Structural Surgery

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Maintaining a functional facility during construction was the top priority at Philadelphia's Pennsylvania Hospital.

PENNSYLVANIA HOSPITAL, THE OLDEST HOSPITAL IN THE UNITED STATES, ENCOMPASSES AN ENTIRE CITY BLOCK IN THE HEART OF PHILADELPHIA, BOUNDED ON ALL SIDES BY EXISTING CITY STREETS AND SURROUNDING BUILDINGS. So when the hospital needed to expand its critical patient care space, finding additional space became a challenge. The already difficult situation was compounded by the fact that half of the campus area is comprised of landmark buildings and gardens that are required to remain as-is for historical preservation. However, the need for space was very real: The hospital required 24,000 sf of additional new critical patient care space immediately. They also desired the capacity for 48,000 sf of future space, and mechanical support space for both.

Making a Diagnosis

Most of the existing buildings on the portion of campus available for new construction are nine- and ten-story structures. However, there was one existing low-rise building identified as a possibility for vertical expansion—a two-story building with a basement. It was adjacent to much taller buildings on two sides, had a major city street on the third side, and was flanked by the only loading dock ramp for the hospital on the building's fourth side. Despite these perimeter constraints, the building had one important feature—there was clear space available above it which could be used for vertical expansion.

Complications Arise

The numerous challenges associated with expanding this existing building soon became apparent. First and foremost, the building housed the hospital's emergency department and ambulance receiving area on the first floor, and it was paramount the emergency department remained in full operation at all times during construction. The building also contained large concrete vaults in the basement for radiology imaging. Finally, the surrounding taller buildings, city streets, and steep loading dock ramp had to stay fully intact and in service at all times.

To complicate matters further, it was soon discovered that the existing building structure had no reserve capacity for vertical expansion; some of the existing columns were so small that concerns rose that the structure as constructed would not meet today's more stringent seismic code requirements.

An engineering study was conducted to investigate the possibility of strengthening the existing structure to support up to two additional floors. The study showed that virtually every column would require strengthening, and many of the existing footings were inadequate. The team—Pennsylvania Hospital's Steve Wanta, Construction Managers Barclay-White/SKANSKA, and Ballinger's Architects and Structural Engineers—discussed the possibility of supporting the new construction by bridging over the 110 ft by 110 ft existing building. Given the space constraints, tight working conditions, and length of span, steel trusses seemed to be the only viable option. Samuel Grossi and Sons, Inc., a steel fabricator and erector, was consulted for constructability and erection issues, and for early pricing estimates.

Treating the Problem

With minimal disruptions to hospital operations in mind, the team further developed the engineering design concepts, constructability issues, and architectural and mechanical planning requirements. The schematic called for six major steel trusses spaced 20 ft apart, bridging an 80 ft clear span over the existing building with an additional 18 ft cantilever at one end. One end of the trusses would be supported beyond the existing building by new steel columns and braced frames straddling the loading dock ramp. At the other end, six new "long" steel columns would be threaded down through small holes placed in the existing building. The new columns were to be situated along a corridor wall, midway between the existing columns to avoid interference with existing foundations.

The new foundations would consist of concrete-filled steel "pin" piles embedded 10 ft into rock in order to avoid any possibility of differential settlements between the new and existing structures. The piles would be installed in short segments within the shallow overhead space of the existing basement. Four-ft-long threaded pipe pile segments would be spliced together to construct each pile as it was advanced into the ground. Finally, pile caps would be poured, ready to receive each new column.

After the foundations were placed, the long columns would be installed through the existing building and attached to the existing building framing at each floor. Two braced frames in each direction would then be installed to provide lateral stability for the combined new addition and existing building.

Minimally Invasive Surgery

At all times, the design was predicated on the need for continuing emergency department operations within the first floor of the existing building. New column locations were selected near the perimeter of the department area. To maintain safety and contain dust, 30-in.-square column enclosures were constructed to create small boxed-out areas around the holes that each of the six new columns would be threaded through. In order to avoid the difficulty of spray-fireproofing the members once they were in place, the new columns were

Story-high steel trusses spanning over an existing structure were the only option for expanding on the tight site.

New columns were threaded through small openings in the existing structure.

instead fireproofed with intumescent paint prior to installation. The new columns were also positioned clear of the radiology vaults in the basement, such that the basement floor slab could be easily removed and replaced after new piles and pile caps were installed. The new concrete slab and steel framing for the added third floor would be posted above the existing roof prior to erection of the trusses, to act as an additional safety barrier during erection.

Six main steel trusses bridge across the existing building, and served as the primary sipport system for six new floors. To keep the truss diagonal members from interfering with the architectural space requirements, the trusses were placed within the required new mechanical floor at the fifth level. Major mechanical units were laid between the trusses, and the mechanical distribution was coordinated between the diagonals. The new fourth floor, below the trusses, was supported by wide flange shapes hanging from the fifth-floor truss bottom chord. Design provisions allow for up to four floors to be posted directly from the truss top chord panel points.

Condition Stabilized

Two of the six trusses were integrated directly into new lateral-braced frames for the building, parallel to the trusses. These braced frames were located directly above the existing loading dock ramp clear of the existing building. The diagonal braces stop above the ramp for the necessary truck clearance, and develop directly into heavy moment-resisting frames at the base. In the opposite direction, there are also two new braced frames. Again, one was positioned along the loading dock ramp such that it could be constructed outside of the existing building. Only one of the four braced frames was required to be placed within the existing building.

By connecting the existing building to the new braced frames with added struts at the second and third floors, the combined buildings were able to comply as a unit with current code requirements for wind and seismic bracing. In addition, stiffening the existing building in this manner enabled the existing columns to directly support the added third floor. Finally, it enabled the new "long" columns that were threaded through the existing building to be effectively braced by simply connecting them at each existing floor. Overall bracing design was confirmed through computer modeling using both RAM Structural System software and STAAD Finite Element Analysis software.

Positive prognosis

The major design and construction challenges had been solved, including installing new deep foundations within an existing basement, erecting long-span steel trusses across an occupied building, and integrating lateral bracing between the new addition and existing building. Along the way, many other considerations unique to this type of project were identified by the design team and systematically resolved. Such issues included jointing of the brick façade to allow for truss deflection due to future floor construction, fireproofing of the structure in extremely tight spaces, and bridging new column footings across existing hospital utility tunnels.

In the end, the hospital emergency room and ambulance drive-through had remained entirely operational during construction, and the hospital now had the ability to provide much-needed additional critical patient care. The prognosis for the future is bright; because of the design capacity of the steel trusses, there is now the ability for the hospital to add 48,000 sf of future space above the trusses whenever it is needed. MSC

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Engineering Software
RAM Structural System, STAAD 2000

Detailer, Steel Fabricator, and Erector
Samuel Grossi and Sons, Inc., Philadelphia, AISC member

Detailing Software
Design Data

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