SUPPORT OF THE MORRIS ISLAND LIGHTHOUSE USING MICROPILES

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

HISTORY OF THE MORRIS ISLAND LIGHTHOUSE (MIL)

The Morris Island Lighthouse is located between the Jetties leading to the Charleston, South Carolina harbor and Folly Beach, South Carolina. The present structure is the third lighthouse to occupy this location. The first navigational aid was erected in 1673 and consisted of a raised pan filled with pitch, which was set afire at night to guide early ships. The next structure was built in 1767 and constituted the first real lighthouse, standing 42 feet in height.

In 1838 a second lighthouse was built on the site. It measured 102 feet tall and featured a revolving light. This structure lasted until 1862 when Confederate troops destroyed it to deny its use to Union troops as a lookout during the War of Northern aggression. Navigators steered these waters without a lighthouse for nearly a decade until 1876, when the current structure was built under the direction of the U.S. Army Corp of Engineers. A review of documents authored by Peter C. Hains, Major of Engineers, U.S. Army indicate the foundation of the new lighthouse consisted of 264 wooden piles (15" yellow pine, of unknown length, but possibly as much as 56 feet long). On top of these piles a "grillage" was constructed and a concrete cap, approximately 11 feet in height was built to transfer the weight of the lighthouse to the piles and ultimately to the bearing soil strata below. In 1886, the Charleston area suffered a major earthquake (7.6 magnitude). Major damage was done throughout much of the area including a slight "list" of the lighthouse to the northeast. It is said that the cast of the beacon was reduced from 18 miles to approximately 6 miles, causing much distress to navigators until the beacon platform was re-leveled. This list of the tower structure is evident to the present day.

The current lighthouse structure was originally built approximately 1200 feet from the shoreline of the Atlantic Ocean. Over the years the Corp of Engineers have undertaken several programs to aid navigation and to keep the Charleston harbor open to increased shipping demands. Significantly, around the turn of the last century a pair of Jetties were constructed, drastically changing the approach direction for ships entering the Charleston harbor. In subsequent years the harbor began to experience accelerated siltation. In an effort to prompt a natural flushing mechanism for the harbor, an opening of several hundred yards across was accomplished near the shore intersection with the South Jetty. This breach, known locally as "Dynamite Hole" partially met its intended purpose, however the new flow of water began to rapidly scour the ocean face of Morris Island, located directly South of the "hole". Within a few short years, the beach of Morris Island was eroded to such an extent that the MIL now sits surrounded by the sea.

The original lighthouse was designed so that the wooden piles would always be below the existing water table of Morris Island. The theory being that the piles would not rot or deteriorate as long as they were continually submerged. The scouring of the soil

[1]President, 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

surrounding the structure resulted in the piles being exposed to salt water, but more importantly, to water born parasites such as ship worms or tereda worms, as they are locally known. The introduction of these organisms led to severe deterioration of the original support piles. The deterioration of the lighthouse structure and foundation led to the current effort to save the lighthouse from the harsh Atlantic environment. An organization known as “Save the Light” bought the structure in 1999, and is spearheading the effort to “Save the Light”.

SAVE THE LIGHT, INC. (STL)

Save the Light, Inc. was formed in 1996. Its sole purpose is to facilitate the saving of the Morris Island Lighthouse structure. The lighthouse function was discontinued in 1962 by the U.S. government. The structure was sold to a private owner and in subsequent years it began to show the results of decades and neglect as the harsh environment of the ocean took its toll. Although the light has long been extinguished, the lighthouse itself represents an intricate and permanent place in the history and culture of the local area. This particular lighthouse has survived the ravages of nature, the torment of war and the follies of man as it has stood sentry for the community that is James Island and the Charleston area. It is more than a symbol, it is a major part of the local heritage and maritime culture.

In the months and years after it acquired the light, STL, Inc. has worked to raise the funds needed to restore this structure both structurally and in time, aesthetically. The repairs completed through 2008 represented Phase I of those repairs. Phase I basically cleaned up decades of early efforts and repairs aimed at delaying the inevitable deterioration around the structure. In the fall of 2009, STL, Inc. requested proposals from pre-qualified firms to develop a design/build concept to preserve and strengthen the existing foundation. After several months of receiving and reviewing these proposals, a design/build team was selected and a contract of approximately $2 million was executed.

DESIGN ANALYSIS

The design of the project was begun with several unknown properties. Key answers needed before a final design could be completed included: determining the weight of the structure; understanding the design intent of the original foundation; the condition of the original foundation components and the strength of the existing materials; the condition of the tower structure and its impact on the intended repairs, and other conditions that may become evident as the project continued.

The initial exploration of the structure yielded much information. Key among these findings were the weight of the structure (4400 tons), the average strength of the concrete foundation (3000 psi ave), the strength of the bricks (2300 psi ave), and a general understanding of the original design intent as well as the general condition of the original support structure.

Although many of the properties of the existing foundation remain a mystery, enough became known to lead the design/build team to the conclusion that the existing foundation piles were deteriorated to the point that they could not be counted on to support the structure into the future. It was therefore decided that Micropiles would be

installed with the intent that they carry 100% of the weight of the structure, thus discounting any residual contribution of the original foundation piles. Another key element investigated was the soil profile immediately adjacent to the structure. Although the original designer did accumulate some knowledge of this profile, the team lacked enough modern technical information and/or description to confidently proceed with the final design. Current and modern soil boring information was a critical element for this project.

The final design assumptions were accumulated based on information obtained from the site by the design/build team. Due to the complexity and logistics of the site, every member of the team was involved in gathering this critical information.

FINAL FOUNDATION DESIGN

As outlined above, several key design elements became clear after modern soil borings were obtained and as the site was investigated. This information led the designers to conclude that the structure could be supported on Micropiles and the load of the structure could be transferred to those piles. A theoretical pile length was calculated based on soil data collected and a test pile program was developed to confirm these assumptions.

An inspection and testing program was developed to monitor the work as it progressed. Key elements of this program included the test pile program, installation of monitors on the existing tower and existing foundation system, and the installation of tilt meters around the structure. These instruments enabled the geotechnical and construction services engineer to monitor and understand what was going on within and without the structure, long before such information would normally be readily apparent.

A key concern of everyone involved with the project was the tower structure's ability to withstand the installation of the new support system. Much attention was given to the condition of the existing tower as well as the forces that would be placed on it during construction. The Micropile system used on this project produced virtually no adverse loads or impact to the existing structure.

The final design of the project included the installation of 68 micropiles with an allowable compressive design capacity of 75 tons per pile. The piles were to be placed on a predetermined spacing which would allow the load of the existing structure to be transferred and supported by the new piles. In addition to the new pile support system, filter fabric and subsequently sand was to be placed in the space between the existing structure and the sheet pile wall constructed under Phase I of the restoration process.

CONSTRUCTION

The significance of saving time was crucial to the ultimate success of the project as crews were in a race with the calendar with anticipation of the fall hurricane season. Early in the procurement process everyone involved recognized the very real possibility that the lighthouse structure may not have the ability to survive another major storm. At the very least, it was known that construction would be difficult or impossible during the fall storm season. For this reason, every effort was made to maximize the time spent at the site. Crews were set up working 3, 13-hour days per week, per crew. With two separate crews operating on a rotating schedule, there was work going on six days a

week with Sundays off. This held true throughout the project and was instrumental in completing the project ahead of the projected schedule and “beating the clock” to the storm season.

The gathering of core samples and the coring in anticipation of the Micropiles continued until a jack-up barge could be mobilized to the site. On June 7, 2010, the marine contractor mobilized and lifted the barge on the site and immediately began to place sand into the cell. The buildup of sand enabled the placement of Micropile equipment into the cell and the test pile program was begun by placing 2 test piles and appropriate reaction piles. After sufficient curing of the test piles was completed, a load test was conducted by the geotechnical engineer and the final pile design was confirmed.

The Micropile system selected for this project was the TITAN system, manufactured by Ischebeck. Titan Micropiles consist of a continuously threaded, hollow reinforcing rod as the load carrying steel member, together with a grout body of Portland cement grout with a minimum compressive strength of 5000 psi. This system allows for the transfer of tensile and compressive forces from the friction between the threaded rod via the grout body and the soil. The grout body functions as a conduit of the radial friction with the soil, provides stiffness against buckling, and corrosion protection for the steel.

After the pile length and diameters were determined and verified, the placement of production piles began. Production rates varied somewhat due to several reasons. Chief among the limiting factors was the weather and the ability to re-supply the construction supplies. Everything had to be transported from land by barge and/or tug boat, usually on a daily basis. Wind, weather and the resulting wave action greatly affected and hindered this operation. Items needing transport included fuel, several tons of steel rods, hundreds of tons of cement and surprisingly enough, thousands of gallons of fresh water. One of the most frustrating occurrences on the project was when, although surrounded by the Atlantic Ocean, work came to an abrupt halt when crews ran out of fresh water used in the Micropile installation.

The Micropiles were installed on two concentric rows around the base of the lighthouse structure. They were placed in a staggered fashion to insure that no eccentric loads were placed on the lighthouse during construction that would destabilize the existing support. The installation of Micropiles actually became one of the least problematic efforts on the project.

The procedure for installing Micropiles is in fact the system’s greatest advantage. The process utilizes equipment that can be mobilized and placed on sites where normal driven pile equipment is not practical. While driven piles are certainly possible over water, on projects such as the Morris Island Lighthouse, mobilization of the equipment needed would have been prohibitive. A second and equally important advantage of the Micropile system is the total lack of vibration which would have been present had driven piles been attempted. Micropiles in general are not considered as a method to replace driven piles, but instead are traditionally used where mobilization, vibration, accessibility and even noise are major limiting concerns for the given project.

Micropiles are however being used on larger and more complex projects. The strengths being achieved are becoming more and more predictable and are far more substantial than in the past. Verifiable and repeatable tests have yielded compressive loads of well over 150 tons in compression, 50 tons in tension and lateral loads of 9 to 11 kips in the Charleston area. As with any deep foundation system, these load

characteristics are site specific and should only be relied on with respect to the soil characteristics of a given site.

The procedure for placing Micropiles is fairly straight-forward. A threaded, hollow rod with a drill head is rotated into the ground. As the rod is extended down, a drilling grout mixture is pumped through the hollow rod thus removing the coil cuttings from the hole. When the rods have been drilled to the design depth, a structural grout is pumped through the rod. This grout enters the hole at the bottom and lists the lighter drilling grout up and out of the hole. When all of the drilling grout is gone, the Micropile is basically complete with a steel rod in the center of a structural grout column.

After the final Micropile was placed, the entire cell was filled with sand to a point approximately 18 inches below the top of the existing sheet pile wall. The sand was completely surrounded by filter fabric to ensure the sand would not be eroded by the surrounding waters. The filter fabric was then capped with excess grout castings, left over from the Micropile installation. Future work on the restoration effort will include placement of additional rip-rap around the structure as funds become available.

The final component of Phase II was the construction of a permanent dock platform to be utilized in the future. After the dock was completed, the jack-up barge was lowered and demobilized on Friday, July 30th, thus ending construction of Phase II of the restoration of the Morris Island Lighthouse.