

**MICROPILE APPLICATION FOR SEISMIC RETROFIT PRESERVES  
HISTORIC STRUCTURE IN OLD SAN JUAN, PUERTO RICO**

by

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**ABSTRACT**

As part of planned renovations and alterations to the existing U.S. Post Office and Courthouse (USPO&C) in Old San Juan, P. R., a seismic retrofit of the existing timber pile supported structure consisting of supplemental drilled micropiles was specified. This retrofit was required to bring the building into conformance with the 1987 upgrade of the Puerto Rico Building Code relative to seismic design. This paper presents a case study illustrating design details, construction procedures, and load testing data.

**INTRODUCTION**

The existing U.S. Post Office and Courthouse building in Old San Juan, Puerto Rico, was originally constructed in 1914. A major addition followed in 1940, and the structure represents an important historical landmark in the 500 year old harborfront area of the city (Figure 1). The building is founded primarily on Raymond Step Taper piles and timber piles and is underlain by potentially liquefiable fine silty sand.

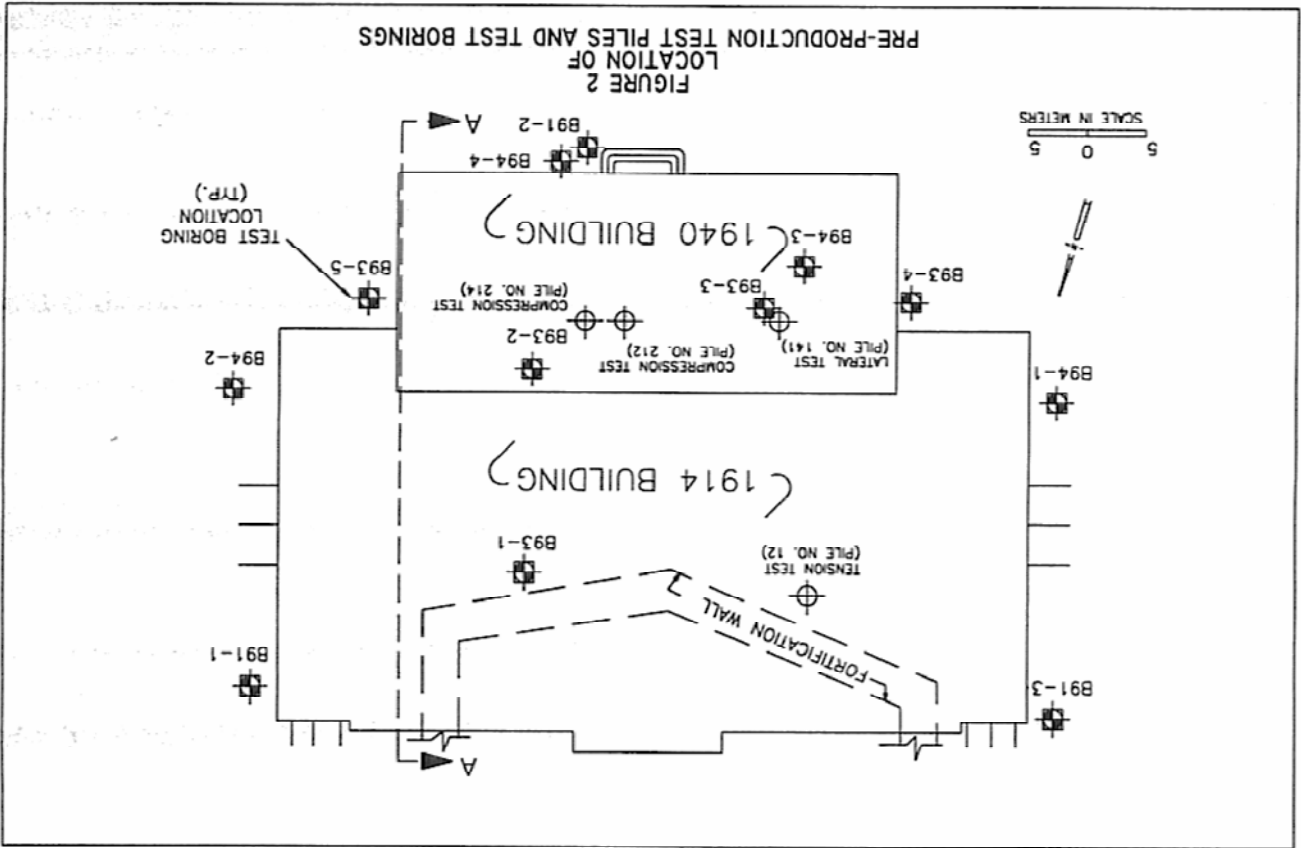
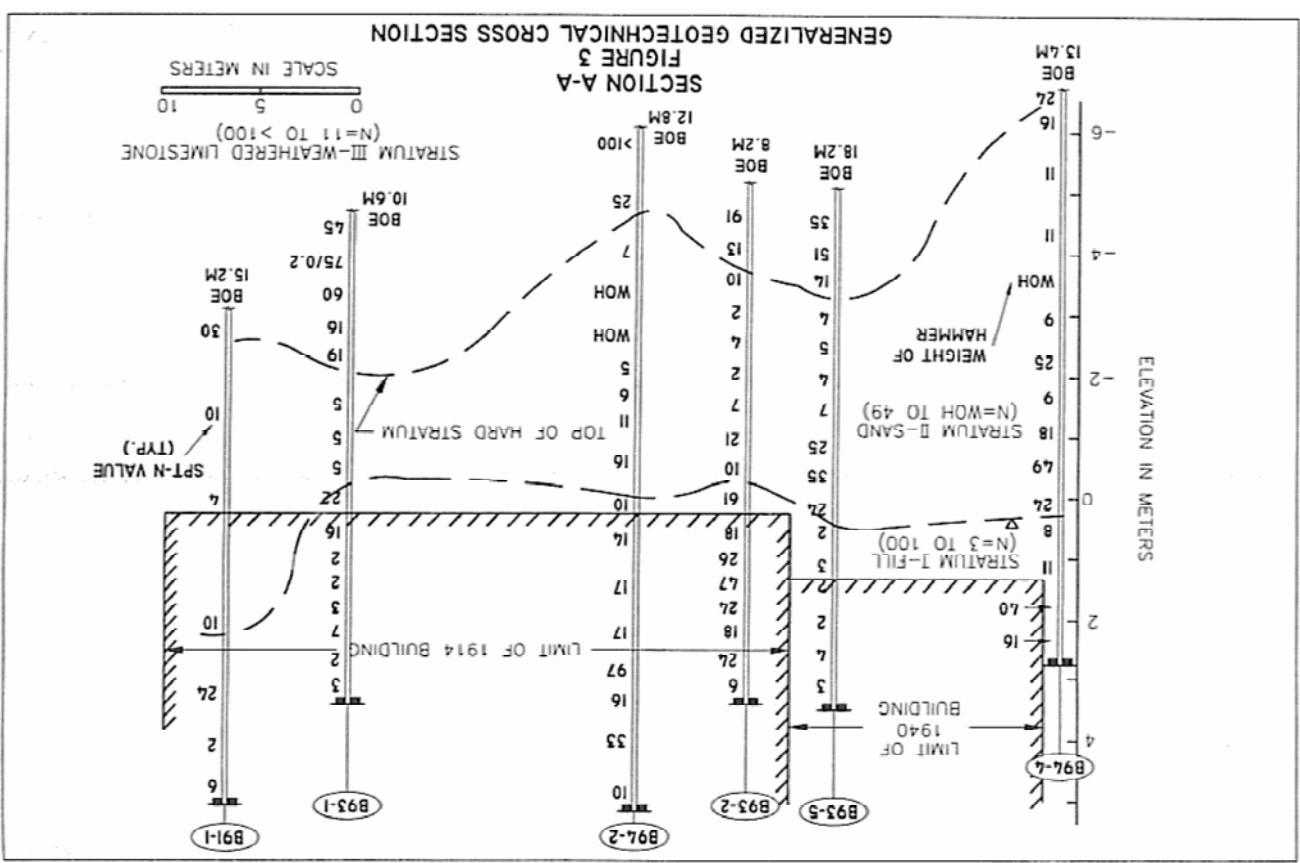
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Stratum III: Below the sand stratum is a layer of weathered limestone and stiff clay. The stratum was described as medium to very hard, sandy to silty clay and clayey silt. This clay stratum was referred to in the contract documents as the "Hard Stratum" and was anticipated as the bearing stratum for the micropiles. SPT "N" values ranged from 11 to greater than 100 blows per 0.30 m.

Groundwater levels were anticipated to range in depth from 2.4 to 4.2 m (8 to 14 ft.) below existing ground surface level.

The ground surface elevation around the USPO&C varies between approximately El. 7.3 m (24 ft.) on the north side of the site to El. 2.6 m (8.5 ft.) on the south side.

#### Site Conditions

The structure is surrounded by very narrow streets which are frequented by many tourists. The building is six stories tall and is a massive masonry wall bearing structure with internal columns. The 1914 wing is founded partially on massive piers (northerly section) and partially on timber piles. The timber piles were driven to the top of Stratum III. The 1940 addition appears to have been founded on Raymond piles.

The micropiles required for the seismic upgrade were all located inside the building, where access was often severely limited, and work was conducted in low headroom conditions. During installation of the foundation piles, a number of site specific challenges were faced by the micropile contractor, including:

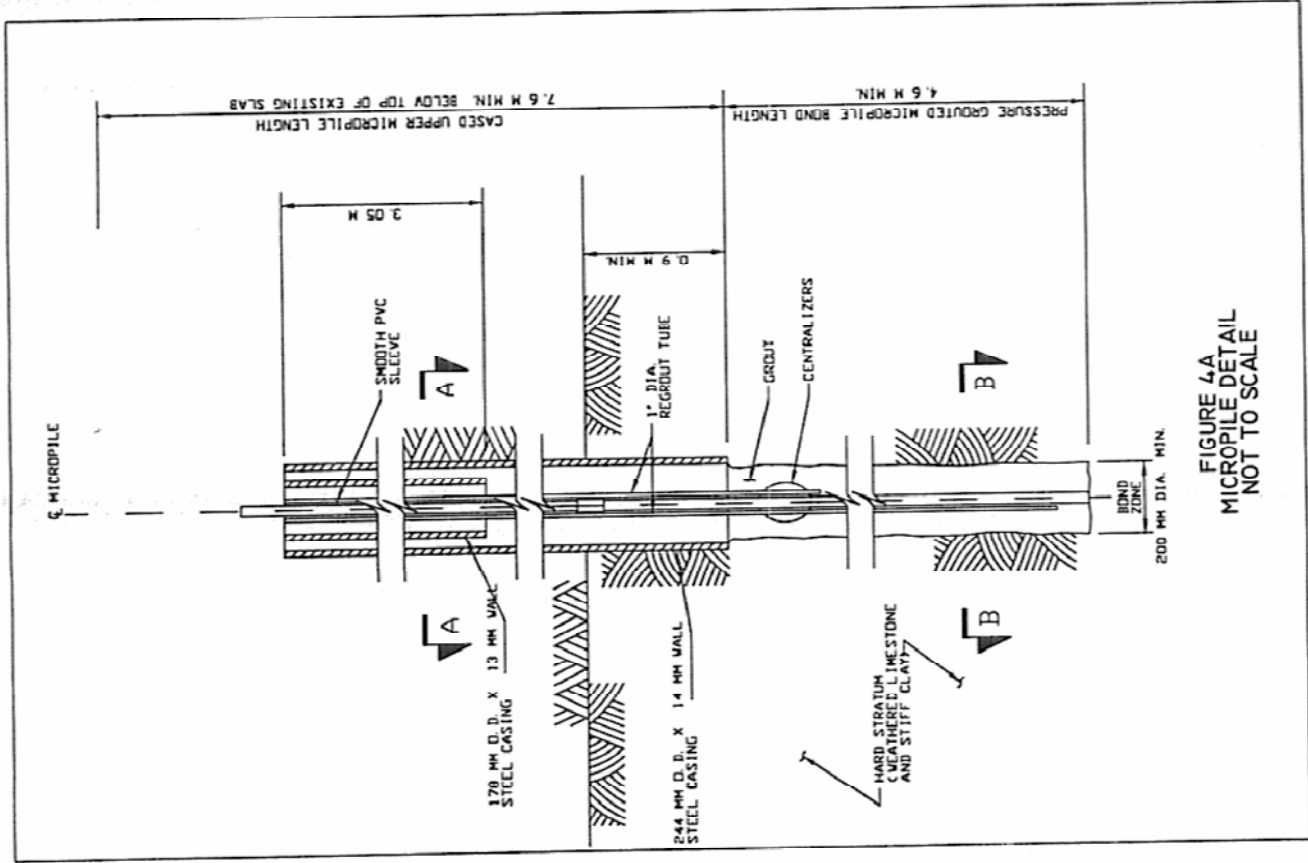
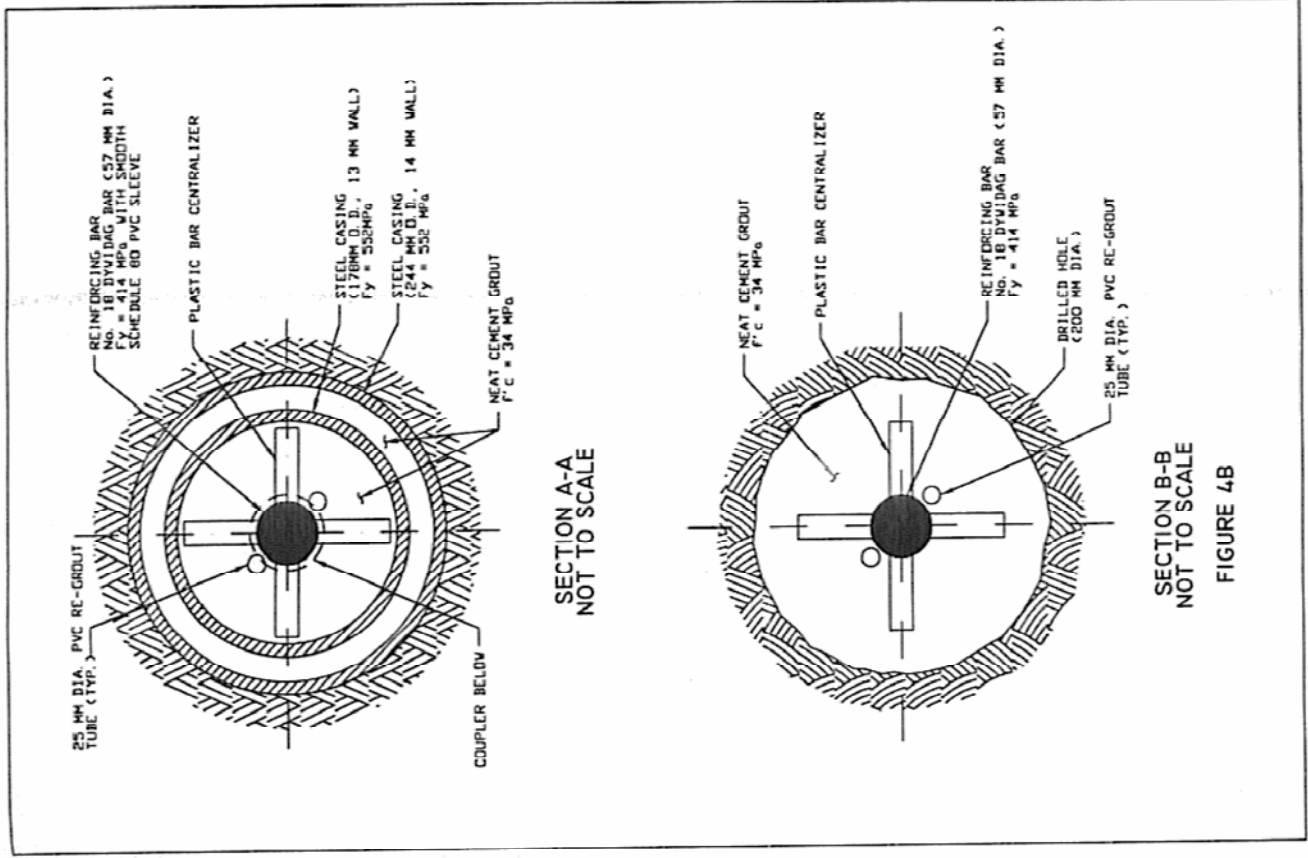
- Simultaneous overhead demolition and site clearance by another contractor;
- Encountering an old basalt block fortification wall dating from the 1600's;
- Existence of numerous other "obstructions" such as the existing 406 mm (16 in.) diameter timber piles, 1.8 m (6 ft.) thick pile caps, masonry footings and the remains of walls and footings from a demolished customs house building; and,
- Water rationing during a period of severe local drought and high ambient temperatures, which severely impacted drilling and grouting activities.

These challenges were each overcome by judicious initial design, and a flexible and responsive construction effort.

#### MICROPILE DESIGN

To date, micropiles have been infrequently used outside California when significant lateral loads, such as the 44 kN (5 ton) design capacity specified for this project, are anticipated. Conventional piles with a larger section modulus, such as steel H, concrete-filled steel pipe, or precast concrete piles have been selected. However, due to the special technical and logistical requirements of this project, micropiles proved the most appropriate choice. Special design considerations and the following criteria were stipulated by the Owner's consultant:

- The piles had to have a minimum outside diameter of 241 mm (9.5 in.);
- The pile design was to assume a "pinned connection" to the pile cap. Lateral pile load capacities and bending moments are affected by the type of connection. A pinned pile top connection (free to rotate) will have larger lateral deflections but the pile will experience smaller bending moments than a fixed (restricted against rotation) connection. Based on the Owner's consultant's analysis of existing piles at the site, they specified a pinned connection. The maximum allowable deflection of the pile subjected to the design lateral load of 44 kN (5 tons) at the top was 13 mm (0.5 in.);
- The micropile outer steel casing had to remain in-place and had to be socketed at least 0.9 m (3 ft.) into the "Hard Stratum" underlying Stratum II. However, the bottom of the steel casing had to be terminated no less than 7.6 m (25 ft.) below the top of the existing floor slab;
- The steel casing had to have a minimum wall thickness of 13 mm (0.5 in.); and, in the design calculations the wall thickness of the outer steel casing had to be reduced by 3 mm (1/8 in.) to allow for potential corrosion of the pile;
- The top 3.05 m (10 ft.) of the reinforcing steel in the micropile had to be encased by a smooth PVC sleeve sealed on both ends so as to preclude intrusion by the grout. (i.e. to develop a "free length").



- The 28-day compressive strength of the grout used in the piling could be no less than 34 MPa (5,000 psi); and,
- The maximum yield stress of the steel used in the micropile was limited to 552 MPa (80,000 psi).

As shown on Figures 4A and 4B, the approved design, prepared by Structural Preservation Systems and its subconsultants, incorporated a 244 mm (9-5/8 in.) diameter outer steel casing which was socketed a minimum 0.9 m (3 ft.) to the "Hard Stratum." Below the steel casing, an approximate 240 mm (8 in.) diameter hole was drilled a minimum of 4.6 m (15 ft.) into this stratum. A No. 18 steel Dywidag reinforcing bar was required for internal reinforcement. Additionally, a 3.1 m (10 ft.) length of 178 mm (7 in.) diameter, 13 mm (0.5 in.) wall thickness, 552 MPa (80,000 psi) yield stress steel casing was required in the upper 3.05 m of the micropile to provide sufficient resistance to lateral loads to satisfy the performance criteria.

While this second 178 mm (7 in.) steel casing is not typical for static micropile design, it was required to keep deflections below the allowable limit for the design lateral load. It was also required to keep the bending and shear stresses in the upper portion of the pile below the required limits.

#### INSTALLATION PROCEDURES

Micropile installation was performed with electro-hydraulic track-mounted drill rigs. The 244 mm (9-5/8 in.) diameter outer casing was drilled in 1.5 m (5 ft.) long sections, using water to flush the drill cuttings. This outer casing was drilled a minimum of 0.9 m (3 ft.) into the "Hard Stratum." A 4.6 m (15 ft.) deep bond zone was then drilled with a 200 mm (7-7/8 in.) diameter roller bit, again using water to flush the drill cuttings.

Once the hole was flushed clean of all drill cuttings, grout was pumped through the drill rods until fresh grout returned to the ground surface. The drill rods were then removed from the pile. The No. 18 Dywidag bar was then inserted into the pile with spacers and regrout tubes securely attached. The 3.05 m (10 ft.) long section of 178 mm (7 in.) diameter steel casing was then inserted into the top of the pile.

After all the steel reinforcing was installed, a pressure cap was screwed onto the top of the 244 mm (9-5/8 in.) outer steel casing, and the pile was pressurized to a maximum of 0.69 MPa (100 psi).

Grout was mixed in a colloidal mixer, and consisted of Type I/II with a water/cement ratio of 0.45. A retarder, Pozzolith 300R, was added at the rate of  $0.12 \times 10^3 \text{ m}^3$  (4 fluid oz.) per 0.44 kN (100 lbs.) of cement to ensure sufficient workability in the challenging site conditions, featuring high temperatures and long pumping distances.

#### PRE-PRODUCTION LOAD TESTING

Four load tests were conducted prior to production pile installation in accordance with applicable American Society of Testing and Materials (ASTM) standards to confirm the capacity of the installed piles when subjected to twice the design compressive, tensile and lateral loadings.

The contract specifications stipulated the following acceptance criteria for the various types of micropile load tests:

##### Compression Load Test

- Load vs. Movement curve is less than the theoretical elastic compression of the pile, plus 3.8 mm (0.15 in.), plus one percent of the pile diameter in inches;
- Net movement at the pile top is not greater than 13 mm (0.5 in.) following rebound from the maximum test load;
- 150 percent of the design load, 801 kN (90 tons), must reach the top of the Hard Stratum during the maximum test load; and,
- The maximum test load is 1068 kN (120 tons).

##### Lateral Load Test

- Maximum allowable deflection at the top of the pile is 13 mm (0.5 in.) at design load during the last cycle; and,
- Design load is 44 kN (5 tons), the maximum test load is 88 kN (10 tons).

##### Tension Load Test

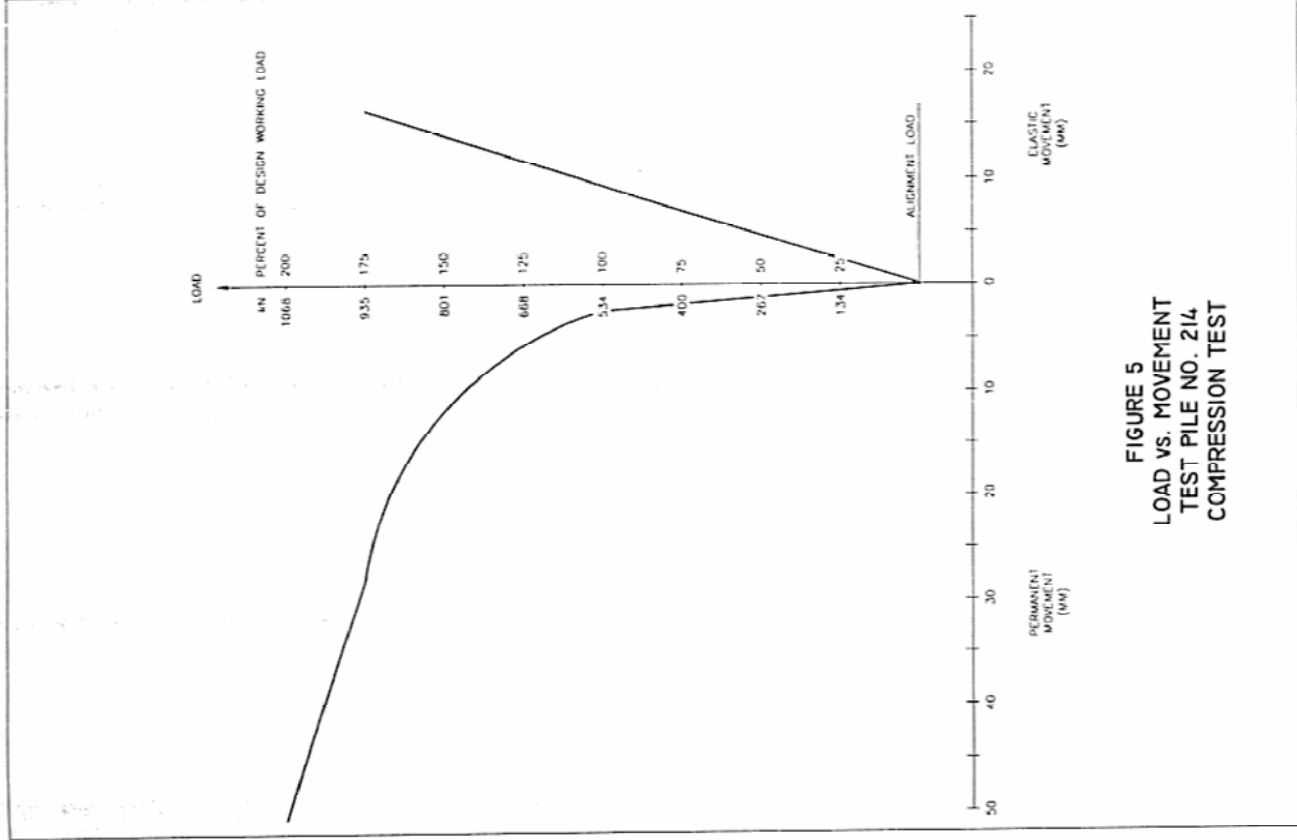
- Net upward movement does not exceed 13 mm (0.5 in.) at the pile head after removal of the maximum test load;
- No continuous upward movement (creep) without increase in load; and,
- Maximum test load is 712 kN (80 tons).

#### Compression Load Tests (Piles 214 and 212)

Pile No. 214, was the first pile installed, and a combination of difficult ground and construction problems resulted in an effective bond zone only 3.4 to 3.7 m (11 to 12 ft.) long. In addition, the global pressure grouting method subsequently used on all piles, (i.e. through the head) was not efficiently applied on this pile. It was, therefore, unlikely that the decompressed grout around the bond zone was effectively recompact during the installation process. Nevertheless, the decision was made to continue with the test, and the pile was loaded to 200 percent of the design load (i.e. 1068 kN (120 tons)) using a 300 ton hydraulic jack and adjacent production piles as reaction piles. After unloading (Figure 5), the movement at the top of the test pile was 52.2 mm (2.056 in.), which was in excess of the specified acceptance criterion.

The pile was then regouted through the post grout tubes, which had been installed in the test pile as a contingency measure. The pile was subsequently re-tested. As shown in Figure 6, the net movement at the top of the pile, following rebound from the maximum test load, 1068 kN (120 tons) was 3.20 mm (0.126 in.). The results of the re-test met the acceptance criteria and the pile was approved as a production pile. A comparison of the permanent movements recorded before and after post grouting clearly highlights the benefits of the post-grouting operation.

A mechanical telltale was installed in the test pile down to the top of the Hard Stratum to evaluate the amount of load reaching there during the load test. Additionally, as a backup to the telltale, the internal reinforcing bar in the pile was isolated from the grout, from the ground surface to the top of the hard stratum. A PVC sheathing was installed over the reinforcing bar this entire length. A coating of grease was applied to the sheathing prior to installation to reduce the bond between the grout and the sheathing. Below each reinforcing bar coupling in the pile, styrofoam blockouts were installed to allow the reinforcing bar to move without being restricted by the grout.



**FIGURE 5**  
LOAD VS. MOVEMENT  
TEST PILE NO. 214  
COMPRESSION TEST

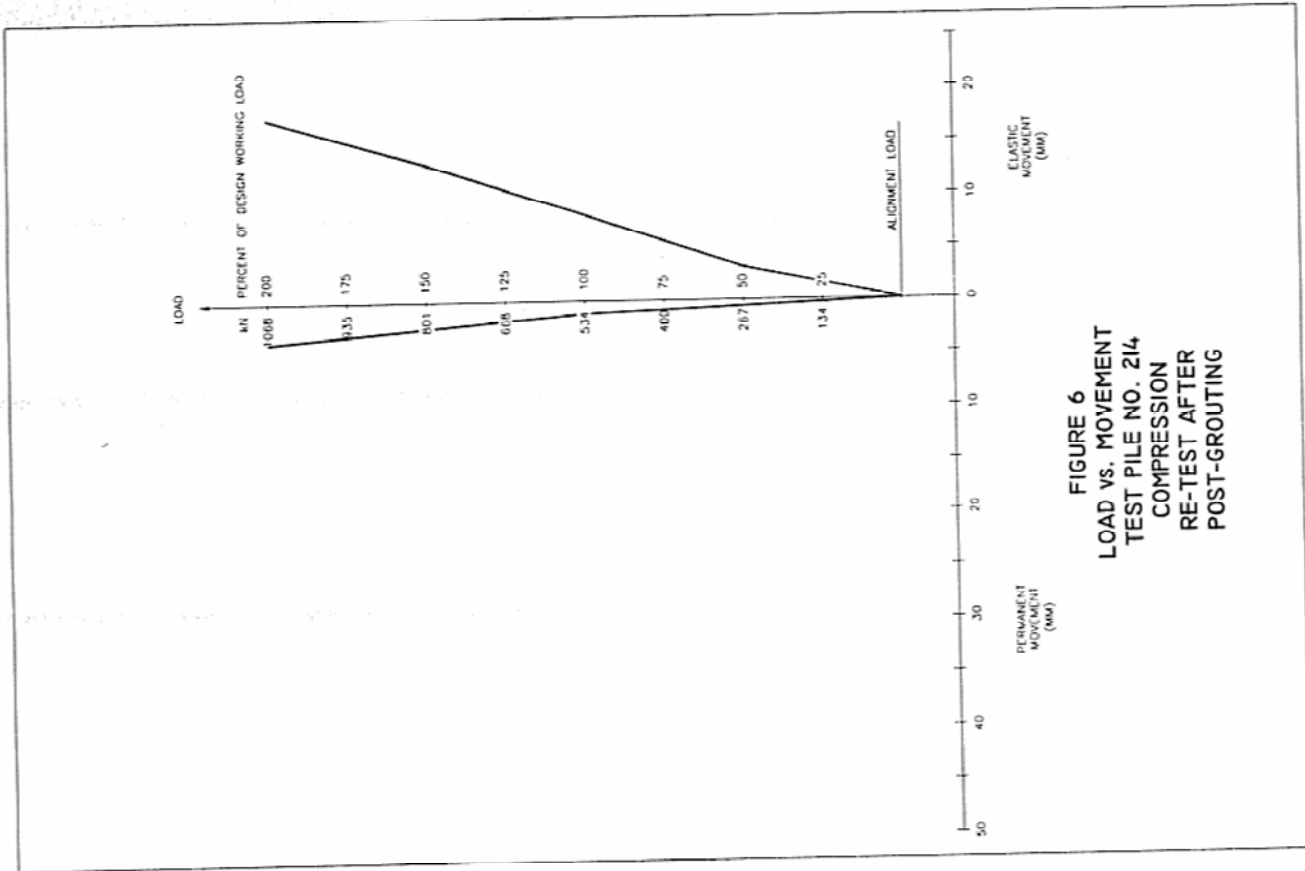


FIGURE 6  
LOAD vs. MOVEMENT  
TEST PILE NO. 214  
COMPRESSION  
RE-TEST AFTER  
POST-GROUTING

Based on analysis of the telltale movements, the load at the top of the Hard Stratum was 827 kN (93 tons) when 1068 kN (120 tons) were applied at the pile top. This is equivalent to 155 percent of the design load and thus satisfied the specified criterion.

Nevertheless, given the uncertainties over the construction of Pile 214, a second compression load test was conducted on Pile No. 212. As shown in Figure 7, the measured total movement at the pile top was 15.2 mm (0.600 in.) at 1068 kN (120 tons), of which 5.41 mm (0.213 in.) was permanent. The analysis of the telltale movements indicated that the load at the top of the Hard Stratum was 667 kN (75 tons) when 1068 kN (120 tons) were applied at the pile head, equivalent to only 125 percent of the design load. Based on analysis of the elastic deflection of the reinforcing bar, it was determined that the free length was less than foreseen, and that the reinforcing bar must have bound up in the pile during testing. Nevertheless, acceptance of the pile was recommended since it was capable of supporting the design loads consistent with the intent of the designer. The compression load test was therefore approved.

#### Lateral Load Test (Pile No. 141)

The loading was applied with an Enerpac RC106 hydraulic jack with a rated capacity of 89 kN (10 tons). During the lateral load test, the lateral deflection was recorded as 11.4 mm (0.448 in.) at 44 kN (5 tons) design load on the last cycle during unloading from the 200 percent load. This was less than the 12.7 mm (0.5 in.) allowable deflection at the top of the pile and the lateral load test was approved. Figure 8 shows elastic and permanent movement recorded during the pile loading. Because the pile is laterally supported by soil, the elastic movement was non-linear.

#### Tension Load Test (Pile No. 12)

During the tension load test, the total movement at the pile top was recorded to be 19.3 mm (0.760 in.) at a maximum load of 712 kN (80 tons) with a permanent movement of 5.87 mm (0.231 in.) after unloading. The net upward movement did not exceed the specified maximum of 12.7 mm (0.5 in.) at the head of the pile after removal of the maximum test load. In addition, since no continuous upward movement (creep) without increase in load was observed, the tension load test was approved (Figure 9).

#### FINAL REMARKS



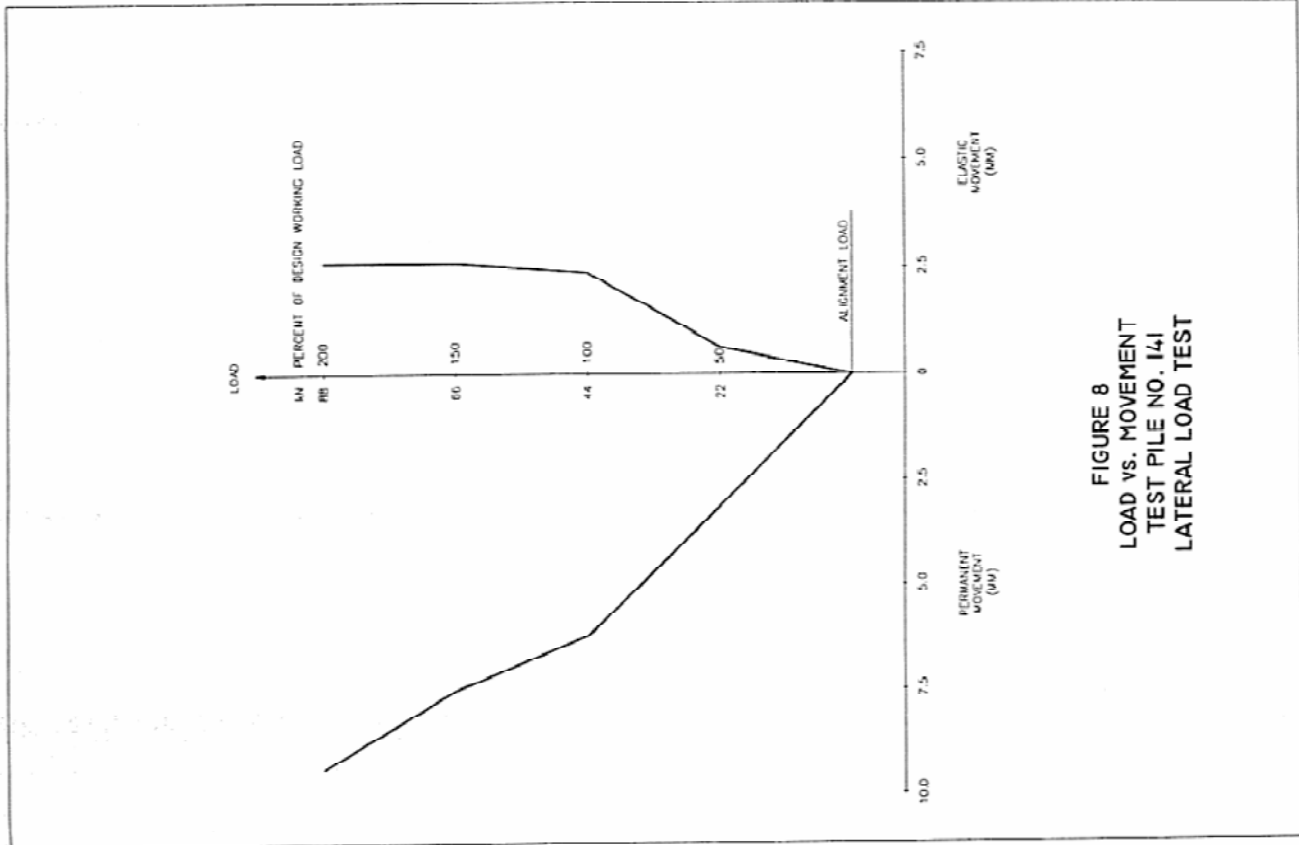


FIGURE 8  
LOAD VS. MOVEMENT  
TEST PILE NO. 141  
LATERAL LOAD TEST

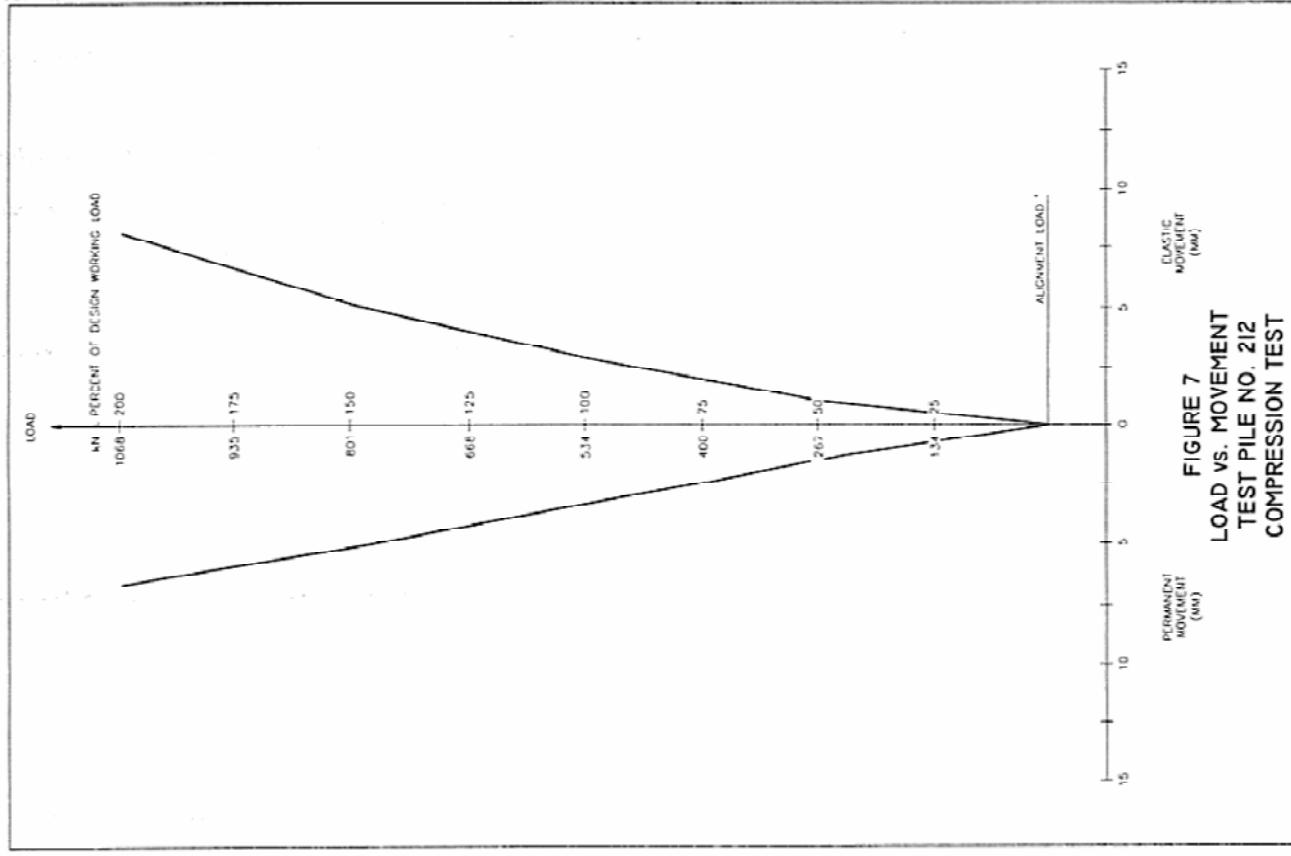


FIGURE 7  
LOAD VS. MOVEMENT  
TEST PILE NO. 212  
COMPRESSION TEST

Despite the challenging design requirements and the very difficult construction impediments, the micropile installation was successfully completed during a three month period in the summer of 1997. This case history again illustrates the adaptability of micropiles in such conditions, and further underlines their excellent performance in test loading programs in compression, tension and lateral loading.

As building codes are updated to address our better understanding of soil-structure interaction during seismic events, it is anticipated that more building renovations of historic structures, similar to the one described in this paper, will be required. Supplemental foundation support provided by micropiles has been utilized for scores of building renovations. However, slender micropiles typically have not been considered when there are significant lateral load capacity and deflection requirements, as is required for a seismic retrofit. Piles with a larger section modulus, such as steel H, concrete filled steel pipe, or precast concrete piles have typically been considered. As has been shown, properly designed and constructed micropiles can be utilized for seismic renovations. Micropiles may be used to help preserve other historic, architecturally significant structures in seismically active areas.

#### ACKNOWLEDGMENTS

The General Services Administration, New York, New York, was the Project Owner. The Project Architect was Finegold Alexander & Associates, Inc., Boston, Massachusetts. Metcalf & Eddy, Wakefield, Massachusetts, served as Project Structural Engineer. Vazquez Castillo, Vazquez Agrait & Associates, San Juan, Puerto Rico, served as Geotechnical Engineering Consultant to the Owner.

Trataros, New York, New York, was the General Contractor for this project. Structural Preservation Systems, Baltimore, Maryland, was the Micropile Subcontractor to the General Contractor.

ECO Geosystems, Venetia, Pennsylvania, provided Technical Support to Structural Preservation Systems. Haley & Aldrich, Inc., Silver Spring, Maryland, served as Geotechnical Consultant to Structural Preservation Systems, and designed the micropiles and load tests.

#### REFERENCES

Project reports, specifications, and drawings.

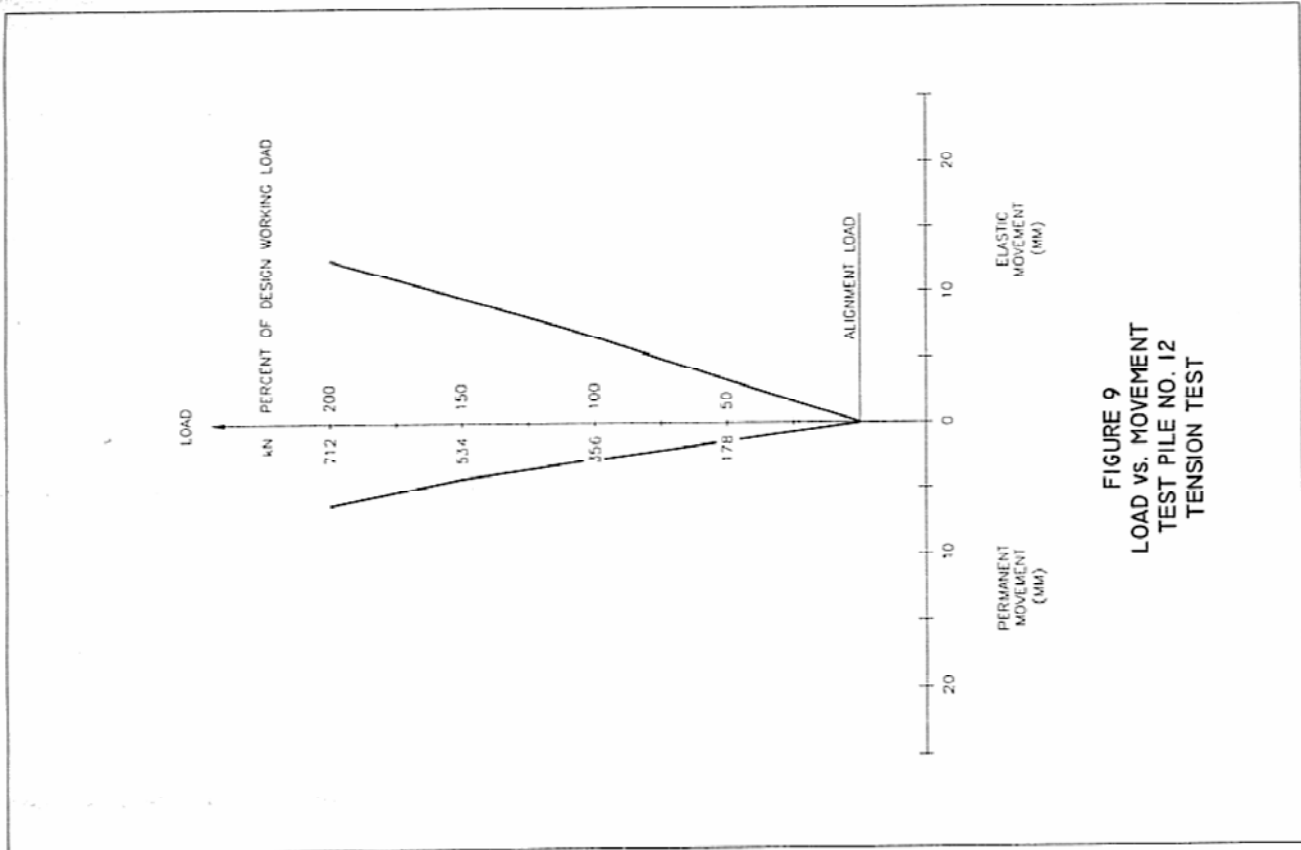


FIGURE 9  
LOAD VS. MOVEMENT  
TEST PILE NO. 12  
TENSION TEST

U.S. Department of Transportation, Federal Highway Administration, Drilled and Grouted Micropiles: State-Of-Practice Review, Vol. I-IV, Report No. FHWA-RD-96-016, 017, 018, 019. McLean, Virginia. U.S. Department of Transportation, Federal Highway Administration, 1997.

ASTM D1143, "Standard Test Method for Piles Under Static Axial Compressive Load".

ASTM D3966, "Standard Test Method for Piles Under Lateral Loads".

ASTM D3689 "Standard Test Method for Individual Piles Under Static Axial Tensile Load".