BLADE PILE AND METHOD FOR INCREASING THE BEARING STRENGTH OF PILE

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References Cited
UNITED STATES PATENTS
3,646,766 3/1972 Hilton et al. 61/53.64
FOREIGN PATENTS OR APPLICATIONS
428,202 9/1926 Germany 61/53.5

ABSTRACT

A pile and a method for increasing the bearing strength of a pile in which a pile having a helical, flexible blade is rotated or screwed into a pre-augered hole in the permafrost. Several embodiments are disclosed for reducing friction on the blade, by changing the shape of the blade or precutting a groove for the blade. Another embodiment of the method includes introducing a fill material between the surfaces of the blades and between the pile and the soil surrounding the pile and blades.

21 Claims, 10 Drawing Figures
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BLADE PILE AND METHOD FOR INCREASING THE BEARING STRENGTH OF PILE

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to an improved pile for use in permafrost and to a method for increasing the bearing strength of pile in permafrost soil.

2. Description of the Prior Art

U.S. Pat. No. 3,217,791 discloses a pile suitable for use in arctic soils which remain substantially frozen throughout the year. My U.S. Pat. application, Ser. No. 114,258, entitled "Method and Apparatus for Improving Bearing Strength of Piles in Permafrost," filed Feb. 10, 1971, now U.S. Pat. No. 3,706,204 discloses a pile having rings secured to the lower portion of the pile. The pile is inserted into a hole with the ringed portion of the pile being confined to the permanently frozen region of the hole. The hole is pre-augered to a diameter exceeding the diameter of the rings with the interspace between pile and hole filled by a suitable slurry backfill. In some installations, the specialized type of equipment required to handle the slurry backfill is not available. In some cases, suitable materials for the backfill are also either not available or because of sub-freezing temperatures are difficult to store. As a result backfilling techniques have limitations for use in many regions of the arctic.

SUMMARY OF THE INVENTION

It is an object of this invention to provide a method of increasing the available bearing strength of permafrost soil by the use of a pile which is screwed into a pre-augered hole in the permafrost soil.

It is another object of this invention to provide a method of improving the available bearing strength of permafrost soil at locations where backfill techniques are impractical.

It is an object of this invention to provide a unique pile which distributes the stress acting on the soil surrounding the pile substantially uniformly throughout the length of the pile.

It is another object of this invention to provide a pile having a radially extending flexible spiral blade.

Basically these objects are obtained firstly by providing a pile having a spiral blade which may with conventional equipment be screwed into a hole in the permafrost that is preaugered to a diameter less than the major diameter of the blade. Secondly uniform distribution of the stress along the length of the pile is obtained by using flexible members extending outwardly from the pile so that limited strain is permitted at the uppermost members without failing the surrounding soil. The flexible members can be rings or segments of rings as in my earlier application Ser. No. 114,258, a spiral blade as in the present invention, or any other suitable radial extensions of the pile. Preferably, a combined flexible spiral blade provides the maximum advantages.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a sectional view in a permafrost soil illustrating a preferred form of bladed pile embodying the principles of this invention.

FIG. 2 is a fragmentary section illustrating a preferred form of spiral blade.

FIGS. 3-5 illustrate alternate forms of cutting or forming blades to pre-cut a groove in the soil. FIG. 6 illustrates an alternative form of blade. FIG. 7 illustrates a typical stress strain curve for idealized frozen soil. FIGS. 8 and 9 are charts showing a comparison of stress versus depth of conventional pile and pile embodying the principles of this invention. FIGS. 10A-10D are schematic illustrations of one method of installing bladed pile.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 illustrates a typical pile installation for use with this invention. A pile 10 which may be solid, hollow, primarily solid with an axial bore for permitting flow of liquids to the bottom of the pile, or hollow pile of the type used to remove heat from the permanently frozen region of the soil, such as the thermopile illustrated in my prior patent No. 3,217,791 and shown herein as the preferred embodiment. The thermopile illustrated is provided with longitudinal heat distributing fins 12 and a sealed internal pressure pipe or vessel 14 which contains a heat transferring liquid of a type described in said patent. The pile is constructed to support a beam or other structural member 16. In accordance with the teachings of this invention, the pile is provided with spiral blade or fin 18. Preferably the blade is limited to a lower portion of the pile which is inserted below the generally defined top level 19a of the permanently frozen region 19 of the soil surrounding a pre-augered hole 20. As in said earlier patent application, Ser. No. 114,258, the preferred form of pile does not have a blade in the seasonal-thaw area above the permafrost so that jacking forces due to thawing are reduced. The pre-augered or otherwise formed hole 20 is of a diameter greater than the diameter of the pile 10 but less than the major diameter of the blade 18 so that the blade 18 must cut into the soil surrounding the hole.

The blade 18 can be welded or otherwise secured to the pipe 14 along a spiral in a manner similar to a screw thread. Preferred designs range from 4 gauge to as thin as 16 gauge, possibly even to 25 gauge. The required thickness of the blade, however, is partially controlled by the radial extent or "height" of the blade away from the pipe. The greater this dimension, the thicker the blade must be for a specifically designed unit stress. It is a unique feature of this invention, however, that some flexure occurs and is actually desired to improve the loading on the pile. One of the basic problems in soil, and particularly in frozen soil, is the fact that very little strain of the frictional surface, i.e., the soil surface at which failure occurs, is required to build up a failure stress. This is best shown in FIG. 7. As illustrated in the stress-strain diagram, little movement of the surface of the pile is required to exceed the ultimate shearing stress of the soil to result in failure. In fact, compression, that is reduction in length, of the pile under loading can actually exceed the strain required for failure. This is best illustrated in the diagrams of FIG. 8. Point U1 indicates the first ultimate failure point on a stress distribution curve during initial loading of the pile. As can be seen, it occurs at the uppermost region of the soil. The stress distribution is indicated by the curve E1 with Y1 indicating the yield zone of the soil. It can thus be seen that stress occurs on the soil surrounding the
pile at its maximum near the top of the pile and at its minimum a substantial distance up from the bottom of the pile. That is, the lowermost regions of the pile during initial loading of a conventional pile do not stress the surrounding soil to any appreciable extent at all—rather all of the stress is born by the soil near the top of the pile. After failure of the soil and subsequent loading, the stress distribution occurs lower along the pile as indicated by curve E2, Y2, and U2. If the pile is again loaded to its ultimate at point U2, the soil will again fail. Subsequent loadings are indicated on curves E3, Y3, U3 and curves E4, Y4 and U4 indicating in each case that the stress distribution along the pile becomes lower along the pile for each subsequent loading. As is apparent from these curves, the frictional resistance to resist failure of the soil is limited to a region less than the entire length of the pile, substantially reducing the bearing capacity of the pile. For this reason, most of the strain during initial loading generally is assumed by the upper layers of the soil and in longer piles it is necessary to fail the upper layers of soil before the lower layers of soil can assume any loading.

Using a flexible blade either of a spiral type as in this application, or non-spiral rings as in my prior application, Ser. No. 114,258, the pile is free to move downward as it is compressed with less movement of the tip of the blade so that the tip of the blade stays below the yield stress of the soil to prevent failure. This means that the average overall stress of the total depth of the pile can be greatly increased by obtaining a more uniform loading from the top to the bottom of the pile. Such a stress distribution for the flexible blade is illustrated in FIG. 9 which illustrates that the soil even at the bottom of the flexible bladed pile is subjected to stress during initial loading. The flexure of the blade is, of course, limited to some extent by the frozen soil between the blade. Stated differently, the upper portions of the pile are still loaded first, as in conventional pile, however, in the bladed pile, this means only a temporary higher stress condition followed by creep and strain of the soil in contact with and along side the blade then followed by bending of the blade. The maximum bending of blade occurs at the upper limits of the pile and the least bending at the lower limits of the pile. The degree of flexibility or stress strain characteristics of the blade tip will be a function of the thickness of the blade, the height of the blade, and the type of material used.

The stress, height (radial) and strain characteristics of the blade can be further modified by the use of a laterally tapered fin as illustrated in FIG. 6, as well as by the spacing of the levels of the blade. The rapidity with which the blade deforms might also be altered by the presence of a void along the base of the blade such as where a slight oversized hole is provided for the pile or pipe, as shown in FIG. 1, and by using water, which is more plastic, or a bentonite soil, which freezes gradually over considerable differences in temperature, providing a more plastic base around the inner ends of the blade. Still another alternative method is to press-stress the rings downwardly by a short term pre-loading for an even greater load capacity.

It is thus seen that a flexible blade, whether spiral or non-spiral, provides advantages over any type of pile used in permafrost soil. It is also apparent that even a rigid spiral blade is uniquely advantageous for use with non backfill application. With a spiral blade, as mentioned earlier, the pile can be screwed into the ground in a pre-augered hole. The blade 18 only cuts the soil. The torque required for installation of the pile depends on the size and length of the pile as well as the blade spacing, height, and thickness. Where a void is left between the pile and the soil, this void can be filled with a water or slurry backfill if these materials are readily available. One technique for applying the backfill is to extrude it under pressure through a center tube such as 24 so that the slurry is forced upwards around the pile 10 between the blade 18. An alternative technique is to feed the fill material around the top of the pile between the blade at the contact with the surface of the soil as the pile is being rotated into the ground so that the fill material fills the space between the blade as the pile is lowered. Both of these techniques are presently usable with existing equipment.

One of the limitations on this type of spiral bladed pile is the torque required to rotate or screw into the ground. For a given pile size and length this torque is a function of friction. The friction is the function of the individual surface friction of any pile surface in contact with the soil and includes the blade surfaces, the angle of the blade, the degree of imbedment of the blade into the soil, the condition of the soil through which the blade is cutting, and any additional lubrication that results from ice in soil, thawing, water or other lubricant added. As the diameter of the blade gets larger, the torque from friction becomes more critical and there is a greater chance of the maximum torque exceeding that available from existing conventional pile rotating equipment.

Friction can be reduced by coating the surface of the pile and blade with a lubricant. For example, the pile may have a hydrophobic type lubricating surface or a corrosion limiting surface which could be applied with a material of lower friction value. On conventional piles, these types of low friction surfaces tend to reduce the bearing qualities of the pile and thus are a disadvantage. In the use of the bladed pile configuration, the low-friction coating does not reduce the bearing characteristics of the pile as the coatings are not along the surface of potential failure which occurs at the tips of the blades. Thus, by proper coating or other lubricating techniques, the torque requirement can be reduced without limiting the bearing characteristics of the pile.

The longitudinal radiation fins 12 shown in FIG. 1 are useful in transferring heat to the pile during drilling in warm seasons to thaw the permafrost and decrease friction. Heating to reduce friction of the permanently frozen region can also be applied by liquid carried down the pile through the center tube 24 while drilling. Vaporization of the thermopile fluids would then transfer heat to the colder portions of the pile which would include the blade. This tends to thaw the permafrost in direct contact with this blade which reduces the friction. Another technique is to apply heated air through the center tube allowing it to spiral up along the blade. The application of heated air or liquid through the center tube 24 has the added advantage of directly heating the blade surfaces and at the leading lower blades which do the initial cutting where friction reduction is most desired. In the case of a winter installation, if the unit were pre-pressurized as a thermopile there is a tendency for condensation to occur at the top rather than at the side. This can be countered in several ways dur-
ing installation: one is supplying heat down the center tube through the pressurizing fluid and two, by putting an insulated muf{ over the exposed portion of the pile.

Another technique for reducing friction is to use thicker blades such as the forming blades 30, 32 and 34 in FIGS. 3 - 5, respectively, at the lower end of the pile to act as a pilot so that there is less drag on the following spiral blade. In this technique the forming blades can have a sharpened edge to increase cutting efficiency. FIG. 3 indicates a forming blade 30 for cutting a groove substantially thicker than the pile blade 18. The blade is of substantially less height so that the tip of the pile blade still enters the soil in firm intimate contact therewith. In FIG. 4 the forming blade 32 is tapered and is of the same height as the pile blade 18. The taper converges to a thickness less than the thickness of the pile blade at its radial tip. In FIG. 5 a forming blade 34 is curved to a thickness less than that of pile blade 18 at the outer tip of the pile blade. The thicker forming blades at the lower end of the pile will act as a pilot so there will be less drag on the following spiral blade 18.

Alternately, in a particular problem condition, a special dummy pile can be used with extra strong blade of slightly less height and greater thickness and treated to have a lower frictional surface resistance where it might not otherwise be economically practical on the actual installed pile. Such a dummy pile is threaded into the hole and backed off and then the actual pile to be used in construction is inserted and screwed in the same groove with no actual loss in the bearing value. FIGS. 10A - 10D illustrate a typical example of a method following the technique of using a dummy pile. In FIG. 10A a borehole 40 is first augered to the desired depth. Next a dummy pile 42 is screwed into the hole 40 cutting a spiral groove 41 of an outer diameter and thickness corresponding to one of the forming blade shapes shown in FIGS. 3 - 5. Next the dummy pile is backed off and removed from the bore and finally a pile is threaded down into the bore with the blade 18 engaged with the soil in the grooves cut by the dummy pile.

While a preferred form of the apparatus and method for improving the bearing strength of permafrost soils has been illustrated and described, it should be understood that further alternative will be apparent to those skilled in the art without departing from the principles of the invention. Accordingly, the invention is not to be limited to the specific techniques described but rather is to be limited only by a literal interpretation of the claims appended hereto.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A pile for use in soil having a permanently frozen region and a seasonal-thaw region comprising a pile having a loading supporting upper end, means for securing a load bearing construction member to said upper end, said pile having a lower portion adapted to be placed in a hole in said permanently frozen region and having an outer spiral screw blade threadable into the soil surrounding said hole for increasing the shear strength between the pile and the surrounding soil.

2. The pile of claim 1 said spiral screw having a base secured to said pile and a radially outer relatively flexible but stress resisting body capable of withstanding a substantial bending load prior to yielding and then again withstanding a substantial further bending load after yielding wherein the stress on the soil surrounding the hole during loading is distributed along the entire length of the pile by allowing upper blades on the pile to deflect rather than shear the soil surrounding those blades.

3. The pile of claim 1 said spiral blade having a leading cutting edge at the bottom of the pile to reduce friction between the blade and the surrounding soil when screwing the pile into the soil.

4. The pile of claim 1 said blade having a friction reducing coating.

5. The method of increasing the bearing strength of a pile in soil having a permanently frozen region and a seasonal-thaw region of the type having an upper end secured to a load-bearing construction member, comprising providing a spiral blade on the pile on a lower portion thereof, forming a hole having a diameter greater than the diameter of the pile but less than the diameter of said spiral blade, and screwing said blade into the soil surrounding said hole whereby downward movement of said pile due to loads imposed on said construction member causes stress in the soil between and around said blade.

6. The method of claim 5 said step of screwing including the steps of first cutting a spiral groove in the soil of a diameter greater than the hole diameter, and second screwing the blade into the previously cut groove.

7. The method of claim 6 said blade being limited to the lower portion of the pile and said step of screwing including screwing the blade into the permanently frozen region of the soil with substantially all of the blade being below the seasonal thaw region.

8. The method of claim 5 including the step of adding a fill material to the hole as the blade is screwed into the ground.

9. The method of claim 7 wherein the fill material is added between adjacent blades as they are entering the hole.

10. The method of claim 7 wherein the fill material is forced up through the blade from the bottom of the hole.

11. The method of claim 5 said screwing step including heating the blade as it is rotated in the hole.

12. The method of claim 5 said blade being relatively flexible but capable of sustaining bending loads, and including the step of flexing the upper end of the blade by loading the pile downwardly for causing downward movement of the pile relative to the radially outer tip of the upper end of the blade to load the soil located axially downward of the upper end of the blade and thereby increase the stress of the soil around the lower end of the spiral blade.

13. The method of claim 12 including the step of pre-stressing the blade axially downward.

14. A pile for use in soils having permafrost and seasonal-thaw regions comprising a pile body having a load supporting upper end, means for securing a load bearing construction member to said upper end, said pile body having a plurality of flexible appendages radially extending over a substantial area from said body and engageable into said soil of said permafrost region, said flexible appendages being capable of withstanding a substantial bending load prior to yielding and then again withstanding a substantial further bending load.
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after yielding for allowing upper blades on the pile to deflect rather than shear the soil surrounding those upper blades to distribute the stress of the soil surrounding the pile body along more of the length of the pile body.

15. The pile of claim 14 said pile body having a lower portion insertable into the permafrost below said seasonal-thaw region and said side appendages being confined to said lower portion.

16. The pile of claim 14 said appendages being spirally arranged on said pile body and including a forming blade at the lower end of the pile body having a radially inner end for greater thickness along the length of the pile body then the remaining appendages but a radially outer end of less thickness along the length of the pile body than the remaining appendages at the outer end of the remaining appendages to act as a pilot and reduce friction between the soil and the appendages when the pile body is screwed into the soil.

17. The method of increasing the bearing strength of a load bearing pile of the type having an upper end secured to a load-bearing construction member and having a pile body and a plurality of load sustaining but flexible radially extending appendages secured to said pile body comprising forming a hole for receiving at least said pile body, inserting said pile body into said hole, and joining said appendages to soil surrounding said pile body, loading said pile to effect downward movement of said pile body, and flexing upper appendages to allow at least some further movement of said pile body without shearing the joined soil.

18. The method of claim 17 said appendages including an elongated continuous spiral blade, said step of forming a hole including forming the diameter of the hole less than the diameter of said spiral blade, said step of inserting the pile body into the hole including screwing the blade into the soil surrounding the hole.

19. The method of claim 18 said soil including a permanently frozen region below a seasonal-thaw region, said blade terminating upwardly below said seasonal-thaw region.

20. The method of claim 17 said hole having a diameter greater than said appendages, said step of joining the appendages to soil surrounding said pile body including filling the hole around and between said appendages.

21. The method of claim 20 said soil including a permanently frozen region below a seasonal-thaw region, said blade terminating upwardly below said seasonal-thaw region.

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