A Pennsylvania healthcare facility needed additional clinical space in a tight urban center. So it expanded the only way it could: up.

Taking It to the Limit

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LIKE MANY URBAN healthcare centers, Lancaster General Hospital gradually expanded by adding one building after another—until it filled an entire square city block in the historic heart of Lancaster, Pa.

And when the facility needed to add new private patient rooms, the only option for growth, without demolishing an existing hospital building, was to vertically expand a wing known as the Stauffer Building. The building, which occupies the northeast corner of the hospital's site, was constructed in 1974 as a single-story, steel-framed facility (plus a basement level) but was designed to accommodate six floors, with two new levels added in 1979. By fully leveraging the capacity of the existing steel frame, the project's design team was able to provide a much larger addition than what was originally thought possible. Dubbed the Frederick Building, the upsized building opened this past spring.

The first task for CannonDesign, the structural engineer, was to evaluate the capacity of the existing building to determine how extensively it could be expanded while keeping the original structural systems intact. The columns and footings appeared to be capable of supporting four additional floors, as originally designed, but this limited addition did not provide sufficient space to meet the hospital's long-term needs. As this was the only reasonable location available for a vertical expansion, the hospital asked the design team to explore what structural modifications would be required to expand to the maximum height allowed by zoning, which would involve six more floors as opposed to four.

To maximize the area for the building, the design team decided to expand the existing building one bay to the east, demolish a one-story section along the south side and redesign that one-story section as a full-height expansion. Contiguous to the western side of the Stauffer Building is the hospital's eight-story North Wing. The hospital's Lime Street Building, a 10-story clinical tower, is located across an alley to the south

opposite: The original building was designed with expansion in mind.

above: Steel rises alongside the existing hospital buildings.

below: The project uses approximately 936 tons of new structural steel.

Existing columns required extensive modification to transfer braced frame forces to the foundation.

Braced frames and moment frames serve as the new lateral force-resisting system.

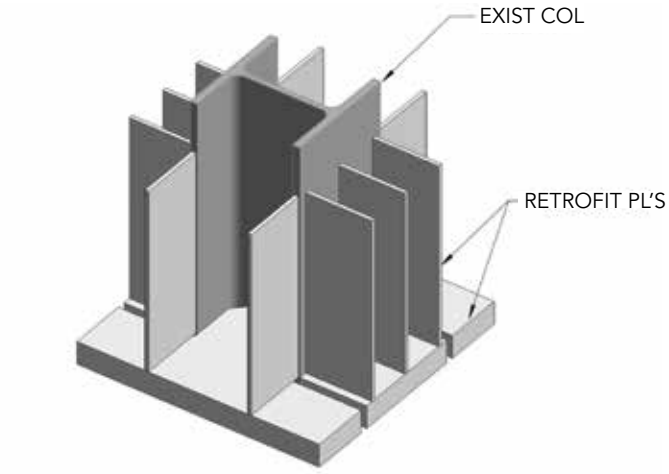
and joined to the Stauffer Building by a series of bridges. To improve connectivity across the complex and to maximize site use, the hospital elected to build a nine-story link to connect the new program with each floor of the Lime Street Building.

The Vertical Expansion

The structural investigation proceeded on several fronts, beginning with a study of the existing gravity framing. At the beginning of the design process, a model of the existing building was developed in RAM Structural System, and the impact of the new structure was evaluated. The result of this analysis showed that many of the spread footings and baseplates were inadequate to accommodate the new work, and at least a dozen columns would be overstressed.

The column footings were bearing directly on sound rock, and CannonDesign engaged the owner's geotechnical consultant to determine whether a higher bearing capacity could be obtained. Their sampling and testing of rock cores indicated that the bearing capacity could be safely increased by 50%, which reduced the need for extensive footing alterations. Where structural modifications were required, new spread footings were cast above and around the existing ones at the basement level. Vertical plates were then welded at the base of the existing columns above the footings as a mechanism to transfer the full axial load to a new base plate.

While it was possible to accommodate retrofit work in the Stauffer Building's basement, modifying overstressed columns on the upper floors would be difficult, since they housed clinical spaces expected to remain operational during construction. In an effort to minimize this impact, the owner's testing agency obtained coupon samples from the existing columns to determine the true yield stress of the A36 steel. The test results showed that the actual yield stress of the columns was significantly higher than the published value of 36 ksi. This eliminated the need to reinforce half the columns originally shown to be overstressed. Where necessary, steel plates were added between the flanges of overstressed columns to increase their axial capacities and improve buckling performance.



New base plates transfer column loads to enlarged footings at the basement level.

Lateral Force-Resisting System

With a strategy in place to address the new gravity loads, focus shifted to the lateral force-resisting system (LFRS). The original Stauffer Building and the 1979 vertical addition had been constructed with partially restrained moment connections at each beam-column interface. However, the design team quickly determined that these connections did not provide adequate strength or stiffness to resist the current code-required wind or seismic loads without significant modifications, much less a taller vertical expansion.

The full-height additions to the south and east provided locations where a new LFRS could be installed in both directions, with limited impact on the existing beams, columns and foundations. In an effort to minimize disruption to the existing program, the design team provided an entirely new LFRS of braced frames and moment frames within these areas. Even with these efforts, it was necessary to provide an additional braced frame within the existing structure, which required extensive retrofit work. Here, CannonDesign worked closely with steel fabricator Stewart-Amos Steel and construction manager Benchmark Construction to develop structural details and sequencing that would minimize disruption to patients and staff without compromising the accelerated construction schedule.

Creating Connections

Designing the structure that would link the expanded Stauffer Building to the existing Lime Street Building posed several unique challenges. The narrow site, the presence of site utilities and existing foundations—some of which were above grade—meant that a deep foundation system using micropiles was the most effective approach to add both vertical load and uplift capacity without overstressing adjacent foundations. Obstructions were not limited to the area below grade; the owner required that the existing bridges between the two buildings remain operational during construction. To accommodate this, CannonDesign worked with Benchmark to develop a carefully coordinated erection and demolition sequence that would remove each bridge only after the sur-

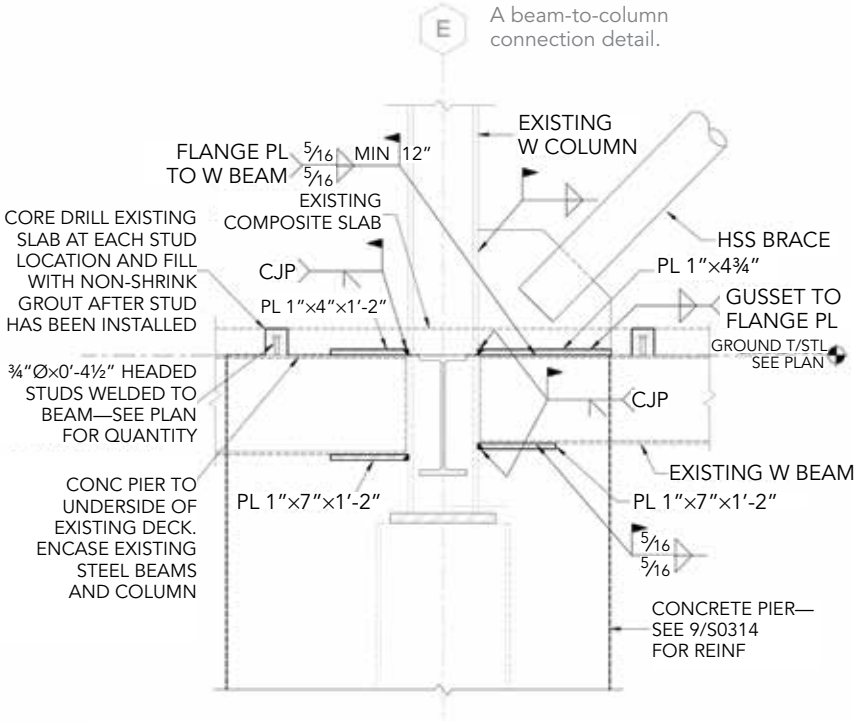
rounding structure had been completed and an alternative path of travel between the buildings was established.

Changes Midstream

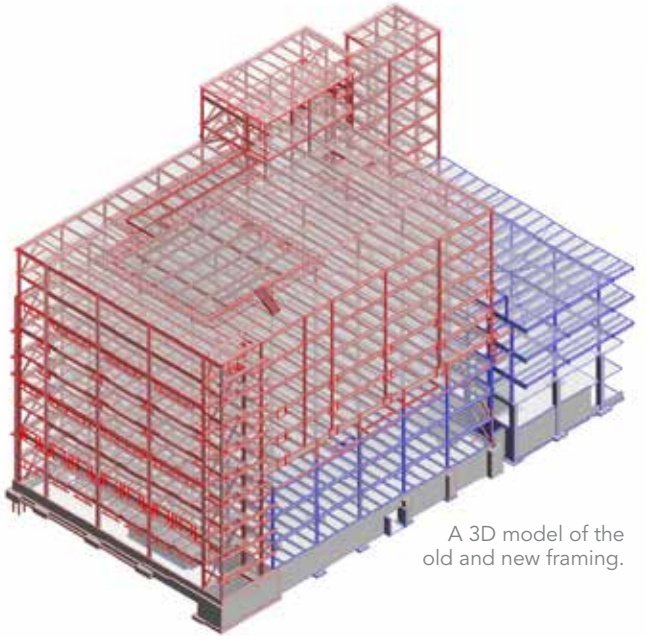
Several months after construction began, the hospital asked CannonDesign and Benchmark to investigate the feasibility of reducing the overall project cost by approximately $10 million without sacrificing program. At this point, foundations were largely complete and more than half the steel had already been fabricated. Working closely with Benchmark, Stewart-Amos and the subcontractors, CannonDesign developed a strategy to exceed the cost-reduction goal while minimizing any adverse impact to the project schedule. During this highly collaborative process, Stewart-Amos helped the structural designers simplify cladding support details that had not yet been fabricated; the structural design team helped fabrication move forward after determining that most areas of the building would not require any structural alteration. Where modifications were required, CannonDesign and Stewart-Amos found opportunities to reuse and repurpose members that had already been fabricated in ways that minimized rework.

During the redesign process, studies showed it was significantly less expensive to locate all of the mechanical equipment on the existing third floor structure rather than the new roof level. CannonDesign quickly determined that the existing non-composite beams and girders would be unable to support this new load, but could be strengthened by adding headed studs to achieve composite action. As the existing connections were found adequate, all retrofit work could be accommodated from above, eliminating disruption on the occupied level below. Once again, the versatility of structural steel—for this building, approximately 936 tons in all—proved essential to achieving the project goals.

A nine-story steel-framed link building connects the new addition to the existing hospital campus.



A beam-to-column connection detail.



A 3D model of the old and new framing.

A new nursing staff station.

The inherent difficulty of providing an economical structural design for the vertical expansion of a large urban hospital on a congested site demands a close working relationship between the architect, engineer, construction manager and steel fabricator. For Lancaster General, these same challenges meant that structural steel provided the most viable, cost-effective solution—one that provided needed flexibility to accommodate design changes during construction. ■

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The original Stauffer wing remained operational as it was encapsulated by the new steel framing.