High-Tech High Rise

By William D. Bast, S.E., P.E., Jeffrey D. Brink, P.E., Kevin Doetzl, S.E., P.E., and Steven P. Shanks, E.I.T.

Steel was the solution for the challenging geometry of Chicago's first high-rise technology center.

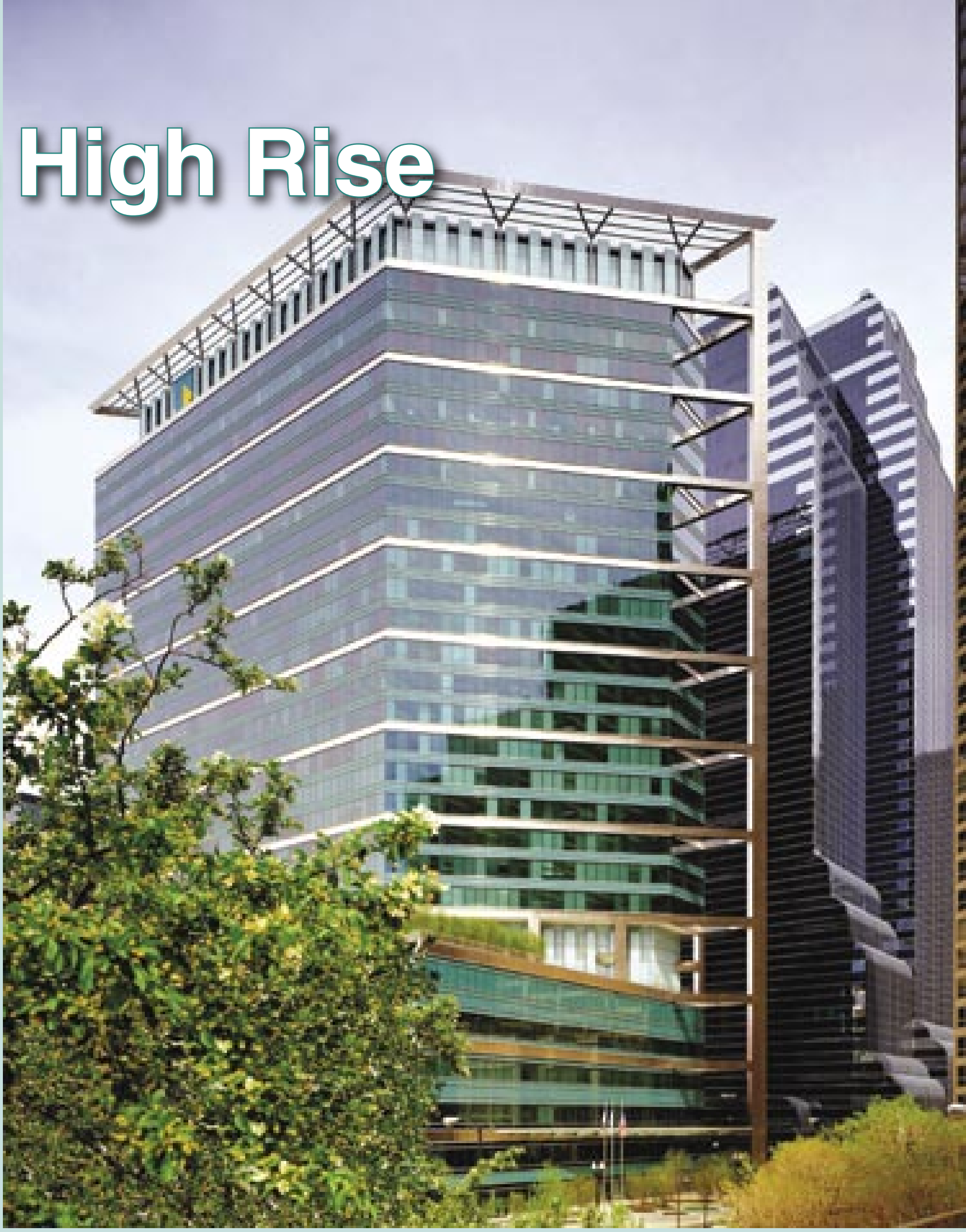


Photo courtesy of Jon Miller/Hedrich Blessing.

Completed March 2004, ABN AMRO Plaza houses over 4,000 employees in Chicago's first high-rise building designated as a technology center. Constructed to consolidate operations for Netherlands-based ABN AMRO, parent company of Chicago-based LaSalle Bank, the phased project will eventually include a second tower.

Phase I involved the design and construction of a 31-story high-rise with approximately 1.3 million sq. ft of office and light-industrial space. The estimated $400 million building includes redundant electrical supplies, on-site emergency generators with uninterruptible power supply (UPS) systems, a raised floor air and cable distribution system, a data processing center, state-of-the-art security systems, a roof garden above the six-story podium, and training and conference center space. There are 375 below-grade parking spaces over two basement levels.

Core Considerations

The building features a composite steel and concrete structure. Lateral force resistance is provided by a concrete core wall with link beams. The configuration of the core was dictated by space planning and site restrictions. The nominally 30′-wide core reduces in length at selected levels, coordinating with elevator requirements. The challenge was to develop an efficient structural system that satisfied all serviceability and strength requirements within a relatively inefficient core geometry.

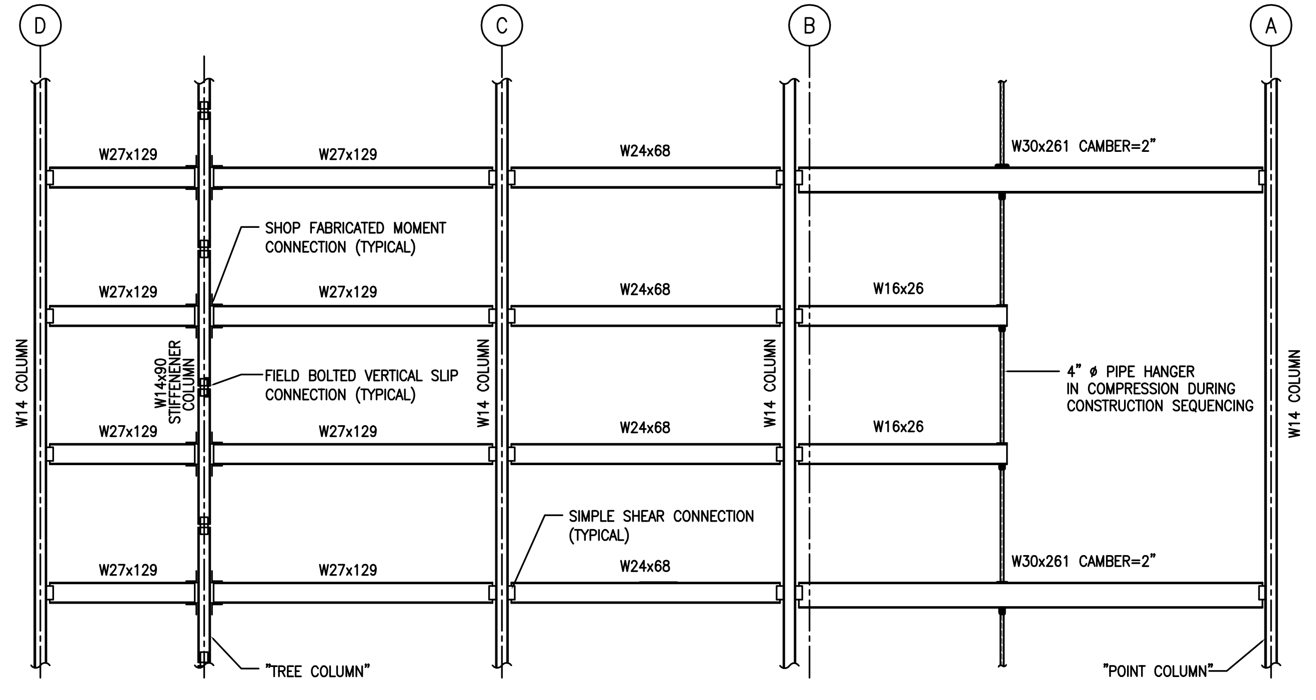
Thornton-Tomasetti Group (TTG) engineers developed ETABS© models of the lateral system with varying distributions of stiffness to define upper and lower bounds of movement. Given the limited width available within the building, the location of the elevator setbacks was adjusted to provide the required capacity to resist loads on the broad face of the building. Wall thicknesses were then adjusted to reach the desired drift targets for each model.

The first mode of vibration was predominately rotational, followed by weak and strong axis translational modes, respectively. This occurred primarily because of the relatively small 30′ by 150′ concrete core within a typical floor footprint of 120′ by 300′, and because of offsets of up to 10′ between the centers of mass and rigidity of the building. Wind tunnel testing using force-balance techniques conducted by wind engineering and microclimate consulting firm Rowan Williams Davies & Irwin, Inc. (RWDI) confirmed that an $H/400$ deflection limitation with reduced wind loads (compared to code-prescribed loads), obtained from the wind tunnel testing, exhibited acceptable dynamic behavior.

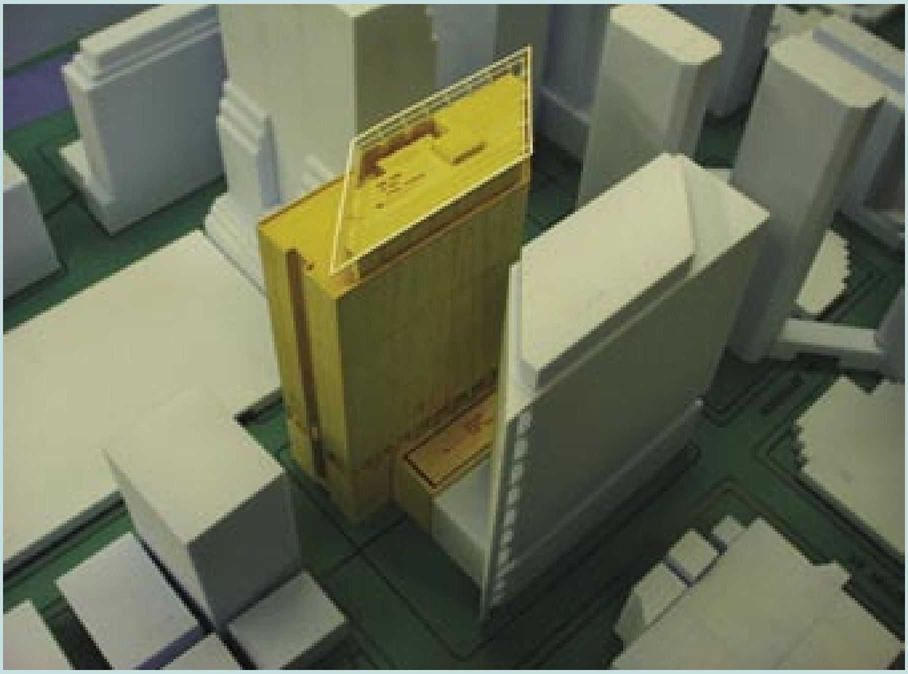
The final design consisted of "flange" walls 20″ thick from the base through level seven, 17″ thick to level 17, and 14″ thick to the roof. The "web" walls are a constant thickness of 14″ in order to comply with elevator equipment requirements.

Structural Steel Framing

A composite steel structural system was selected for the typical floor framing



An elevation view of the diagonal wall on the southwest side of the building shows several of the building's features, including the "point column," the "tree column," and the hanger/compression struts.



The model used in the wind tunnel study shows both phases of the project. The present tower is shown in yellow, while the future tower is white.

above the ground level. Ease of erection, availability of material, and flexibility in design made composite steel the preferred choice for this office and technology center application.

Typical composite steel beams span 45′ from the concrete core to the exterior wall of the building, creating a large column-free space around the perimeter of each floor. This afforded great flexibility in interior planning and allowed for a wide range of program uses, such as data centers, office space, and a cafeteria, to occupy the majority of the floor plate without interruption by the structure. The concrete core provides an ideal location for the building's service functions, such as rest rooms, elevators, and mechanical and electrical chases.

The typical 30′-0″ by 45′-0″ bay was divided into three deck spans using W18 beams spaced at 10′-0″ on center. At the core, the W18 beams are supported by simple shear connections to embed plates cast into the concrete of the core wall. At the exterior, W21 spandrel girders span the 30′ between columns and support the W18s. The composite slab—3″ painted composite metal deck with an additional 2½″ of lightweight concrete—was selected to span the 10′ between beams.

Planning for Tolerances

To facilitate successful interface between different tolerance requirements for the structural steel floor framing and the reinforced concrete core, TTG set forth three specific requirements.

First, special core wall construction tolerances were specified on the construction documents, which addressed core wall thicknesses, variations from plumb, and variations in the location of embedded plates, sleeve sizes and locations, and door and other blockouts. For example, over the entire height of the building the core wall variation in plumb was specified to be no more than 1½″.

Second, an entire page in the construction documents was devoted to erection elevations for compensation of shortening in order to achieve a certain degree of floor levelness in consideration of elastic, creep, and shrinkage shortening as applicable to the concrete core and structural steel column elements.

Finally, the steel floor framing connection to the concrete wall was established by using oversized embedded steel plates with shear studs and bar anchors. A steel shear plate was field-welded to the embedded plate, with horizontal long slotted holes and high-strength snug-tight bolts for the plate-to-beam connection.

Serviceability

Consideration of floor vibration effects was addressed by using AISC's *Design Guide 11: Floor Vibrations Due to Human Activity.* This method permitted computation of the expected accelerations for the combined girder/core wall and beam system under walking excitation conditions. Judgment was used in considering the fixity under service conditions for the beam-to-core wall connection. A continuity factor greater than 1.0 was used to account for the fixity of this condition. Also considered were the expected effects of some amount of damping from the raised floor system in the use of the damping ratio factor, beta. The final computations predicted acceleration limits below the 0.5% of gravity set forth for office buildings in the design guide.

Trapezoidal Footprint

Architectural creativity was facilitated by flexibility afforded by the steel framing, which was exposed at several locations. The most dramatic architectural feature is the trapezoidal shape of the building's footprint. Little modification to the standard bay was required to accommodate this geometry. Near the southeastern corner of the building, the floor slab is truncated 30′ from the point of the trapezoid. However, the column spacing continues beyond the envelope of the building, where a single column at the point of the trapezoid rises uninterrupted for the entire height of the building. Standing alone, this stainless steel-clad point column, braced at every third story, creates the defining aesthetic of the building.

The remaining columns in the diagonal wall of the trapezoidal shape maintain the spacing of the 30′-0″ typical bay. A particular structural challenge was posed by the design team's preference to avoid placing an off-grid column at the corner of the diagonal wall where the floor slab is truncated. To support the floor framing at this corner, a three-story compression/tension strut was created within the structure of the diagonal wall. This system incorporates the girders that brace the point column at every third story. From these girders, a series of hangers extends to support the corner of the building at the two floors below. For construction, however, general contractor Turner Construction suggested that TTG design the strut as a compression member to facilitate steel erection in sequence.

Further down on the diagonal wall, TTG introduced a non-load bearing vertical "tree" column that was moment connected to the girders to develop bending resistance and thereby reduce deflections in the spandrel element. This combination of struts/hangers and deflection controls within this system was an elegant solution to the problem of supporting the floor at the truncated corner without the need for a column transfer or an ill-placed column at the lobby and parking levels.

Roof-level Steel Trellis

Another defining architectural feature is the roof-level steel trellis, which overhangs the footprint of the building like a cornice. It highlights the building's trapezoidal shape, particularly at the southeast corner where the trellis is supported by the point column. Constructed from exposed HSS, the trellis is formed by a series of horizontal members running parallel to the roof line, which encircle the top level of the structure like a halo.

HSS columns at the mechanical penthouse rise above the roof and branch off to create "Y" columns, which cantilever out from the face of the building at 45° angles and support the horizontal tubes of the trellis. The uppermost horizontal member in the trellis is clad in stainless steel, similar to the cladding of the point column, and tops out this unique architectural feature. An intermediate coat of epoxy paint and a finish coat of acrylic polyurethane enamel was used for the remainder of the exposed HSS.

The exposed structural steel aesthetic also influences many secondary architectural features in the three-story interior lobby. A hanging pedestrian bridge, constructed of custom-fabricated exposed HSS and steel knife-plate members, links the mezzanine level on either side of the lobby. The bridge is suspended by a 1″ diameter hanger rod hung from the fourth floor framing, which are staggered on either side of the bridge at approximately 21′ on center. To meet Chicago's requirements for a minimum one-hour fire rating, the reinforced concrete and structural steel bridge uses intumescent paint and an underside sprinkler system.

At the lobby's exterior, exposed steel and glass canopies employ knife plate details similar to those used in the pedestrian bridge.

Curtain Wall Considerations

Echoing the motif of expressed structural steel, the curtain wall features stainless steel spandrel panels at every third floor. In the floors between, insulated vision glass is separated by spandrel panels of fritted glass that are tinted green—a reference to ABN AMRO's corporate color. The combination of stainless steel, green glass, and vision glass makes a striking visual statement.

The curtain wall system is supported at each floor by embedded steel plates cast into the top side of the concrete surface of the composite slab floor system. Incorporating these plates not only allowed flexibility and tolerance in the curtain wall's construction, but also ensured that no torsional moments would be applied to the relatively small steel spandrel girder.

Gravity loads for each story of curtain wall are supported by simple angle connections welded to the embedded plates. To allow for movement, the gravity connections occur at the floor above (at the top of each curtain wall segment), with vertical slip connections at the floor below. Wind loads are laterally resisted at each story by the top side connection at both the floor above and below. The use of embedded plates was simplified by the fact that the raised floor system easily hides the connections. The system was simple to design and detail, and proved to be quick and efficient to install in the field.

Coordination

Construction proceeded smoothly due to close coordination of the design team and general contractor. A key tool that assisted communication was Citadon, an Internet-based system for processing project correspondence, including RFIs, field sketches, and submittals, which greatly reduced transit time for documents.

To maintain the fast-paced project schedule, two tower cranes were used: one located near the north end within the footprint of the building and another at the south end adjacent to the exterior diagonal wall. Construction of the concrete core wall preceded erection of the steel superstructure by approximately four to 10 floors. The core wall was placed in one-floor-high lifts by means of a walking formwork system, which was supported on the core itself. This system set the pace for the building's construction.

Logistically, the vacant lot for the project's future second tower afforded a large staging ground. Trailers housing the construction offices, access to and from the site, and an area for the steel shakeout were all located outside the footprint of the building.

From the initial schematic design to final placement of ABN AMRO's corporate logo atop the building, the project combined efficiency, creativity, and prudent decision-making to create a building that is as architecturally intriguing as it is economical. ★

William Bast is a senior vice president of Thornton-Tomasetti Group. Kevin Doetzl is an associate of Thornton-Tomasetti Group. Steven Shanks and Jeffrey Brink were members of the TTG engineering team during construction of the project.

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