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# GROUTING PATTERNS AND POSSIBILITIES WITH HELICAL PIERS

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**Abstract:** The experimental procedures and results are presented for a one-tenth scale laboratory investigation of changes in achievable grouted zones through alterations in helical pier parameters. The parameters investigated were the location of the grouting holes with respect to the position of the helices, the grouting pressure and the rate of helical pile installation. The results showed that the total treated volume was 40% to 158% greater than the grouted volume and that the thickness of the treated zone beyond that which was strictly grout was 15% to 61% of the radius of the grouted, cross-sectional area, which was largely controlled by the diameter of the bottom helix. Increases in pressure generate non-linear improvements with increasing effectiveness at higher pressures. The placement of grout holes beneath the bottom helix was shown to be more effective in grout delivery than the standard industry practice of placing the holes above the helix.

## I INTRODUCTION

The use of grouted helical piers to rehabilitate decaying pile groups and to increase the load carrying capacity of existing foundations is a fairly new, contractor-driven innovation (Schaefer, 1997; Shvets et al., 1996). As such, to date most published information on such applications focuses on specific case histories, and consequently there are no widespread, agreed upon standards for the design, installation, inspection, or testing of grouted helical piers. Fundamental to all of this is an absence of a published methodology to predict the size and shape of the grouted mass. Despite the increasing popularity of the technique (Carville and Walton, 1995; Pack, 2000), previous research has provided limited guidance as to prediction of grout flow patterns based on such key parameters as soil type, angle of helix, grout hole placement, grouting pressure, and water/cement (w/c) ratio (Perko and Rupiper, 2000; Rogers, 2002). A major problem with grouting in sands is prediction of a consistently achievable treated area. Increasing fluidity by altering the w/c ratio promotes grout travel but decreases strength as a function of the weaker grout mix and through potential material segregation. Alternatively, increasing pressure may endanger nearby structures by risking grout breakthroughs.

This paper presents the preliminary results of a one-tenth scale laboratory study investigating patterns and volumes of grouted zones based on changes to grout hole location, grouting pressure, and installation methods. These results are a portion of a study of one-tenth scaled testing in a non-cohesive soil done as part of a large experimental program to investigate the enhancement capacity of ground reinforcement methods around existing pile groups (Manke, 2004).

## II BACKGROUND INFORMATION

Vickars and Clemence (2000) distinguishes two different methods of grouted helical pier installation: pull-down piers and micropiers. This experimental study was based on the micropier method, which typically employs a pier constructed of a pair of 10-18" diameter helices attached to a 4" outer diameter pipe. While the helices pull the pier into the ground, grout is introduced into the soil through the holes in the shaft. The grout is introduced under gravity flow through the stem of the helical pier, exiting the shaft through holes located above the lower helix. To increase grout flow, compaction fins are placed as hoods over the holes to create a better void around the shaft, thereby, promoting grout dispersion.

### III EXPERIMENTAL PROGRAM

Full-scale micropier configurations and installation methods were generally followed in selection of the prototype. An important difference between the model and the prototype was, however, in the use of pressurized air to force the grout through the model pier, while the prototype relies strictly on gravity-induced flow. This was in part a requirement because of the negligible moisture content in the soil; it was intentionally oven-dried to meet the requirements of the larger testing program (Manke, 2004) and facilitated more controlled specimens. Another distinction was in the absence of the fins. Initial scaled laboratory tests showed no difference in the zone of grout reach with the fins, thus they were not included in the production testing. The pressurized grouting most likely superceded the role of the fins.

Each of the experimental runs was performed in a five gallon bucket filled with a poorly-graded, oven-dried sand (Figure 1). The sand had a maximum and minimum density of 110 and 91.0 pcf, respectively. All helical pier installations occurred in soil of 94.5 pcf (relative density approximately 25%); limitations of the testing arrangements precluded higher relative densities. Each bucket was filled with sand and compacted by vibration to the target density.

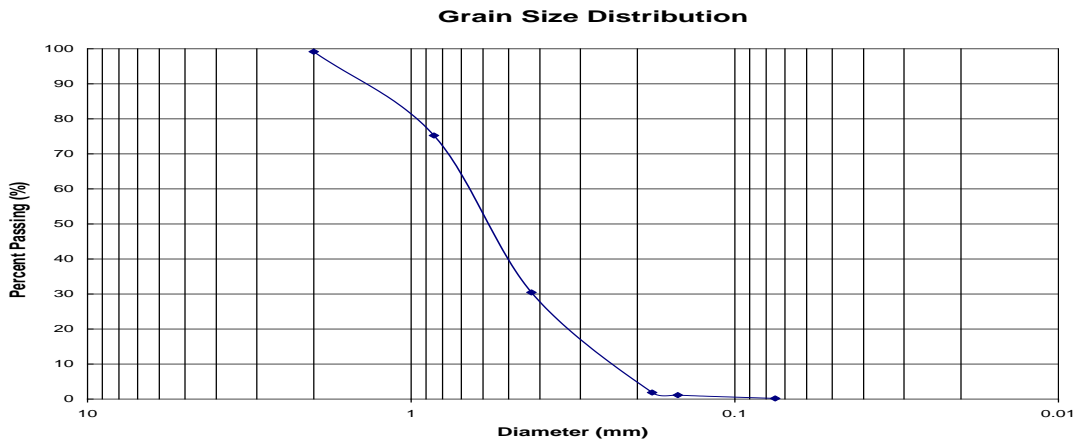


Figure 1: Grain Size Distribution Curve

#### A. Equipment

The grout was prepared in and pumped from a thick-walled metal cylinder. (Figure 2). The cylinder was configured such that an air intake and pressure release valve were located at the top of the container, and a grout exit nozzle was positioned at its base. The pressure release valve was used after each trial to prevent excess container deformation and to provide an absolute air pressure. A large metal plate was bolted to the top with a rubber gasket and a small amount of lubricant to create an airtight seal. A circular piece of plywood of a slightly smaller diameter than the cylinder was also placed inside the cylinder, atop the grout, to ensure that the pressure was evenly distributed and to promote grout flow.

A grout swivel was constructed out of a PVC cylinder, two PVC shafts, a reducing flange, four hose clamps, and two rubber sleeves (Figure 3). The PVC cylinder was threaded on one side and had a fixed reducing flange on the other. A shaft was inserted into the fixed reduction flange that was self-securing from inside the cylinder. The reducing flange was then screwed into the threads of the open end of the cylinder; the other shaft was then inserted into the flange that was secured from inside the

cylinder. Both shafts were then covered by rubber sleeves and attached to the shafts by hose clamps. This assembly allowed the pier and the two exterior shafts to spin freely, while keeping the cylinder fixed and air tight. Such an arrangement was necessary to be able to simultaneously grout and drive the helical pier.



Figure 2: Pressurized Grout Tank

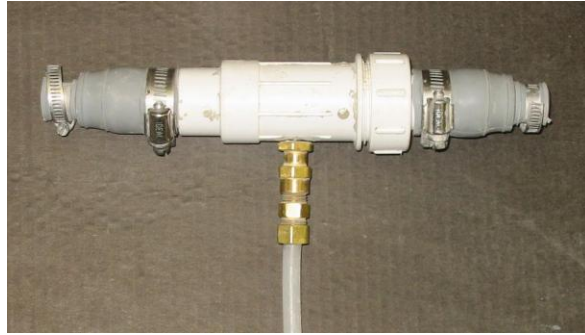


Figure 3: Grout swivel .

The piers were constructed of 36" long, aluminum rods with a .50" outer diameter and a .37" inner diameter. Both of the helices consisted of a fender washer with a 2" outer diameter cut and bent to a pitch of 3/8" (Figures 4-6). The helices were placed 7" apart, with a 180° offset (Figure 5). The upper portion of the pier had a 2" slot (Figure 6) to accommodate grout flow into the pier from the grout swivel.

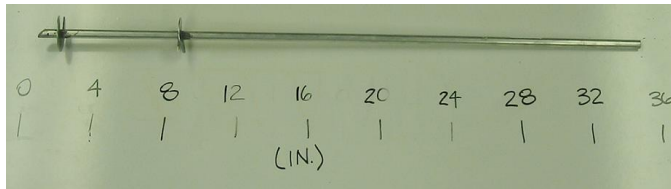


Figure 4: Model Helical Pier with Two Helices



Figure 5: Helices (Close up of Figure 4)

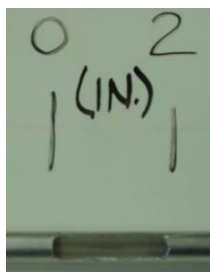


Figure 6: Grout Slot in Helical Pier (Close up of Figure 4).

## B. Scope

The three variables investigated were the grout hole location, the grout pressure, and the installation rate. Three different grout hole arrangements all focusing on the bottom helix. In the first case, holes were drilled below the helix. In the second arrangement, the holes were installed above the bottom helix, which reflects industry practice. In the third scenario, there were holes both above and below the helix. In all cases, the grout holes were a pair of 1" openings drilled 180° from each other. The bottoms of the helical piers were closed to prevent grout loss and clogging of the shaft. Throughout the testing a 0.6 w/c mix was used for the grout.

The installation pressure was tested at 6 psi, 10 psi, 12 psi, and a variable pressure, which was changed from 6 to 10 to 12 psi at third points along the premarked depth of the shaft. The choice to increase the pressure was to counter the effects of the increasing overburden.

The third investigated variable was the installation method with respect to the energy put into the system. One set of the helical piers were driven into the ground by means of a hand held drill. The rotation rate with respect to advancing the pier into the soil was controlled by increasing the pressure applied to the drill trigger. The rotation of the drill itself was monitored manually by the number of revolutions per minute (roughly 10-20). For the high pressure grout experiments initial insertion rates had to be increased to combat the highly pressurized grout from spraying out of the soil, while the piers were being drilled into the ground. For all cases of the drill installation, as the pier progressed further into the soil, the energy was increased to overcome the additional resistance generated by the additional overburden, thus the technique is designated variable energy (VE) in the results. The alternative method was a constant energy (CE) approach that employed motor/counter weight assembly (see Manke, 2004 for details). This second method produced a slower and more consistent rate, as will be shown below.

## C. Procedure

All specimens were grouted to a depth of 12" during the pier's initial entry into the system. The pier was then removed from the grout inclusion. During pier withdrawal, additional grouting was conducted at the pre-specified pressures (figure 7). For the variable pressure grouting, the pier was grouted out of the sand at a constant 12 psi. Some preliminary tests investigated the impact of grouting only on the way down. No consistent difference in the grout take was observed so this was eliminated from the final testing program.

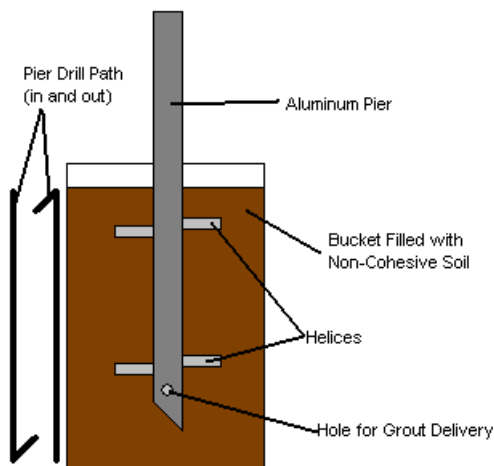


Figure 7: Installation Schematic

## IV RESULTS

The results were evaluated in terms of the consistency of treatment (i.e. geometry), the total treated volume treated and the amount of material treated beyond the area that was strictly grout.

### A. Geometry

Two patterns emerged in the profile of the grouted columns. The most common had a fairly uniform diameter throughout the length of the column, with a conical widening at the top (Figure 8). These will be referred to as smooth columns. The other observed geometry consisted of columns that throughout the height of the column resembled a screw with clearly visible threads that matched 3/8" pitch of the helical piers (Figure 9). These will be referred to as threaded columns. The smooth column was the product typically generated by the installation method. The threaded column occurred when insertion or withdrawal rates were exceptionally slow or when one of the helices broke during the installation process.



Figure 8: Typical smooth pattern.



Figure 9: Threaded column

### B. Treatment Zone versus Grouted Zone

For all of the grouted inclusion a distinct pattern emerged of a large, diameter of grout surrounded by much smaller zone of treated soil. This is most clearly shown in Figures 10 and 11, which depict 2" long sections cut from the upper (1), middle (2), and lower (3) portions of the grouted inclusion.



Figure 10: Cross-section of Smooth Column



Figure 11: Cross-section of Threaded Column

To investigate the amount of soil mixed with the grout, a grouted column was cut along its axis so a cross section could be seen (Figures 10 and 11). The cross section showed a significant decrease in grout/soil interaction from the outside of the column to its center. The center of the column was all grout while the outside was all soil. No appreciable difference was seen in the smooth versus the threaded columns, although the boundary between the grout and the treated soil was more easily distinguished for the threaded columns. In all cases the treated soil possessed air pockets and other defects, and the diameter of the grouted area was dictated by the diameter of the helix.

As shown in Table 1, the thickness of the treated area was influenced by a number of factors. Firstly, the position of the holes below the bottom helix generated approximately 50-100% more treated area than the other arrangements. Secondly, the constant energy method resulted in treated areas that were on average more than twice that of the variable energy method. What can be understood from this is that a slower installation rate facilitates the placement of greater volumes of grout and that although grouting beyond the diameter of the helix does not generate a larger grout column, it does directly impact the zone of treated material by generating a thick skin of treated soil around the grout column. The loss of the bottom helix was shown to generate column diameters as little as 25% of the helix diameter in the entirety of the zone below the upper helix (as discussed in the next section).

Grout Hole Placement	Variable Energy		Constant Energy	
	Treated Volume/ Grouted Volume (%)	Skin Thickness/ Grout Radius (%)	Treated Volume/ Grouted Volume (%)	Skin Thickness/ Grout Radius (%)
Below	1.62	0.27	2.58	0.61
Above	1.40	0.18	1.77	0.32
Both	1.32	0.15	2.03	0.41

Table 1: Results from the volumetric experiments in cm<sup>3</sup>

### C. Quantity of Treatment

For the VE method, the grouted zone was highly consistent with depth, except where damage of a helix (e.g. breaking off) was noted, as seen in Figure 12. In contrast, the CE method, despite its lower input variability, because of the use of a motor (instead of a hand held drill) generated less consistent grouted areas, but substantially more consistent treated zones. The VE method particularly showed variability towards the top of the column. In general, the higher the pressure the worse the consistency was for the VE method. One problem that emerged quite frequently with the CE method was a complete failure in any treatment as shown in the "CE Above" series, where there was no material to measure at the 12" depth, meaning that no measurable treatment occurred at that point.

A major question related to the effectiveness of higher pressures generating expanded treatment areas. The results in Table 2 are the volumes of treated volume normalized by the treated volume at the maximum experimental pressure (12 psi). The VE method was largely immune to changes in pressure, but with the CE method a clear pattern emerges, where the treated zone increase between 3% and 7% with each addition 1 psi. The increase is greater at the higher pressures. It should, however, be noted that there are real limitations both in the laboratory and in the field to increasing the grouting pressure both in terms of the equipment capacity and with respect to risking blow outs. Even at 12 psi there was a substantial amount of difficulty preventing the grout from migrating up the outside of the helical pier, as this was a path of less resistance than radial travel through the soil.

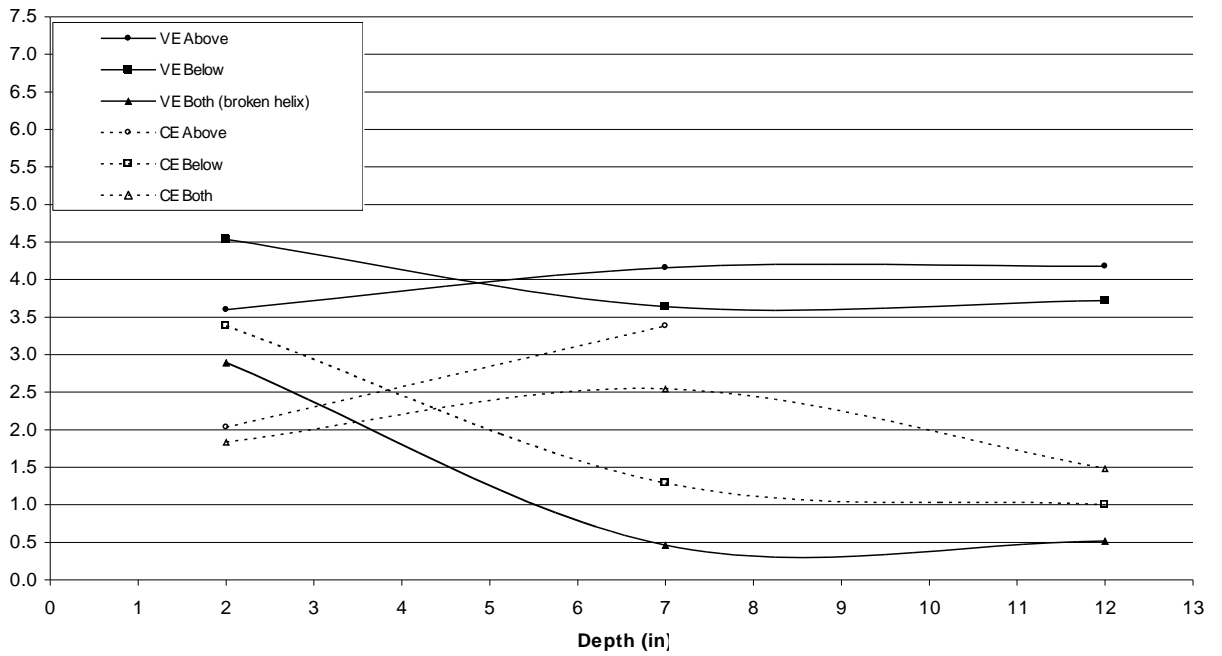


Figure 12: Grouted Area with Depth for Individual Grouted Columns

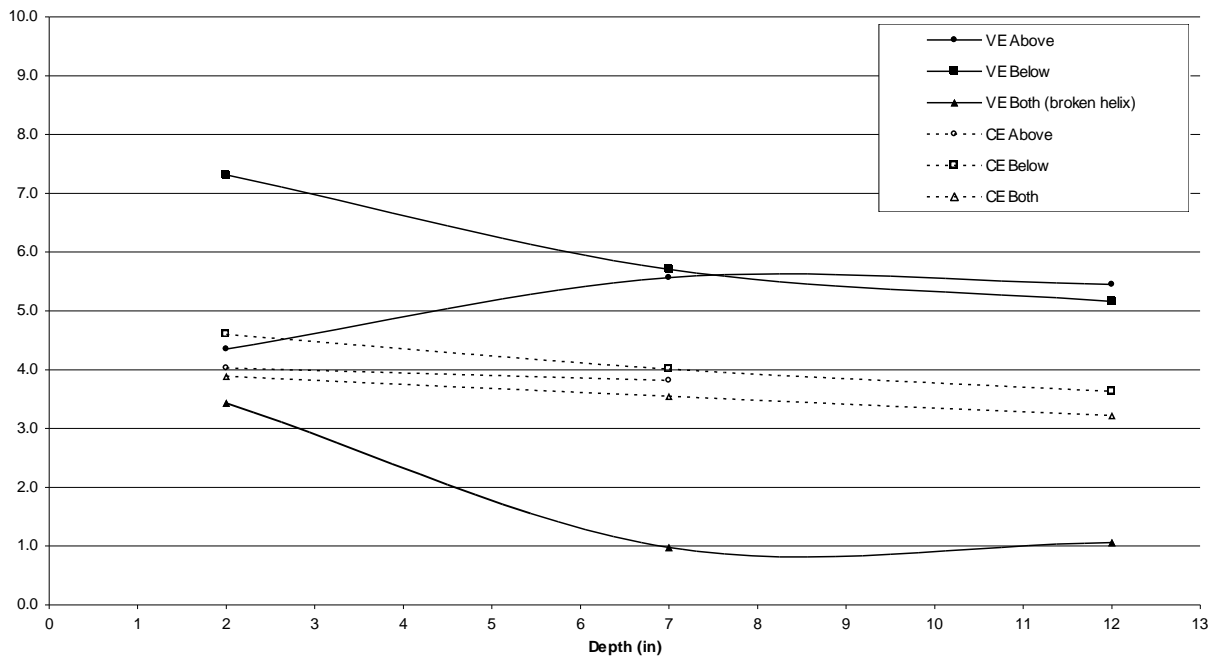


Figure 13: Treated Area with Depth for Columns Shown in Figure 12



	Installation Pressure/ Installation Pressure at 12 psi			
	6 psi (%)	10 psi (%)	12 psi (%)	Variable (%)
Variable Energy	1.00	1.13	1.00	0.97
Constant Energy	0.71	0.86	1.00	0.89

Table 2: Average Volume as Percentage of Achieved at 12psi

## V. CONCLUSION

As opposed to current industry practice, placement of holes below the bottom helix was shown to be better in delivering grout, because although they do not change the extent of treated zone (especially once some overburden is present (Figure 13)), the amount of treatment is at least 20% higher respect to the amount of grout introduced into the system, thus it is a more economical arrangement.

The choice of helix size directly controls the size of the grouted area. Thus if this parameter needs to be altered, changing the grouting pressures and installation methods has relatively little influence. Understanding the role predictably of being able to generate a preselected grout column diameter is also useful as the total treated area and the thickness of the grouted soil around the grout core both can be expressed as a function of the grouted core.

In general, the impact of increased pressure was limited and in part dictated both by the installation method and the level of overburden. What could, however, be seen is that the impact of the treatment improved non-linearly with increasing grout pressure.

## ACKNOWLEDGEMENTS

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