Engineering Roadmap For New Construction Helical Pile Design

The Leading Edge In Helical Foundations

MacLean Dixie HFS™

Building Solid Foundations

ISO 9001:2008
QSR-938

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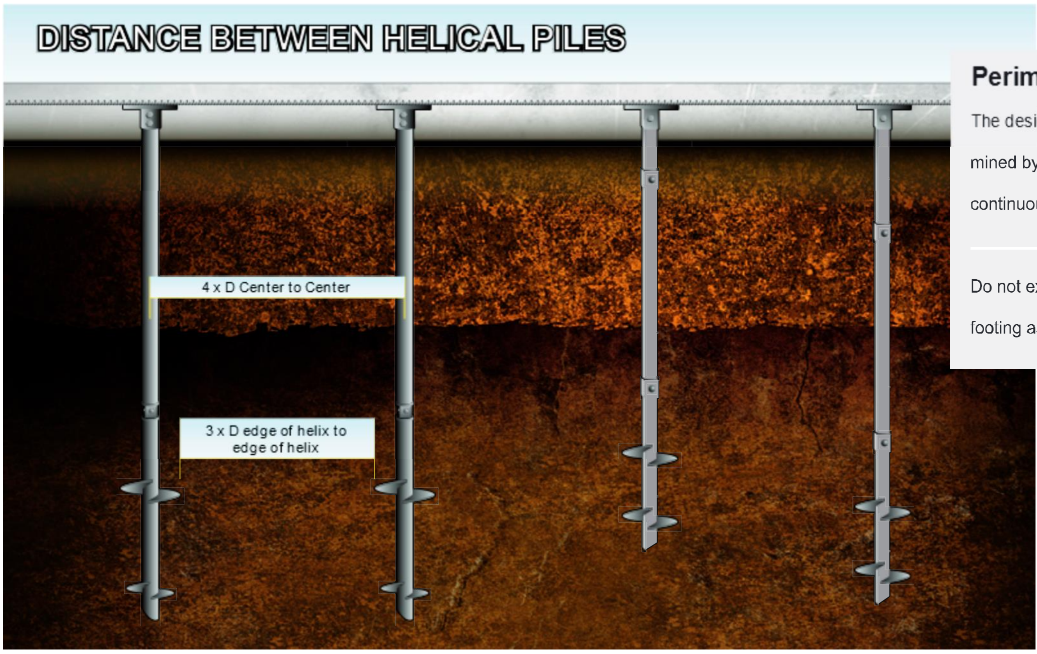
Before You Begin

For the preliminary design of a new helical pile foundation, the following information should be collected:

- The loading conditions, including:
  - o What is the compression load?
  - o What is the tension load?
  - o What is the lateral load?
  - o Is the lateral load eccentric, i.e, is it being applied to the pile some distance above the ground surface?
  - o Are seismic loads a consideration for this project?
- The structural floor plan of the proposed building
  - o Are there heavily loaded interior columns?
  - o Are piles installed at different locations within the building going to see very different load conditions?

Pile Spacing Requirements

The helical pile spacing will be determined through a combination of the structural load requirements, the structural integrity of the foundation components, and the minimum spacing requirements of the piles themselves. The minimum allowable pile spacing is 3 times the diameter of the largest helix measured edge-to-edge, or 4 times the diameter of the largest helix measured from center-to-center. Since spacing requirements apply only to the helices and not the shafts, a slight batter during installation of the piles can provide a convenient method of maintaining the minimum spacing.



Perimeter Pile Design

The design load on perimeter piles can be determined by multiplying the load per linear foot of the continuous footing by the allowable pile spacing.

Do not exceed the maximum span length of the footing as provided by the structural engineer.

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Shaft Selection

Choose a shaft based on the required project loads by looking at the design tension or compression columns or the ultimate tension or compression columns on Table 1, depending upon whether you are using design or ultimate loads, and whether it is tension or compression that controls the design.

Table 1

Description	Designation	Kt	Torsional Capacity (ft-lbs)	Max Design Tension (lbs)	Max Design Compression (lbs)	Ultimate Tension (lbs)	Ultimate Compression (lbs)
1.50" RCS	D6	10	5,500	30,000	27,500	60,000	55,000
1.50" RCS (High strength)	D7	10	7,000	35,000	35,000	70,000	35,000
1.75" RCS	D10	10	10,000	50,000	50,000	100,000	100,000
2.00" RCS	D15	10	15,000	75,000	75,000	150,000	150,000
2.875" O.D. Pipe (0.203" wall)	P28	8	7,500	40,000	30,000	80,000	60,000
2.875" O.D. Pipe (0.276" wall)	P28H	8	9,000	50,000	36,000	100,000	72,000
3.500" O.D. Pipe (0.216" wall)	P35	7	11,400	50,000	40,000	100,000	80,000
3.500" O.D. Pipe (0.300" wall)	P35H	7	15,000	70,000	52,500	140,000	105,000
4.500" O.D. Pipe (0.237" wall)	P45	6	20,000	70,000	60,000	140,000	120,000
4.500" O.D. Pipe (0.337" wall)	P45H	6	26,000	100,000	78,000	200,000	156,000
8.625" O.D. Pipe (0.1875" wall)	P8	5	44,500	120,000	100,000	240,000	200,000

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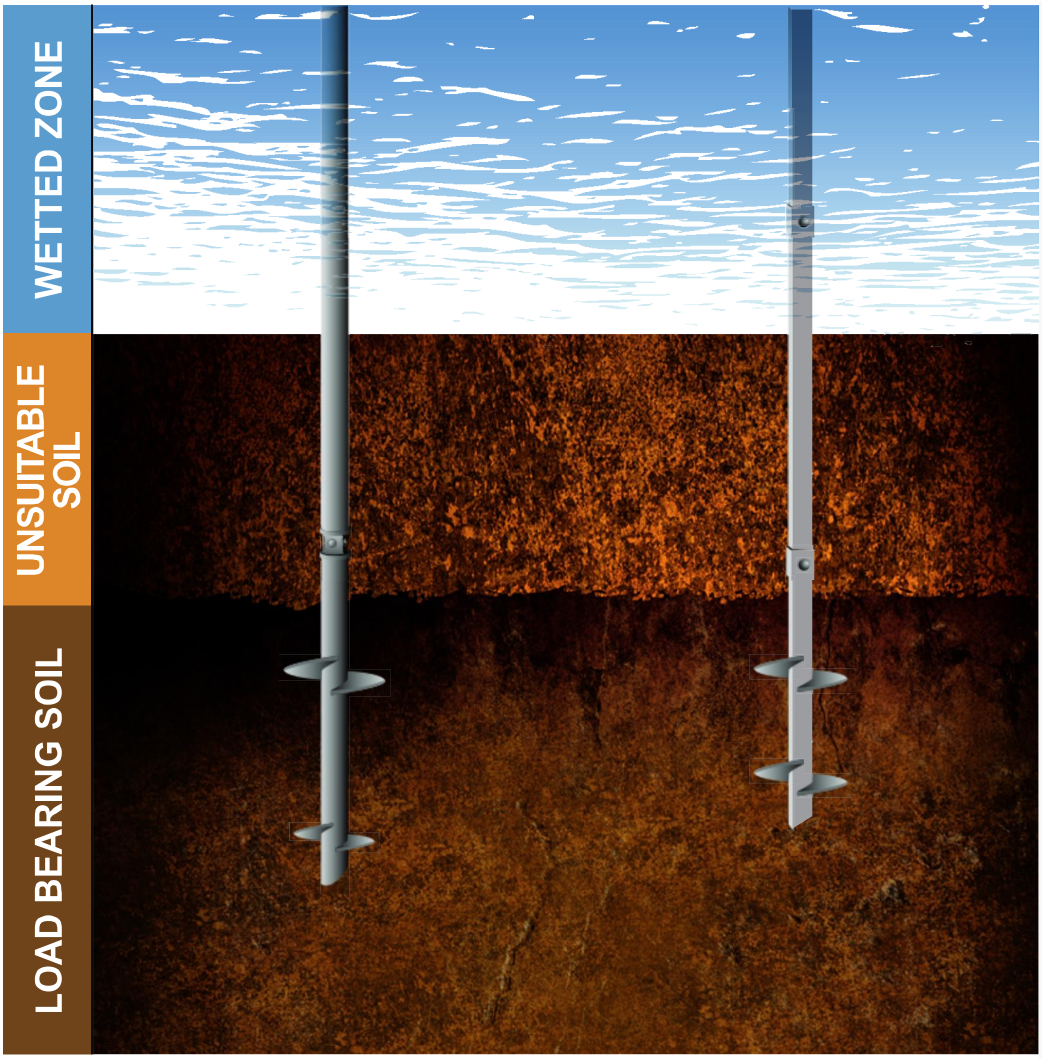
Design Requirements

Based on Soil Boring Logs, what zone(s) of unsuitable soil are present within the building footprint? Identify the unsuitable soil zones in order to develop a minimum tip embedment of the pile. Be sure to utilize only the Soil Boring Log(s) that are located within the foundation's footprint. Refer to geotechnical or site condition reports to review for Water Table notations that identify significant wetted zone depths in order to specify helical pile embedment to penetrate the wetted zone into load bearing strata that is unaffected by seasonal wetting and drying.

Helical Pile design requires that the piles be installed an additional distance equal to 3 times the largest helix once the soil resistance / installation torque has been achieved in order to seat the helices in load bearing strata.



***Example 1**: A helical pile with multiple helices such as a 10"-12"-14" configuration. The largest helix shall determine the additional pile embedment length. In this example the pile must be advanced an additional 3.5 feet of embedment.*

***Example 2**: A helical pile that is designed with a single helix of 12" diameter must be advanced an additional 3' once the proper soil resistance has been achieved.*

The sample calculation matrix on the last page of this Roadmap is provided as an example to demonstrate how the bearing capacity and pull-out capacity calculations are performed. The calculation table can be used as is below or expanded for a deeper soil profile for your own project. Alternately, a spreadsheet program, such as Excel could be set up to perform the calculations automatically using this Roadmap as a guide.

Depth [Column A]:

The depth below grade at a suitable increment (1-foot is usually sufficient) is entered in the first column.

Soil Type [Column B]:

The soil type at the corresponding depth is entered here. For the purposes of calculating helical pile foundation capacities it is sufficient to label a soil CLAY, for cohesive soils, SAND, for frictional SOILS, or MIXED, for soils that exhibit both cohesive and frictional properties.

SPT-N [Column C]:

The Standard Penetration Test "N-value" is entered here in blows per foot. This parameter will be used to calculate the soil strength parameters and unit weights.

Unit Weight (γ) [Column D]:

Based on the soil type and "N-value," the following empirical correlations can be used to determine the unit weights of the soil layers. Note that below the water table the unit weight of water (62.4 pcf) must be subtracted to determine the buoyant weight of the soil.

$\gamma = 0.9 \times N + 95$ (for clay)

$\gamma = 0.8 \times N + 90$ (for sand)

$\gamma = 105$ (for mixed soil)

Cohesion (C) [Column E]:

For soils labeled CLAY, the cohesion is approximately equal to N/8. SAND soils have a cohesion of 0 for our purposes. MIXED soils will be conservatively assigned a cohesion value of N/16, or half of would it would have been if the mixed layer were being modeled as CLAY.

Angle of Internal Friction (φ) [Column F]:

For soils labeled CLAY, the internal friction angle is 0 for our purposes. SAND soils will have a friction angle of 27 + 0.31*N. MIXED soils are assigned a friction angle 5 degrees lower than it would have if the mixed layer were being modeled as a sand. NOTE: Regardless of the N-value, we recommend that the value of the internal friction angle be limited to a maximum of 42°.

NOTES about soil strength perameters:

These empirical correlations between the soil parameters and the result of the Standard Penetration Test are generally conservative. If direct laboratory measurements of the soil parameters are available, they should be used instead of the empirical values.

Helix Diameter [Column G]:

Write the nominal diameter of the helices (from Table 2) that will be attached to the selected shaft in this column at the depths they will be installed to. Remember, the helices must be installed in order of increasing diameter, with the smallest helix at the bottom. Additionally, each helix must be spaced along the shaft a distance of 3 times the diameter of the lower helix.

Table 2

Shaft ->	D6	D7	D10	D15	P28	P28H	P35	P35H	P45	P45H	P8
6 inches	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
8 inches	0.308	0.308	0.303	0.303	0.278	0.278	0.278	0.278	0.236	0.236	0.303
10 inches	0.501	0.501	0.495	0.495	0.473	0.473	0.473	0.473	0.43	0.43	NA
12 inches	0.724	0.724	0.719	0.719	0.711	0.711	0.711	0.711	0.668	0.668	NA
14 inches	1.002	1.002	0.996	0.996	0.993	0.993	0.993	0.993	0.95	0.95	0.659
16 inches	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.984
20 inches	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.766
24 inches	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2.719

Helix Area [Column H]:

Determine the bearing area of the chosen helix in this column by cross referencing the helix diameter and the shaft type on Table 2. Write this value in this column.

Average Overburden Pressure for Compression Calculation (σc) [Column I]:

This column is the average value of the sum of the soil unit weights within a zone below the helix equal to 3 times the diameter of the helix. It is used for the calculation of the compression capacity of the pile.

Average Overburden Pressure for Tension Calculation (σt) [Column J]:
This column is the average value of the sum of the soil unit weights within a zone above the helix equal to 3 times the diameter of the helix. It is used for the calculation of the tension capacity of the pile.

Average Cohesion for Compression Calculation (Cc) [Column K]:
This column is the average value of the cohesion within a zone below the helix equal to 3 times the diameter of the helix. It is used for the calculation of the compression capacity of the pile.

Average Cohesion for Tension Calculation (Ct) [Column L]:
This column is the average value of the cohesion within a zone above the helix equal to 3 times the diameter of the helix. It is used for the calculation of the tension capacity of the pile.

Bearing Capacity Factor (Nq) [Column M]:
Find the appropriate bearing capacity factor based on the friction angle of the soil on Table 3 and write it in this column. This is a unitless parameter used in the Terzaghi bearing capacity equation. It is a function of the friction angle of the soil and is used in the capacity calculation for frictional soils, it can be assumed as zero for CLAY soils.

Bearing Capacity Factor (N_C) [Column N]:
This is a unitless parameter used in the Terzaghi bearing capacity equation. For this bearing capacity factor we use a value of 9 for a CLAY or MIXED soil, this parameter can be entered as 0 in the table for a sand soil as it will not factor into the capacity calculations for SAND.

Ultimate Compression Capacity [Column O]:
The compression capacity of the helix in this row is found using the Terzaghi general bearing capacity equation:

$$Q^{C}_{ult} = A_h \times (N_q \sigma_c + N_c C_c) = H \, X \, (M \, X \, I + N \, X \, K)$$

Ultimate Tension Capacity [Column P]:
The compression capacity of the helix in this row is found using the Terzaghi general bearing capacity equation:

$$Q^{C}_{ult} = A_h \times (N_q \sigma_c + N_c C_t) = H \, X \, (M \, X \, J + N \, X \, L)$$

Finally, sum the capacities of the individual helices, divide by 1,000 to convert pounds to kips, and write the results in the sum boxes. These are the ultimate capacities (compression and tension) of the helix plate configuration installed to the depth that you have selected. Compare the bearing capacity results to the project requirements and add or subtract helices, or increase or decrease the installation depth to find an optimal pile for your project.

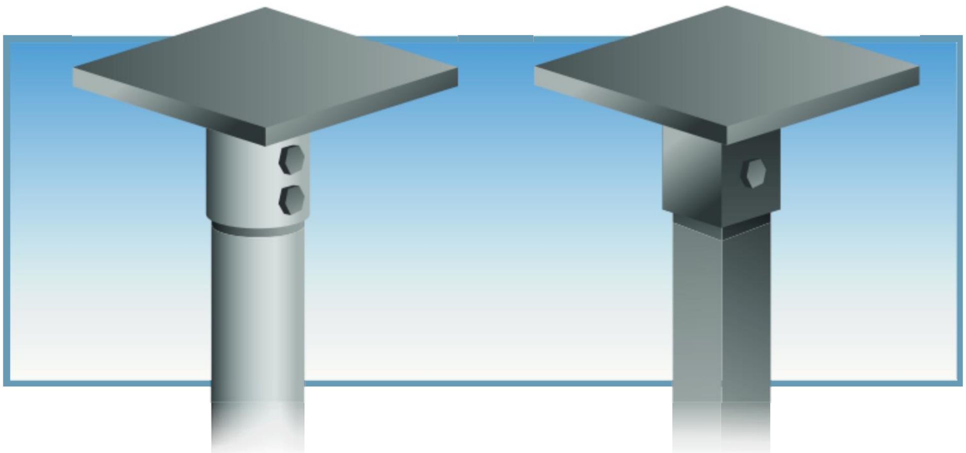
Table 3

Φ	Nq
20	4.463
21	4.959
22	5.514
23	6.138
24	6.841
25	7.632
26	8.526
27	9.538
28	10.685
29	11.989
30	13.473
31	15.169
32	17.110
33	19.338
34	21.903
35	24.864
36	28.294
37	32.279
38	36.928
39	42.369
40	48.762
41	56.308
42	65.250
43	75.899
44	88.642
45	103.971

Bracket Requirements

Consult the table below to determine the bracket that will be replaced for the top of the pile to embed into the footing or pile cap. In the event that tension loads exist, be sure to specify the bracket must be connected to the extension with appropriate connection bolts.

NEW CONSTRUCTION BRACKET FOR 2-7/8", 3-1/2", 4-1/2" PIPE PILES-MECHANICAL RATING										
CATALOG NUMBER	CAT. PREFIX	SHAFT (O.D. x wall thickness)	W	L	T	BOLT(in)	QTY.	GR.	MAXIMUM COMPRESSION LOAD (kips)	ALLOWABLE COMPRESSION LOAD (kips)
NCB060604P28	P28	2-7/8" O.D. X .203"	6"	6"	1/2"	3/4	2	5	60	30
NCB080804P28	P28	2-7/8" O.D. X .203"	8"	8"	1/2"	3/4	2	5	60	30
NCB060604P28	P28H	2-7/8" O.D. X.276"	6"	6"	1/2"	3/4	2	5	72	36
NCB080804P28	P28H	2-7/8" O.D. X.276"	8"	8"	1/2"	3/4	2	5	72	36
NCB080804P35	P35	3-1/2" O.D. X .216"	8"	8"	1/2"	7/8	2	5	80	40
NCB101006P35	P35	3-1/2" O.D. X .216"	10"	10"	3/4"	7/8	2	5	80	40
NCB101006P35	P35H	3-1/2" O.D. X .300"	10"	10"	3/4"	7/8	2	5	105	52.5
NCB101006P45	P45	4-1/2" O.D. X .237"	10"	10"	3/4"	1	2	5	120	60
NCB101006P45	P45H	4-1/2" O.D. X .237"	10"	10"	3/4"	1	2	5	156	78



Additional Design Concerns

Is the buckling capacity of the shaft an important consideration due to a significant unbraced length? Is the pile cap designed to be encased in the footing? If the pile cap is to be encased within the footing; does the pile cap need to be galvanized? Please consult the most recent MacLean Dixie Engineering Reference Manual for additional information regarding these, and other potential design concerns.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
Depth (ft)	Soil Type	SPT-N (bpf)	γ(pcf)	C (psf)	Φ°	Helix Diameter (in)	Helix Area (sq. ft.)	σ_c (psf)	σ_t (psf)	C_c (psf)	C_t (psf)	N_q	N_c	Q_{ult}^{c} (lbs)	Q_{ult}^{t} (lbs)
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