AHPAC

African Helical Pile & Anchor Company

"Let's Anchor It!"

e-mail: **info@ahpac.co.za** Website: **www.ahpac.co.za** Cell: 082 440 3315

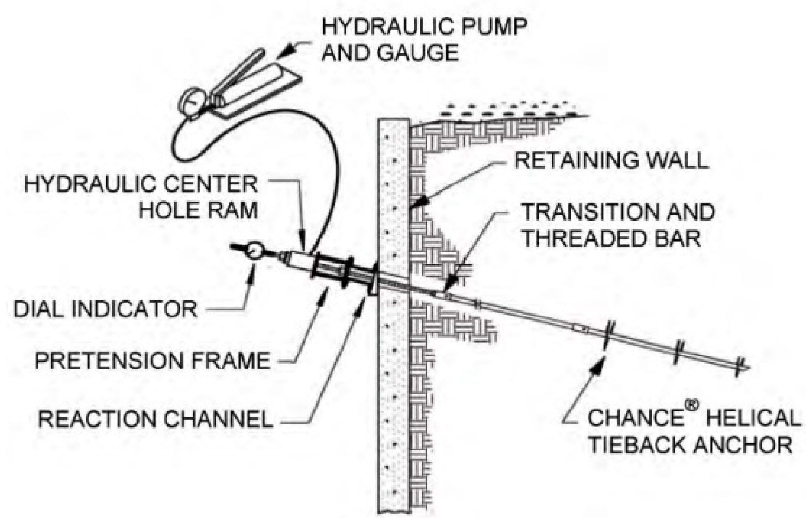
AHPAC is a reseller of helical pile products manufactured by HELICALANCHORS INC. This Load Testing document has been adopted from Hubbell Power Systems, a manufacturer of Helical Pile products located in the United States of America to assist design professionals and contractors with a quick reference guide. The information provided is based on their experience of their products which they manufacture as well as the installation of their products undertaken in the United States.

Disclaimer

The information in this manual is provided as a guide to assist design professionals with their design as well as with the development of project specifications. Installation conditions, including soil and structure conditions, vary widely from location to location and from point to point on a site. Independent engineering analysis and consulting building codes and authorities should be conducted prior to any installation to ascertain and verify compliance to relevant rules, regulations and requirements. AHPAC shall not be responsible for, or liable to you and/or your customers for the adoption, revision, implementation, use or misuse of this information.

STATIC LOAD TESTS (TIEBACKS)

It is recommended that the Field Load Tieback Test be conducted under the supervision of a Registered Professional Engineer. The engineer will specify the test and measurement procedure, load increments, time intervals and acceptable ultimate deflection consistent with specific project and load conditions. If the required ultimate load and test ultimate load results are close, the engineer may choose to adjust the tieback spacing, the length of installation to achieve greater installation torques, and/or the helical plate configuration on each tieback to achieve the desired Factor of Safety (FS).



Hardware Configuration for Performing a Load Test on a Retaining Wall
Figure 1

TEST PROCEDURE

WARNING! DO NOT ALLOW ANYONE TO STAND BEHIND OR IN LINE WITH THE THREADED BAR AND JACK DURING THIS TEST. SERIOUS INJURY MAY OCCUR IF A COMPONENT FAILS DURING TESTING.

1. Determine the required length of the helical tieback anchor to locate the helix plates into the target soil stratum as determined from the project boring logs. Use this data to select the tieback design and ultimate tension capacity and the estimated installation torque. Install the helical tieback anchor to the determined length and torque requirements.
2. If the soil overburden has not been excavated from behind the wall, connect the thread bar adapter/transition to the helical tieback by reaching through the hole in the wall. Install the continuously threaded bar, reaction channel, hydraulic ram (loading device), pretension frame (if required), dial indicator (or other measuring device such as Total Station Unit), hydraulic pump and gauge (see Figure 1). The magnitude of the test pressure is determined as follows:

$$\text{PT (test pressure) Mpa} = \frac{\text{DL (design load) kN x FS (Factor of Safety = 1.25 to 2.5)}}{\text{A (effective cylinder area) m}^2}$$

NOTE: The effective cylinder areas (A) are available from the manufacturers of center hole rams (i.e., Enerpac, Power Team, Simplex, etc).

The load application system, i.e., center hole ram and pump, shall be calibrated by an independent testing agency prior to the load testing of any tiebacks.

An Alignment Load (AL), usually 5% to 10% of the Design (Working) Load (DL), should be applied to the helical tieback anchor prior to the start of field load tests. The initial alignment load helps to remove any looseness in the tieback shaft couplings and thread bar transition system.

3. Pre-Production Tests (Optional): Load tests shall be performed to verify the suitability and capacity of the proposed helical tieback anchor, and the proposed installation procedures prior to the installation of production tiebacks. The owner shall determine the number of pre-production tests, their location and acceptable load, and movement criteria. Such tests shall be based, as a minimum, on the principles of the performance test as described below. If pre-production tiebacks are to be tested to their ultimate capacity, then an additional purpose of the pre-production tests is to empirically verify the ultimate capacity to average installing torque relationship of the helical tiebacks for the project site.

Anchor Tension Load Test in Minneapolis, MN
Figure 2

Testing above the performance test maximum applied load of 125% x DL should follow the loading procedures and increments as given in the Static Axial Load Tests (Compression/Tension) section to follow.

4. Performance Tests:
The number of tiebacks that require performance testing shall be defined in the project specifications. The minimum number of tiebacks for performance testing shall be two (2). Helical tieback anchors shall be performance tested by incrementally loading and unloading the tieback in accordance with the Performance Test Schedule (see Table 1). The applied load shall be increased from one increment to the next immediately after recording the anchor movement. The load shall be held long enough to obtain and record the movement reading at all load increments other than the maximum test load. The maximum test load (1.25 x DL) shall be held for a minimum of 10 minutes. Anchor movements shall be recorded at 0.5, 1, 2, 3, 4, 5, 6, and 10 minutes. Refer to Acceptance Criteria on page 10 for additional hold periods, if required, and acceptable movement criteria.

5. Proof Testing:
All anchors which are not performance tested shall be proof tested. The proof test shall be performed by incrementally loading the helical anchor in accordance with the Proof Test Schedule (see Table 2). The load shall be raised from one increment to another after an observation period. At load increments other than the maximum test load, the load shall be held for a period not to exceed two (2) minutes. The two minute observation period shall begin when the pump begins to load the anchor to the next load increment. Movement readings shall be taken at the end of the two minute observation period. The installing contractor or engineer shall plot the helical anchor displacement vs. load for each load increment in the proof test. The 1.25DL test load shall be maintained for five (5) minutes. This five minute observation period shall commence as soon as 1.25DL is applied to the anchor. Displacement readings shall be recorded at 0.5, 1, 2, 3, 4, and 5 minutes. Refer to Acceptance Criteria on page 10 for additional hold periods, if required, and acceptable displacement criteria.

Performance Test Schedule, Table 1

PERFORMANCE TEST SCHEDULE				
CYCLICAL LOAD INCREMENTS (%DL/100)				
AL	AL	AL	AL	AL
0.25DL*	0.25DL	0.25DL	0.25DL	0.25DL
	0.25DL	0.50DL	0.50DL	0.50DL
		0.75DL*	0.75DL	0.75DL
			1.00DL*	1.00DL
				1.25DL*
				Reduce to lock-off load#

AL = Alignment Load, usually 10 to 15% of DL.
DL = Design (Working) Load
* The dealer/installing contractor shall plot the helical anchor movement for each load increment marked with an asterisk (*) in the performance schedule and plot the residual displacement at each alignment load versus the highest previously applied load.
# Helical tieback anchors which are performance tested may be completely unloaded prior to the lock-off load procedure. Final adjusting to the lock-off load does not require further movement readings.

Proof Test Schedule, Table 2

PROOF TEST SCHEDULE	
LOAD TEST SCHEDULE (%DL/100)	OBSERVATION PERIOD (MIN.)
AL	AL
0.25DL	2.0
0.50DL	2.0
0.75DL	2.0
1.00DL	2.0
1.25DL	5.0
Reduce to lock-off load#	

AL = Alignment Load, usually 10 to 15% of DL.
DL = Design (Working) Load
# Helical tieback anchors which are proof tested may be completely unloaded prior to the lock-off load procedure. Final adjusting to the lock-off load does not require further displacement readings.

STATIC AXIAL LOAD TESTS (COMPRESSION/TENSION)

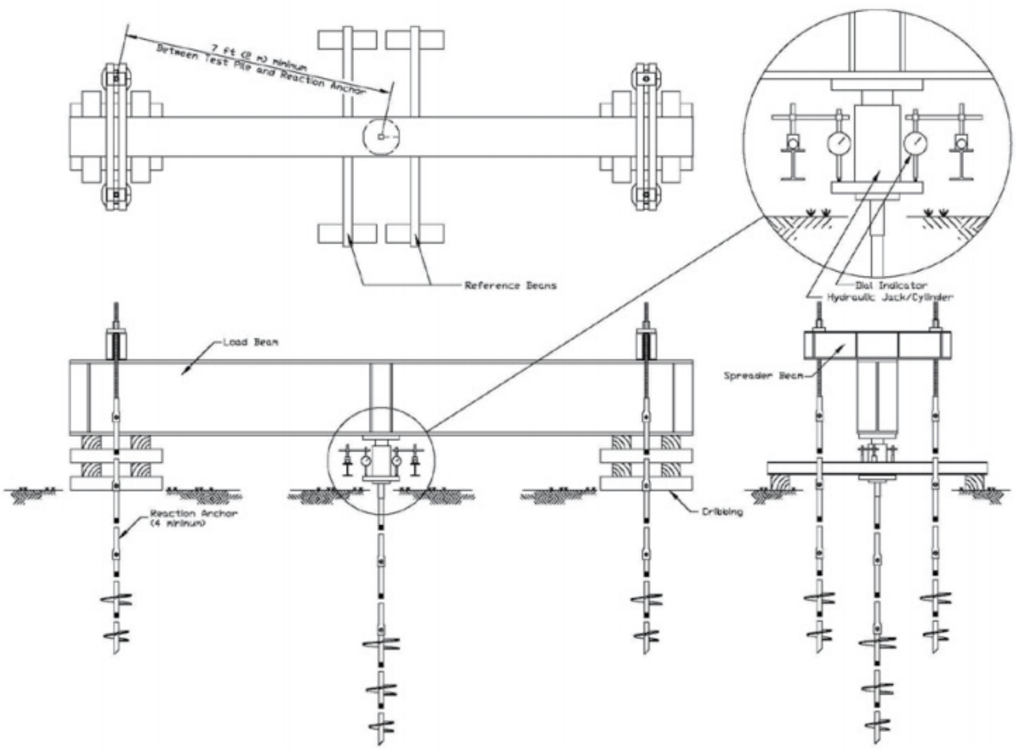
PRE-PRODUCTION LOAD TESTS

Load tests shall be performed to verify the suitability and capacity of the proposed helical anchor/pile, and the proposed installation procedures prior to installation of production helical anchors/piles. These load tests shall be performed prior to the installation of the production helical anchors/piles. The Owner shall determine the number of pre-production load tests, their location, acceptable load and displacement criteria, and the type(s) of load direction (i.e., tension, compression, or both). An additional purpose of pre-production tests is to empirically verify the ultimate capacity to the average installing torque relationship of the helical pile/anchor for the project site with the torque measurement equipment used for the project. Pre-production helical pile/ anchor installation methods, procedures, equipment, and overall length shall be identical to the production helical anchors/piles to the extent practical except where approved otherwise by the Owner. It is recommended that any field load test for compression or tension be conducted under the supervision of a Registered Professional Engineer. The engineer will specify the test and measurement procedure, load increments, time intervals, and acceptable ultimate displacement consistent with specific project and load conditions. Test procedures shall conform to ASTM D-1143-07, Standard Test Method for Pile under Static Axial Compressive Load and/or ASTM D3689-07, Standard Test Method for Pile under Static Axial Tension Load unless otherwise specified by the engineer. These ASTM specifications do not specify a particular method to be used, but rather provide several slow-testing and quick-testing optional methods. Citing the

Canadian Foundation Engineering Manual, 2007: "The slow-testing methods . . . (outlined by the ASTM D1143-07. . . are very time-consuming. When the objective of the test is to determine the bearing capacity of the pile, these methods can actually make the data difficult to evaluate and disguise the pile true load movement behavior, thereby counteracting the objective of the test. The benefit of the (slow) test methods lies in the additional soil-pile behavior information, occasionally obtained, which the interpreting engineer can use, when required, in an overall evaluation of the piles. ". . . For routine testing and proof testing purposes, the quick methods . . . are sufficient. Where the objective is to determine the bearing capacity of the pile . . . the quick test is technically preferable to the slow methods." Therefore, the following test procedure is based on the "Quick Load Test Method for Individual Piles". This test procedure shall be considered to meet the minimum requirements for load testing. It is not intended to preclude local building codes, which may require the use of other testing methods as described in the ASTM specifications.

PRE-PRODUCTION LOAD TESTS

1. Determine the depth to the target stratum of soil from the geotechnical site investigation report that includes boring logs. Use these data to select a pile/anchor design capacity, ultimate capacity and estimate the installation torque at the target stratum and depth.
2. Set the spacing and install the four reaction anchors at the test site (see Figure 3). The recommended spacing between the test pile and the reaction anchors is at least 5D, where D = diameter of the largest helical plate. For tension only tests, the reaction anchors are not required.
3. Install the test helical pile at the centroid of the reaction anchors to the target depth and torque resistance. For tension tests, install the test anchor at the desired location to the target depth and torque resistance.
4. Mount the two anchor beams on the four reaction anchors/piles and the reaction beam between the anchor beams (see Figure 3). For tension tests, center the reaction beam over the anchor and support each end of the beam on cribbing or dunnage. The helical reaction piles are not required if the surface soils have sufficient bearing strength to support the cribbing/dunnage under the applied loading without excessive deflections.
5. Install a load cell, hydraulic load jack, actuator and pressure gauge. The center hole load jack will be mounted below the reaction beam for a bearing (compression) test (see Figure 3) and above the reaction beam for an anchor (tension) test. A solid core hydraulic jack can be used for compression tests.
6. Set the displacement measuring devices. Deflection measuring devices can include analog dial or electronic digital gauges (must be accurate to .025mm) mounted on an independent reference beam, a transit level surveying system, or other types of devices as may be specified by the engineer.
7. Apply and record a small alignment or seating load, usually 5% to 10% of the design load. Unless otherwise defined, the ultimate test load shall be assumed equal to 200% of the design load. Hold the seating load constant for 10 minutes or until no further displacement is measured.
8. Set the displacement measuring device(s) to zero.
9. Axial compression or tension load tests shall be conducted by loading the helical anchor/pile in step-wise fashion as shown in Table 3 to the extent practical. Pile/anchor head displacement shall be recorded at the beginning of each step and after the end of the hold time. The beginning of the hold time shall be defined as the moment when the load equipment achieves the required load step. There is a generalized form for recording the applied load, hold periods, and pile/anchor head deflections provided at the end of this Section.
10. Test loads shall be applied until continuous jacking is required to maintain the load step or until the test load increment equals 200% of the design load (i.e., 2.0 x DL), whichever occurs first. The observation period for this last load increment shall be 10 minutes or as otherwise specified. Displacement readings shall be recorded at 1, 2, 3, 4, 5 and 10 minutes (load increment maxima only).



Basic Compression Field Test Set-up
Figure 3

Indoor Compression Test
Figure 4

11. The applied test load shall be removed in four approximately equal decrements per the schedule in Table B-3. The hold time for these load decrements shall be 1 minute, except for the last decrement, which shall be held for 5 minutes. Refer to Acceptance Criteria on page B-13 for acceptable movement criteria.

PRODUCTION LOAD TEST PROCEDURES (OPTIONAL AS SPECIFIED)

1. Follow the test setup procedures listed under Pre-Production Load Test Procedures (Items 1 through 7), except the maximum test load to be applied to the pile/anchor is the Design Load (DL). (This may be the only type of load test conducted depending on the conditions.)
2. The Contractor shall perform axial load tests on the number and location of helical piles as specified by the Owner. At the Contractor's suggestion, but with the Owner's permission, tension tests may be performed in lieu of compression tests up to 1.00 DL for helical piles with sufficient structural tension capacity. The requirements of Table 4 may be regarded as a minimum, however, it is not recommended to test production helical piles to values of up to 2.0 DL unless the helical pile's failure load is significantly higher than 2.0 DL. The maximum production helical pile test load shall be determined by the Owner. For example, ASTM D1143 stipulates testing to 2.0 DL.

Pre-Production Test Schedule, Table 3

PRE-PRODUCTION TEST SCHEDULE			
CYCLICAL LOAD INCREMENTS (%DL/100)			
Load Increment	Hold Period (Min.)	Load Increment	Hold Period (Min.)
AL	1.0	AL	1.0
0.20DL	4.0	0.50DL	4.0
0.40DL	4.0	1.00DL	4.0
0.60DL	4.0	1.20DL	4.0
0.80DL	4.0	1.40DL	4.0
1.00DL	4.0	1.60DL	4.0
0.75DL	4.0	1.80DL	4.0
0.50DL	4.0	2.00DL	10.0
0.25DL	4.0	1.50DL	4.0
		1.00DL	4.0
		0.50DL	4.0
		AL	5.0
AL = Alignment Load, usually 10% of DL; DL = Design (Working) Load			

3. Axial compression or tension load tests shall be conducted by loading the helical pile/anchor in the load sequence as shown in Table 4. Anchor/pile head displacement shall be recorded at the beginning of each step and after the end of the hold time. The beginning of the hold time shall be defined as the moment when the load equipment achieves the required load step. The observation period for this last load increment shall be 5 minutes or as otherwise specified. Displacement readings shall be recorded at 0.5, 1, 2, 3, 4, and 5 minutes (load increment maxima only).

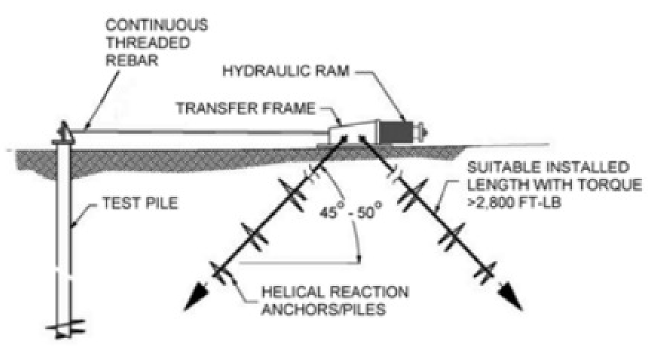
4. The applied test load shall be removed in four approximately equal decrements per the schedule in Table 4. The hold time for these load decrements shall be 1 minute, except for the last decrement, which shall be held for 5 minutes. Refer to Acceptance Criteria on page 10 for acceptable displacement criteria.

STATIC LOAD TESTS (LATERAL)

Helical pile/anchor offer maximum benefits structurally when loaded axially (concentrically) either in tension or compression. In certain design situations, the anchors/piles may be subjected to lateral loads and it is important to establish their lateral load capacity. Such applications may include support for communication equipment platforms, foundations for light poles, and sign standards or use as foundation systems for modular homes. It is recommended that the Field Lateral Load Test on pile/anchor be conducted under the supervision of a Registered Professional Engineer. The engineer will specify the test and measurement procedure, load increments, time intervals, and acceptable ultimate deflection consistent with specific project and load conditions. If the desired ultimate lateral load capacity and test lateral load capacity results are close, the engineer may choose to increase the diameter of the anchor/pile shaft and/or use a concrete collar on the anchor/pile head in order to achieve the desired Factor of Safety. Lateral load tests shall be conducted in accordance with ASTM D-3966-07, Standard Test Method for Piles under Lateral Load.

Production Test Schedule (Optional - as Specified), Table 4

PRODUCTION TEST SCHEDULE	
LOAD INCREMENT	HOLD PERIOD (MIN.)
AL	0
0.20DL	4.0
0.40DL	4.0
0.60DL	4.0
0.80DL	4.0
1.0DL	5.0
0.60DL	1.0
0.40DL	1.0
0.20DL	1.0
AL	5.0
AL = Alignment Load, usually 10 of DL. DL = Design (Working) Load	



Lateral Load Test Equipment Configuration
Figure 5

Lateral Load Test Apparatus
Figure 6

TEST PROCEDURE

1. In order to conduct a lateral load test on an installed pile/anchor, it is necessary to install a reaction anchor system. The reaction anchor system consists of helical pile/anchor installed at a battered angle, and using a test apparatus setup such as shown in Figure B-5. Once the reaction anchor system is installed, the test pile/ anchor is installed to the specified estimated depth and design torque.
2. Threaded steel bar or cable shall be used to connect the test pile to the reaction anchor frame. A hydraulic ram and pressure gauge is installed to apply the test load(s) and to measure the applied force.
3. Set the displacement measuring devices. Displacement measuring devices can include analog dial or electronic digital gauges (must be accurate to 0.025mm) mounted on a reference beam, a transit surveying system, or other type of device as specified by the engineer.
4. For the Load Capacity Tests, follow steps 7 through 11 in the Static Axial Load Tests on page 6 & 7.
5. A failure criterion is often established by the project engineer and will reflect project specific conditions. The load versus lateral deflection is plotted. Interpretation of these results to determine the ultimate and working lateral load capacities often requires engineering judgment. Refer to Acceptance Criteria on page 10 for acceptable displacement criteria.

ACCEPTANCE CRITERIA

Static Load Tests (Tiebacks)

PRE-PRODUCTION AND PERFORMANCE TESTS

The net displacement shall not exceed 1.27mm during the first log cycle of time, i.e., 1 min to 10 min. If the anchor movement between the one (1) minute and ten (10) minute readings exceeds 1.27mm, then the 1.25 DL test load shall be maintained for an additional 20 minutes. Displacements shall be recorded at 15, 20, 25, and 30 minutes. Net displacement is the difference between the movement recorded at the initial time increment and the final time increment of the log cycle of time. The initial time increment is 1 min and the final time increment is 10 min for the first log cycle of time for Pre-Production and Performance Tests. The net displacement shall not exceed 2.54mm during the final log cycle of time (examples, 3 min to 30 min, 6 min to 60 min, etc). If the acceptance criteria is not satisfied, then the anchor test shall be continued for an additional 30 minutes. Displacements shall be recorded at 45 and 60 minutes.

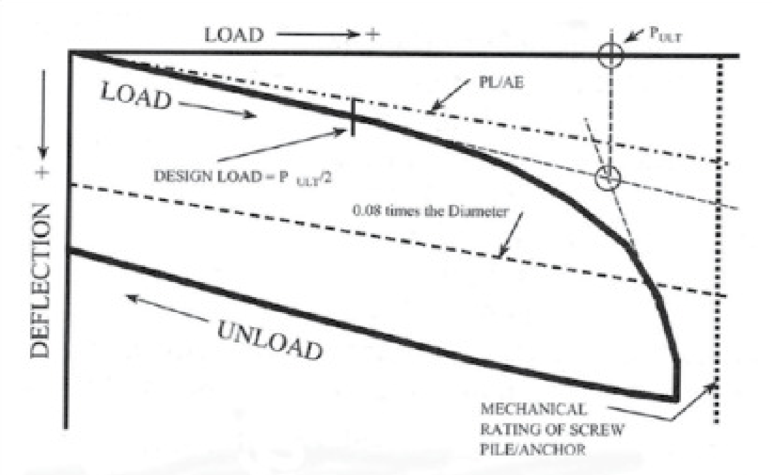
PROOF TESTS

The net movement shall not exceed 1.27mm during the first log cycle of time, i.e., 0.5 min to 5 min. If the anchor movement between the one-half (1/2) minute and five (5) minute readings exceeds 01.27mm, then the 1.25 DL test load shall be maintained for an additional 5 minutes. Displacements shall be recorded at 6 and 10 minutes. The net displacement shall not exceed 2.54mm during the final log cycle of time (examples, 1 min to 10 min, 3 min to 30 min, etc). If the acceptance criteria is not satisfied, then the anchor test shall be continued for an additional 20 minutes. Displacements shall be recorded at 15, 20, 25, and 30 minutes.

Static Axial Load Tests (Compression/Tension)

PRE-PRODUCTION LOAD TESTS

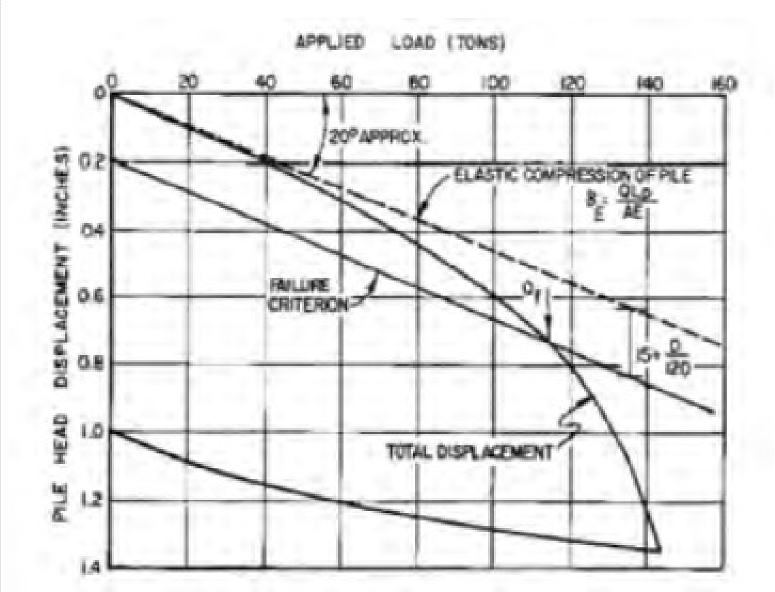
Acceptance of the load test results is generally governed by the building code for that jurisdiction and is subject to review by the structural designer. The structural designer determines the maximum displacement the structure can withstand without undue loss of function or distress. The acceptance criteria must be defined prior to conducting the load test. The load displacement data may be plotted for a quick overview of the results. Figure 7 shows a sample test plot. Various building codes have their own acceptance criteria, which is generally a limit on deflection at the factored load. A fast way to determine the ultimate geotechnical capacity is by use of a technique called the "intersection of tangents." This is accomplished by graphically constructing two tangent lines. One line is drawn tangent to the second "straight line" portion of the load curve, which is beyond the curved or non-linear portion of the load deflection curve. The other line is drawn tangent to the initial "straight line" portion of the load deflection curve. The point where the two tangents intersect identifies an estimate of the ultimate capacity.



Sample Compression Test Load-Deflection Curve
Figure 7

An example of a Code-based acceptance criteria for the allowable capacity is the Chicago and New York City Code, which calls for the design load to be the lesser of:

1. 50% of the applied load causing a net displacement (total displacement less rebound) of the pile of 0.254mm per ton of applied load, or
2. 50% of the applied load causing a net displacement of the pile of 12.7mm. Net displacement is defined as the gross displacement at the test load less the elastic compression.

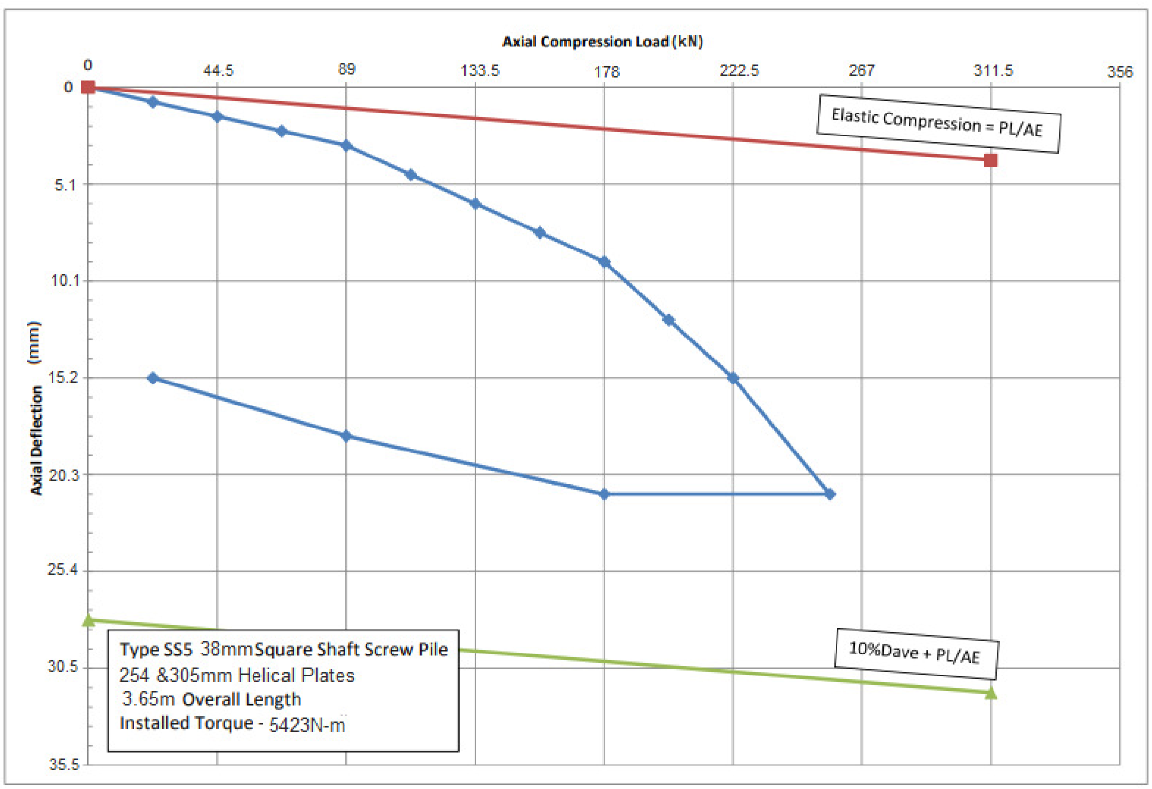


Davisson Method for Determining Net Displacement
Figure 8

Other allowable capacity acceptance criteria include:

- Maximum total displacement under a specified load.
- Maximum net displacement after the test load.
- Maximum displacement under the design load, or various techniques such as that defined by the Davisson Method (1973) and shown in Figure 8.

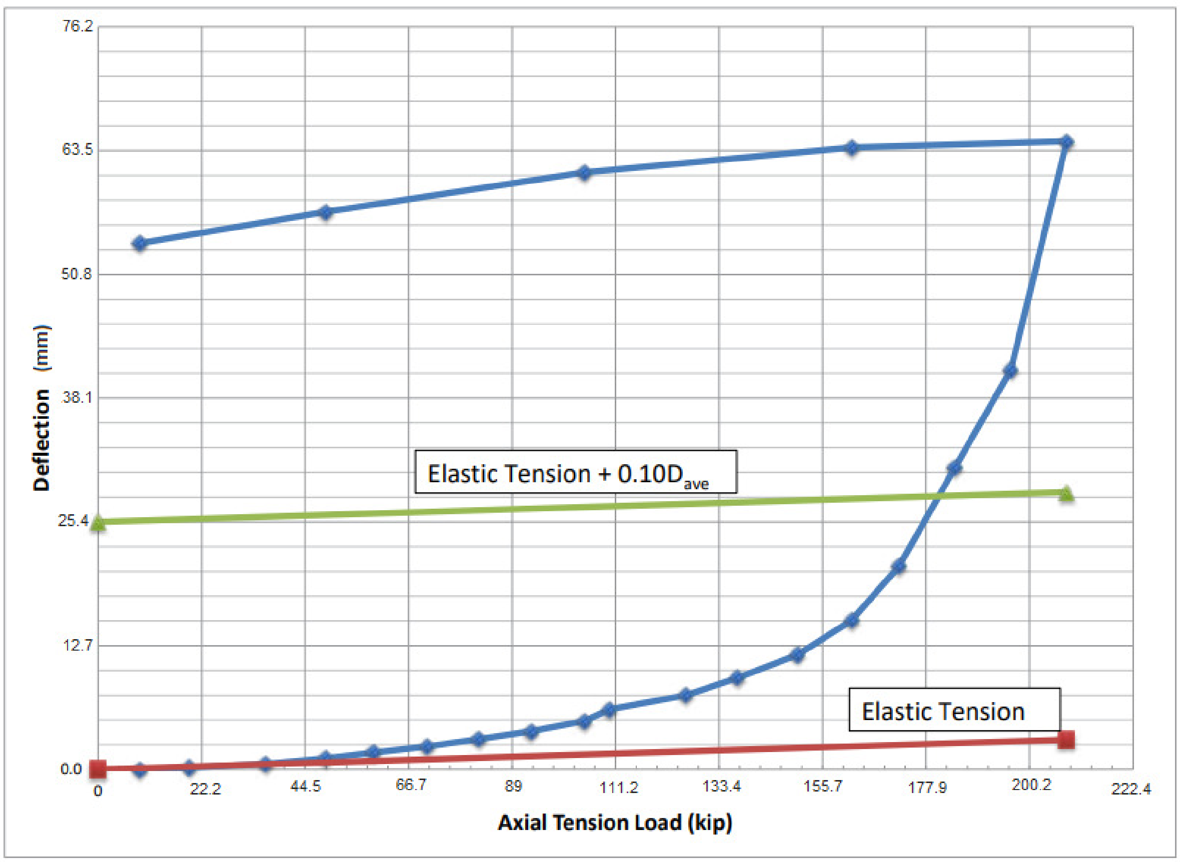
The recommended acceptance criteria for the allowable geotechnical capacity for helical piles/anchors is 1/2 of the applied test load causing a net displacement (gross displacement less the elastic compression/tension) not to exceed 0.10 times the average diameter of the helix plate(s). This is the acceptance criteria used in ICC-ES Acceptance Criteria AC358 for Helical Systems and Devices.



ASTM D1143 "Quick Test" Compression Plot
Figure 9

Figure 9 is a plot of results from a compression "quick test" per ASTM D1143-07 of a 3.65m long, 38mm square shaft helical pile having 254mm and 305mm helix plates. It was installed in the residual fine grained soils of Roanoke, Virginia and tested immediately after installation. The load-displacement curve is completely below the elastic compression line, indicating no skin friction was acting on the shaft during the test. The load-displacement curve does not cross the PL/AE + $0.10D_{ave}$, which indicates the maximum test load is less than the ultimate geotechnical capacity of the helical pile.

Figure 10 is a plot of results from a tension "quick test" per ASTM D3689-07 of a 4.87m foot long, 38mm square shaft helical anchor having 203mm, 254mm and 305mm helix plates. It was installed in the residual fine grained soils of Centralia, MO and tested immediately after installation. The load-displacement curve is completely above the elastic tension line (red line), indicating no skin friction was acting on the shaft during the test. The load displacement curve crosses the PL/AE + $0.10D_{ave}$ line at approximately 182kN. The average installation torque over the last three readings was 4677N-m. The torque correlation method (K_t) of capacity prediction says the ultimate geotechnical capacity is 4677 x 32.7 = 153kN, using a K_t of 32.7m^{-1}. The tested ultimate geotechnical capacity based on 10% average helix diameter net displacement is 182kN. Therefore, the K_t based on the load test is 182kN/15.3kN = 11.9 rounded off to 12.



ASTM D3689 "Quick Test" Tension Plot
Figure 10

Production Load Tests (OPTIONAL)

Some projects are large enough in size to justify the expense of several production tests. Production tests are useful to verify helical anchor/pile capacity at multiple locations across the project site, especially with varying soil conditions. The net displacement of helical anchor/piles at the allowable load (1/2 the geotechnical capacity) typically ranges between (25 mm) and (51 mm) total vertical movement as measured relative to the top of the helical anchor/pile prior to the start of testing. The Owner or structural engineer usually determines what the allowable displacement is, and it must be defined prior to conducting the Production Load Test. Limiting axial net deflections of 25.4mm to 38mm at the ultimate geotechnical capacity are typical.

STATIC LOAD TESTS (LATERAL)

Acceptance Criteria for Helical Systems and Devices AC358 states the allowable load capacity shall be equal to half the load required to cause (25 mm) of lateral deflection as measured from the ground surface. The acceptance criteria must be defined prior to conducting the Lateral Load Test. The acceptance criteria must be realistic in its magnitude so as not to potentially damage the structure. Limiting lateral deflections of 25.4mm at the ultimate load capacity have been used on some projects. It is suggested that large lateral loads be resisted through some other means (such as helical anchors, battered helical piles, or enlarged concrete pile caps/grade beams).

References:

1. AC358 Acceptance Criteria for Helical Systems and Devices, ICC-Evaluation Services, June 2013 Revision.
2. ASTM D1143-07, Static Load Test Method for Piles under Static Axial Compressive Load, American Society for Testing and Materials, Philadelphia, PA.
3. ASTM D3689-07, Standard Test Method for Pile under Static Axial Tension Load, American Society for Testing and Materials, Philadelphia, PA.
4. ASTM D-3966-07, Standard Test Method for Piles under Lateral Load, American Society for Testing and Materials, Philadelphia, PA.
5. Canadian Foundation Engineering Manual, Canadian Geotechnical Society, 1985.
6. Crowther, Carroll L., Load Testing of Deep Foundations, John Wiley and Sons, 1988.
7. Davisson, M.T., High Capacity Piles, Department of Civil Engineering, Illinois Institute of Technology, Chicago, IL, 1973.
8. Hubbell Power Systems, Technical Design Manual Edition 4, 2018