Trump International Hotel and Tower, Chicago

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Summary

When completed in 2009, Trump International Hotel and Tower, Chicago will rise to a height of 345.6 m (415.1 m including the spire). Designed by Skidmore, Owings & Merrill LLP (SOM) the 92 story Trump Tower will be the tallest concrete building in the United States, and the tallest building built in North America since the completion of Sears Tower in 1974. New ground is being broken through a series of high performance concrete mixes designed by Prairie Material Sales, Inc. and employed by SOM on the project. It is believed to be the first application of 110 MPa self-consolidating concrete pumped and placed to an elevation up to 200 meters above grade. The paper presents detailed structural engineering aspects of the tower design including a description of the reinforced concrete systems chosen for the project, design for occupant perception of motion due to wind, design challenges and the creative use of high strength concrete for this landmark tower.

1. Structural System Summary

A core and outrigger system provides lateral stability for the Trump Tower. Large outrigger elements at the mechanical levels tie the concrete core to perimeter columns, significantly increasing the building's lateral stiffness as well as its resistance to overturning due to wind.

The core is located at the center of the building and consists of four I-shaped and two C-shaped walls. The webs of these I- and C-sections are oriented in the north-south direction, are 460mm thick, and are 12.5m long. The flanges of the sections are oriented in the east-west direction, are 1.2m thick, and range from 2.7 to 6.7m in length (Figure 2). Flanges of adjacent core walls are connected by 1.2m wide by 0.8m deep reinforced concrete link beams.

The outrigger effect is most pronounced in the shorter direction of the building (north-south), as the width of the lateral system increases from 15 to 43m when the perimeter building columns are engaged. The outriggers are large reinforced concrete wall-beams (1.7m wide and 5.3m deep) that extend from the flanges of the core walls to the exterior columns at three of the double-height mechanical floors in the tower (Levels 28-29, 50-51, and 90-91). These outrigger levels occur just below the building set-back levels, and the outriggers also serve as transfer girders, as the columns are relocated at the façade setbacks. At the lowest building setback (Level 16) transfer girders allow for a column-free space at the ten parking levels. Perimeter belt walls at the roof and the three mechanical levels provide additional torsional stiffness and redundancy, as well as serving to equalize column loads along the perimeter.

Typical residential floors are 230mm thick flat plates spanning up to a maximum of 9.1m without perimeter spandrel elements. This construction minimizes the structural depth of the floor, allowing higher ceiling heights. Tower columns are typically 600 by 1200mm rectangular sections at the top of the building and 1800mm diameter circular sections at the base.

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The tower will be supported by total of 57 rock caissons. The tower columns will be supported by 33 of these rock caissons up to 2.4m in diameter and stabilized by a series of caisson caps and grade beams. A 3m thick concrete mat under the core walls transfers their enormous loads into a grid of the 24 - 3m diameter drilled shaft rock caissons that extend about 25m down where they are socketed 1.8m into solid Chicago limestone bedrock.

2. Design and Utilization of High Performance Self-consolidating Concrete

Because of the magnitude of the applied loads and the scale of the outrigger elements, the structural engineering design for these elements was unique and extremely challenging. Large tie forces are resisted by top and bottom longitudinal reinforcing and vertical ties. The heavy longitudinal reinforcing steel must pass from the thicker outrigger through the thinner core wall web to transfer forces between the columns and core. To reduce congestion, all primary reinforcing bars in the outrigger levels are U.S. Grade 75 (520 N/mm^2 yield strength). Further, in three especially-tight locations, high strength structural steel plates with welded shear studs are used in lieu of reinforcing bars to transfer the necessary forces through the core wall web.

A series of high performance concrete mixtures, specified by SOM and designed by Prairie Material Sales, Inc., are advancing the state-of-the-art. Concrete strengths of 83 MPa (cylinder strength) at 90 days have been specified for all vertical column and wall elements up to Level 51. Local areas in the outrigger zones, however, require 110 MPa (cylinder strength) concrete at 90 days. Because the 110 MPa concrete is located in areas with high reinforcement congestion, self-consolidating concrete (SCC) with a minimum flow spread of 600mm has been specified. Further, to reduce the heat gain in the massive elements, the high performance SCC incorporates slag cement, fly ash, and silica fume as well as portland cement.

The tower structure is designed to limit the perception of motion during wind events by the building occupants to acceptable levels, and for this the stiffness of the concrete is critical. The modulus of elasticity of the high strength concrete was therefore specified to at least achieve the modulus of elasticity values indicated in ACI 318 equations. To meet this as well as the minimum strength requirements, the producer is using dense limestone coarse aggregate, with a topsize aggregate size of 12mm.

In contrast to the stringent minimum strength requirements in ACI 318, concrete modulus of elasticity may be specified on an average basis. Somewhat lower modulus values in local areas are therefore acceptable as long as the average value remains as specified. Further, such modulus values may be obtained at a much later date.

3. Conclusion

The completion of the Trump International Hotel and Tower is scheduled for spring of 2009; however, based upon the phased-occupancy plan, the hotel has been in operation since early 2008, well before the scheduled topping out of the structure in mid 2008. To date, project milestones met have included the demolition of the existing Sun Times building in March of 2005, completion of the rock caissons in August of 2005, and the $3800m^3$ continuous 22 hour placement of SCC for the core mat on September 29, 2005. Also, as part of the development, the Trump Organization replaced the adjacent 1920's era Wabash Viaduct, completed on November 19, 2005. As of April 2008, the Trump Tower structure has risen above Level 65 (15 stories past the final setback at Level 51).