How Many Piers?

By Gary Collins, P.E.

A clear-cut guide to helical pier spacing

Introduction

Helical pier spacing is not an exact science. How many does it take to support a structure adequately or repair a settling foundation? Every 5 feet or perhaps every 8 feet as some suggest for a residence? Moreover, if these distances are standard practice, how much of a safety factor is there?

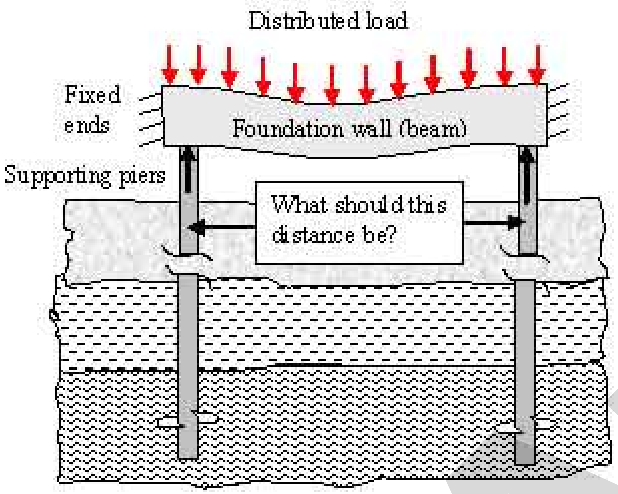

Figure 1. Foundation wall (beam) and support piers in soil

The answer depends on the supporting soil, the weight of the structure, the size of the foundation wall, and whether it's a repair job or new structure. In addition, there are safety factors to be added depending on the condition of the structure and the potential damage to people and property if a structure fails. A hospital or school needs a larger safety margin than a residence.

The contractor that is installing piers to repair a simple settling deck or house corner often does not need an engineer. Codes differ. For the installer who needs good guidelines, what can he use to find an answer? This article aims to help fill that need by giving some guidelines and charts that are simple and yet structurally safe. [1] The reader is also referred to very fine articles related to loads and spacing at the Helical Pier World website:www.helicalpierworld.com/engineering. [2]

Approach

The approach is very straightforward. Pier spacing is governed by four things:

- The load the soil can take
- The load the pier can take
- The load the foundation wall can take.
- The maximum allowable settlement the structure can take.

1. The load the soil can take

Starting with the load the soil can take, a report on the soil down to bedrock must be made. With this in hand, full knowledge of the underlying load bearing capacity is revealed. It's a simple matter, then, of dividing the weight of the structure by the number of piers such that each pier carries less than allowable load on the soil. For this article's examples, load bearing values given by the following table will be assumed.

Table 1. Presumptive load-bearing values of foundation materials[3]

Class of material	Load-bearing pressure (pounds per square foot)
Crystalline bedrock	12,000
Sedimentary and foliated rock	4,000
Sandy gravel and/or gravel (GW and GP)	3,000
Sand, silty sand, clayey sand, silty gravel and clayey gravel (SW, SP, SM, SC, GM and GC)	2,000
Clay, sandy clay, silty clay, clayey silt, silt and sandy silt (CI, ML, MH and CH)	1,500

Using the crystalline bedrock value of 12,000 psf bearing capacity, three structural examples will be used: a one, two, and three story structure which could be a residence, a condo, or an apartment. The size will be 60 ft x 40 ft for a total of 2400 sq ft. per floor. Assume brick veneer and a 9 ft high foundation wall 8 inches thick and 9 ft high.

The single story structure

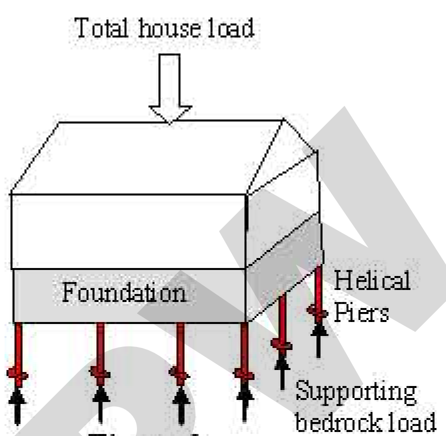

Figure 2

The weight on the piers is the total weight of the structure divided by the number of piers.
For total load assume:

- - Roof snow load of 40 psf snow load (code in Boulder CO),
- - 10 psf roof structure and 40 psf first floor [4]

- Brick veneer 9' high is 315 lbs/lineal ft.

The *house* load per square foot is the snow load + roof structure + first floor structure = 40+10+40=90 psf.

The total house load will therefore be 90 lb/sq ft x 2400 sq ft = 216,000 lbs. This will be divided ¾ on the outer foundation and ¼ on inner supports. Doing the math, the load of the house bearing on the foundation = 810 lbs/lineal ft.

The above are the loads *without* brick veneer or the load of the concrete foundation walls. Add to this 315 lbs/lineal ft of brick veneer and 900 lb/lineal ft of concrete[5] foundation wall. Then brick +foundation +house=2025 lbs/lineal ft of supported by piers. For a 200 ft perimeter, the load = 405,000 lbs. This must be divided among the piers.

The goal is to get the loading on each pier down below 12,000 psf/pier, the maximum the soil can carry according to Table 1. Assuming each pier has a bearing area of 1.6 sq ft (two helices of 12" diameter each), there must be a minimum of 405,000 lbs/12,000 psf divided by 1.6 ft^2/pier, or 21 piers around the perimeter. For a safety factor of 2, there should be 42 piers.

40 piers fit into an even spacing on the 60 ft side and the 40 ft side of 5 ft between piers. Each pier is loaded with 10,125 lbs over 1.6 sq ft of helix, or 6449 psf on the soil, giving a safety factor of 1.9.

The two story structure

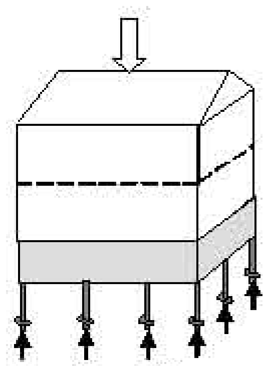

Figure 3

The difference compared to example 1 is that there is a second floor and twice the height of brick veneer. To maintain a pier spacing of 5 ft, use two helices of 12" diameter. After doing the mathematics, the load would be 13,500 lbs for each pier. This gives a bearing load on the soil of 8600 psf, giving a safety factor of 1.4.

The brick veneer is very heavy, weighing 315 lbs per lineal foot for each additional story. If the two stories of brick are removed from the load equation, the bearing load for each pier drops to 6600 psf, giving a safety factor of a little more than 1.8.

The three story structure

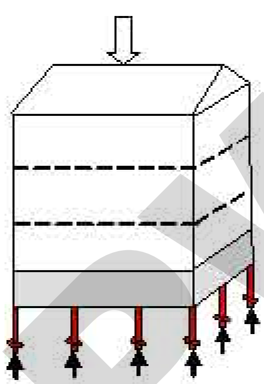

Figure 4

The brick veneer is much too heavy for the 3 story structure to be supported by two 12" dia pier helices with any reasonable spacing. Removing the brick from the load equation and maintaining a 5 ft spacing as above, the load on the soil is 7740 psf, giving a safety factor of 1.6

2. The Load the pier can take

Turning to the second item, the load the pier can take, the type of loading must be considered. It is *torque loading* while the pier is being installed. It is *axial compressive loading*once the pier is installed and the load is put on it.

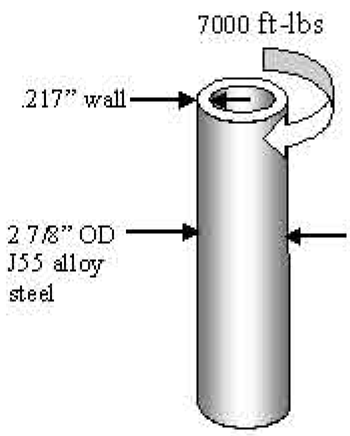

Figure 5

For torque, typical values for Colorado bentonite are 7000 ft-lbs for an 8" diameter helix. Calculations show that the resulting shear stress in the torque tube is less than 9000 psi (allowable is 18,000 psi). This gives a safety factor of 2.

For compressive loading, the above illustrations show this can range from 10,000 to 15,000 lbs per pier. The resulting compressive stress is about 15,900 psi (with an allowable stress in J55 alloy of 55,000 psi). This gives a safety factor over 3. If a larger factor is needed, simply increase the wall thickness.

Buckling due to compressive load or knotting due to torque is not a problem since the soil usually provides adequate enclosure restraint for both. If the intermediate soil is soft, sheathing with pull-down micropiles is a possibility.[6]

3. The load the foundation can take

The third consideration, the foundation load is the most complex to calculate but the least to matter because the loads prove to be insignificant. It is illustrated by Figure 1 and Figure 6, where the distributed load together with fixed supports at the ends causes the beam to bend in the manner shown.

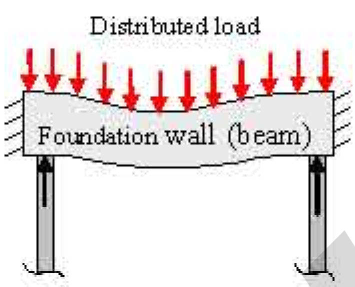

Figure 6

Calculations show that the maximum bending stress is not in the middle; it is at each support and amounts to only 4 psi. Moreover, putting two rows of rebar in the upper and lower sections of the foundation wall does not reduce the stress at all. This is because the concrete wall area is so massive compared to the small area of the #5 rebar (5/8" diameter) that the rebar contributes essentially nothing to the strength. It only holds the concrete together when it cracks.

4. The settlement the structure can take

This is specified by the structural engineer. It is usually in the order of ¼" (6 mm). This can be designed for and is dependent on the safety factor, that is, the ultimate load/design load that the pier can take. These methods are described in the Department of Transport's publication FHWA-IF-99-02 on page 290.

Conclusion

From the above, it is clear that of the four elements, soil load, pier load, the foundation load, and the structural settling, the most important by far is the soil load. Pier spacing needs to be governed by that.

If the pier *column* load and overstressing is of some concern, the safety factor can be increased by simply increasing the column wall thickness. As for the foundation load, it is not a concern because of the very small stresses.

Table 2, Summary Table.

Pier spacing in crystalline bedrock for various loads and pier geometries with the safety factor shown

	2-7/8" pier, one	**2-7/8" pier, one**	**2-7/8" pier, twin**	**2-7/8" pier, twin**

	10” dia. helix	12” dia. helix	10” dia. helix	12” dia. helix
Conventional light frame residential construction, no brick veneer				
1 story	4 ft, sf =1.0	5 f sf =1.1	8 ft, sf =1.0	8 ft, sf =1.4
2 story	3 ft, sf =1.0	4 ft, sf =1.1	5 ft, sf =1.3	5 ft, sf =1.8
3 story	2 ft, sf =1.3	4 ft, sf =1.0	5 ft, sf =1.1	5 ft, sf =1.6
4” brick veneer over light frame residential construction				
1 story	3 ft, sf =1.1	4 ft, sf =1.2	5 ft, sf =1.3	5 ft , sf =1.9
2 story	2.5 ft, sf =1.0	3 ft, sf =1.2	4 ft, sf =1.2	5 ft, sf =1.4
3 story	2.0 ft sf =1.0	4 ft. sf =1.0	5 ft, sf =1.1	5 ft, sf =1.6

As an example, if a builder was designing a 1 story house with brick veneer and wanted 5 ft between piers, he should choose a 2 7/8” diameter pier with twin 10” diameter helices. The safety factor with this would be 1.3.

Some engineers feel this table is too conservative and that the spacing is too close. They point out that the IRC load bearing values (Table 1) are conservative to begin with. In addition, the load bearing calculations must include soil resistive friction on the shaft and an expanded bearing area for the helix several diameters down, Figure 7. This all adds up to a safety factor of at least 3 over the numbers in Table 2. That is, one could use 3 times the spacing shown, or choose the spacing shown with a safety factor of 3 times greater.

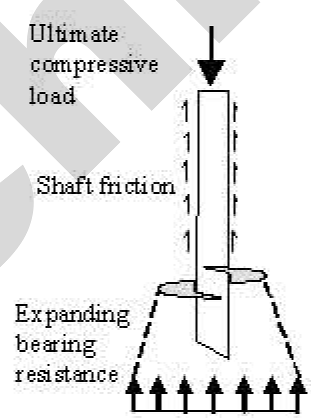

Figure 7. Friction and expanded loading

The above table can also be extended to include different pier geometries and different soil conditions. It is meant only as a guide to help the estimator plan the job. If there are additional questions about it, an engineer should be consulted.

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[1] These are only guidelines for estimating the job. The contactor should consult a professional engineer if there is question about any aspect of loading, beam size, materials, or reinforcement.
[2] Perko, Howard, *Installation Torque as a Predictor of Helical Pier Axial Capacity*. Also see Sieder, Gary, *What an Engineer Needs to Know*.
[3] Table R401.4.1, 2003 International Residential Code, page 61
[4] 2003 International Building Code, page 275
[5] A density of 150/cu ft is used
[6] See illustrations at websites such as:http://www.hubbellpowersystems.com/powertest/transmission/TNN_transmission/July01_7-9.pdf