The first tower to open at the original World Trade Center site, 4WTC maximizes its space and views with creative column construction.

FOUR at the Fore

BY RICHARD B. GARLOCK, P.E.

Joe Woolhead

FOR THE PAST SEVERAL YEARS, the World Trade Center site has been gradually rebuilding, structure by structure.

The fundamental design approach to 4 World Trade Center (4WTC), the first tower to open, was twofold: Create a strong and efficient structure to enable an appropriately quiet and dignified presence, and activate and enlighten the immediate urban environment in a high-profile setting.

Richard B. Garlock (richard.garlock@lera.com) is an associate partner with Leslie E. Robertson Associates.

Bounded by Greenwich, Liberty, Church and Cortlandt Streets, the 72-story, 977-ft-tall, $1.2 billion building has 2.3 million sq. ft of above-grade space, 1.9 million sq. ft of which is office space. Floors 15 through 54 feature a 44,000-sq.-ft typical floor plate in the shape of a parallelogram. Floors 57 to 72 are trapezoidal in shape and open toward the southern tip of Manhattan, triangulating from the lower floors to gently bring focus down to the National September 11 Memorial and Museum.

One of the goals for the building was to maximize office floor views, including keeping corner offices free of columns. The design team responded by creating a framing system with steel perimeter columns, encased in concrete, and core walls located to optimize structural and programmatic efficiency. The lease span distance from core wall to perimeter wall is 45 ft on the west, north and south sides and 35 ft on the east side. The framing system incorporates six column-free building corner cantilevers ranging in length from 20 ft to 45 ft and four 80-ft-long clear spans along each side of the building. This design provides expansive views of the city and allows for six corner offices or corner conference rooms per floor, instead of the more traditional four. The ac-

Photos: Courtesy of LERA

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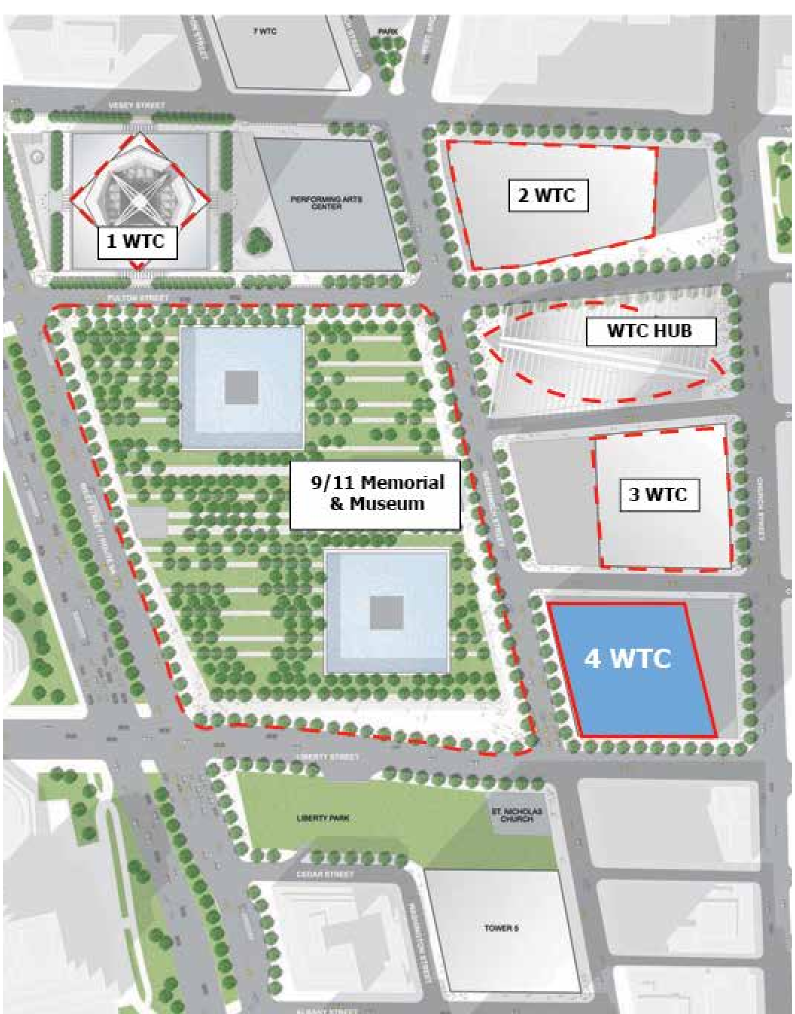
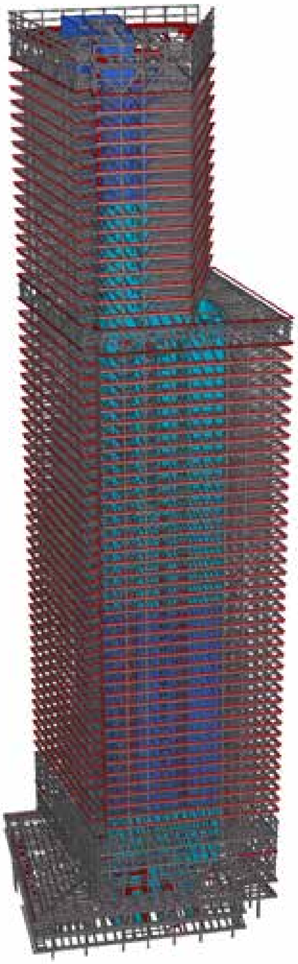
▼ 4WTC's location in relation to the rest of the WTC site.



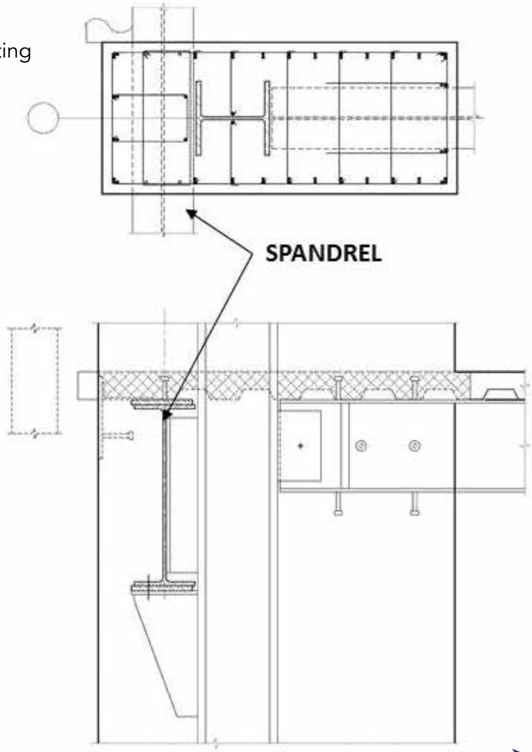
The building sits at the southeast corner of the WTC site.

A 3D structural model of the building.



Full-floor-depth trusses were used at the mechanical levels.

Steel spandrel beams connecting to concrete columns.



The lobby, under construction.

Erection of steel-framed stairs.

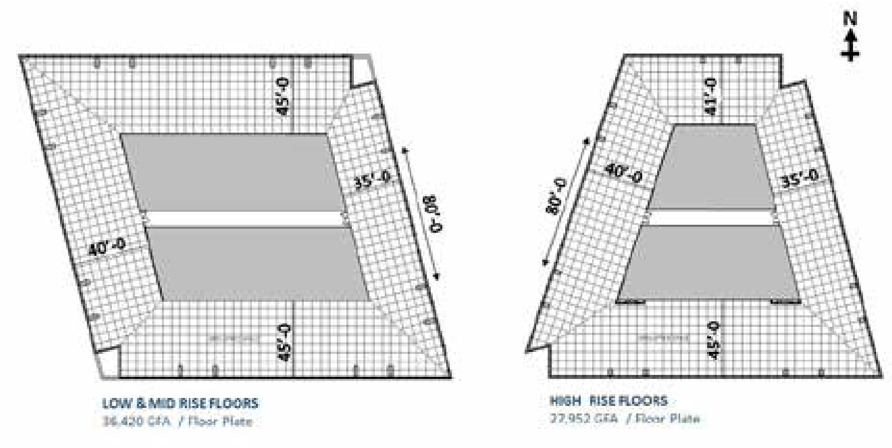
The column-free lobby.

companying arrangement of four columns per side provides the columns with a continuous vertical load path through the rigidly programmed subgrade levels, thus avoiding costly column transfers.

Universal Sequence

The universal sequence for shear wall buildings is to erect the core wall first, but with 4WTC general contractor Tishman deemed that a structural steel frame would rise first and then be encapsulated by reinforced concrete. Structural engineer Leslie E. Robertson Associates (LERA) embraced this approach and recommended encapsulating the perimeter columns.

The use of composite columns at the perimeter allowed for offsetting the spandrel girder from the steel erection column, which provided several efficiencies. First, the spandrel splices were moved away from the columns and towards the point of inflection on the spandrel. This is the location where the moment changes from positive to negative, allowing for partial moment connections rather than the full plastic moment connection normally required in such situations. Second, the splice locations were

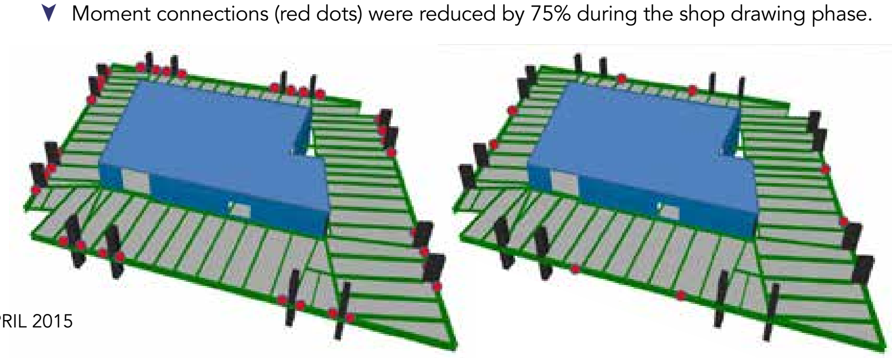


▲ The two different floor layouts: parallelogram and trapezoid.

▼ One of the goals for the building was to maximize office floor views, including keeping corner offices free of columns.

▲ The downtown Manhattan skyline; 1WTC is at center and 4WTC is the tallest building to the right.

▼ Moment connections (red dots) were reduced by 75% during the shop drawing phase.



adjusted to stay within the maximum piece length allowed for trucks in New York City (75 ft), which increased the speed of erection by reducing the number of crane picks per floor. Third, the spandrels were moved close enough to the edge of slab to allow for standard pour stop details to be used throughout the job without the need for expensive and time-consuming strapping or angle outriggers. Lastly, during the shop drawing phase, Tishman coordinated with the subcontractors on the shop addition of curtain wall embeds, pour stops and other erection items on the spandrel to further increase the speed and safety of erection. In the end, these efforts reduced the number of moment connections by 75%.

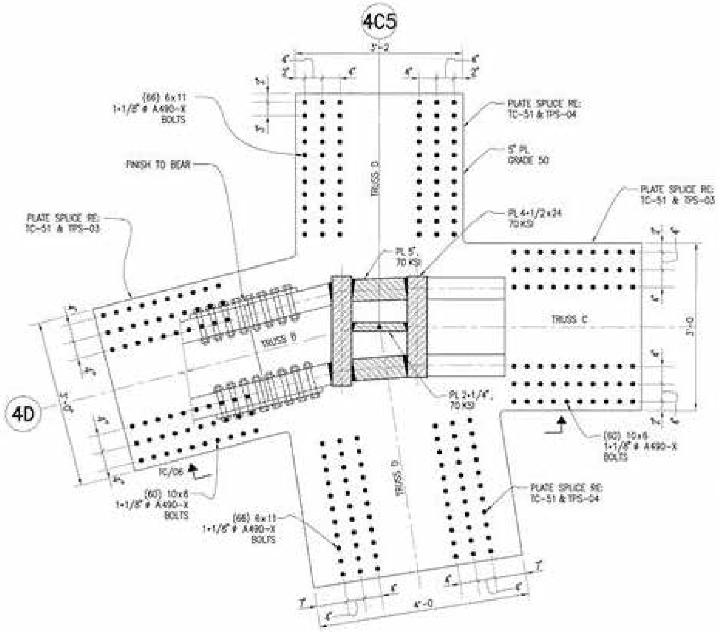
The necessary stiffness required for the long spandrel was accomplished by a nominal W36 rolled steel section with cover plates located at the points of maximum positive and negative bending, and the cover plates were shop welded and stopped short of spandrel field splice locations. These simplifications from more traditional design and construction techniques helped offset the costs of cantilevers and long-span layouts associated with the four columns per side.

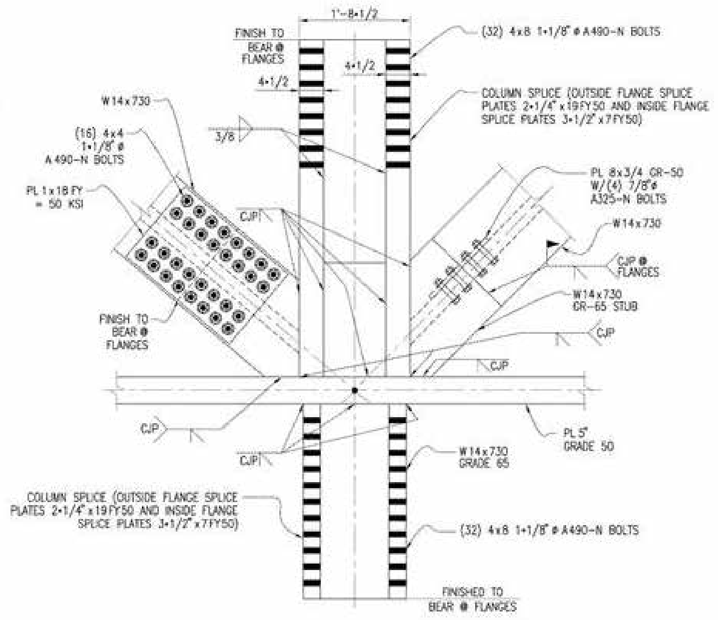
Core Coordination

The building core structure that surrounds the elevators, stairs, bathrooms and mechanical shafts is comprised of two linked concrete tubes that are connected using built-up steel link beams that span over a central corridor and connect to the concrete walls. Typically, link beams attach to an erection column set near the face of the concrete wall, but this condition can require a massive moment connection. With 4WTC, LERA proposed shifting the erection column back from the face of the wall, such that the engagement of the steel link beam to the concrete wall was provided by embedment. The increase in material was offset by the elimination of the steel-to-steel moment connections.

At the building mechanical levels, the increased load requirements determined that full-floor-depth trusses were needed to efficiently manage the 80-ft clear span and 45-ft cantilever. As such, W14 wide-flange sections located at the floors are turned so that flanges are vertical, allowing for direct force transfer through the intersecting flanges and avoiding large gusset plates.

In addition, the project was on a very constrained site, which was accessible only from Church and Liberty Streets. The ground floor was designed to support heavy truck traffic and material storage to address these constraints, and basement





◄ ▼ Sample drawings illustrating the complexity of some of the bolted connections.

construction included a portion of the site to the north to allow for a roadway to be constructed at grade level.

Using approximately 24,000 tons of steel in all, 4WTC became the first tower to open on the original 16-acre World Trade Center site, which is still seeing major construction today. ■

For more on two other Word Trade Center site projects—1WTC and the National September 11 Memorial and Museum—see "Rising to the Top" (02/2014) and "Trident True" (01/2014), both available at www.modernsteel.com.

Owner
Port Authority of New York and New Jersey

Developer
Silverstein Properties

General Contractor
Tishman Construction

Architects
Maki and Associates
Adamson Associates

Structural Engineer
Leslie E. Robertson Associates (LERA)

Steel Team

Fabricators
MRP, LLC, South Plainfield, N.J.
(AISC Member/AISC Certified)
Banker Steel Company, LLC, Lynchburg, Va.,
(AISC Member/AISC Certified)
Littell Steel Co., New Brighton, Pa.
(AISC Member/Certified)
Metro Iron Corp., Amityville, N.Y. (AISC Member)

Detailer
Automated Steel Detailing Associates, Ltd., Toronto
(AISC Member)