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Higher Wind Towers on the Rise

Post-tensioned segmental technology allows record heights and efficiencies

by James D. Lockwood, Matthew J. Chase, and Steven T. McRory

A U.S. record high wind tower, with a hub height of 115 m (377 ft), was recently commissioned in Adams County, IA. The patented tower system was developed by Siemens Wind Power in partnership with Wind Tower Technologies (WTT) of Boulder, CO, using the precast segmental construction method. Precast segmental construction has proven to be highly competitive in the bridge industry on large viaducts—projects in which standardization is common. The new tower system is fabricated on site, eliminating the disruptions and costs inherent with transporting large steel tower sections over roads and bridges from remote locations to the project site. Using on-site concrete fabrication, the tower base diameter is nearly unrestricted, thereby allowing tower heights to be limited only by zoning permits and erection equipment.

According to Luis Carbonell, Civil Engineering Manager of Siemens, the segmental concrete technology provides their company an opportunity to introduce a new tower concept from the ground up that is aligned with the company's market strategy.

The market size projection for utility-scale wind energy production in the United States is estimated to exceed 47 GW over the next 5 years, resulting in the projected installation of over 17,000 new towers in steel and concrete in this period. This creates a large opportunity for the concrete industry to compete in this growth market.

The significance of taller towers is higher energy production in many geographic markets where increased wind speeds exist with height. The market opportunity for concrete wind towers in North and South America is high as the wind market trends toward taller towers.

The ACI Foundation invites you to learn more about concrete's always advancing role with wind turbine towers at the Strategic Development Council's Technology Forum #40. The Forum will feature presentations concerning concrete and wind turbine towers on September 8-9, 2016, at the DoubleTree Salt Lake City Airport Hotel, Salt Lake City, UT. Register at ***www.ConcreteSDC.org****.*

On-site Tower Segment Casting

One contributing challenge in the wind industry today is transporting large steel tubular sections. Transportation costs of steel towers are high, and clearance restrictions on state department of transportation (DOT) highways and bridges limit the diameter of the lower sections of the tower and thus the height of the tower. This can only be overcome using heavier steel wall sections or high-strength steel, and each of these are less cost effective than increasing the diameter of the base. As the industry grows and new geographic markets develop, higher hub heights, well above 100 m (328 ft), are more desirable and improve the cost benefits of on-site precast towers.

115 m precast concrete wind tower with 108 m (354 ft) rotor

On-site precasting of the tower segments not only removes limitations on the diameter of the tower base and corresponding height but it also allows the use of local labor and locally sourced materials such as reinforcing steel, aggregates, cement, and admixtures. Further cost-saving opportunities are offered when the foundation contractor and concrete tower contractor can coordinate sourcing of materials from the same batch plant.

To achieve the required speed of construction, the concrete tower segments are match cast together, resulting in a tight fit between segments when installed. The geometry of the tower is therefore largely set in the casting yard with minor provisions for alignment adjustments during erection.

Formwork installed in precast yard to match-cast next segment

Concrete finishing of segment joint in preparation for next casting

Finished segments in storage ready for installation into the tower

Technology Transfer

The technology of precast segmental construction involves match-casting one segment against the next in series. When assembled and post-tensioned together during erection, a continuous structure is created. This construction method has evolved to be very competitive in the bridge industry on larger projects that lend themselves to an industrialized, on-site construction method. The repetitive nature of wind towers on an individual wind farm lends itself very well to this industrialized on-site manufacturing approach.

Precast segmental bridge construction using match-cast joints

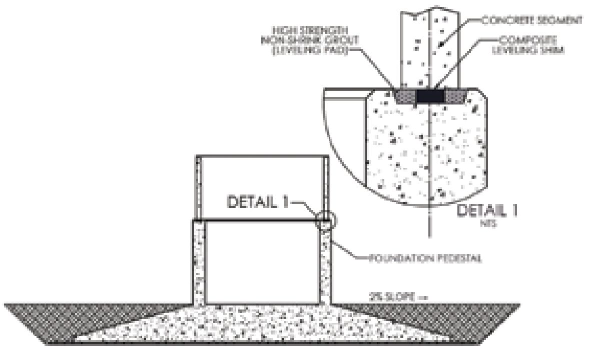
Cast-in-Place Foundation

The cast-in-place foundation for the Siemens precast tower incorporates an annular pedestal wall that enables the precast tower to connect to the foundation using a grouted joint that provides a uniform transfer of forces. The connection, located close to ground level, is the only grouted joint in the tower. By separating the cast-in-place foundation activities from the precast tower activities, the project owner maintains the flexibility of negotiating the foundation construction contact separate from the tower construction contract.

The Siemens concrete tower foundation is similar to that used for a steel wind tower foundation; however, because the concrete tower weight exceeds that of a steel tower for the equivalent load carrying capacity, the foundation quantities for a concrete tower can be reduced in comparison to the

Cast-in-place foundation placed prior to casting pedestal wall and backfilling with soil

foundation quantities needed for a steel tower. The precast tower system is installed onto the foundation's pedestal wall and secured to the foundation using post-tensioning. This connection has benefits over steel tower connections, whereby mechanical anchor bolts extend through steel flange plates, reducing future maintenance of these mechanical components.



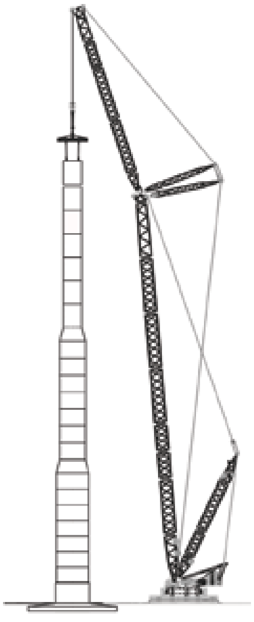
Foundation to pedestal wall schematic

The first known utility scale wind tower in production was the TVINDkraft tower in Denmark in 1975, constructed using cast-in-place concrete. Since that project, the European wind power market has evolved toward manufacturing and transportation of steel tower sections bolted together on site. This solution was transferred to the Americas over the past 20 years. With wind towers increasing in height and carrying larger rotors and turbines, innovative concrete tower designs and construction techniques are becoming increasingly important.

The precast segmental tower solution may change the wind industry's landscape. During the development of the system, the importance of speed in construction of the wind towers was critical. The use of match-casting to eliminate grouting of the joints during segment stacking is an important differentiator in constructing the concrete tower.

The concrete tower is stepped to optimize the use of formwork. The transition from concrete to steel near the top of the tower allows for a standardized steel top section for the yaw attachment and cabling platforms.


Precast segment lifted by crane for placement onto the tower


Schematic of tower erection


Precast segments fully stacked and post-tensioned to foundation

Project Credits

Testing and construction

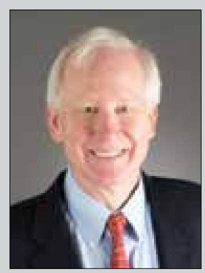
Full-scale fabrication and testing of the tower sections were completed in early 2015. These activities were followed by the construction of a fully operational turbine tower in Iowa, both constructed by Baker RD Concrete Construction, Clovis, NM. EFCO Forms, Des Moines, IA, provided formwork to Siemens for casting the tower segments. Schwager Davis, Inc., San Jose, CA, supplied and installed post-tensioning for the turbine tower constructed in Iowa.

Technical team

The technical team was assembled from a group of experienced professionals with expertise in precast segmental bridge design and construction, large utility scale tower engineering, and the knowledge of wind farm logistics and schedule requirements. Principals included Siemens Wind Power Americas—Luis Carbonell, Steven McRory, and Francisco Morales; and Wind Tower Technologies—Jim Lockwood, Matt Chase, and Panos Kiousis. The Peer Review team comprised Thornton Tomasetti, Chicago, IL, and Denver, CO; and International Bridge Technologies, San Diego, CA.

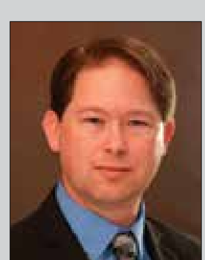
Selected for reader interest by the editors.

From left: Matt Chase, Steven McRory, and Jim Lockwood inspecting formwork prior to the next concrete placement



ACI member **James D. Lockwood** is the CEO and founder of Wind Tower Technologies, Boulder, CO. He has over 30 years of experience in structural engineering, product development, and design/build projects. Lockwood has worked 15 years in the field of precast segmental bridge design and construction with Figg & Muller Engineers and Jean Muller International (JMI). During his tenure with JMI, he established and managed JMI's Chicago and New York City offices. Lockwood received his BSCE from the University of Cincinnati, Cincinnati, OH, and his MSCE from the University of Washington, Seattle, WA. He is a licensed professional engineer.

Matthew J. Chase is the Director of Wind Tower Technologies. As a structural engineer, his relevant design experience dates back to 2006. Over the past 8 years, Chase has designed and been involved in the construction of wind towers and wind tower foundations for industrial-scale wind farm projects around the world. He received his bachelor's degree from the University of Wyoming, Laramie, WY. He is a licensed professional engineer in 10 states, a member of the American Society of Civil Engineers (ASCE), and a contributing member of IEC PT06 Concrete Group.



Steven T. McRory is a Principal Engineer at Siemens Energy, Inc., Orlando, FL. As a structural engineer, his design experience dates back to 2005. Over the past 11 years, he has designed and been involved in the construction of bridges, major infrastructure projects, wind turbine towers, and wind turbine foundations. McRory received his bachelor's and master's degrees from the University of Central Florida, Orlando, FL. He is a licensed professional engineer.