**MICROPILE FOUNDATION REPAIR AND UNDERPINNING, ARTS AND SCIENCE MUSEUM, UNIVERSITY OF PUERTO RICO, MAYAGUEZ**

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Authored by: John R. Wolosick, P.E.

Eduardo Bonar, B.S.C.E.

Peter J. Nufer, P.E.

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John R. Wolosick, PE[1], Eduardo Bonar, B.S.C.E.[2], Peter J. Nufer, PE[3]

## INTRODUCTION:

An historic structure at the University of Puerto Rico (UPR), Mayaguez was damaged during Hurricane George in 1998. George was the largest hurricane to strike Puerto Rico since Hurricane Hugo in 1988. While the damage from Hugo was concentrated mainly around San Juan, George struck the island at the east central coast around Roosevelt Roads and passed directly over the entire island. Mayaguez is located on the west central coast, and is the home of the UPR. Damage from wind and rain in Mayaguez was severe.

The Arts and Science Museum was originally constructed around 1930 as St. Mary's Hospital. The building was converted to the Institute of Tropical Agriculture in 1952. The building later served as the Office of Academic Administration. The original structure is shown in Figure 1.

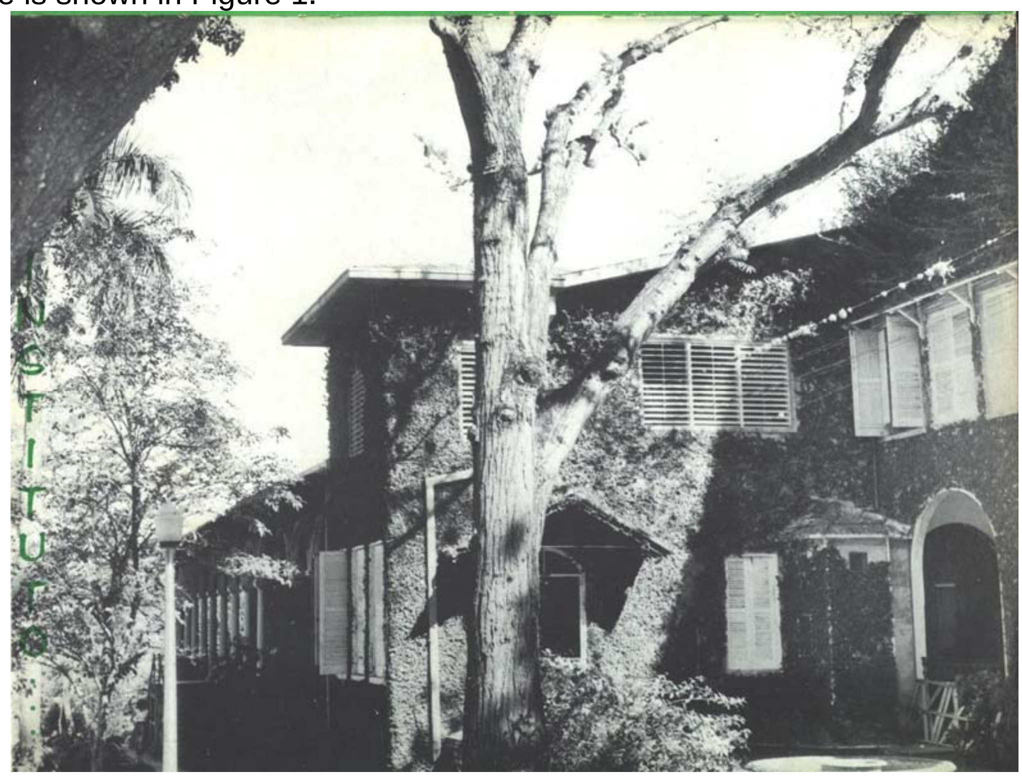


**Figure 1**

[1] Director of Engineering, Hayward Baker Inc., 515 Nine North Court, Alpharetta, GA 30004 USA, phone(770)442-1801, fax(770)442-8344, jrwolosick@haywardbaker.com
[2] Senior Project Manager, Gabriel Fuentes, Jr. Construction Company, P.O. Box 363825, San Juan, PR 00936-3825, phone(787)785-9065, fax(787)740-4366, bonar@fuentespile.com
[3] Senior Project Manager, Hayward Baker Inc., 515 Nine North Court, Alpharetta, GA 30004 USA, phone(770)442-1801, fax(770)442-8344, pjnufer@haywardbaker.com

The entire roof of the structure was completely torn off by the hurricane, leading to total destruction of the contents of the building. Figure 2 shows the structural damage following the hurricane. Reconstruction plans required several years. Construction was begun in 2005. The renovation design required new and separate support of the proposed new roof structures since it was determined that the original walls could not support the proposed loadings. Due to the confined access as well as low headroom conditions at many locations, micropile foundations were selected to support the new roof structures.

The micropile foundations were provided as a design/build service by Hayward Baker Inc. and Gabriel Fuentes, Jr. Construction Company, Inc.

**Figure 2**

## FOUNDATION INVESTIGATION AND GEOLOGIC SETTING:

Nine borings were drilled to investigate the foundation conditions. An old fill layer, about 3 feet (1 m) to 6 feet (2 m) thick was found near the surface. Below the fill, highly plastic silt with high moisture contents averaging about 45 percent, were found at the site. The shear strength of the silts was low, generally around 800 psf (38 kPa). No groundwater levels were detected by the borings. Post-grouted micropiles were recommended by the Geotechnical Consultant.

## FOUNDATION CONSTRUCTION:

The micropile foundation construction was initiated at the beginning of the reconstruction project. A total of 62 micropiles were installed. Most of the micropiles were constructed in limited headroom conditions. See Figure 3 for the plan view micropile layout. Access to the main level piles was obtained by lifting the drill rig with a crane and setting it within the roofless building. The basement piles were accessed by tramming the drill rig down the basement hallway.

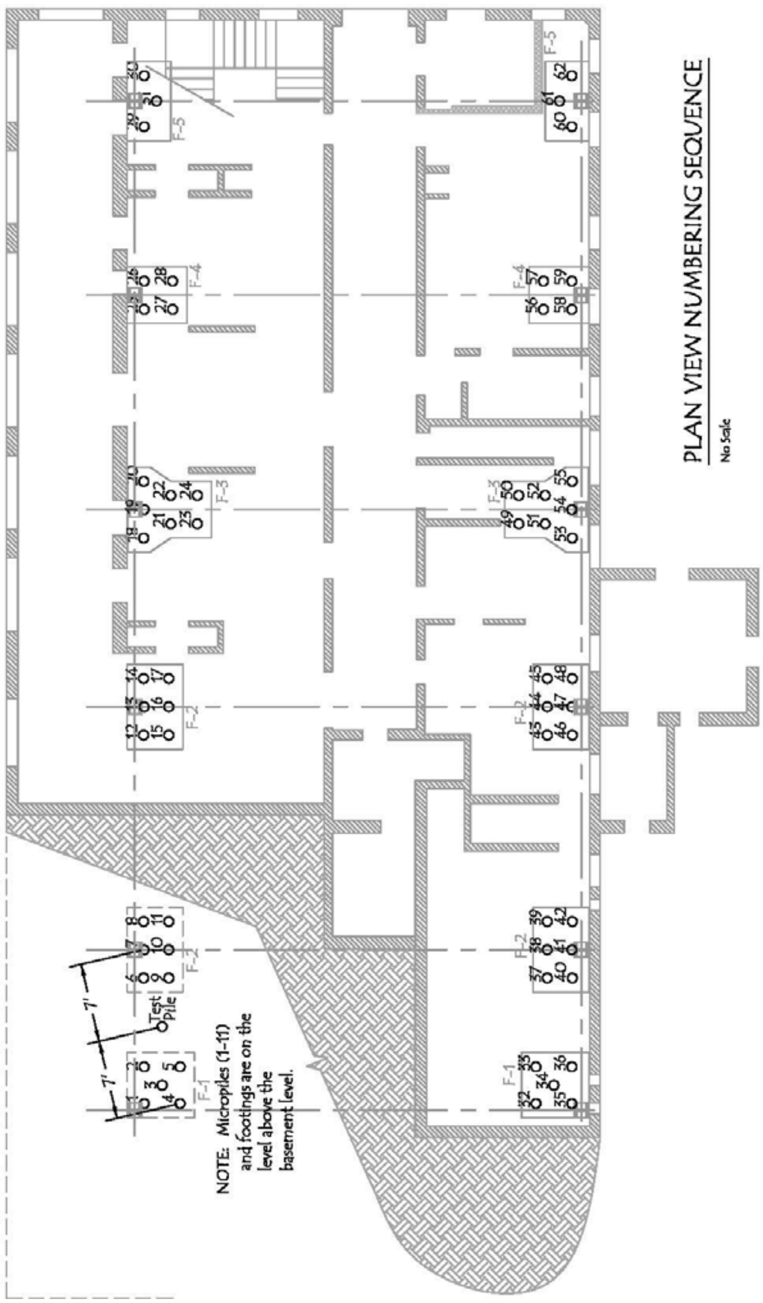


**Figure 3**

Design loads for the micropiles were 25 tons in both compression and tension. Hollow stem augers were used to drill the piles. See Figure 4 which shows drilling in low headroom conditions. After drilling, the piles were tremie grouted using a neat cement grout with a water/cement ratio of 0.45. The micropiles were reinforced with a full-length Grade 95 (655 MPa) #11 steel bar. The bars were placed in 5 foot (1.5 m) sections in the low-headroom conditions and coupled together as they were placed down the drill hole. Multiple sleeve post-grouting pipes (tubes-a-manchette) were attached to the steel reinforcing bar as it was lowered in the drill hole.


**Figure 4**

In addition, for simple attachment to the piles caps, a thin-walled steel pipe, 10 ft. (3 m) long, was placed into the wet grout at the top of each pile. This pipe acted to confine the grout around the reinforcing bar and provided a tidy pile butt. A bearing plate was also included since the piles were also designed to resist uplift forces. See Figure 5 for a typical micropile cross-section.

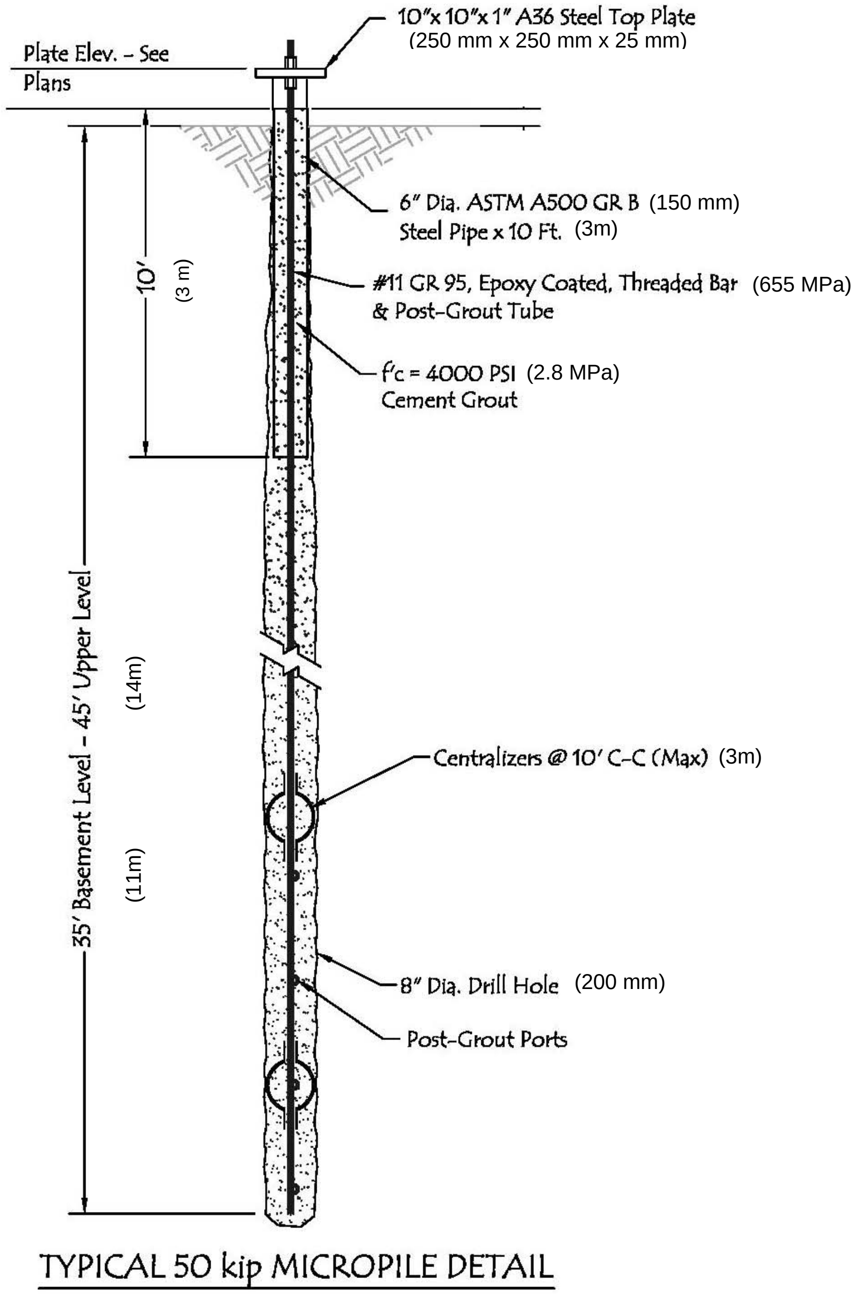


**Figure 5**

Figure 6 shows a typical pile cap layout, prior to excavation for the cap. The Figure shows the drill hole, the post-grout tubes with PVC petcocks at the top, the full-length steel reinforcing bars and a short piece of bar that is wired to the 10 foot (3 m) long, thin-walled steel pipe. This wire suspends the steel pipe at the top of the pile.

**Figure 6**

Post-grouting of the piles was prescribed to obtain the design loads in the soft silt utilizing an 8 inch (200 mm) diameter drill hole and a 25 foot (7.6 m) long bond zone, located below the fill layer. Therefore, the total pile lengths were 35 feet (10 m). The post-grouting was generally performed the day after pile installation. Approximately 5 cubic feet (142 liters) of cement grout was injected, using a high-pressure hydraulic piston pump, from the top of the pile. The piston pump operated off of the hydraulics of the skid-steer loader. The loader was used to carry the pump from pile cap to pile cap. Typical post-grouting break-out pressures were 300-350 psi (21-25 bar). Continuous pumping was observed at about 250 psi (17 bar). See Figure 7, which shows the post-grouting procedure.

The piles were installed using an electric powered Klemm 704 drill rig. Electricity was provided by a diesel powered generator located outside the building structure. The grout was mixed and pumped using a Colcrete 10/10 colloidal mixer with a moyno pump.

**Figure 7**

Figure 8 shows excavation for the pile cap and the final micropile configuration after the bearing plates have been attached.

**Figure 8**

**INITIAL LOAD TESTING:**

An initial load test, utilizing drilled and post-grouted tie-down anchors was completed on a sacrificial pile, located within the building on the first floor. Production micropiles were used for the reaction anchors to support the test beam. Therefore, the tension resistance of the piles was also proved by monitoring the tension reaction piles. See Figure 9 for an illustration of the test set-up.


**Figure 9**

The compression test was initially loaded to two times the design load and then rebounded to measure permanent set (0.09 inch, 2.3 mm). Then the pile was loaded to 2.5 times the design load as required by the specifications. A graph of the test is shown on Figure 10. The Davisson criteria line is shown on the graph. This criteria was intersected at 2.5 times design loading at a total deflection of 0.435 inch (11 mm).

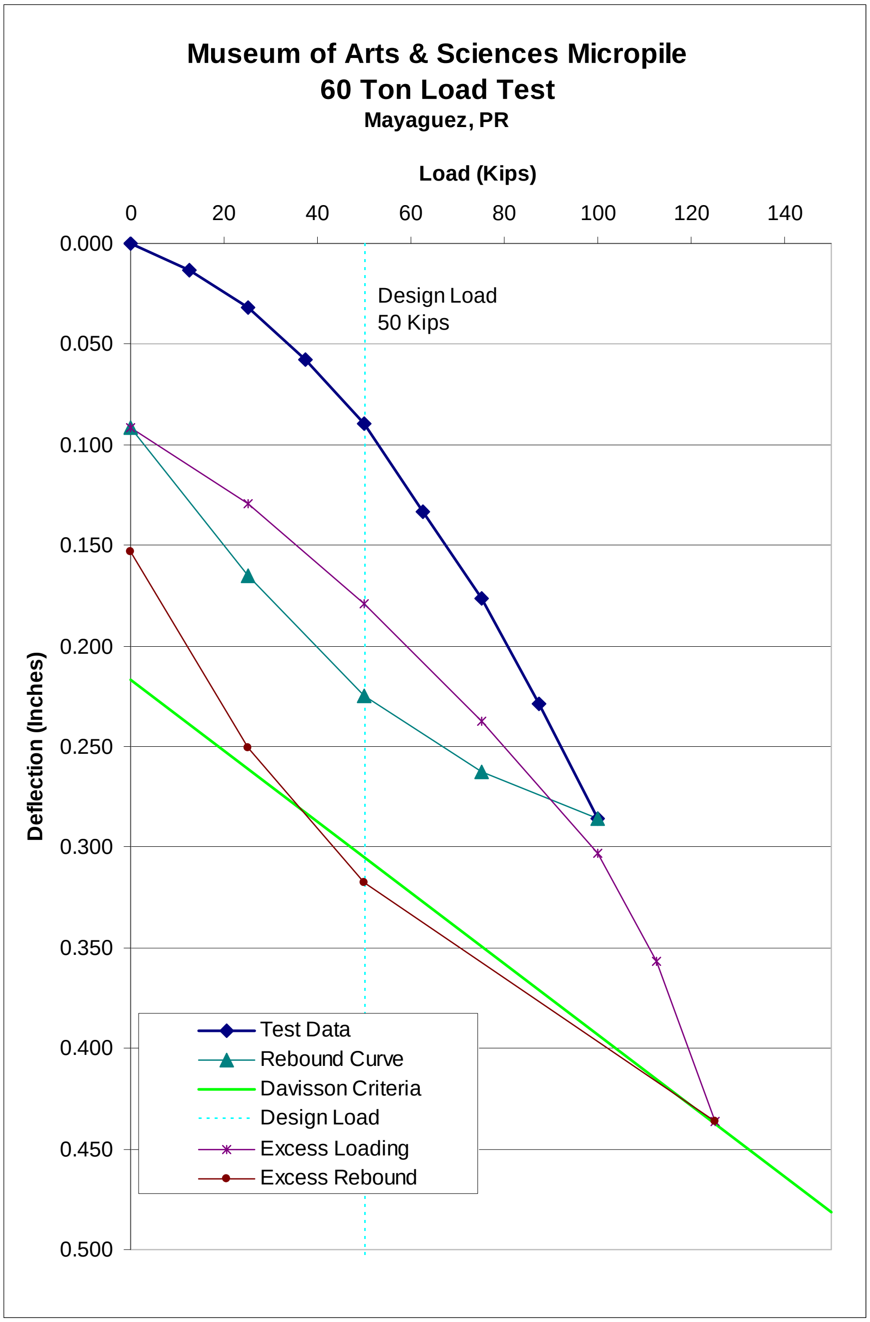


**Figure 10**

**CONCLUSIONS:**

The micropiles were completed during the early winter of 2005. Micropiles provided the ideal foundation installation in the confined space and limited access environment to support the new columns and roof structures. Micropiles also allowed for the installation of new columns adjacent to the existing structures with minimum disturbance of the existing shallow foundations. The new columns and roof structure are shown in Figure 11.

**Figure 11**

Figure 12 is an artist's rendition of the final construction. The completed building will incorporate the old 1930's structure with a modern, more hurricane resistant roof structure. The use of micropiles allowed confined access and installation of new structures without disruption of the existing foundations and walls.

**Figure 12**

**Acknowledgements:**
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General Contractor: E. Montalvo Silva Construcciones, Inc.
Geotechnical Engineer: A. Manuel Gutierrez, Ph.D., P.E.
Foundation Contractors: Hayward Baker Inc. and Gabriel Fuentes Jr. Construction Co.

**References:**

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2. “Construccion del MuSA”, Antonio A. González Quevedo, PhD, PE, Director Oficina de Investigación Institucional y Planificación, Recinto Universitario de Mayagüez, Universidad de Puerto Rico at Mayaguez.