Beneficial Use Case Study

Burj Khalifa

Coal Combustion Product Type
Class F Fly Ash

Project Location
Dubai, United Arab Emirates

Project Participants
Skidmore, Owings & Merrill, William Frazier Baker, Samsung C&T Corporation, Ash Resources, CTL Group, Emaar, Hyder Consulting, Turner International, Doka, Unimix

Project Completion Date
2010

Project Summary
Burj Khalifa, a 163-floor concrete multi-use tower in Dubai, UAE, stands as the world's tallest building, at 2717 feet. The 465,000-square-foot building houses a hotel, as well as commercial, office, residential, retail, and entertainment space. High-strength concrete, supplemented with fly ash, was chosen for the construction material partly in response to the harsh environment in the region, but nonetheless brought with it logistical and engineering challenges.

Project Description
According to the building's architects—Skidmore, Owings & Merrill—the intent from the outset was for Burj Khalifa not only to be the tallest building in the world, but also the tallest freestanding man-made structure. With that as a goal, proper site characterization, material selection, mix design and testing, building shape, and construction logistics all became paramount.

The groundwater in which Burj Khalifa's substructure sits is extremely corrosive, with chloride and sulfate concentrations of up to 4.5% and 0.6%, respectively—higher even than those found in sea water. As a result, design of the piles and raft foundation focused on durability. Each of the 194 piles used to support the raft utilized a concrete mix of 25% fly ash, 7% silica fume, and a water-to-cement (W/C) ratio of 0.32—and measured 1.5 meters in diameter and 43 meters long. Piles were designed to support 3000 tons apiece, although load tests showed they could bear more than twice that amount. In total, 5300 tons of DuraPozz fly ash, sourced from Ash Resources' Lethabo, South Africa, plant, was used in the pilings. Piles were protected by a special waterproofing membrane to inhibit corrosion.

The piles were then locked together by a 3.7 meter-thick concrete raft that spans the tower's footprint. The durability and performance criteria for the raft were exacting, and sample blocks were made to test for shrinkage, modulus of elasticity, and heat of hydration. Ultimately, the 12,500-cubic-meter raft incorporated a concrete mix containing 40% fly ash and a W/C ratio of 0.34. The completed raft used a further 2350 tons of DuraPozz fly ash, helping to limit peak temperatures and the potential for cracking during mass placements in the hot desert climate.

The high-performance concrete tower itself was designed as a "Y" shape around a hexagonal core for maximum lateral and torsional stiffness and to limit the effects of wind on the super-tall structure. Pumping concrete to heights of nearly 2000 feet proved to be an engineering challenge—but one that was overcome using four different mixes with incorporation of fly ash to help ensure workability. During construction, Dubai-based ready-mix concrete maker Unimix set a world record for the highest single-stage pumping of concrete—helping to prove the viability of high-performance concrete as a preferred material in super-tall building construction.

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