Structural Innovations of Lotte World Tower

By SawTeen See, P.E., C.E., Dist. M.ASCE, M. Eng., Leslie Earl Robertson, P.E., C.E., S.E., D.Sc., D.Eng., NAE, Dist. M.ASCE, AIJ, JSCA, AGIR, and Edward J. Roberts, P.E.

Leslie E. Robertson Associates was an Award Winner for its Lotte World Tower project in the 2016 NCSEA Annual Excellence in Structural Engineering Awards Program in the Category – New Buildings over $100M.

At 1,820 feet (555 meters) tall, the 123-story Lotte World Tower stands as the first supertall building in South Korea, more than 1.8 times taller than the previous tallest building (located in the nearby city of Incheon). The building topped out in December 2015 and the tower's mast, dubbed the "Lantern," was complete in March 2016. Designed by architects Kohn Pedersen Fox Associates and structural engineers Leslie E. Robertson Associates (LERA) of New York, the $2.5 billion tower and adjacent development features a variety of usages, including office, retail, hotel, officetel (a combination office and apartment common in Korea), parking, museum, and observation space.

The tower's tapered shape – with sloping concrete core walls in the middle third of the building and columns sloping in two directions – creates a unique environment on every floor. Occupying the majority of the tower (from the ground level to the 71st floor), the office and officetel floors are steel framed with a slab-on-truss deck, whereas the hotel floors (from levels 87 to 101) are concrete flat slabs with drops. The diagrid structure at the top of the building contains premium office, museum, and observation floors, which are also steel framed with a slab-on-truss deck. The tower sits on top of a 21.3-foot thick mat (6.5 meters), with piles reinforcing the ground. These piles are not connected to the mat, to conform to Korean building regulations. Though the tapered shape of the building led to challenging structural complexities, it was effective at minimizing wind loads.

The tower's primary lateral load and gravity system consists of eight concrete mega-columns, concrete core walls and a series of outriggers and belt trusses located at the mechanical, refuge, sky lobby, and hotel amenity floors. The belt trusses transfer the diagrid "lantern" structure to the column configuration of the hotel floors, as well as the columns of the hotel floors to the mega-columns at the officetel and office floors. Level 5 to Level 7 are hung from the lowest belt truss. Only two levels of outriggers tying the perimeter mega-columns to the concrete core were needed to control the tower's drift and lateral accelerations due to wind loads. The 10-foot 9-inch by 10-foot 9-inch (3.3-meter by 3.3-meter) mega-columns at the ground level (unbraced for the first eight levels) are comparatively small compared to other towers of similar height and even qualify as slender members.

LERA worked closely with the architects to strike a balance between the structural efficiency gained by adding columns and the need to preserve open floor plans. Several structural designs were studied: a system of concrete mega-columns with relatively small intermediate steel columns at the perimeter; a system of long-span spandrels with clear spans between concrete mega-columns; and a combination of the two. The owner, Lotte, selected a system of long-span spandrels for the office and officetel floors, with spans of up to 80 feet (24.5 meters) between mega-columns. At the building corners, the long-span spandrels cantilever 46 feet (14 meters) beyond the mega-columns while bending to follow the building's curved floors. These corners posed significant challenges for meeting the stringent deflection and vibration floor criteria. In response, LERA designed a series of 1-story-high deflection control posts at every other floor, aligned with the cladding mullions. Since these small members are not required for strength, they were not fireproofed. Higher up the building, the hotel floors are supported by perimeter steel columns that are spaced at the module of the hotel room partitions and transferred through belt trusses.

The design for gravity and lateral loads from wind and earthquakes is only one element of a grander structural design. For the Lotte World Tower, robustness and redundancy were foremost considerations in the design. At the outset of the project, LERA's team of engineers studied various disproportionate collapse scenarios, including the loss of members in either the belt trusses or the steel perimeter columns. As a result, some belt truss members were increased in size where required.

The effects of creep and shrinkage also had to be taken into account, such as differential settlements between the perimeter and the services core. The potential imbalance of the floor was partly addressed by vertically cambering the mega-columns during construction, allowing forces to be transferred through the outrigger members as the mega-columns settle further than the concrete core. LERA recommended delaying the final connections of the outriggers to mitigate the force transfer in the short term, while also designing for the potential force transfer due to long-term creep and shrinkage.

The tower topped out in 2016 and stands as the fifth tallest building in the world.▪

SawTeen See is the Managing Partner at LERA. She led the structural design of the Lotte World Tower, Seoul, South Korea.

Dr. Leslie E. Robertson, an internationally acclaimed structural engineer, has transformed urban and rural landscapes through pioneering and innovative designs. Among a plethora of notable projects, Dr. Robertson led the structural design of the World Trade Center, New York, NY.

Edward J. Roberts is the Project Manager at LERA. His expertise in 3D modeling has advanced the development of LERA's analysis software.