Helical Piers in Frozen Ground

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Introduction

Helical piers create a light weight-foundation that can be used either in compression or tension. They may be classified as micro piles due to their small diameter and the fact that they may be installed in restricted areas using small equipment. Due to their light weight, ease of installation and little ground disturbance they are becoming very popular in remote building sites such as arctic villages in Alaska (Figures 1 and 2). Conditions in these places include often permanently frozen soils, which changes the dictating design criteria from bearing capacity and consolidation settlement to creep settlement. Current design methods are not suitable for helical piers in frozen ground, which limits their use. Therefore, Alaska Science and Technology Foundation (ASTF) is funding a research to develop guidelines for design of helical piers in frozen ground. This paper introduces the helical piers, their installation in frozen ground, and the new research in the University of Alaska Anchorage (UAA).

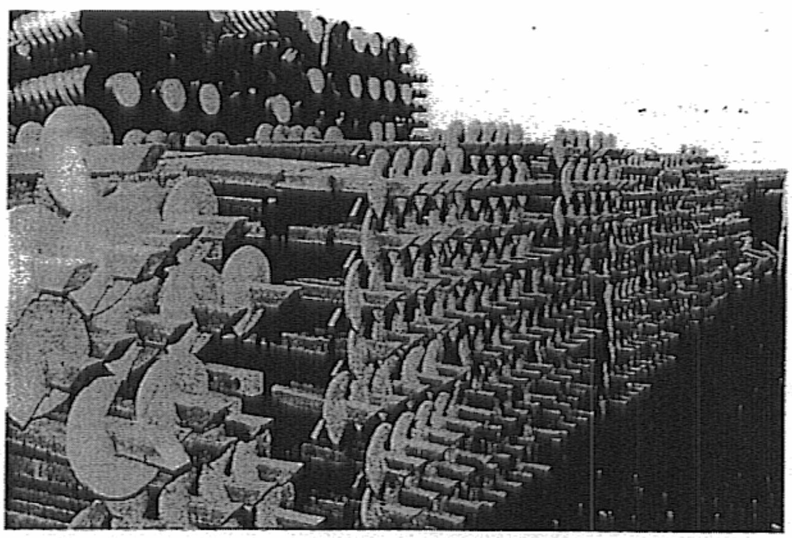

Figure 1. Helical Pier Stockpile in St. Helens, Alaska

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Figure 2.Insignificant Ground Disturbance

Helical Piers

The helical piers come in many shapes and sizes. Typically they consist of a central shaft that is made from square or round sections that can be either solid or hollow. To this shaft is connected from 1 to 4 spiral plates (Figure 3) that are designed to mobilize more soil under normal loading conditions than a conventional pile.

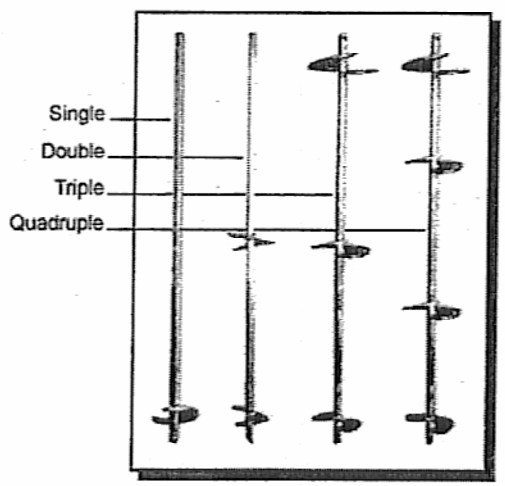

Figure 3. Helical Pier Lead Sections.

Applications

The helical piers are used for a variety of applications. In compression, they are used as building foundations for new structures, underpins for existing structures and as support for boardwalks, utilidors, fence posts, light posts etc. In tension, the helical piers, often called helical anchors, are used as soil anchors for retaining walls, and to resist wind loads for tall structures.

In Figure 4, the utilidors in Selewik, Alaska, are founded on helical piers, but the boardwalk is still waiting for upgrading. The helical piers are also great in resisting the "pile jacking" that is occurred to the old boardwalk in Figure 4.

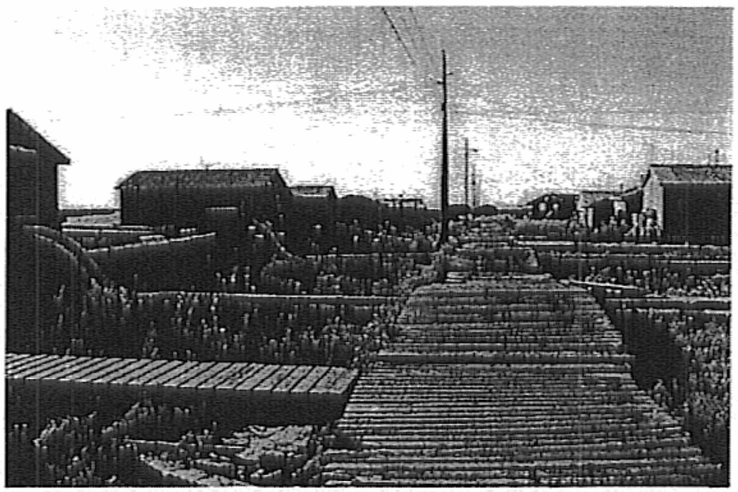

Figure 4. Typical Uses for Helical Piers: Boardwalks and Utilidors

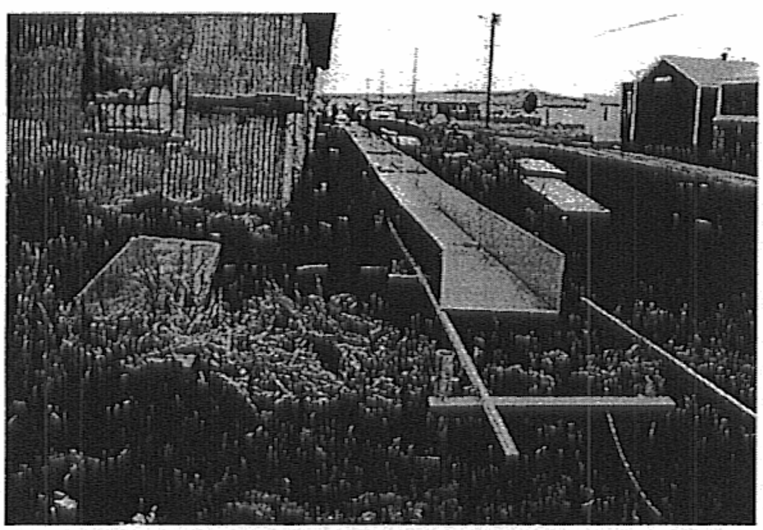

Figure 5. Utilidor under Construction in St. Helens, Alaska

Installation

Helical piers are installed by applying a torque on the pier shaft. The pier then augers itself to the ground. On frozen ground, additional vertical pressure may be required. If the piers are installed in a very cold ice rich permafrost, a 2-in. diameter pilot hole may also be required.

Design Methods

Current design method for determining the capacity of helical piers in thawed soils is based on bearing capacity equation. According to Ladanyi and Johnson[3], it is not appropriate to analyze deep circular foundations in frozen soils on the basis of Prandtl-type bearing capacity equation and separate settlement analysis using Boussinesq's stress-distribution theory and compressibility of soil. In frozen soil, the temperature and undrained creep become predominant in the determination of allowable foundation pressures. Therefore, Ladanyi and Johnson developed an alternative method for predicting the time and temperature dependent creep settlement and the bearing capacity of frozen soil under deep circular loads. The method based on the cavity expansion method is not very user friendly, and therefore there is still room for another design tool.

The purpose of the project at the UAA is to develop a finite element model (FEM) that will be used to analyze existing pier configurations and to create design curves with different soil temperatures and soil properties. The finite model will be evaluated by conducting a full-scale test at the US Army Corps of Engineers Cold Regions Research and Engineering Laboratory (CRREL) in Hanover, NH.

The following are the main objectives of this analysis. 1) Large Model: This model will analyze the soil stresses and displacements immediately after the pier is subjected to its design load. This data is also critical for the development of more detailed analysis using sub-modeling techniques. 2) Small Model: The small model is a sub model of the large model. It will analyze the stresses developed within the spiral structure by using results from the large model analysis. 3) Installation Failure Model: A detailed model of the spiral structure subjected to a torsional load during installation will provide insight into the failure mechanism of helical piers during construction. 4) Creep Model: Creep analysis will be conducted to determine the long-term displacement and soil stress in frozen ground.

Figures 6 to 8 gives an example of the stresses and deformations in the pier itself and the surrounding soil. The results will be used to create user-friendly design curves for foundation engineers, and may also be used to optimize the pier configurations.

Conclusions

Helical piers are versatile foundation elements that meet especially needs for cold regions and frozen ground. However, the finite element analysis shows that the traditional bearing capacity equations are not adequate design tools for helical piers with multiple helixes. New design guidelines will be published as an end result for this research.

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[3] Ladanyi, B., and Johnson, G.H., "Behavior of Circular Footings and Plate Anchors Embedded in Permafrost," Canadian Geotechnical Journal, Vol. 11, pages 531-553, 1974.

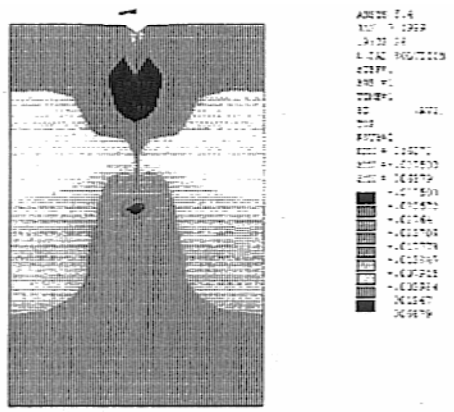

Figure 6. Vertical Stress Distribution in the Soil Volume[4]

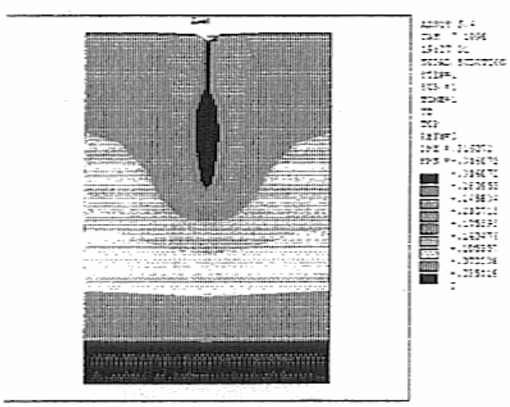

Figure 7. Vertical Displacement Distribution in Soil Volume[1]

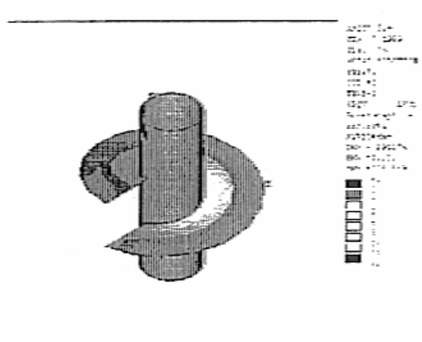

Figure 8. Von Mises Equivalent Stress on Spiral Structure[1]

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[4] Finite Element Modeling of Helical Piers in Frozen Ground, Proceedings of the Tenth International Conference on Cold Regions Engineering, Lincoln, NH, August 16-19, 1999