Recommendation

Execution of special geotechnical works- Steel Screw Piles.

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DEPARTMENT OF THE BUILT ENVIRONMENT
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by

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30 June 2025

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Contents

1 Scope

Screw piles have only recently begun to be used as foundation solutions in Denmark. However, interest in screw piles as alternatives to traditional foundation methods has grown significantly, particularly following the introduction of CO_2 reduction requirements in the construction sector—especially for single-family homes.

Recent studies have demonstrated that replacing conventional concrete strip foundations and concrete floor slabs with screw piles can reduce CO_2 emissions by up to 85% for a single-family house.

Historically, screw piles have struggled to gain traction in Danish construction practices, primarily due to the lack of well-documented performance data. The installation process of screw piles is critical, as it fundamentally defines their load-bearing capacity. To date, no standards or guidelines exist that clearly describe how these piles should be installed and documented to ensure the same level of structural reliability as traditional foundation solutions.

This document has been developed specifically to address that gap, by providing clear guidance on the design, installation, and documentation of screw piles for use in Danish construction. Part 1 of this document (Chapters 1–3) presents the evidence and rationale underlying the documentation requirements set forth in Part2 (Chapter 4- 10). Part 2 is written in the format of a standard.

One of the key challenges associated with screw piles is the lack of design standards. Each manufacturer produces piles with different geometries and configurations, which influences the interaction between the pile and soil, particularly with respect to installation resistance and failure mechanisms.

This guideline is based on research results obtained through the Grand Solution project: Day to Day Foundation – Innovative and Cost-Effective Solutions for Future Housing Construction Using Ground Screw Foundations. The project has received financial support from Innovation Fund Denmark under grant agreement no. 9090-0051A.This recommendation is based on research outcomes obtained through the Innovation Project Day-to-Day, as well as on practical experience gained through full-scale testing of various screw pile types in different soil conditions. https://innovationsfonden.dk/da/i/historier/skruefundamenter-skal-goere-byggeri-mere.

This recommendation focuses specifically on steel screw piles, as these are the most commonly used type in traditional house construction and in multi-store buildings up to four floors.

In addition to steel screw piles, concrete screw piles are also available on the market and are primarily used in larger building projects. Their design principles and installation methods differ significantly from those of steel screw piles and are not covered in this document.

The aim is to provide engineers, contractors, and authorities with a technically consistent framework that ensures structural reliability and compliance with sustainability objectives.

2 Terms and definitions

Screw piles are foundations designed to be screwed into the ground to provide structural support. The main components of a ground screw include the lead section, extensions, couplings, helical bearing plates, and pile cap, as shown in Figure 2-1. The lead section enters the ground first and features a tapered pilot point or an open pipe, usually one or more bearing plates, or a continuous thread. Extension sections drive the lead section deeper until the desired stratum is reached. These extensions may have additional helical bearing plates but often consist only of a central shaft and couplings. Typically, the couplings are bolted male and female sleeves. The central shaft is generally a hollow tubular round section. They serve as foundations for houses, commercial buildings, light poles, solar panels, pedestrian bridges, and sound walls, among other applications. Additionally, ground screws are used to underpin, and repair failed foundations or to reinforce existing foundations to support new loads. They can be installed vertically, horizontally, or at various angles, supporting both horizontal, tensile and compressive loads.

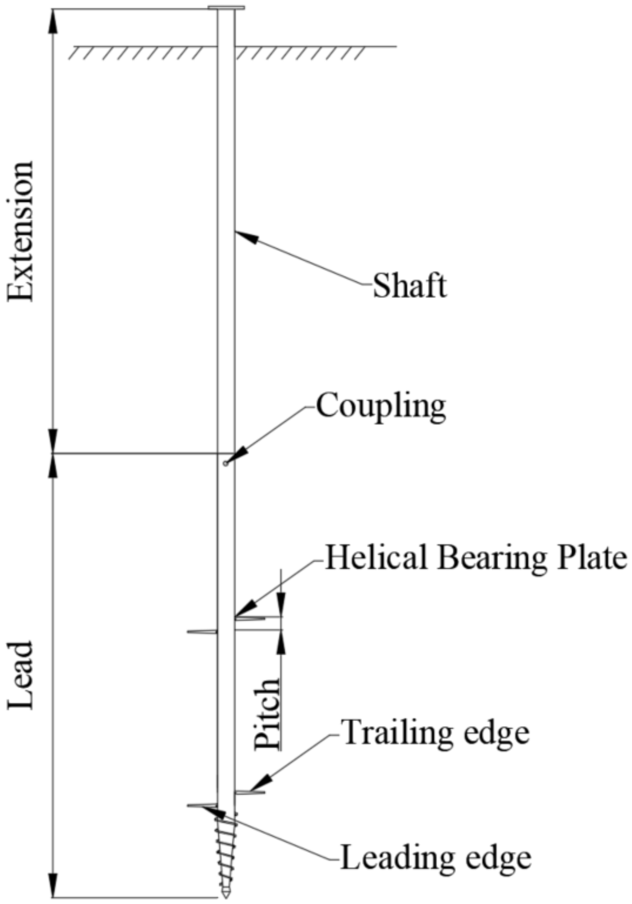


Figure 2-1 The main components of a Ground Screw

In Figure 2-2, different forms and designs of steel screws piles are shown. There is a distinction between helical piles and continuous helical piles/screw piles. A helical pile is designed with one or more bearing plates welded to a round or square tube. The tube can be open, as seen in a), b), and c), closed, or tapered, as seen in g) and i). A continuous helical pile has a continuous thread welded to a tapered steel pipe, as seen in d), e), and h). Helical piles are extensively used in the USA for all types of foundations, comparable to traditional

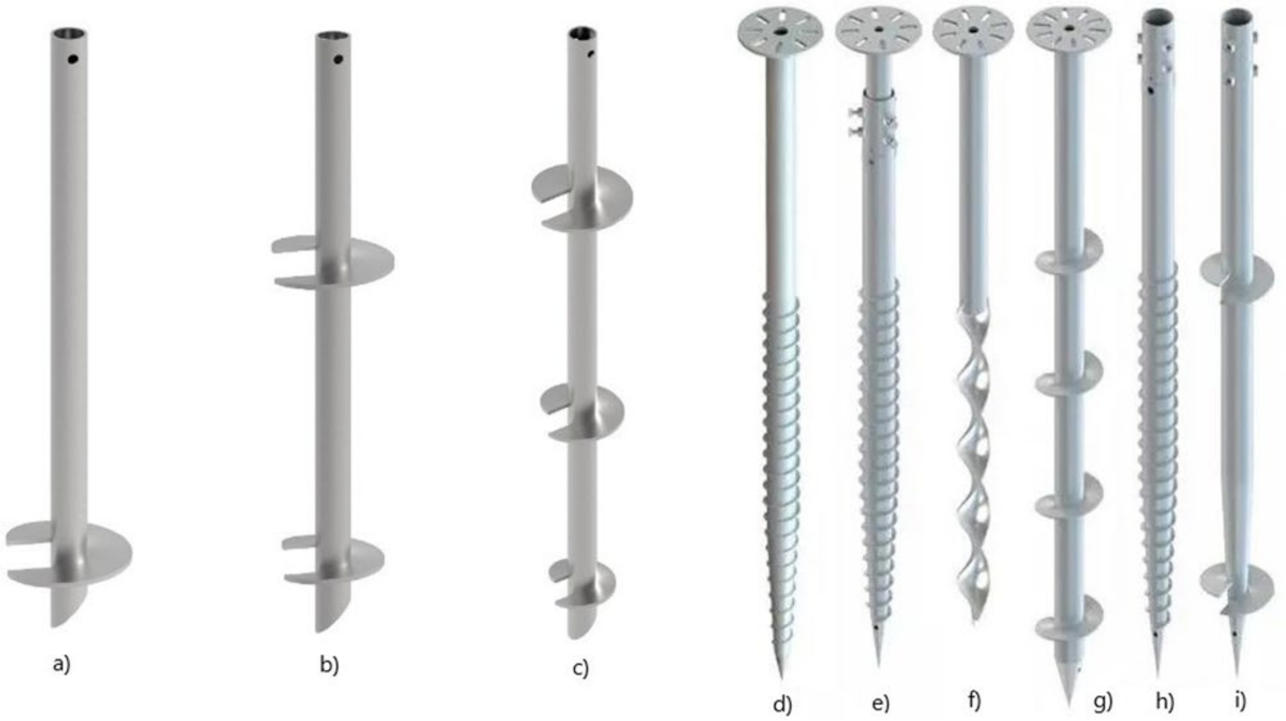


Figure 2-2 Different types of ground screws. A distinction is made between helical piles a), b), c), g), i) and continuous helical piles d), e), f), h).

concrete and steel piles. Continuous helical piles have traditionally been used for smaller constructions such as single-family, row, and summer houses and are the most commonly used in Denmark.

3 Ultimate bearing capacity of screw piles – a review

There is a need to estimate the potential compression, horizontal and tensional capacity of screw piles before installation. For this purpose, it is necessary to be able to determine the bearing capacity geostatically based on measured soil strength parameters, or simply on in-situ test data such as SPT, CPT, or vane shear strength**.** The capacity and potential of helical piles have been researched since the late seventies.

A ground screw pile is characterized as a partial displacement pile. These piles are found to possess greater stability and higher surface friction in soil when compared to traditional driven piles in steel and concrete.

Two analytical expressions for the ultimate bearing capacity of helical piles are extensively applied: the individual bearing method and the cylindrical shear method.

- In the individual bearing method, each helix behaves independently, giving the ultimate bearing capacity by summing all individual helix capacities, as shown in Figure 3-1 a) Meyerhof and Adams (1968).
- Mitsch and Clemence [1985] introduced the cylindrical shear method. It is assumed that the helices are spaced close enough so that the soil in between them forms a plug, thereby having three contributions to the axial capacity: end resistance, shear resistance along the shaft, and shear resistance along the cylindrical shear surface. This is depicted in Figure 3-1 b)

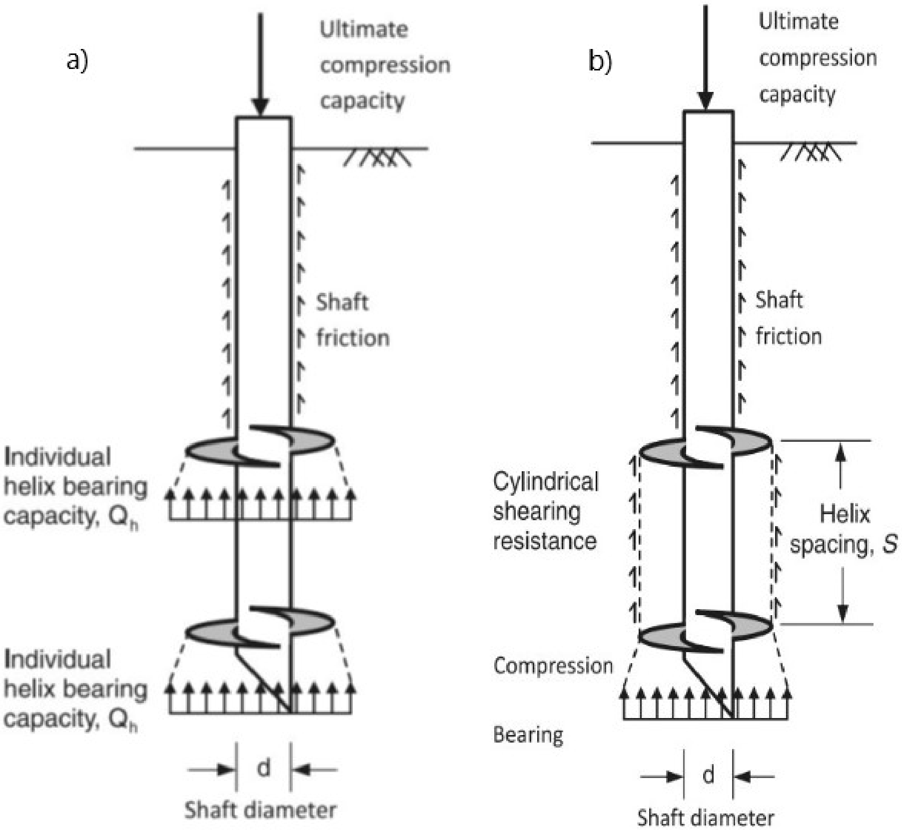


Figure 3-1 a) The individual bearing method. b) Cylindrical shearing method for helical piles [Nasr, M.H., 2004]

3.1 Parameters controlling the bearing capacity.

The geometry of the investigated helical pile governs the applicability of the individual bearing method and the cylindrical shear method. Specifically, the spacing between two adjacent helices, which is reflected in the spacing ratio S/D_h, determines which analysis method to use. D_h is the diameter of the bearing plate, as shown in Figure 3-2. The spacing ratio for which the soil plug develops was investigated by Rao and Prasad. [1993]. The research used the spacing ratio to reduce the ultimate bearing capacity by increasing the spacing between adjacent helices. There are different conclusions regarding which maximum spacing ratio governs the failure mode from cylindrical shear to individual bearing, though the lowest value concluded is $S/D_h < 1.5$ [Rao and Prasad, 1993].

D. Zhang et al. [1998] introduce the embedment ratio H_t/D_h to the spacing ratio S/D_h and state that they are the main factors affecting helical piles' bearing capacity, as shown in Figure 3-2 . The research also investigated the difference between helical piles' ultimate bearing capacity in compression and tension installed in cohesive and cohesionless soils. Smaller ultimate capacities were obtained for helical piles with smaller S/D_h than larger S/D_h under compression installed in cohesive soil. In contrast, helical piles with smaller S/D_h under compression installed in cohesionless soils produced higher ultimate capacities than those with larger S/D_h. Additionally, D. Zhang et al. [1998] imply that the ultimate capacity of helical piles is controlled by inter-helix spacing. However, it does not affect the ultimate capacity of helical piles in tension.

Lutenegger [2009] states that the spacing between the uppermost and lowermost helices controls cylindrical shear resistance. The ultimate capacity in tension depends on the embedment depth, which is directly proportional to the embedment ratio H_t/D_h. Research from Sakr [2009] showed that increasing the

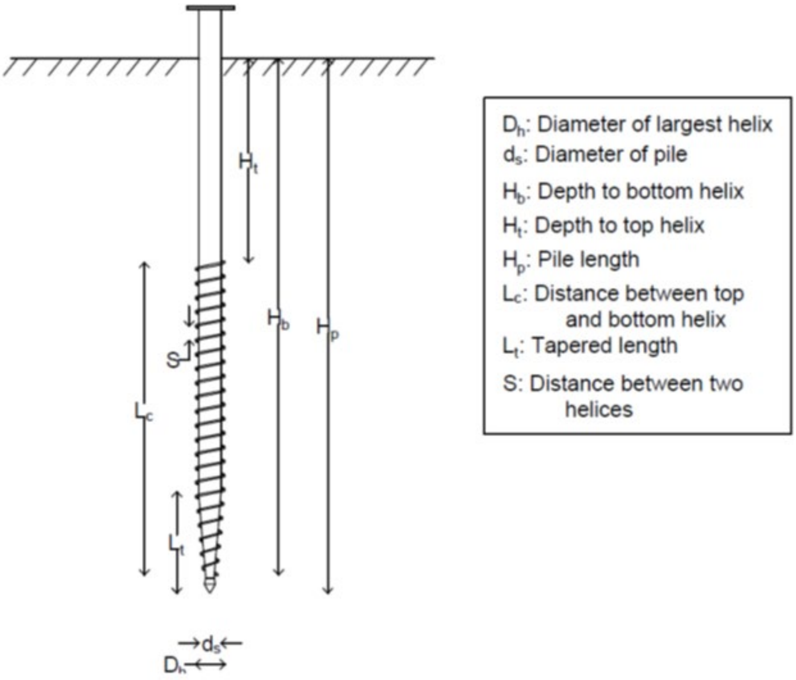


Figure 3-2 Geometry of screw pile.

embedment depth increases the shaft friction resistance against uplift. Conversely, Perko [2009] investigates the minimum embedment depth for helical piles where the theoretical capacity calculations are applicable since the theory is developed based on deep mode behaviour. Moreover, insufficient embedment depth can lead to shallow failure. Figure 3-3, investigate two analytical methods by performing controlled laboratory test with different relative density D_r.

Firstly, the Mitsch and Clemence method is studied which is based on the failure mechanism of cylindrical shear (Mitsch and Clemence, 1985). Originally, this method was developed for predicting the uplift capacity of helical anchors however, it is modified to account for compressive loading by introducing the bearing capacity factor instead of the uplift capacity factor (Mohajerani, Bosnjak and Bromwich, 2016). The other analytical method studied is a further development of the Mitsch and Clemence cylindrical shear method where Perko's method is derived from soil pressures and static solution, unlike Mitsch and Clemence theory, which is based on failure lines and a kinematic solution (Perko, 2009). The main factors studied by Mitsch and Clemence are the coefficient of lateral earth pressure and friction angle, where Perko's method focuses more on the ultimate bearing pressure and soil shear strength (Perko, 2009), (Mitsch and Clemence, 1985).

Soil conditions affect the ultimate capacity of helical piles as the ultimate capacity relies on soil parameters as well as soil properties such as the undrained shear strength, adhesion and cohesion factors, effective soil unit weight and the angle of internal friction. D. Zhang et al. [1998] states that the ultimate capacity in cohesive soils is similar in both tension and compression as the resistance is due to friction. Conversely, in cohesionless soils, the resistance in compression is slightly higher due to the impact of end-bearing resistance. The ultimate capacity can differ in tension and compression due to changes in soil properties caused by soil disturbance. The individual bearing method achieves its peak at a higher settlement than the cylindrical shear method because of its assumption on the failure zone, which makes it reach its peak at a lower settlement.

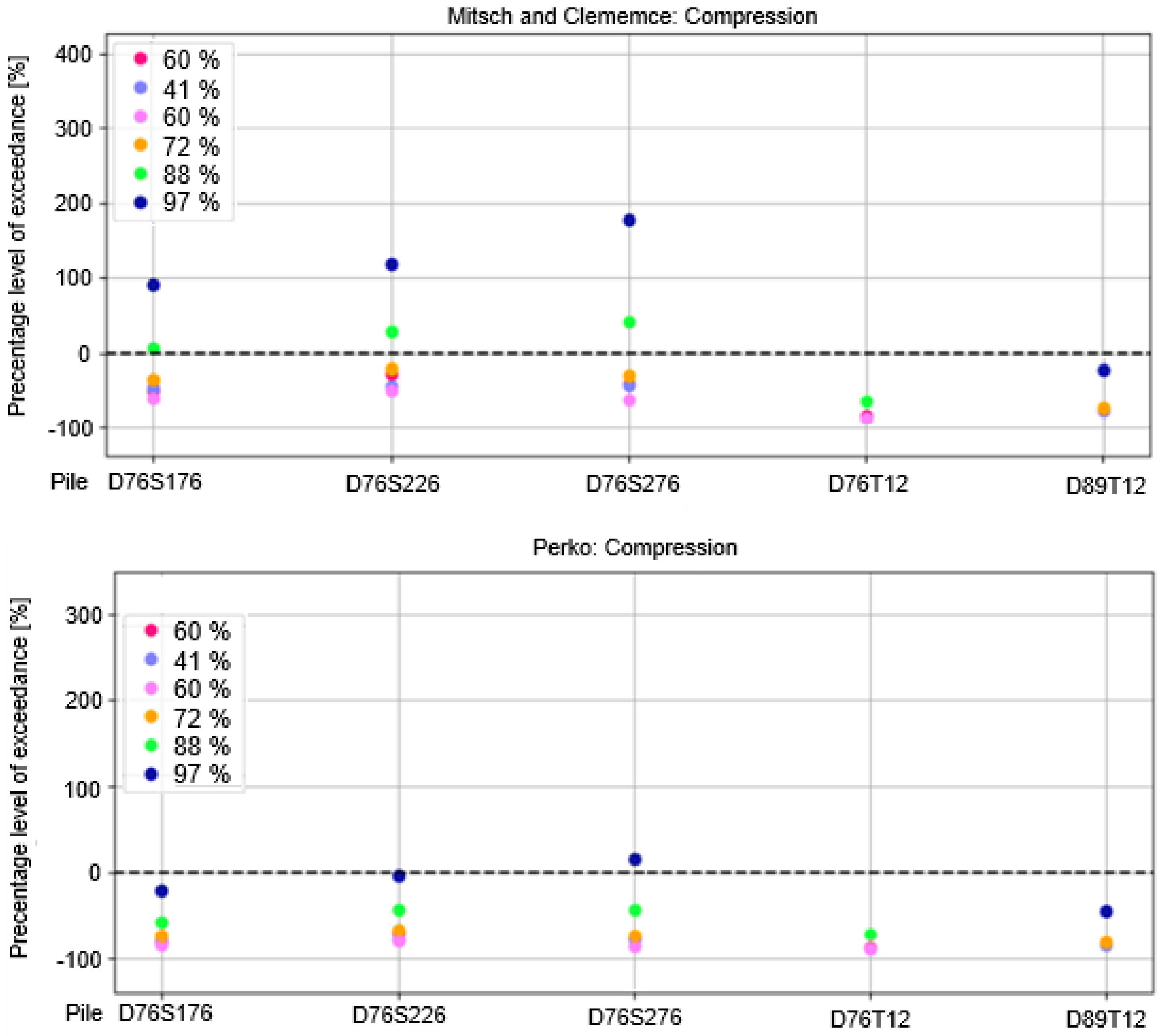


Figure 3-3 Percentage level of exceedance for deference pile type. The tests are performed with different relative densities D_R (41 -97 %) as described in Andreasen and Ibsen [2025] and compared to bearing capacities calculated after a) Mitsch and Clemence. b) Perko in compression.

Tappenden and Sego [2007] conclude a major variety of the accuracy when it comes to predicting ultimate screw pile capacities from theoretical expressions. Calculations performed on 26 full-scale screw piles showed that results range from underestimating by 60% to overestimating by 150% for different methods used to predict the bearing capacity of the tested piles. Similar findings are reported by Andreasen et al. [2024] and shown in Figure 3-3. The figure shows the Percentage level of exceedance (PLE) for different pile geometries and different relative densities D_r. PLE is defined as:

$$PLE = \frac{R_{therory} - R_{measured}}{R_{measured}} 100 \quad [\%] \tag{1}$$

The load-bearing capacity of screw piles cannot be reliably documented using current framework of geostatic calculations. While such calculations can be useful for initial estimations during the design phase, they are unsuitable for verifying actual performance. This limitation is primarily due to the wide variation in pile geometries, which makes it impractical to develop a universal analytical model capable of accurately capturing all relevant failure mechanisms, as shown in Figure 3-3. Furthermore, experimental studies conducted at Aalborg University have demonstrated that improper installation procedures can reduce bearing capacity by up to 70%. Andreasen and Ibsen [2025].

In Figure 3-4 installation torque and compressive capacity plot with respective colormaps to indicate:

a) Variations of relative density, D_r and b) Advancement Rate, (AR) are shown. The Advancement Ratio is defined as:

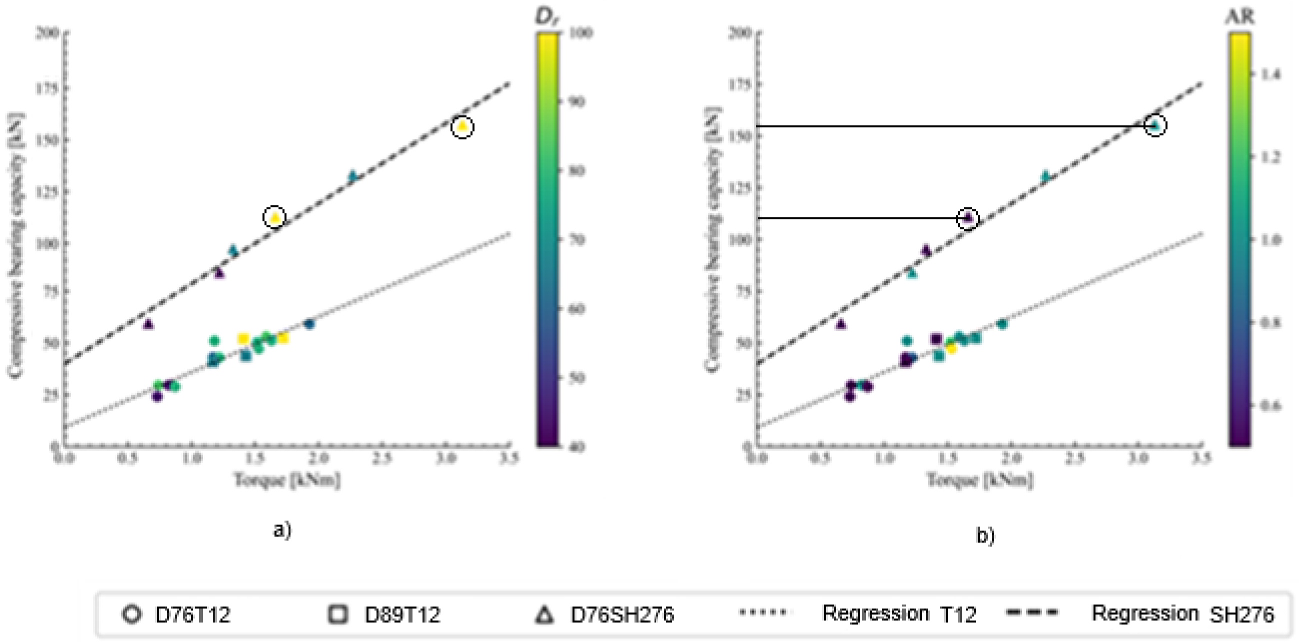
$$\text{AR} = \text{Vertical penetration per rotation/helix pitch} \quad [-] \tag{2}$$

To illustrate the dominant effect of the Advancement Ratio (AR) on bearing capacity, two identical tests are highlighted with circles in the figure. Both tests used a single-helix pile (D76SH276) installed in soil with a relative density of Dr = 97%. The only difference lies in the installation method. In the first test, ideal installation was achieved with AR = 1, meaning the pile advanced vertically by one pitch length per revolution. In the second test, AR = 0.5, indicating that the pile rotated twice to achieve vertical penetration equivalent to one pitch. This reduced advancement ratio caused soil loosening, significantly decreasing compressive bearing capacity from 155 kN to 110 kN — a reduction of approximately 30%.

Based on these results, Andreasen and Ibsen [2025] conclude that reliable verification must be based on installation control and in-situ performance monitoring, rather than purely theoretical calculations.

In summary, the bearing capacity of screw and helical piles is primarily governed by the following three factors:

- The soil profile into which the pile is installed.
- The geometry of the pile, including shaft diameter, helix pitch, number of helices, and their spacing.
- The advancement ratio (AR)



a)

b)

Figure 3-4 Installation torque and compressive bearing capacity plot for laboratory data for screw piles with different AR. Colormaps are used to indicate variations of relative density, Dr and advancement rate, AR. Andreasen and Ibsen [2025].

3.2 Torque to bearing capacity.

Hoyt and Clemence (1989) proposed an empirical relationship between installation torque and bearing capacity. The empirical equation relates the average of the last 3 rotations installation torque, to the ultimate capacity, where the two measurements are correlated by the empirical factor, which is known as the friction correlation factor (Kc).

The two-regression line shows this relationship in Figure 3-4 and seen dependent on the pile geometry. Thus, each geometry has it owns new Kc and it is dependent of the in soils type. The torque-to-bearing capacity method provides a direct means of estimating the axial load-bearing capacity of screw piles. This approach is conceptually comparable to CPT-based design methods used for conventional piles.

The figure shows test results on: Pile D76T12, which has a shaft diameter 76 mm, and a continuous thread of 12 mm welded on a tapered steel pipe. Pile D89T12, which has a shaft diameter 89 mm, and continuous thread 12 mm welded on a tapered steel pipe. Pile D76SH276, which has a shaft diameter 76 mm and a single helix welded on a tapered steel pipe with a helix diameter of 276mm.

During installation, the torque applied to the pile reflects the frictional resistance mobilized along the shaft and helices. The friction correlation factor describes the relationship between installation torque and compressive bearing capacity.

Based on the results illustrated in Figure 3-4. It can be concluded that the installation effects are captured in the model since the bearing capacity increases along with the installation torque as emphasized and studied in Andreasen and Ibsen [2025].

When properly calibrated, friction correlation factors Kc can be used to verify the load-bearing capacity of installed piles.

To use the Kc factor correctly, it must be calibrated specifically for the site:

- The soil profile
- The pile geometry
- The advancement ratio (AR)
- The rotational speed during installation

This calibration shall be based on static or dynamic load tests performed at the installation site, ensuring that the estimated bearing capacity accurately reflects in-situ behaviour.

The installation torque is influenced by all four parameters listed above. However, including installation speed as a variable introduces a risk of misinterpretation: a poorly installed pile with a low advancement ratio (e.g., AR ≈ 0.5) may still generate a high torque if installed at excessive speed. This can result in false assumptions about the pile’s performance. Therefore, to ensure accurate assessment, all three key parameters — torque, advancement ratio, and rotational speed — must be measured continuously, digitally, and with verified accuracy, during the installation.

3.3 Installation log

The bearing capacity of a screw pile foundation can only be verified if continuous measurements of installation depth, rotation, and installation torque are recorded throughout the installation process and documented in an installation log, as illustrated in Figure 3-5. Alternatively static load tests shall be performed on each pile.

If installed incorrectly, a screw pile essentially functions as a soil auger. Installers often unintentionally use screw piles as drilling tools when they encounter hard soil layers or obstructions before reaching load-bearing strata.

One of the advantages of steel screw piles is that they can be easily unscrewed and relocated if they encounter an unexpected obstruction during installation.

When an obstruction is encountered during installation, there are generally three options:

- The pile is unscrewed and repositioned, and the superstructure design is adjusted to reflect the new pile location.
- The pile is drilled through the obstruction (i.e., “overfligted” AR<1) and installation continues until it reaches the intended load-bearing layer.
- In this case, bearing capacity may only be assigned from the depth where proper installation resumes - defined by an AR close to 1 (i.e., one helix pitch per rotation).
- The pile is load-tested, provided there is sufficient confidence that it has stopped in load-bearing material - not on a boulder or obstruction within fill or loose soil.

The installation log can confirm that each pile has been correctly installed and that the design torque threshold has been achieved. It functions as the equivalent of a pile driving record for conventional foundations. In line with standard practice for traditional piling systems, it serves as the basis for verifying load-bearing capacity through static or dynamic load testing on 5% of the installed piles (A minimum of 3 piles, with the same soil type and pile geometry, shall always be tested). Without the installation log, every pile must be individually static tested, as no reliable alternative exists.

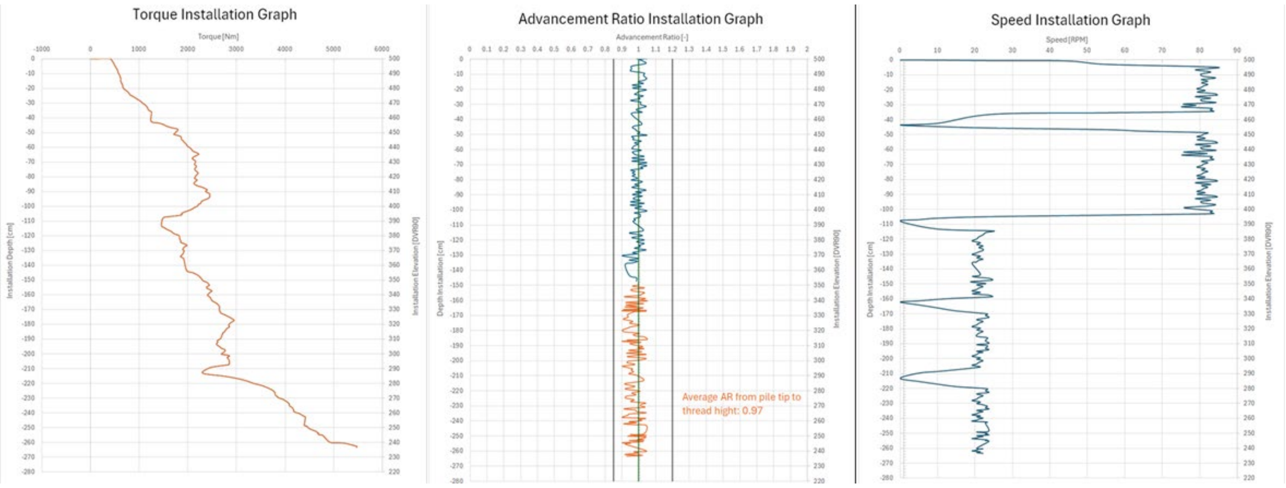


Figure 3-5 Installation log shows installation torque, advancement ratio and rotation speed plotted against depth.

3.4 Misconceptions about Torque as a standalone indicator

There is a common misconception that screw pile bearing capacity can be verified solely based on torque measurements, without consideration of soil type, advancement ratio, or rotational speed.

This view is inconsistent with well-established knowledge - such as CPT-based methods - where tip resistance is known to be strongly influenced by both soil friction and penetration rates.

As illustrated in Figure 3-6, bearing capacity is highly dependent on soil type. The same measured friction can correspond to a wide range of actual capacities, depending on fines content. Therefore, the friction correlation factor (Kc) must be calibrated site-specifically, and installation speed in the bearing layers should be kept below 20 RPM (rotations pre minute) to avoid misinterpretation.

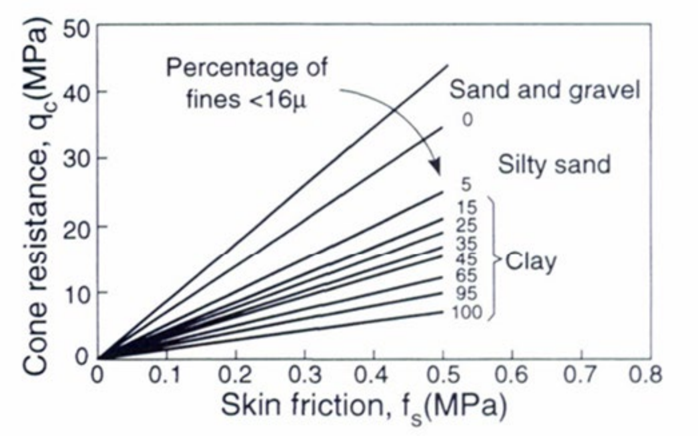


Figure 3-6 Cone resistance as a function of friction. The same measured friction can correspond to a wide range of actual capacities, depending on fines content. (from Begemann, 1965)

Consequently, reliable documentation of a screw pile's bearing capacity cannot be based on torque measurements alone, but shall the also document the following four variables during installation:

1. Soil profile
2. Pile geometry
3. Advancement Ratio (AR)
4. Rotational speed

Only the first three variables influence the actual bearing capacity of the pile. Rotational speed does not affect the load-bearing behaviour of the installed pile; it only increases installation resistance and torque measurement. This discrepancy can lead to severely misleading interpretations if torque is used as the sole capacity indicator.

Below, experimental and in-situ examples highlight why torque must always be evaluated with AR, rotation speed, and soil type to document the load-bearing capacity.

3.4.1 Experimental and field evidence

The following case studies highlight why torque must always be evaluated in conjunction with advancement ratio, rotation speed, and soil type when assessing or verifying the load-bearing capacity of screw piles.

Pile types considered:

- D76T12 – Shaft diameter 76mm, continuous thread 12mm welded on a tapered steel pipe.
- D89T12 – Shaft diameter 89mm, continuous thread 12mm welded on a tapered steel pipe.
- D76S276 – Shaft diameter 76mm, single helix welded on a tapered steel pipe. Helix diameter 276mm.
- D89S289 – Shaft diameter 76mm, single helix welded on a tapered steel pipe. Helix diameter 289mm.

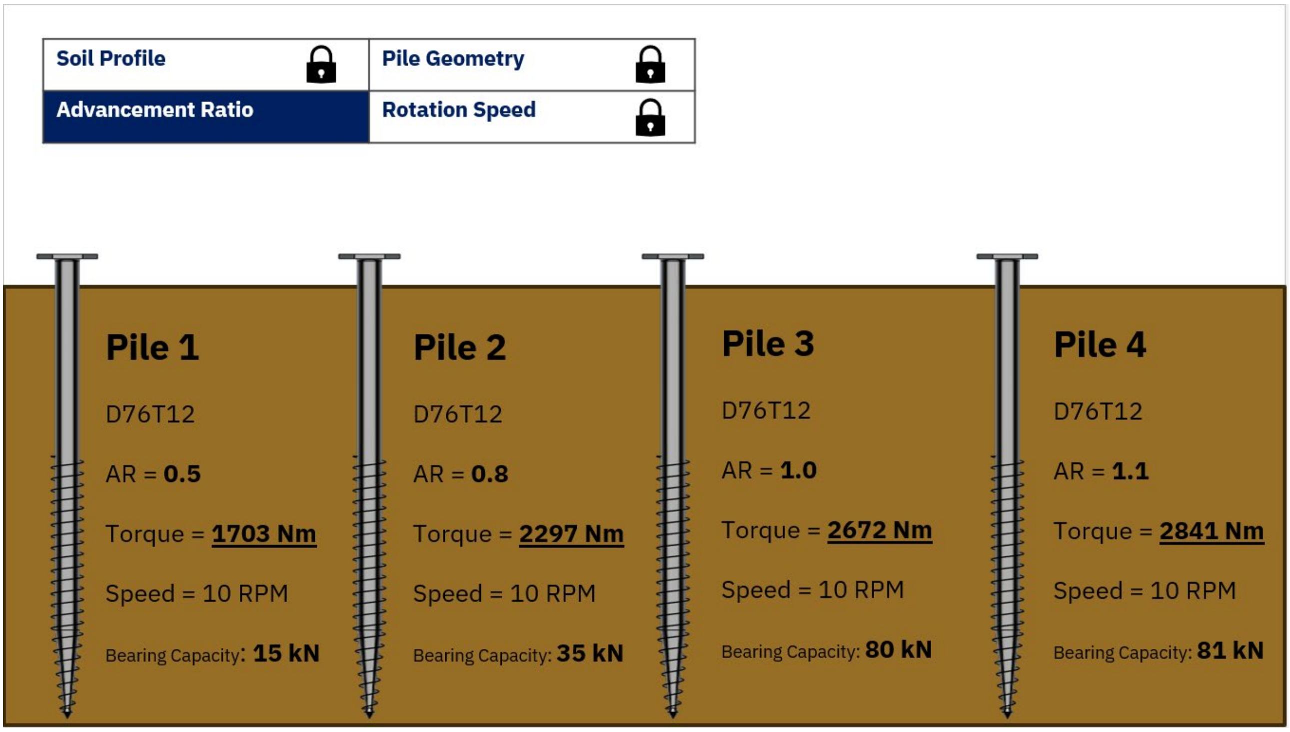


Figure 3-7 Four identical screw piles were installed with ARs of 0.5, 0.8, 1.0, and 1.1 respectively.

Example 1: Advancement Ratio alone affects capacity significantly

The following variables are held constant: Soil profile, pile geometry, rotation speed (10 RPM)
Variable changed: Advancement Ratio.

Four identical D76T12 screw piles were installed with ARs of 0.5, 0.8, 1.0, and 1.1 respectively. Even though the last rotation torque increased with AR, the static load test revealed a dramatic difference in compression capacity—from 15 kN (AR = 0.5) to 51 kN (AR = 1.1), as shown in Figure 3-7.

Conclusion: Overturning (AR < 0.8) causes soil loosening, reducing torque and bearing capacity—only ARs near 1.0 yield optimal performance. Torque measurement without AR context is meaningless.

Example 2: Pile geometry alone changes both torque and capacity

The Following variables were held constant: Soil profile, Advancement Ratio (AR) = 1.0, Rotation Speed = 10 RPM.

Variable changed: Pile geometry.

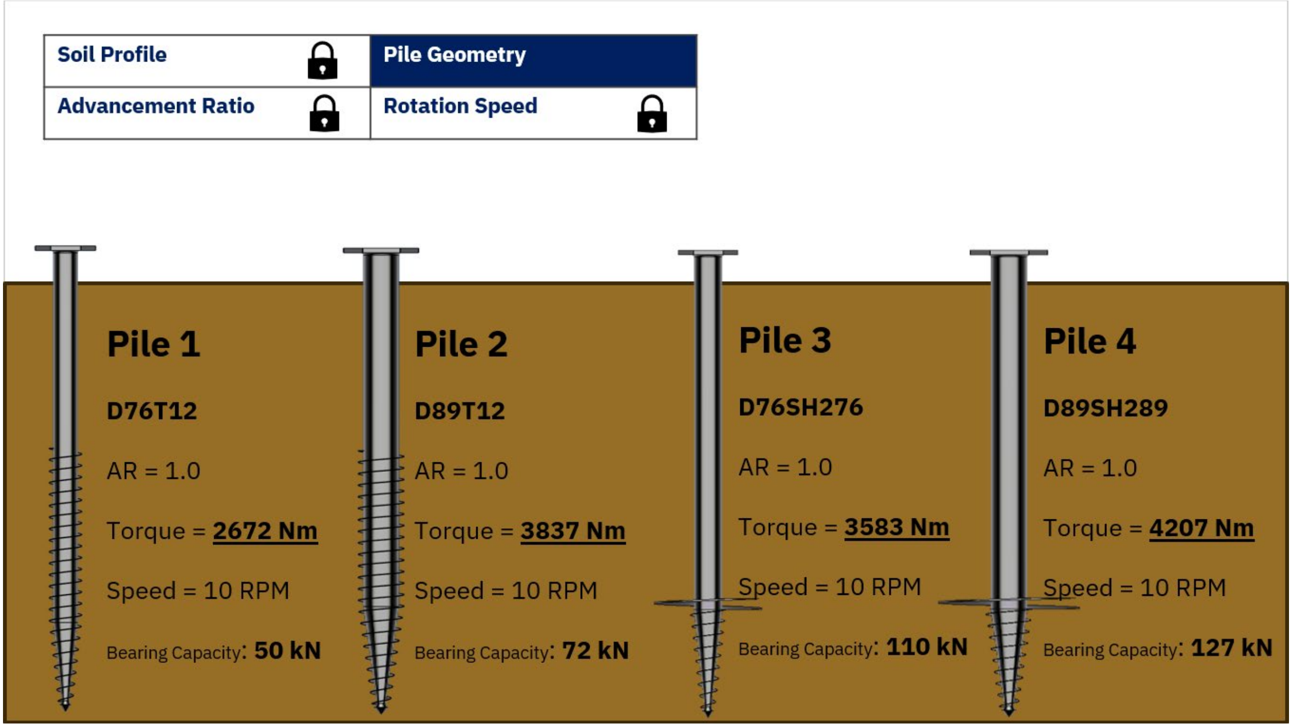


Figure 3-8 Four piles with different pile geometries.

At first glance, one might assume that Pile 2 would have a higher capacity than Pile 3, because it measured higher torque. Despite lower torque Pile 3 had a significantly higher bearing capacity (110 kN vs. 72 kN), as seen in Figure 3-8.

This clearly shows that torque alone cannot be used to compare piles with different geometries. Larger or more aggressive helix designs (as in helix piles) can dramatically increase bearing capacity without a proportionate increase in torque.

Conclusion: Pile geometry must always be documented and considered in any evaluation of installation data.

Example 3: Torque increases with speed – but capacity does not

The following variables were held constant: Soil profile, Pile geometry (D76T12), AR = 1.0
Variable changed: Rotation speed.

When rotation speed was varied from 5 to 80 RPM, torque increased from 2100 to 3800 Nm — without any change in bearing capacity, which remained stable at 50 kN, as shown in Figure 3-9.

Conclusion: Faster installation inflates torque measurements, creating a false impression of higher bearing capacity. Bearing capacity remains unchanged. This shows that speed must be measured and reported alongside torque.

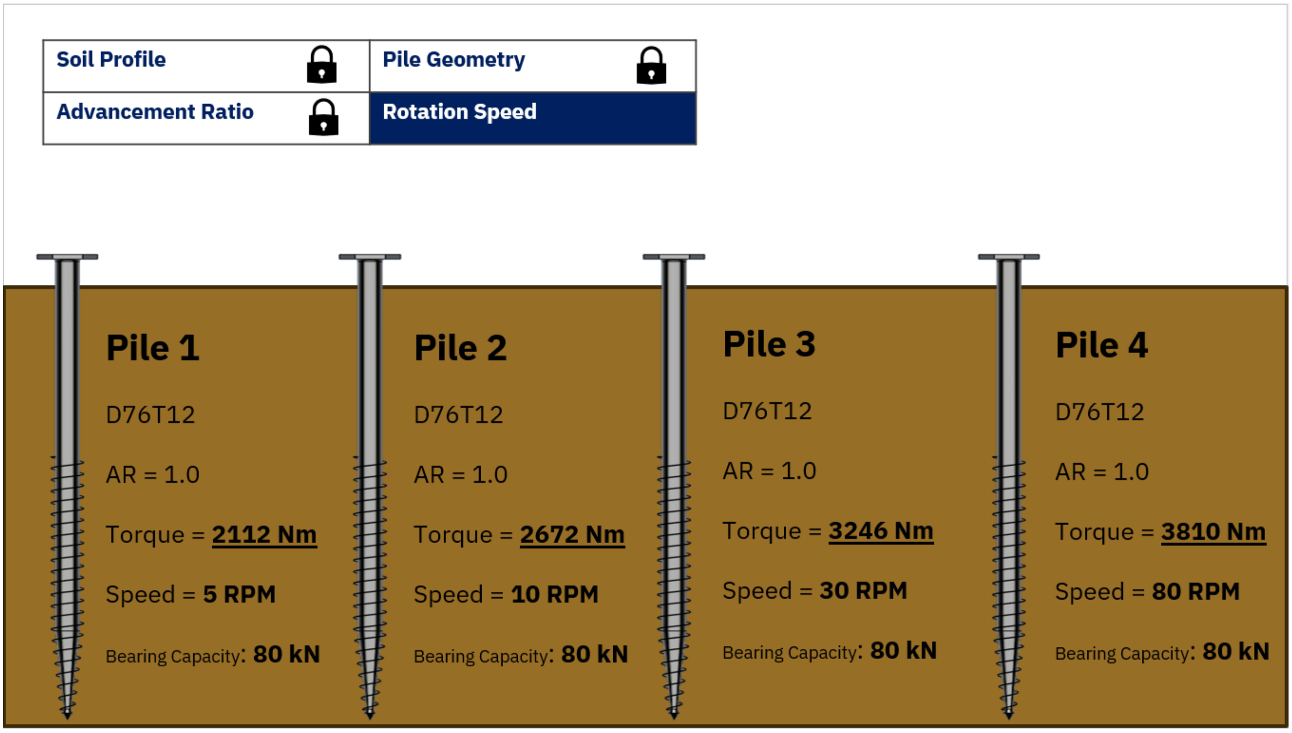


Figure 3-9 Four identical piles were installed at different rotation speed.

Example 4: Real Project – same geometry, inconsistent performance

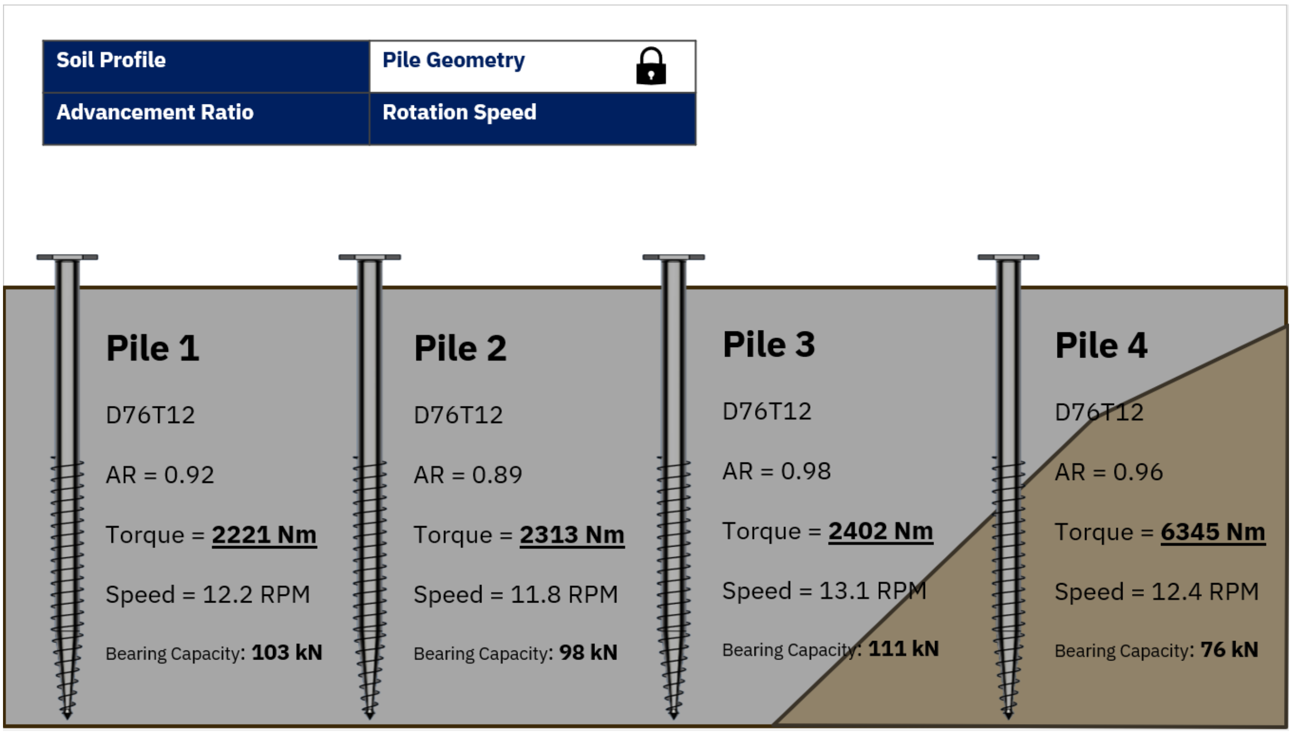


Figure 3-10 Four identical piles were installed in glacial till.

Identical piles installed in glacial till showed ARs of 0.89–0.98 and torque values of approximately 2200 to 6300 Nm. One pile showed nearly 3x torque yet the lowest bearing capacity (76 kN vs. 111 kN), as shown in Figure 3-10.

Conclusion: Soil variability (e.g. transition from clay to dense sand) and changes in AR or RPM can drastically skew torque measurements. In this case, high torque came from sand resistance but resulted in poorer capacity.

Example 5: Torsion alone cannot predict anything reliably

Four piles showed similar torque values (~3100 Nm) but drastically different bearing capacities, ranging from **32 kN** to **102 kN**, as shown in Figure 3-11

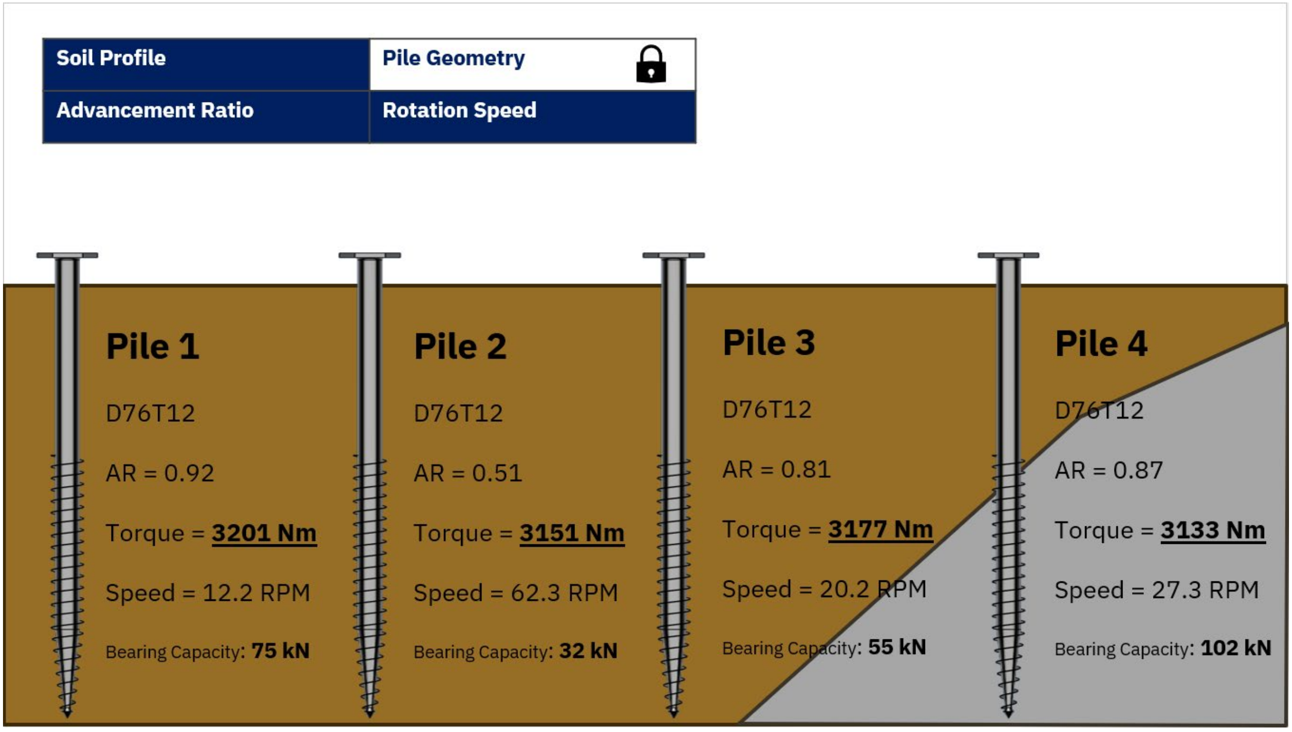


Figure 3-11 Four piles installation with similar torque values.

The reasons were different combinations of:

- AR (from 0.51 to 0.92)
- Rotation speed (from 12 to 62 RPM)
- Soil types (sand vs. clay)

Conclusion: Even when torque values are close, bearing capacities can vary by over 300%. Without full documentation of AR, speed, and soil profile, making conclusion on bearing capacity from torque alone is impossible.

3.4.2 Final conclusion

These findings are based on controlled laboratory experiments and real in-situ case studies. They demonstrate that evidence-based documentation of screw pile performance requires full installation monitoring — including:

- Torque
- Advancement Ratio (AR)
- Rotation Speed
- Soil Conditions

Only when all these parameters are digitally and continuously recorded can load-bearing capacity be safely inferred or reduced-scale testing regimes (e.g. 5% static testing) be applied. Every pile must be individually static tested without these measurements, as no reliable alternative exists.

3.5 Measuring and documenting torque

Figure 3-12. Direct method: In-line transducer placed between the torque head and the screw pile being installed.

Accurate documentation of installation torque is critical for the documentation of correct installed, especially when using the torque-to-bearing capacity method, for screw and helical piles. Despite the widespread use of oil pressure-based systems for convenience, recent research highlights that these indirect methods introduce significant and systematic inaccuracies, see Ibsen and Andreasen [2025].

Figure 3-12 shows the use of a direct measurement system. The transducer is placed between the torque head and the screw pile being installed. Examples of Direct Torque Measurement Systems are shown in Figure 3-13 a) whereas examples of Indirect Torque Measurement using Hydraulic Pressure are shown in b) and c).

Figure 3-13. a) Examples of Direct Torque Measurement Systems. b) and c) Examples of Indirect Torque Measurement Using Hydraulic Pressure.

Hydraulic systems used for measuring torque are inherently unreliable in non-isolated configurations—where oil pressure also drives tower and machine movements. Under such conditions, measured torque values can deviate by an average of 66%, with peak deviations exceeding 8000% during installation start-stop phases.

Indirect methods suffer from multiple physical and operational weaknesses: temperature-dependent viscosity fluctuations, air entrapment (cavitation), undetected leaks, contamination, and delayed system response times. These issues are further aggravated by sensor drift and the lack of standardization across machines and torque heads, making calibration highly variable. Attempts to improve these systems with differential pressure sensors or improved oil filtering have not resolved the core issue: oil pressure is not directly proportional to torque and is sensitive to too many uncontrolled variables, Ibsen and Andreasen [2025].

In Figure 3-14 the oil pressure error measured from one machine over a working day is shown. The error is calculated based on the last torque measured by the direct and indirect transducers at each installed pile. The measured error varies from -14 % in the morning to 42% at the end of work compared to the torque

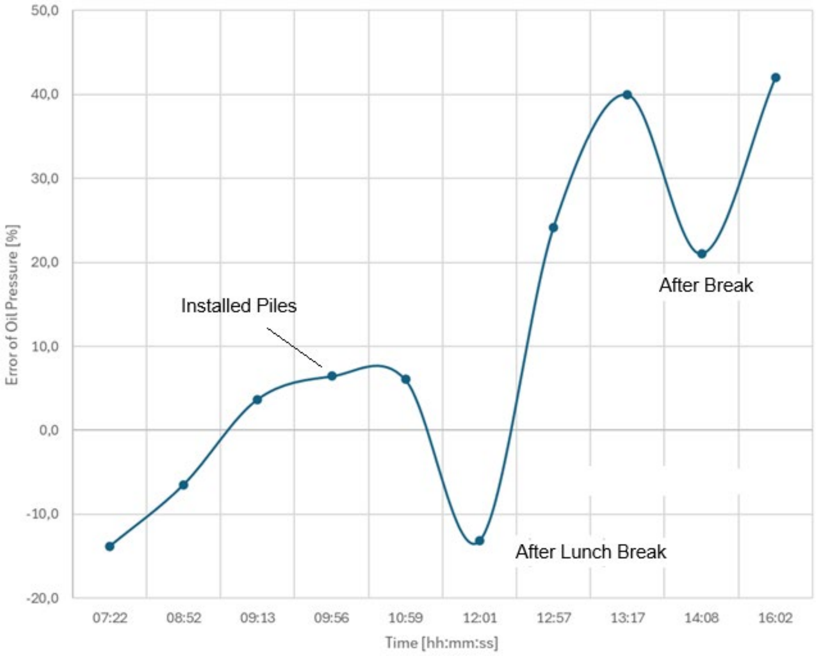


Figure 3-14 Oil pressure error measured from one machine over a working day. The error is calculated based on the last torque measured by the direct and indirect transducer at each installed pile.

measured by the direct method. It is seen that breaks during the day are also visible and influence the measured torque from the indirect system.

Indirect methods suffer from multiple physical and operational weaknesses: temperature-dependent viscosity fluctuations, air entrapment (cavitation), undetected leaks, contamination, and delayed system response times. These issues are further aggravated by sensor drift and the lack of standardization across machines and torque heads, making calibration impossible. Attempts to improve these systems with differential pressure sensors or improved oil filtering have not resolved the core issue: oil pressure is not directly proportional to torque and is sensitive to too many uncontrolled variables.

In contrast, direct measurement systems, based on strain gauge technology, offer precise, real-time readings of torque. These in-line transducers, mounted between the drive head and the screw pile, provide values that are independent of machine hydraulics. Their compact form factor, high accuracy (often <0.1%), and ability to capture dynamic load responses make them ideally suited for field conditions. Furthermore, they simplify documentation and meet the increasing demand for traceable, digital QA systems in foundation engineering.

Given the critical role of torque in determining and documentation of the load-bearing capacity of screw piles, and the extensive evidence of measurement errors in indirect systems, the use of direct torque measurement should be mandated in all installations where torque-based verification is applied. Annual calibration of electronic transducers and inclusion of calibration certificates in project documentation should become standard practice.

Conclusion: Transitioning from oil pressure to direct torque measurement systems is not only a matter of precision, but also essential for structural reliability, safety, and compliance with modern engineering standards.

3.6 Coating and Corrosion Protection

Coatings and connections for corrosion protection must comply with the design requirements. The protection must remain intact, particularly near the joint elements, and meet the project's specifications.

The choice of protection method should be based on the environmental exposure class (in accordance with EN ISO 12944 or national standards) as well as the intended service life (typically 50 or 100 years). The most effective protection is often achieved through a combination of methods (e.g., structural oversizing + coating + sacrificial anodes). Documentation must be provided in accordance with DS/EN 1993-5.

For steel screw piles, corrosion is a critical factor affecting the load-bearing capacity of both screw blades and steel tubes. The load-bearing capacity of these structural elements must be documented through calculations.

Steel piles with a wall thickness of 3.6 mm should not be used for buildings covered by the building regulations, as they typically do not meet the required design service life of 50 years.

Note: Example of the required calculation for the service life and internal load-bearing capacity of a galvanized steel tube with a diameter of Ø76 mm and a wall thickness of 3.6 mm. The tube is galvanized with 70 µm of zinc, and double-sided corrosion is considered. The vertical internal load-bearing capacity of the screw pile is calculated at 80 kN with an eccentric load application of 20 mm and no horizontal load. Figure 3-15 illustrates the calculation of the pile installed in saline soil, which is commonly found in summer house areas and coastal regions. Additionally, it shows the reduction in the pile’s internal load-bearing capacity as a function of service life.

Table 3-1 presents the pile’s service life calculations under various environmental conditions for design loads of 30 kN and 50 kN. There is used double-sided corrosion.

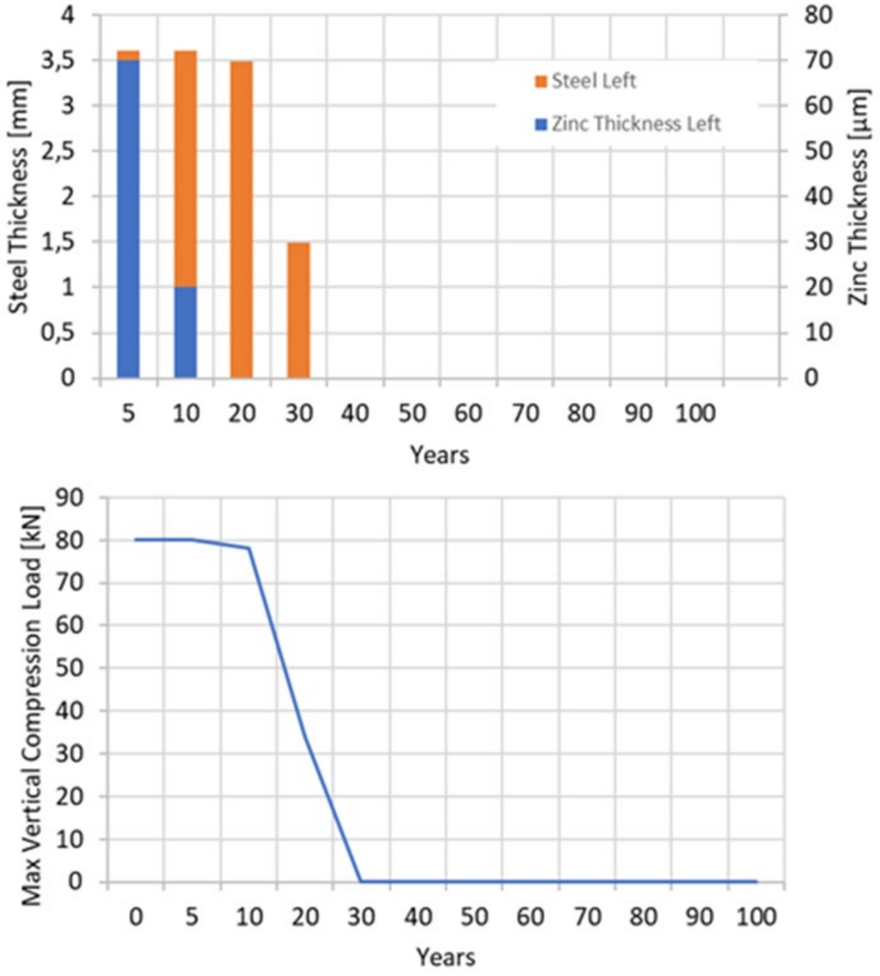


Figure 3-15 Calculation of Service Life and Internal Load-Bearing Capacity of Galvanized Steel Tube Ø76 mm with a Wall Thickness of 3.6 mm. The tube is galvanized with 70 µm of zinc, and double-sided corrosion is considered.

Table 3-1 Presents the pile’s service life calculations under various environmental conditions for design loads of 30 kN and 50 kN.

Vertical Load (kN)	30	50
Water-Saturated, Neutral pH	50 years	38 years
Low pH < 5	30 years	20 years
Saline Soil	21 years	16 years

4 Normative references

A screw pile project shall be treated in the same manner as a conventional pile foundation project and shall be designed in accordance with the Danish National Annexes to the Eurocodes:

Building Regulation (BR18).
DS/EN 1990:2023 Eurocode 0: Basis of structural and Geotechnical Design.
DS/EN 1990 DK NA:2024 – National Annex to Eurocode 0: Basis of structural design.
DS/EN 1993-1-1 DK NA :2019 Steel structures – General rules and rules for buildings.
DS/EN 1993-5 DK NA: 2015 Steel structures – Part 5: Piling.
DS/EN ISO 1461:2022: Hot dip galvanized coatings on fabricated iron and steel articles – Specifications and test methods.
EN 10210: Hot finished structural hollow sections of non-alloy and fine grain steels – Technical delivery conditions.
EN 10219: Cold formed welded structural hollow sections of non-alloy and fine grain steels – Technical delivery conditions
EN ISO 11960: Petroleum and natural gas industries – Steel pipes for use as casing or tubing for wells.
EN ISO 12944 – Corrosion Protection of Steel Structures by Protective Paint Systems.
DS/EN 1997-1 DK NA:2021 Geotechnical design -Part 1: General rules
EN 1997-2 DA NA:2013. Geotechnical design -Part 2: Ground investigation and testing.
EN ISO 22477-1:2018: Geotechnical investigation and testing – Testing of geotechnical structures – Part 1: Testing of piles: static compression load testing.
EN ISO 22477-2:2023: Geotechnical investigation and testing – Testing of geotechnical structures – Part 2: Testing of piles: static tension load testing.
EN ISO 22477-10:2016 — Geotechnical investigation and testing – Testing of geotechnical structures – Part 10: Testing of piles: rapid load testing.

Geotechnical boreholes with strength testing must be conducted. The screw pile foundations shall be designed according to Geotechnical Category 2 (GC2). Boreholes must reach a depth that ensures sufficient knowledge of the soil conditions well below the pile toe level. This must be performed to enable a proper design evaluation of bearing capacity, negative skin friction, and settlement analysis.
Single-family houses, row houses, and summer houses are placed in Consequence Class CC2, and according to the Danish Building Regulation (BR18), these types of buildings are normally placed in Structural Class KK1, also when founded on screw piles.

4.1 Special for screw piles

A screw pile is characterized as a displacement pile, and it is recommended that a screw pile project shall be documented in accordance with DS/EN 1990:2023 Annex D rules for design assisted by testing.
This is primarily due to two reasons:

- Geostatic equations cannot adequately handle the wide variety of screw pile designs. Geotechnical calculations must be performed with the specific pile design to represent the failure mechanism and thus, the bearing capacity with sufficient accuracy. The calibration shall be carried out based on static load tests with constant deformation rate, both for compression and tension, and with the actual soil types.

- A screw pile is, in principle, a soil auger if not installed correctly. Proper installation requires that the screw be continuously advanced at the pitch of the helical blade.

The bearing capacity of a screw pile in any project can only be documented if continuous measurements of advancement ratio (depth per rotation compared to the pitch), rotation speed, and installation torque are conducted during installation and documented by a digital installation log. This allows verification that the screw piles are correctly installed and that a design based on a minimum torque has been achieved for each pile.

DS/EN 1990:2023, Eurocode – Basis of structural and geotechnical design, section 7.3, states:

1. Physical testing may be used to determine parameters for use in design.
2. Testing may determine the performance of a structure or structural member as specified by the relevant authority or, where not specified, as agreed for the specific project by the relevant parties.

Note: Physical testing is carried out, for example, in the following circumstances:

- a) If adequate calculation models are not available.
- b) To confirm by control checks the assumptions made in the design.

5 Geotechnical investigations

5.1 General

5.1.1

Geotechnical investigation shall comply with the requirements specified in **EN 1997-1 DA NA:2021** and **EN 1997-2 DA NA:2013**.

5.1.2

The depth and scope of the investigation must be adequate to identify all ground layers and formations that may influence the construction. This includes determining the relevant geotechnical properties and verifying ground conditions. For example, where end bearing is intended, the investigation must confirm that the bearing stratum is not immediately underlain by weaker soil layers that could lead to punching failure or excessive settlements.

5.1.3

Relevant experience from similar foundation projects under comparable ground conditions - especially near the site - should be considered when defining the investigation's extent. Reference to prior experience is acceptable, provided it is supported by appropriate verification methods (e.g., SPT, CPT, Pressuremeter tests (PMT), or similar in-situ testing).

Note: EN 1997-2 provides recommended investigation depths and content guidance.

5.1.4

The geotechnical report shall be made available in time to ensure the reliable design and execution of displacement piles.

5.1.5

The adequacy of the geotechnical investigation must be verified specifically for the design and construction of displacement piles.

5.1.6

If the investigation is insufficient, **additional geotechnical investigations** shall be carried out.

6 Materials and properties

6.1 General

6.1.1 All materials and products shall meet the requirements set in the respective European Standards, the provisions valid in the place of use, and the provisions given in the project specification.

6.1.2 All constituents' supply sources shall be documented and not changed without prior notification.

6.2 Prefabricated screw piles

The materials and fabrication of steel piles shall, as a minimum, comply with:

EN 1993-1; EN 1993-5; EN 10210 or EN 10219 or EN ISO 11960 when hollow sections (e.g., tubes) are used.

6.3 Coating and corrosion protection

Coatings and compounds for corrosion protection shall comply with the design specifications. The continuity of protection, close to the connection elements, shall comply with the specifications and the design.

The choice of protection method should be based on the environmental exposure class (per EN ISO 12944 or national standards) and the intended design life (typically 50 or 100 years). The most effective protection often comes from combining methods (e.g., structural over-dimensioning + coating + sacrificial anodes). Documented according to DS/EN 1993-5.

For steel screw piles corrosion will be an issue for the structural load-bearing capacity of both the helixes and the steel pipe. The load-bearing capacity of these structural elements must be documented by testing or advanced calculation.

7 Design considerations

7.1 General

7.1.1

The design shall be based on the relevant provisions of EN 1990 through EN 1999 (Eurocodes 0 to 9), as referenced in Clause 4.

7.1.2

This report provides design provisions related to execution aspects that are not addressed in the 7.1.1 but may influence the design or detailing of screw piles.

7.1.3

The design shall define the type and dimensions of the screw piles and verify that the chosen installation method is suitable for the specific ground conditions and environmental constraints.

Note: This may often be confirmed based on prior experience with comparable projects.

7.1.4

Without relevant experience regarding the feasibility of installation, one or more trial installations (screw-driving tests) shall be performed at selected locations before commencing the main works.

Note: Screw-driving tests provide insight into the required installation torque, necessary equipment, and driving techniques. They also help assess the influence of pile installation on soil behaviour and the surrounding environment. Furthermore, such tests can define installation criteria and offer initial estimates of pile length and load-bearing capacity.

7.1.5

Any design or specification requirements related to driving assistance techniques shall be considered when evaluating the pile's screwability.

7.2 Internal load-bearing capacity

7.2.1

The internal load-bearing capacity of the pile and connections shall be determined based on the eccentricity introduced by the installation maximum placement tolerance and the vertical, horizontal, and moment loads acting on the pile cap. The structural components include the shaft, couplings, and helical bearing plates. The anticipated steel corrosion at the end of the design life shall be accounted for by reducing the effective cross-section accordingly.

7.2.2

Steel screw piles are installed by applying both torque and downward thrust at the top of the pile. Therefore, the pile's torsional and compressive strength must be documented to withstand the installation effects.

7.2.3

Geometrical tolerances shall be specified for the screw pile and shall be included in the structural design, including the verification of potential column effects and second-order moments.

7.2.4

If the actual tolerances exceed the specified limits, the potential overstressing of any structural component shall be evaluated. Appropriate corrective actions should be implemented where necessary, such as installing additional piles.

Note: For example, horizontal and vertical alignment tolerances may affect the eccentricity of loads applied to the pile head, thereby influencing column effects and second-order moments.

7.3 Installation

7.3.1

If screw piles are not installed correctly but are over-rotated, they effectively function as soil augers, loosening the surrounding soil. Proper installation requires that the penetration per revolution (PPR) corresponds to the pitch of the helical blades within the soil layer expected to contribute to the pile's bearing capacity. This corresponds to an Advancement Ratio (AR) of 1.0.

The advancement ratio (AR)—defined as the vertical advancement per revolution relative to the blade pitch—is the principal parameter governing both installation quality and bearing capacity. If the pile is "over-rotated," AR becomes less than 1.0. However, even when PR < 1.0, the pile may still be classified as a screw pile and possess some bearing capacity.

Screw piles installed with an AR deviating more than ±0.1 from the mean of the installed piles are not considered to belong to the same population. If a population is defined with a wider spread than ±0.1, partial factors and correlation factors must be determined in accordance with the principles of DS/EN 1990:2023, Annex D – Design assisted by testing.

To compare the bearing capacities of piles installed within the same geotechnical unit—that is, piles belonging to the same population—the rotational speed must be consistent, i.e., within ±5 revolutions per minute (RPM). When penetrating the bearing stratum with the helical section, the rotational speed should be in the range of 5 to 15 RPM. Piles installed at different rotational speeds may exhibit varying torque resistance (installation moment) despite having similar bearing capacities. Therefore, torque measurements cannot be compared if the rotational speed exceeds the specified tolerance

7.3.2

To ensure reliable load-bearing performance, the advancement ratio (AR) shall be continuously monitored with depth and actively controlled throughout installation.

7.3.3

Screw piles should be installed with an AR between 0.8 and 1.1 at the depth where the helices engage the load-bearing soil volume.

Note: This range corresponds to an estimated variation of ±10% in compressive bearing capacity. This level of variation is generally acceptable for engineering practice and aligns with recommendations from CCC (2012), the New York City Building Code (2014), and BS 8004 (2015).

7.3.4

The bearing capacity of a screw pile foundation can only be reliably verified if continuous l measurements of advancement ratio, rotation speed, and installation torque are recorded during installation and documented in an installation log.

This documentation shall verify that each pile has been installed correctly and that the design torque threshold has been met. The installation log is functionally equivalent to a pile driving record. It provides the basis for verifying load capacity through static or dynamic load testing on 5% of the installed piles, in accordance with standard practice for conventional pile foundations.

7.3.5

If a screw pile has been partially uninstalled or reversed within the load-bearing soil layer, it shall be re-installed such that the pile tip extends beyond the zone affected by the previous uninstallation. To ensure reliable load transfer and proper documentation of the installation, one of the following corrective actions must be taken:

1. The pile shall be extended so that the entire helix assembly is located beneath the previously disturbed soil zone.
2. Alternatively, the pile shall be subjected to a static or dynamic load test to verify its load-bearing capacity.

7.4 Geotechnical bearing capacity

7.4.1

The installation process entirely governed the soil's geotechnical resistance, such as end bearing and shaft friction. As a result, geostatic calculations can only provide initial estimates of the required pile length and load-bearing capacity. They cannot be used to verify or document the pile's ultimate capacity.

7.4.2

The governing failure mechanism, which is influenced by the inter-helix spacing ratio (S/D_h), determines the appropriate design method for a given pile.

The spacing between helices is sufficiently small for continuous helical piles, so the pile should be designed using the cylindrical shearing method.

For $S/D_h > 2$, the axial bearing capacity shall be determined using both the individual bearing method and the cylindrical shearing method, and the lower value shall be adopted in design.

The axial bearing capacity shall be determined exclusively by using the individual bearing method for single-helix piles.

7.4.3

For continuous steel helical piles, the coupling between the lead and subsequent extension sections is typically done using bolted connections. The bolt heads often protrude 10–30 mm beyond the shaft diameter, resulting in the surrounding soil being cut away to a larger diameter than the shaft.

When bolted couplings protrude beyond the outer diameter of the shaft, or when the coupling itself encloses or extends outside the shaft geometry, the shaft friction along the extension sections shall be disregarded in the calculation of axial resistance.

Note:
Such couplings disturb the surrounding soil during installation, as the protruding bolts or oversized connectors carve into the borehole wall. This can result in a gap or loosened annulus forming around the pile, preventing direct contact between the pile and the surrounding soil.

To avoid these issues, it is strongly recommended to use flush-fit connections (e.g., set screws or internal couplings) that do not exceed the shaft diameter, thereby preserving shaft-soil interaction and maintaining valid assumptions regarding axial shaft resistance.

7.4.4

Small shaft diameters (50–150 mm) limit the ability of vertically installed helical piles to transfer horizontal loads to the surrounding soil. If horizontal load transfer is required, it must be verified through calculation or test.

However, if protruding bolted connections or oversized couplings are used, the extension sections above the lead section shall be considered unsupported for horizontal load transfer. This is due to the potential gap between the pile and the soil, which prevents lateral resistance from mobilizing until significant displacement occurs. This also applies to screw piles made of square tubes.

As a result:

- No horizontal load-bearing capacity may be documented by calculation in these sections.
- Horizontal capacity must instead be verified by static testing for all horizontal load directions.

In accordance with DS/EN 1997-1:2007, section 7.8(5), verification of column effects is generally not required for piles embedded in soil with an undrained shear strength cu > 10 kPa. This provision is revised in the new EC7-3, clause 6.6.2.5 (6). However, guidance is available in EC7-3, Annexes C.12 and C.13.

If contact between the pile and the surrounding soil is absent, this passive support cannot be assumed and must be considered in the structural design of the pile's load-bearing capacity

7.5 Torque to bearing capacity.

7.5.1

The torque-to-capacity method is a direct approach for estimating the axial bearing capacity of screw piles and is analogous to CPT-based design methods for conventional piles.

The installation torque reflects the frictional resistance encountered by the pile during installation. The relationship between installation torque and bearing capacity is expressed through the torque correlation factor (Kc), which can be used to compare piles installed within the same population—that is, within the same geotechnical unit.

If installation torque is to be used as an indicator of bearing capacity, the piles must belong to the same population in terms of installation procedure (rotational speed, penetration ratio) and must comply with the requirements specified in Section 7.3.

To determine the torque correlation factor Kc between installation torque and compressive bearing capacity, a minimum of three static load tests must be conducted on piles from the same population but with differing final installation torques.

7.5.2

To verify pile capacity, the Kc factor must be site-specifically calibrated to the actual pile geometry, soil profile, advancement ratio and rotation speed used during installation.

This calibration shall be based on static or dynamic load tests conducted at the installation site to ensure accurate validation of the bearing capacity derived.

7.5.3

Although Kc values inherently account for the influence of the advancement ratio (AR), a substantial reduction in bearing capacity can result in unacceptably large deformations. This underscores the importance of strictly controlling the AR range specified in Clause 7.3.3 during installation to avoid such performance issues.

7.5.4

The partial safety factors to be used in conjunction with the torque-to-bearing capacity method shall be determined in accordance with either Annex D of DS/EN 1990:2007 or Annex F of the Danish National Annex (DK NA) to DS/EN 1990.

8 Execution

8.1 General

8.1.1

All work shall be planned, carried out, and documented in a manner appropriate to the application.

8.1.2

All reasonable precautions should be taken during installation operations, including pile, equipment, and material handling, to ensure safety on and around the site and minimize the risk of damage and influence of vibrations and noise on people and adjacent properties.

8.1.3

Before starting installation work, an execution plan shall be prepared and approved. This plan shall describe:

- The installation method and equipment to be used,
- The global sequence of pile installation, and
- The monitoring systems document installation parameters (e.g., torque, advancement ratio, rotational speed).

All monitoring systems used for installation control shall be:

- Calibrated according to the required accuracy standards (see Table 8.1),
- Verified for correct operation before installation begins, and
- Documented as part of the execution records.

Calibration certificates shall be available for inspection at the construction site.

Table 8-1: Minimum Accuracy Requirements for Monitoring Equipment.

Parameter	Required Accuracy	Measurement Method	Notes
Torque	±2% of full-scale value	Calibrated strain gauge-based torque transducer	Oil pressure-based systems are not acceptable due to poor resolution and high error.
Advancement Ratio	±1 mm (vertical per rotation)	Continuous depth and rotation tracking with encoder	AR = penetration per revolution/helix pitch.
Rotational Speed	±1 RPM	Internal machine encoder or external rotation sensor	Important to avoid torque overestimation due to high-speed installation.

8.1.4

Where possible, Screw-driving tests should be installed close to positions of soil investigation. Combined with static or dynamic load tests on the test pile, such tests can define installation criteria and offer initial estimates of pile length and load-bearing capacity.

8.1.5

The effect of ground heave on previously installed piles shall be checked.

8.2 Construction tolerances

8.2.1 Unless specified otherwise, steel screw piles on land shall be installed within the following geometrical deviations:

Plan location of vertical and raking piles (measured at the working level):

- $e \leq 0{,}02$ m

inclination of vertical piles:

- $i \leq i_{max} = 0{,}04$ (0,04 m/m)

i is the tangent to the angle between the pile's designed and as-built centre line.

8.3 Equipment and Method.

8.3.1

The torque, rotational speed, and applied thrust shall be selected to ensure that the pile or drive tube can penetrate to the prescribed depth or achieve the required resistance without causing damage to the pile or inducing unacceptable soil disturbance.

8.3.2

A direct method shall be used to measure installation torque. This involves the use of an in-line torque measurement device positioned between the torque drive head and the screw pile. These devices are typically equipped with an internal electronic load cell and provide a digital display or are connected to a data logger, allowing for accurate and real-time torque measurement. The advantage of this method is that it offers machine-independent reading, unaffected by hydraulic system variations.

8.3.3

Indirect torque measurement based on hydraulic oil pressure shall not be used, as it does not provide a sufficiently accurate or reliable representation of the actual torque applied during installation.

8.3.4

The pile penetration shall be measured using a system that is independent of the movements of the installation machine.

8.4 Instrumentation requirements

To ensure reliability and comparability of data across projects, the following minimum accuracy requirements must be met:

Table: 8-2 Instrumental requirements.

Parameter	Measurement Method	Maximum Allowable Error
Torque	Calibrated, isolated system (e.g., strain gauge-based)	±2%
Advancement Ratio	Depth vs. rotations, calculated live	±1 mm
Rotational Speed	Integrated sensor or encoder	±1 RPM

Using oil pressure or uncalibrated transducers is unacceptable due to the lack of accuracy and traceability.

9 Supervision, monitoring, and testing

9.1 Supervision

9.1.1

The execution of any type of displacement pile shall require careful supervision and monitoring of the work.

NOTE 1: This includes supervision and the specified monitoring for the surrounding constructions.

NOTE 2: Clause 10 gives the additional provisions to take into account for the establishment of the execution specification for the supervision, control and testing of piles.

9.1.2

Control of the execution shall be in accordance with the project specifications and comply with EN 1997-1, EN 13670, EN 1090-2 and this standard.

9.1.3

The following items shall be supervised and controlled during the various phases of construction:

a) Preliminary work prior to the construction phase:

- Location of piles.
- Materials.

b) Piles construction:

- Installation method (tools and equipment), dimensions and depth.
- Placing (depth, position)

NOTE Not all items are applicable to each type of displacement pile.

9.2 Verification of Placement and Inclination

After completion of the installation, the contractor shall verify:

- The x/y positional deviation.
- The inclination deviation is measured relative to the vertical or designed rake.

A pile that exceeds these tolerances must be reported to the project's structural engineer for assessment. The structural design must account for additional eccentricities introduced by positional errors, ensuring long-term stability under the full design load.

9.3 Testing Requirements

When the installation is properly documented as described above, the number of required static load or dynamic tests may be reduced to 5% of the installed piles (with a minimum of 3 test piles), assuming:

- Piles are of identical geometry,
- Installed using the same method and equipment,
- In uniform soil conditions.

In projects involving variation, whether in soil type or pile type, each unique combination must meet the minimum 5% (with a minimum of 3 test piles) test requirement individually. For example:

Table 9-1: Testing Requirements.

Condition	Required Testing
Screw piles in sand	5% static tests or a minimum of 3 tests
Screw piles in clay	5% static tests or a minimum 3 tests

Each test should be representative of the installed pile's actual conditions and must include both compression and tension load testing when relevant.

9.4 Load Testing

9.4.1

Two test methods are permitted for verifying the bearing capacity of screw and helical piles: static load testing and, under certain conditions, dynamic load testing.

Two types of static load tests may be applied:

- Compression testing
- Tension testing

The distance to reaction systems or reaction piles shall comply with the requirements specified in EN ISO 22477-1 for micropiles, i.e., a minimum of 1.5 m or 2.5 times the helix diameter.

9.4.2

Compression testing may be conducted as follows:

Failure test:
Used for the calibration of analytical models, torque-to-capacity models, and dynamic models, as well as for the determination of partial factors. The load is applied at a constant deformation rate (mm/min) until either:

- 10% of the pile diameter (thread diameter), or
- Minimum settlement of 100 mm—whichever value is greater.

The ultimate bearing capacity is determined based on the load–displacement curves while accounting for the characteristics of the superstructure. Piles that do not exceed the permissible settlement and remain within the design load may be reused.

Suitability test:
Performed using incremental load steps (typically 25%, 50%, 75%, and 100% of the characteristic load), with each step held constant while measuring deformation. The pile may remain part of the foundation if the performance criteria are verified.

9.4.3

Tension testing may be conducted as follows:

Failure test:
Performed at a constant rate of deformation (mm/min) until tensile failure occurs. These piles may be retained as part of the permanent structure.

Suitability test:
Conducted in accordance with EN ISO 22477-2 using incremental loading (25%, 50%, 75%, and 100% of the characteristic load). Each load step is held to observe deformation, creep, or failure. The pile may remain in the foundation if the performance criteria are satisfied.

The choice of load test method shall be coordinated with the geotechnical and structural engineer based on the project class, potential reuse of the tested pile, and the significance of the structure.

9.4.4

Dynamic load tests may only be used if validated against previous static failure tests performed on the same pile type, in comparable soil conditions, and installed using the same method. The correlation must be documented and demonstrate a reliable relationship between dynamic and static bearing capacity values.

The determination of partial factors and correlation coefficients shall comply with the principles outlined in DS/EN 1990:2023, Annex D – Design assisted by testing.

In the absence of such established correlations, verification of bearing capacity shall be based solely on static load testing.

10 Documentation

Documentation and Control Plan for Screw and Helical Pile Projects

This section provides a complete overview of the required documentation for screw and helical pile foundation projects, structured according to Danish Building Regulation BR18 and referencing SBI Anvisning 271 and DS/EN standards. The structure ensures full compliance for projects in all structural classes (KK1, KK2, KK3, KK4). The documentation is divided into "A"-series (Design basis), "B"-series (Control plans and execution documentation), and roles (installer vs. construction engineer).

10.1 A-Series – Design Basis

Table 10-1: A-Series – Design Basis.

Document	Title	Responsible Party	Description
A1.1	Basis for Design	Construction Engineer	Describes load assumptions, design methods, ground conditions, and references to standards.
A2.1	Soil Investigation Report	Geotechnical Specialist	Geotechnical Category (GC2), stratigraphy, CPT/SPT logs.
A3.1	Static Calculations – Internal Capacity	Installer / Manufacturer	Full documentation of each pile type's axial, bending, and shear capacity, including corrosion loss and eccentricity from tolerances.
A3.2	Static Calculations – Connection Capacity	Installer / Manufacturer	Documentation of all bolted or welded connections. Includes shear (Clipping), hole bearing, eccentricity, component strength, and moment capacity.
A3.3	Static Calculations – Horizontal Capacity	Construction Engineer / Geotechnical Specialist	FEM or P-Y curve-based documentation using project-specific soil profiles. Must include pile group effects and eccentric loads. If protruding bolts or larger connections than the shaft are used, horizontal bearing capacity requires testing.
A3.4	Geostatic Calculation-Geotechnical axial capacity	Construction Engineer / Geotechnical Specialist	Calculation of pile lengths and diameters shall be based on the elevation of the top of the load-bearing stratum and the results of strength tests conducted within the soil profile.

10.2 B-Series – Control Plan and Execution Documentation

Table 10-2: B2 – Control Plans.

Document	Title	Responsible Party	Description
B2.1.2	Static Control Plan – Design	Construction Engineer	Overview of all design-stage control activities. References to A-series.
B2.2.1	Static Control Plan – Execution	Installer / Construction Engineer	Describes supervision, testing strategy (static/dynamic), documentation of tolerances, etc.

Table 10-3: B3 – Component and Material Traceability.

Document	**Title**	**Responsible Party**	**Description**
B3.1	Pile Type Identification and Marking	Installer / Manufacturer	Overview of pile types used, with batch numbers and serial markings. Should allow cross-reference to internal capacity documentation (A3.1).
B3.2	Connection Component Traceability	Installer / Manufacturer	Bolts, couplings, or weld joints must be logged per pile ID with batch numbers and quality grades.
B3.3	Material Delivery and Receipt Logs	Installer	Verification of delivered components vs. design specification. May include delivery slips and visual inspection logs.
B3.4	Certificate Register (Steel, Welding, Galv.)	Installer	Index to B4.1.1–B4.1.3 documents, referenced per pile ID or batch. Ensures traceability for audits.

Table 10-4: B4 – Execution Documentation.

Document	Title	Responsible Party	Description
B4.1.1	Material Certificates – Steel	Installer	Steel batch certificates for piles, incl. yield strength, elongation, etc.
B4.1.2	Welding Documentation	Installer / Manufacturer	Includes WPQR or calculation of weld capacity.
B4.1.3	Galvanization Certificate (if used)	Installer / Manufacturer	Documented compliance with DS/EN ISO 1461 or equivalent.
B4.2.1	Monitoring System Calibration Log	Installer	Calibration certificates for torque, AR, and RPM sensors. Must meet the accuracy from Table 8.1.
B4.2.2	Installation Logs	Installer	Installation plots present raw and processed data from the digital unit (torque, AR, speed) for each installed pile.
B4.2.3	Pile Installation Plan (Projected)	Construction Engineer	Overview of intended pile layout and length plan.
B4.2.4	As-Built Pile Plan and Commentary	Installer	This is a comparison to the projected plan. It includes pile IDs, pile types, actual depths, placement, and reasons for changes (obstructions, extensions, etc.).

Table 10-5B5 – Test Reports.

Document	Title	Responsible Party	Description
B5.1.1	Static Load Test Report	Construction Engineer / Installer	Test setup, photos, displacement data, and failure mode. Refer to EN ISO 22477-1/-2.
B5.1.2	Dynamic Load Test Report	Construction Engineer / Installer	Setup description, equipment, and hammer efficiency. Refer to EN ISO 22477-10. If used for design, it must be correlated with a static test.
B5.1.3	Static-to-Dynamic Correlation Documentation	Installer	Plot comparisons of test values from both methods. They must be of the same pile type and soil profile.
B5.1.4	Evaluation of Negative Skin Friction (SLS)	Construction Engineer	Using geostatic formulas where applicable.

10.3 Verification of Placement

- All piles must be checked for:
  - **x/y deviation** (max ±20 mm)
  - **Inclination** (typically ≤ 0.04 m/m)
- The structural engineer must assess any deviations to verify that they do not exceed design assumptions.

10.4 Summary

This checklist ensures that all necessary documentation is collected and submitted for screw pile foundation projects across all structural classes. The installer and the engineer have clearly defined responsibilities, enabling full traceability and regulatory compliance.

11 Bibliography

Andreasen, D. K., Ibsen, L. B., & Koteras, A. K. (2024). Evaluating the reliability of existing methods for predicting installation torque of screw piles in saturated sand: a comparative study. I N. Guerra, M. Matos Fernandes, C. Ferreira, A. Gomes Correia, A. Pinto, & P. Sêco e Pinto (red.), Geotechnical Engineering Challenges to Meet Current and Emerging Needs of Society: PROCEEDINGS OF THE XVIII EUROPEAN CONFERENCE ON SOIL MECHANICS AND GEOTECHNICALENGINEERING (1st Edition pp. 315-319). CRC Press. https://doi.org/10.1201/9781003431749-32.

Andreasen, D.K. and Ibsen, L.B. (2025). Full-scale laboratory investigation of installation effects and advancement rate for tapered continuous helical and helical piles in saturated sand. Canadian Geotechnical Journal.

BS 8004:2015+A1:2020. British standard – Code of Practice for Foundations.

Begemann, H.K.S [1965]. The friction jacket cone as an aid in determining the soil profile. Proceedings of the 6th International Conference on Soil Mechanics and foundation Engineering, Montreal 1, 17-20.

CCC (2012). Construction Code Communicator, New Jersey Department of Community Vol. 24.

Hoyt, R.M. and Clemence, S.P. (1989). Uplift capacity of helical anchors in soil. Proceedings, 12th International Conference on Soil Mechanics and Foundation Engineering, Rio de Janeiro, Brazil, vol. 2, pp. 1019-1022.

Lutenegger, A.J., (2009). Cylindrical shear or plate bearing: Uplift behaviour of multi-helix screw anchors in clay. In: Contemporary Topics in Deep Foundations. American Society of Civil Engineers, USA, pp. 456–463.

Meyerhof G.G and Adams J.I (1968). The Ultimate Uplift Capacity of Foundations. Canadian Geotechnical Journal November 1968. URG: https://doi.org/10.1139/t68-024

Mitsch, M. and Clemence, S. (1985). The Uplift Capacity of Helix Anchors in Sand', American Society of Civil Engineers pp. 26–47.

Mohajerani, A., Bosnjak, D. and Bromwich, D. [2016]. Analysis and design methods of screw piles: A review, Soils and Foundations 56(1), 115–128. URL: http://dx.doi.org/10.1016/j.sandf.2016.01.009.

Nasr, M.H., 2004. Large capacity screw piles. In: Proceedings of the International Conference: Future Vision and Challenges for Urban Development. Cairo, Egypt, 20–22 December, pp. 1–15.

New York City Building Code (2014). New York City.

Rao, S.N and Prasad, Y.V.S.N [1993]. Estimation of uplift capacity of helical anchors in clays. Journal of Geotechnical Engineering, Vol 119, No. 2

Sakr, M. [2009]. Performance of helical piles in oil sand. Canadian Geotechnical Journal 46(9), 1046–1061.Bibliography.

Perko, H.A. (2009). Helical piles: a practical guide to design and installation. Wiley, Hoboken.

Tappenden, K.M and Sego, D.C (2007). Predicting the axial capacity of screw piles installed in Canadian soils. OttawaGeo2007 conference

Zhang, D., et al. (1998). The role of CPT tests in determining soil properties for helical piles.