Comprehensive Design Example 1: Light Commercial Structure

Problem

Build a new (lightly loaded single story) commercial building on a typical clay soil profile as given on a single boring. The profile consists of the upper 10'-0 of highly plastic clay (CH), Plasticity Index (PI) = 35; cohesion C = 2000 psf; unit weight (γ) of 105 pcf. The swell potential is this layer is estimated to be 2 inches. The top 10'-0 layer is underlain by 20' of stiff to very stiff low plasticity clay (CL) that has an SPT blow count (N) = 20. The boring was terminated at 30 feet without encountering the water table. No further soil parameters or lab data given.

Possible solution

Support the structure on a grade beam and structural slab, which is in turn supported by helical screw foundations. Isolate the foundation and slab from the expansive subgrade by forming a 2" void, using a cardboard void form. Void form details can be found on the architectural drawing "Pier and Grade Foundation Plan" located in Step 10. Assume the water table is at the soil boring termination depth. This is typically a conservative design assumption when the water table is not encountered. The stiff to very stiff clay soil in the 20-foot thick layer is probably at or near 100% saturation (volume of water is the same as the volume of the voids).

Step 1: Feasibility

- **Site Access** – The site is road accessible, no overhead or underground obstructions, but the owner is concerned about potential damage to neighboring sites due to vibration and noise.
- **Working Loads** – The structure is single story, so the working loads are probably considerable less than 100 kip per pile.
- **Soils** – Boulders, large cobbles, or other major obstructions are not present in the bearing stratum. The clay soil does not appear to be too hard to penetrate with helical screw foundations. See Table 8.3 for determining if helical screw foundations are feasible, and if so, which product family to use.
- **Qualified Installers** – Local A.B. Chance Co. certified dealer is available and can get competitive bids from a second certified dealer 20 miles away.
- **Codes** – Local building codes allow both shallow and deep foundations.

Cost-bid must be competitive with other systems. Owner may pay a small premium to "protect" the investment in the structure.

Step 2: Soil Mechanics

See statement of problem above

Step 3: Loads

- **Exterior Grade Beam** – The dead and live loads result in 3 kips per lineal foot on the perimeter grade beam (12" wide x 18" deep). The grade beam is designed to span between piles on 8'-0 centers. Therefore, the design or working load per pile is 3 kip/ft x 8 ft = 24 kip. Per Step 3 and 4, a factor of safety of 2 is recommended. Therefore, the required ultimate capacity per exterior pile is 24 x 2 = 48 kip compression.
- **Internal Columns** – The dead load results in 9 kips per column. The live load results in 20 kip per column. The total dead and live load per column is 9 + 20 = 29 kip/column design or working load. Per Step 3 and 4 a factor of safety of 2 is recommended. Therefore, the required ultimate capacity per interior pile is 29 x 2 = 58 kip compression. The required ultimate loads for both the exterior grade beam and internal columns are well within the load ratings of A.B. Chance Co. product families.
- **Lateral Loads** – The piles are not required to resist any lateral loads.

Step 4: Bearing Capacity
Find the ultimate bearing capacity in the stiff to very stiff clay using hand calculations.

Bearing Capacity: $Q_{ult} = A_h(cN_c + q'N_q + 0.5\gamma'BN_\gamma)$ Eq. 4.1

For saturated clay soils, the second term of Equation 4.1 becomes zero since the angle of internal friction (ϕ) is assumed to be zero for saturated clays, thus $N_q = 0$. The third term (base term) may be dropped because B is relatively small. The simplified equation becomes:
$Q_{ult} = A_h cN_c = A_h c9$ Eq. 4.7

From Equation 4.8, c (ksf) = N/8 = 20/8 = 2.5 ksf. At this point, an iterative process is required. Select a helix configuration that is believed can develop the required ultimate capacity. Try 10"-12" twin helix with a minimum of 5'-0 embedded into the bearing stratum which is the stiff low plasticity clay starting 10 ft below grade. From Table 8.1, the helix area of a 10" helix is 76.4 in^2 or 0.531 ft^2; the helix area of a 12" helix is 111 in^2 or 0.771 ft^2.

Substituting:
$Q_{10} = 0.531\ ft^2 \times 2.5\ ksf \times 9 = 11.95$ kips
$Q_{12} = 0.771\ ft^2 \times 2.5\ ksf \times 9 = 17.35$ kips

$Q_t = SQ_h = 11.95 + 17.35 = 29.3$ kips Eq. 4.2

Another trial is required because the total ultimate capacity ($Q_t = 29.3$ kip) is less than required. Try a three-helix configuration (10"-12"-14") with a minimum of 5'-0 embedded in the bearing stratum. From Table 8.1, the helix area of a 14" helix is 151 in^2 or 1.05 ft^2.

$Q_{14} = 1.05\ ft^2 \times 2.5\ ksf \times 9 = 23.63$ kips

$Q_t = \Sigma Q_h = 11.95 + 17.35 + 23.63 = 52.93$ kips

To achieve the necessary safety factor of 2, two helical piers with a 10"-12" helical configuration can be used under the internal columns (29.3 x 2 = 58.6, say 59 kips ultimate capacity) and a single helical screw foundation with a 10"-12"-14" helical configuration can be used under the perimeter grade beam. The termination of the helical screw foundation in a concrete cap or grade beam should be made with an appropriately designed pile cap or a purchased “new construction” termination. This will allow the foundation to rise up, should the swell ever exceed the 2" void allowance, but to shrink back and rest on the pier tops.

• Check bearing capacity by using HeliCAP Engineering Software
See attached printout of the tabular data where the twin helix (10"-12") Q_{ult} = 29.2 kip @ 29.3 kip, OK; and the triple helix (10"-12"-14") Q_{ult} = 52.8 kip @ 52.93 kip, OK

A.B. Chance Company

HeliCAP SUMMARY REPORT

Job Name: Design Manual for New Construction

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Water Table Depth: None

Job Number: Example 2

Boring No: B-1

Anchor Use: Compression

Capacity Summary

Anchor Number	Anchor Family	Helix Depth (ft)	Helix Capacity (kips)	Total Anchor Capacity (kips)	Recommended Ultimate Capacity (kips)	Torque (ft-lbs)
Anchor 1	Angle: 90 Datum Depth: 0 Length: 18					
12" helix	SS 5	15	17.3t 17.3c	29.2t	29.2t	2925
10" helix	SS 5	17.5	11.9t 11.9c	29.2c	29.2c	
Anchor 2	Angle: 90 Datum Depth: 0 Length: 21					
14" helix	SS 5	15	23.6t 23.6c			
12" helix	SS 5	18	17.3t 17.3c	52.8t	52.8t	5287
10" helix	SS 5	20.5	11.9t 11.9c	52.8c	52.8c	

Soil Profile

Top of Layer Depth (ft)	Soil Type	Cohesion (lb/ft2)	N	Angle of Internal Friction (Degrees)	Unit Weight (lb/ft3)
0	Clay	2000	0	0	105
10	Clay	2500	20	0	120

Steps 5 and 6: Lateral Capacity and Buckling

• **Lateral Capacity** – None is required in the statement of the problem. In reality, horizontal loads, due to wind, will be resisted by net earth pressure (passive-active) on the grade beam and/caps. See Step 5 for an explanation of earth pressure resistance.

• **Buckling Concerns** – The soil density and shear strength is sufficient to provide lateral confinement to the central steel shaft. This is supported by the fact that the SPT blow count is greater than 4 for the top clay layer (see Step 6 for explanation). Should analysis be required, the Davisson method, (Step 6) may be used to determine the critical load.

Step 7: Corrosion

No electrochemical properties were given for the clay soil. Generally, undisturbed, i.e. non-fill material tends to be benign as little oxygen is present and the ions that are present in solution are not washed away due to flowing water or fluctuating water level. In the absences of soil data, one useful guide to use on the "judgment side" is to observe the use of corrugated metal pipe (CMP) by the local Department of Transportation (DOT). If the DOT uses the CMP, the likelihood is that the local soils are not very aggressive.

Step 8: Product Selection

Ultimate capacity for a 10"-12" configuration per Step 4 was 29 kip, and the ultimate capacity for a 10"-12"-14" configuration was 53 kip. Table 8.2 shows that Hubbell/A.B. Chance Co. Type SS5 product family can be used, since 53 kip is within its allowable load range. Note that Table 8.2 assumes a K_t of 10^{-1}.

For the 10"-12" configuration, the minimum depth of 18'-0 can be achieved by using a lead section, which is the first pile segment installed and includes the helix plates, followed by two or three plain extensions. For the 10"-12"-14" configuration, the minimum depth of 21'-0 can be achieved by using a lead section followed by three or four plain extensions. The exact catalog items to use for a specific project are usually the domain of the contractor. The A.B. Chance Co. certified dealer is familiar with the standard catalog items and is best able to determine which ones to use based on availability and project constraints.

The head of the helical screw foundation is to be approximately 1'-0 below grade in the grade beam or cap excavation, which will put the twin-helix screw foundation tip 18'-0 below the original ground level and the three-helix screw foundation tip 21'-0. These are minimum depths, required to locate the helix plates at least 5'-0 into the bearing stratum. On large projects, it is advisable to add 3 to 5% extra extensions in case the soil borings vary considerably, or if widely spaced borings fail to indicate differences in bearing depths.

Step 9: Field Production Control
Use K_t = 10 ft^{-1} for Hubbell/A.B. Chance Co. Type SS material if testing is not done prior to production work (see Step 9). The minimum depth and minimum installing torque must both be achieved. If the minimum torque requirement is not achieved, the contractor should have the right to load test the helical screw foundation to determine if K_t is greater than 10 ft^{-1}. Verification testing is often done in tension since it's simpler and less costly to do than compression testing, and the compressive capacity is generally higher than tension capacity, which results in a conservative site-specific K_t value.

Estimate Installing Torque for field production control and specifying the minimum allowable without testing.

$Q_{ult} = K_t T$, or $T = Q_{ult}/K_t$ Eq. 9.1

Internal columns: $T = Q_{ult}/K_t$ = 29,000 lb/$10^{-1\ ft}$ = 2,900 ft-lb - say 3,000 ft-lb for the minimum average torque taken over the last three readings.

Perimeter grade beam: $T = Q_{ult}/K_t$ = 53,000 lb/$10^{-1\ ft}$ = 5,300 ft-lb - say 5,500 ft-lb for the minimum average torque taken over the last three readings.

Note that the torque rating for Hubbell/A.B. Chance Co. Type SS5 product family is 5,500 ft-lb – OK.

Step 10: Product Specifications
See Step 10 for MANU-SPEC™ or Hubbell/A.B. Chance Co. model specifications. See also the sample architectural drawings for suggested details and notes. NOTE: It is recommended the specifier use the internet version available from www.abchance.com for the latest revisions.

Step 11: Load Test
Since this is a small project with low loads in "normal" soils, use the torque correlation method as the driving criteria and omit the "optional" load test. A test can be done per Step 11 should some need arise to resolve an anomaly.