior walls and spandrel beams approached 3,000 tons, which exceeded the capacity of available steel shapes. The design team therefore decided to use composite columns. The typical composite column sizes were 26 in. by 42 in. encasing W14×257 steel columns and 26 in. by 48 in. encasing W14×311 steel columns. The specified compressive strength for the concrete was 6,000 psi.

The composite columns were installed and constructed by shoring the existing concrete spandrel beams on each side of the composite columns and saw-cutting the spandrel beam and floor to match the final column dimensions. The steel columns were then installed through the openings, followed by the installation of the reinforcing steel, formwork and concrete placement. The existing concrete spandrel beams were connected to the composite columns using steel saddles and brackets welded to embed plates cast in the composite columns. The composite columns extended above the 10th floor—the level at which the plain steel column sections were adequate.

These columns allowed the use of steel column sections that were readily available and that could be lifted by the tower cranes. The overall column dimensions were also reduced as compared to conventionally reinforced concrete columns, thereby minimizing loss of floor space and disruption of the existing facility. The addition of the composite columns also reduced the member sizes of the exterior wall/trusses, resulting in a substantial cost savings to the project and significantly reduced deflection concerns associated with the wall/truss system thanks to the decreased span lengths.

The existing concrete floor system and spandrel beams were shored and then saw-cut to make room for the composite columns. In the final configuration, the existing concrete framing is support by steel brackets and saddles welded to embedments cast into the composite column.

Built-up Stacked Beams

Since temporary shoring was not feasible for erecting the exterior wall/trusses, a means to erect them between the new composite columns was needed. There simply was not enough clearance for steel trusses, and there were no readily available steel sections with the adequate strength and stiffness to span 101 feet, support the weight of the sixth-floor slab, and support the steel framing for the exterior wall trusses above. Also, tower crane and site delivery constraints restricted available options.

To overcome these obstacles, built-up stacked beams were designed and used for the long spandrel girders. Cambered W40×215 and W24×104 steel beams were each shipped in two pieces and individually field-spliced on the ground. The W40 beams were erected, and then the W24 beams were set on top of them, bolted together and field-welded to provide the required built-up stacked beam section. After erection of the stacked beams, the remainder of the sixth-floor framing was erected. Although the stacked beams were designed to allow placement of the sixth-floor slab followed by erection of the exterior wall trusses, the construction manager requested that steel erection be allowed to continue through the eighth floor prior to placing the sixth-floor slab, to expedite the schedule. After the sixth floor was completed, the specified erection sequence required the erection of the exterior wall/truss and floor framing through the 10th floor, placement of the eighth-floor slab, erection of wall/truss and floor framing through the 12th floor, and placement of the 10th-floor slab. Once the 10th-floor slab was complete, the remainder of the erection and slab placement was at the contractor's discretion. Estimated deflections at the sixth floor were calculated and shown on the structural drawings for each step of the erection sequence. The deflections were monitored in the field to verify the structure behavior during construction.

Castellated Girders

When it came to the task of bridging the 72-ft span between the exterior wall/trusses, several options were investigated including steel trusses, long-span steel joists, and castellated girders. Based on pricing provided by the steel fabricators, the decision was made to use 60-in. deep composite castellated girders spaced up to 33 ft, 8 in. o.c., with infill framing consisting of conventional composite steel beams. The castellated girders ranged in size from CB60×167 to CB60×235 at the main floors, and up to CB60×297 at the mechanical penthouse floor. The typical floor slab consists of a 5½-in. lightweight concrete slab including a 2-in. composite metal floor deck. Mechanical ductwork was run through the holes in the widely spaced castellated girders, allowing 10-ft ceiling heights with a floor-to-floor height of only 16 ft. The castellated girder fabricator provided a database file of the 60-in.-deep sections for use with RAM Structural System software. The RAM Steel computer model was then provided to the fabricator to complete the final girder designs and connections. The main structural steel fabricator, castellated girder fabricator, and structural engineer had to work together to coordinate the connections of the beams to the castellated girders and these girders to the stacked beams and exterior wall/trusses.

On the seventh through 12th floors, the curved portion of the new building containing the therapy gyms extends over an adjacent building. This section of the building is supported by the new northwest addition structure and by cantilevering one of the 60-in. castellated girders at each floor approximately 24 ft.

Exterior Wall/Trusses

The exterior wall/trusses consist of a series of two-story-tall stacked diagonal truss/hanger elements from the sixth floor to the 14th floor that span between the composite columns along the east and west

To span the 72 ft between the exterior truss/wall systems on either side, 60-in.-deep castellated girders were used to support conventional composite infill framing.

faces of the building. Each truss consists of three bays with the two-story braces in the end bays and an open middle bay (mimicking a modified Pratt truss). The top and bottom chords of each two-story truss are designed for the axial loads calculated for the completed building and for each stage of construction. Along the east wall, the typical diagonal brace size is W14×159 and the typical intermediate column elements (between the composite columns) range from W14×145 at the upper levels to W14×211 at the lower levels. Along the west wall, the typical diagonal brace size is W14×193 and the intermediate columns range from W14×145 up to W14×283. The exterior wall trusses also provide the lateral load resistance in the north-south direction for the sixth through 14th floors.

Lateral-Load-Resisting System

Lateral-load resistance is provided by special reinforced concrete shear walls for the first six floors, transitioning to ordinary steel concentric braced frames above the sixth floor. The lateral-load elements are typically located around new stair and elevator shafts in the new south, north, and northwest additions. The exterior wall/truss framing also serves as the lateral-load-resisting system in the longer north-south direction of the structure for the sixth floor and above. The load is transferred from the exterior wall/trusses out to the concrete shear walls between the sixth and eighth floors using large, diagonal two-story braces. With the exception of the exterior wall/trusses, steel tubes as large as HSS12×12×$^5/_8$ were used for the diagonal braces.

Based on the building use and soil characteristics of the site, the building falls into Seismic Design Category "D" per the 2002 Kentucky Building Code (2000 IBC). The braced frames and associated connections were designed in conformance with the AISC *Seismic Provisions for Structural Steel Buildings*. A modal analysis was performed to reduce design lateral forces. There was close collaboration with the steel fabricator in developing connection details and providing loading information. The fabricator provided the final connection designs for review by the structural engineer.

The floors of the existing five-story building were tied into the new floor framing, and the lateral loads of the existing building are resisted by the new lateral-load-resisting elements in order to bring the existing structure into compliance with current codes.

Foundation System

The foundation system consists of 18-in.-diameter, 160-ton capacity, auger-cast concrete friction piles extended to a depth of 60 ft. This system is typical for the deep sandy soils near the Ohio River in downtown Louisville. At the composite columns, special equipment was required to install "low-headroom" piles from within the existing basement with overhead clearance of only 10 ft.

Sum of the Parts

In all, the project utilized 2,900 tons of structural steel and 485 tons of castellated girders. The nine new floors and mechanical penthouse were completed and occupied in early 2006. The original structure is currently being gutted, reclad to match the new construction, and renovated to include a new ground-level lobby, patient drop-off/drive-through, and 125,000 sq. ft of future development space. All of this expansion and renovation will help the high-tech facility serve Frazier Rehab and Jewish Hospital well into the 21st century. MSC

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