MICROPILES USED FOR DEEP FOUNDATION SUPPORT AT THE RITA LIDDY HOLLINGS SCIENCE CENTER AT THE COLLEGE OF CHARLESTON, CHARLESTON, SOUTH CAROLINA

William L. Snow, Sr.[1], William B. Wright, PE[2], & Will Snow, Jr., PE[3]

Charleston, South Carolina is one of the fastest growing metropolitan areas in the Southeastern part of the United States. Occupying the largest footprint in downtown Charleston, the College of Charleston is experiencing a similar growth, but in a confined area. In an effort to supply a growing student body with state of the art facilities, the College is continually renovating existing structures and occasionally, building new ones. The Rita Hollings Science Center Building combines both renovation and new construction. In order to review the final foundation design and construction, some basic facts and history unique to this area must be understood.

1. Charleston, South Carolina is located immediately adjacent to the Atlantic Ocean. The peninsula which represents downtown is located between the Ashley and Cooper rivers. Local custom holds that The Ashley and Cooper rivers merge together into Charleston harbor to form the Atlantic Ocean. From a geotechnical viewpoint, Charleston is in fact a unique location for a modern metropolis in that there is no bedrock to support the structures of the city. In addition, the city is in an active seismic zone which mandates the evaluation of lateral loads as well as liquefaction when considering foundation support systems. To accommodate the support of all structural design, the design professional must utilize deep foundations (piles) supported in the Cooper River Marl formation, which is not subject to liquefaction. Given the potential for seismic events as well as the frequency of hurricanes and resultant wind loads, for all practical purposes, all structures must be designed for axial as well as lateral support in the foundations as well as the buildings themselves.
2. The College of Charleston is basically landlocked in its historic footprint. All new physical facilities must be contained within that footprint, which is compact in nature. In 2010, a major construction project utilized driven piles as the primary foundation support. Although piles have been driven in the Charleston area for generations, this project took place during final exams at the College. The disruption from vibration as well as noise was more than a minor annoyance. In short, after much discussion, the Board of Directors of the College banned driven piles for all future projects, unless the designer could guarantee no disruptions from the process.
3. The Rita Hollings Science Center was designed as a renovation of the existing building attached to a newly constructed building as well as vertical expansion basically tripling the square footage of the facility. Since the original structure was built in the 1960's the entire foundation had to be upgraded and enhanced to support the vertical expansion as well as to meet current IBC codes.

[1]Palmetto Gunite Construction Co., Inc., PO Box 388, Ravenel, SC 29470, 843-889-2227, snowwl@aol.com
[2]Terracon Consultants, Inc., 1450 5th St. W., North Charleston, SC 29405, 843-514-0016, wbwright@terracon.com
[3]Terracon Consultants, Inc., 2201 Rowland Ave., Savannah, GA 31404, 912-200-9120, will.snow@terracon.com

4. Given the need for increased axial and lateral load requirements, coupled with the fact that driven piles were not practical for the facility; the designers looked to alternative deep foundation support systems.

In 2014, design was begun and a dual system of foundation support was included in the construction documents. Micropiles were indicated for the support of the renovation of the existing structure. Auger cast piles were specified for the adjacent new construction phase of the project. The project bid in early 2015, based on the project documents. When the bids were opened, the total price exceeded the engineer's estimate. Before the contract could be awarded, the owner entered intense discussions with the low bidder in an effort to find a way to reduce the overall cost of the project. Although the final negotiations did not bring the price down to the engineer's estimate, there was enough savings to prompt the owner to accept the general contractor's proposal and a contract was signed by both parties.

One area of significant savings was found when the designers accepted a proposal from the micropile contractor, Palmetto Gunite Construction Co., Inc., to substitute cased micropiles in lieu of the specified auger cast piles. Much of the savings were the result of the cost associated with the extremely tight working conditions that were much more favorable to micropiles when comparing the equipment needed and the storage required for the disposal of dirt resulting from the auger cast pile process.

The micropile contractor working with design professionals from Terracon Consultants, Inc. and Theodore Padgett, PE, PC – Consulting Engineer provided a design for the micropiles which provided support for the same loads as the auger cast piles with only minor changes to the pile caps with regard to spacing and connections to the micropiles. To fulfill the contract requirements for both the original micropiles as well as the micropiles offered as a substitute for the auger cast piles, test piles and reaction piles were installed at several locations on the project.

The test pile program consisted of seven (7) load tests for which, 5 piles were located at production locations and one pile was located at a non-production location, due to congestion constraints on the project site. The test piles and their corresponding tests were as follows:

- 3 axial compression piles designated TP-2, TP-3 and TP-4 (75 feet in length)
- 2 axial tension piles designated TP-5 and TP-6 (75 and 80 feet in length)
- 2 lateral tests on piles designated TP-1 and TP-5 (75 and 80 feet in length)

All axial load testing was conducted in general accordance with ASTM D1143-07. The results of the three static axial compressive tests were evaluated utilizing the Modified Davisson method, which was considered appropriate for cast-in-place piles such as the micropiles used on this project.

The chart listed below presents the results of the analysis for the load tests for this project:

Table 1. Results of the analysis for the load tests for this project.

Compression Load Tests Summary

Test Pile	Pile Depth (ft.)	Pile Design Diameter (in)	Maximum Loading (kips)	Ultimate Capacity (kips)[1]	Allowable Capacity (F.S=2.0)	Allowable Capacity (F.S=2.5)
TP-2	75	10	200	200	100	80
TP-3	75	10	200	200	100	80
TP-4	75	9	145	130	65	52

1. Based on IBC 2012-1810.3.3.2

Tensile Load Tests Summary

Test Pile	Pile Depth (ft.)	Pile Design Diameter (in)	Maximum Loading (kips)	Net Axial Deflection (in)	Ultimate Capacity (kips)[1]	Allowable Capacity (F.S=1.5)	Allowable Capacity (F.S=2.5)
TP-5	80	9	126 [2]	1	113	75	45
TP-6	75	10	98	0.8	98	65	39

1. Ultimate capacity analysis based on IBC 2012-1810.3.3.1.5
2. Net axial deflection of 1.3 inches at maximum loading

Lateral Load Tests Summary

Test Pile	Pile Depth (ft.)	Pile Design Diameter (in)	Maximum Loading (kips)	Net Lateral Deflection (in)	Ultimate Capacity (kips)[1]	Allowable Capacity (F.S=2.0)	Allowable Capacity (F.S=2.5)
TP-1	80	9	22	0.5	22	11	8.8
TP-5	75	10	15	1	15	7.5	6

1. Ultimate capacity analysis based on IBC 2012-1810.3.3.2

Source: Terracon Consultants, Inc.

Micropiles were chosen for this project for several reasons. First and foremost was the absence of noise and vibrations during the installation process. Most of the project was to take place while classes were in session. The project itself was located nearly in the center of campus so any noise and vibrations such as pile driving would produce, was unacceptable to the owner.

Another serious issue concerning vibrations, is that many of the buildings near the project are unreinforced masonry. This is an issue throughout the Charleston peninsula and surrounding historic areas. Many of the structures referred to survived the 1886 earthquake and have been under serious stress from that event for over 130 years. It is simply not possible to determine over a large area whether the structures can withstand extensive vibrations, given their overall condition. Alternate forms of foundation support such as micropiles and auger cast piles eliminate the concern for serious vibratory loads.

As stated above, the final structure will be a combination of new construction and upgrading the existing structure. The original project documents called for micropiles to be constructed beneath the original structure to bring that building up to modern codes and to support the vertical expansion loads. Auger cast piles were originally shown on the contract drawings to support the new construction portion of the structure. The designer basically only considered the head room of the two phases of the project. Simply put, they felt the existing structure could not support the equipment required for auger cast, but outside the structure, there was unlimited headroom and they believed the auger cast could be installed cheaper than micropiles.

Before the final documents were completed, the micropile contractor offered a design-build option that utilized micropiles instead of auger cast for the new construction as well. This method was accepted for several reasons. The number one reason was that it was cheaper overall to use micropiles. The second consideration was the site was extremely small making it very difficult to move a crane around for the auger cast option. Storage and disposal of earthen spoils would also be problematic due to the small surrounding streets, especially when students were present. The last consideration was that the overall load requirements were easily within the capabilities of the cased micropiles proposed for all axial as well as lateral loads. Early load testing provided test results which made acceptance of the micropile option an easy decision for the structural engineer.

In the end, 149 micropiles were installed on the outside of the existing structure and 154 were installed on the inside. The piles installed on the outside of the building were 10-inch diameter piles extending into the marl to a depth of 75 feet below grade with a 10 inch casing installed to a depth of 5 feet from the top of the pile. The 148 micropiles installed on the inside of the structure were 9-inch diameter extending into the marl to a depth of 80 feet from the surface with no casing.

The micropile installation was considered a success for this project for several reasons. The micropile portion of the $45M project was the only sub-contract efforts that were completed on time with no additional change orders. This was an extremely confined workspace as well as a very complicated work sequence. Being on time and on budget was noticed by not only the professionals directly associated with the project, but also by the entire local Engineering/Construction community. The fact that there was no excessive noise, vibrations or significant traffic congestion associated with daily spoil removal, insured that micropiles will continue to be considered the standard deep foundation support system throughout this historic city when similar site conditions are present.