One World Trade Center
Structure

A product of both historic loss and future goals for Lower Manhattan, the building's structural steel frame maximizes safety, construction efficiency, and tenant experience.

Editor's note: Because of security requirements for One World Trade Center and surrounding properties, certain information on the grade, size, and type of structural steel has been omitted.

SIMPLY PUT, ONE WORLD TRADE Center's structure consists of a concrete core and a steel perimeter moment frame. But there is nothing simple about the design of this 1,776-foot tall crystalline icon—the most significant of the new construction at the 16-acre World Trade Center site both from a symbolic point of view, and in terms of sheer size.

At its base, the structure's massive 110-by-110-foot concrete core, whose walls are as much as 4 feet thick, is bigger than most towers being built today. By comparison, Rafael Viñoly's recently topped-out 432 Park Avenue, also in Manhattan—which, at 1,396 feet, surpasses One WTC's 1,368-foot-high roofline—can fit inside of it.

Notably, the "tube" design of the original Twin Towers took much of the structural duty away from the buildings' center and placed it with the exterior walls. In One WTC's hybrid structure, both are equally important. "Having a robust core has a lot of value," says Ahmad Rahimian, Director of Building Structures at WSP Group, who worked with the architects at SOM on both One WTC and the previously completed Seven WTC, in addition to several other structures at Ground Zero. "The core brings stiffness and strength, and securely houses all the mechanical distribution, and especially all means of egress—the inadequacies of the Twin Towers' stairs were a problem."

The building's perimeter features a framing system that uses approximately 45,000 tons of high-strength structural steel, used along with the prequalified ductile beam-column connections. At the lower levels, multi-floor "super diagonals" encircle the building like a belt. At the uppermost floors by the mechanical levels, outriggers connect the perimeter columns to the core. The structural system at the perimeter allows for load shedding, or the transfer of loads to other locations. "On a theoretical level, the moment frame creates a rope out of all of the perimeter beams so that if the thing that is supporting that rope goes away—two columns, for example—that rope goes into tension and pulls the forces back to the core, which is where they want to go," explains SOM's Kenneth Lewis.

At One WTC, life safety is paramount. "The engineering of the original Twin Towers was brilliant," Lewis says. "It created robust buildings against forces of wind and earthquake that were incredibly light. However, it did not anticipate what happened to them—I don't think anyone could have." To provide optimum egress and firefighting capacity, the new building features extra-wide pressurized stairs, concrete protection for all sprinklers and emergency

Taken together, the perimeter and core systems make One World Trade Center safer than either system could make it on its own.

Left The tower under construction in 2011 amid massive infrastructure improvements adjacent to the site.
Facing top An aerial view of One WTC and the National September 11 Memorial site.
Facing bottom From left: typical low-, mid-, and high-rise floor plans illustrate the tower's tapering form.

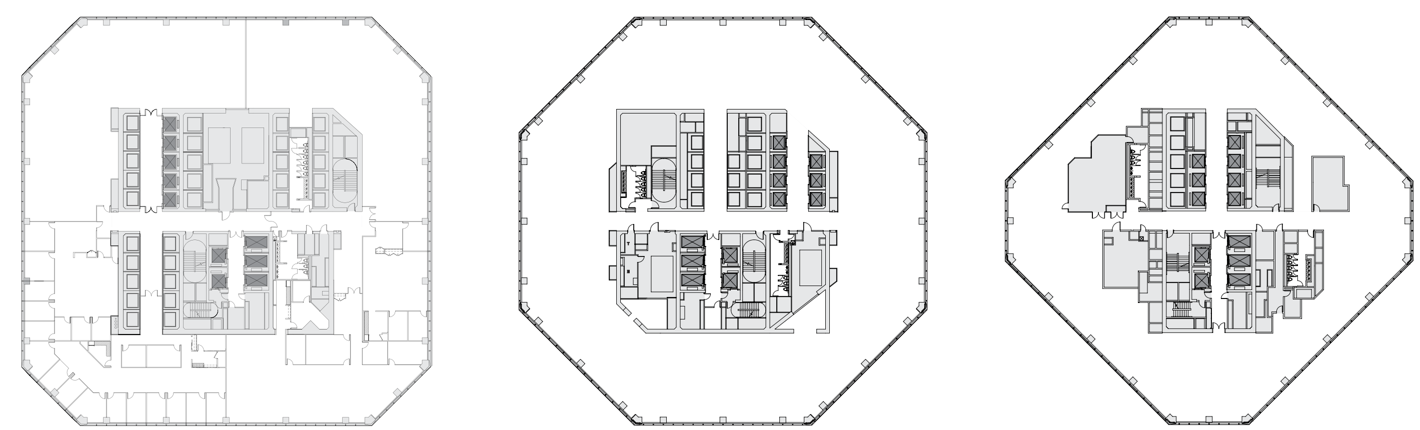
risers, interconnected redundant exits, additional stair exit locations at all adjacent streets, and direct exits to the street from tower stairs. To safeguard the building against the threat of vehicle-delivered explosives, the lower portion of the fortified base features 28-inch-thick concrete walls that shelter the area of the 60-foot-high lobby, though this is an added feature and does not contribute to the tower's structural integrity.

"We really pushed the concrete system to produce a 14,000 psi concrete—that was the first time it was done in New York City," says Rahimian. "One thing we had with this project that was nice is that the Port Authority has its own material testing lab. We worked for months to streamline the mixes."

As the over three million-square-foot building tapers, some of the cells within the core drop off, and its walls decrease in thickness to a minimum of two feet. The narrowing of the building geometry not only accommodates the project's gross area requirement, but also creates an aerodynamic shape that reduces the wind effect on the tower. "There's a practical reason why the top of the building is smaller than the bottom, not just the usual notions of load," explains Lewis. "In the old World Trade Center, you'd get to the higher floors and there were these 70- to 90-foot spans from the core, which was relatively small, to the perimeter, leaving large areas with no daylight. You want the floor area to be smaller so people are closer to the glass."

The floor system within the concrete core is a formed cast-in-place concrete beam and flat slab system, while the floor area outside the core is concrete on composite metal deck supported on steel beams and connected via shear connectors. That column-free floor system spans

This page and opening page: James Ewing/OTTO; facing page top: Iwan Baan; facing page bottom: One World Trade Center



Left Concrete walls more than 2 feet thick shelter the lobby; slots allow daylight into the space.
Above Most members of the tower's design and construction team also worked together on 7 World Trade center, a project that allowed them to test many of the safety strategies they would later use on One WTC.

This spread: James Ewing

between the core and the perimeter—with a maximum span of 47 feet—for construction efficiency and flexibility of tenant use.

At the building's apex, a 441-foot-tall spire—comprising three circular communication platform rings and a needle-like mast—is mounted atop a reinforced concrete mat that is directly supported by the tower's concrete core. According to Rahimian, that mat is strong enough to be the foundation for a 40-story building.

The tower structure extends 70 feet below grade passing through four subterranean levels where some of its structural components required repositioning to clear the PATH commuter train tracks that cross the building at the lowest basement level. The foundation and below-grade structure are founded on Manhattan bedrock using spread and strip footings with bearing capacities of 60 tons per square foot or better. Space constraints due to the proximity of existing train lines—which remained operational throughout construction—required excavating deeper into the rock at select locations in order to achieve a higher bearing capacity of up to 114 tons per square foot. Rock anchors/tie downs extending 80 feet into the rock were installed to resist the overturning effect from extreme wind events.

The symbolic significance of One WTC, rising to a record-breaking height from the ashes of the worst attack on American soil, forced designers to create a heavily reinforced tower with structural and life safety redundancies that exceed existing codes to withstand a potential similar attack while preserving life and the building itself. Taken together, the perimeter and core systems make One WTC safer than either system could make it on its own. ☐

ONE WORLD TRADE CENTER STRUCTURE

Location: **1 World Trade Center, New York, NY**
Architect: **Skidmore, Owings & Merrill LLP**, *New York, NY*
Developer: **1 World Trade Center LLC** (a wholly owned corporation by the Port Authority of New York and New Jersey and the Durst Organization), *New York, NY*
Structural Engineer: **WSP Cantor Seinuk**, *New York, NY*
Mechanical Engineer: **Jaros Baum & Bolles**, *New York, NY*
Spire, Communications Rings, Cable Net Wall Engineer: **Schlaich, Bergermann und Partner Gmbh**, *New York, NY*
Protective Design Engineer: **Weidlinger Associates**, *New York, NY*
Construction Manager: **Tishman Construction Corporation** (An AECOM Company), *New York, NY*
Curtain Wall Commissioning Consultant: **Israel Berger and Associates**, *New York, NY*
Structural Steel Erector: **DCM Erectors Inc.**, *New York, NY*
Architectural and Ornamental Metal Fabricator: **Airflex Corp., Inc.**, *Farmingdale, NY*
Architectural and Ornamental Metal Erector: **Tower Installation**, *New York, NY*
Curtain Wall Fabricator and Erector: **Benson Industries, Inc.**, *New York, NY*
Metal Deck Erector: **DCM Erectors Inc.**, *New York, NY*