Chapter 3

Helical Torque Anchors™
Design Examples

- Heavy Weight New Construction
- Light Weight New Construction
- Basement Wall Tieback Anchors
- Retaining Wall Tieback Anchors
- Foundation Restoration
- Motor Output Torque
- Ultimate Capacity from Field Data

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Design Example 1 – Heavy Weight New Construction – Cohesionless Soil

**Structural Details:**
- New Building – 2 story house with basement
- Estimated weight 3,700 lb/ft
- Working load on foundation piles – 30,000 lb
- Top of pile to be 12” above the soil surface
- Soil data:
  - 6 feet of sandy clay fill (CL), stiff
    - Density = 110pcf
  - 30 feet of medium grained, well graded sand (SW), medium dense, SPT “N” = 22
    - Density = 120 pcf  \( \phi = 34^\circ \)
    - Water table = 14 ft
    - Recommended target depth = 18 ft.

**Torque Anchor™ Design:**

1. **Select the proper capacity equation and collect the known information.**

Because the soil on the site is cohesionless, Equation 1b from Chapter 1 is used:

\[
P_u = \Sigma A_H \left( \frac{q}{N_q} \right) \quad \text{Where:}
\]

\[
P_u = 30,000 \text{ lb}
\]

\[
FS = \text{Factor of Safety} = 2.0
\]

\[
P_u \times FS = 30,000 \text{ lb} \times 2.0 = 60,000 \text{ lb.}
\]

\[
h_{mid} = 18 \text{ ft.}
\]

(Choose the target depth to be 18 ft. This is the measurement from the surface to midway between the helical plates.)

\[
q = \gamma \times h_{mid}
\]

\[
q = (110 \text{ lb/ft}^3 \times 6 \text{ ft}) + (120 \text{ lb/ft}^3 \times 8 \text{ ft}) + (120 - 62) \text{ lb/ft}^3 \times 4 \text{ ft} = 1,852 \text{ lb/ft}^2
\]

\[
N_q = 24 \quad \text{“N” = 22 (Chapter 1 - Table 7)}
\]

Use Equation 1b to solve for the helical plate area that is needed.

\[
\Sigma A_H = \frac{P_u}{q \times N_q}
\]

\[
\Sigma A_H = \frac{60,000 \text{ lb}}{1,852 \text{ lb/ft}^2 \times 24}
\]

\[
\Sigma A_H = 1.35 \text{ ft}^2
\]

2. **Select the ECP Helical Torque Anchor™ suitable to support the load.**

Referring to Chapter 1, Table 2 the 2-7/8” diameter x 0.262 wall thickness tubular pile shaft is selected as most economical for this application. Our project requires 60,000 pounds of compressive strength. The selected pile shaft has a Compressive Load Limit of 100,000 pounds and a Useable Torsional Strength of 9,500 ft-lbs.

Referring to Chapter 1, Table 10 the combination of helical plates is selected from the row opposite the 2-7/8” shaft size. At least 1.35 \( \text{ft}^2 \) of bearing area is needed to support an ultimate capacity of 60,000 pounds. The data
from the 2-7/8” diameter shaft on Table 10 in Chapter 1 is reproduce here:

- 6” Dia. = 0.151 ft²
- 8” Dia. = 0.304 ft²
- 10” Dia. = 0.500 ft²
- 12” Dia. = 0.740 ft²
- 14” Dia. = 1.024 ft²

Select the combination of 8”, 10”, and 12” diameter plates on the 2-7/8” diameter tubular shaft.

\[ \Sigma A_H = 0.304 + 0.500 + 0.740 = 1.544 \text{ ft}^2 \]
\[ \Sigma A_H > 1.35 \text{ ft}^2 \]

This plate combination provides a total area of 1.54 ft², which exceeds the required plate area of 1.35 ft², arrived at from Equation 2b.

Designation for the selected Torque Anchor™ configuration is found in the product list on Page 7. The product selected is:

**TAF-288-84 08-10-12**

3. **Installation Torque**: Equation 2 in Chapter 1 calculates the estimated installation torque.

**Equation 2**: \( T = \frac{P_u}{k} \), Where,
- \( P_u = 60,000 \text{ lb. (30,000 Working Load x 2.0)} \)
- \( K = 8.5 \) (Chapter 1 - Table 12)
- \( T = 60,000 \text{ lb / 8.5 ft}^{-1} \)
- \( T = 7,100 \text{ ft-lb} \)

4. **Torque Anchor™ Capacity Verification**: A review of Table 2 in Chapter 1 indicates that the 2-7/8” diameter Torque Anchor™ has a *Useable Torsional Strength* of 9,500 ft-lb. The torque requirement of 7,500 ft-lb is 21% below the torsional limit of the shaft. The selection should work for this application based upon the soil report stating that the soil is sandy clay fill and homogenous sand with no mention of rocks, debris or other obstructions. A review of Table 11 in Chapter 1 shows that three 3/8” thick helical plates have a mechanical ultimate capacity of 120,000 pounds (40,000 lb x 3), which is double our requirement for this installation, so the mechanical capacity of the pile assembly exceeds the project requirements.

5. **Installed Product Length**: The installed length required to accomplish this design is a summation of all the lengths previously provided and determined.

- A. The pile cap is placed 1 ft. above grade level
- B. \( h_{mid} = 18 \text{ ft} \)
- C. Length from mid-plate to pile tip
  (Recall that the helical plates are spaced at three times the diameter of the nearest lower plate.)

\[ h_{tip} = [(3 \times 8” \text{ dia})+(3 \times 10” \text{ dia})]/2 = 27” \]
\[ h_{tip} = 2-1/2 \text{ ft} \quad (Round \ up \ to \ 30”.) \]
\[ L = 1 \text{ ft} + 18 \text{ ft} + 2-1/2 \text{ ft} \]
\[ L = 21-1/2 \text{ feet} \]

6. **Torque Anchor™ Specifications**

The specified Torque Anchor™ assembly will consist of the following:

- **TAF-288-84 08-10-12** This is a 2-7/8” diameter tubular product, having a standard length of 7 feet long, with an 8”, a 10”, and a 12” diameter plates that are 3/8” thick,
- **TAE-288-84** Extension, which is 7 feet long and includes coupling hardware. The coupling overlaps the previous section by 6 inches, which provides an effective length of the extension section at 6-1/2 feet. – Two extension sections are required
- **TAE-288-60** Extension, which is 5 feet long with coupling hardware. The coupling overlaps the previous section by 6 inches, which provides an effective extension length of 4-1/2 feet. – (One extension may be required.)
- **TAB-288 NC** Pile Cap that fits over the 2-7/8” diameter tubular shaft and has a 3/4” x 8” x 8” bearing plate.

The total length of the assembled products from the list is actually 24-1/2 feet long. The Torque Anchors™ shall be installed to minimum depth of 21-1/2 feet at the locations designated on the plan and must develop a sufficient compressive strength as determined by the minimum average installation torque of 7,100 ft-lb at this specified target depth or lower.

**End Design Example 1**
Design Example 1A – Heavy Weight New Construction – “Quick and Rough” Method

Design Details:
- Compressive Service Load = 30,000 lbs at each pile. (See Figure 7 above.)
- The soil information about the site indicated 6 feet of stiff sandy clay fill (CL) followed by 30 feet medium dense sand (SP)

ECP Torque Anchor™ Design:  The soil data provides only a rough description of the soil on the site with no SPT, “N”, values or any indication of water table. The quick estimating method for designing the compression piles to support the structure is used. The thorough analysis for this project using the bearing capacity equations was demonstrated in Design Example 1 above. Comparison between the results of the two methods will be discussed.

1. Determine the Soil Class. Referring to the Soil Classification Table (Chapter 1 - Table 9) a Soil Class between 4 and 5 is selected based upon the description of the soil.

2. Ultimate Helical Pile Capacity. The engineer provided the Service Load (or working load) on this project based upon his knowledge of the calculated structural loading. Because the pile must have the capability to support more than just the service capacity, a Factor of Safety must be added to the Service Load to obtain the Ultimate Capacity of the pile design. In this case, a factor of safety of 2.0 is used to arrive at 60,000 pounds per pile ultimate capacity.

3. Select the proper compression pile from the estimated capacity graphs. Referring to Graph 4 from Chapter 1 (reproduced below), notice that the capacity line for a Torque Anchor™ with 10”, 12” and 14” diameter helical plates attached crosses between Soil Class 4 & 5 at 60,000 pounds. The 10”, 12” and 14” diameter plate configuration is selected for the design.

4. Check the Shaft Strength and Torsional Strength to see which shaft is suitable. Refer to Table 2 in Chapter 1 and select the 2-7/8 inch diameter tubular shaft that has sufficient capacity to support the load, and has sufficient torsional shaft strength for installation. The required ultimate capacity for each pile is 60,000 lbs. The 2-7/8 inch tubular product, with 0.262 inch wall thickness, has an Axial Compressive Load Limit rating of 100,000 pounds and a Practical Load Limit based on Torsional Strength of 80,000 pounds assuming a Useable Torsional Strength of 9,500 ft-lbs. The 2-7/8 inch diameter, 0.262 inch wall helical pile provides suitable torsional capacity and a sufficient practical load limit to exceed the ultimate load requirement of 60,000 pounds. The choice is verified.
5. **Installation Torque.**
Use Graph 6 from Chapter 2 or Equation 2 from Chapter 1 to determine the installation torque requirement for these piles.

Find a capacity of 60,000 pounds on the left side of Graph 6 and move horizontally to where the graph line for 2-7/8 inch diameter shafts intersects with 60,000 pounds. Read down to determine that the motor torque requirement is 7,000 ft-lb.

\[ T = 7,000 \text{ ft-lb, min.} \]

Calculation from Equation 2 shows a comparison of results between the formula and the graph.

**Equation 2:** \[ T = \frac{P_o}{k} \]
Where,
\[ P_o = 60,000 \text{ lb} \quad k = 8.5 \text{ (Table 12)} \]
\[ T = 60,000 \text{ lb} / 8.5 \text{ ft}^2 = 7,059 \text{ ft-lb} \]
\[ T = 7,100 \text{ ft-lb} \] (Not a significant difference)

6. **Minimum Embedment Depth.** The minimum depth requirement from the surface to the shallowest plate on the pile must be at least six times the diameter of the 14” dia. top helical plate. (Chapter 1, Page 16)
\[ D = 6 \times (14 \text{ in} / 12 \text{ in/ft}) = 7 \text{ feet} \]
\[ D = \text{Minimum Vertical Depth} = 7 \text{ feet.} \]

7. **Minimum Required Shaft Length.** Helical plates are spaced at three times the diameter of the next lower plate. The selected configuration was 10-12-14. The additional shaft length from the plate closest to the surface to the pile tip must be determined and added to minimum vertical depth just determined.

\[ L = 7' + L_{tip} \] (Length from 10” to the 12” plates) + (Length from 12” to the 14” plate)
\[ L = 7' + (3 \times 10" \text{ Dia})/12" + (3 \times 12" \text{ Dia})/12" \]
\[ L = 7' + 2.5' + 3' = 12-1/2 \text{ ft} + 1 \text{ ft above grade} \]
provides the minimum shaft length

**Minimum Shaft Length = 13-1/2 ft**

The least amount of shaft needed for this project would be a 7 foot lead section plus a 7 foot extension (with a coupled length of 6-1/2 feet) provides 13-1/2 feet total.

8. **Torque Anchor™ Specifications.** The minimum pile assembly shall consist of:

- **TAF-288-84 10-12-14** – 2-7/8” diameter tubular shaft with 0.262” wall thickness that has a 10”, a 12” and a 14” diameter plate on the 7’-0” long shaft,
- **TAE-288-84** extension – 7’ extension & hardware. (Additional extensions will likely be needed to reach required shaft torsion.)

**End of Example 1A**

**Review of Results of Example 1 & 1A**

One can see that the result obtained by the “Quick and Rough” analysis clearly suggested a larger pile than predicted the calculations. The “Quick and Rough” system was designed to be conservative and this example demonstrates this. It is likely that the pile design of Example 1A will reach the required shaft torque at more shallow depth than the 8-10-12 pile. The pile must terminate at least 12-1/2 feet below grade to accurately predict capacity. Termination at this shallow depth may not be acceptable to the engineer because the water table located at 14 feet below grade. (Not mentioned in the soil data in this example.) This type of problem can appear when using incomplete soil data and **Torque Anchor™ Capacity Graphs** to obtain a “Quick and Rough” design.
Design Example 1B – Heavy Weight New Construction – Weak Soil

In this variation, the same construction load and soil conditions prevail as stated in Design Example 1 with the exception that five feet of very weak soil now exists directly below the surface.

Additional Design Details:
- The soil data revealed a least five feet of very loose sand fill and very soft clay organic soil near the surface.
- Standard Penetration Test values for this weak layer were, “N” = 1 to 3 blows per foot - Soil Class = 8
- Below 5 feet the soil profile is the same as shown in Design Example 1.

ECP Torque Anchor™ Design: The soil data here suggests that below the initial five feet of very weak soil, the soil profile is similar to the soil in Design Example 1. Referring to Example 1, it can be recalled that the pile configuration required supporting the 60,000 pound ultimate load on pile using an 8-10-12 inch diameter plate configuration. The 2-7/8 inch diameter tubular shaft, with 0.262 inch wall thickness, had a sufficient Axial Compressive Load Limit to support the design load and sufficient Useable Torsional Strength to install the pile under the soil conditions represented in Design Example 1.

Knowing that there exists a layer of extremely weak (Class 8) soil near the surface on this site is important information because helical piles have slender shafts and require sufficient lateral soil support against the shaft to prevent shaft buckling under full load.

1. Determine the Buckling Strength. Table 2 in Chapter 1 lists the Axial Compression Load Limits for helical pile shafts when the shafts are installed into soil that provides sufficient lateral support along the pile shaft. Testing has suggested that shaft buckling is not an issue when the soil has a SPT value, “N” ≥ 5 blows per foot for solid square shafts and “N” ≥ 4 blows per foot for tubular shafts. In this design example there exists a five foot layer of very weak Class 8 soil consisting of loose sand and soft organic clay located just under the surface. These very weak soils overlay inorganic clay that is able to support the required load where the soil will provide sufficient lateral shaft support. However, an Axial Compressive Load Limit of 100,000 pounds shown in Table 2 for a 2-7/8 inch diameter with 0.262 inch wall tubular shaft is not valid when this shaft passes through the Class 8 soil with SPT values reported to be between 1 and 3 blows per foot.

Instead of using Table 2 from Chapter 1 for the compressive load limit on the shaft, one must understand that the upper layer of soil is not able to provide sufficient lateral support to the shaft to prevent bucking. Table 15 in Chapter 1 Conservative Critical Buckling Load Estimates (reproduced below) demonstrates this quite clearly for various soil strengths and types. Referring to Table 15, it can be seen that the estimated buckling strength for the 2-7/8 inch diameter, 0.262 inch wall helical Torque Anchor™ shaft when it passes through soil consisting of very loose sand fill and soft organic clay having SPT values that range from “N” = 1 to 3 blows per foot is only 48,000 pounds.

This soil is not capable of lateral shaft support for 60,000 pound ultimate compressive load without concern for the shaft buckling within the weak upper level soils.

<table>
<thead>
<tr>
<th>Table 15 Conservative Critical Buckling Load Estimates</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Shaft Size</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>1-1/2&quot; Sq</td>
</tr>
<tr>
<td>1-3/4&quot; Sq.</td>
</tr>
<tr>
<td>2-1/4&quot; Sq.</td>
</tr>
<tr>
<td>2-7/8&quot; Dia x 0.203&quot;</td>
</tr>
<tr>
<td>2-7/8&quot; Dia x 0.262&quot;</td>
</tr>
<tr>
<td>3-1/2&quot; Dia x 0.300&quot;</td>
</tr>
<tr>
<td>4-1/2&quot; Dia x 0.337&quot;</td>
</tr>
</tbody>
</table>

2. Select a Pile Shaft with Suitable Buckling Strength. The axial ultimate compressive capacity requirement for this project is 60,000
pounds on pile shaft. The selected shaft from Design Example 1 must be changed to a stiffer shaft to be able to successfully pass through the very week upper soil strata without buckling. A larger diameter tubular shaft is able to offer more shaft stiffness called Moment of Inertia or resistance to buckling. Referring once again to Table 15 (above); notice the row labeled “3-1/2 inch dia. x 0.300” shows a conservative estimated buckling load capacity of 78,000 pounds for the larger diameter shaft. Because there exists very weak soil near the surface in this example, the pile shaft diameter must be increased to provide resistance to shaft buckling when the fully loaded pile passes through these weak soils.

3. Torque Anchor™ Specifications. The Torque Anchor™ plate configuration remains as originally determined in Design Example 1 to support the structural load, but the shaft diameter must be increased to the 3-1/2 inch diameter, 0.300 inch wall tubular shaft for increased buckling strength:
- TAF-350-84 08-10-12 Lead Section
- TAE-350-84 Extension Section (2 required)
- TAB-350-60 Extension Section
- TAB-350 NC Pile Cap that fits over the 3-1/2” tubular shaft and has a 3/4” x 8” x 8” bearing plate.

4. Installation Torque. The larger diameter tubular shaft now required passes through the soil less efficiently. This soil friction effect was fully discussed at the beginning of Chapter 2. As a result, when the design requires a change in shaft size, the installation torque requirement must be recalculated and will be higher for larger diameter shafts. A check of Table 12 in Chapter 1 shows that the 3-1/2 inch diameter shaft has a recommended efficiency factor, “k” = 7-1/2 as compared to “k” = 8-1/2 that was used to estimate installation shaft torsion requirement for the 2-7/8 inch diameter tubular shaft. Use Equation 4 introduced in Chapter 1 and repeated in Chapter 2 to calculate the new installation torque requirement for the larger diameter pile shaft.

\[ T = \frac{P_n}{k} \]

Where,
- \( P_n = 60,000 \text{ lb} \)
- \( k = 7.5 \) (Table 12 – Chapter 1 & 2)

\[ T = 60,000 \text{ lb} / 7.5 \text{ ft}^1 = 8,000 \text{ ft-lb} \]

\[ T = 8,000 \text{ ft-lb, minimum} \]

Earth Contact Products recommend that a Registered Professional Engineer conduct the evaluation and design of Helical Torque Anchors™ where shaft buckling may occur due to the shaft being installed through weak soil or in cases where the shaft is fully exposed without lateral shaft support.

End of Example 1B

Review of Results of Example 1 & 1B

It is very important to remember that buckling is an issue when a pile shaft passes through weak soils anywhere along the length of the shaft. The key numbers to remember here when looking at soil data are the Standard Penetration Test, “N”, values throughout the depth of the borings. Watch for soil strata that are weaker than “N” < 4 blows per foot for solid square shaft installations and “N” < 5 blows per foot for tubular shafts. When such weak soils may be encountered, a check of the buckling strength of the selected shaft diameter is necessary.

Whenever the shaft must extend above ground in the air or in water without any later support at all, On the last page of Chapter 1, Graph 8 is provided to give ultimate load estimates for various shaft configurations relative to the length of exposed and unsupported column height.
Design Example 2 – Light Weight New Construction – Cohesive Soil

Structural Details:
- New building – single story brick veneer house on monolithic concrete slab on grade
- The estimated weight is 1,269 lb/lineal ft on the 18” tall steel reinforced perimeter beam
- The client wants Torque Anchors™ on the perimeter of the structure because of lot fill.
- Top of shaft to be one foot below soil surface
- Soil data:
  4 feet of poorly compacted fill – “N” = 5
  6 feet of silty clay (CH) – “N” = 5 to 7
  15 feet of very stiff clay (CL) –
  “N”= 25 to 30 blows per foot.

Torque Anchor™ Design:
1. Select suitable pile spacing and working load from the description of the foundation beam.
   Use Equation 3 from Chapter 1 to determine the working load on the helical pile. From Graph 2 - Chapter 6, for an 18” beam choose “X” = 7 ft.

Equation 3: \( P_0 = (\text{"X"}) \times (w) \times (\text{FS}) \)

Where,
- \( P_0 \) = Ultimate Capacity of Torque Anchor™ (lb)
- \( w \) = Foundation Load (lb/ft) = 1,269 lb/lineal foot
- \( \text{FS} = 2.0 \)
- \( \text{"X"} \) = Product Spacing = 7 ft

\( P_0 = 1,269 \text{ lb/ft} \times 7 \text{ ft} \times 2.0 \)
\( P_0 = 17,766 \text{ lb} \) (Use 18,000 lb.)

\( P_0 = 18,000 \text{ lb} \)

2. Select the proper ultimate capacity equation and collect the known information. Because the soil on the site is cohesive (clay), Equation 1a from Chapter 1 is used:

Equation 1a: \( \Sigma A_H = P_0 / (9c) \) Where:
- \( P_0 = 18,000 \text{ lb} \)
- \( c = 3,400 \text{ lb/ft}^2 \) (Table 5 – Assume “N” = 27 bpf)

\( \Sigma A_H = P_0 / (9 \times 3,400) \)
\( \Sigma A_H = 18,000 \text{ lb} / 30,600 \text{ lb/ft}^2 \)
\( \Sigma A_H = 0.59 \text{ ft}^2 \)

3. Select the ECP Helical Torque Anchor™ suitable to support the load. The requirement states an ultimate compressive capacity of 18,000 lb. Referring to Table 2 in Chapter 1 the 1-1/2” solid square pile shaft is an economical choice because it has an Axial Compressive Load Limit rating of 70,000 pounds and a Useable Torsional Strength of 7,000 ft-lbs.

Referring to Table 10 – Chapter 1, select a combination of plates from the row opposite the 1-1/2” square shaft size. At least 0.59 ft² of bearing area is required:
- 6” Dia. = 0.181 ft²
- 8” Dia. = 0.333 ft²
- 10” Dia. = 0.530 ft²
- 12” Dia. = 0.770 ft²

The combination of 8 inch diameter plates on the 1-1/2” solid square shaft is selected.
\( \Sigma A_H = 0.333 + 0.333 = 0.67 \text{ ft}^2 > 0.59 \text{ ft}^2 \) - O.K.
This plate combination provides a total area of 0.67 ft², which exceeds the required 0.59 ft². As an alternate, a single 12” diameter plate could be selected with a projected area of 0.77 ft².

The product designation for the standard length Torque Anchor™ product is selected from the standard product listing on Page 5:

**TAF-150-60 08-08**

4. **Installation Torque**: Equation 2 in Chapter 1 gives an estimation of the required installation shaft torsion. It is determined as follows:

**Equation 2**: \( T = \frac{P_u}{k} \)

Where,

\[ P_u = 18,000 \text{ lb} \]
\[ k = 10 \text{ (Table 12)} \]
\[ T = 18,000 \text{ lb} / 10 \text{ ft}^1 \]
\[ T = 1,800 \text{ ft-lb} \]

5. **Torque Anchor™ Capacity Verification**: A review of Table 2 in Chapter 1 indicates that the 1-1/2” solid square bar Torque Anchor™ has a **Useable Torsional Strength** of 7,000 ft-lb, which is nearly four times the required installation torque. There was no mention of rocks, debris or other obstructions in the project information. This is excellent product for this project. Table 9 in Chapter 1 shows the **Ultimate Mechanical Helical Plate Capacity** of 80,000 pounds (40,000 lb x 2) for the two 3/8” thick helical plates. The mechanical capacity of the selected pile configuration is more than adequate.

6. **Installed Product Length**: The stiff silty clay has been targeted as the soil where the helical plates will be founded. A depth of 18 feet is selected to set the plates below the weaker soils. This places the plates within the middle of the very stiff clay stratum. The installed length required to accomplish this design depth is:

- The depth from the surface to bearing = 18 ft.
- The pile cap is specified at one foot below grade level = 18 ft – 1 ft = **17 feet**

The distance to midway between the twin 8 inch plates is 1 ft. (8” x 3D₃ = 24 in/2 = 12 inches)

The minimum shaft length requirement is:

\[ L = 17 \text{ ft} + 1 \text{ ft} = 18 \text{ ft} \]

7. **Torque Anchor™ Specifications**: The Torque Anchor™ assembly is specified from the standard products listed near the beginning of Chapter 1:

- **TAF-150-60 08-08**, which is a 1-1/2” solid square bar product on a standard 5 foot long shaft, with twin 8 inch diameter 3/8” thick plates
- **TAE-150-84** Extension, which is 7 feet long, but the coupling overlaps 3 inches providing an effective length of 6’-9”. The extension includes coupling hardware. Two extensions are required.
- **TAB-150 NC** Pile Cap that fits over the 1-1/2” square bar and has a 1/2” x 6” x 6” bearing plate.

The total length of the assembled products from above is exactly 18-1/2 feet long. Placements shall be 7 feet on center along the perimeter grade beam and must develop an average installation torque of 1,800 ft-lb or more at the target depth of 18 feet. It is recommended that additional extension be on hand in case the shaft torque requirement is not achieved at 18 feet.

**End Design Example 2**

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**Technical Design Assistance**

Earth Contact Products, LLC. has a knowledgeable staff that stands ready to help you with understanding how to prepare preliminary designs, installation procedures, load testing, and documentation of each placement when using ECP Torque Anchors™. If you have questions or require engineering assistance in evaluating, designing, and/or specifying Earth Contact Products, please call us at 913 393-0007, Fax at 913 393-0008.
Design Example 2A – Light Weight New Construction – “Quick and Rough” Method

Design Details from Design Example 2:
- The ultimate capacity on each pile spaced at 7 feet on center is 18,000 pounds
- Top of shaft to be one foot below soil surface
- Soil data:
  4 feet of poorly compacted fill followed by 6 feet of silty clay (CH) over 15 feet of very stiff clay (CL)

ECP Torque Anchor™ Design: Because this is a compressive load application and there is some poorly compacted fill exists the selection of Soil Class must be conservative.

1. Determine the Soil Class.
Referring to the Soil Classification Table (Table 9 – Chapter 1) and noticing that the clay on the site is very stiff, Soil Class 4 is selected. The poorly compacted fill should not be a problem at this light loading as long as the helical plates are founded into the underlying very stiff clay.

2. Select the proper compression pile configuration from the estimated capacity graphs. Referring to Graph 3 from Chapter 1 (reproduced right), notice that the capacity line for an anchor with two 8” diameter helical plates attached crosses the midpoint of Soil Class 4 at 22,000 lb. The 8” – 8” diameter plate configuration is selected for the design.

3. Check the Shaft Strength and Torsional Strength to see which shaft is suitable. Refer to Table 2 in Chapter 1 to find a shaft with a suitable Axial Compression Load Limit and sufficient Useable Torsional Strength. The 1-1/2 inch solid square shaft has an Axial Compression Load Limit rating of 70,000 pounds based upon an installation torsional limit of 7,000 ft-lbs. The selected pile shaft provides suitable Useable Torsional Strength and a sufficient practical load limit to exceed the ultimate job load requirement of 18,000 pounds. Table 9 in Chapter 1 shows the Ultimate Mechanical Helical Plate Capacity of 80,000 pounds (40,000 lb x 2) for the two 3/8” thick helical plates. The selected and verified pile configuration is TAF-150-60 08-08 and is smaller than recommended from the earlier calculations in Design Example 2.

4. Installation Torque. Use Graph 6 from Chapter 2, please see Graph 6 on next page (or Equation 2 from Chapter 1) to determine the installation torque requirement for these piles. The ultimate capacity requirement is 18,000 pounds. Find this value on the left side of Graph 6 and find the intersection of 18,000 pounds with the graph line for solid square shafts. Then read down to determine the motor torque requirement of 1,800 ft-lb.

\[ T = 1,800 \text{ ft-lb, minimum} \]

Calculating the installation torque from Equation 2: (shown here for comparison)

**Equation 3:** \[ T = \frac{P_a}{k}, \text{ Where,} \]

\[ P_a = 18,000 \text{ lb} \quad k = 10 \text{ (Table 12)} \]

\[ T = 18,000 \text{ lb} / 10 \text{ ft}^3 = 1,800 \text{ ft-lb} \]

\[ T = 1,800 \text{ ft-lb, minimum – O.K.} \]
5. Minimum Embedment Depth. In Chapter 1, Page 16 of this manual, there is a discussion about helical products being deep foundation elements. The formulas presented herein are based upon “deep foundation theory”. For the results of the calculations, tables and graphs to be accurate, there must be sufficient soil burden over the anchor or pile. Deep foundation theory dictates that the minimum depth from the surface to the shallowest plate must exceed six times the largest diameter.

Minimum Embedment Depth:

\[ D = 6 \times d_{\text{largest plate}} = 6 \times (8 \text{ in}/12 \text{ in}) = 4 \text{ ft} \]

*Notice: The soil information provided on this project stated at least 10 feet of soft soil existed below the surface before reaching stiff to very stiff clay. The “Minimum Vertical Depth” for this design is invalid and the pile must be installed deeper than ten feet.

\[ D = \text{Minimum Vertical Depth} > 10 \text{ feet} \]

6. Minimum Required Shaft Length. The shaft length between the two 8” plates must be determined and added to the 10 foot, minimum vertical depth. In addition, the engineer stated that the termination point for the pile caps shall be one foot below grade.

\[ L = 10' - 1' + (3D_e)/2 = 10 \text{ ft} \]

\[ L = 10 \text{ ft} \]

The least amount of shaft required to exceed the minimum depth is a 5 foot lead and a 7 foot extension.

*Because the soil profile is known to be weak near the surface, a 10 foot long extension should be considered because it offers a depth of 15-3/4 feet (14-3/4 feet of shaft plus 1 ft depth to the pile cap. Additional extensions could be required if the torsion requirement of 1,800 ft-lb is not achieved between 10 ft and 15-3/4 ft depth.

7. Torque Anchor™ Selection:

- **TAF-150-60 08-08** – 1-1/2 inch solid square shaft that has two 8” diameter plate on the 5’-0” long shaft.
- **TAE-150/120** extension – 10’ extension section of hardware, (9’-9” effective length). It is recommended to have additional extensions on hand should the target shaft torsion not be achieved at 15-3/4 feet below grade.
- **TAB-150 NC Pile Cap** that fits over the 1-1/2” square bar and has a 1/2” x 6” x 6” bearing plate.

**End of Example 2A**

Review of Results of Example 2 & 2A

One can see that the result obtained by the “Quick and Rough” analysis clearly suggested the same pile design as determined by the calculated analysis. Therefore the TAF-150 08-08 is a valid design and should work well on this project. Recall that the calculated analysis used 18 feet dept to bearing.

* Example 2A, “Quick and Rough” method is not able to compensate for the fill soil near the surface. Recall that the graphs are based upon capacities of helical piles installed into *homogeneous soil*, which means that the soil is consistent at all depths. Clearly this is not the case in this example because of the fill soil. A pile installation deeper than 15-3/4 feet might be required to support the load.
Design Example 3 – Basement Wall Tieback Anchor -- Cohesive Soil

Structural Details:
- Cast concrete basement wall is 8 feet tall and 10 inches thick.
- Unknown soil backfill against the wall is 7 feet high.
- The only soil information about the site is that there exists inorganic clay (CL), stiff to very stiff – 115 pcf

**Torque Anchor™ Design:** Because there is so little information about the soil on this project, the designer will have to make judgments about the conditions on the site.

1. **Estimate the lateral soil force against the wall.** Equation 5 presented in Chapter 1 is selected because hydrostatic pressure must be assumed as part of the reason for the damage to the wall.
   \[ P_H = 45 \times (H^2) \]
   Where, \( H = 7 \) ft  
   \[ P_H = 45 \times 49 = 2,205 \]
   \( P_H = 2,205 \text{ lb/lineal foot} \)

2. **Ultimate Tieback Capacity.** Choose a Torque Anchor™ spacing of 5 ft on center as typical for a damaged basement wall of unknown construction. Use Equation 8 from Chapter 1 to determine the Ultimate Capacity on the Torque Anchor™.

   **Equation 8:**  \( T_u = (P_H) \times ("X") \times FS \), Where:  
   \( T_u = \text{Ultimate Tieback Capacity} \) \(
   P_H = \text{Horizontal Soil Force on Wall} \) \(
   \text{lb/lin.ft} \)
   \( FS = \text{Factor of Safety} \) (Typically 2:1 permanent support and 1.5:1 for temporary support)  
   “X” = Center to Center Spacing of Tiebacks - ft

   In this example, the ultimate capacity becomes:
   \[ T_u = 2,205 \text{ lb} \times 5 \text{ ft} \times 2 \]
   \[ T_u = 22,050 \text{ lb} \]

3. **Select the proper bearing capacity equation and collect the known information.**

   Because the soil on the site is cohesive, Equation 1a – Chapter 1 is used:

   **Equation 1a:**  \( \Sigma A_H = T_u / (9c) \), Where:
   \( T_u = 22,050 \text{ lb} \)
   \( c = 2,000 \text{ lb/ft}^2 \)

   (Table 5 - Chapter 1 – Stiff to Very Stiff Clay)

   \[ \Sigma A_H = 22,050 \text{ lb} / 18,000 \text{ lb/ft}^2 \]
   \[ \Sigma A_H = T_u / (9 \times 2000 \text{ lb/ft}^2) \]
   \[ \Sigma A_H = 1.23 \text{ ft}^2 \]

4. **Select the ECP Helical Torque Anchor™ configuration suitable to support the load.**

   Referring to Table 2 – Chapter 1 choose the 1-1/2” solid square pile shaft. An ultimate tensile strength for this job is 22,050 lb and the 1-1/2 inch solid square shaft an **Ultimate Limit Tension Strength** rating of 70,000 pounds and a **Useable Torsional Strength** of 7,000 ft-lbs.

   Referring to Table 10 – Chapter 1 (reproduced on next page), a combination of plates is selected from the projected plate areas in the row opposite the 1-1/2” solid square shaft size. At least 1.23 ft² of bearing area is needed:

   \[ 6" \text{ Dia.} = 0.181 \text{ ft}^2 \quad 8" \text{ Dia.} = 0.333 \text{ ft}^2 \]
   \[ 10" \text{ Dia.} = 0.530 \text{ ft}^2 \quad 12" \text{ Dia.} = 0.770 \text{ ft}^2 \]
   \[ 14" \text{ Dia.} = 1.053 \text{ ft}^2 \]

   \[ \Sigma A = 0.530 + 0.770 = 1.30 \text{ ft}^2 \]

   The combination of 10” and 12” diameter plates on the 1-1/2” solid square shaft provides a total area of 1.30 ft², which exceeds our requirement of 1.23 ft².
Table 10. Projected Areas of Helical Torque Anchor Plates

<table>
<thead>
<tr>
<th>Helical Plate</th>
<th>6&quot; Dia.</th>
<th>8&quot; Dia.</th>
<th>10&quot; Dia.</th>
<th>12&quot; Dia.</th>
<th>14&quot; Dia.</th>
<th>16&quot; Dia.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shaft</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-1/2&quot; Sq.</td>
<td>0.181</td>
<td>0.333</td>
<td>0.530</td>
<td>0.770</td>
<td>1.053</td>
<td>1.381</td>
</tr>
<tr>
<td>1-3/4&quot; Sq.</td>
<td>0.175</td>
<td>0.326</td>
<td>0.524</td>
<td>0.764</td>
<td>1.048</td>
<td>1.375</td>
</tr>
<tr>
<td>2-1/4&quot; Sq.</td>
<td>0.161</td>
<td>0.314</td>
<td>0.510</td>
<td>0.750</td>
<td>1.034</td>
<td>1.361</td>
</tr>
<tr>
<td>2-7/8&quot; Dia</td>
<td>0.151</td>
<td>0.304</td>
<td>0.500</td>
<td>0.740</td>
<td>1.024</td>
<td>1.351</td>
</tr>
<tr>
<td>3-1/2&quot; Dia</td>
<td>0.130</td>
<td>0.282</td>
<td>0.478</td>
<td>0.719</td>
<td>1.002</td>
<td>1.329</td>
</tr>
<tr>
<td>4-1/2&quot; Dia</td>
<td>0.086</td>
<td>0.239</td>
<td>0.435</td>
<td>0.675</td>
<td>0.959</td>
<td>1.286</td>
</tr>
</tbody>
</table>

* Projected area is the face area of the helical plate less the cross sectional area of the shaft.

The Torque Anchor™ tieback product designation TAF-150-60 10-12 is selected from the Standard Product Tables near the beginning of Chapter 1. This anchor configuration will provide the 22,050 pound ultimate capacity required for tension support when spaced at 5 feet center to center along the wall.

5. Installation Torque. Use Equation 2 from Chapter 1, or use Graph 6 from Chapter 2 shown in the example above to calculate the installation torque requirement for this anchor.

Equation 2: \( T = T_u / k \), Where,
\[
T_u = 22,050 \text{ lb}
\]
\[
k = 10 \text{ (Table 12, below from Chapters 1 & 2)}
\]
\[
T = 2,200 \text{ ft-lb}
\]

The torque must be developed for a long enough distance to insure that the helical plates are properly embedded to develop the required tension capacity. The torque requirement must be averaged over a distance of at least three times the diameter of the largest plate. The 2,200 ft-lbs must be continuous for a minimum distance of 3 feet (12" diameter plate x 3 dia.) before terminating the installation.

6. Minimum Horizontal Embedment: Determine the Minimum Embedment Length from Equation 9 in Chapter 1. (Also see Figure 3 – Chapter 1, which is reproduced on next page for reference.)

\[
L_0 = H + (10 \times d_{\text{largest}})
\]

\[
H = \text{Height of Soil} \ (7 \text{ ft})
\]
\[
d_{\text{largest}} = \text{Largest Plate Dia.} \ (12 \text{ in} = 1 \text{ ft})
\]

\[
L_0 = 7 \text{ ft} + (10 \times 1 \text{ ft})
\]

\[
L_0 = 17 \text{ ft}
\]

Minimum Horizontal Embedment = 17 feet

7. Calculate the Critical Depth:
Use 6 \( d_{\text{largest plate}} \). (Discussed Page 31)

\[
6 \times 1 \text{ (ft)} = 6 \text{ feet} \ (\text{See Figure 3, below.})
\]

Critical Depth = 6 feet.

8. Select Installation Angle and Determine Product Length. Position the anchors to penetrate the wall at two feet below the soil surface. (Note: This is three feet from top of basement wall.) From Step 7 it was determined that the Critical Depth, “D”, of 6 feet is required, which means that the 12" diameter plate must terminate at least 4 feet lower than where the anchor shaft penetrated the wall. Select an installation angle of 15° and determine the minimum installed product length that will provide the additional 4 feet of soil depth required at the 12” plate to achieve critical depth.

This can be determined as follows:

\[
L_{15 \text{ deg}} = (4 \text{ ft} / \sin 15^\circ)
\]

\[
L_{15 \text{ deg}} = 4 \text{ ft} / 0.259 = 15-1/2 \text{ ft}
\]

The minimum distance from the wall to the 12” plate when installed at a 15° downward angle is 15-1/2 feet to insure meeting the critical depth requirement of 6 feet. Comparing the minimum horizontal embedment length of 17 feet from Step 6 to the 15-1/2 foot length required for obtaining Critical Depth at 15° installation angle; it is clear that 17 feet of horizontal length of embedment from the wall is the controlling distance. The additional length of shaft required to get to the 10 inch diameter plate to the required distance of 17 feet at a shaft installation angle of 15° downward must be calculated.

Table 12. Soil Efficiency Factor “k”

<table>
<thead>
<tr>
<th>Torque Anchor Type</th>
<th>Typically Encountered Range “k”</th>
<th>Suggested Average Value, “k”</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-1/2” Square Bar</td>
<td>9 - 11</td>
<td>10</td>
</tr>
<tr>
<td>1-3/4” Square Bar</td>
<td>9 - 11</td>
<td>10</td>
</tr>
<tr>
<td>2-1/4” Square Bar</td>
<td>10 - 12</td>
<td>11</td>
</tr>
<tr>
<td>2-7/8” Diameter</td>
<td>8 - 9</td>
<td>8-1/2</td>
</tr>
<tr>
<td>3-1/2” Diameter</td>
<td>7 - 8</td>
<td>7-1/2</td>
</tr>
<tr>
<td>4-1/2” Diameter</td>
<td>6 - 7</td>
<td>6-1/2</td>
</tr>
</tbody>
</table>

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Use the equation shown in Chapter 1 on Table 13 for a 15° downward angle.

\[ L_{15~\text{deg}} = [H + (10 \cdot d_{\text{largest}})] \times 1.035 \]
\[ L_{15~\text{deg}} = [7 \text{ ft} + (10 \times 1 \text{ ft})] \times 1.035 = 17.6 \text{ feet} \]

**Total Shaft Length Needed:**

\[ L_{\text{Total}} = L_{15} + L_{T_\text{ip}} \] (Where \( L_{T_\text{ip}} = 3D_{10'} \))
\[ L_{\text{Total}} = 17.6 \text{ ft} + (3 \times 10'')/12'' \]
\[ L_{\text{Total}} = 17.6 \text{ ft} + 2.5 \text{ ft} = 20.1 \text{ ft} \]

Use \( L_{\text{Total}} = 20 \text{ ft} \quad \alpha = 15° \)

Specify required product length by selecting standard product assembled lengths exceeding 20’ long.

8. **Torque Anchor™ Specifications.** The Torque Anchor™ assembly will consist of products selected from the Standard Product Selection near the beginning of Chapter 1.

- **TAF-150-60 10-12** - 1-1/2” solid square bar with a 10” and a 12” diameter plate attached to a standard 5’-0” long shaft length.
- **TAE-150-60** extension – 5’ extension bar & hardware are specified for ease of installation in the basement. (4’-9” effective length). Three extensions are required.

(Possibly four extensions could be needed for if insufficient shaft torsion is measured at 20 ft.)

- **TAT-150** – Light Duty Transition that connects from 1-1/2” square bar to a 22” length of continuous threaded rod, with hardware.
- **PA-SWP** – Stamped steel wall plate that measures 11” x 16”

The length of all of the Torque Anchor™ shafts plus the threaded bar that penetrates the wall is 19’-3” + 20” = 20’-11”. The anchors shall mount along the wall on 5 feet on center at 3 feet from the top of the basement wall. (Two feet below soil level) The anchors are angled down at 15°. The tieback must be installed to a minimum shaft length of 20 feet and must develop an average installation torque of 2,200 ft-lb or greater for a minimum distance of at least 3 feet after reaching 17 feet, otherwise the anchor must be driven deeper using additional extension sections until the torque requirement is satisfied.

End of Example 3
Design Example 3A – Basement Wall Tieback Anchor – “Quick and Rough Method”

**Mandatory Installation Requirements**
Before beginning a complicated basement tieback anchor design like Design Example 3A using the “Quick and Rough” method with only general information and data from graphs and tables; the following Mandatory Installation Requirements MUST ALWAYS BE DEFINED in the final design before the “Quick and Rough” method will be successful.

Before performing a “Quick and Rough Design” for a basement tieback system, the following items MUST be defined and included for a “Safe Use” design:

1. The anchor must penetrate the wall at least 3 and 5 feet from the floor of an 8 foot tall basement wall. (This is also valid for a 9 foot basement wall with no more than eight feet of soil overburden.
2. There must be at least two feet of soil above the penetration point for the tiebacks.
3. Ground water must be assumed present behind the wall.
4. Unless otherwise given, the working soil load on the wall shall be assumed to be 3,250 lb/lin ft. of wall. To obtain the load on each placement, multiply 3,250 lb/lineal ft by a Factor of Safety = 2 and by the spacing of the anchors on the wall (feet).
5. Unless otherwise given, the maximum spacing of tiebacks shall be no more than 5 feet on center with a downward angle 15°.
6. A minimum installed shaft length of 22 feet from the wall to the tip of the tieback assembly shall be used when the largest helical plate on the shaft is 12 inches diameter. If the largest plate diameter is 14 inches the minimum installed shaft length at a 15° downward is 25 feet.

**IMPORTANT:** If the tieback reaches maximum torque before obtaining the length requirement, the helical plate area MUST be reduced and the anchor MUST be installed to the minimum length stated above, or the possibility that the anchor will load the wall and fail exists.

If any of the conditions are encountered that are substantially different from what is normally encountered, an analysis and design shall be performed by a Registered Professional Engineer, or the engineer needs to review and approve your design.

**Structural Details:** The only data available:
- Cast concrete basement wall is 8 feet tall and 10 inches thick.
- Backfill against the wall is 7 feet - Unknown soil
- The only soil information given: There exists inorganic clay (CL), stiff to very stiff – 115pcf in the area

1. **Determine the Soil Class.** Referring to the Soil Classification Table (Chapter 1 - Table 9) the soil class of 4 - 5 is selected based upon the soil description being “stiff to very stiff clay”. 
2. **Ultimate Helical Pile Capacity.** In this design the largest spacing allowed is selected – five feet on center. The Ultimate Design Load for the project is estimated at:
   \[ T_u = 3,250 \text{ lb/lin ft} \times 2 \times 5 \text{ ft} = T_u = 32,500 \text{ lb per anchor} \]

3. **Select the proper tieback anchor from the estimated capacity graphs.** Referring to Graph 3 from Chapter 1 (reproduced on next page), notice that the capacity line for an anchor with an 10” and 12” diameter helical plate suggests a capacity in excess of at 32,500 lb at Soil Class between 4 - 5. The 10”-12” diameter plate configuration is selected for the design.

4. **Check the Shaft Strength and Torsional Strength to see which shaft is suitable.** Refer to Table 2 to verify that the 1-1/2 inch solid square shaft has sufficient capacity to support the tensile load, and has sufficient torsional shaft strength for installation. The required ultimate capacity for each anchor is 32,500 lbs. (Step 2.) The 1-1/2 inch solid square shaft has an **Ultimate Limit Tension Strength** rating of 70,000 pounds and a **Useable Torsional Strength** of 7,000 ft-lbs. The selected helical pile provides suitable torsional capacity and a sufficient practical load limit to exceed the ultimate load requirement of 32,500 pounds. The choice is verified.

5. **Installation Torque.** Use Equation 2 from Chapter 1, (or Graph 6 demonstrated in Design...
Example 2A) to calculate the installation torque requirement for this pile.

**Equation 2:** \( T = \frac{P_a}{k} \), Where,
- \( P_a = 32,500 \text{ lb} \)
- \( k = 10 \) (See Table 12 in Design Example 3)
- \( T = 32,500 \text{ lb} / 10 \text{ ft}^{-1} = 3,250 \text{ ft-lb} \)
- \( T = 3,300 \text{ ft-lb}, \text{ minimum} \)

6. Torque Anchor™ Specifications.
- **TAF-150-84 10-12** – 1-1/2 inch round corner solid square shaft that has a 10 inch diameter and a 12” diameter plate attached to a 7’-0” long shaft.
- **TAE-150-60** extension – 5’-0 extension section & hardware. This extension has a coupled length of 4’-9”. The installation will need four extensions to exceed 22 feet total length.
- **TAT-150** – Light Duty Transition that connects from 1-1/2” square bar to a 20” length of continuous threaded rod, with hardware.
- **PA-SWP** – Stamped steel wall plate that measures 11” x 16”

The items shown below are from the list of Mandatory Installation Requirements at the beginning of this example. These requirements MUST always be included when designing “Quick and Rough” basement tieback projects.

7. Mandatory Installation Requirements:
- Anchors shall be installed at 3 to 6 feet from the floor of the standard 8 foot basement wall.
- Anchors shall have a minimum of two feet of soil cover from point of penetration of the wall to the ground surface.
- Anchors shall be installed with a declination of 15°.
- These anchors with 12” diameter largest helical plates shall be installed to a length not less than 22 feet.
- Anchors shall achieve installation shaft torsion of at least 3,300 ft-lb over the final three feet of installation prior to termination.

End of Example 3A

**Review of Results of Example 3 & 3B**

One can see that the result obtained by the “Quick and Rough” analysis suggested a similar anchor configuration as predicted by using the bearing capacity equation. Because this is a general use “Quick and Rough Design” there are design parameters put in place to cover most situations with an eight foot tall basement wall (or nine foot wall with no more than eight feet of soil overburden). In addition, many installation requirements MUST be followed to provide a safe design when a “Quick and Rough” design method is used. These installation requirements were explained in the Design Example 3B. If the job not typical, consult a Registered Professional Engineer.
Design Example 4 – Retaining Wall Tieback Anchor -- Cohesionless Soil

Structural Details:
- New construction steel reinforced cast concrete retaining wall = 12 ft tall
- Backfilled with granular fill at the wall with free flow drainage tiles at the footing
- The soil information about the site indicated medium to coarse gravelly sand (SP), Medium dense = 130pcf
- Standard Penetration Blow count “N” = 20 blows per foot at 10 feet deep
- $\Phi = 32^\circ$

1. Estimate the lateral soil force against the wall. Equation 6 in Chapter 1 is selected because the design specifies that the hydrostatic pressure is relieved by the drainage system.

**Equation 6:** $P_H = 24 x (H^3)$, Where, $H = 12$ ft.

$P_H = 24 x (12' x 12') = 3,456$ (Use 3,500)

$P_H = 3,500$ lb/lineal foot

2. Select a Torque Anchor™ and make an analysis to see if it is suitable. In this example the TAF-175-60 08-10-12 is tried, a 1-3/4” solid square bar product with an 8”, 10” and a 12” diameter helical plate attached. From the soil data available the soil is cohesionless; Equation 1b from Chapter 1 is used:

**Equation 1b:** $T_u = \Sigma A_H (q N_q)$

Where,

$A_8^r = 0.328$ ft$^2$ (From Table 10 – Chapter 1)

$A_{10}^r = 0.524$ ft$^2$ (See also pg 63 above.)

$A_{12}^r = 0.764$ ft$^2$

$\Sigma A_H = 0.328 + 0.524 + 0.764 = 1.62$ ft$^2$

$q = \gamma \times h_{mid}$

$h =$ Design Embedment = 10 ft. is selected

(This is the measurement from the ground surface to where the 12” diameter helical plate is located when the tieback is fully installed - See Figure 10, below.)

$\gamma =$ Soil density = 130 lb/ft$^3$

$N_q = 23$ (“N” = 20 & $\Phi = 33^\circ$) Table 7 Chapter 1

$T_u = 1.62$ ft$^2 x (130$ lb/ft$^2 x 10$ ft) x (23)

$T_u = 48,438$ lb

3. Torque Anchor™ Spacing. Determine the Torque Anchor™ spacing along the wall for the configuration selected. Use Equation 4 from Chapter 1.

**Equation 4:** “X” = $T_u / [P_H x (FS)]$. Where,

“X” = Product Spacing

$T_u =$ Ultimate Capacity on Torque Anchor™

$P_H =$ Lateral Force on Wall (lb/lin.ft)

$FS =$ Factor of Safety (Typically 2.0:1)

“X” = 48,438 lb/[3,500 lb/lin.ft x 2 (FS)] = 6.9’

4. Installation Torque & Embedment. Use Equation 3 – Chapter 1 to calculate the installation torque for this anchor.

**Equation 3:** $T = T_u / k$ Where,

$T_u = 48,438$ lb (Step 3)

$k = 10$ (Table 12 – Chapter 1)

$T = 48,438$ lb/10 ft$^{-1} = 4,844$ ft-lb.

$T = 4,900$ ft-lb
The torque must be developed for a distance great enough to insure that the helical plates are properly embedded to develop adequate tension capacity. The torque requirement must be averaged over a minimum distance of at least three times the diameter of the largest plate. The installer must average at least 4,900 ft-lbs through a distance of 3 feet. (Three times the 12” diameter plate.)

5. Select Installation Angle and Product Length. The anchors penetrate the wall at 3-1/2 feet below the soil surface. (This is approximately 0.3 times the wall height.) Recall that embedment depth was selected at 10 ft in Step 2. This means that the depth below the soil surface to the location of the 12” helical plate must be at least 10 feet. Try using an installation angle of 15° and determine the product length that will provide the 10 feet of vertical embedment required. (The required depth of embedment is 10 ft. Recall that the distance from the top of grade level to where the anchors will penetrate the wall is 3-1/2 feet. The additional depth required by the anchor is 6-1/2 feet (10 ft - 3-1/2 ft) = 6-1/2 feet.)

The shaft length required at 15° to achieve the 6-1/2 foot vertical depth is calculated using the equation given in Table 13 in Chapter 1 for a declination angle of 15°.

$$ L_{15} = (6-1/2 \text{ ft/sine 15}^\circ) = 6-1/2 \text{ ft/0.259} = 25 \text{ ft} $$

The minimum shaft length at 15° installation angle is 25 feet, which will insure that the 12” diameter plate is located at a total embedment depth of 10 feet below the surface.

Comparing the Minimum Horizontal Embedment length from Equation 9 to the Minimum Embedment Depth (Step 5):

$$ L_0 = 12 + [10 \times 1'] = 22 \text{ ft}. $$

It is clear that $L_{15} = 25$ ft (Length to insure required 10’ soil embedment depth determined in Step 5) exceeds the Minimum Horizontal Embedment requirement.

The 10 ft depth of embedment also exceeds the Critical Depth, “$D$” = 6 x d$_{12}$ = 6 x 12”/12 = 6 ft

$$ L_{15} = 25' > L_0 = 22' \text{ using } D = 6 $$

Use $L_{15} = 25$ ft

Minimum Required Shaft Length:

$$ L = L_{15} + L_{tip} \text{ (Distance shallowest plate to tip)} $$

Where:

$$ L_{tip} = (3 \times d_{plate1}) + (3 \times d_{plate2}) $$
$$ L_{tip} = [(3D \times 8’’ dia)+(3D \times 10’’ dia)]/12 $$
$$ L_{tip} = 4-1/2 \text{ ft} $$
$$ L = L_{15} + L_{tip} = 25 \text{ ft} + 4-1/2 \text{ ft} = 29-1/2 \text{ ft} $$
$$ L = 29-1/2 \text{ feet } \alpha = 15^\circ $$

6. Torque Anchor™ Capacity Verification: A review of Table 2 – Chapter 1 indicates that the 1-3/4” solid square bar Torque Anchor™ has a Ultimate Limit Tension Strength of 100,000 lb and a Useable Torsional Strength of 10,000 ft-lb. The project ultimate tension capacity and torsional requirement are approximately one-half of the mechanical and torsional capacity of the product. There was no mention about rocks, debris or other obstructions in the soil so installation should be smooth. A check of Table 11 – Chapter 1 indicates that three 3/8” thick helical plates have an ultimate capacity of 120,000 pounds (3 x 40,000 lb), so the total mechanical capacity of the anchor is satisfactory.

7. Torque Anchor™ Specifications. The required Torque Anchor™ assembly consists of:

- TAF-175-84 08-10-12 - 1-3/4” solid square bar, on a standard 7’ long shaft with 8”, 10” & 12” dia. plates,
- TAE-175-84 extensions - 7 feet long & hardware (6’-9” effective length) – Three extensions are required.
- TAE-175-60 extensions - 5’ long with hardware (4’-9” effective length) – One extension is required.
- TAB-175 T Tension Pile Cap – 3/4” x 8” x 8” pile cap with bolt and nut. The pile cap bolts to the anchor shaft and will be incorporated into the concrete new construction wall.

The actual assembled length of the specified Torque Anchor™ system is 32 ft.

The anchors shall mount along the wall at 7 feet center to center at a distance of 3-1/2 feet from the top of the proposed wall. The anchors shall be installed at a downward angle of 15° from horizontal. The tiebacks must be installed to a length greater than 29-1/2 feet and must develop an average installation torque of 4,900 ft-lb or more for a minimum distance of at least 3 feet beyond an installed length of 26 feet, otherwise the anchor shall be driven deeper until this torque requirement is satisfied.

End of Example 4
Design Example 5 – Foundation Restoration – Cohesive Soil

Structural Details:
- Two story wood frame house with wood composition siding.
- Foundation consists of 20” wide by 18” tall steel reinforced concrete perimeter beam with a 4” thick concrete slab cast with the perimeter beam.
- The corner of structure has settled 2”
- Top of pile will be 12” below the soil surface
- Soil data: There are two feet of consolidating, poorly compacted fill overlaying 20 feet of inorganic clay (CL), stiff.
- SPT “N” blow count was measured between 8 to 12 blows per foot increasing with depth

Torque Anchor™ Design:
1. Determine the foundation load: Breaking down weights of structural elements can be found in the Simplified Tables of Structural Foundation Loads in Tables 2 through 9 in Chapter 5, ECP Steel Piers™ Design, later in this manual. The foundation loads are estimated below:
   - Footing – 20” x 18” 360 lb/ft
   - Slab Floor, Carpet & Pad 195
   - Wood Frame Walls – 2 Story 176
   - 2nd Floor – 14’ Span, Carpet & Pad 98
   - Roof – 6’ in 12’ Composition, 14’ Span 171

   Total Dead Load 1,000 lb/ft
   - Live Load – Slab 120
   - Live Load – 2nd Floor, 14’ Span 180
   Total Live Load 300 lb/ft

   w = Distributed Load = 1,000 + 300 = 1,300 lb/ft
   w = 1,300 lb/lineal foot

2. Select a Suitable Pile Spacing and Determine Ultimate Torque Anchor™ Load: This is not a heavy structure, so for economy the solid square bar Torque Anchor™ configuration is chosen for this restoration along with Utility Brackets to transfer the structural load to the pile shaft. Using Graph 2 in Chapter 5, select pile spacing, “X”, at 7-1/2 feet on the perimeter beam. (Note arrow on graph.) Determine the working load on the piles from Equation 4 – Chapter 1.

   Equation 4. \( P_u = \text{“X” x w x (FS)} \)

   Where,
   - “X” = Product Spacing = 7-1/2 feet (Selected)
   - w = 1,300 lb/lineal foot (Step 1)

   3. Determine the helical plate area required from the known information: Because the soil on the site is cohesive, Equation 1a from Chapter 1 is used:

   \[ \Sigma A_u = \frac{P_u}{(9c)} \]  Where:

   \( P_u = 7-1/2 \text{ ft x 1,300 lb/ft x 2 = 19,500 lb} \)

   FS = Factor of Safety (Use 2.0)

   \( P_u = 19,500 \text{ lb} \) (Step 2)

   \( c = 1,250 \text{ lb/ft”} \) Average “N” = 10 (assumed)

   (Table 5 - Chapter 1)
\[ \sum A_H = P_u / (9 \times 1,250) = 19,500 \text{ lb} / 11,250 \text{ lb/ft}^2 \]
\[ \sum A_H = 1.73 \text{ ft}^2 \]

4. Select the ECP Helical Torque Anchor™ suitable to support the load.

Referring to Table 2 – Chapter 1 the 1-1/2” solid square pile shaft is selected. It has an Axial Compression Load Limit rating of 70,000 pounds and a Useable Torsional Strength of 7,000 ft-lbs.

Referring to Table 10 – Chapter 1, we will select our combination of plates from the list opposite the 1-1/2” shaft size. We must provide at least 1.67 ft² of bearing area:

- 6” Dia. = 0.181 ft²
- 8” Dia. = 0.333 ft²
- 10” Dia. = 0.530 ft²
- 12” Dia. = 0.770 ft²
- 14” Dia. = 1.053 ft²

The combination of 12” & 14” diameter plates on the 1-1/2” solid square shaft provides a total area of 1.82 ft².

TAF-150-60 12-14

5. Installation Torque. Use Equation 2 – Chapter 1 to calculate the installation torque for this anchor.

\[ T = T_u / k \]
Where,

\[ T_u = 19,500 \text{ lb} \] (Step 2)
\[ k = 10 \] (Table 12 – Chapter 1)

\[ T = 19,500 \text{ lb} / 10 \text{ ft} \]
\[ T = 1,950 \text{ ft-lb} – \text{ Use } 2,000 \text{ ft-lb} \]

6. Torque Anchor™ Capacity Verification: A review of Table 2 – Chapter 1 indicates that the 1-1/2” solid square bar Torque Anchor™ has a Useable Torsional Strength of 7,000 ft-lb, which is more than adequate for this application. The product selection should work based upon the soil report stating that the firm to stiff clay becomes more dense as the depth increases. There was no mention of rocks, debris or other obstructions. Table 11 – Chapter 1 verifies that two 3/8” thick helical plates have a mechanical ultimate capacity of 80,000 pounds. The mechanical capacity of the pile is excellent.

7. Installed Product Length. Termination depth is targeted in the stiff silty clay where the helical plates will be situated. The data indicates that the soil has a variance in the Standard Penetration Test (SPT) blow count, “N”, between 8 and 12 blows per foot. It is estimated that the pile would reach the desired shaft torsion at a mid-plane depth of about 13 feet.

Minimum Required Shaft Length:

\[ L = h_{mid} + L_{Tip} - h_F \]
Where:

\[ h_{mid} = 13 \text{ ft} \] (The depth from the surface to midway between plates on the shaft.)
\[ L_{Tip} = (3D_{Plate}) / 2 \]
\[ L_{Tip} = (3 \times 12” \text{ dia} / 2 = 18 \text{ in} \]
\[ L_{Tip} = 1-1/2 \text{ ft} \]
\[ h_F = 1 \text{ ft} \] (The pile cap will terminate at the Utility Bracket approximately 12 inches below grade level.)

\[ L = 13 \text{ ft} + 1-1/2 – 1 \text{ ft} \]
\[ L = 13-1/2 \text{ feet} = \text{ Shaft length estimate} \]

8. Torque Anchor™ Specifications: Specify the necessary Torque Anchor™ components:

- TAF-150-60 12-14 - 1-1/2” solid square bar lead section on a standard length 5 feet long shaft with a 12” and 14” diameter plate.
- TAF-150-60 Extension – 1-1/2” solid square bar extension 5 feet long with hardware, 2 required (The coupling overlaps 3 inches providing an effective length of 4’-9”)
- TAB-150-SUB-150 Utility Bracket. This foundation bracket fits over the 1-1/2” square bar and mounts to the perimeter beam. The bearing plate provides 68-1/4 in² at the bottom of the foundation for load transfer.

The total length of the assembled Torque Anchor™ is 14-1/2 ft.

The Torque Anchors™ shall be spaced at 7-1/2 feet center to center along the perimeter grade beam and must develop an average installation torque of 2,000 ft-lb or more during the last 3 feet of the installation. Depth is 13-1/2 feet.

Note: It is recommended to order additional extension sections because the target torque might not be achieved at 13-1/2 feet.

9. Foundation Restoration. Once all of the Torque Anchor™ piles have been installed and the Utility Brackets mounted, the structure may be restored to as close to the original elevation as the construction will permit.

- A pile cap, lift assembly and hydraulic jack are installed at each placement.
• All hydraulic jacks are connected to a hand pump and gauge through a manifold system that distributes equal pressure to all jacks.

• The hand pump is actuated, transferring the structural load from the soil below the footing to the Torque Anchor™ shafts. As the structure responds and a portion of the foundation reaches the desired elevation, the jack(s) supporting the restored area(s) are isolated and the pressure at the jack(s) recorded.

• The restoration process continues until the structure is satisfactorily restored, and all jacks have been isolated and their pressures recorded.

• All installation and restoration data is transferred to a Project Installation Report. This report should include, but is not limited to, project identification, equipment used, product installed, final installation torque, installed depth, lifting force required to restore the structure and lift measurement. This data must be recorded for each placement.

• Review the report and calculate actual factors of safety on the installation to see if the design requirements have been satisfied.

10. Actual Load vs. Calculated Load and Installed Factor of Safety: The installation data must be compared to the calculated values. This enables the designer to verify the accuracy of the design. In addition, actual project factors of safety should be verified, as shown below.

The actual factor of safety for each pile installation is calculated, a slight variation of the typical factor of safety formula is used.

**Equation 12: Project Factor of Safety**

\[ FS_{\text{job}} = \frac{P_{u,\text{job}}}{P_{w,\text{job}}} \]

Where:

- \( P_{u,\text{job}} \) = Installed EstimatedUlt. Capacity – lb
- \( P_{w,\text{job}} \) = Installation Torque x k
- \( P_{w,\text{job}} \) = Lifting Force to Restore – lb
- \( P_{w,\text{job}} \) = Jack Pressure x Cylinder Area

The Project Installation Report data is used to calculate the actual factors of safety for each Torque Anchor™ placement:

\[ FS_{\text{Actual}} = \frac{T_{\text{Final}} \times k}{P_{\text{Lift}}} \]

- Pile 1: \( FS_{p1} = 2.22 \)
- Pile 2: \( FS_{p2} = 2.07 \)
- Pile 3: \( FS_{p3} = 2.66 \)

**PROJECT INSTALLATION REPORT**

<table>
<thead>
<tr>
<th>Placement Identification</th>
<th>Pile 1</th>
<th>Pile 2</th>
<th>Pile 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Final Install Torque, ft-lb</td>
<td>2,000</td>
<td>1,950</td>
<td>2,050</td>
</tr>
<tr>
<td>Pile Depth, ft</td>
<td>18.5</td>
<td>16</td>
<td>16.5</td>
</tr>
<tr>
<td>Force to Lift, lb</td>
<td>9,000</td>
<td>9,400</td>
<td>7,700</td>
</tr>
<tr>
<td>Amount of Lift, in</td>
<td>1-1/2</td>
<td>1-3/4</td>
<td>2</td>
</tr>
<tr>
<td>Actual Factor of Safety</td>
<td>2.22</td>
<td>2.07</td>
<td>2.66</td>
</tr>
</tbody>
</table>

Soil tends to be non-homogeneous and normally installation torque varies from point to point on a project; in addition, the load on a footing is usually not uniform due to different architectural elements in the design of the structure. Pile 2 had slightly lower shaft torsion than required and had a slightly higher working load. This resulted in the lowest Factor of Safety. Pile three was on a lightly loaded part of the building an had a large Factor of Safety.

**End Design Example 5**

**Review of Results of Example 5**

Comparing the calculated design working load of 8,818 lb per pile \( P_w = w \) (Step 1) x “X” (Step 2) = 1,300 lb/ lineal ft x 7-1/2 ft = 9,750 lb) to the actual lifting forces one can see that all working pile loads are slightly lower than predicted by the calculations. These differences between calculated and actual working loads are not significant and are related to the fact that actual loads on the footing are not uniform along the footing. The actual factors of safety for the installation on this project demonstrate that the project has actual factor of safeties within normal tolerances. The project has a safe design.
Design Example 5A – Foundation Restoration – “Quick and Rough” Method

Design Details from Design Example 5:
- Two story wood frame house with slab foundation and wood composition siding.
- Foundation consists of 20” wide by 18” tall steel reinforced concrete perimeter beam
- Top of pile to be 12” below the soil surface
- Soil data: Two feet of consolidating poorly compacted fill was found overlaying 20 feet of inorganic clay (CL), firm to stiff.

ECP Torque Anchor™ Design:

1. Determine the foundation load: Use Table 2, Ranges for Typical Average Residential Building Loads that can be found in Chapter 5 of this manual. A portion of Table 2 from Chapter 5 is shown below. (This table does not include snow loads. Snow loads must be added for the job location.)

<table>
<thead>
<tr>
<th>Building Construction (Slab On Grade)</th>
<th>Estimated Foundation Load Range (DL = Dead – LL = Live)</th>
</tr>
</thead>
<tbody>
<tr>
<td>One Story Wood/Metal/Vinyl Walls with Wood Framing – Footing with Slab</td>
<td>DL 750 – 850 lb/ft</td>
</tr>
<tr>
<td></td>
<td>LL 100 – 200 lb/ft</td>
</tr>
<tr>
<td>One Story Masonry Walls with Wood Framing – Footing with Slab</td>
<td>DL 1,000 – 1,200 lb/ft</td>
</tr>
<tr>
<td></td>
<td>LL 100 – 200 lb/ft</td>
</tr>
<tr>
<td>Two Story Wood/Metal/Vinyl Walls with Wood Framing – Footing with Slab</td>
<td>DL 1,050 – 1,550 lb/ft</td>
</tr>
<tr>
<td></td>
<td>LL 300 – 475 lb/ft</td>
</tr>
<tr>
<td>Two Story 1st Floor Masonry, 2nd Wood/Metal/Vinyl with Wood Framing – Footing with Slab</td>
<td>DL 1,300 – 2,000 lb/ft</td>
</tr>
<tr>
<td></td>
<td>LL 300 – 475 lb/ft</td>
</tr>
<tr>
<td>Two Story Masonry Walls with Wood Framing – Footing with Slab</td>
<td>DL 1,600 – 2,250 lb/ft</td>
</tr>
<tr>
<td></td>
<td>LL 300 – 475 lb/ft</td>
</tr>
</tbody>
</table>

From the description of the project, the total foundation load (except snow loads) can be roughly estimated for this structure from Table 2. The portion of Table 2 reproduced is for slab on grade foundation loads, which is the type of foundation on this project that supports a two story residence that has wood composition siding.

To determine the estimated foundation load, look down the first column until the “Two Story” description that most closely matches the job house is found. Reading across to the other column provides a range of foundation dead load weights for this kind of residential structure. Dead loads range between 1,050 and 1,550 lb/lin.ft and the live load estimates run from 300 to 475 lb/lin.ft.

A judgment about the quality of construction is used to select the foundation loads from within the ranges. For Design Example 5A careful judgment about the construction suggests using DL = 1,200 lb/lin.ft and LL = 375 lb/lin.ft. The average perimeter loading to be used for the “Quick and Rough” design is 1,575 lb/lin.ft.

2. Determine the Soil Class. The soil was reported only as still clay. Referring to the Soil Classification Table - Table 9 (Chapter 1), Soil Class 6 is selected. Keep in mind that little soil information available and there is concern about the poorly compacted fill near the surface.

3. Select a Suitable Pile Spacing and Determine Ultimate Torque Anchor™ Load: This is not a heavy structure so the solid square bar Torque Anchors™ configuration is chosen for this restoration along with Utility Brackets are the most economical products to use to transfer the structural load from the foundation to the pile shaft. Use Graph 2 from Chapter 6, to select pile spacing, “X”. (See below)

A loading of 1,575 lb/lin. ft is slightly higher than the 1,500 lb/ft line on the graph. This line will be used to select the spacing and then the spacing will be adjusted to reflect the load higher than the graph curve. Read across from the 18 inch footing height to an estimated 1,575 lb/ft position, then drop down to see the pile spacing of 6-3/4 feet. 6-3/4 feet center to center is selected for “Safe Use” design.

“X” = 6-3/4 feet
4. Determine Ultimate Torque Anchor™ Load:
Use Equation 3 from Chapter 1 to determine the ultimate capacity per pile:

**Equation 3.** $P_u = ("X") \times (w) \times (FS)$:

Where,

"X" = Product Spacing = 6-3/4 feet
$w$ = 1,575 lb/linear foot (Step 1)
FS = Factor of Safety (Use 2.0)

$P_u = 6-3/4 \text{ ft} \times 1,575 \text{ lb/ft} \times 2 = 21,263 \text{ lb}$

5. Select the proper pile configuration:
Referring to Graph 4 from Chapter 1 (reproduced below), notice that the capacity line for 12" and 14" diameter helical plates attached to shaft crosses just above 20,000 pounds at the center of Soil Class 6. The 12" and 14" diameter plate configuration is selected for the design.

6. Check Shaft Strengths and Torsional Strengths to see which shaft is suitable: Refer to Table 2 in Chapter 1 to find a shaft with a suitable Axial Compression Load Limit and sufficient Useable Torsional Strength. The 1-1/2 inch solid square shaft is selected because it has an Axial Compression Load Limit rating of 70,000 pounds based upon an installation torsional limit of 7,500 ft-lbs. This pile exceeds the ultimate job load requirement of 21,263 pounds. The selected and verified pile configuration is TAF-150-60 12-14.

7. Installation Torque. Use Graph 6 from Chapter 2, shown next page to determine the installation torque requirement for the piles. The Ultimate Capacity requirement is 21,263 pounds. Find 22,000 pounds at the left side of Graph 6 look horizontally to the graph line for solid square shafts, read down to torque of 2,200 ft-lb.

$$T = 2,200 \text{ ft-lb, minimum}$$

Just for comparison, the installation torque is calculated: from Equation 2 in Chapter 1:

**Equation 2:** $T = P_u / k$, (from Chapter 1)

$P_u = 21,263 \text{ lb} \quad k = 10 \text{ (Table 12)}$

$$T = 21,263 \text{ lb}/10 \text{ ft} = 2,127 \text{ ft-lb} \quad T = 2,200 \text{ ft-lb}$$

8. Installed Product Length. Termination depth is the stiff clay. It is likely that the pile would reach the desired shaft torsion at a depth somewhat beyond the unconsolidated soil near grade. The minimum depth is the summation of the Critical Depth (Chapter 1, page 16) plus the distance to the lowest plate.

**Minimum Required Shaft Length:**

$$L_{min} = D_{Critical} + L_{Tip}$$

Where:

$D_{Critical} = 14" \text{ dia.}/12" \times 6 \text{ ft (Page 16)}$

(Critical Depth = 6 x diameter of largest plate.)

$L_{Tip} = 12" \text{ dia.}/12" \times 3 = 3 \text{ ft}$

(Plates spaced at 3 x diameter.)

$L_{min} = (14"/12" \times 6") + (12"/12" \times 3) = 10 \text{ ft}$
“Safe Use” design suggests that the piles be installed deeper than ten feet below grade because there is weak and consolidating fill soil near the surface. A longer standard shaft length of 12 feet, minimum, is selected.

9. Torque Anchor™ Specifications: The selected Torque Anchor™ assembly is specified:

- **TAF-150-60 12-14** – 1-1/2 inch solid square shaft that has a 12” and a 14” diameter plate on the 5’-0” long shaft,
- **TAE-150-84** extension – 7 foot extension section & hardware. (6’-9” effective length)
- **TAB-150-SUB Utility Bracket** This foundation bracket fits over the 1-1/2” square bar and mounts to the perimeter beam. The bearing plate provides 68-1/4 in² at the bottom of the foundation for load transfer.

It is recommended that additional extensions (TAE-150-60 extension – 5 foot extension section & hardware - 4’-9” effective length or TAE-150-84 extension – 7 foot extension section & hardware - 6’-9” effective length) be on hand in case the shaft torque requirement is not achieved at 12 feet.

**End of Example 5A**

**Review of Results of Example 5 & 5A**

One can see that the result obtained by the “Quick and Rough” analysis clearly suggested the same pile that was determined by the analysis that used the bearing capacity equations. There were some variations in the design because a higher footing load and higher installation torque were predicted by the “Quick and Rough” method. This was caused in part by the higher ultimate load suggested by the “Quick and Rough” tables and graphs from Chapter 5. Once again, similar results were determined from the “Quick and Rough” design method, but good judgment estimating the quality of construction is most important in selecting proper data from the tables and graphs for more accurate results.
Design Example 6 – Motor Output Torque

The heavy weight new construction pile design presented in Design Example 1 required shaft torsion of 7,100 ft-lb be applied to the 2-7/8 inch diameter Torque Anchor™ shaft to achieve the ultimate capacity requirement of 60,000 pounds. In Design Example 1B, where weak soil was present, the torsion requirement was determined to be 8,000 ft-lb on a 3-1/2 inch diameter tubular shaft to be able to achieve the same 60,000 pound ultimate pile capacity.

Project Details Provided from the Field:

- New Building – 2 story house with basement
- Ultimate Capacity = 60,000 lb
- Torque Motor Available = Pro-Dig X12K5
- Design 1 – Avg. Pressures at termination depth - 2-7/8” dia. = 1,900 psi at inlet & 200 psi at outlet
- Design 1B – Avg. pressures at termination depth, 3-1/2” dia. = 2,150 psi at inlet & 200 psi at outlet
- Pressures averaged over final three feet of depth

Equation 11 introduced in Chapter 2 is used to convert pressure differential across the hydraulic gear motor into shaft output torque.

\[
\text{Equation 12: Motor Output Torque} \quad T = K \times \Delta P
\]

1. Differential Pressures: Before using Equation 11, the pressure differential, or \( \Delta P \), from the field must be determined. The Motor Torque Conversion Factor – “K” must also be identified for the Pro-Dig X12K5.

The Pressure Differential across the motor is determined as follows:

\[
\Delta P = \text{Inlet} \psi - \text{Outlet} \psi \\
\Delta P = P_{in} - P_{out}
\]

\( \Delta P \) from Design Example 1:

\[
\Delta P_{\text{Example 1}} = 1,900 \psi - 200 \psi = 1,700 \psi
\]

\( \Delta P \) from Design Example 1B:

\[
\Delta P_{\text{Example 1B}} = 2,150 \psi - 200 \psi = 1,950 \psi.
\]

2. Motor Torque Conversion Factor, “K”: The Motor Torque Conversion Factor – “K” is found on Table 16 in Chapter 2. (A portion of the table is shown below.)

Looking in the “Model Number” column of Table 16, the X12K5 Torque Motor data is found. Reading to the right the value for the Motor Conversion Factor, “K”, for this motor is determined to be “K” = 4.20.

3. Motor Output Torque: Once the differential pressure across the hydraulic torque motor has been calculated (Step 1) and the value for “K” determined (Step 2), the values can be used in Equation 11 to determine the actual torque that was applied to the pile shaft at termination depth.

\[
\text{Equation 11: Motor Output Torque} \quad T = K \times \Delta P
\]

Where,

\[
T = \text{Hydraulic Motor Output Torque - ft-lb} \\
K = \text{Torque Motor Conversion Factor – (Table 16)} \\
\Delta P = P_{in} - P_{out} = \text{Motor Pressure Differential}
\]

Confirm proper installation torque for Design Example 1.

\[
\begin{align*}
T_{\text{Example 1}} &= 4.20 \times 1,700 \psi \\
T_{\text{Example 1}} &= 7,140 \text{ ft-lb}
\end{align*}
\]

7,140 ft-lb > 7,100 ft-lb - O.K.

Confirm proper installation torque for Design Example 2.

\[
\begin{align*}
T_{\text{Example 1B}} &= 4.20 \times 1,950 \\
T_{\text{Example 1B}} &= 8,190 \text{ ft-lb}
\end{align*}
\]

8,190 ft-lb > 8,000 ft-lb - O.K.

Table 16. Hydraulic Torque Motor Specifications

<table>
<thead>
<tr>
<th>Illustration</th>
<th>Model Number</th>
<th>Torque Output ft-lb</th>
<th>Motor Torque Conversion Factor – “K”</th>
<th>Maximum Pressure psi</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PRO-DIG</strong></td>
<td>L6K5</td>
<td>6,335</td>
<td>2.53</td>
<td>2,500</td>
</tr>
<tr>
<td></td>
<td>L7K5</td>
<td>7,644</td>
<td>2.55</td>
<td>3,000</td>
</tr>
<tr>
<td></td>
<td>X9K5</td>
<td>9,663</td>
<td>3.22</td>
<td>3,000</td>
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<tr>
<td></td>
<td>X12K5</td>
<td>12,612</td>
<td>4.20</td>
<td>3,000</td>
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<tr>
<td></td>
<td>T12K</td>
<td>5,597/12,128</td>
<td>2.24/4.85</td>
<td>2,500</td>
</tr>
</tbody>
</table>

End Design Example 6
Design Example 6A – Motor Output Torque “Quick and Rough Method”

The heavy weight new construction pile design presented in Design Example 1 specified that when installed on the site, torsion of 7,100 ft-lb was needed on the 2-7/8 inch diameter Torque Anchor™ shaft to reach the ultimate capacity requirement of 60,000 pounds.

In Design Example 1B where weak soil was present the torsion requirement increased to 8,000 ft-lb on the 3-1/2 inch diameter tubular shaft to achieve the same 60,000 pound ultimate pile capacity.

Determine Motor Output Torque: Graph 9 introduced in Chapter 2 is used to convert pressure differential across the hydraulic gear motor into shaft output torque. Referring to Graph 9 (reproduced below); the output torque of the X12K5 motor can be determined once the pressure differentials across the installation motor are determined.

\[ \Delta p = \text{Inlet psi} - \text{Outlet psi} \]
\[ \Delta p = p_{in} - p_{out} \]

\[ \Delta p \text{ from Design Example 1:} \]

\[ \Delta p_{\text{Example 1}} = 1,900 \text{ psi} - 200 \text{ psi} \]
\[ \Delta p_{\text{Example 1}} = 1,700 \text{ psi} \]

\[ \Delta p \text{ from Design Example 1B:} \]
\[ \Delta p_{\text{Example 1B}} = 2,150 \text{ psi} - 200 \text{ psi} \]
\[ \Delta p_{\text{Example 1B}} = 1,950 \text{ psi} \]

With the actual field measured pressure differentials calculated, one can find the actual installation motor torque at pile termination depth on Graph 9. Locate 1,700 psi and 1,950 psi values at the bottom of the graph. Then read upward until the motor curve line for the X12K5 motor is reached. Read horizontally to the left where the Output Torque at the Shaft” where can be found.

Design Example 1 output shaft torsion is determined to be estimated at 7,250 ft-lbs.

Design Example 1B had a pressure differential of 1,950 psi pressure differential, which produced an output torque estimated at 8,200 ft-lb.

Proper installation shaft torque is confirmed for Design Examples 1 and 1B

End Design Example 6A

Review of Results of Example 6 & 6A

One can see that the result obtained by the “Quick and Rough” analysis suggested the shaft torsion from field data was sufficient to provide the load capacity. The calculated method and the “Quick and Rough” solutions for the actual installation shaft torque values were similar.
Design Example 7 – Ultimate Capacity from Field Data

In this exercise the anticipated ultimate capacities of the pile designs from Design Example 1 and 1B will be determined. This information will be used to confirm that the installed piles meet or exceed the design requirements set out in the original designs.

Equation 2 from Chapter 1 is used to calculate the ultimate compressive capacity of the pile based upon data provided from the field. Recall that the Design Example 1 - Heavy Weight New Construction Project required an ultimate capacity at each pile of 60,000 pounds.

**Equation 2: Helical Pile Ultimate Capacity**

\[ P_u = k \times T \]

Where,

- \( P_u \) or \( T_u \) = Ul. Capacity of Torque Anchor™ - (lb)
- \( T \) = Final Installation Torque - (ft-lb)
- \( k \) = Empirical Torque Factor - (ft⁻¹)

Calculating the ultimate pile capacity using data from Design Example 1:

Ultimate Capacity of the 2-7/8” diameter, 0.262 wall piles installed in Example 1 (\( P_u \) Example 1):

Where,

- \( k = 8.5 \) (Table 12)
- \( T_{\text{Example 1}} = 7,140 \) ft-lb (Design Example 6)

\[ P_u = 8.5 \times 7,140 = 60,690 \text{ lb} \]

\[ P_u = 60,690 \text{ lb} > 60,000 \text{ lb} \text{ O.K.} \]

Calculating the ultimate pile capacity using data from Design Example 1B:

Ultimate Capacity of the 3-1/2” diameter piles with 0.300 inch wall thickness that were installed in Design Example 1B = \( P_u \) Example 1B:

Where,

- \( k = 7.5 \) (Table 12)
- \( T_{\text{Example 1B}} = 8,190 \) ft-lb (Design Example 6)

\[ P_u = 7.5 \times 8,190 = 61,425 \text{ lb} \]

\[ P_u = 61,425 \text{ lb} > 60,000 \text{ lb} \text{ O.K.} \]

The results of the calculations confirm the ultimate capacity determined from the field data exceeds the design ultimate capacity stated in the specifications of Design Examples 1 and 1B.

End Design Example 7

**Design Example 7A – Ultimate Capacity from Field Data – “Quick and Rough” Method**

This exercise will determine the ultimate pile capacity based upon field data using the “Quick and Rough” method. The comparison between the calculated design specifications and the actual field capacity will verify whether the pile installation is satisfactory.

Design Example 6A determined that the output torque at the motor shaft was 7,250 ft-lb at the termination of the pile installation. Graph 7 from Chapter 2 (shown on the next page) provides a method to demonstrate the ultimate capacity of the installed helical product. A comparison to the design requirement will determine if the installed pile capacity exceeds the specified ultimate capacity.

Estimate the location on the horizontal axis for shaft torsion of 7,250 ft-lb slightly to the right of the 7,250 ft-lb grid line and read up to the plot line for the 2-7/8 inch diameter shaft configuration. The legend near the top of the graph provides choices between square shafts and various tubular shafts. Read upward from the 7,250 ft-lb “Motor Torque” line until the bold dashed line that represents the 2-7/8 inch diameter shaft configuration is encountered. Then move horizontally to the vertical axis at left to see if installed pile ultimate capacity exceeds 60,000 pounds.

Looking carefully at the point where the horizontal plot intersects the “Ultimate Capacity” axis, the field generated shaft torsion at the termination of the pile installation shows to be slightly above 60,000 lb. This verifies that the actual installed pile capacity exceeds design specifications.

End Design Example 7

**Review of Results of Example 7 & 7A**

The value in using the “Quick and Rough” method is that it provides rapid results from the graphs. This method cannot tell exactly how much the field installation exceeded the design requirements, but it confirms whether the installation meets or exceeds specifications. If the engineer wants to know the actual installed ultimate capacity, then it must be calculated.
Technical Design Assistance
Earth Contact Products, LLC. has a knowledgeable staff that stands ready to help you with understanding how to prepare preliminary designs, installation procedures, load testing, and documentation of each placement when using ECP Torque Anchors™. If you have questions or require engineering assistance in evaluating, designing, and/or specifying Earth Contact Products, please call us at 913 393-0007, Fax at 913 393-0008.