EXPANDER BODY PILES RESUPPORT STRUCTURE

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INTRODUCTION

A novel piling system has been utilized for the first time in the USA to resupport a condominium building at 1080 Beacon Street in Brookline, MA. This structure was built in 1909 and is supported on timber piles. The structure settled up to 9.0 inches into the 1970s and has continued to this day. There are indications that the settlement has accelerated at localized sections resulting in cracking of the masonry walls and tilted columns. The city of Brookline directed the condo association to remedy this situation due to increasing safety concerns.

An extensive investigation was begun in 1972 which revealed that the building is supported on untreated timber piles. However, none of the 30 piles that were exposed demonstrated any significant signs of wood decay which was assumed to be the primary cause.

A test pit exploration program was performed in 2015 by McPhail Associates. The groundwater table was noted to be at or above the top of the piles and it was confirmed that wood deterioration was not evident. However, it was noted that some of the piles were fractured in the upper two to three feet. Six pile load test were performed during this program. Four of the tests indicated that those piles had ultimate capacities of 21 to 26 tons. The other two had much lower ultimate capacities – 3.5 and 12 tons. Prior testing of other piles indicated ultimate capacities of 12.5 to 19 tons.

As noted above, deterioration of the wood piles was ruled out as the cause of the settlement of this structure. A review of the existing building loads, the spacing of the timber piles at various foundations, the results of the pile load tests and the cracking of the top of some of the piles clearly indicated that the ultimate capacity of the foundation piles had been exceeded. That is, there was a combination of a deficiency in the number of piles and/or that some or most of the piles did not develop an adequate capacity.

SOLUTION

A conventional drilled micropile system along with extensive grade beams were developed to support the structure. This piling solution proved to be very expensive and time consuming due to the low headroom conditions where the pile installation would take place and the relatively long depth of the piles. The Expander Body piles were introduced to the project as a way to reduce both. An extensive pile load test was performed to demonstrate the ability of this system to provide the required design capacity. Subsequently, Hub provided a proposal which reduced the cost of the pilings by 40% and the schedule by about 50%. The key to these reductions is the much shorter length of the piles: 30 feet vs 75 feet. This also reduced the volume of drill spoils that the project would be required to manage and dispose.

A total of 233 piles were required with design capacities of 60 and 80 tons. The installation of production piles began on November 1, 2018 and were completed on March 18, 2019. Figure 1 provides a layout of the piles.

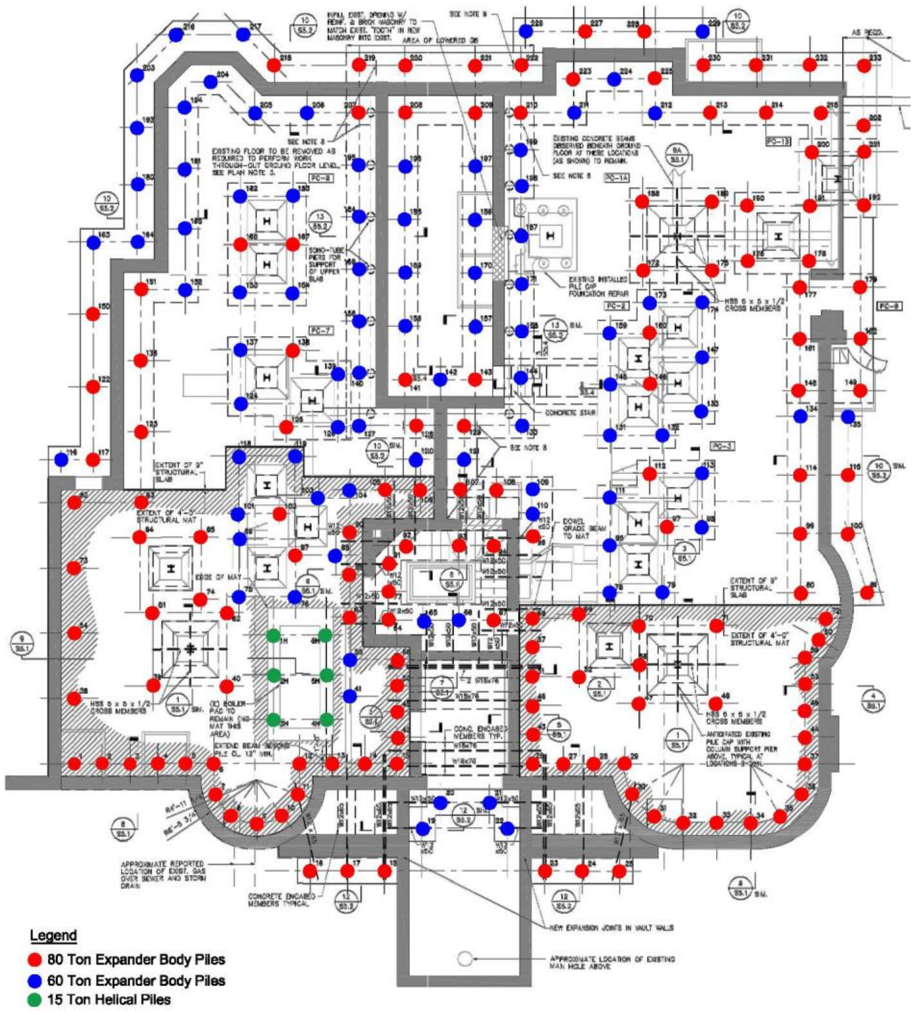

Figure 1: Layout of Piles

HISTORY OF THE EXPANDER BODY PILE

The EB pile was developed by a Swedish company, Soilex, in the late 1970's. Soilex was part of Atlas-Copeo. EBs were first utilized as tieback anchors and, later, as pilings to underpin structures in Stockholm. The use of EBs expanded to new foundation pilings in the Scandinavian countries.

The EBs were initially tested in the USA by Terra Drilling in the mid 1980s in the Boston area and on a Colorado DOT project. A Bolivian company, Incotec, acquired all the rights to the

EBs in 1993 and have made significant improvements to the design and installation of the EBs. Incotec has installed over 25,000 EBs in South America.

SUBSURFACE CONDITIONS

Several soil borings were available and showed the site to be underlain with fill, organic silts and alluvial sands. The latter were extensive in depth and varied in density. All the EBs were installed within the upper 5 ft. of the sand layer. Refer to Figures 2 and 3 for the soil profile for the project. Figure 2 represents the north side of the site and Figure 3 the south side of the project.

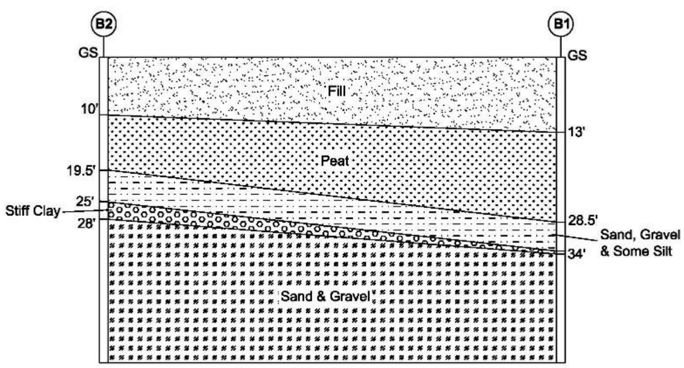

Figure 2: North Side Soil Profile

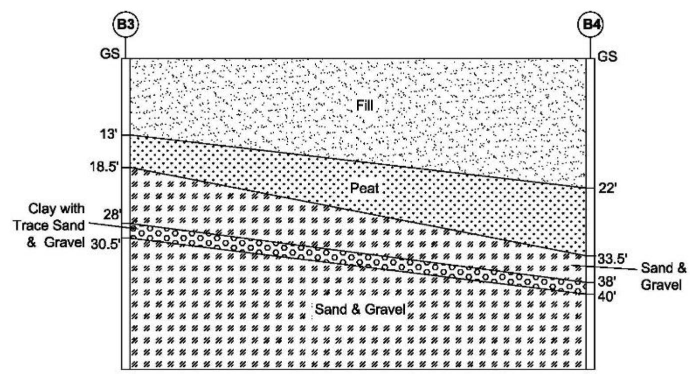

Figure 3: South Side Soil Profile

PILE LOAD TEST

A pile load test was performed in compression during the design stage to confirm that the proposed EB pile alternate would provide the required design capacity. The location of the test pile was selected by McPhail near Boring B-1 which exhibited the least dense sand throughout the site. Refer to Figure 4 for a log of this boring. The test pile was installed on 3/22/18 and tested on 3/30/18. Refer to Figure 5 for a schematic of the test pile and two reaction piles in profile. Figure 5 also provides a detailed view of the components of the EB test pile. Refer to Photos 1 to 3 which show the various phases of the pile load test in progress.

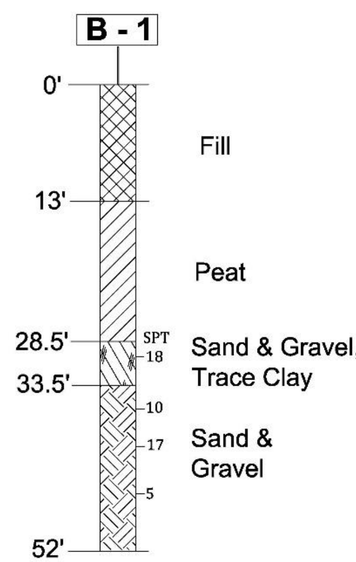

Figure 4: Test Pile Boring

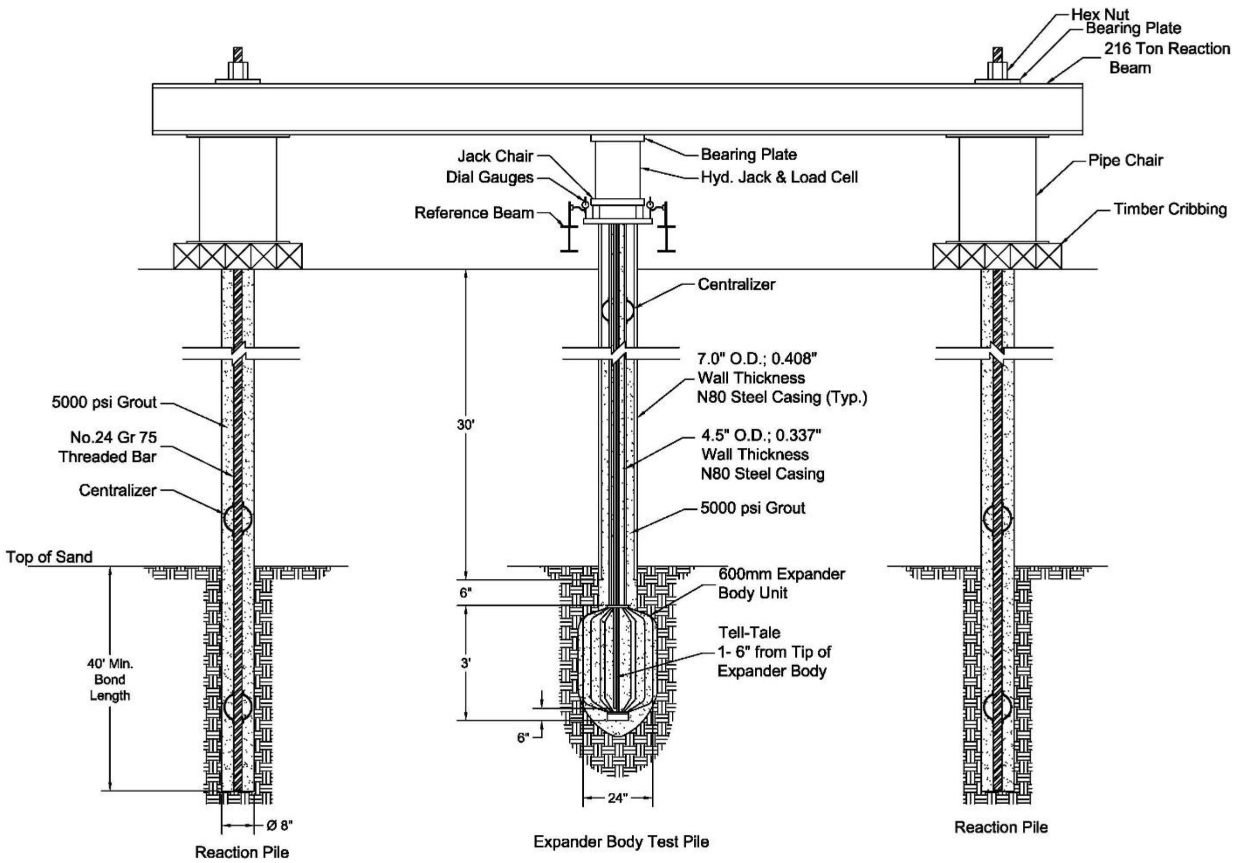

Figure 5: Test Pile Setup

Photo 1: Drill the Test Pile on the South Side of Building

Photo 2: Expander Body Element

Photo 3: Test Frame Setup

Figure 6 provides a plot of settlement v load. Initially, the test pile was loaded to twice the highest design load (160 tons). After the creep rate was acceptable at this test load, it was unloaded to zero and reloaded to 180 tons. The purpose of the higher test load was to document that a higher design capacity could be achieved.

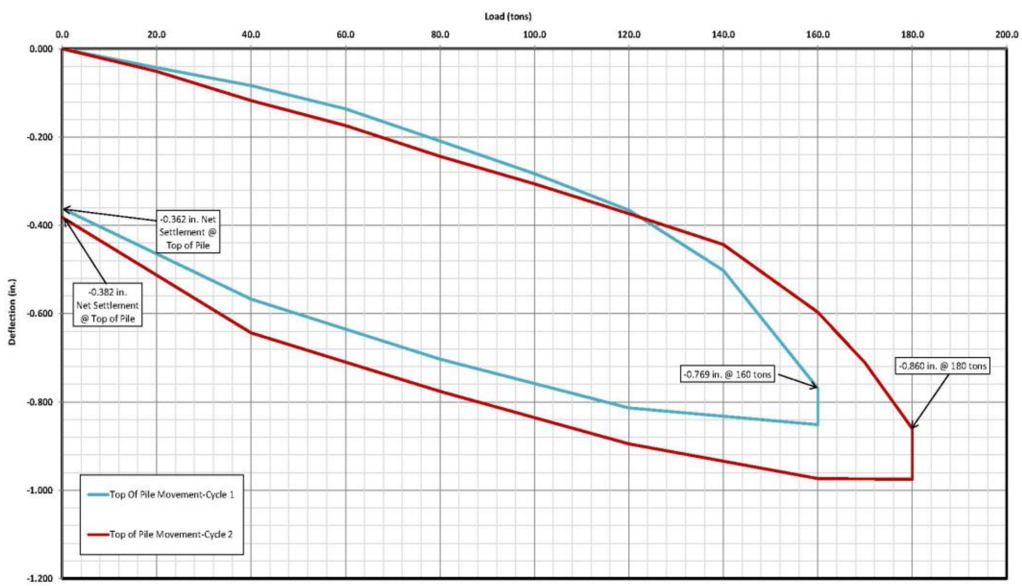

Figure 6: Settlement v. Load for Test Pile

The top of the test pile showed a total movement of 0.769" and 0.860" at 160 and 180 tons, respectively. The net settlements were 0.362" and 0.382" at 160 and 180 tons, respectively. This is well below the code requirement of 0.50".

SITE CONDITIONS

The EBs were installed within the basement of the condo building after extensive demolition and excavation to the top of the existing grade beams. The headroom within the structure after this preparatory work was completed ranged from less than 9ft to a maximum of 12 ft. Access into and within the basement was extremely difficult and was limited by the load bearing walls that had to remain fully intact. Refer to Photos 4 to 6 which show the difficult logistics within the basement.

Photo 4: Drilling Next to Existing Columns

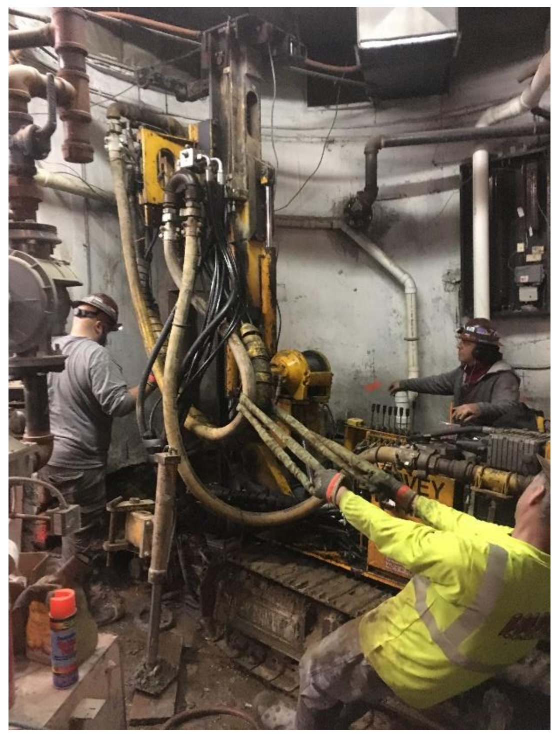

Photo 5: Drilling in the Boiler Room

The condo was fully occupied with the exception of the basement units, which comprised the work area. Access and egress for the nearly 200 inhabitants were a major concern and added to the logistical difficulties as one egress through the work area was required at all times. The general contractor worked diligently ahead of the EB operation providing temporary walkways.

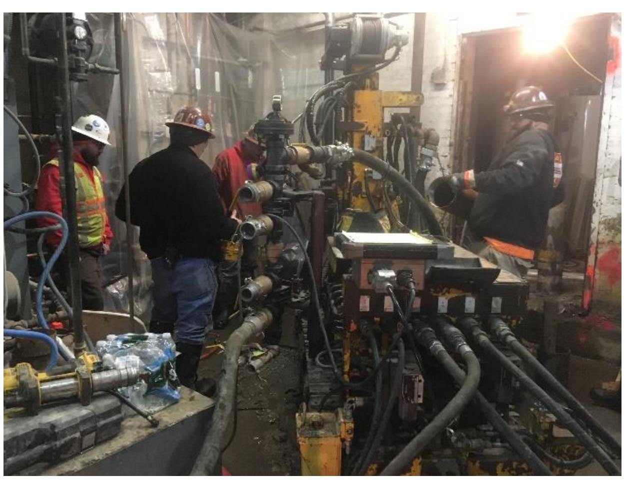

Photo 6: Drilling in Tight Corner

The north side of the first floor was partially below the exterior grade elevation. In order to provide the minimum required

Photo 7: Hand Hoist Used to Install Expander Body

headroom for the drill rigs, the site contractor was forced to excavate as much as four feet below current grade. This raised a concern with unbalanced earth pressures on the exterior walls and the project was forced to excavate only small areas a time. The EBs had to be installed within small sections at a time which resulted in a very inefficient operation between the EBs and the site work.

Low profile drill rigs, DK-515 and Khlemm 702, were utilized to drill all the piles. The drill rigs had modular masts and were modified from the standard 12 ft to as little as 8 ft when required. The majority of the drill changes were 5ft, yet, when the mast was reduced to accommodate the lower height restricted areas, 2.5 ft drill changes were needed. Refer to Photos 7 to 9 which show these rigs in full mode.

To increase overall efficiency and to allow the drill rigs to focus on drilling only, a “jacking” device was developed by Hub for this project to extract the casing after the EB components were installed and the primary grouting was completed. This was done with a second crew which would lower the EB

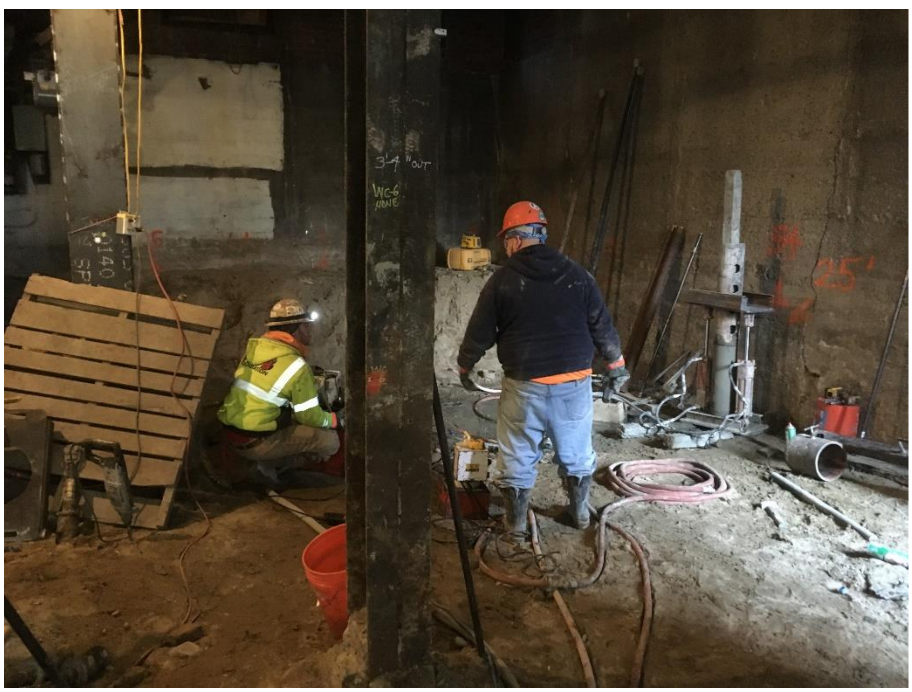

Photo 8: Hydraulic Casing Extraction Setup

down the casing using a hoist, also developed by Hub, which was fastened to the casing. Refer to Photos 10 and 11 which show this system in use. The tight access and difficult logistical challenge forced many operations to be performed manually as only one small bobcat could enter the building portal and maneuver through the work area safely.

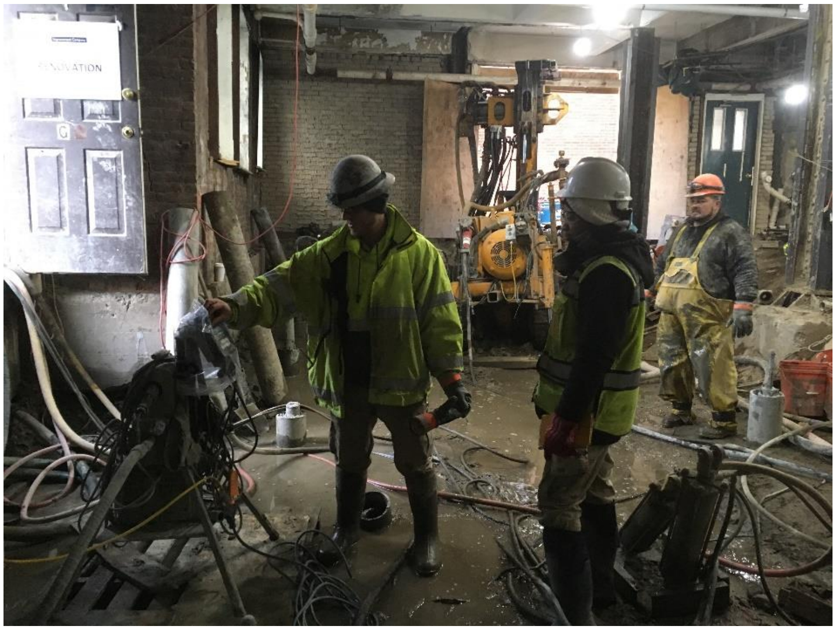

Photo 9: Monitoring and Recording the Grouting & Expansion of the EBPs

EXPANDER BODY PILE DESCRIPTION

The Expander Body (EB) pile consists of a drilled pile with a folded steel section at the bottom that is expanded with cement grout injected under pressure. Refer to Figure 7 which depicts the expansion process. EBs are produced in three sizes: the EB 300, EB600 and EB 800. The EB 600 (600mm) was selected for this project to provide the required design capacities of 60 and 80 tons.

Figure 7: Phases of Expansion of the Expander Body Element

The EBs develop their capacity from a combination of end bearing at the tip of the expanded base and side friction along the sides of the expanded body. Note that the expansion process increases the density of the soils immediately around the EB. This was noted in this project whereby successive piles required higher pressures to fully expand the EB. Also, the post-grouting process, in addition to filling any voids directly below the base of the EB, improves the density of the soils directly below the base of the EB via the injection of additional grout under pressure.

INSTALLATION PROCEDURES

The EBs were installed similarly to drilled micropiles. Refer to Figure 5 which shows the overall details of the EB components.

1. A 7 5/8" OD steel casing was drilled approximately 5 ft into the top of the sand layer, which was a total depth of 30 to 35 feet for all the piles;
2. The EB section along with the full height riser pipe were installed in lengths of 5 ft.;
3. The inside of the casing was then grouted full height;
4. The casing was extracted approximately 4 ft. to ensure that the EB could fully expand and not contact the carbide teeth of the casing shoe. Note that the small gap that develops between the top of the expanded EB and the bottom of the casing is structurally covered by a 3 ft. long section of 5.5" OD steel pipe and 3.5" OD steel pipe (riser pipe) which is used to expand the EB.
5. The EB was expanded with grout through the riser pipe using a high pressure piston pump to a maximum pressure of 500 psi;
6. Once the EB was expanded, the tip of the EB was grouted through a secondary grouting tube. The purpose of the secondary grouting is to ensure that any voids below the EB that could develop during the expansion were filled.

QUALITY CONTROL

One of the benefits of the EB pile and its expansion is the ability to document the volume of grout being pumped and the pressure utilized throughout the entire expansion process. In essence, each installation is the equivalent of performing a pressuremeter test which will translate to a modified pile load test on each pile installed and expanded. Figure 8 shows the plot of grout volume v pressure for the EB test pile. The 54 gallons of grout that expanded the test pile was replicated within 98% for all 233 production piles. The maximum pressure of 270 psi was exceeded in at least 75% of the piles. We noted that the full expansion of successive piles required a higher pressure due to the densification of the sand from the prior pile. Refer to Figure 9 which show the volume pressure plot a production pile.

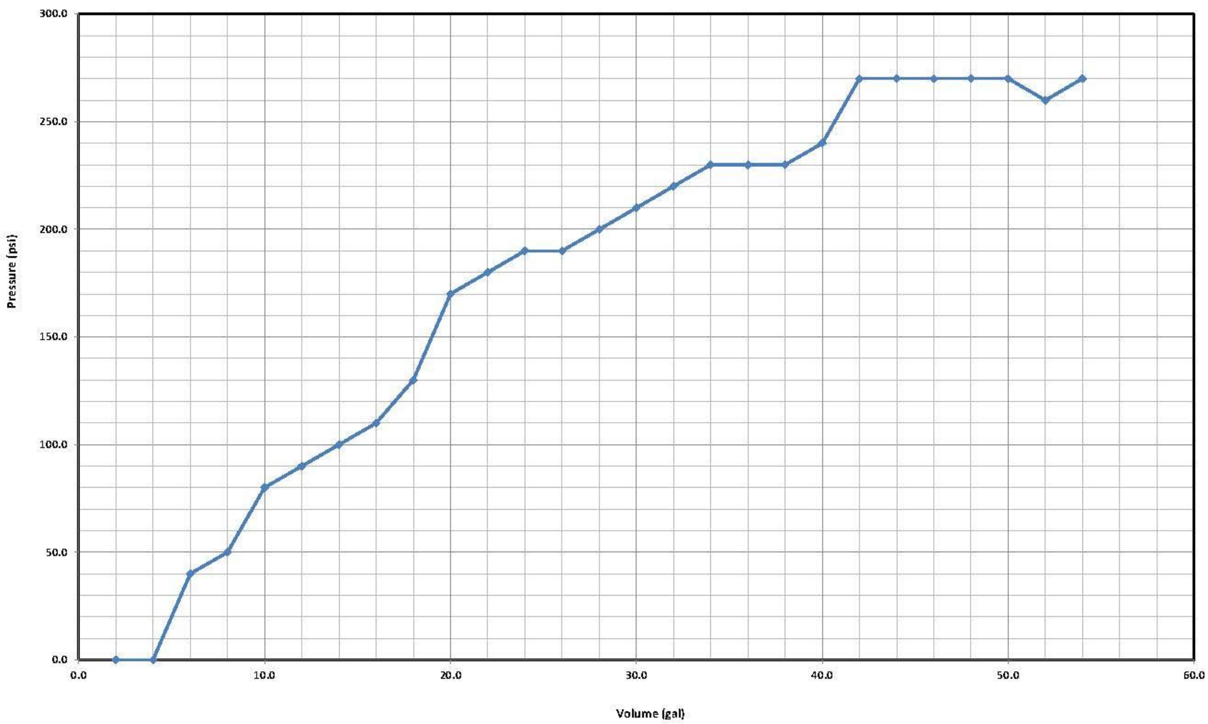

Figure 8: Primary Grouting of Test Pile

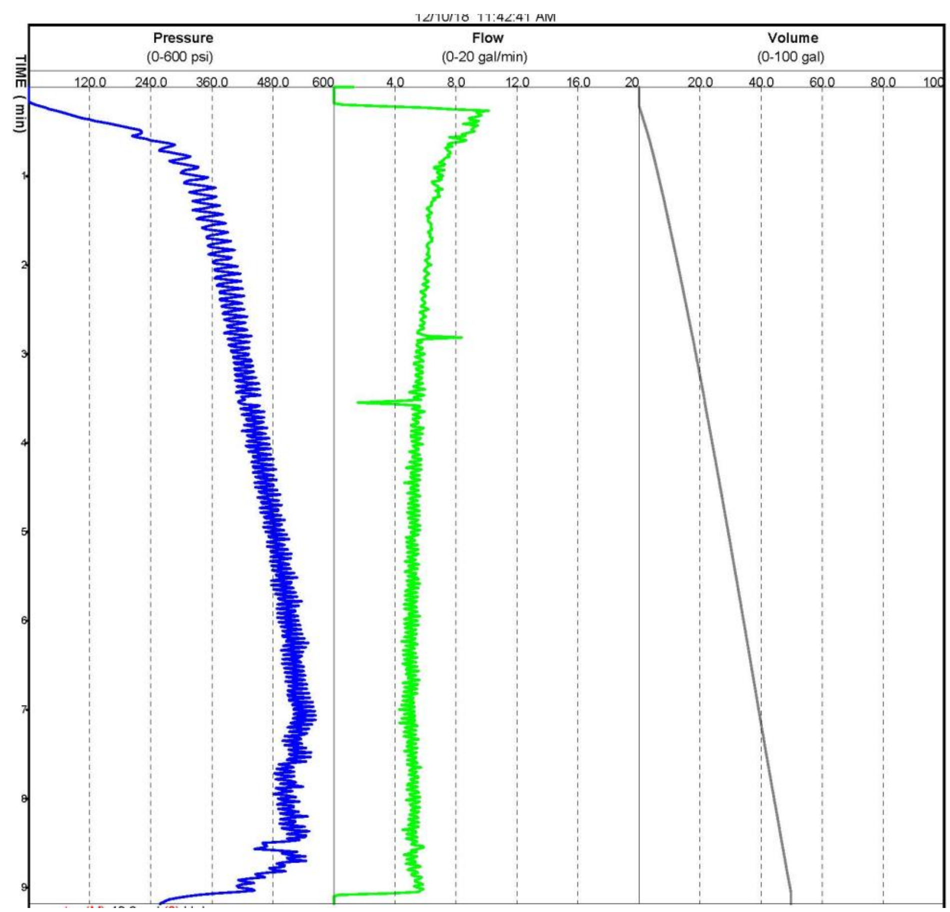

Figure 9: Grouting Report for Production EBP

CONCLUSION

This project provided the ideal opportunity to utilize EBs in lieu of conventional micropiles. The ability to use much shorter (over 40 ft. shorter) piles in a very challenging logistics setting with less than 12 ft. of headroom allowed the EBs to be more economical and with a shorter installation schedule. The presence of the alluvial sandy deposit within a relatively short depth was the initial critical component. EBs can also be utilized on projects where a relatively thin layer of marine sand overlays a marine clay or similar softer soils.

Although Incotec has installed thousands of EBs in cohesive soils, Hub's experience to date has been in granular soils. Hub has performed several pile load tests at various projects in New England. The maximum test loads have ranged from 132 to 270 tons. In all cases, the tests on the EBs compared favorably or performed better than those on conventional minipiles.