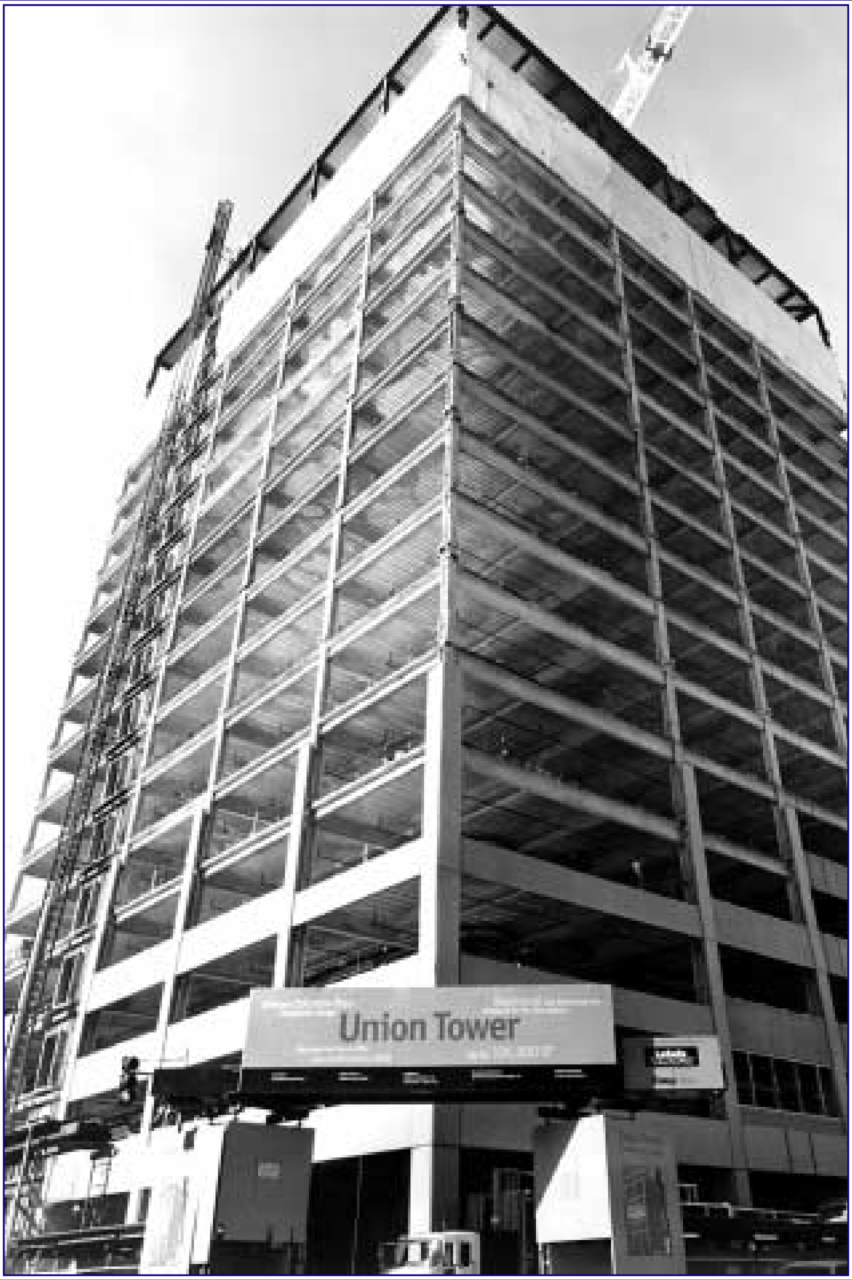
Column-Free Office Space Rises In Chicago's Loop

30'x45' bay provides maximum tenant flexibility and increases leasing marketability



By David E. Eckmann AIA, S.E. P.E.

SURGING DEMANDS FOR RENTABLE OFFICE SPACE IN CHICAGO has created a need for more tall buildings in Chicago's downtown Loop area. Though many tall buildings have been proposed, the first speculative office building to get out of the ground since the late 1980s is Union Tower.

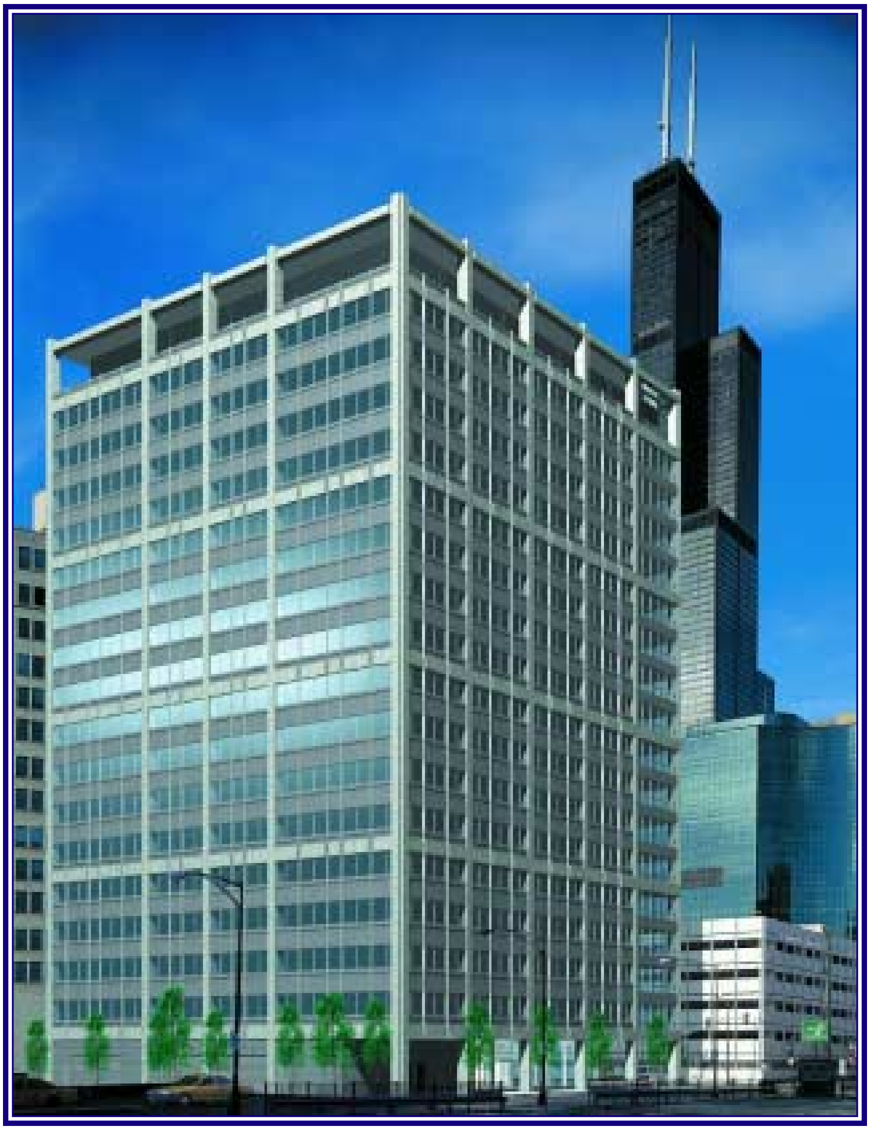
Union Tower, an 18-story state-of-the-art office tower located in the desirable West Loop area, is a 330,000 square foot speculative office building. The office space is comprised of 21,000 square foot floor plates designed to accommodate cabling, mechanical, and open floor plan needs of the 21st century. Located a block from the historic Union Station train station, the 250' tall Union Tower benefits from access to two train stations, the "el" and ample adjacent parking.

The design of Union Tower is intended to maximize the tenant's flexibility - maximizing usable floor space, while minimizing circulation space. The developer, Development Resources, LLC, also had an aggressive construction schedule, requiring occupancy in 1999. OWP&P Architects, an architectural engineering firm located in Chicago, Illinois was retained to design Union Tower on a fast-track schedule. OWP&P worked with Brininstool & Lynch, the lobby and common tenant space designer, to optimize the building's marketability while abiding by budgetary constraints and zoning requirements.

Upon review of the client's request for maximum tenant flexibility, OWP&P suggested using large bay sizes, offering potential tenants the ultimate in tenant flexibility—a column-free space. The type of building, the requirement for flexible use, and the required speed of construction made steel the obvious structural material of choice..

Using a 30'x45' bay, the developer could obtain a column-free floor plan with steel girders that span from columns at the exterior wall to a vertical circulation core in the center of the building. Other benefits resulted from the column free space—more rentable square footage, uninterrupted executive parking at the first floor, as well as more flexible use for the first floor lobby and retail space.

The building, currently under construction, is evolving into a new glass and precast landmark in Chicago's West Loop.



Union Tower features a 30'x45' bay, resulting in column-free space, more rentable square footage, uninterrupted executive parking at the first floor and more flexible use for the first floor lobby and retail space.

FOUNDATIONS & TOWER CRANE

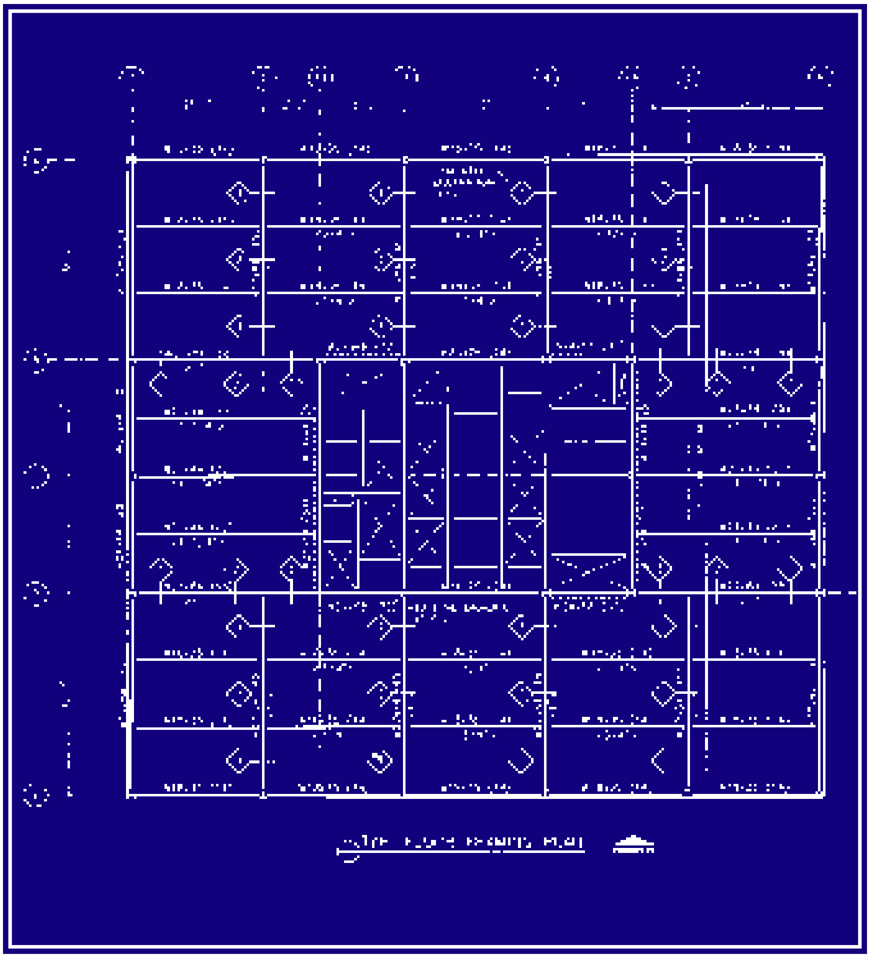
The foundation for the building is a series of belled drilled piers that extend 75' below grade to a hard sandy strata above the hardpan. Grade beams span between the drilled piers to support the weight of precast concrete walls and steel columns that must be located within inches of the property lines.

The foundation system also needed to support a tower crane near the center of the building. The tower crane was necessary to erect the steel structure, the precast cladding, and other heavy materials. The crane had to be located within the building extents, because there was no available space on the small city lot. The tower crane cantilevered from a foundation platform and extended above the top of the structure. The crane was raised in two lifts, first to the ninth floor, and then when the structure was erected to that level, the crane was raised to the top of the building.

SUPERSTRUCTURE—BAY SIZE STUDY

The developer was interested in marketing a 9'-0" ceiling height for each floor of the building. The 30'x45' bay sizes required deeper framing members than a system with smaller bays. At the same time, the premium for increasing the building height was approximately $20,000 per lineal foot. Multiple methods of framing the bays were investigated. Since Power Contracting and Engineering Corp., the general contractor, was involved with the project team from the beginning of the project, they were able to study the cost/benefits of many framing schemes. The contractor was able to analyze, and provide timely answers to the ever elusive questions:

- Is 2" metal deck with more beams less expensive than 3" metal deck with fewer beams?
- Is it better to use a heavier



gage deck and fewer beams, or a lighter gage deck with more beams?

The team decided that maximizing the span capabilities of the metal deck, and erecting as few beams as possible was the most economical solution. Using a 3" galvanized metal deck (18 gage) with 3¼" lightweight concrete topping, it was possible to support the design loads and achieve the required two-hour floor fire rating. To keep the floor-to-floor heights as low as possible, the steel framing was oriented so that secondary composite beams span the short direction into the longer composite girders. The girders were limited to W27's and cambered for the dead load. Penetrations were installed in the girder webs to accommodate the mechanical ductwork. The results are large bays with 9' ceiling heights and only 12'-10" floor-to-floor heights.

This floor system reduced steel tonnage, increased repetition of members, and minimized the number of beams and girders that needed to be "picked" at each level of framing - allowing for quicker erection of the building structure. An increase to the vertical circulation core size prior to issuing the fast-tracked structural drawings created another savings opportunity for the project. The increase in core size reduced the girder spans to 43'. The 2' difference was enough to eliminate a beam per bay and have the metal deck supported at one-third points as opposed to one-quarter points. The elimination of a beam, multiplied by the number of bays, and again by the 18 floors, generated a $70,000 savings to the client.

Lateral System

Several lateral systems for the building were discussed at the beginning of the project. However, there seemed to be only one obvious choice—a braced steel frame. The layout of the core was designed to allow for diagonal members to be located in each direction on all four sides of the core. In fact, the core layout allowed symmetrical bracing on each side of the core. These factors, along with the contractor's insistence that a braced frame could be constructed much more quickly than any type of concrete core, led to the braced frame decision.

The profile of the bracing was a series of single diagonal braces. The diagonal braces were located to allow for door openings through the braced bays. The braces also did not clutter the upper corners of each bay with gusset plates and connections that would prevent distribution of large mechanical ductwork supplied from the core. The overall building drift, as well as the inter-story drift at each level, was limited to h/500. To best utilize column groupings and column splice locations, moment connections were incorporated at the top twelve levels of the building to meet the drift criteria.

Initially, the diagonal members were designed as rectangular HSS sections, taking advantage of their greater weak-axis moment of inertia. However, the contractor advised that for this particular application, HSS sections were approximately 3 times the cost of wide flange sections. Therefore, details were revised, and wide flanges were incorporated as the diagonal bracing members.

Special Design Considerations

Several unique design considerations were addressed on this building that are not typically considered for shorter building types. The first consideration was elastic column shortening. Due to the height of the building, and particularly due to the weight of the precast concrete cladding panels that span 43' between exterior columns, the loads on the W14x500 columns were substantial. It was significant enough that the steel fabricator increased the column lengths by 1/16" per floor. One-sixteenth of an inch may not sound like much, but when it is multiplied by the number of floor, it adds up to almost 1½"of anticipated column shortening—enough to make the difference between the building's cladding fitting and not fitting. As expected, while the steel frame was erected, the floor slabs placed, and the precast panels erected, the building shortened to the correct design elevations.

Two faces of the building are pulled inward 20' at the first floor to create a colonnade at the street level. Therefore, some of the two-story columns below the second floor are not enclosed within the heated building structure. As a result, those columns will be subjected to significant temperature differentials. The thermal stresses in those columns were analyzed, and the columns were designed so that the internal stresses caused by seasonal changes in column length (elongating/shortening), combined with the compressive stresses of the gravity loads above, did not exceed the column capacity.

It was also important to seriously consider floor vibration for this building. Since it is a speculative office building without an identified tenant, it is not clear how this building will be used. Depending on the tenant, the floors may be filled with workstations, or they may be completely open, with virtually no floor damping. The more critical case, the open floor plan, was designed and determined to be within acceptable vibration limits.

The layout of the core was designed to allow for diagonal members to be located in each direction on all four sides of the core.

Learning from the Fabricator/Erector

A post-construction discussion was held with the contractor and erector to determine what things went well on the project, and what can be done to improve the erection of the next project. In general, this project went up extremely quickly, and with few problems. However, a few things were learned:

When column sizes were grouped and column splice locations were determined, it was obvious that the columns could be grouped into either two-story or three-story height segments. To comply with OSHA fall-protection height limits, steel is generally erected in two-story segments. However, fewer column splices and longer column lengths could lead to substantial cost savings. We asked the contractor and steel fabricator about their preference. They said that that the longer columns (and fewer column splices) would be the most economical solution. However, when the longer columns were erected, the erector discovered that it was difficult to erect the building in two story segments, and still keep the building plumb. After the first two floors were in place with the three-story columns, the erector needed to erect another three-story column to complete the second two-story segment of building height. This meant that columns were extending to the sixth floor when the erector was trying to "make" (connect) the steel on the third and fourth floors. To keep columns plumb, the erector didn't feel they could detail (tighten bolts) the steel at the lower levels until the steel was erected to the sixth floor. Obviously, this slowed down the building erection, and complicated the temporary bracing of the steel. The lesson learned on this project is that it may sound more economical to fabricate longer columns, but it would have been far less difficult for the erector to erect the structure with two-story column segments.

The erector appreciated the fabricator's extensive use of bolted details. Virtually all field connections were bolted, even the column splices and diagonal braces. The erector felt this saved them a great amount of time. The erector also enjoyed working with the 3" metal deck. Their opinion was that the deck was stiffer, and therefore, easier to handle and work on. What the erector did not appreciate however, was the slab edge detail at the perimeter of the building. Since the structure was fast-tracked, and the steel was to be fabricated prior to decisions on slab edge locations or precast wall panel supports, a bent plate pour-stop was shop attached to the perimeter members at each floor. The local iron workers union, however, have a safety requirement that no vertical projection from a steel member can be within five-feet of where the iron worker needs to make a connection to that member. What this meant was that the vertical leg of the bent plate needed to be field cut from each beam, and then replaced after the supported member was erected and attached. This was a time consuming process.

In retrospect, the erection of the entire structure went smoothly. Even with a two-month fast-track design period, everyone agreed that the project team worked well together, and that the use of structural steel created a structure that was simple and efficient. The result is a structure that meets the clients needs and was easy to fabricate and erect.

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Project Team

Structural Engineer:
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Architect:
OWP&P Architects

Lobby and Common Tenant Space Designer:
Brininstool & Lynch

Developer:
Development Resources, LLC

General Contractor:
Power Contracting and Engineering Corp.