Monitoring Torque to Determine Helical Pile Capacity

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The torque correlation method is a well-documented and accepted method for estimating or verifying helical pile capacity. In simple terms, the torsional resistance generated during helical pile installation is a measure of soil shear strength and can be related to the bearing capacity of the pile with the following equation:

$$Q_u = K_t \times T$$

Where,
Q_u = Ultimate Pile Capacity (lb)
K_t = Empirical Torque Correlation Factor (ft^{-1})
T = Final Installation Torque (ft-lb)

The correlation of installation torque to helical pile capacity is generally accepted for the most commonly used shaft sizes with outside diameters up to about 4.5 inches, with some discussion about whether this method can be used for shaft sizes up to about 6 inches. For larger shaft sizes, the capacity of helical piles is generally determined by theoretical methods and then verified with full-scale load testing.

ICC-ES AC358 recognizes the following helical pile shaft sizes and default K_t factors for conforming systems, since the installation torque to capacity ratios have been established with documented research:

- 1.5 to 1.75-inch solid square shaft $K_t = 10\ ft^{-1}$
- 2.875-inch OD round shaft $K_t = 9\ ft^{-1}$
- 3.0-inch OD round shaft $K_t = 8\ ft^{-1}$
- 3.5-inch OD round shaft $K_t = 7\ ft^{-1}$

Monitoring torque is therefore a key process during the installation of helical piles. A number of devices are available to assist in determining torque and, ultimately, the calculation of pile capacity. These devices range from simple pressure gauges to more sophisticated electronic data acquisition systems. A few of those devices are presented below.

Dual hydraulic pressure gauges can be used to measure the "pressure drop" across a hydraulic torque motor. This method is based on the principle that the work output of the torque motor is directly related to the measurement of the pressure drop across the motor as force is applied. To measure the pressure drop, one gauge is placed in line with the feed from the hydraulic pump or machine to the drive head. A second gauge is placed in line with the return from the drive head back to the pump (Figure 1). The return line pressure is subtracted from the feed line pressure resulting in the determination of "differential" pressure. The installation torque can be calculated relative to the differential pressure by applying the gear motor multiplier (GMM) provided by the drive head manufacturer. Most drive head manufacturers provide correlation charts for quick conversion of differential pressure to torque.

Figure 1: Dual pressure gauges mounted to arm of excavator

Some operators choose to use a single gauge on the feed line side only, rather than to use a second gauge to measure back pressure. This can result in decreased accuracy and over-estimating of applied torque if back pressure is under-estimated or ignored all together.

Differential pressure gauge technology measures the feed and return line pressures to determine the pressure drop across the motor, but with ports for the lines within a single-gauge body. The differential pressure, as in the case of the TruTorque model (Figure 2), is related to torque by the GMM for a specific drive head and the dial face is manufactured to provide a reading of torque rather than pressure. A different differential pressure gauge is therefore needed for each drive head.

Figure 2: TruTorque Gauge

Electronic pressure indicators measure the feed and return line pressures with electronic pressure transducers. Low voltage power is supplied to the unit by either a portable battery pack or a direct connection to an appropriate low voltage source generated by the installation equipment. Instead of analog gauges, electronic indicators such as the PT Tracker by Marian Technologies (Figure 3) typically have a digital screen output to provide a direct reading of torque, which is generated by a pre-programmed relationship of the pressure drop across the motor and the GMM for the drive head being used. Some units have a selector switch that allows for torque readings with various motors. Some models also allow for data acquisition and/or bluetooth technology.

Electronic torque transducers such as the Pro-Dig® Intelli-Tork system (Figure 4) are placed in line with the tool string. Torque is a true real time measurement and is generated continually during the installation of a helical pile or tieback. The Intelli-Tork system uses electronic strain gauge technology to measure the torque applied between the two flanges and then transmits the data via bluetooth wireless technology to a hand-held PDA. The PDA based system and software provide a remote visual indication of the torque during the installation. Software provided with the instrument has the ability to log the torque, depth and installation angle. Torque transducers can be recalibrated as needed to ensure accuracy. In turn, a properly calibrated torque transducer can be used to calibrate analog gauge systems relative to differential pressure.

Figure 3: PT Tracker

Installation torque should be monitored and documented at intervals specified by the engineer of record. At a minimum, torque readings should be obtained at the end of installation of each lead section and extension. In more critical applications, torque readings may be obtained for every foot of pile installation in order to develop a relative soil strength profile with depth. Torque should also be recorded every foot during the last three to five feet of installation for tension piles or tiebacks. The average installation torque over that length may then be used to determine the tension capacity.

Figure 4: Pro-Dig® Intelli-Tork

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Jeff is involved in product design, product verification testing, preliminary design applications, project consulting, conducting installation, sales and marketing training, as well as developing and presenting eduction-based material. Jeff routinely travels throughout the United States and Canada to consult with local installing contractors about general or project-specific needs, and to present technical information to engineers, architects and general contractors.