Project
Retail development and associated infrastructure in Orland Park, Ill.

Geotechnical engineer
Malcolm Pirnie, Inc., Chicago

Product application
Geopier Rammed Aggregate Piers created a reinforced zone in soft clay soils to support engineered fill, shallow-foundation retail structures, roadways, and parking areas.

Making marginal sites work

Aggregate pier soil reinforcement overcomes challenging compressible soils.

BY BRENDAN T. FITZPATRICK, P.E.; EVAN M. VLAEMINCK; AND WAYE SHEU, Ph.D., P.E.

In urban locations, the demand for undeveloped real estate that is both suitable for shallow foundation retail construction and within easy reach of the target customer base far surpasses availability. Developers and owners increasingly are forced to consider marginal sites that, because of challenging subsurface conditions, are typically more difficult or expensive to develop. Support options such as overexcavation and replacement, preloading and wick drains, or deep foundations are costly, time-consuming, or both.

But cost and schedule considerations still drive most construction projects. The project team is responsible for finding the optimum site-improvement option, one that not only is technically effective for support of the proposed structure, but also can be delivered in the most cost-efficient and timely manner. For construction of a 116,000-square-foot Lowe's home improvement store on the 44-acre LaGrange Road site in Orland Park, Ill., a suburb of Chicago, that solution proved to be the Geopier Rammed Aggregate Pier (RAP) System.

The overall scope of the proposed development included retail outlets, as well as infrastructure to support the facilities, including new roadways, parking lots, and utilities. Although surrounded by retail expansion, the site had remained undeveloped because of construction difficulties related to the underlying compressible clay soils. For this project, soil explorations performed by geotechnical engineers Malcolm Pirnie, Inc., of Chicago confirmed that portions of the site contained as much as 26 feet of very soft, compressible lean clay underlain by very stiff clay. Groundwater was about 6 feet below grade, making overexcavation and replacement an unlikely option. With a planned finished floor elevation of 694 feet and existing grades ranging from elevations 685 feet to 695 feet, as much as 10 feet of new, engineered fill was needed to reach final grades.

Settlement of about 2 feet was anticipated in response to placement of the fill soils. Of more importance was the estimated two-year time period required for these settlements to occur naturally to allow for shallow footing construction. This was unacceptable to the owner, so Malcolm Pirnie considered several alternatives to address both the fill settlement magnitude and duration, and the building support. These included preloading and wick drains, pile foundations and structural slabs, lightweight fill, and the Geopier RAP soil-reinforcement system.

Malcolm Pirnie recommended the Geopier soil-reinforcement system because of its lower overall construction cost, favorable long-term performance, faster installation schedule, reduced settlement magnitude and duration, and favorable construction sequence. The Geopier system would provide an improved subgrade, allowing the site to be developed similar to sites with competent subsoils.

The 44-acre site of a Lowe's home improvement store and retail development in Orland Park, Ill., required as much as 10 feet of engineered fill on top of as much as 26 feet of compressible clay soil.

Subsequent to Malcolm Pirnie's recommendation, Geopier Foundation Company representatives met with project engineers at Lowe's Companies' headquarters to provide technical details on the Geopier system. This meeting furnished a level of confidence in the effectiveness of the system, given the prevailing site conditions, and underscored Malcolm Pirnie's initial recommendation.

Geopier Rammed Aggregate Pier elements are installed by drilling 30-inch-diameter holes to depths ranging from 7 feet to 30 feet below working grade; placing controlled, thin lifts of stone aggregate within the cavities; and compacting the aggregate using a high-energy, patented 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 stone laterally into the sidewall of the excavated cavity. The lateral stress increase reduces the compressibility of the surrounding soil and promotes positive coupling of the RAP element and soil to create a composite, reinforced soil zone.

Additionally, when constructed from open-graded (clean) stone, the RAP elements act as vertical drains to reduce settlement durations. Thus, the soil-reinforcement solution provides the benefit of site stabilization and stiffening to provide settlement reduction, while also reducing the time required for the settlement to occur.

Design and installation

Jim Bullard, P.E., of Geopier Foundation Company worked closely with the project design team and general contractor, Gioffre Companies, Inc., Dublin, Ohio, to develop the RAP solution for the Orland Park Lowe's site. This resulted in 30-inch-diameter RAP elements spaced at up to 9.5 feet on-center within the building footprint for support of the new fill. Additional piers were installed beneath the proposed footing locations to provide higher levels of stiffening (see Figure 1, page 40).

In areas of the roadway, the RAP elements also were designed to be installed 9.5 feet on-center to support 8 feet of fill. All RAP elements were designed to reinforce completely the soft clay soils that ranged in depth from 10 feet to 26 feet.

Considering the stiffened characteristics of the composite RAP-reinforced zone, combined with the positive drainage effects of the piers, settlements of the engineered fill were estimated to be three to four times less than the settlement of the fill placed on unreinforced soil. Of equal importance, estimated duration to reach maximum settlement was approximately two to three months. This time was anticipated to be an order of magnitude faster than the alternative method of surcharge without subgrade improvement.

Following completion of settlement from the new fill, total and differential building settlements were estimated to be

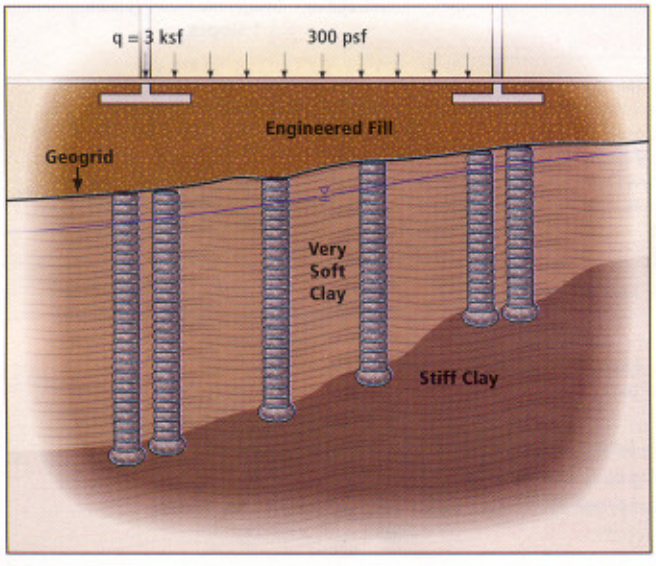
Crews installed more than 5,700, 30-inch-diameter Geopier Rammed Aggregate Piers in about 90 days. Pier depth ranged from 7 feet to 30 feet below grade.

1 inch and 1/2-inch, respectively.

Installation of more than 5,700 Geopier RAP elements began first within the building footprint because this area represented the critical path for the project. Following footprint pier installation, Gioffre Companies placed successive layers of geogrid and stone over the tops of the piers to facilitate uniform settlement development and to provide a stable working platform for engineered fill placement. The Geopier installation crew then moved on to the roadway stabilization areas.

The use of the Geopier System for soil reinforcement was a new concept for Gioffre Superintendent Lee Roy Smith. "The compressible clay was like gray toothpaste," he said. "The Geopier System worked well and offers really good benefits for these types of soils. The installation crews were very professional. They worked long shifts, six days a week, which was a definite scheduling benefit." With as many as four crews working concurrently, total RAP installation for the structure and roadway areas was completed in approximately 90 days.

Figure 1: Geopier Rammed Aggregate Piers were installed through the soft clay layer, spaced at up to 9.5 feet on-center within the building footprint for support of the new fill. Additional piers were installed beneath the proposed footing locations to provide higher levels of stiffening.



Settlement monitoring

During and after fill placement, settlement platforms were monitored across the site to evaluate when the settlement resulting from the engineered fill had reached an asymptotic level so that building construction could proceed. Results indicated that the majority of the settlement occurred within a period ranging from three weeks to three months from initial fill placement. The longer settlement durations occurred specifically in the areas of the site containing the greatest thicknesses of new engineered fill, which coincided with the deepest soft clay deposits. These time periods were considerably shorter than the two-year estimate provided for surcharging the site without subgrade improvement.

Upon release of the building pad, Gioffre rapidly went to work constructing shallow footings to support column and wall loads of as much as 100 kips and 6 kips per linear foot, respectively. The footings were designed for an allowable bearing pressure of 3,000 pounds per square foot (psf) developed within the new engineered fill. A 5-inch-thick, unreinforced slab-on-grade was placed within the building to support the pressures of 300 psf.

Following completion of settlement within the parking areas and new roadways, utilities were excavated, installed, and backfilled. Pavement sections will be placed on the engineered fill supported by the Geopier reinforced soil. Depending upon anticipated traffic loads, the 8-inch crushed stone pavement sub-base will be topped with asphalt or concrete.

While many solutions were available to address the site-development needs, concern about project costs and schedule demands required innovative thinking by the design team. Use of the Geopier Rammed Aggregate Pier System to reinforce the soft, compressible soils helped keep Lowe's on track at a cost that was more attractive than other options. ■

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