The World's Tallest Building

The Burj Khalifa

By William F. Baker, P.E., S.E., FIStructE and James J. Pawlikowski, S.E., LEED AP

Skidmore, Owings & Merrill LLP received an Outstanding Project Award for the Burj Khalifa project in the 2010 NCSEA Annual Excellence in Structural Engineering awards program (Category – International Structures).

The goal of the Burj Khalifa Tower is not simply to be the world's highest building; it's to embody the world's highest aspirations. Such a project goal by necessity requires pushing current analysis, material, and construction technologies to literally new heights. However, as such a building height has never before been attempted, it is also necessary to ensure all technologies and methods utilized are of sound development and practice. As such, the designers sought to be able to use conventional systems, materials, and construction methods, modified and utilized in new capacities, to achieve such a lofty goal.

The Tower is 828 meters (2717 feet) in height, and is the world's tallest building in all three categories defined by the Council on Tall Buildings and Urban Habitat. In fact, Burj Khalifa is approximately 319 meters (1047 feet) taller than the previous record holder, Taipei 101 in Taiwan. The construction of the Tower began in January 2004, with its official opening occurring January 4, 2010. The Burj Khalifa Tower is the centerpiece of a $20 billion development located just outside of downtown Dubai, UAE. The project consists of the Tower itself, as well as an adjacent Podium structure, and separate 12-story Office Annex and 2-story Pool Annex. The 280,000 square-meter (3,000,000 square-foot) reinforced concrete multi-use Tower is predominantly residential and office, and also contains retail and a Giorgio Armani Hotel.

The architects and engineers worked closely together from the beginning of the project to determine the shape of the Tower, in order to provide an efficient building in terms of its structural system and in its response to wind, while still maintaining the integrity of the initial design concept. The floor plan of the tower consists of a tri-axial, "Y" shaped plan, formed by having three separate wings connected to a central core. As the Tower rises, one wing at each tier sets back in a spiraling pattern, further emphasizing its height. In addition to its aesthetic and functional advantages, the spiraling "Y" shaped plan was also utilized to shape the Burj Khalifa to reduce the wind forces on the Tower. The setbacks provide many different floor plates, resulting in many different widths to the Tower over its height. This stepping and shaping of the Tower has the effect of "confusing the wind" – wind vortices never get organized over the height of the building because at each new tier the wind encounters a different building shape.

The structural system can be described as a "buttressed" core, and consists of high performance reinforced concrete wall construction. Each of the wings buttress the others via a six-sided central core, or hexagonal hub. Corridor walls extend from the central core to near the end of each wing, terminating in thickened hammer head walls. Perimeter columns and flat plate floor construction complete the system. At mechanical floors, outrigger walls are provided to link the perimeter columns to the interior wall system, allowing the perimeter columns to participate in the lateral load resistance of the structure; hence, all of the vertical concrete is utilized to support both gravity and lateral loads. The result is a tower that is extremely stiff laterally and torsionally. It is also a very efficient structure, in that the gravity load resisting system has been utilized so as to maximize its use in resisting lateral loads. The top of the Tower consists of an approximately 230-meter (750-foot) tall structural steel spire, and the entire Tower is founded on a 3.7-meter (12-foot) thick reinforced concrete raft foundation, supported by reinforced concrete bored piles which are 1.5 meters (5 feet) in diameter and 43 meters (141 feet) in length (194 piles total).

The Burj Khalifa Tower utilized the latest advancements in construction techniques and material technology. The walls and perimeter wing columns were formed using Doka's SKE 100 automatic self-climbing formwork system, and consist of concrete ranging from C60 (8700psi) to C80 (11600psi) cube strength. Floor slabs were poured on MevaDec panel formwork. Construction sequence had the central core walls and slabs placed first, with the wing walls and slabs next, and the wing nose columns and slabs following. Three primary tower cranes were located adjacent to the central core, with each continuing to various heights as required. High-speed, high-capacity construction hoists were utilized to transport workers and materials to the required heights. A specialized GPS monitoring system was developed to monitor the verticality of the structure, due to the limitations of conventional surveying techniques. Structural steel for the spire was erected as much as practical on the ground and lifted into place, both to minimize crane time and to simplify connections.▪

William F. Baker, S.E., P.E., FASCE, FIStructE is a Partner with Skidmore, Owings & Merrill, LLP and can be reached at ***william.baker@som.com***

James J. Pawlikowski, S.E., LEED AP is an Associate Director with Skidmore, Owings & Merrill, LLP and can be reached at ***james.pawlikowski@som.com***