Load Test Results

Axial tension (uplift) pile capacity

The results of tensile (uplift) load tests are presented in *Figure 5* in the form of load displacement curves for piles T1 and T2. Both piles had the same configurations except pile T1 installed in stiff clay had triple helixes spaced at 2.5D (1.77 m), where D is the diameter of the helix, while pile T2 installed in soft clay had helixes that were spaced at 3D (2.134 m). It can be seen from *Figure 5* that load displacement curves for both piles were linear at the initial part of the uplift load up to a settlement of about 1 mm and load of about 100 kN. It should be noted that pile T1 installed in stiff clay showed softer response manifested by the larger displacement at the same load level compared to pile T2. However at higher displacement levels, the load-displacement curves were highly nonlinear and pile T2 reached a plunging failure of about 445 kN at displacement level of about 15 mm (i.e. 2.5 per cent of the helix diameter). The uplift load test for pile T1 was stopped at load level of about 300 kN while pile T2 was tested until failure. The ultimate capacity of pile T1 was extrapolated based on the shape of load-displacement curve and the results are presented in *Table 3*.

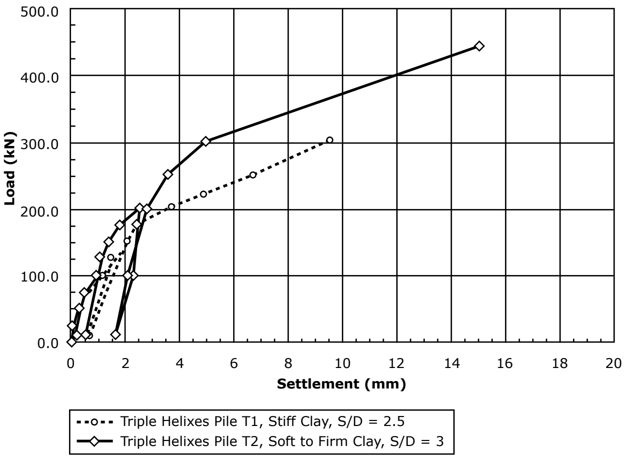

Figure 5. Load vs. displacement curves for axial tension (uplift) load tests

Table 3. Pile load test results

Pile No	Soil Conditions	Ultimate Pile Capacity (Qult) kN	Ultimate Settlement (mm)
Compression Test Results			
C1	Stiff clay	677	50
C2	Soft to firm	772	50
Tension (Uplift) Test Results			
T1	Stiff clay	370	15
T2	Soft to firm	445	15

Conclusions

The results of the axial compression and tension load tests performed in soft to firm or stiff clays demonstrated the suitability of helical pile foundations for the power transmission lines in Northern Manitoba. The results of the load testing program confirmed that the helical pile is a viable deep foundation option for construction of power transmission towers in remote areas and demonstrated their advantages.

The results of the full-scale load tests are also used to validate the theoretical model used for helical pile design installed in soft and stiff high plastic clays. The results indicated that the cylindrical shear failure mechanism control the behavior of helical piles with spacing ratio up to three installed in clay materials.

References

ASTM D 1143-81, 1981. Standard Test Method for Piles Under Static Axial Compressive Load; (Reapproved 1994). *Annual Book of ASTM Standards*, 1997, 04.08: 95-105.

ASTM D 3689-90, 1990. Standard Test Method for Individual Piles Under Static Axial Tensile Load; (Reapproved 1995). *Annual Book of ASTM Standard*, 1997, Vol. 04.08, pp. 366-375.

Helical Piles for Power Transmission Lines

Case Study in Northern Manitoba, Canada

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Introduction

Helical piles have been used with great success as the foundation platform for power transmission line towers. The installation methods and equipment make most locations, but primarily remote areas, far less challenging and cost prohibitive than the traditional deep foundation options. Additional advantages over other typical deep foundation options are: they provide significant uplift resistance and as well can be immediately loaded after installation. This paper summarizes a case study of helical pile foundations supporting power transmission lines located in northern Manitoba, Canada. The site conditions, pile installation and performance of foundations are described in the following sections.

Subsurface Stratigraphy

Pile load tests were carried out in two different soil conditions including either soft to firm clay or stiff high plastic clay with silt varves that extended along the entire embedded depth of the piles. The groundwater level was measured at the existing ground surface. The undrained shear strength parameters obtained from undrained compression (CIUC) triaxial tests are summarized in *Table 1* below. Residual undrained shear strength values were used to estimate the axial capacities of the helical piles.

Table 1. Soil design parameters

Soil Type	Undrained Shear Strength, Cu (kPa)	
	Peak	Residual
Soft to firm clay	30	18
Stiff clay	60	30

Screw Pile Configuration

Four pile load tests were carried out including two compression and two uplift load tests. The helical pile configurations used for the pile load test program consisted of two piles with triple helixes spaced at either 2.5D or 3D, where D is the helix diameter, for guy anchors (i.e to resist uplift loads) and two piles with either three or four helixes for tower support (i.e. to support compression loads). The schematic front view of helical piles tested in this study are summarized in *Figure 1* (page 2) and pile configurations are summarized in *Table 2* (page 3).

Pile Installation and Test Setup

The helical piles tested in this study were manufactured and installed by Almita Manufacturing Ltd. of Ponoka, Alberta. Helical piles were installed through the use of mechanical torque applied at the pile head. A typical pile installation is presented in *Figure 2*. Torque levels applied during pile installation were continuously recorded and penetration depth was continuously measured. Final measured torque at the end of pile installation and total embedment depths are also summarized in *Table 2*. The maximum torque measured during installation for three helix and four helix piles (C1 and C2) installed in stiff clay and soft to firm clay were similar. However, the maximum torque for guy anchor T2 was higher than that of T1 by about 15 percent due to higher spacing ratio. The embedment depth for the three helix pile was 7.5 m while the embedment depth for four helix pile was 10.8 m. For guy anchors the embedment depths were 7.9 m for both piles.

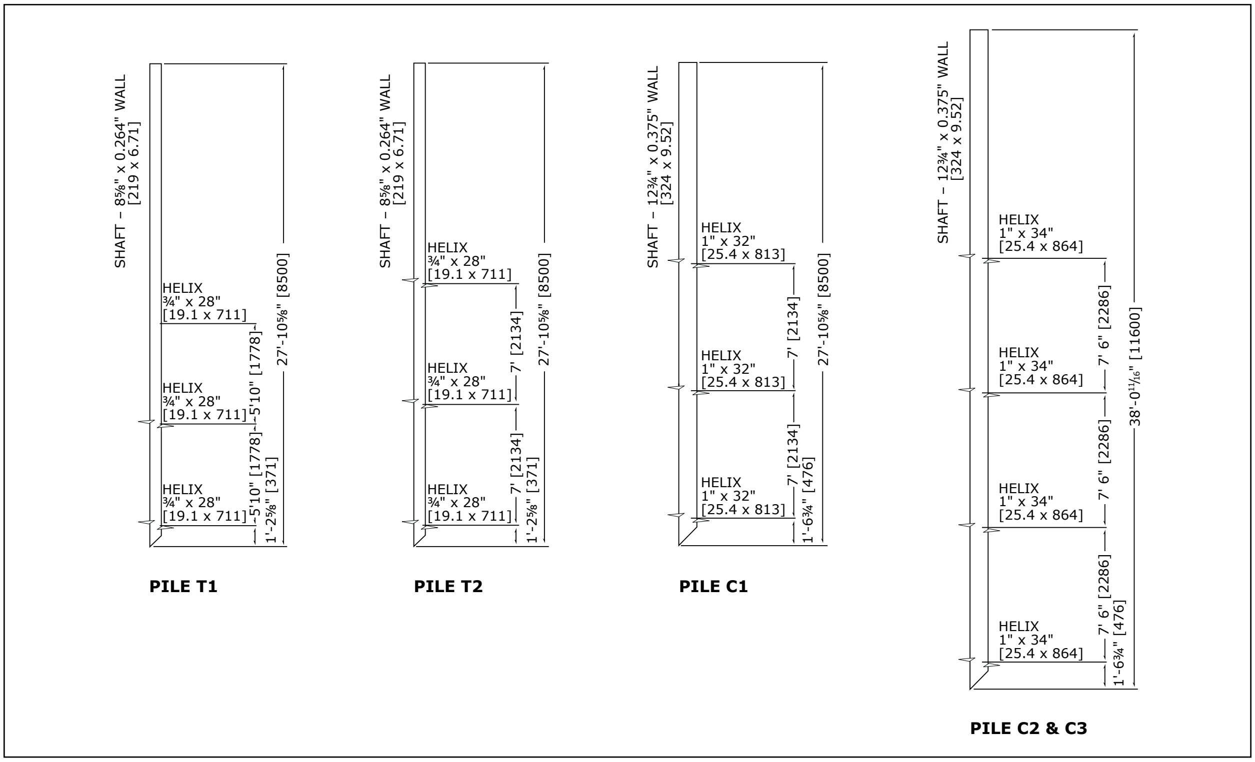

Figure 1. Helical pile configurations

The pile load test setup consisted of two reaction piles and a test pile. The reaction piles were positioned at spacing of 6 m (about four helix diameters from the tested pile). *Figure 3* shows a typical axial tension (uplift) load test setup. Axial pile load tests were conducted according to the ASTM D-1143 Quick Load Test Method for Piles under Static Axial Compressive Load and ASTM D-3689 Quick Load Test Method for Piles under Static Axial Tensile Load. Loads were applied in increments of approximately 10 per cent of the estimated pile capacity in 10-minute time intervals.

Figure 2. Typical pile installation

Load Test Results

Axial compressive pile capacities

The results of compressive load tests are presented in *Figure 4* in the form of load settlement curves. It can be noted from *Figure 4* that load settlements were linear at the initial part of the load-settlement curve up to a settlement of about 3 mm and corresponding loads of about 200 kN. At higher settlement levels piles showed a nonlinear load-settlement

Figure 3. Typical axial tension (uplift) load test setup

followed by plunging failure at settlement of about 50 mm and corresponding loads of 677 kN and 772 kN for piles C1 and C2, respectively. The ultimate compressive load capacities for piles C1 and C2 are presented in *Table 3*. Cycles were carried out at loads of about 245 kN and 490 kN indicated that the effect of cyclic loading had a minor effect on the response.

It is noted from *Figure 1* that pile C2 with four helixes installed in stiff clay offered higher resistance compared to pile C1 with triple helixes installed in soft to firm clay. This behaviour suggested that the cylindrical shear failure mechanism is mobilized. In cylindrical shear failure mechanism the load at the pile head is resisted by three components, including the skin friction along the shaft, the developed cylindrical shear resistance between the helixes and the surrounding soil and end bearing of the bottom helix (for compression load tests) or the top helix(for uplift load tests). For pile C2 with four helixes, the cylindrical shear resistance component was considerably higher than that of pile C1 with triple helixes due to the larger surface area.

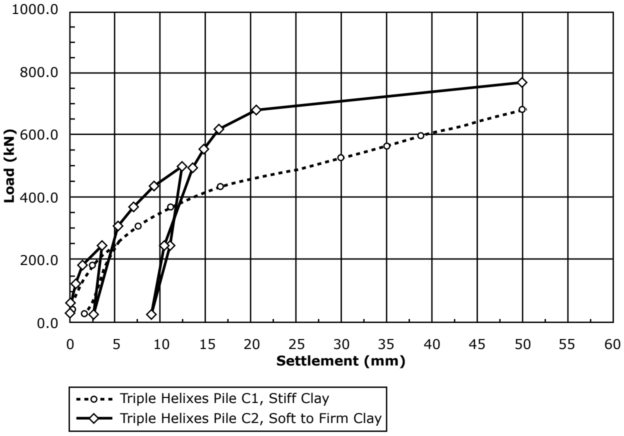

Figure 4. Load vs. settlement curves for axial compression load tests

Table 2. Summary of pile installation

	Pile Configuration					
Pile No	(Dia. (m) x Length (m) x No. of helixes x Helix thickness (mm) x Helixes Dia. (m)	Spacing between helixes (m)	Test Type	Soil Type	Installation Torque kN.m (ft.Ibs)	Embedment Depth (m)
C1	Triple helixes (0.324 x 8.5 x 3 x 25.4 x 0.813)	2.134	Compression	Stiff clay	94.9 (70,000)	7.5
T1	Triple helixes (0.219 x 8.5 x 3 x 19 x 0.711)	1.778	Uplift	Stiff clay	52.9 (39,000)	7.9
C2	Four helixes (0.324 x 11.6 x 4 x 25.4 x 0.864)	2.286	Compression	Soft to firm	94.9 (70,000)	10.8
T2	Triple helixes (0.219 x 8.5 x 3 x 19 x 0.711)	2.134	Uplift	Soft to firm	61.0 (45,000)	7.9