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Laying The Foundation For Positive Reinforcement

Poor-quality soils at a construction site can wreak havoc on foundation systems. Fortunately, there are methods to counteract the problem.

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Wind farm construction presents unique challenges specifically related to wind farms' often rural settings. Unlike urban construction, where accessibility to sites and transportation of materials and supplies may be far less of a concern, development and construction of roadways and turbine structures present considerable risks for cost and schedule overruns for contractors and owners.

As the wind industry continues to grow, many design teams are identifying ways to control the construction risks to keep projects on schedule and within budget. Two such areas include the use of structural geogrids for roadway stabilization to improve traffic methods and performance, as well as the use of rammed aggregate systems to deliver reliable foundation support.

In the development of wind farm sites, the costs associated with the construction of access roads and crane platforms can be significant. This is especially the case in areas where poor-quality soils are encountered, resulting in the need for a greater aggregate thickness – perhaps one to two feet for some projects.

One major wind farm contractor recently commented that the cost of these structures can be as much as 15% to 20% of the overall development cost.

For more than 25 years, geogrids have been used successfully to reduce the amount of aggregate required for the construction of unpaved roads and working surfaces, such as crane platforms, piling platforms and lay-down areas. Supplied in rolls up to 16 feet wide, geogrids consist of high-tensile-strength polymer formed into an open, grid-like structure that facilitates the partial penetration of large granular particles.

Following compaction, individual aggregate particles are confined by the geogrid apertures and each other. This results in a significantly stiffer layer and an opportunity to reduce the amount of aggregate required. Typically, this leads to a 40% to 50% reduction in the overall cost of the access roads and crane platforms.

In many cases, wind farm developers and their contractors rely on their previous experience in determining the required thickness of access roads and crane platforms. Sometimes, this works quite well, but when the soils turn out to be worse than anticipated, excessive rutting – or even failure of the road – can occur, leading to time delays and an unanticipated increase in construction costs. It is equally possible that without undertaking a detailed analysis of the soil and trafficking conditions, particular structures could turn out to be over-designed, leading to an unnecessary increase in material costs.

With the introduction of reliable and proven design methods (particularly in the early 2000s), technology now exists to ensure that access roads and crane platforms are designed safely and cost-effectively every time. Key to the undertaking of an accurate analysis is a thorough understanding of the subgrade conditions likely to be encountered at the time of construction.

Ideally, this should be determined by the geotechnical engineer of record when the site is originally investigated. Unfortunately, many geotechnical studies often concentrate almost exclusively on the turbine foundations and pay little attention to the other construction activities associated with the development of wind farms.

Under these circumstances, some geogrid manufacturers provide supplementary support services whereby they are willing to undertake additional on-site testing of the soils closest to the surface. This facilitates the acquisition of a set of reliable design parameters.

Getting out of the rut

Geogrids were first used on a wind farm in the late 1990s and have subsequently been adopted successfully for more than 100 projects, including 34 projects in North America. In almost all these cases, the geogrid was installed on top of the existing subgrade in order to reduce the amount of aggregate used for an access road or working surface.

An excellent example of this approach is illustrated by a recent 200 MW wind project in the Midwest constructed during 2009. During Phase I of the project, the contractor experienced significant serviceability problems with the access roads, particularly in the turning radii constructed at road junctions. Excessive rutting and general surface deformation resulted in the need for low traffic speeds and regular maintenance of the road surface.

In the end, it was necessary to use between 18 inches and 24 inches of aggregate in order to provide a stable surface that could support the heavily loaded vehicles.

In anticipation of similar issues being encountered during Phase II of the project, the decision was made to investigate alternative methods of construction, particularly for the turning radii that were subjected to the greatest dynamic loading. The geogrid manufacturer undertook an initial assessment of the soil conditions, and an appropriate set of design parameters were selected.

The Giroud-Han (G-H) design method was used to determine the required aggregate thickness for a conventional unreinforced road and geogrid-reinforced structure.

The 25-inch thickness predicted using the G-H method for an unreinforced road was in close agreement with the road section that had performed well during the Phase I construction. A geogrid-reinforced thickness of only 12 inches was predicted for the same level of performance, which would result in a 52% reduction in the amount of aggregate required. A full-scale field trial was undertaken to ensure the validity of the design, and ultimately, 70,000 square yards of road were stabilized using a geogrid at the project site.

Geogrid technology is not new. The first geogrid-reinforced roads were constructed almost 30 years ago and are still performing well today. However, it is fair to say that innovation over the last five to 10 years has been significant, with the establishment of more reliable and accurate design methods. Several of these methods have been recognized by government agencies, such as the Federal Highways Authority.

In addition, new types of geogrid products have been developed that provide increased performance at a lower cost. Much like the application of geogrids that provides cost and schedule efficiency from the reduction of material import and handling and improved performance, vertical ground stabilization approaches using rammed aggregate solutions provides an alternative to conventional over-excavation and replacement or pile foundations for wind-turbine towers.

Turbine foundations

On sites where competent soils exist, the most commonly used solution is a shallow inverted-T concrete foundation. Unfortunately, poor soil conditions present more challenges and require more time and money to treat properly. While shallow foundations on the unreinforced soft soils may be an option, this approach is often too expensive and time-consuming, as foundation sizes grow to such large dimensions to provide adequate bearing and settlement control.

The traditional treatment of poor soils by simply excavating and replacing is sure to perform. Besides the question of cost, the time and schedule challenges required to excavate and remove materials to sufficient depth, transport large quantities of aggregate to the site and battle potential weather impacts often make this an unacceptable option for contractors looking to maintain schedules.

Although the costs of deep foundations, such as piles or caissons, on individual tower sites are, in many cases, reason enough to look for alternatives, transportation of materials and equipment to remote areas often make this an undesirable solution for many sites. The aggregate system approach utilizes much smaller amounts of aggregate than typical over-excavation and replacement options, and is constructed with readily available, local materials.

Soil reinforcement

The concept of vertical soil reinforcement is quite simple: The rammed aggregate system is installed in soft or loose soils by replacing the poor soil with highly compacted, thin lifts of rock. Alternatively, a displacement process can be used in situations where drilling is not feasible, such as in saturated sands. Above all, the goal is to improve the stiffness of the soil to support the turbines during construction and operation.

In both cases, thin lifts of aggregate are densified using a beveled tamper and hammer, which delivers vertical ramming energy.

While the roadways at the aforementioned Midwestern wind farm were reaping the benefits provided by geogrid reinforcement, a number of the turbine locations in Phase II that were exhibiting poor soils also benefited from the rammed aggregate pier (RAP) form of reinforcement.

The project designer identified a number of areas where soft to medium stiff clay was encountered, with the additional area also containing layers of loose sand. With shallow groundwater complicating plans for any removal and replacement options, the design team selected a rammed aggregate element option to meet the performance requirements for the project.

The RAP design incorporated closely spaced piers toward the outer foundation edges to provide increased support for large overturning pressures and piers beneath the center of the turbine to support vertical loads and develop sufficient stiffness characteristics.

Coordinating closely with project contractor Aristeo Construction, installations using both the displacement and replacement systems were accomplished in typically two days per site. Test results on the installed piers showed less than 0.5 inches of deflection at stress levels of more than four times the design bearing pressure. NP

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