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Green Foundations Matter In A Green Industry

Alternative technology from one foundation solutions provider combines the benefits of cost-effectiveness, performance and green construction.

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Foundation support solutions have changed and adjusted over recent years as tower heights have grown alongside the industry itself. Wind tower foundations are adapting to accommodate the increased loads generated during both normal operating conditions and maximum sustained conditions.

Foundation system selection undoubtedly must consider performance, quality, constructability and cost. Often overlooked, however, are potential adverse or beneficial environmental impacts distinctively characteristic of certain foundation methods.

Shallow foundation support

In ideal situations where existing soils exhibit sufficient strength and stiffness characteristics to support the tower loads, foundations are often designed as large hexagonal or octagonal concrete mat foundations bearing on natural soils. This approach is typically the most cost-effective solution for tower foundation design.

Construction of foundations directly on natural soil supports is a green construction solution that avoids more elaborate foundation support solutions, thereby reducing the detrimental impacts and increased carbon footprints related to foundation options on soft soil sites.

Overexcavation and replacement

Soil conditions often are less than desirable at tower locations, driving design teams, contractors and owners to alternative and more costly – and more resource-depleting – foundation support solutions. In these cases, solutions often depend on the depth of the poor soils.

When poor soils extend to shallow depths below the tower foundation, massive removal (overexcavation) of the poor soil and replacement in thin, controlled lifts with high-quality engineered aggregate – similar to material used for roadway construction – is a desirable solution.

Tower foundations are designed as large mat foundations, the same as those supported on natural competent soils. Performance of towers supported on engineered fill have shown to be acceptable, provided sufficient quality-control steps are taken during construction to place the material in a well-compacted state.

Overexcavation and replacement for foundation support is often economical so long as the poor soil is limited in depth. However, the cost savings are quickly lost if local groundwater depths require dewatering to perform the excavation and backfill placement. An additional challenge includes construction delays as a result of inclement weather, typically resulting in the inability to properly place the engineered fill.

Massive earthwork operations for wind tower foundations utilize naturally occurring, local materials to construct the engineered fill, a process that eliminates the use of man-made materials from non-renewable sources. However, fossil fuel consumption by earthmoving equipment and by trucks transporting unsuitable soils to landfills results in a significantly larger carbon footprint compared to towers supported on natural competent soil.

Deep foundations

As an alternative to shallow foundations supported on either natural or engineered material, deep foundations are used to bypass thick zones of soft or compressible soils to transfer foundation loads to more competent bearing materials. Deep foundations may consist of driven steel, timber or concrete piles, drilled concrete shafts or grouted auger-cast-in-place piles and may extend to depths of 50 feet to 100 feet or greater, depending on the local soil conditions.

Towers supported on deep foundations require extensive analysis to

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evaluate not only the vertical capacity of the pile group, but also the lateral capacity to resist the high lateral loads induced on the foundations. The use of the pile foundations may result in additional steel or high-strength concrete in the foundation in order to resist the high concentrated pile loads compared to shallow foundations. While deep foundations can be a more expensive foundation solution, with the cost growing considerably with the depth to competent soil, towers exhibit superior performance relative to settlement and bearing.

The superior performance comes at a cost, both financially and environmentally. In addition to the initial high material cost, pile-supported tower foundations may result in longer construction schedules, often related to slow installation of the piles or delays in material fabrication or delivery to the remote sites. Steel pile foundations incorporate energy- and resource-depleting manufactured materials, such as steel or concrete. Typically, piles use material that is manufactured or fabricated at locations hundreds or thousands of miles away from the construction site. Concrete production, while local, is also energy-intensive and ozone-depleting. The combination of the energy-intensive manufacturing process and the significant transportation efforts required for deep foundations to arrive at the site increases the carbon footprint of the foundation solution.

Environmentally friendly foundation technology was used at the Victory Wind Farm, shown here. Photo courtesy of Geopier Foundation Co. Inc.

Alternate technology

As the industry has grappled with the balance of cost, performance, ease of construction and environmental sustainability, an innovative approach for tower support has gained momentum. This alternative solution has been used for about 20 years to provide soil reinforcement solutions or foundation support in the commercial, industrial, manufacturing and power markets. Today, this same ground improvement technology is used to provide improved strength and stiffness of soft or compressible soils.

An example of this system involves drilling a 24-inch- to 36-inch-diameter cavity, (depending on design requirements), placing thin lifts of aggregate within the cavity and vertically ramming the aggregate using a high-energy beveled impact tamper.

During construction, the high-frequency energy delivered by the modified hydraulic hammer, combined with the beveled shape of the tamper, not only densifies the aggregate vertically to create a stiff aggregate pier, but also forces aggregate laterally into the sidewall of the hole, resulting in a lateral stress increase in surrounding soil. The lateral stress increase reduces the compressibility of the surrounding soil and promotes positive coupling of the aggregate system element and the soil to create an improved composite, reinforced soil zone.

The system is designed to reinforce the poor foundation soils, which improves the bearing pressure of the reinforced zone beneath tower foundations, controls total and differential settlement (i.e., angular distortion) of the foundations, and improves the rotational and dynamic stiffness values to achieve the desired tower performance. The soil reinforcement designs are developed on a project-specific basis depending on the site conditions and the tower loading conditions.

This system is uniquely suited for green construction. Locally available natural aggregate or even recycled concrete is used for construction of the piers. In addition, the volume of material used beneath the foundation typically is only 10% to 20% of the material required for massive overexcavation and replacement. These factors limit the excessive fossil fuel required for material delivery and disposal, as compared to other solutions. In addition, the equipment used for the pier installation consists of only two or three small excavators, thereby further limiting fossil fuel consumption and dramatically reducing the carbon footprint of the foundation construction activities.

Iowa application

This tamper technology has been used in Europe for wind turbine

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Foundation construction at the Victory Wind Farm in Iowa
Photo courtesy of Geopier Foundation Co. Inc.

A foundation is prepared for a wind farm in Iowa
Photo courtesy of Geopier Foundation Co. Inc.

support for nearly a decade. Given the larger tower sizes and increasing foundation loading demands, coupled with the dramatically accelerated rates of tower construction, more U.S. projects now are installing the system. MidAmerican Energy's wind project sited in Carroll and Crawford counties in Iowa used the impact tamper technology for 42 of the project's 72 new towers.

Soil conditions at the tower locations were explored by a local geotechnical engineering consultant. The study found the site consisted of up to 35 feet of soft to stiff, silty clay underlain by competent glacial till soils. Groundwater was generally encountered at only 13 feet below grade. Shallow foundations bearing on till or engineered fill were used for areas in which the glacial till was encountered at shallow depths below the foundations. Where competent soil was beyond cost-effective excavation limits, the tamper technology was used to reinforce soft clay extending to depths of up to 20 feet below existing ground elevations.

Contractors utilized the alternate foundation technology to reduce the cost and time required for support of the 50-foot octagonal foundations to support the 80-meter-tall towers. Soil reinforcement typically was completed within two to three days at each tower location, with pier installation rates ranging from 30 to 50 piers per day.

Performance of the impact tamper solution was verified in the field using quality-control observations and testing, including full-scale modulus testing. This testing process is similar to a full-scale pile load test that applies pressure to the installed aggregate system element. The test is performed to evaluate the stress-deflection behavior (i.e., stiffness) of the pier and verify the performance under the design stress levels. The modulus test results for the project typically showed deflections of less than half an inch at over 21,000 pounds per square foot, a pressure of more than six times the maximum applied pressure from the foundation.

The solution used considerably smaller volumes of locally occurring aggregate than would have been required for deeper overexcavation and replacement. The combination of the reduced overall hauling time and accelerated construction time resulted in reduced emissions and a greener foundation solution.

The increasing number and size of wind towers today is driving the need for reliable and cost-effective foundation support solutions. In an industry developed to provide a green energy source, the tamper technology combines the benefits of cost-effectiveness, performance and green construction into one foundation support solution.

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