Brace Yourself!

Steel framing provides flexible layouts in this recent mid-rise residential condominium project in Chicago. The building facade features exposed steel elements that mirror the structure behind the sleek steel and glass curtain wall.

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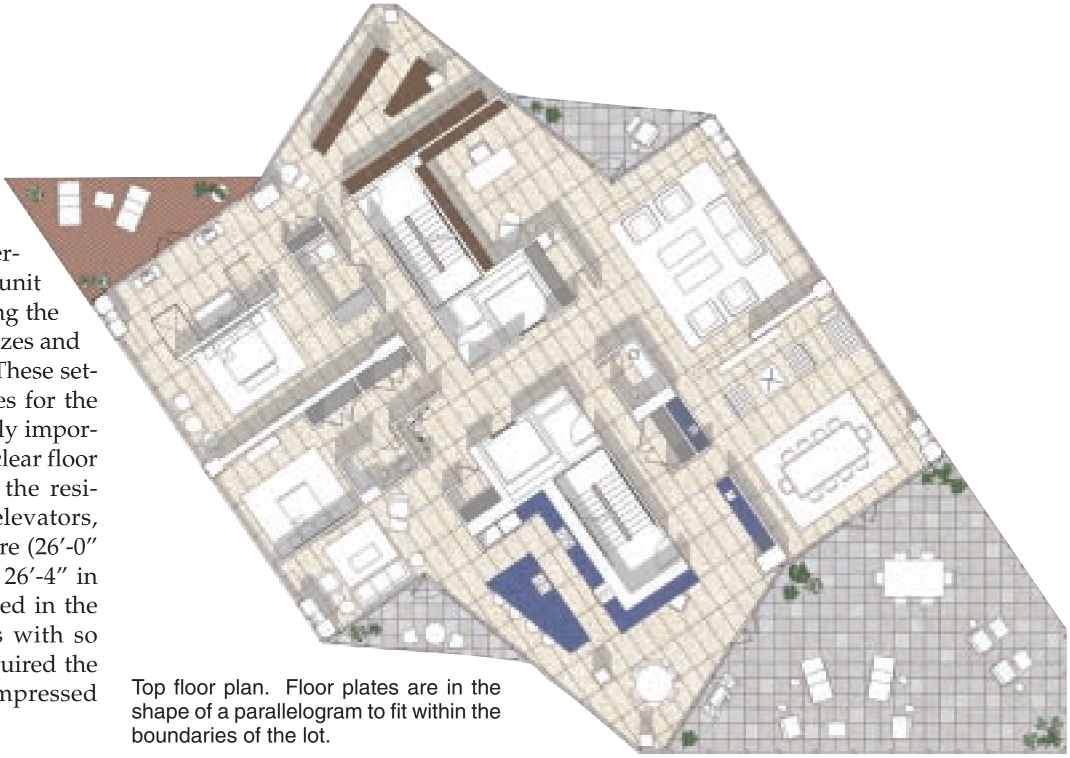
Erie on the Park is one of newest mid-rise residential condominium buildings in Chicago's popular River North neighborhood, an area populated with mid-rise condominium buildings and lofts converted from warehouses. Located at 510 W. Erie Street, the 25-story steel-and-glass-clad structure presents a unique façade among its concrete and masonry neighbors.

The building site is in the shape of a parallelogram, with existing neighboring buildings built up to the property line on the east and west sides, a major street on the south side and an alley to the north. The dimensions of the site, and consequently the largest floor plates, are approximately 90′ between the existing buildings and 120′ between the street and the alley. The building consists of three concrete stories at the base topped by 22 stories framed in wide-flange shapes with steel joist floors. The typical floor-to-floor height is 10′-8″.

The lateral system is comprised of concrete shear walls at the base and three-story steel "mega-braces" in the steel stories. The foundation system consists of grade beams and caissons. Unlike typical mid-rise construction, there is no basement. Consequently, a structural slab was designed at the base of the building to act as a rigid diaphragm and transmit the base shear to all of the caissons.

PRIMARY OBJECTIVES

The primary objective of the building program was to optimize the space within the tight confines of the site. As a result, the 275′ high condominium building stretches to the maximum height allowed for the area. The maximum square footage allowed for the building's footprint is 266,000 sq. ft. and is accomplished by extending the floor plates to within inches of the lot line on three sides. The owner wanted the building to encompass a range of floor plans and unit sizes, including large penthouse apartments with terraces. Twenty-three different unit layouts were designed creating the need for varying floor plate sizes and setbacks at the upper levels. These setbacks create space for terraces for the upper level residences. Equally important to the owner was a 9′-0″ clear floor to ceiling height. Access to the residences is provided by two elevators, located in a small elevator core (26′-0″ in the north-south direction, 26′-4″ in the east-west direction) located in the center of the floor plate. As with so many projects, the owner required the design solution meet a compressed construction schedule.



Top floor plan. Floor plates are in the shape of a parallelogram to fit within the boundaries of the lot.

CHOOSING STEEL

When schematic studies began, the design team believed the owner's criteria lent itself to a concrete building design. The typical bay size was 26′ by 26′, making flat plate construction an option, provided that no interior beams were necessary. This solved the gravity system; however, the lateral system was more of a challenge. Due to the length and the geometry of the floor plate and the location of the small, square core, the analysis of wind pressures showed the inadequacy of a shear wall system, as it did not provide sufficient torsional resistance, and moment frames would have been required at the building perimeter.

Next, the design team studied steel schemes. Two proposals were presented to the owner: (1) composite rolled shape members and (2) rolled shape members in the east- west direction supporting steel joists in the perpendicular direction. Composite steel rolled shapes and metal deck were not shallow enough to provide the 9′ clear finished floor to ceiling heights desired by the owner and the architect. However, closely spaced joists supported on rolled shape girders resulted in 9′ ceiling heights, while also allowing longer spans between columns than could have been achieved with concrete.

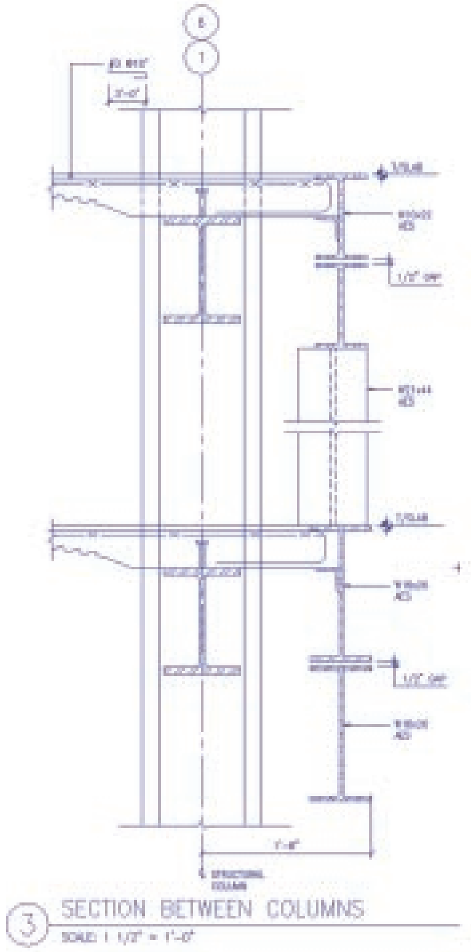
Having concluded that the gravity system was reasonable, the next step was to tackle the lateral system. It was clear the lateral system could not work as a brace system in only the core for the same reasons the shear wall system failed to perform. However, collaboration with the architects helped Thornton-Tomasetti conceive of a very efficient use of steel bracing by using two 90′ dividing walls that spanned across the floor plate in the east-west direction. It was immediately apparent that within these walls was the perfect place for three story high mega-braces.

To solve the lateral wind pressures in the north-south direction, the architect agreed to move the mega braces to the exterior of the building, and the owner was pleased by the notion of expressing a structural steel brace as part of the exterior cladding. The braces in the north-south direction are also three-story, but unlike those in the dividing wall, only occupy a 52′ width.

The final decision to build the structure as a steel building was made by the owner/contractor for this development. The owner strongly felt that changing concrete formwork from floor to floor in 25-story building, particularly considering the non-uniform floor plates of the upper levels, would cause unaffordable delays.

The owner liked the expression of steel on the exterior and truly believed that at the scheduled time for construction, steel was a faster end date than concrete. By the selection of materials, the engineer found opportunities in collaboration with the architect to use

West elevation of 510 W. Erie. The steel and glass curtain wall stands out against the surrounding masonry buildings.



Section showing both structural and architecturally exposed steel. The 1'-8" separation was held constant around the building's perimeter.

dividing walls to camouflage the steel bracing on the building's interior and expose the bracing at the exterior, solving any torsional issues.

In addition to the superstructure limitations, the owner required that at least one garage space be provided per unit, since parking is at a premium in downtown Chicago. Parking was accommodated in the concrete base of the building and in the first two levels of steel framing, which are framed with rolled shapes and 3″ composite deck with 4½″ of normal weight concrete topping. Four levels of a six story precast concrete parking garage adjacent to the building connect to the parking levels of the main building.

JOISTS AND SHAPES

As previously described, the typical floor plate of the building is in the shape of a parallelogram. The gravity system consists of W12 beams and girders and 14K joists. The typical bay length is 26′ and the joists are spaced at about 2′-7″ on center. Half-inch conform deck with 2″ of normal weight concrete is used to create a total floor sandwich thickness of 17″. The use of joists allows the sprinkler piping and mechanical ducts to run through the framework and raises the soffit to within an inch of the bottom of the joists. As the girders supporting the joists are depressed 2½″, it was possible to make them composite girders, which helped to limit the depth of the members to 12″. A 2″ composite deck with 3″ normal weight concrete topping is used in the core, where joists are omitted from the framing. At the mechanical penthouse level, 18K joists spanning 26′ at 2′-7″ on center with rolled shape girders varying from 16 to 24″ are used due to the heavier loads and snowdrifts. The floor deck at the mechanical penthouse level is a 2″ metal deck with 2½″ normal weight concrete topping. The roof consists of W12 rolled shapes and 3″ roof deck. The columns are W14s, and the typical floor-to-floor height is 10′-8″. RAM Structural System was used to model the gravity system. Joist floor vibrations were checked using Steel Joist Institute's Steel joist vibration program.

Joists and rolled shapes used in the typical floor framing made the structure very light, which was beneficial in the column design but provided an obstacle in the column base plate design. Since the tower was very tall but light, large tensile forces developed in two of the columns at the base of the steel framing due to overturning moment. The tension was resisted with large tensile base plates anchored into the concrete shear walls. Another obstacle was encountered in the construction of the building due to the light joist construction. In typical steel construction, the steel for the floor level to be constructed is picked and laid on the floor immediately below. However, with the steel joists and half-inch conform deck, the floor system was not strong enough to hold the weight of the steel for the next floor. Although each steel pick with the crane came from the ground, resulting in a slightly longer than anticipated time to place the steel, this did not seem to impede the speed of erection. The building was constructed at an average rate of one floor per week, including the architectural steel cladding.

LATERAL SYSTEM

The lateral system comprises three story high chevron mega-braced frames. Each chevron consists of a 52′ spandrel beam at the base, two 42′ diagonals and a 33′ column bisecting the chevron. Four chevrons form a rectangular box at the center of the building, with two legs of the box extending in opposite directions at the exterior of the building. There are seven three-story high mega-frames and one two-story mega-frame for a total of eight chevrons stacked vertically. By using the steel mega-braces and pushing two of the braces to the outer edges of the building, both torsional accelerations and lateral drift are well under the acceptable limits. Eliminating the need for a concrete core, the architects gained more flexibility in laying out the units. ETABS software was used to model the lateral system. Due to the irregular shape of the building, the city of Chicago required that a wind tunnel test be conducted. Wind pressures and building accelerations were determined by Rowan, Williams, Davies & Irwin, Inc. from Ontario, Canada. No unusual wind pressures were found, and torsional accelerations were within acceptable limits.

EXPOSED STEEL

The 510 W. Erie building is clad in glass and architecturally exposed steel. The architecturally exposed steel mimics the braces on two of the building's faces. The exposed steel reveals components of the buildings structure while hiding the fireproofing required for the structural steel. The architecturally expressed chevrons differ from the structural chevrons in beam size and in fabrication. The cladding chevrons are comprised of W10 and W16 spandrels with W12 columns and W21 diagonals. The structural chevrons have W12 spandrels, W14 columns, and W8 and W10 diagonals. To meet an AESS Specification for fabrication tolerances Zalk Josephs, the fabricator, built a jig to assemble the architectural chevrons in their shop. Since they were to be used as cladding, the frames were weather welded and shipped as modular units to the site, and the windows were fitted within these frames. The structural mega-braces were erected in a conventional manner at the site. Bolted connections were used for the structural braces to save time and cost. Spandrels are wrapped in architecturally exposed W21s to mask the interior floor system creating a ribbon of steel around the building at each level. All of the architecturally exposed steel is painted with white TNEMEC paint system. The overall steel tonnage for the building was approximately 2,005 tons, including the architectural steel, and the total cost of the project was roughly $25 million.

XSTEEL

At the early stages of design, Thornton-Tomasetti suggested to the owner that a steel drafting/fabrication program might be a useful tool to reduce time in creating shop drawings. The premise was that since steel sizes are drawn by design engineers first in 3-D modeling programs used for analysis (i.e. ETABS, RAM Structural System), why not use a program that allows the geometry and the members to be exported straight from the analysis and into fabrication. This process would save time and reduce potential errors when transferring information from analysis programs translated into the 2-D in AutoCAD environment. Also, since the building is three dimensional in reality, a 3-D modeling tool could be useful to spot problem areas or difficult connections before being sent to the fabricator and would eliminate the need for steel shop drawings. In an attempt to accelerate the steel production, a 3-D model of the building in Tekla Corporation's Xsteel was created, excluding the bottom three concrete stories. Thornton-Tomasetti Engineers created the Xsteel model because of the difficult geometry involved in the building because it made sense for the engineers already familiar with the building to construct the model. The building is clad in architectural steel, and the program allowed Thornton-Tomasetti to model the architecturally exposed structural steel along with the structural steel to see how the two looked together. It was very important to the owner that the architectural steel conceal the gusset connections between the braces, columns and beams.

The Xsteel program was used by Dowco, the project's steel detailer, to detail the steel connections of the building. The computer program created a 3-D model that included an extruded image of each piece of steel. The detailers used the model in Xsteel to graphically add their connections. The 3-D model was then be sent to the steel fabricator, who fabricated the steel by reading the information directly from the model, eliminating the need for steel shop drawings. Additionally, the architects used the model to see how the structure fit within the architecture.

Overall, using Xsteel for the first time in Thornton-Tomasetti's office was a positive experience in spite of some challenges along the way. The architectural design was not finalized at the time the model was created, so subsequent changes to the architecture (such as the core dimensions) had large impacts on the model and were time-consuming to remedy. Using Xsteel as a design tool has the potential to help overall discipline coordination on complicated projects and is clearly the wave of the future.

The use of steel both structurally and architecturally allowed the design team of Erie on the Park to create a distinctive building. While steel joists and rolled shapes are not typical in residential mid-rise construction, this combination of materials proved to be an economical and efficient way to frame the structure. It gave the developer and the design team the opportunity to achieve an aesthetic structure, unlike any other that could have been created with other structural materials.

Joseph Burns, P.E., S.E., A.I.A., served as the Principal in charge of the 510 W. Erie project. Carol Post P.E., S.E., is a Senior Associate, and Garret Browne S.E. is an Associate; both served as Project Managers. Suzanne Provanzana is a Senior Engineer and design team member. All are with Thornton-Tomasetti Engineers in Chicago, IL.

3-D rendering from Xsteel showing a portion of floor framing and structural bracing.

3-D rendering from Xsteel showing bracing.

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Smithfield Properties, Chicago, IL

STRUCTURAL ENGINEER
Thornton-Tomasetti Engineers, Chicago, IL

ARCHITECT
Lucien Lagrange Architects, Chicago, IL

STEEL FABRICATOR
Zalk Josephs Fabricators, Stoughton, WI (AISC member)

JOIST FABRICATOR
Canam Steel Corporation, Washington, MO (AISC member)

STEEL ERECTOR
Area Erectors, Rockford, IL (NEA member)

STEEL DETAILER
Dowco Consultants, Ltd., Vancouver, BC, Canada (NISD member)

GENERAL CONTRACTOR
Wooten Construction, Ltd., Chicago, IL

SOFTWARE
Xsteel, RAM Structural System, ETABS