Providing Adaptable Hospital Facilities in the Changing Healthcare Environment

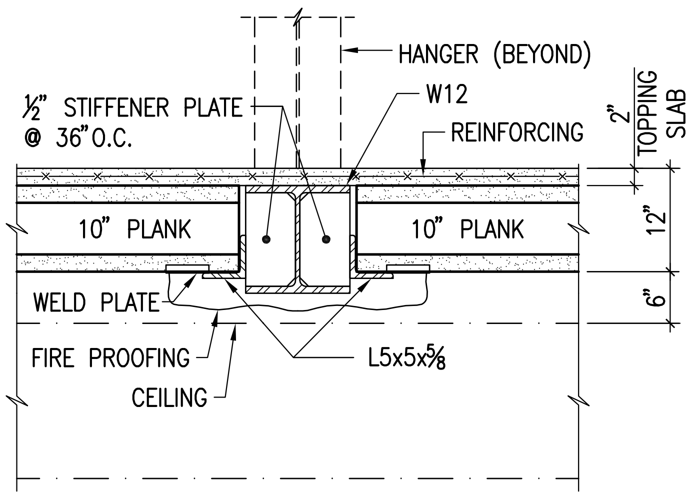
By John Tracy, P.E., LEED AP

As Massachusetts General Hospital (MGH) prepares to celebrate its bicentennial anniversary in 2011, construction is nearing completion on the Lunder Building, its Building for the Third Century (B3C) of Healthcare. The Lunder Building is a 186-foot tall, 530,000 square-foot structure with 12 stories above grade and 3 stories below grade. The new inpatient medical facility expands the existing hospital with state-of-the-art emergency rooms, procedure rooms, patient rooms, and services. Blending the infrastructure of a modern building with the existing functions of an operational hospital offered unique structural challenges to support the continuation of patient care.

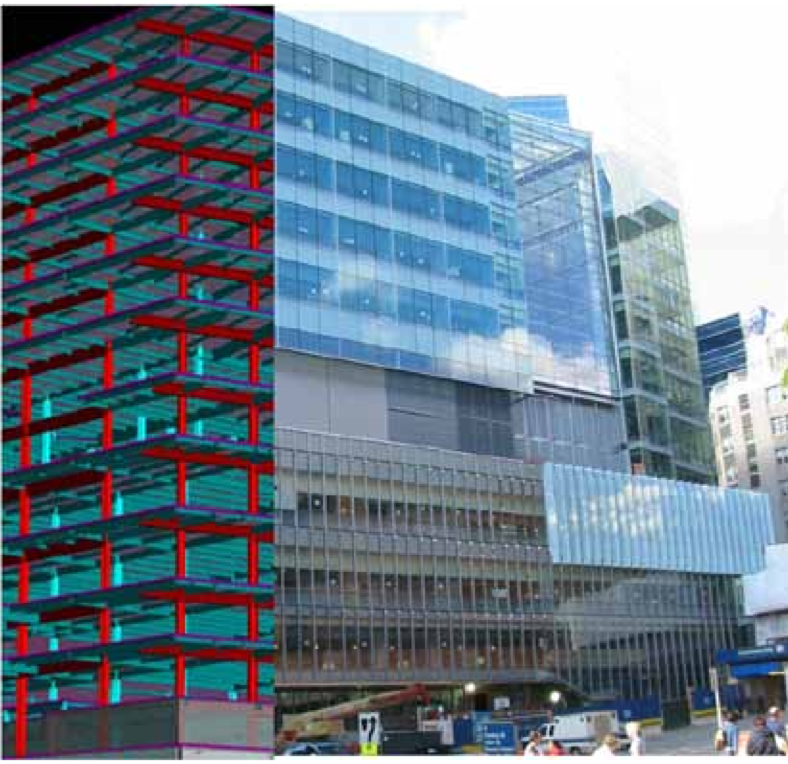
Massachusetts General Hospital's main campus is a network of 13 buildings located on a dense urban site in Boston, MA. Limited site area, matching adjacent program spaces, plan irregularities, and accommodations for the latest medical technology dictated the use of multiple structural building materials and systems to serve the programming needs of the different spaces. The primary design objective was ensuring that the hospital had the clearances and flexibility to use the latest medical technologies to best serve the needs of their patients. Hospitals are buildings with specific programmatic functions, which drove innovative structural decisions with patient care objectives in mind.

Site and Foundations

The limited site for the B3C is bounded on one side by the existing emergency room entrance that needed to remain accessible 24/7 during construction. On two other sides are existing, operational hospital spaces with sensitive patient care functions. The fourth side of the site is Fruit Street, which serves as an entry point to nearby outpatient buildings and remained open to traffic through construction. These tight urban boundaries limited lay-down area and drove the use of up-down construction, where the superstructure erection and basement excavation occurred simultaneously, to streamline the construction schedule and maximize contractor access to the site.



Innovative structural solutions using hangers, upset beams and precast prestressed hollowcore slabs maximized the space above the ceilings for medical functions.



Structural design of hospitals provide value by easy adaptation to future requirements.

The primary foundation consists of 30-inch thick reinforced concrete diaphragm (slurry) wall panels at the perimeter, and interior structural steel columns encased in reinforced concrete load-bearing elements (LBE) at the interior. The slurry walls extend to bedrock as a groundwater cutoff measure.

The surrounding existing buildings date to the early 20th century. Supplemental 70-ton drilled mini-piles maximize the building footprint on the available site and limit construction vibrations near the surrounding buildings. Under an existing overhang, mini-piles were also used for access of a low-clearance rig.

Below Grade

The three stories below grade have 14-inch thick, reinforced two-way concrete slabs spanning up to 40 feet. Normally reserved for underground parking in urban, slurry wall construction, the basements at the Lunder Building are occupied by clinical patient space and hospital support services. A continuous corridor around the perimeter of the foundation wall provides access for monitoring and controlling moisture-related problems and supports a dry, clinical environment. The slabs allow for continuous perimeter drainage trenches and universal access holes at the slurry panel joints. The slabs support live loads up to 150 pounds per square foot and accommodate pits for future equipment needs. To maximize floor area, the below grade structural steel columns are not encased and steel brackets were designed to support the full load of the slabs.

The B3C's cancer treatment center occupies the lowest floor, 50 feet below street level. Concrete vaults with 4-foot thick high-density concrete walls and ceilings up to 6½ feet thick for radiation shielding encase the linear accelerator treatment rooms. The walls act as above-grade beams spanning between drilled caisson foundations to limit the depth of excavation and allow continuous waterproofing below the slab. Accommodations were made for conversion between linear accelerator treatment and proton therapy treatment. A highly coordinated 12-foot deep pit and associated embedments support a 30-ton gantry structure for the proton therapy equipment. The hospital will have the flexibility to tailor the treatment of patients to changing demands and evolving equipment.

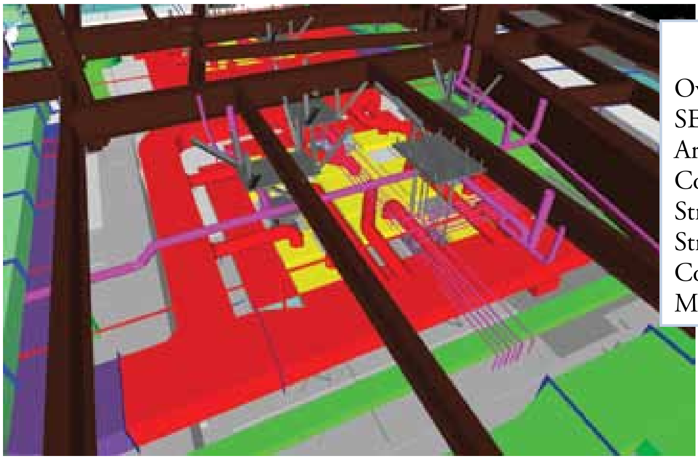
Reduced beam sections (RBS) were selected to meet the Special Moment Frame requirements.

Shear links were added at the transfer levels to add stiffness to the structure.

Gravity Framing

The loading dock and ambulance entry functions are located within the building footprint. To accomplish the receiving space, a one-story high transfer truss spans over the loading dock to support the framing above. The interior ambulance bay is column free thanks to a structural system that partially suspends the floors above with hangers from the upper transfer floors.

For the B3C to expand the functions of the existing hospital, the lower procedure floors match the elevations of the existing buildings. Resulting floor-to-floor heights are as low as 11½ feet, and leave little room to accommodate the infrastructure required in modern procedure rooms with conventional structural steel construction used elsewhere on the project. To expand the space in the procedure rooms, precast prestressed, hollowcore concrete slabs span up to 34 feet between upset structural steel beams. Only 12 inches thick, the resulting structural floor plates leave the ceiling space to accommodate



State-of-the-art BIM tools were used to coordinate the dense structural, MEP and architectural systems in this state-of-the-art hospital. Courtesy of Turner Construction Company, Inc.

Project Team

Owner – Partners Healthcare, Boston, MA
SER – McNamara/Salvia Inc., Boston, MA
Architect – NBBJ, New York, NY
Construction Manager – Turner Construction, Boston, MA
Structural Steel Fabricator – Isaacson Structural Steel Inc., Berlin, NH
Structural Steel Erector – James F. Stearns Co, Inc., Pembroke, MA
Concrete Contractor – S&F Concrete Contractors, Inc., Hudson, MA
MEP Engineers – Thompson Consultants, Inc. Marion, MA

the latest medical technologies and the mechanical, electrical, and plumbing utilities needed for the spaces to function. Upset beams minimize the floor depth by framing to the hangers also supporting the ambulance bay.

The designers recognized the need for beam web openings at composite slabs-on-metal floor deck framing. Through careful coordination with the mechanical engineer and contractor, the construction documents indicate the openings so that two-thirds were furnished during shop fabrication. Beam depths were increased where necessary early in design to allow larger openings; the net effect of the structure and mechanical interactions resulted in a higher ceiling to meet Department of Public Health guidelines.

The Lunder Building has three levels of stacked procedure space. For hospital operations, taking adjacent procedural spaces out of service to retrofit another space is undesirable. The Lunder Building design incorporates the flexibility to support new ceiling-hung or floor-mounted equipment without disrupting the operations of spaces above or below for future retrofits. Additional reinforcement in the slabs, and floor capacities locally enhanced, allow new and future equipment to be flexibly located and mounted directly to the floor slabs from above or below. Most of the equipment has strict serviceability requirements for which supports suspended to the ceilings were analyzed in advance to reduce future impacts to the space.

Project Application of BIM Education

Building Information Modeling (BIM) was an important tool during design and construction to coordinate the congested utilities through the medical spaces. The construction manager created a BIM command center in the field office for subcontractor tradesmen to coordinate and input changes into a central model prior to delivery and installation of materials on the site.

With the emergence of BIM as a universal tool in building construction, focus has shifted to BIM education. New hires that have had formal education with the latest software are most familiar with creating the models and maneuvering elements to make quick changes. The software is extremely helpful at identifying conflicts and clashes, but in the constrained spaces, the software does not solve the problems without human interaction and experienced engineering judgment. The design and construction teams held frequent meetings in the BIM command center to evaluate and resolve clashes.

The design and construction team committed early in the project to using 3D technology to identify clashes prior to construction, and remediate them immediately. The success of these efforts has led each team to fully embrace BIM technologies on future projects. For project delivery, BIM is a tool that can improve communications, safety, quality, schedule and budget.

Lateral Framing

The building program and irregularities of the site discouraged the use of a central core. Diagonal bracing would interfere with the adaptability of the space. The modular patient room column grids transfer at the lower floors. Upper floors use perimeter cantilevers to maximize patient room space, moving columns from the perimeter. Considering these limitations, moment frames were used close to the exterior of the building for the lateral force resisting frame of the Lunder Building.

For its height, occupancy category and poor site class the code required Special Moment Frames. Prequalified Reduced Beam Sections (RBS) met the seismic detailing requirements. Shear links at the transfer levels provide additional lateral stiffness to meet the code seismic drift requirements ($0.010h_{sx}$) for the hospital as an essential facility required for post-earthquake recovery.

Summary

New demands on the hospital industry to reduce the cost of healthcare require careful planning of new facilities that will be able to adapt to the latest technologies. From the beginning of design for the Lunder Building through construction, the proposed medical equipment for use in the building went through multiple changes as the users continued to study the latest available equipment for patient care.

Structural engineers can provide best value to their healthcare clients by designing buildings that are able to adapt to similar changes over the life cycle of the building. The equipment needs to fit, the hospital has to perform its function, and infrastructure design efficiencies are secondary to patient care functions. This creates opportunities for structural innovation where conventional load paths do not meet these needs. Value is provided to the owner by providing an adaptable structural layout where future modifications require limited additional work.

With enhancing patient care an objective in all decisions, the highly coordinated efforts of the design team and construction team on the Lunder Building have produced a building that serves the needs of the hospital now and in the future.▪

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