

# Manitoba Hydro – Bipole III, Keewatinohk Converter Station

## Draft - Helical Pile Installation Criteria and Production Testing Recommendations

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### 1.0 Introduction

This technical memorandum provides draft helical pile installation criteria and draft recommendations for beginning of production testing (called pre-production testing for clarity) and production verification testing of American Piledriving Equipment (APE) HD™ helical piles at the proposed Bipole III, Keewatinohk Converter Site near Gillam, MB. This document is a follow-up to the Helical Pile Test Program Results dated September 17, 2015 provided under separate cover. These recommendations were not included with the load testing program results and must be considered draft now because final recommendations for production testing require structural loading and maximum allowable service limit deflections; these have not been provided by the structural designers at this time.

Unless loads become significantly more than estimated, the production pile will be a 245 mm outside diameter, 13.8 mm wall, 457 mm single helix (9.625- x 0.545- x 18- inch) open ended pile.

### 2.0 Preliminary Installation Criteria for Axial Compression

The following are preliminary recommendations for pile installation criteria for axial compression in the Converter Building and Transformer areas and Filters 3 and 4, all locations where the pile must be founded below the unstable permafrost. These criteria must be revisited after final design loading is determined:

- Predrill to at least the minimum toe embedment depth shown on the Plans with the 305 mm (12-inch) Polar Penetrator.
- Screw the pile past the end of the predrilled hole until “refusal” torque, defined as greater than approximately 244 kN-m (180 kip-feet). This final torque may be lowered if loads are small compared to the test loads and the pile penetrates sufficiently for uplift resistance (see below).

- Sound the depth of the soil plug before each 6.10 m (20-foot) pile extension section is added. If the plug is in excess of approximately 10 feet, drill it out before adding each extension. Do not drill the interior past the bottom of the predrilled hole.
- If a large boulder is encountered within the unstable permafrost depth that can be penetrated with the production sized Polar Penetrator or a similar sized downhole hammer, but cannot be passed by the helical pile, drill through the boulder with a 457 mm downhole tool, but cease using that tool as soon as the boulder is passed, in order to preserve uplift resistance. See discussion on uplift below. If uplift demands are small, this criteria may not apply.

As shown by the results of the test on HP2-3, which torqued up to refusal with very little penetration below the bottom of the predrill, penetration below the bottom of the predrilled hole is not important for axial compression resistance as long as the torque is high. However, penetration below the bottom of the predrilled hole or into backfill sand wedged within the confines of the predrilled hole are likely to be critical for uplift resistance.

The installers may also want to experiment with using a slightly larger (e.g., 356 mm) pre-drilling bit to speed construction. The axial compression tests show no detriment to resistance from the larger predrilled hole and at the depths of the piles in the transformer building and with the pile helix completely filling the pre-drilled diameter and cutting into undisturbed soil, there is no soil mechanics-related reason to expect that a slightly larger predrill would have a significant impact on axial compressive capacity.

Installation criteria for Filters 1 and 2 cannot be estimated without a better understanding of the potential loads. At a minimum, the piles will have to be founded with the helix below the design seasonal frost depth of 5 m. Based on constructability trials during the load testing program and experience at the Keeyask Camp site to the south, predrilling may not be needed to found the piles below the 5 m depth if they can be installed when the frost depth is limited to about 1 to 1.5 m, but will be needed for late winter and spring conditions when the frozen depth is larger. A minimum of 2 pre-production, non-instrumented tests are recommended to determine minimum depth and torque to capacity relationships for the Filter 1 and 2 site.

### 3.0 Axial Compression Production Verification Testing

A program of production axial compression testing is recommended to verify that axial compression resistance at other locations is similar to that measured at the two axial compression test sites. As a start, approximately 0.5 percent of the planned production piles with a factored resistance to factored load ratio less than 4 should be tested in axial compression as a first order of work. The factored resistance would be the lesser of the 4 axial compression tests performed in this program for the converter building/transformer site, and the resistance determined for the Filter 1 and 2 site determined in the pre-production testing described above. The tests should be spatially distributed around the proposed pile locations at the site. These tests would be non-instrumented.

If the results of the tests on the original 0.5 percent of production piles show factored resistance at least 2 times higher than factored loads and total deflections at service loads are within the structurally tolerable limits, then additional testing would not be needed. If the factored resistance is between 1 and 2 times the factored loads or deflections are excessive, then the number of verification tests should be increased to 1 percent of the pile number.

If the loads stay within the ranges estimated in the Helical Pile Test Program Results document, then additional instrumented axial compression load tests to verify deformation under dead load plus thaw-induced drag load are probably not needed. The tests are quite time consuming and complex when performed during good weather. The reliability of the data obtained during the anticipated pile production start-up, scheduled for November 2015, may be low, and results to date suggest that if piles

can be advanced to the bottom of predrilled 15 or 20 m holes, that the skin friction resistance along the pile will be small. However, as a contingency for unforeseen conditions or changes in loading, costs for up to 4 instrumented tests may be advisable.

## 4.0 Additional Tests to Define Installation Criteria for Uplift Resistance

Pre-drilling diameter, embedment depth into the undisturbed till, and backfill placement and compaction will have significant impacts on uplift resistance. Once the uplift loads, beyond those induced by seasonal frost jacking, are known, the following program of testing is recommended:

### 4.1 Pre-Production Testing - No Permafrost Areas (Filter Building 1 & 2 – Test Area 5)

Golder Associates have determined that there is no permafrost at this location, so the minimum pile toe (or top of helix in this case) depth is 5 m, to withstand seasonal frost jacking loads. A program of testing for the worst case, encountering a boulder at the bottom of the predrilled hole, is recommended as the minimum amount of uplift testing. Additional testing to optimize the depth of penetration needed below the bottom of the predrilled hole can be considered if the boulder simulation case requires more than one standard 3.05 m (10-foot) add section.

#### **Uplift Test Pile 1 – Boulder at Bottom of Predrill Simulation**

- Predrill with the production tool to 5.3 m (=5 m design frost depth + 0.3 m from pile toe to top of helix)
- Screw pile in to 5.3 m (17.5 feet)
- Test in uplift without backfilling

#### **Uplift Test Pile 2 – Non-passing Uplift Test Pile 1 and Impassible Boulder within Depth of Predrill Simulation**

- Predrill with the 457 mm (18-inch) Polar Penetrator to 8.2 m (27 feet)
- Backfill with uncompacted sand to the ground surface
- Screw in the pile to 8.2 m
- Test in uplift

If the test passes, go on to production phase testing as described below. If the test does not pass, drill a new 456 mm predrilled hole to 8.2 m and backfill with sand compacted in 2 m loose lifts with a flat plate compactor to a depth of 5 m and with loose sand above 5 m. Install **Uplift Test Pile 2a** and test.

If Uplift Test 2a fails, reevaluation of the simulation and field calls for further testing may be necessary. In reality, it is likely that the boulder could be removed and the pile could penetrate into undisturbed material below the predrill to develop uplift capacity. That required depth will be determined by Uplift Test Pile 3.

#### **Uplift Test Pile 3 – Required Penetration below Predrill Depth**

- Predrill with the production tool to 5.3 m
- Screw the pile in 2 m below the bottom of the predrill (half way between the condition of test pile 1 and the condition of HP5-1 that was tested in this program)

### 4.2 Pre-Production Testing – Filter Building 3 & 4

The unstable permafrost depth in this area is 15 m.

#### **Uplift Test Pile 1**

- Predrill with the production tool to 15 m

- Screw in the pile to 15 m
- Backfill with loose sand to the ground surface

The instrumentation from the axial compression tests suggests that there is almost no skin friction in the upper 5 m, so we do not need to be concerned about discounting it when looking at frost jacking resistance. If this test fails, continue with Uplift Test Pile 2, otherwise only production verification testing is needed.

#### **Uplift Test Pile 2**

- Predrill with the production tool to 15 m
- Screw in the pile to 15 m
- Compact sand around the pile in 2 m loose lifts with the mandrel compactor to a depth of 5 m if frost jacking is the controlling case, or to the ground surface if other uplift loading controls design

#### 4.3 Pre-Production Testing – Converter Building and Transformers

If the results from pre-production uplift testing at the two Filter Building Sites show ample resistance for the loads at the Converter Building and Transformers, then pre-production testing could be completed on production piles instead of non-production piles. At least one test pile predrilled to 20 m and installed with the procedure described for Uplift Test Pile 1 or 2 (whichever was needed for a passing tests) at Filter Building 3 & 4 is recommended in the north section of the Converter Building and one in the south section of the Converter Building. A 15 m predrilled pile should be tested in the location of heaviest uplift loads in the center of the Converter Building or Transformers.

### 5.0 Production Verification Uplift Testing with Installation Method Established

Repeat the test for the “just-passing” condition on 1 percent of production piles in each of the different areas if the factored resistance to load ratio is less than 2. If the resistance to demand ratio is greater than 2, repeat the test on 0.5 percent of production piles.

### 6.0 Preliminary Installation Criteria and Testing for Lateral Resistance

Lateral loads are very poorly understood at this time. At a minimum to provide a uniform working surface, the annulus between the installed pile shaft and the predrilled hole should be backfilled with sand mounded above the finished surface and compacted with a plate compactor. Additional compaction and/or head fixity may be needed if the lateral loads are large.

It is almost certain that there will be some locations with a large boulder that will require removal with a tool as large as the helix diameter. Therefore, we recommend performing at least 2 pre-production tests with a 457 mm (18-inch) predrilled hole allowed to cave overnight, then backfilled with sand – one uncompacted and one compacted.

If lateral service loads are larger than 4 times the loads that resulted in service limit deflections in the test program, then production verification load tests should be performed on at least 0.5 percent of the production piles. If the results of these initial tests show service limit deflections at loads less than 2 times the service loads, then additional lateral load testing should be performed to total 1 percent of the production piles with those higher loads.

Lateral load testing must be performed with the active zone thawed. These load tests can be performed in production pile locations, but should be done at the beginning of construction before the ground begins to freeze. If freezing conditions are anticipated before testing can begin, insulating blankets should be placed in possible test locations to minimize delays for ground thawing.

## 7.0 Summary of Potential Production-Phase Load Testing

The preliminary recommendations above have been summarized in a tabular form to assist in production planning. Table 1 lists the number of pre-production and production verification tests that might be needed for the project. The far right hand 3 columns total the number of tests for each area assuming that there are 2000 total piles.

Future pile load testing should be conducted in areas that have not be previously disturbed by pile testing activities.

<b>Table 1</b>					
<b>Summary of Potential Production-Phase Load Testing</b>					
<b>Location</b>	<b>Pre-Production Tests</b>	<b>Production Verification Tests</b>	<b>Total Assumed Number of Tests<sup>(1)</sup></b>		
			<b>Low</b>	<b>Medium</b>	<b>High</b>
<b>Axial Compression</b>					
Filters 1 & 2	2	See below	2	See below	
Other Yard and Converter Building Piles	0	Contingency for up to 4 instrumented 0.5 to 1 percent of piles with factored loads < 4 X lowest test pile factored resistance	0	14	24
		Compression Total	2	14	24
<b>Uplift</b>					
Filters 1 & 2	2 to 4	See below	2		4
Filters 3 & 4	1 to 2	See below	1		2
Converter Bldg and Transformers	3 + contingency for 3 more over entire site	See below	0		3
All site	0	0.5 to 1 percent of piles with factored loads < 4 X lowest test pile factored resistance	0	10	20
		Uplift Total	3	10	29
<b>Lateral</b>					
All Sites	2	0.5 to 1 percent of piles with service loads > 4 X load that resulted in service limit deflection on load tests	2	10	20
<sup>(1)</sup> Based on assumption of 2000 piles total					