Highly loaded helical piles in compression and tension applications: A case study of two projects

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ABSTRACT
Helical piles are traditionally considered for use in applications as tension anchors for retaining wall tiebacks or shoring, and as compression piles in light to medium load situations including temporary, residential and single storey commercial structures. Helical piles are very capable of fulfilling requirements in highly loaded applications, and are commonly the most efficient option at doing so. Two different instances of high load applications in both compression and tension where helical piles fulfilled all requirements and proved to be the most efficient solution are presented.

RÉSUMÉ
Les pieux d'acier vrillé sont considérer traditionnellement pour les applications d'ancres en tension pour des murs de soutènement ou des murs d'étayage ainsi que pour les applications de charges légères ou moyenne en compression qui inclus des structures temporaire, a simple étage, résidentiel et commerciale. Les pieux d'acier vrillé sont capables de rencontrer les exigences pour des applications à hautes charges et sont considérer la méthode la plus efficace pour ce but. Cette rédaction présente deux cas différent pour des applications de haute charges en compression et en tension ou des pieux d'acier vrillé on rencontré les exigences du projet et on démontré a être la méthode la plus efficace.

1 INTRODUCTION

The use of helical piles in high load applications has been limited due to designer concerns of buckling and excessive settlement. Many designers are comfortable with traditional foundation methods, a lack of familiarity with helical piles, and minimal evidence supporting the capabilities of them resulting in helical piles being overlooked for many design situations. The increasing requirements for tension loads, and seismic loading has led to helical piles being considered more commonly in new construction applications. Increased amounts of test data, as well as design improvements like the addition of grout columns for lateral support, continue to improve the possibilities of this technology. Two different projects using helical piles in highly loaded compression and tension applications are presented, with design challenges and requirements, and test results.

2 MULTI-STOREY HOSPITAL

A new hospital was designed for construction in 2002. It was a multi-storey 32,500 square metres building for a 10 hectacre site near Woodstock, Ontario. Figure 1 is a projected image of the hospital after completion.

Figure 1. Hospital rendering

This 2002 design was developed using the 1995 Ontario Building Code. The project was, however, not followed through until 2007, when the 2006 Ontario Building Code came into effect, with new stringent seismic design codes. This resulted in two options for the designers: to redesign the building or to retrofit the existing foundation design to meet the new codes.

2.1 Design Challenges

The process of completely redesigning the building to new codes would have been time consuming and expensive. Retrofitting the existing foundation design to accommodate the new code was deemed to be the best option, as it could be completed quickly, with only moderate expense. The new design required ultimate loads of 200 kips in compression, and 160 kips in tension, with 588 helical piles necessary. Although helical piles are able to maintain this type of loading, the use of them on a new construction job of this magnitude was relatively unheard of.

2.2 Load testing

Load tests were required to determine the capacities of helical piles installed on site to ensure they were capable of supporting the required loads. 13 load tests were completed: 5 compression tests, and 8 tension tests. The site was divided into 4 areas, and load tests were completed in each of the 4 areas due to the large area. Each test was completed following ASTM Quick Load Test Method guidelines for Static Axial Tensile or Compressive Loads. The general soil conditions for the entire site were consistent. There was a 1.5 to 2m sandy silt layer, with approximately 3m of silt till below. Underneath that was a very dense sand and gravel layer about 5m thick with n-values greater than 50. The lowest deflection values were obtained with a triple helical configuration of 6, 8, and 8-inch helices and are summarized in Table 1.

Table 1. Summary of test results

Test Area	Test Type	Depth (ft)	Test Load (kips)	Deflection (inches)
South	Tension	18	180	1.011
South	Compression	19	250	0.381
East	Tension	23	180	0.832
West	Tension	18	180	0.645
North	Tension	15	180	1.168

All test piles were installed to 23,500 ft-lbs of torque during installation. The load-deflection curves for each test are shown in Figures 2 through 6.

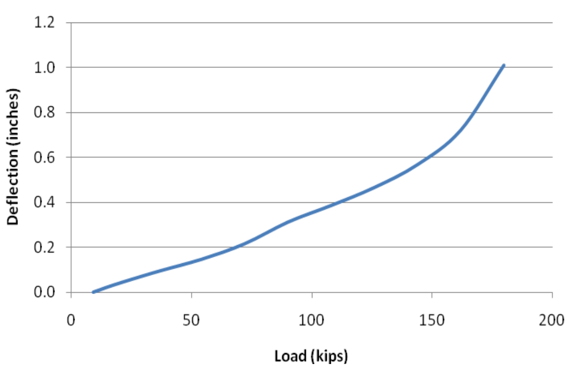

Figure 2. South area tension test

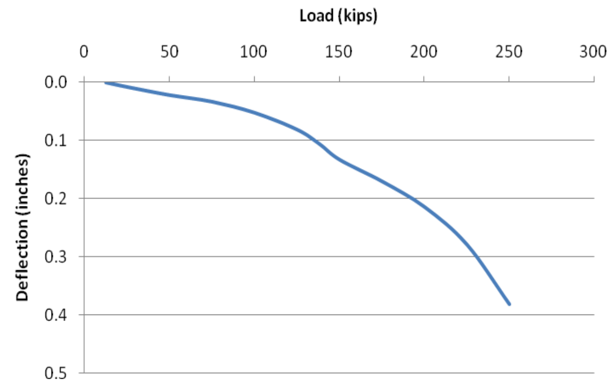

Figure 3. South area compression test

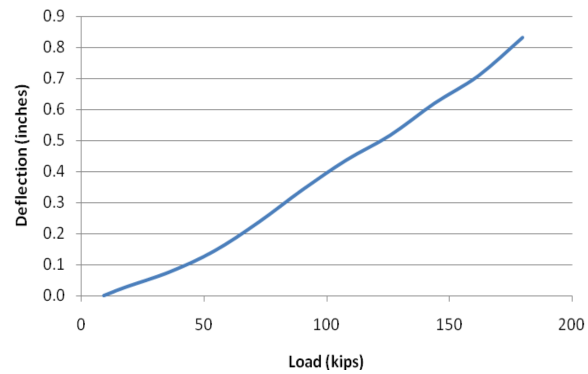

Figure 4. East area tension test

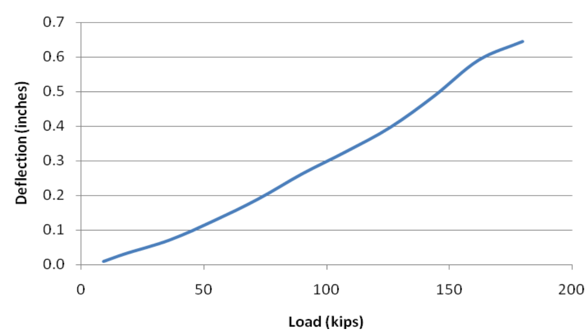

Figure 5. West area tension test

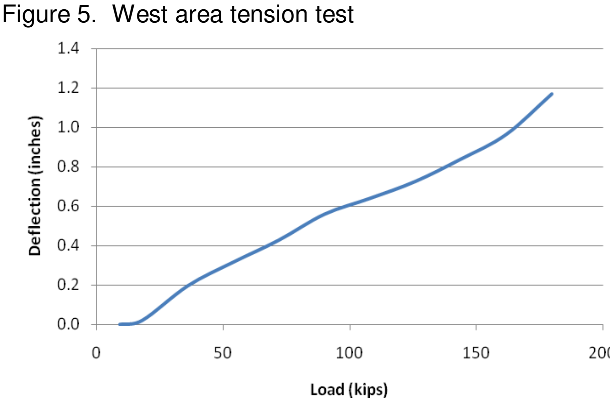

Figure 6. North area tension test

2.3 Production

Based on test results, a helical configuration of 6, 8, and 8-inch diameters was selected and installation criteria were developed. A minimum installation depth of 15 feet was required, as well as an installation torque of 23,500 ft-lbs. During the installation, the piles were installed to a torque of 20,000 ft-lbs, removed, the void was filled with grout, and then the pile was installed to the required installation torque and depth. In some instances where the helical pile was unable to reach 15 feet, they were removed, and predrilled with another pile with smaller helix diameters. The installation of 588 helical piles for this project was successfully completed in 45 working days.

3 MULTI-STOREY CONDOMINIUM

A 13-storey condominium tower was designed for construction in Cambridge, Ontario along the east bank of the Grand River. Figure 7 is a projected image of the completed project.

Figure 7. Condominium tower rendering

The site was the location of a former factory and was subject to a remedial clean up prior to construction.

3.1 Design Challenges

The soil on site was variable and had a very high water table due to being directly beside a river. Borehole data from this site indicated a loose fill layer up to 2 metres below surface, and a 4m thick loose silt layer across the site. Underneath was a dense silty sand layer ranging from approximately 6 to 8.5m below surface. A layer approximately 1m thick of sand, gravel and cobbles was underneath, and below that, a sand and gravel layer with n-values above 50. Many alternatives were considered for the foundation including pipe piles, "H" piles, caissons and helical piles.

3.2 Load testing

In order to determine the most efficient foundation design, testing had to be completed. In order to minimize issues with cobbles, higher capacity helical piles were used with a larger installation machine. The larger machine allowed increased crowd (downward pressure applied to pile during installation) be applied on the piles during installation, and the higher capacity piles enabled the piles to reach the desired depths without exceeding the torque capacity because of the increased crowd. 10 helical pile load tests were completed on site using different size solid steel, square shaft piles, with various helical configurations. The test results indicated a 2-inch solid steel, square shaft helical pile with an 8, 10, and 12-inch helical configuration was the most effective pile design in the soil conditions. The installation torques for each pile were recorded; however, they were deemed ineffective at establishing a load capability because a consistent torque could not be established. All tests were completed following ASTM standards for Quick Load Test Method. The tests used to select the pile design used are summarized in Table 2.

Table 2. Test results summary

Test number	Depth (ft)	Test Load (kips)	Deflection (inches)
1	17	256	1.295
2	19	258	1.515
3	28	288	1.535

The complete load-deflection test results are shown in Figures 8 through 10.

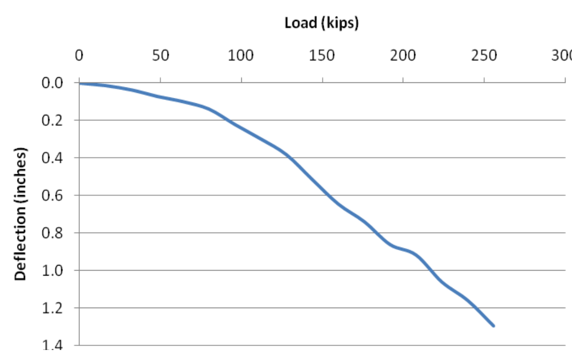

Figure 8. Test #1

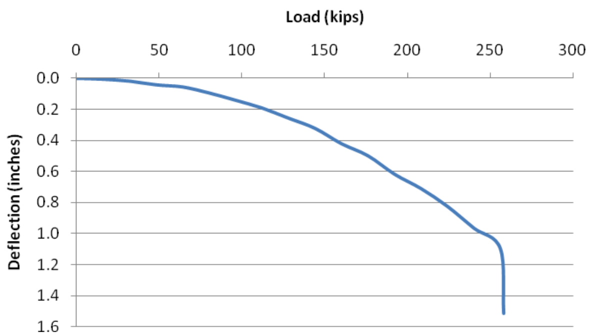

Figure 9. Test #2

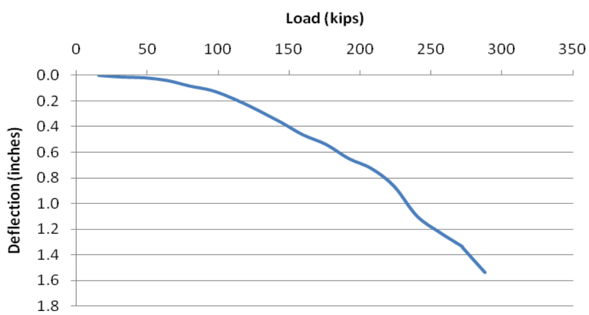

Figure 10. Test #3

3.3 Production

The results of the completed load tests showed helical piles were the most cost effective solution. Helical piles produced no spoils and no vibrations that might have caused issues with surrounding structures. Based on the test data, design criteria included a minimum pile depth of 15 feet, and a minimum of 6.5 ft into the sand and gravel layer. All piles were installed complete with a 6-inch diameter grout column. 730 helical piles were installed on this site in 40 working days. These piles were able to resist an ultimate load of 285 kips in compression.

4 CONCLUSIONS

The ultimate load capacities of helical piles in compression and tension make them an increasingly effective foundation solution in many new construction applications. Load test data indicate that solid steel, square shaft helical piles can resist loads significantly higher than the rated ultimate capacity. Cohesionless soils also offer increased grout yields per pile which typically results in increased load capabilities. Solid steel, square shaft helical piles are able to withstand higher installation torques than other shaft types, increasing the ultimate capacity of the pile. Both examples indicate that helical piles can be used to resist capacities in both tension and compression to high loads, even well beyond the manufacture's rated capacity when installed correctly.

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REFERENCES

ASTM International. 2008. Standard Test Methods for Deep Foundations Under Static Axial Compressive Load.