One World Trade Center

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WSP was an Award Winner for the One World Trade Center project in the 2013 NCSEA Annual Excellence in Structural Engineering awards program (Category – New Buildings over $100M).

Standing at 1,776 feet (541 m), One WTC is the tallest building in the country. One World Trade Center serves as a national monument as well as a tribute to the "freedoms" emanating from the Declaration of Independence adopted by the United States of America in the year 1776. One WTC rises from a footprint that, at 200 feet by 200 feet, is the same size as those of the original Twin Towers. With its main roof at 1368 feet (417m) above ground, it is designed to reach the same height as the original towers. The addition of a 408 feet (124m) tall spire rising from the main roof completes the tower as it soars to its symbolic height.

One World Trade Center's program includes 3 million square feet of new construction above ground and 500,000 square feet of construction of subterranean levels. The tower consists of 71 levels of office space and eight levels of MEP space. It also includes a 50-foot high lobby, tenant amenity spaces, a two-level observation deck at 1,242 feet (379m) above ground, a "sky" restaurant, parking, retail facilities and access to public transportation networks. It provides a world-class model of life safety and security, energy efficiency and environmental sustainability.

The tower structure is composed of a "hybrid" system combining a robust concrete core with a perimeter ductile steel moment frame. The reinforced concrete core wall system at the center of the tower acts as the main spine of the tower, providing support for gravitational loads as well as resistance to wind and seismic forces. The core is approximately square in footprint with a depth of about 110 feet at the base, large enough to be its own building. It houses mechanical rooms and all means of egress. The core structure is compartmentalized with additional interior shear walls in orthogonal directions.

The core wall thickness varies along the height of the tower. The concrete strength ranges from 14,000 psi to 8,000 psi for foundation, columns and tower core walls, and 8,600 psi to 4,000 psi for slabs. The walls are interconnected over the core access openings using steel link beams embedded into the concrete walls.

The floor system within the concrete core zone is a cast-in-place concrete beam and flat slab system. The floor area outside the core is concrete on composite metal deck supported on steel beams and connected via shear connectors. The column-free floor system spans between the core and the perimeter steel moment frame for construction efficiency and maximum flexibility of tenant use.

The tower height and its slenderness imposed stringent demands on the overall strength and stiffness of the structure. In order to meet those demands in an economical way, high strength concrete of up to 14,000 psi was utilized. Previously, the highest concrete compressive strength used in New York City was 12,000 psi.

The key factor to successful and consistent results in such demanding concrete mixes is the quality control and tight monitoring of its mix components, as well as the use of local materials that are readily available. In addition, the high strength concrete used for the thick concrete walls, defined as mass concrete, required a particular concrete mix to meet the most stringent of demands. This was accomplished by limiting the Portland cement content in the mixes, substituting ice for mix water, and shifting pour schedules to cooler parts of the day. Radio Frequency Identification Devices (RFID) data-loggers were imbedded in the concrete to measure internal concrete temperature, heat of hydration, and maturity of the newly constructed walls. This facilitated early formwork removal, helping to shorten the construction cycle. Excessive heat of hydration during the curing process would expose the concrete to Delayed Ettringite Formation (DEF), and produce thermal cracking, which could result in reduced concrete compressive strength and modulus of elasticity. A concrete mix design test program, in collaboration with the Port Authority Materials Division, Engineer of Record and the concrete producers, was established to create the appropriate mix designs.

Self-Consolidating Concrete (SCC) was used for all concrete requiring strengths greater than 8,000 psi. Due to the high density of reinforcing steel at the base of the building, most of the (SCC) mixes were consolidated with internal and external vibrators.

All mixes contained supplemental cementitious materials, fly ash, and granulated ground blast furnace slag cement and silica fume, as required. The use of these materials substantially contributed to the building's United States Building Council LEED Gold rating.

Due to the height and slenderness of the structure, the mix proportions for the core were designed for creep, shrinkage and Modulus of Elasticity. Paying careful attention to the coarse aggregate, type and volume were critical in order to obtain a Modulus of Elasticity in excess of 7 million pounds per square inch.

As of February 2014, construction of One WTC structure is complete. The One World Trade Center tower incorporates numerous innovative engineering solutions, some of which were presented here. If we could to go back and change anything, it would be the circumstances under which we were invited to engineer this symbolic building. That said, the design and construction of this project is the result of a relentless collaborative effort between numerous design and construction teams over a period of several years, with a resolute focus on the goal of creating an iconic tower reaffirming the preeminence of New York City.▪

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For additional information about this project refer to the article *The Rise of One World Trade Center* which appeared in the November 2012 issue of STRUCTURE® magazine.