



**This page:** Bank of America Tower, under construction here, consists of 2.1 million sq. ft of office space in 55 floors.

**Opposite page:** The building, just across Bryant Park from the New York Public Library, adds a new structural icon to Midtown Manhattan.

Photo by: Severud Associates

# Growing UP in Manhattan

BY ANDREW MUELLER-LUST, P.E.

**Well-studied use of structural steel allows Bank of America Tower to rise in New York City.**

**TRADERS ARE ALREADY AT WORK IN BANK OF AMERICA TOWER AT** One Bryant Park, the new headquarters for Bank of America's New York City operations, which will be completed in 2009. When the steel for the architectural spire topped out at 1,200 ft this past December, it completed the structural work for 2.1 million sq. ft of office space spread vertically over 55 stories. At the lower end of things, the new skyscraper also includes three cellar levels, an underground pedestrian passage, and a restored Broadway theater. To make all of this come together, an equally sizeable effort by the project team was needed, especially for the structural steel design.

## Studies in Steel

Many studies were performed early in the design phase to ensure that the structural systems used were economical and would help maintain the project's aggressive construction schedule. Once the basic floor plan at the base of the building—a rectangle with 15-ft-wide extensions at the northeast and southwest corners—was established, various concrete and steel framing systems were compared. Based on

the schedule requirements of the construction manager, structural steel was chosen.

With the framing system set, additional studies were performed to determine how best to support the northeast and southwest extensions. The typical span from the core to the exterior is 40 ft. At the extensions, the span would increase to 55 ft and consequently, the typical filler beam would increase from 18 in. to 24 in. in depth. This would have presented problems to the mechanical engineers who needed as much space above the ceiling as possible. A second line of columns would have resulted in the lowest tonnage but also more pieces to erect. In addition, the closely spaced column grids were not as attractive to space planners.

Cantilevering, therefore, became the only method of supporting the floor extensions. At 15 ft long with a depth restriction of 18 in., the cantilever beams were controlled by deflection. To keep the tonnage as low as possible, still more studies were carried out. Neither cantilevering every beam (too many moment connections) nor cantilevering at the columns only (very heavy sections) was an acceptable solution. Instead, small vertical members were installed to tie the tips of the cantilevers (located on the columns



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only) from floor to floor. This allowed live load to be shared by several floors, which significantly reduced the tonnage.

Although Bank of America Tower is rectangular at its lower floors, the skewed and sloping walls that give the building its distinctive, faceted shape make the floor plates very irregular for the upper two-thirds of its height. Because every floor above the 18th is different, keeping the steel framing reasonably uniform at each successive level required further study, this time in conjunction with the architect. Their investigation of the curtain wall compared the effect of mullions that remained vertical in true elevation to mullions that appeared vertical only when projected onto major axis planes; the exterior columns would align with the mullions in either scheme.

The second mullion scheme was preferred by the architect and owner, which was also beneficial structurally, as it allowed the exterior columns to maintain their relative alignment to the core and produced framing plans where only the length of the beams (and not their locations in plan) varied at each level of the building.

To close out the structural steel framing studies, different approaches were investi-



Sloped exterior walls—as shown here, transitioning to a vertical wall—give the building its distinct faceted shape.

gated to accommodate the sloping surfaces of the façade. Keeping the columns vertical and transferring them every few floors produced transfer girders much too deep to fit above the ceilings. Even stepping the columns—i.e., offsetting vertical columns at every floor—proved infeasible, especially at the lower floors; although each individual offset is small, the shear that would have to be transferred is very high.

Sloped columns, alternatively, allowed for a smooth transfer of vertical load while having the least architectural impact as well. Still, the induced horizontal loads had to be taken into account, especially at the transition from vertical to sloped. At most locations, this was handled with an upsized tie beam and connection. At the 3rd, 4th, 11th, and 12th floors, however, where all of the columns at the southeast corner of the building slope inward simultaneously, horizontal trusses were necessary to deliver the large lateral loads to the core shear walls.

### Coordinated Core Construction

Once structural steel was chosen for the floor framing, braced frames at the building core were investigated for the lateral system. For center-core buildings, where elevator banks are typically arranged back-to-back, this is the logical choice since the bracing does not interfere with occupant circulation or mechanical systems. However, for other reasons, the owner wanted to harden the stair and elevator shafts by enclosing them within concrete walls. Con-

sequently, reinforced concrete shear walls were also studied.

Whenever concrete and steel are used together, development of efficient details to combine the two materials, as well as coordination of the two trades, can become issues. In other cities, steel buildings with concrete cores often use a “jump-formed” system where the concrete walls are constructed first using self-climbing formwork. The steel framing follows below and connects to plates that are embedded in the core walls. Traditionally, however, this system has not been used in New York City, where steel erection almost always precedes concrete work on buildings where both materials are used. Consequently, such buildings are usually designed as steel frames with concrete encasement. The resulting details are inefficient and slow to construct, mainly due to problems associated with the formwork.

To maintain the pace of construction but simplify the connection details and concrete formwork, modifications to the steel framing were studied that would allow a self-climbing formwork system to be used, similar to traditional jump-formed buildings. The formwork system consists of a multi-level hoisting platform that is supported on the inside face of the concrete shear walls. The platform provides work areas for installation of the reinforcement; the inner and outer forms also hang from the platform. Using vertical rails, the platform raises itself (like an inchworm) along with the forms after each lift of wall

is placed. Upward movement of the inner forms is not usually a problem (since the platforms are located within elevator banks) but raising the outer forms is impeded by the floor framing.

The building’s core is framed with columns and beams as it would be for a conventional steel building but this framing is much lighter, because it only needed to support at most 12 stories before it was encased in concrete. To accommodate the outer forms, slots were framed in every floor surrounding the core. Each slot was about 3 ft wide and 30 to 40 ft long (depending on which side of the core the slot was located). The outer member of each slot supports the floor framing, and at each end a girder transfers the gravity load to the core columns. As erection of the steel frame progressed, placement of concrete on the floors followed behind, leaving the slots open. The slots allowed the outer wall forms to come up from below as wall construction progressed. Finally, the slots were closed up with framed concrete slabs, along with the elevator lobbies and stairs within the core walls.

Another complication of the combined steel and concrete system is the transition from steel to concrete at the top of each elevator bank. For the high-rise and high mid-rise elevators, the steel column above simply bears on the concrete wall below it. For the low mid-rise and low-rise elevators, however, the load accumulated in the columns is much too great for simple bearing. To spread the load at each of these loca-

tions over a greater width of concrete wall, two supporting trusses at right angles to each other were encased within the concrete. During steel erection, the trusses transferred the temporary load to the core columns below. Now encased in concrete, the truss bottom chords deliver the load from each column above in bearing to a 30-ft length of shear wall below.

### New Life for an Old Theater

Although primarily an office building, One Bryant Park also houses the new Henry Miller's Theatre, a first-class Broadway venue. The original theater, on the northwest quadrant of the site, was built in 1918 and at more than 90 years old, had almost reached the end of its useful life; the theater was in use up until it went dark for demolition. The theater's façade has Landmark status—as does its box office lobby, known as the Oval Room—and had to be maintained in the reconstruction. Unlike the Oval Room, which was disassembled and stored for reinstallation later, the façade could not be removed, even temporarily. Instead, a steel framework cantilevering from the sidewalk was installed that braced the façade from the outside. This allowed the existing theater to be demolished and the new theater to be built in its place. After the façade was reattached to the building framing, the temporary bracing was used as scaffolding to facilitate restoration of the brick and terracotta before being removed.

The theater's new 1,055-seat auditorium is acoustically isolated from the build-

ing that surrounds it. (Contrary to expectation, the isolation is not intended to protect the theater audience from unwanted noise from the building but to protect the traders, who work 24/7, from the distractions that could be produced by a Broadway performance). To accomplish the isolation, double lines of framing and columns located on the sides and back of the auditorium create a 4-in.-wide joint. Independent bracing on the east and west sides of the auditorium resist lateral loads longitudinally. Transversely, bearing pads bridge the joint—with no significant loss of acoustic isolation—to transfer lateral loads to the building's diaphragms and shear walls.

The auditorium's location within the building required the transfer of several of the podium columns. Originally, 20-ft-deep trusses located at the front and back of the fly tower and lounge area carried the load to columns on either side of the auditorium. The trusses would have been the most efficient system but during erection would have required temporary supports along their span. To eliminate the need for shoring and reduce overall erection time, plate girders were investigated as an alternative. Single-plate girders would have been too heavy and too deep to lift over the existing façade, so instead, each plate girder was built up from three 7-ft-deep full-length sections. Making this substitution allowed steel erection over the theater to proceed without interruption. At the exterior of the building, a vierendeel truss was employed to minimize obstruction of the view from the windows.

### Complex Made Simple

During the building's design, it seemed that nothing was easy. Even something that is usually straightforward—typical floor framing, for instance—required a significant amount of study and investigation; incidentally, the tower has no “typical” floor. As a result of these careful analyses and with the valuable input of all team members, simple, economical—and in many cases elegant—solutions emerged. **MSC**

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### Architectural Topping

Although only 945 ft high at the peak of its curtain walls, it is the Bank of America Tower at One Bryant Park's 300-ft-high architectural spire that makes the building so tall. A latticed tower of 12.75-in.-diameter pipes with a central cylindrical mast, the spire was originally intended to be entirely welded to produce the clean appearance desired by the architect. Early in the construction phase of the building, however, concerns were raised about performing field welding 1,200 ft above street level as well as the erectability of some of the larger components. To allay the concerns of the owner and construction manager, bolted connections were developed. To address the architect's aesthetics concerns, the connections were designed to be as simple and minimal as possible.

Because the spire is composed primarily of steel pipes, bolted flange connections were the first to be considered.

An early proposal by the steel contractor located this type of splice connection a few feet above each of the horizontal levels of the spire, spaced vertically at 25 ft. Although relatively straightforward from a fabrication point of view, the effect was not visually appealing. The architect preferred a more symmetrical approach, with the splices located at the centerline of the horizontal members. Of course, this meant splitting the horizontal members in two. Clearly, a pipe section would not be practical in this case, so a pair of built-up tee sections, with their flanges back-to-back, were substituted. At each joint, one tee is connected to the lower section of the spire and the other to the upper section; the tee flanges were bolted to each other in the field. This detailing had the added advantage of allowing completely braced and stable sections of the spire to be assembled in a staging area before being lifted into their final position.

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