noted at each pier and recorded on the field log. The ***actual verified Factor of Safety*** between installation pre-load and final lock off can then be confirmed. *Table 6-1* is an example of the driving (installation) and lift forces that could be involved in the installation of Atlas Resistance® Piers.

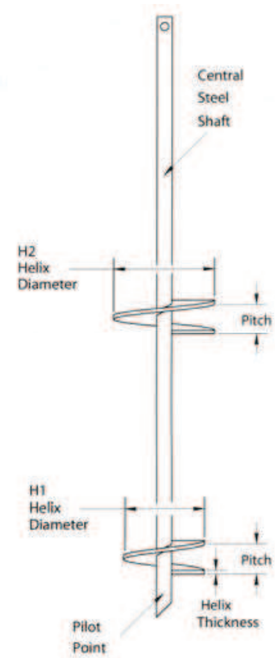
Refer to the *Atlas Resistance® Standard, Heavy Duty and Modified 2-Piece Pier Systems Model Specification in Appendix C* of this Technical Design Manual for detailed installation instructions.

Installation Load vs Lift Load
Table 6-1

FIRST STAGE			DRIVE	LIFT	SECOND STAGE			F/S
INSTALLATION LOAD SUMMARY	STD. DRIVE CYLINDER EFFECTIVE AREA (SQ. IN) 8.29				PIER LIFT/LOCK SUMMARY	STD LIFT RAM EFFECTIVE AREA (SQ. IN) 5.15		DRIVE vs LIFT
PIER NUMBER	PSI	LOAD			PIER NUMBER	PSI	LOAD	
1	4,200	34,818			1	4,000	20,600	1.7
2	4,600	38,134			2	4,000	20,600	1.9
3	4,600	38,134			3	4,500	23,175	1.6
4	4,800	39,792			4	4,500	23,175	1.7
5	5,000	41,450			5	4,800	24,720	1.7

CHANCE® HELICAL ANCHORS/PILES

By definition, a helical anchor/pile is a low soil displacement foundation element specifically designed to minimize disturbance during installation. In their simplest forms, helical anchors/piles consist of at least one helix plate and a central steel shaft (*see Figure 6-4*). The helix geometry is very important in that it provides the downward force or thrust that pulls a helical anchor/pile into the ground. The helix must be a true ramped spiral with a uniform pitch to maximize efficiency during installation. If the helix is not formed properly, it will disturb the soil rather than slice through it at a rate of one pitch per revolution. The central steel shaft transmits the driving energy or torque from the machine to the helix plate(s). The shaft should have a slender size and shape in order to reduce friction during installation. A helical anchor/pile functions very similar to a wood screw except that it has a discontinuous thread-form and is made to a much larger scale.



Helical Anchor/pile
Figure 6-4

INSTALLATION TORQUE/LOAD CAPACITY RELATIONSHIP

Before installation, a helical anchor/pile is simply a screw with a discontinuous thread and a uniform pitch. When installed into soil, a helical anchor/pile functions as an axially loaded end-bearing deep foundation. The helix plates serve a two-fold purpose. The first purpose is to provide the means to install the helical anchor/pile. The second purpose is to provide the bearing element means for load transfer to soil. As such, helical anchor/pile design is keyed to these two purposes, both of which can be used to predict the ultimate capacity.

Section 5 detailed how helix plates act as bearing elements. The load capacity is determined by multiplying the unit bearing capacity of the soil at each helix location by the projected area of each helix. This capacity is generally defined as the ultimate theoretical load capacity because it is based on soil parameters either directly measured or empirically derived from sounding data.

This intent of this section is to provide a basic understanding of how installation torque (or installation energy) provides a simple, reliable means to predict the load capacity of a helical anchor/pile . More importantly, this prediction method is independent of the bearing capacity method detailed in *Section 5*, so it can be used as a “field production control” method to verify load capacity during installation.

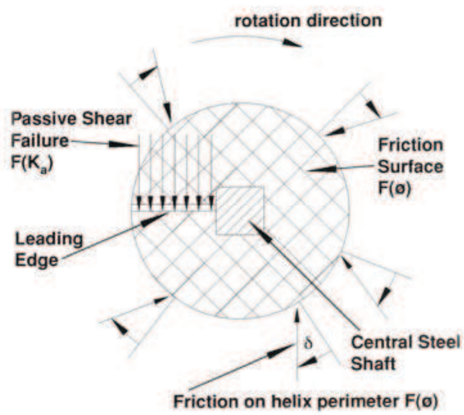
The installation torque-to-load capacity relationship is an empirical method originally developed by the A. B. Chance Company. CHANCE® Civil Construction has long promoted the idea that the torsion energy required to install a helical anchor/pile can be related to the ultimate load capacity of an anchor/pile. Precise definition of the relationship for all possible variables remains to be achieved. However, simple empirical relationships have been used for a number of years. The principle is that as a helical anchor/pile is installed (screwed) into increasingly denser/harder soil, the resistance to installation (called installation energy or torque) will increase. Likewise, the higher the installation torque, the higher the axial capacity of the installed anchor/pile. Hoyt and Clemence (1989) presented a landmark paper on this topic at the 12th International Conference on Soil Mechanics and Foundation Engineering. They proposed the following formula that relates the ultimate capacity of a helical anchor/pile to it's' installation torque:

$$Q_{ult} = K_t \times T \qquad \text{(Equation 6-1)}$$

where: Q_{ult} = Ultimate uplift capacity [lb (kN)]
K_t = Empirical torque factor [ft^{-1} (m^{-1})]
T = Average installation torque [lb-ft (kN-m)]

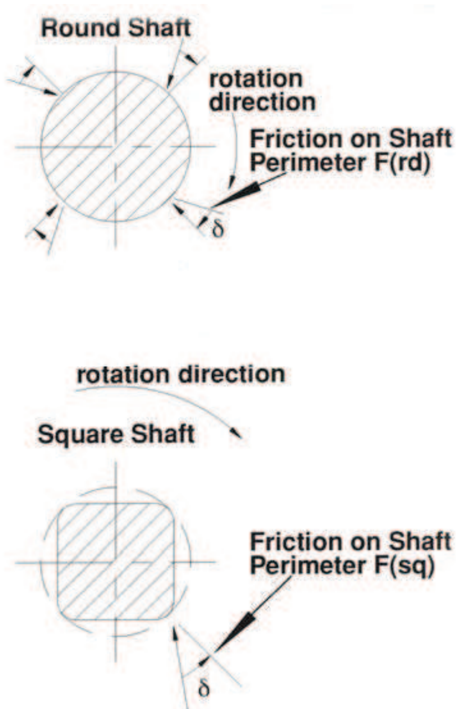
Hoyt and Clemence recommended K_t = 10 ft^{-1} (33 m^{-1}) for square shaft (SS) and round shaft (RS) helical anchors/piles less than 3.5" (89 mm) in diameter, 7 ft^{-1} (23 m^{-1}) for 3.5" diameter round shafts, and 3 ft^{-1} (9.8 m^{-1}) for 8-5/8" (219 mm) diameter round shafts. The value of K_t is not a constant - it may range from 3 to 20 ft^{-1} (10 to 66 m^{-1}), depending on soil conditions, shaft size and shape, helix thickness, and application (tension or compression). For Chance® Type SS square shaft helical anchors/piles, K_t typically ranges from 10 to 12 ft^{-1} (33 to 39 m^{-1}), with 10 ft^{-1} (33 m^{-1}) being the recommended default value. For Chance® Type RS pipe shaft helical anchors/piles, K_t typically ranges from 6 to 10 ft^{-1} (20 to 33 m^{-1}), with 8 ft^{-1} (26 m^{-1}) being the recommended default for Type RS2875; 7 ft^{-1} (23 m^{-1}) being the recommended default for Type RS3500.300; and 6 ft^{-1} (20 m^{-1}) being the recommended default for Type RS4500.337.

Locating helix bearing plates in very soft, loose, or sensitive soils will typically result in K_t values less than the recommended default. This is because some soils, such as salt leached marine clays and lacustrine clays, are very sensitive and lose considerable shear strength when disturbed. It is better to extend the helical anchor/pile beyond sensitive soils into competent bearing strata. If it’s not practical to extend the helical anchor/pile beyond sensitive soils, testing is required to determine the appropriate K_t.



Top View of Helix
Figure 6-5

Full-scale load testing has shown that helical anchors/piles typically have at least the same capacity in compression as in tension. In practice, compression capacity is generally higher than tension capacity because the anchor/pile bears on soil below rather than above the helix plates, plus at least one helix plate is bearing on undisturbed soil. Soil above the bearing plates is slightly disturbed by the slicing action of the helix, but not overly disturbed by being "augured" and removed. Typically, the same values of K_t are used for both tension and compression applications. This generally results in conservative results for compression applications. A poorly formed helix shape will disturb soil enough to adversely affect the torque-to-capacity relationship, i.e., K_t is reduced. To prevent this, CHANCE® Civil Construction uses matching metal dies to form helix plates which are as near to a true helical shape as is practically possible. To understand all the factors that K_t is a function of, one must first understand how helical anchors/piles interact with the soil during installation.



Friction Forces Action on Central Shafts
Figure 6-6

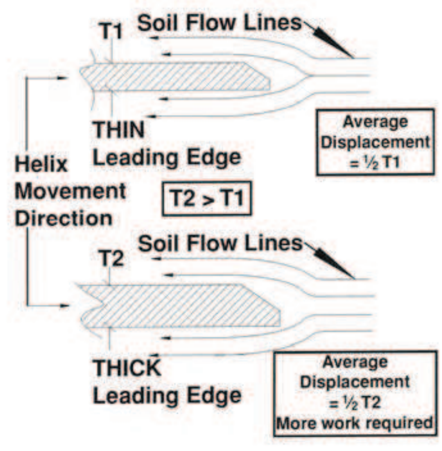
Torque Factors

There are two main factors that contribute to the torque resistance generated during an anchor/pile installation, friction and penetration resistance. Of the two factors, friction is by far the larger component of torque resistance.

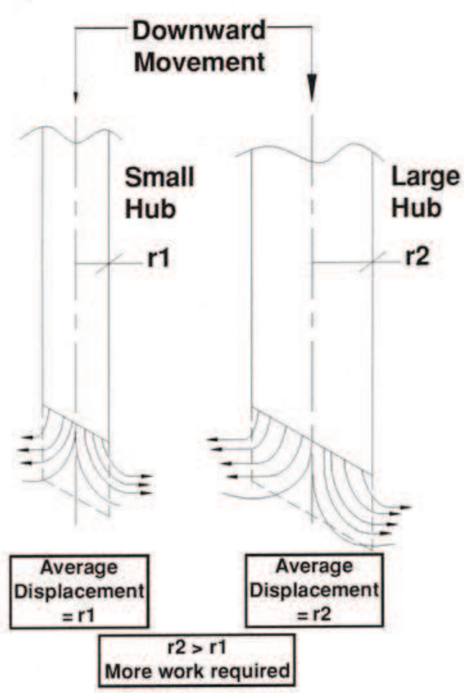
Friction Has Two Basic Parts:

(1) Friction on the helix plate and friction along the central steel shaft. Friction resistance increases with helix size because the surface area of the helix in contact with the soil increases with the square of the diameter (*see Figure 6-5*). Likewise, friction resistance increases with pitch size, i.e., the larger the pitch, the greater the resistance. This is analogous to the difference between a coarse thread and a fine thread bolt. Basic physics tells us that "work" is defined as force times distance. A larger pitch causes the helix to travel a greater distance per revolution, thus more work is required.

(2) Friction along the central steel shaft is similar to friction on the helix plate. Friction resistance increases with shaft size because the surface area of the shaft in contact with the soil increases as the diameter increases. An important performance factor for helical anchors/piles is the helix to shaft diameter ratio (H_d/S_d). The higher the H_d/S_d ratio, the more efficient a given helical anchor/pile will be during installation. Friction resistance also varies with shaft shape (*see Figure 6-6*). A round shaft may be the most efficient section to transmit torque energy, but it has the disadvantage of full surface contact with the soil during



Section View of Leading
Edge with Flow Lines
Figure 6-7



Hub/Pilot Point with Flow Lines
Figure 6-8

installation. When the central steel shaft is large (> 3" [76 mm] in diameter) the shaft friction resistance contributes significantly to the total friction resistance. However, a square shaft has only the corners in full surface contact with the soil during installation, thus less shaft friction resistance. Friction energy (energy loss) required to install a helical anchor/pile is related to the helix and shaft size. The total energy loss due to friction is equal to the sum of the friction loss of all the individual helix plates plus the length of shaft subjected to friction via contact with the soil.

Penetration Resistance Has Two Basic Parts:

(1) Shearing resistance along the leading edge of the helix plate and penetration resistance of the hub pilot point. Shearing resistance increases with helix size because leading edge length increases as the diameter increases. Shearing resistance also increases with helix thickness because more soil has to be displaced with a thick helix than with a thin helix (*see Figure 6-7*). The average distance the soil is displaced is equal to approximately 1/2 the helix thickness, so as the thickness increases the more work (i.e., energy) is required to pass the helix through the soil.

(2) Penetration resistance increases with shaft size because the projected area of the hub/pilot point increases with the square of the shaft radius (*see Figure 6-8*). The average distance the soil is displaced is approximately equal to the radius of the shaft, so as the shaft size increases, the more work (i.e., energy) is required to pass the hub/pilot point through the soil.

The penetration energy required to install a helical anchor/pile is proportional to the volume of soil displaced times the distance traveled. The volume of soil displaced by the anchor/pile is equal to the sum of the volumes of all the individual helix plates plus the volume of the soil displaced by the hub/pilot point in moving downward with every revolution.

Energy Relationships

Installation energy must equal the energy required to penetrate the soil (penetration resistance) plus the energy loss due to friction (friction resistance). The installation energy is provided by the machine and consists of two components, rotation energy supplied by the torque motor and downward force (or crowd) provided by the machine. The rotation energy provided by the motor along with the inclined plane of a true helical form generates the thrust necessary to overcome the penetration and friction resistance. The rotational energy is what is termed "installation torque." The downward force also overcomes penetration resistance, but its contribution is usually required only at the start of the installation, or when the lead helix is transitioning from a soft soil to a hard soil.

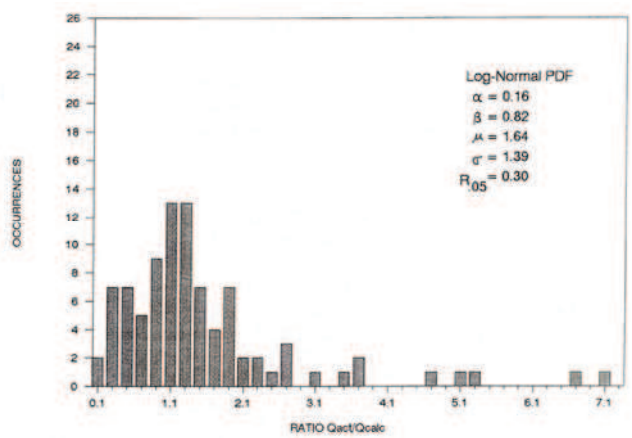
From an installation energy standpoint, the perfect helical anchor/pile would consist of an infinitely thin helix plate attached to an infinitely strong, infinitely small diameter central steel shaft. This configuration would be energy efficient because penetration resistance and friction resistance is low. Installation torque to capacity relationships would be high. However, infinitely thin helix plates and infinitely small shafts are not realistically possible, so a balanced design of size, shape, and material is required to achieve consistent, reliable torque to capacity relationships.

As stated previously, the empirical relationship between installation torque and ultimate capacity is well known, but not precisely defined. As one method of explanation, a theoretical model based on energy exerted during installation has been proposed [Perko (2000)]. The energy model is based on equating the energy exerted during installation with the penetration and friction resistance. Perko showed how the capacity of an installed helical anchor/pile can be expressed in terms of installation torque, applied downward force, soil displacement, and the geometry of the anchor/pile. The model indicates that K_t is weakly dependent on crowd, final installation torque, number of helix plates, and helix pitch. The model also indicates that K_t is moderately affected by helix plate radius and strongly affected by shaft diameter and helix plate thickness.

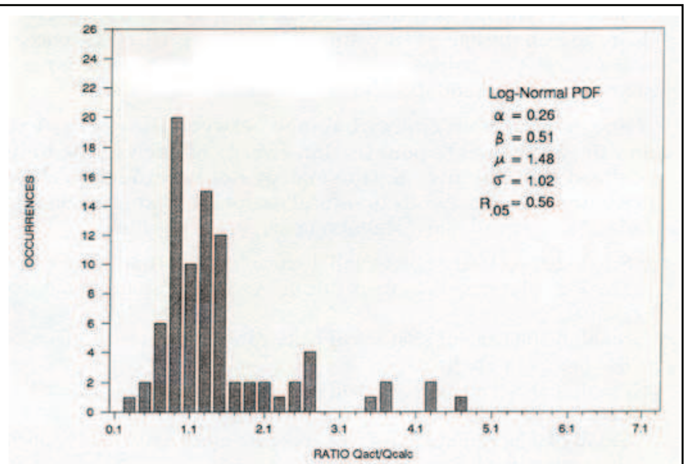
The important issue is energy efficiency. Note that a large shaft helical anchor/pile takes more energy to install into the soil than a small shaft anchor/pile. Likewise, a large diameter, thick helix takes more energy to install into the soil than a smaller diameter, thinner helix. The importance of energy efficiency is realized when one considers that the additional energy required to install a large displacement helical anchor/pile contributes little to the load capacity of the anchor/pile. In others words, the return on the energy "investment" is not as good. This concept is what is meant when CHANCE® Civil Construction engineers say large shaft diameter and/or large helix diameter (>16" diameter) anchors/piles are not efficient "torque-wise."

If one considers an energy balance between the energy exerted during loading and the appropriate penetration energy of each of the helix plates, then it can be realized that any installation energy not specifically related to helix penetration is wasted. This fact leads to several useful observations. For a given helix configuration and the same available installation energy (i.e., machine):

1. Small displacement shafts will disturb less soil than large displacement shafts.
2. Small displacement shafts result in less pore pressure buildup than large displacement shafts.
3. Small displacement shafts will penetrate farther into a given bearing strata than large displacement shafts.
4. Small displacement shafts will penetrate soils with higher SPT "N" values than large displacement shafts.
5. Small displacement shafts will generate more axial load capacity with less deflection than large displacement shafts.
6. K_t varies inversely with shaft diameter.



Individual Bearing Method
Figure 6-9



Torque Correlation Model
Figure 6-10

Reliability of Torque/Capacity Model

Hoyt and Clemence (1989) analyzed 91 load tests at 24 different sites with sand, silt and clay soils all represented. All of the tests used in the study were short term; most were strain controlled and included a final loading step of imposing continuous deflection at a rate of approximately 4 inches (102 mm) per minute. This final load was taken as the ultimate capacity. The capacity ratio Q_{act}/Q_{calc} was obtained for each test by dividing the actual capacity (Q_{act}) by the calculated capacity (Q_{calc}). Q_{calc} was calculated by using three different load capacity models: (1) cylindrical shear, (2) individual bearing, and (3) torque correlation. These data were then compared and plotted on separate histograms (*see Figures 6-9 and 6-10*, cylindrical shear histogram not shown).

All three capacity models exhibited the capability of over-predicting anchor/pile capacity. This would suggest the use of appropriate Factors of Safety. However, the authors did not discriminate between "good" and "poor" bearing soils when analyzing the results. In other words, some of the test data analyzed was in areas where the helix plates were located in soils typically not suitable for end bearing, (i.e., sensitive) clays and loose sands.

All three capacity models' mean values were quite close, but the range and standard deviation were significantly lower for the torque correlation method than for the other two. This improved consistency is probably due to the removal of several random variables from the capacity model. Therefore, the installation torque correlation method yields more consistent results than either of the other two methods. The installation torque method does have one disadvantage, however, in that it cannot be used until after the helical anchor/pile has been installed. Therefore, it is better suited to on-site production control and termination criteria than design in the office.

Measuring Installation Torque

The torque correlation method requires the installation torque to be measured and recorded in the field. There are several methods that can be used to measure torque, and CHANCE® Civil Construction has a complete line of torque indicators to choose from. Each one is described below along with its advantages and disadvantages:

- Shaft Twist

  A.B. Chance Company stated in early editions of the *Encyclopedia of Anchoring* (1977) that for standard SS5 Anchors, "the most secure anchoring will result when the shaft has a 1 to 1½ twist per 5-foot section." Shaft twist is not a true torque-indicating device. It has been used as an indication of "good bearing soil" since Type SS anchors were first introduced in the mid-1960's. Shaft twist should not be used exclusive of a true torque-indicating device. Some of the reasons for this are listed below.

  Advantages:

  - Simple, cheap, easy to use.
  - Doesn't require any additional tooling.
  - Visible indication of torque.

  Disadvantages:

  - Qualitative, not quantitative torque relationship.
  - Not very accurate.
  - Shaft twist can't be correlated to installation torque on a consistent basis.
  - Type SS5, SS150, SS175, SS200, and SS225 shafts twist, or wrap-up, at different torque levels.
  - Shaft twist for a round shaft is not obvious without other means of reference.

- Shear Pin Torque Limiter

  A shear pin torque limiter is a mechanical device consisting of two shear halves mounted to a central pin such that the shear halves are free to rotate *(see Figure 6-11)*. Shear pins inserted into perimeter holes prevent the shear halves from rotating and are rated to shear at 500 ft-lb of torque per pin. Required torque can be achieved by loading the shear halves with the appropriate number of pins, i.e., 4000 ft-lb = 8 pins. The shear pin torque limiter is mounted in line with the torque motor and anchor/pile tooling.

  Advantages:

  - Simple design, easy to use.
  - Tough and durable, will take a lot of abuse and keep working.
  - Accurate within ± 5% if kept in good working condition.
  - Torque limiter - used to prevent exceeding a specified torque.
  - Relatively inexpensive to buy and maintain.
  - Easy interchange from one machine to another.

Shear Pin Torque Limiter
Figure 6-11

Disadvantages:

- Point-wise torque indicator, i.e., indicates torque at separate points, not continuously.
- Requires constant unloading and reloading of shear pins.
- Limited to 10,000 ft-lb.
- Sudden release of torsional (back-lash) energy when pins shear.
- Fits tools with 5¼" bolt circle only.

- Mechanical Dial Torque Indicator

  A mechanical dial torque indicator is a mechanical device consisting of a torsion bar mounted between two bolt flanges *(see Figure 6-12)*. This tool measures installation torque by measuring the twist of the torsion bar. The dial indicator reads torque directly. The mechanical dial torque indicator is mounted in line with the torque motor and anchor/pile tooling.

Mechanical Dial Torque Indicator
Figure 6-12

Advantages:

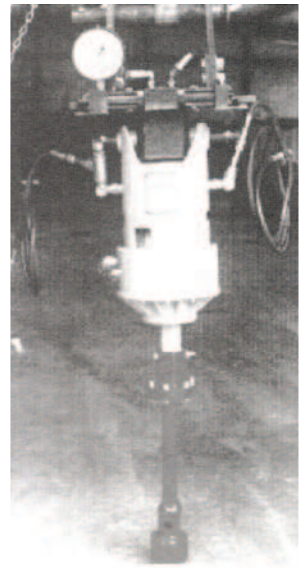
- Never needs recalibration.
- Simple torsion bar design, easy to use.
- Continuous reading torque indicator.
- Dial gauge reads torque directly.
- Accurate within ± 5% if kept in good working condition.
- Fits tools with 5-1/4" and 7-5/8" bolt circles.
- Calibrated with equipment traceable to US Bureau of Standards before leaving plant.
- Can be used as a calibration tool for other types of torque indicators.
- Easy interchange from one machine to another.

Disadvantages:

- Most expensive torque indicator available from CHANCE® Civil Construction.
- Tends to be fragile, especially when used in hard, rocky grounds that cause shock and vibration.
- Not recommended for applications where bending in the tool string occurs, i.e., tieback anchors.
- Not as tough and durable as the shear pin torque limiter.

- DP-1 Differential Pressure Torque Indicator

  A differential pressure torque indicator is a hydraulic device consisting of back-to-back hydraulic pistons, hoses, couplings, and a gauge *(see Figure 6-13)*. Its' operation is based on the principle that the work output of a hydraulic torque motor is directly related to the pressure drop across the motor. The DP-1 hydraulically or mechanically “subtracts” the low pressure from the high to obtain the “differential” pressure. Installation torque is calculated using the cubic inch displacement and gear ratio of the torque motor. The DP-1 piston block and gauge can be mounted anywhere on the machine. Hydraulic hoses must be connected to the high and low pressure lines at the torque motor.



Differential Pressure
Torque Indicator
Figure 6-13

Advantages:

- Indicates torque by measuring pressure drop across hydraulic torque motor.
- No moving parts.
- Continuous reading torque indicator.
- Very durable - the unit is not in the tool string.
- Pressure gauge can be located anywhere on the machine.
- Analog type gauge eliminates "transient" torque peaks.
- Pressure gauge can be overlaid to read torque (ft-lb) instead of pressure (psi).
- Accurate within ± 5% if kept in good working condition.
- After mounting, it is always ready for use.
- Can be provided with multiple readout gauges.

Disadvantages:

- Requires significant initial installation setup time and material, i.e., hydraulic fittings, hoses, oil.
- Requires a hydraulic pressure-to-torque correlation based on the torque motor's cubic inch displacement (CID) and gear ratio.
- For two-speed torque motors, pressure-to-torque correlation changes depending on which speed the motor is in (high or low).
- Requires periodic recalibration against a known standard, such as the mechanical dial torque indicator.
- Sensitive to hydraulic leaks in the lines that connect the indicator to the torque motor.
- Relatively expensive.
- Difficult interchange from one machine to another.

- In-Line Hydraulic Pressure Gauge

An in-line hydraulic pressure gauge is a hydraulic device consisting of a hydraulic pressure gauge mounted in line with the high-pressure hose feeding the torque motor. It is based on the principle that measuring the pressure in the supply line to the hydraulic torque motor can approximate the work output of the motor. Installation torque is estimated by calibrating the gauge against a known reference such as a mechanical dial torque indicator. The gauge can be mounted anywhere on the machine, but the connection to the high pressure line should be as close to the motor as possible.

Advantages:

- Simplest, lowest cost, easy to use torque indicating device.
- Indicates torque by measuring system pressure on the supply side of the machine's hydraulic pump.
- Continuous reading torque indicator.
- No moving parts.
- Very durable - the unit is not in the tool string.
- Analog type gauge eliminates "transient" torque peaks.

Disadvantages:

- Least accurate of the torque indicators listed herein unless field calibrated using either the Shear Pin Torque Limiter or Mechanical Dial Torque Indicator.
- In-line gauge requires a hydraulic pressure-to-torque correlation based on the torque motor being used.
- For two-speed torque motors, the pressure-to-torque correlation changes depending on which speed the motor is in (high or low).
- In-line gauge requires periodic recalibration against a known standard, such as the mechanical dial torque indicator.
- Accuracy is a function of gauge location in the hydraulic system, oil temperature, hydraulic system backpressure, leaks, age of oil (clean or dirty), age of machine, etc.

TORQUE INDICATOR and MOTOR CALIBRATION

All torque indicators require periodic calibration, except for the mechanical dial torque indicator. The mechanical dial torque indicator can be used in the field to calibrate other indicators, such as hydraulic pressure gauges and the DP-1. As torque motors age, the relationship between hydraulic pressure and installation torque will change. Therefore, it is recommended that hydraulic torque motors be periodically checked for pressure/torque relationship throughout their service life. CHANCE® Civil Construction has torque test equipment available to recalibrate torque indicators and torque motors.

INSTALLATION TERMINATION CRITERIA

The Engineer of Record can use the relationship between installation torque and ultimate load capacity to establish minimum torque criteria for the installation of production helical anchor/piles. The recommended default values for K_t of [10 (33)] for Chance® Type SS, [8 (26)] for Type RS2875, [7 (23)] for Type RS3500 and [6 (20)] for Type RS4500 will typically provide conservative results. For large projects that merit the additional effort, a pre-production test program can be used to establish the appropriate torque correlation factor (K_t) for the existing project soils. K_t is determined by dividing the ultimate load capacity determined by load test by the average installation torque taken over the last 3 feet of penetration into the bearing strata. The minimum effective torsional resistance criterion applies to the "background" resistance; torque spikes resulting from encounters with obstacles in the ground must be ignored in determining whether the torsional resistance criterion has been satisfied. The minimum effective torsional resistance criterion (the average installation torque taken over the last 3 feet of penetration) may not be applicable in certain soil profiles, such as, a relatively soft stratum overlying a very hard stratum. Engineering judgment must be exercised. See *Appendix B* for more detailed explanation of full-scale load tests. Large-scale projects warrant more than one pre-production test.

Whatever method is used to determine K_t, the production helical anchors/piles should be installed to a specified minimum torque and overall depth. These termination criteria should be written into the construction documents. *Appendix C* to this Technical Design Manual includes model specifications that contain sections on recommended termination criteria for helical anchors/piles.

Tolerances

It is possible to install helical anchors/piles within reasonable tolerance ranges. For example, it is common to locate and install an anchor/pile within 1 inch (25 mm) of the staked location. Plumbness can usually be held within ± 2° of design alignment. For vertical installations a visual plumbness check is typically all that's required. For battered installations, an inclinometer can be used to establish the required angle. *Appendix C* to this Technical Design Manual includes model specifications that contain sections on allowable installation tolerances for helical anchors/piles.

Torque Strength Rating

Torque strength is important when choosing the correct helical anchor/pile for a given project. It is a practical limit since the torque strength must be greater than the resistance generated during installation. In fact, the central steel shaft is more highly stressed during installation than at any other time during the life of the helical anchor/pile. This is why it is important to control both material strength variation and process capability in the fabrication process. CHANCE® Civil Construction designs and manufactures helical anchors/piles to achieve the torque ratings published in *Tables 7-3 and 7-6* in *Section 7*. The ratings are listed based on product series, such as SS5, SS175, RS3500, etc.

The torque rating is defined as the maximum torque energy that should be applied to the helical anchor/pile during installation in soil. It is not the ultimate torque strength, defined as the point where the central shaft experiences torsion fracture. It is best described as an allowable limit, or "safe torque" that can be applied to the helical anchor/pile. Some other manufacturers publish torque ratings based on ultimate torque strength.

The designer should select the product series that provides a torque strength rating that meets or exceeds the anticipated torsion resistance expected during the installation. HeliCAP® Engineering Software (*see Section 5*) generates installation torque vs depth plots that estimate the torque resistance of the defined soil profile. The plotted torque values are based on a K_t of 10 for Type SS and 8, 7 or 6 for Type RS. The torque ratings published in *Tables 7-3 and 7-6* in *Section 7* are superimposed on the HeliCAP® Torque vs Depth plot, so the user can see at a glance when the estimated torque resistance equals or exceeds the torque rating of a given product series.

In some instances, it may be necessary to exceed the torque rating in order to achieve the minimum specified depth, or to install the helical anchor/pile slightly deeper to locate the helix plates farther into bearing stratum. This "finishing torque limit" should never exceed the published torque rating by more than 10%. To avoid fracture under impact loading due to obstruction laden soils, choose a helical product series with at least 30% more torque strength rating than the expected torque resistance. Note that the possibility of torsion fracture increases significantly as the applied torque increases beyond the published ratings. The need to install helical anchors/piles deeper is better accomplished by reducing the size and/or number of helix plates, or by choosing a helical product series with a higher torque rating.

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