2016 ASCE Ridge Branch Florida Section Project of the Year Grouted Pulldown Micropile foundation design for Four-story Building at Southeastern University, Lakeland, Florida

Introduction and Project Description

Madrid Engineering Group, Inc. (MEG) was requested to review previous geotechnical data by another firm and to complete additional investigations as necessary to provide final design recommendations for a **grouted Pulldown^{TM} Micropile system** (hereinafter referred to as micropile) at the Southeastern University (SEU) campus in Lakeland, Florida. Two new four-story buildings, Building A and Building B, were to be constructed next to each other and connected by a hallway. Both buildings were to be constructed using tilt-up concrete panels, and the majority of the footings were spread footings. However, a portion of the south wall of Building A intersects an existing building that was to remain in-place, therefore the tilt panels in that location required a "cut out" to fit over a portion of the existing building, requiring a span of approximately 37 feet. Concentrated loads were expected on either side of this span, and the foundation could not extend significantly beneath the existing building that would remain in place; therefore spread footings were not an acceptable foundation in this critical area, which was the focus for our design.

An innovative foundation method, Grouted Pulldown micropiles, was selected to be used in this heavily loaded portion of the south wall because the pilings are installed using machine-generated torque to slowly twist into the ground, as opposed to drilling or driving methods which can generate significant vibration and would likely have damaged the existing building. **Based on the loads of the multistory building and the stress concentration at the "cut out", we pushed the limits of this technology to the maximum recommended by the world's leading experts.**

The goal of our design effort was to determine the likely length of the piles, to calculate the available capacity of each pile, and to determine that the selected pile configuration could obtain the required capacity based on observing one initial probe pile installation. Additionally, the existing building foundation needed to be at least partially supported in this area using helical pile underpinning as the existing building's strip footing would be partially undermined during the construction.

Subsurface Information

Previous geotechnical information, including soil borings by others, was reviewed as part of this design. The prior data included Standard Penetration Test (SPT) soil borings, however, the majority of them were just 35 feet deep and were not deep enough to determine pile tip depth, in our opinion. Additionally, several cone penetrometer test (CPT) soundings were done to supplement the SPT data. Construction recommendations were made for most of the new buildings.

To supplement the prior data, MEG completed two additional, deeper SPT borings and two additional CPT soundings. The SPT borings were located on either side of the existing building, near the location of the proposed micropile supported footings. The CPT borings were completed in the adjacent building B footprint, and located to supplement the previous borings. MEG borings extended to and into a very dense/hard competent bearing material to confirm competent bearing material below the likely tip elevation of the micropiles, and were 85 and 77 feet deep. The CPT soundings were also deeper, extending to refusal conditions at 60 feet below grade surface (bgs).

The borings and soundings were similar to each other, generally encountering loose to medium dense sand to silty sand to 30 to 35 feet bgs, then underlain by a predominantly clayey sand to sandy clay layer from 30 to 70 feet deep. For the SPT borings, sampler refusal was encountered at 68.5 to 73.5 feet bgs; at this depth, a cemented hard clay to very dense clayey sand was encountered.

Applied/Working Loads

We worked very closely with the structural engineers for this project, BBM Structural Engineers Inc. (BBM) of Longwood, Florida, who supplied the working loads for the walls as below:

> Existing footing – building to remain in place – 2kips/ft
> Micropile Section – 18 to 29 kips/ft
> Building A spread footings – Design load of 2,500 psf and range in size from 2.5 to 8 feet wide for continuous strip footing and up to over 14 feet square for isolated column footings

Analysis of Settlement

MEG performed a settlement analysis for the existing building foundations based on both existing loading conditions and the new loading conditions for the new adjacent building. The Pulldown Micropiles were designed to minimize settlement as transfer the load of the new building.

Evaluation and Analysis of Grouted Pulldown™ Micropile

The evaluation of the micropile system considered multiple elements primarily including the helix configuration; the design capacity of the combined helices; the design capacity of the grouted shaft above the top helix; the compression of the pile system; the minimum installation torque requirements; a recommended minimum penetration depth; and an assessment of load transfer of the pile cap to the piles (this last was portion was evaluated jointly with BBM). The initial step was to collect deeper subsurface data as close as practical to the proposed pile system location which was gathered from the MEG borings.

We selected a quad-helix square shaft. According to the manufacturer, this system has a maximum rated capacity of 80 kips per pile (with no load test) and a maximum installation torque of 16,000 ft-lbs. The initial design intended to utilize the full rated capacity for this pile of 80 kips per pile with a 4-foot pile spacing. Our evaluation of a probe pile indicated that this pile system can be installed through shallower dense layers and deep enough into the harder competent layer at depth without spinout. The larger helices above the tip provide sufficient resistance to drive the 8” helix near the tip into the competent layer. As such, we were confident this system, with combined capacity from the helices and the grouted shaft, installed to at least 65 feet bgs would provide the axial capacity required. The probe pile information was used, along with soil boring information, to assist with our recommendations for minimum pile tip penetration as well as minimum installation torque.

The subject of load transfer from the pile cap to the piles as well as configuration and location of the pile cap was an on-going design discussion point during the design and construction phases, with MEG and BBM working together. The primary design consideration revolved around the required eccentric loading that would be incurred as a result of the proximity of the existing building and, as a result, is not as simple as placing a single row of piles in the cap. The resulting “fulcrum” design included a 3-pile cap with two piles in compression and one pile in tension. Subsequent loading analyses completed by BBM indicates the pile design loads will be 72 and 33 kips in compression and 20 kips in tension, based on a 4-foot center-to-center pile spacing consistent with the initial design. The compression piles both used the same quad helix micropile system and were referred to as nominal 35 kip and nominal 80 kip design piles. The tension pile was a conventional helical pile with an SS5 square shaft (1.5” x 1.5”).

Another key design concept was that the new building foundation system and the existing building foundation system must remain completely independent from each other. Preliminary foundation details provided depicted a mechanical connection of the new footing to the existing footing; however, MEG determined that this connection could not be made. The load transfer, settlement and overall foundation performance would be different, even where both the existing and new buildings are pile supported and they had to remain as independent systems.

The reason a grouted micropile was selected for this project and not simply a helical pile is that the grout column along the pile shaft significantly reduces the axial compression of the pile system because the grout, in simple terms, performs better in compression than the steel. This is the advantage of the composite pile used by this proprietary system that provides less deflection under higher loads than a conventional helical pile will. The evaluation for this pile system for a 70-foot pile at this site suggested axial compression at the maximum design working load of 80 kips to be on the order of 0.3 to 0.6 inch.

Helical Underpin and Tension Pile

MEG determined that the existing building should be underpinned to both enable pile cap construction, which would undermine the existing footing, and minimize any settlement to the existing building resulting from soil loading associated with the new building construction. After discussions with the manufacturer's representative and in consideration of the loading conditions and for ease of ordering and installation, we recommended using the same combination pile for the tension pile as is to be used for underpinning.

SUMMARY OF CONSTRUCTION MONITORING

In addition to the test pile installation (the purpose of which was to see how deep the micropiles could be installed with the equipment available to the specialty contractor, Certified Foundations, Inc. (CFI) Lakeland), MEG completed construction monitoring and geotechnical design support services during construction of the pile foundation system for the Arts & Media Building A.

There were a total of four types of piles installed for this project. Please see below for type, pile ID nomenclature, and final design loads provided by BBM.

- Nominal 10-kip Underpin Piles: UP-1 through UP-17, 10 kips
- Nominal 20-kip Tension Piles: 20A through 20E, 23 kips
- Nominal 35-kip Compression Micropile: 37A through 37G, 33 kips
- Nominal 80-kip Compression Micropile: 80A through 80J, 75 kips

During the installation of pile Nos. 37A and 80A, the piles "spun out" and the installation torque was reduced significantly below the target torque. Additionally, some of the 35-kip piles did not achieve the target minimum grout column diameter of 5-inches. As a result, MEG recommended adding supplemental piles 37G, 37F, and 80A(S) to the pile program.

The building was provisionally opened in September for the Fall 2016 semester and is performing successfully. MEG is proud to have been able to provide geotechnical services to Southeastern University for this unique, challenging geotechnical design. The resulting foundation designs met all of the requirements for minimal disturbance to surrounding buildings while supporting the new design load. MEG's expertise with problematic soils and difficult access conditions were well-suited for this type of specialty consulting project where we are able to assist structural engineers, contractors and the owner to provide the best possible solution with the available technology.

PHOTOS AND ENGINEERING DIAGRAMS

Photo 1, MEG completing a difficult access SPT boring adjacent to existing building

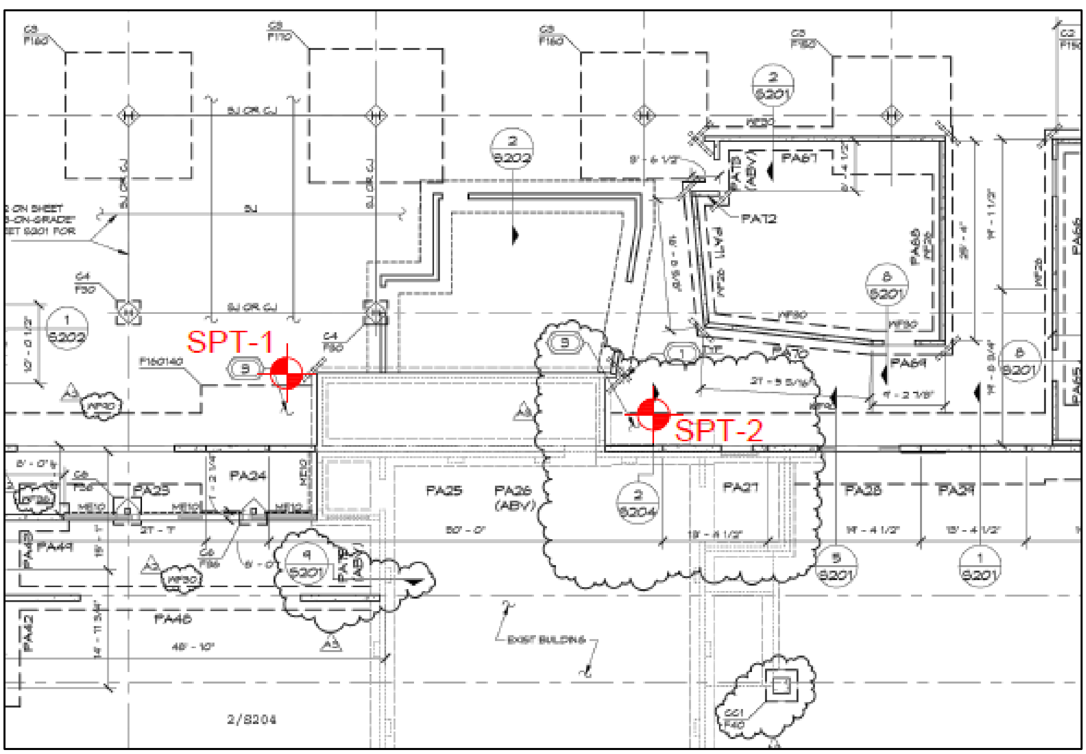

Photo 2, SPT boring locations relative to the existing and proposed buildings

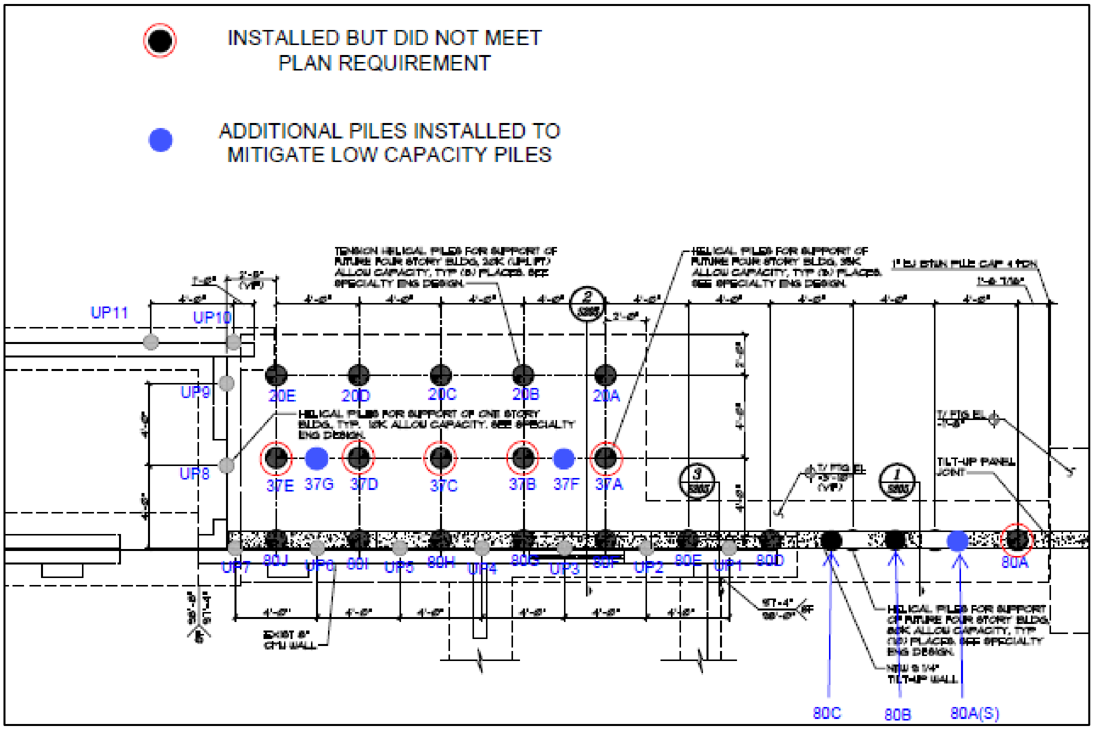

Photo 3, Underpin and Micropile Location Plan (existing building along the bottom)

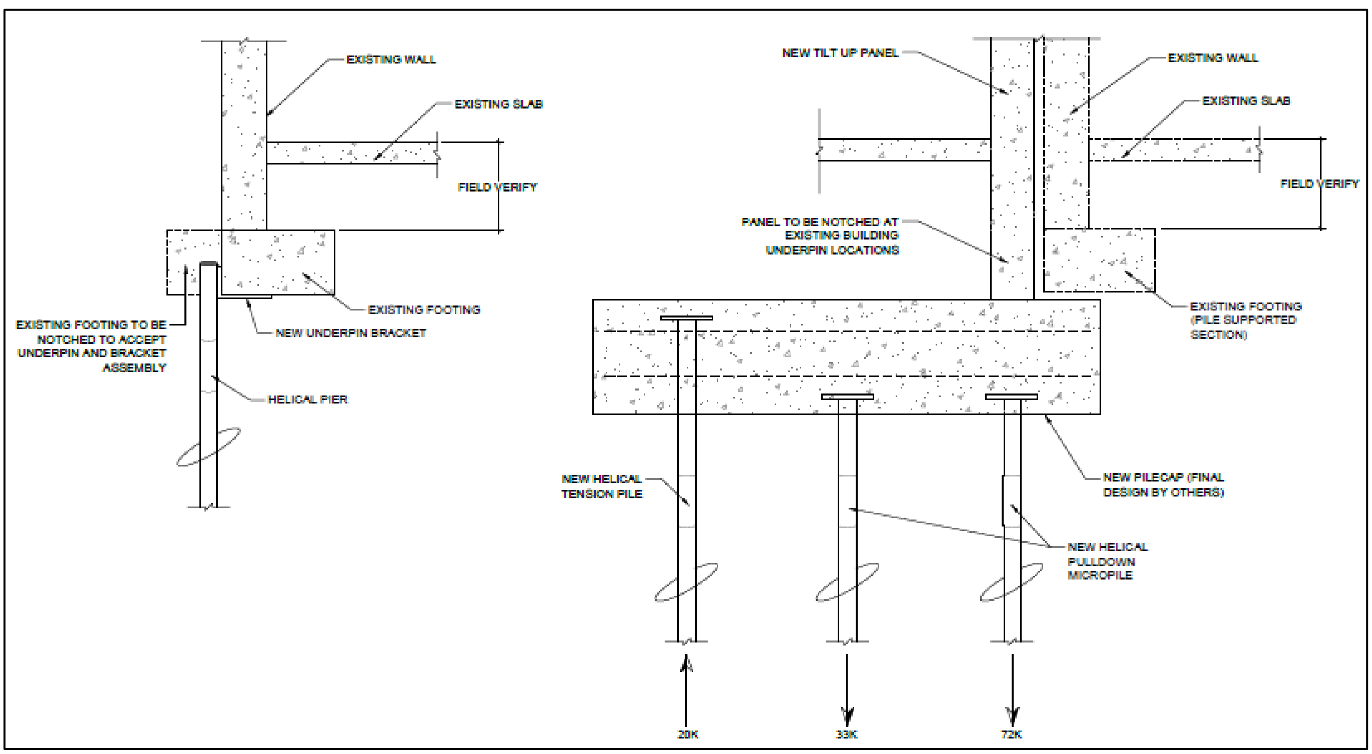

Photo 4, Concept Drawing indicating underpin bracket for existing building and 3-pile system to handle eccentricity issues at the new building foundation

Photo 5, Installation of underpins and foundation brackets along existing building

Photo 6, Construction of pile cap for micropiles adjacent to existing building

Photo 7, Constructed new building with adjacent existing building

Photo 8, Constructed Buildings (Jan 2017)