A new addition to Johns Hopkins Hospital, consisting of two interconnected towers, houses several medical disciplines—and all of the heavy, specialized equipment that comes with them.

# The Two Towers

BY ZACHARY KATES, P.E., MATTHEW HORNE, P.E., AND R. WAYNE STOCKS, P.E.

Zachary Kates/Thornton Tomasetti, Inc.

The Johns Hopkins Hospital New Clinical Building will use nearly 13,000 tons of structural steel.

Courtesy of Perkins+Will

The new building will encompass 1.6 million sq. ft.


**IF THERE IS ONE STAPLE IN HEALTH-CARE DESIGN, IT IS THAT PROGRAM TAKES PRIORITY.** The functionality of the building to serve its doctors and patients is the primary design goal.

This idea is resonant in the structural design for the Johns Hopkins Hospital New Clinical Building. At 1.6 million sq. ft and almost 13,000 tons of structural steel, the facility, located in Baltimore, is one of the nation's largest health-care projects currently under construction. The New Clinical Building (NCB), consisting of two interconnected clinical towers—a cardiovascular and critical care tower, and a children's and maternal care tower—is intended to replace existing, outdated facilities with a flexible, state-of-the-art hospital that fosters collaboration between researchers and those treating patients.

## Why Steel?

The main reason structural steel was chosen for the NCB's framing was that it offered flexibility for future modifications while at the same time provided the most cost-effective structural system. Technology changes quickly within the health-care field and modifications to the structure are inevitable. Steel can be readily adapted to accommodate such changes and can be added to form new mechanical openings and accommodate future floor penetrations. Framing members can be easily cover-plated and strengthened for future heavier loads due to constantly evolving medical equipment.

There were a number of site constraints that also guided the project team toward a steel solution. The site is bounded by busy Orleans Street to the south and the existing Jefferson and MRI buildings to the north. In order to meet the hospital's square footage requirements and counter the tight site, diagnostic and patient room areas were cantilevered over the existing structures using a system of full-depth trusses, plate girders, and diagonal tension members.

R. Wayne Stocks/Thornton Tomasetti, Inc.

To meet square footage requirements and counter the tight construction site, some areas of the new building were cantilevered over existing structures. For example, one eight-floor section cantilevers over the MRI building.

The southwest corner of the existing, low-rise MRI building actually projects into the footprint of the NCB, interrupting almost 120 ft of the building's perimeter support system. Full-depth W14 trusses in combination with built-up plate girders are used to cantilever eight floors of building structure over the MRI building.

The tight East Baltimore site also required that the ambulance entrance be located underneath the building structure. This was accomplished with a series of 60-ft-long, 6-ft-deep built-up plate girders resulting in a column-free, sheltered ambulance parking and turn-around area.

The architectural design gained precious patient room area by using half-bay projections to cantilever over the existing Jefferson Building and over the Orleans Street right-of-way. These half-bay cantilevers were accomplished using tension diagonals that tie into the building diaphragm and ultimately rely on the lateral braced framing system for support. Diagonals were coordinated with patient room walls, resulting in cost-effective square footage and dramatic architectural features. The self-supporting design allowed erection without temporary shoring towers, saving both time and dollars.

## Typical Framing

The typical bay size, 28 ft 8 in. by 28 ft 8 in., was configured to fit two back-to-back patient rooms within one structural bay, optimized by the space planners to minimize overall building area and control overall costs. The typical framing consisted of W21 girders, cambered W16 beams, and 3-in. composite metal deck. Early in the design process the design team chose shallower non-optimized girder depths to gain precious plenum space above the ceiling for added flexibility to the building systems, thus reducing floor-to-floor heights and minimizing building skin area.

## The Pecking Order

The idea of the structural system responding to the programmatic requirements is most apparent in the layout of the lateral braced frame system. The multiple departments and functions that occupy the NCB each have a unique layout and circulation requirements, so stacking of the programs around a simple or consistent braced frame configuration was not practical. Bracing work points were adjusted and coordinated with the architectural design team as needed around doors, hallways, elevators, and building system infrastructure. The resulting layouts included chevron, V-type, single diagonal, and open-bay braces, as well as multiple frames that shift location in plan. Most importantly, the resulting layouts satisfied the programmatic requirements, accommodating the various floor plan requirements of each department.

The complexity of the bracing system required a code lateral system that would allow combinations of bracing types. The system that best fit the design constraints for the NCB was the "Steel System Not Specifically Detailed for Seismic Resistance," or more commonly, the $R = 3$ steel lateral system. This system type is only allowed for buildings with a Seismic Design Category of C or less, which can be difficult to achieve for buildings classified as essential facilities. Due to the low seismicity of the site—confirmed by shear wave velocity testing—the NCB qualified for the $R = 3$ lateral system. In addition to accommodating combinations of bracing configurations, this lateral system type does not require seismic detailing of connections. Standard braced frame connection details saved material, fabrication time, and erection time.

## The Flying MRI

One challenging aspect of the structural coordination was determining the medical equipment design requirements and required plan configuration. Medical equipment has a significant impact on the structural framing because of its heavy loads and strict vibration criteria. Because the steel frame design is one of the earliest items requiring coordination, even before finalization of the user group layouts, Thornton Tomasetti had to work closely with the design team to determine a flexible solution that would incorporate possible design changes in the building layout and equipment selection. This required detailed collaboration with the hospital, medical equipment planners, and architectural team, and clear definition and documentation of the design criteria.

The solution employed at the NCB included categorizing areas into room types, which included MRI rooms, CT scanner rooms, designated operating rooms, and operating rooms that could be upgraded to future interventional suites. The structural loads were determined for each room type, including anticipated ceiling and floor-mounted equipment weight, RF or magnetic shielding, and floor fill requirements. The floor slabs were often depressed to allow flexibility to run conduit, install shielding, and set equipment mounting plates. In addition, floor framing was sized to support thickened floor slabs used to reduce sound transmission into areas above and below the equipment, and was coordinated for heavy moving loads within the installation pathways of the equipment.

Vibration within the building structure is caused by foot traffic and sources such as mechanical equipment and street traffic. The floor framing was designed to control floor vibrations perceptible to the building occupants but also, more importantly, to control vibrations that could affect the image quality of the sensitive equipment such as MRI machines and CT scanners. The design team worked with the owner's vibration consultant to determine appropriate vibration limits for each area of the building. Similar to the equipment loads, many areas were designed to a more strict vibration limit in anticipation of future equipment requirements. The vibration design criteria are clearly documented on the structural documents for use in evaluating future modifications. The combination of load diagrams and clearly stated design criteria within the construction documents has been an invaluable asset to rapidly evaluate user-driven proposed modifications and equipment changes without having to recreate the original design.

The medical field has seen an explosion of technological advances in the past few years. One such development is the intra-operative MRI. While typical MRI machines are floor-mounted, this 24,000-lb MRI is track-mounted to the ceiling, allowing patient scans during surgical operations as well as the flexibility to move between two operating rooms. A steel frame, with strict erection tolerances and slope-deflection requirements, was provided to support the track system. To meet the established vibration criteria and to avoid impact from activity on the floor above, the track beams are supported from supplemental column-to-column beams rather than the floor beams above.

## Success in Collaboration

In order to get a jump-start on construction, the project was separated into two phases. Phase 1 consisted of the below-grade construction including foundations, below-grade steel floor framing, and at-grade steel floor framing. Phase 2 consisted of the superstructure for the common base and two towers. Separate steel fabricators and erectors were assigned to each phase. In order to meet the schedule constraints, the structural team was asked to produce Phase 1 steel construction documents and Phase 2 documents used for steel mill order approximately six months prior to the issuance of architectural construction documents. This required early coordination with the design team to determine medical equipment loads, installation pathways, floor depressions, vibration design requirements, heavy mechanical and piping loads, and mechanical shaft requirements.

A challenging aspect of the project involved post-bid modifications and enhancements to the building. This resulted in modifications to the entry lobbies at both towers, the addition of a wing-shaped, 28-ft cantilevered canopy, and upgrades to the exterior curtain wall system. Frequent and direct communication between Thornton Tomasetti and the steel detailer and fabricator was a key factor in facilitating efficient solutions to these design modifications and helped to minimize the disruption to ongoing shop drawing review and fabrication. True collaboration and the flexibility of the design and construction team allowed the enhancements to be incorporated with minimal impact on the overall steel delivery and erection sequencing. Steel was scheduled to top out in October 2008. MSC

*Zachary Kates is an associate, Matthew Horne is a senior engineer, and R. Wayne Stocks is a principal, all with Thornton Tomasetti, Inc.*

**Owner**
The Johns Hopkins Hospital-Facilities, Design, and Construction, Baltimore

**Architect**
Perkins+Will, Los Angeles, Chicago, New York

**Structural Engineer**
Thornton Tomasetti, Inc., Washington, D.C.

**Construction Manager**
Clark/Banks, A Joint Venture

**Steel Fabricator**
SteelFab, Inc., Charlotte, N.C. (AISC Member) – Phase 2
Helmark Steel, Inc., Wilmington, Del. (AISC Member) – Phase 1

**Steel Detailer**
Prodraft, Inc., Chesapeake, Va. (AISC Member) – Phase 2