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Short Communication

Helical Pile vs Ground Screw in Clay Soil: Experimental and Numerical Study

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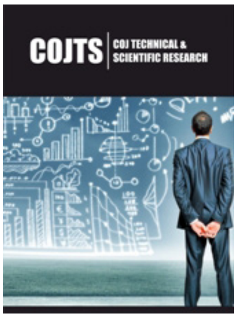
Abstract

Helical piles during the last five years are giving way to the ground screws, that are a particular shape of helical piles, becoming a popular foundation technique in building and civil engineering. In this article we compare the experimental data issued from the bearing capacity tests of a helical pile and a ground screw of equal diameter. Then we use a numerical model using a meshfree software UC3MLib, thus we find a correspondence between helical pile and ground screw behavior.



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Introduction

Helical piles with large helix, a foundation technique that becomes more and more popular because of the ease of implementing and its environmental benefits, leaves place to a more technologically advanced type of lateral discharge piles: ground screws, that can be manufactured by robots and require smaller machines for their implementation. We carried out a test with helical piles and ground screws of the same diameter and same length in the clay soils, in aim to compare their bearing capacity. Then we established a mathematical model of both types of piles, using UC3MLib modeling software. Similar experiments were carried out by Wang [1] or by Chen [2].

Helical piles and ground screws

Helical piles are the metallic piles composed of a round tubular shaft, on which one or several helices are welded. They are installed into the ground without excavation by rotation, gaining the bearing capacity by their tip, and also by the friction of shaft sides against the compressed ground. Actual helical piles descent from their predecessors invented by Alexander Mitchell in 1830-ies (Figure 1). The technique becomes more and more popular because of the ease of installation, low environmental impact and quite reduced cost compared to other types of deep foundations, such as bored piles (Figure 2). Ground screws are similar to helical piles, but in place of a helix they have a thread that goes up higher and their tip is generally longer (Figure 3).

Figure 1: Galvanized screw piles.

Figure 2: Installation of ground screws using a 20 tons excavator.

Figure 3: Galvanized ground screws.

Geometrical data

We were comparing helical piles and ground (Table 1) screws of following parameters. Both, the helical pile as well as the ground screw, were made of S355 carbon steel. Compared to the ground, we consider them as incompressible (Figure 4). We made the helical pile and the ground screw so that the helix/thread area is the same in both cases (Table 2).

Table 1:

	Helical Pile (FERROPIEUX)	GroundScrew (GEOVIS)
Shaft Diameter (mm)	76.1	76.1
Shaft Length (m)	1.5	1.5
Helix/Thread Diameter (mm)	250	90
Pitch (mm)	70	70

Table 2:

Helical pile helix area (S_{hp}) (m^2)	Ground screw thread area (S_{gs}) (m^2)
0,04908739 (420 degrees helix)	0,0501938 (8 steps thread)

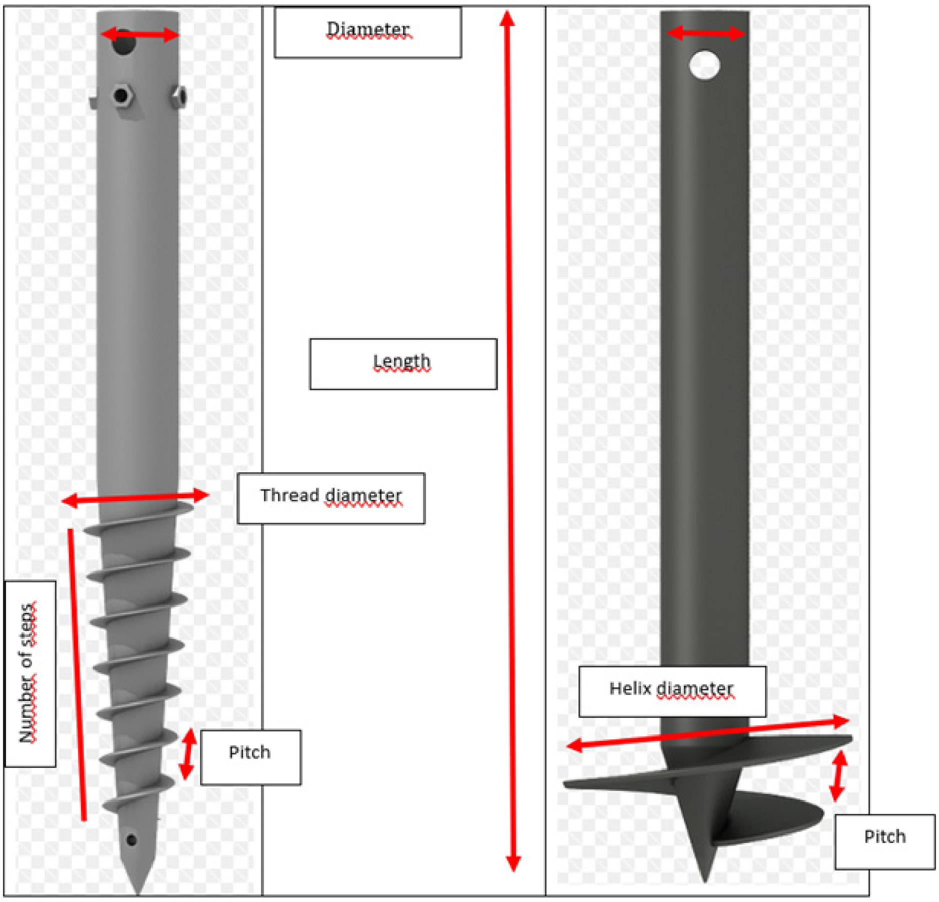


Figure 4:

Geotechnical data

The tests were carried out in November 2023 on the SNCF (French railroad) site at Cubzac-les-Ponts (France), where the soil composition was the following (Table 3). Helical piles and ground screws were installed in the soil on the depth of 1400 mm, so the entire thread and the entire helix remain in the anchoring horizon (Figure 5), which is the clay (Figure 6).

Experimentation procedure

Table 3: Geotechnical properties of the ground where experimentation was carried out.

Horizon	Soil Type	Plasticity Factor of Clay Soils	Index of Porosity	Cohesion (T/ m^2)	Internal Friction Angle φ°	Density γ (T/ m^3)	Depth h (m)
1	Backfilling	-	-	0	-	1.75	0.7
2	Clay	0.68	0.65	0	28°	1.8	>0.7

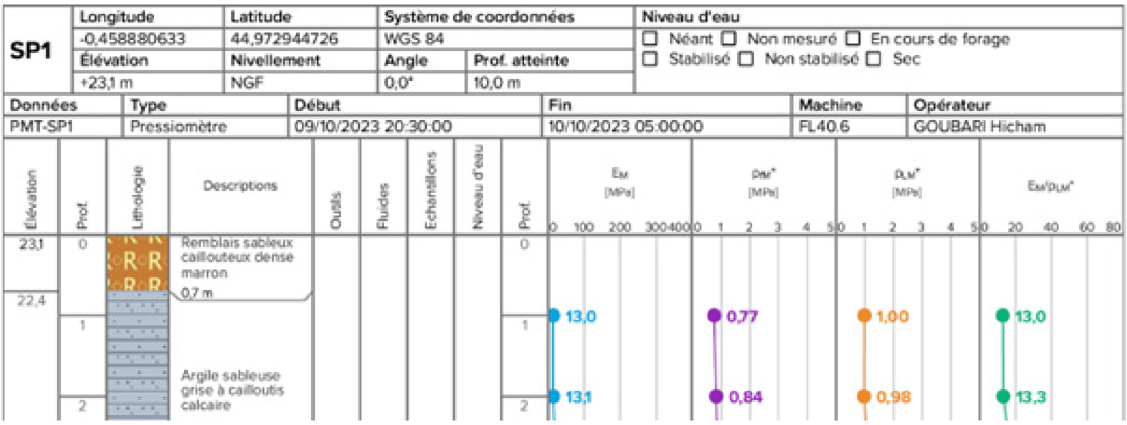


Figure 5: Extract of the geotechnical survey with ground data.

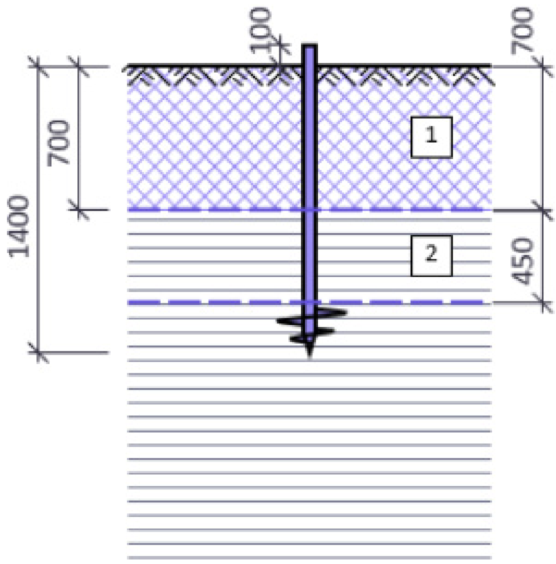


Figure 6: Scheme of installation of helical piles and ground screws in the soil.

The experimentation was carried out following way, similar to the French norm NF P 94-262 requirements. Similar tests are described by Li [3]. Both ground screws are helical piles were installed by pairs. Using the dead weight from the excavator, step by step loads from 100kg to the break load (that will be given further) were applied as axial compression by vertical Z axis using the scaled jack system Enerpac. The load was applied to the tested pile or screw by steps of 100kg, each one was lasting 30 minutes (Figure 7). After 30 minutes, the load was released to 0 and then the next load was applied (Table 4). The loading stages as well as displacement, are given in the Table 4 below (Figure 8). The results can be generalized under the following graphics, that show the load-displacement curves for helical pile and ground screw (Figure 9). We can notice following details:

Table 4: Displacements of the pile under compression load for helical pile and ground screw.

Step	Load (kg)	Displacement (mm)	
		Helical Pile	Ground Screw
1	100	0,3	0,32
2	200	0,6	0,72
3	300	0,95	1,3
4	400	1,27	1,8
5	500	1,49	2,35
6	600	1,83	2,9
7	700	2,24	3,5

8	800	2,59	4,21
9	900	2,93	4,73
10	1000	3,41	5,49
11	1100	3,75	6,01
12	1200	4,32	6,69
13	1300	4,82	7,52
14	1400	5,5	8,25
15	1500	6,26	8,84
16	1600	6,91	9,79
17	1700	7,85	10,3
18	1800	8,62	11,23
19	1900	9,77	12,03
20	2000	10,55	13,01
21	2100	11,5	14,3
22	2200	12,32	15,9
23	2300	13,31	17,2
24	2400	14,6	19,6
25	2500	15,5	21,4

Figure 7: Ground screw GEOVIS before installation..

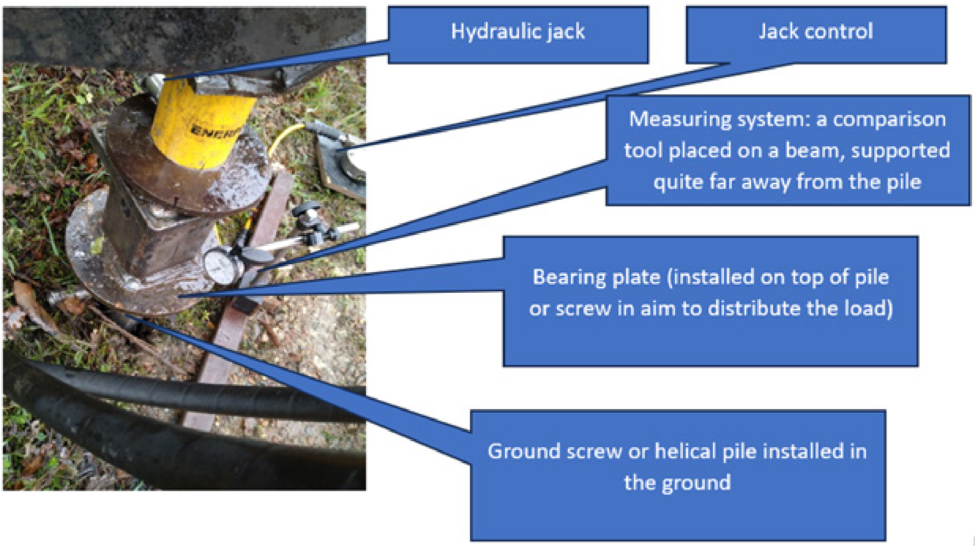


Figure 8: Scheme of the test installation

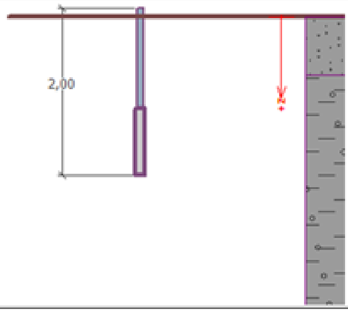
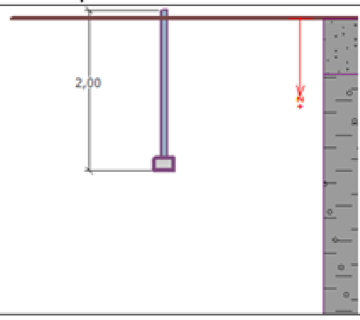
Parameter	Ground screw	Helical pile
Model definition		
Shaft diameter (mm)	76.1	76.1
Helix/thread diameter (mm)	90	120 – 180 - 250
Helix/thread steps number (Number)	2 – 3 – 4 – 6 – 8	1

Figure 9:

a) The ground screw behavior under load is linear since the ground elasticity limit at near the load of 1600kg stays completely linear. This behavior is similar to any friction pile type (such as micropiles, for example). Then the displacement under load becomes polynomial.

b) The helical pile behavior is polynomial in the beginning, until the ground elasticity limit near the load of 1600kg, then becomes linear (as a behavior of a viscous media).

c) As the failure criterium for piles, according to Eurocodes and to specific norms for helical piles, such as the Technical Agreement 3.3/21-1044_V1 [CSTB 2021] is a 10mm displacement, the helical pile fails at 2000kg, however, the ground screw fails at 1600kg.

In general, these results comply well with Meng [4]. So, the trendlines for both datasets (Table 5). We notice that the polynomials are of the same order, however, the ground screw load-displacement diagram increases 1.5 times faster.

Table 5:

Helical Pile	$y = 2E\text{-}06x^2 + 0.0007x + 0.4855$
Ground Screw	$y = 2E\text{-}06x^2 + 0.0021x + 0.6215$

Modeling

In aim to understand the behavior of ground screws compared to the helical piles, we established a model using UC3MLib software v03 (http://geoia.fr, 22/01/2024), which is a meshfree tool designed to simulate the behavior of helical piles and ground screws in the given soil [5].

Two models are studied and compared:

a) Model of a helical pile, with variable helix diameter.

b) Model of a ground screw, with the thread of 2, 4, 6 steps.

Then both models are compared, in aim to find a correspondence between helical pile and ground screw behavior.

Model definition: The ground is modelled as a parallelepiped with dimensions of X= 1m, Y=1m, Z=3m, with the pile centered in X=0.5, Y=0.5, Z=0. The calculation grid is composed of 7,50,000 equi-distributed nodes. Pile and screw models are defined as following (Figure 10).

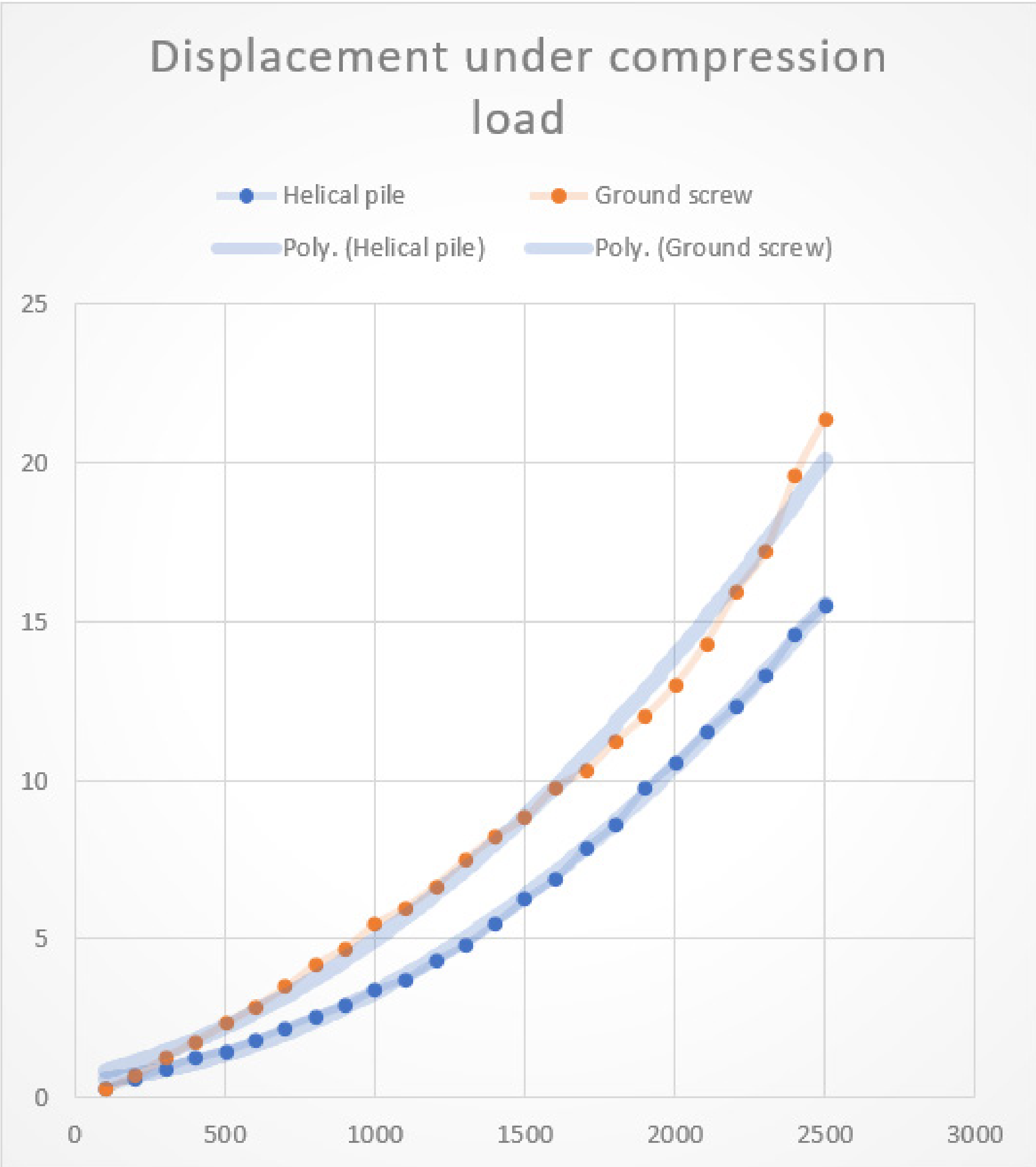


Figure 10: Load-displacement diagrams for helical pile and ground screw with polynomial trendlines.

Ground screw model: Modeling the ground screw with 2, 3, 4, 6 and 8 thread steps we obtain the following load (Figure 11) displacement diagram (Table 6). We notice that the displacement under load of the piles with 4, 6 and 8 threads are mostly the same for equal load values, basing us on Brown [6]. These results correspond to a study carried out by Wang [7].

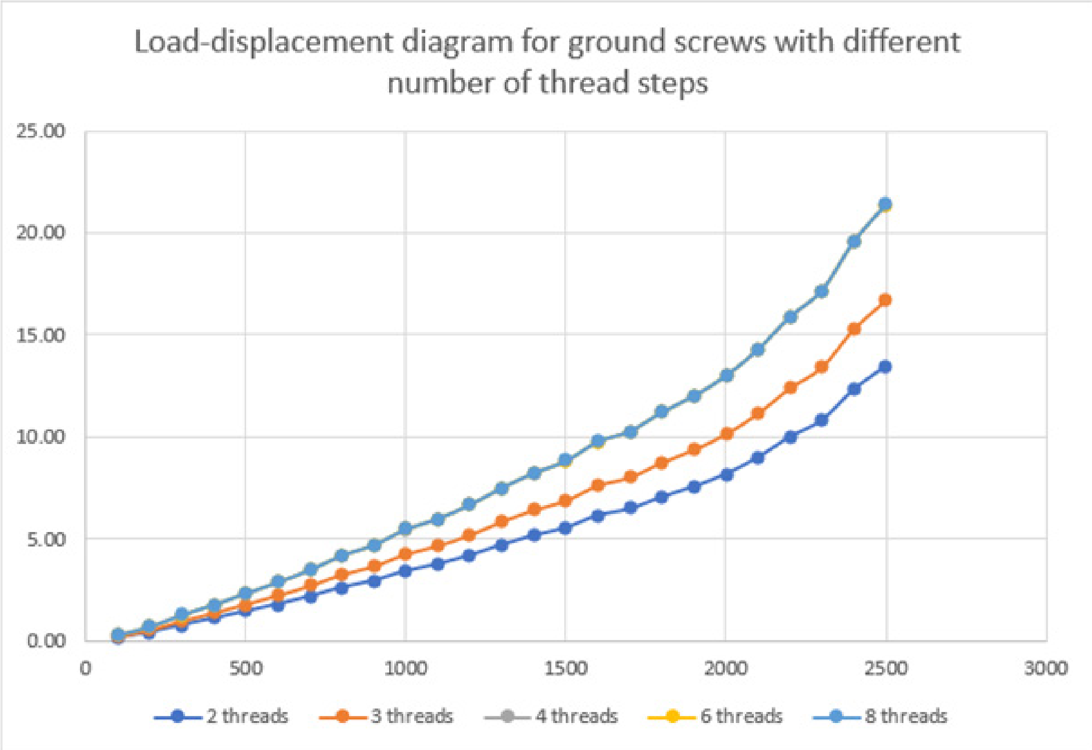


Figure 11: Load-displacement diagram of the ground screws with different number of thread steps.

Table 6: Load-displacement table for ground screws with different number of thread steps.

Load (kg)	Number of Thread Steps on the Ground Screw				
	2 Threads	3 Threads	4 Threads	6 Threads	8 Threads
	Displacement (mm)				
100	0,19	0,24	0,309	0,311	0,32
200	0,45	0,55	0,709	0,711	0,72
300	0,81	1,01	1,289	1,291	1,3
400	1,13	1,40	1,789	1,791	1,8
500	1,47	1,82	2,339	2,341	2,35
600	1,82	2,25	2,889	2,891	2,9
700	2,20	2,72	3,489	3,491	3,5
800	2,65	3,28	4,199	4,201	4,21
900	2,97	3,68	4,719	4,721	4,73
1000	3,45	4,27	5,479	5,481	5,49
1100	3,78	4,68	5,999	6,001	6,01
1200	4,21	5,21	6,679	6,681	6,69
1300	4,73	5,86	7,509	7,511	7,52
1400	5,19	6,43	8,239	8,241	8,25
1500	5,56	6,89	8,829	8,831	8,84
1600	6,16	7,63	9,779	9,781	9,79
1700	6,48	8,03	10,289	10,291	10,3
1800	7,07	8,75	11,219	11,221	11,23
1900	7,57	9,37	12,019	12,021	12,03
2000	8,19	10,14	12,999	13,001	13,01
2100	9,00	11,15	14,289	14,291	14,3

2200	10,01	12,39	15,889	15,891	15,9
2300	10,83	13,41	17,189	17,191	17,2
2400	12,34	15,28	19,589	19,591	19,6
2500	13,48	16,68	21,389	21,391	21,4

Helical piles model: Modeling the helical pile we try, varying the helix diameter, to find the diameter of helix D_{hel}, that gives to the helical pile the bearing capacity equal to the tested (Table 7) ground screw (with 8 thread steps). We notice that the results, closest to the tested ground screw, are obtained with the helical pile with the helix diameter of 127 mm. Thus, we can consider that in this particular case the value of D_{hel} = 127mm. Doing other similar tests with different diameters of shafts, helices and threads, we obtain that the bearing capacity of a helical pile is equal to the bearing capacity of a ground screw of the same diameter, if:

Table 7: Load-displacement diagram of helical piles with different helix diameter.

Load	Helical Pile Helix Diameter (mm)			
	120	127	180	250
	Displacement (mm)			
100	2,50	0,32	0,31	0,3
200	5,00	0,71	0,62	0,6
300	7,92	1,28	0,99	0,95
400	10,58	1,79	1,32	1,27
500	12,42	2,36	1,55	1,49
600	15,25	2,93	1,90	1,83
700	18,67	3,52	2,33	2,24
800	21,58	4,21	2,69	2,59
900	24,42	4,73	3,04	2,93
1000	28,42	5,49	3,54	3,41
1100	31,25	6,01	3,89	3,75
1200	36,00	6,69	4,48	4,32
1300	40,17	7,52	5,00	4,82
1400	45,83	8,25	5,71	5,5
1500	52,17	8,84	6,50	6,26
1600	57,58	9,79	7,17	6,91
1700	65,42	10,3	8,15	7,85
1800	71,83	11,23	8,95	8,62
1900	81,42	12,03	10,14	9,77
2000	87,92	13,01	10,95	10,55
2100	95,83	14,3	11,94	11,5
2200	102,67	15,9	12,79	12,32
2300	110,92	17,2	13,82	13,31
2400	121,67	19,6	15,15	14,6
2500	129,17	21,4	16,09	15,5

Where,

D_{hel} is the diameter of helix of the helical pile

D_{thread} is the diameter of the thread of the ground screw of corresponding diameter.

However, these results are comparable to the results of Zhou [8], that suggest a theorical model of necessary torque of installing a pile into a clay soil. On the other hand, the model of Clemence and Hoyt [9] in this particular case turns out to be very close to the results encountered, as well as [10].

Conclusion

Thus, we conclude following aspects of dimensioning of ground screw by their bearing capacity in clay soils [11,12]:

a) Ground screws bearing capacity is higher than the bearing capacity of a ground screw of the same diameter,

b) Past 4 thread steps, the bearing capacity of ground screw remain the same,

c) To make a helical pile with the bearing capacity equivalent to that of the ground screw of the same diameter, he diameter of the helix must be reduced by square root of 2 times.

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