(54) Title: METHOD AND APPARATUS FOR DRIVING A SUPPORT STRUCTURE INTO A SOLID BASE

(57) Abstract: The present disclosure relates to a method and an apparatus for driving into a solid base a support structure having a helicoidal portion attached to one end of a stem. A rotating force is applied to the support structure so that the helicoidal portion penetrates into the solid base. The rotating force is measured at a plurality of penetration depths. A profile of the solid base is determined based on a correspondence between a plurality of rotating force values and penetration depth values. The support structure may form a pile for driving into the ground. Measurements of penetration depth may account for extension stems added to the support structure.
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METHOD AND APPARATUS FOR DRIVING A SUPPORT STRUCTURE INTO A SOLID BASE

TECHNICAL FIELD

[0001] The present disclosure relates to the field of construction industry. More specifically, the present disclosure relates to a method and an apparatus for driving a support structure, having a helicoidal portion attached to one end of a stem, into a solid base.

BACKGROUND

[0002] Among various types of piles used as parts of building foundations, screwable piles are particularly desirable owing to their low cost and ease of installation. These piles comprise an elongated stem and, at their bottom, a lower helicoidal portion. They may be used in new construction sites, or in existing sites for correcting and stabilizing a foundation suffering from defects due to movement of the ground. Generally speaking, because screwable piles are light, when compared with most other types of piles, their insertion in the ground can be made using relatively light equipment, when compared to machines used for installing heavy piles, while only causing a limited amount of damage on a ground surface.

[0003] A screwable pile may in itself be capable of withstanding a heavy compression load. However, an actual load-bearing capacity obtained when inserting screwable piles in the ground will depend in a large part on a nature of the soil. It is recognized that, on a construction site, various layers of soil may have variable characteristics that change along a depth of a pile and that may also vary from one pile insertion point to another.

[0004] Therefore, there is a need for techniques for determining an actual profile of the soil where one or more screwable piles are inserted into the ground.
SUMMARY

[0005] According to the present disclosure, there is provided a method of driving into a solid base a support structure having a helicoidal portion attached to one end of a stem. A rotating force is applied to the support structure so that the helicoidal portion penetrates into the solid base. A plurality of rotating force values and a plurality of corresponding penetration depth values of the support structure are measured. A profile of the solid base is determined based on a correspondence between the plurality of rotating force values and the penetration depth values.

[0006] According to the present disclosure, there is also provided an apparatus for driving into a solid base a support structure having a helicoidal portion attached to one end of a stem. The apparatus comprises an actuator, a sensor and a determiner. The actuator applies a rotating force to the support structure. The sensor measures a penetration depth of the support structure. The determiner determines a profile of the solid base based on a correspondence between a plurality of rotating force values and a plurality of penetration depth values.

[0007] The foregoing and other features will become more apparent upon reading of the following non-restrictive description of illustrative embodiments thereof, given by way of example only with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] Embodiments of the disclosure will be described by way of example only with reference to the accompanying drawings, in which:

[0009] Figure 1 is a sequence diagram showing operations of a method of driving a support structure into a solid base according to an embodiment;

[0010] Figure 2 is a sequence diagram showing operations of a
method using a hydraulic system for driving a support structure into a solid base according to another embodiment;

[0011] Figure 3 is a sequence diagram showing operations of a method of driving a pile into the ground according to a further embodiment;

[0012] Figure 4 is an example of a screwable pile according to an embodiment;

[0013] Figure 5 is an example of an apparatus for driving a support structure into a solid base according to an embodiment; and

[0014] Figure 6 is an alternative example of an apparatus for driving a support structure into a solid base according to another embodiment.

DETAILED DESCRIPTION

[0015] Various aspects of the present disclosure generally address one or more of the problems of determining a profile of the ground where one or more screwable piles are inserted into the ground. The present disclosure further provides a determination of a profile of various types of solid bases upon insertion of various types of elongated support structures having a helicoidal portion at one extremity.

[0016] The following terminology is used throughout the present disclosure:

[0017] Support structure: structure capable of transferring a load, in compression or in tension, to a solid base.

[0018] Stem: a generally elongated member of the support structure.

[0019] Helicoidal portion: an extremity of the support structure capable of being driven into a solid base by application of a rotating force.
Solid base: any material in which the support structure may be inserted, allowing the support structure to transfer a compression load or a tensile load thereto.

Rotating force: force applied about an axis of the support structure.

Profile: characteristics of a solid base, for example of the ground, along its depth.

Load-bearing capacity: a value of a compression load or a tensile load that the solid base may withstand.

Pile: an elongated support structure for insertion into the ground for carrying a compression load or a tensile load.

Screwable pile: a light pile, insertable into the ground by use of a rotating force.

Construction site: ground surface on which a pile or a plurality of piles may be inserted for supporting a construction.

Load: a mass or a weight to be supported, for example the weight of a construction supported by piles.

Real-time: used to refer to a numerical processing being performed while a physical process, which is a subject of the numerical processing, is actually taking place.

Predetermined threshold: a limit value set for later use.

Hydraulic system: a system using pressure from a fluid to cause or to prevent a motion.

Fluid pressure: a measure of a force per unit area within a liquid, for example an oil pressure within a hydraulic system.

Actuator: a device for exerting a motion on another device.

Determiner: a device for calculating a value based on inputs
applied thereto.

[0034] Frame: a mechanical structure for holding and maintaining other components.


[0036] Monitor: an act for measuring over time, either continuously or at certain intervals.

[0037] Broadly, the present disclosure introduces a method and an apparatus for driving a support structure into a solid object forming a base. The support structure may vary in shape and size but generally comprises a helicoidal portion attached to one end of an elongated stem, the helicoidal portion being designed for insertion into the base. The helicoidal portion of the support structure penetrates into the base by application of a rotating force on the support structure. A profile of the solid base is determined according to measurements of the rotating force applied to the support structure, the measurements being made at various depths of the support structure into the solid base. Application of the rotating force may be stopped when a desired rotating force threshold is attained.

[0038] When the support structure is inserted into the base at an angle, the stem not being normal to the base, the angle of the stem may be factored into a determination of the profile of the solid base. When the stem of the support structure is not sufficiently long for reaching the desired rotating force threshold, extension stems may be added to provide a longer overall penetration depth of the support structure.

[0039] The measurements may be recorded and treated using any computing device, including a smart phone, a personal digital assistant (PDA), and the like. The measurements may also be transmitted over a communication channel, for example by radio communication, between the apparatus for driving the support structure and a remote computing device.
Recorded measurements from plural sites can be stored in a database, on a server, transmitted over the Internet, treated or analyzed.

[0040] The support structure is screwed into the base. However, depending on the intended application of the support structure, on a shape of the helicoidal portion, and depending on the base, the support structure may or may not remain solidly attached to the base after insertion, as would a screw inserted into a solid material. For example, for applications where a compression load is to be applied on the base via the support structure, a capability of the base and of the support structure to withstand any amount of tensile load may be inconsequential. For other applications, the base and the support structure may be capable of withstanding a tensile load, or both a tensile load and a compression load.

[0041] The profile of the solid base may reveal that the solid base is not homogeneous, but rather comprise layers of various materials at various depths. Some of these layers may be capable of supporting heavy loads while others may not. For example, an intermediate layer of solid material may have an insufficient depth for providing a good load-bearing capacity and it may be desired to find a deeper, more solid layer. It is thus useful for many applications, for example for construction sites in which several piles are inserted, to obtain for each pile inserted a site-specific profile of a solid base, such as soil, measured along its depth, for installation of the supporting structures.

[0042] Referring now to the drawings, Figure 1 is a sequence diagram showing operations of a method of driving a support structure into a solid base according to an embodiment. A support structure, having a helicoidal portion attached to one end of a stem, is inserted into a solid base as shown in sequence 100. At operation 110, a rotating force is applied to the support structure, for example at and end of the stem opposite from the helicoidal portion, so that the helicoidal portion penetrates into the solid base. An operation 120, a plurality of rotating force values and a plurality of
corresponding penetration depth values of the support structure are measured. A profile of the solid base is determined at operation 130, based on a correspondence between the plurality of rotating force values and the penetration depth values. As an example, the profile may consist of a two-dimensional graph comprising depth values on a horizontal axis and rotating force values on a vertical axis. Alternatively, the profile may be represented as a two-dimensional array. As yet another example, the rotating force values may be substituted with load-bearing capacity values, calculated on the basis of the rotating force values and accounting for empirical data and for a geometry of the support structure. Of course, the above described alternatives are for illustration purposes and not intended to limit the present disclosure.

[0043] Depending on the profile of the solid base, the support structure may need to be inserted deeply into the solid base and may require an extended stem length. Optionally, application of the rotating force may be stopped at operation 140 upon reaching a preset penetration depth value. This preset penetration depth value may for example represent a full or nearly full insertion of the stem of the support structure. At operation 150, one end of a stem extension may be attached to the end of the stem opposite from the helicoidal portion. Then at operation 160, application of the rotating force may resume by applying the rotating force at another end of the stem extension. If needed, operations 140, 150 and 160 may be repeated until a desired depth, or a desired profile, is reached. Then at operation 170, a load-bearing capacity of the solid base may be determined based on the profile, for example on the basis of a rotating force value at a deepest insertion point of the support structure. Of course, notwithstanding the order of the operations illustrated on Figure 1, measurements of the rotating force values and of the corresponding penetration depth values may be made at all times, including after the attachment of one or more stem extensions. Consequently, the profile of the solid base may contain information related to any intermediate depth reached by the helicoidal portion.
[0044] Figure 2 is a sequence diagram showing operations of a method using a hydraulic system for driving a support structure into a solid base according to another embodiment. As shown in sequence 200, at operation 210, a hydraulic system is used to apply a rotating force to a support structure, having a helicoidal portion attached to one end of a stem, for driving the support structure into a solid base. A fluid pressure of the hydraulic system is measured at operation 220. At operation 230, values of the rotating force are calculated based on fluid pressure values. A profile of the solid base is determined based on a correspondence between a plurality of rotating values and a plurality of penetration depth values at operation 240.

[0045] Further embodiments of the above described method may be applied in the construction industry. A load to be supported by support structures, such as piles, may for example represent an expected weight or mass of a building that is intended to be erect on the construction site. The load may alternatively represent a combined weight or mass of a future parking lot filled with parked vehicles. Those of ordinary skill in the art will appreciate that the foregoing are only few of numerous possible application examples and that the methods described herein may be applied to any type of construction site.

[0046] An estimated load-bearing capacity of the ground may be obtained by preliminary analysis of the construction site. For example, theoretical load-bearing capacity values may be acquired at a subset of pile insertion points of the construction site. The theoretical load-bearing capacity values may be obtained by soil analysis, ultrasound testing, seismic testing, and the like, as is well-known to those skilled in the art. A plan for specific insertion points of piles on the construction site may then be drafted. Construction may then proceed using the sequence of Figure 3, which is a sequence diagram showing operations of a method of driving a pile into the ground according to a further embodiment. As shown in sequence 300, at operation 310, a rotating force is applied to a pile having a helicoidal portion
attached to one end of a stem, for driving the pile into the ground. At operation 320, a plurality of rotating force values and a plurality of corresponding penetration depth values of the pile are measured. A profile of the ground is determined, based on a correspondence between the plurality of rotating force values and the penetration depth values, at operation 330.

[0047] An embodiment of the method may comprise in situ use of an electronic device, for example a PDA or a smartphone, capable of receiving and using real-time measurements of the rotating force to control driving of the support structure. The rotating force may be measured in real-time so that, at operation 340, application of the rotating force may be stopped when a value of the rotating force reaches a predetermined threshold. In some applications, the predetermined threshold consists in a maximum rotating force of equipment used for driving the support structure. In a variant, application of the rotating force may be stopped at operation 340 when a rate of increase of the rotating force, for increasing penetration depths, reaches a predetermined threshold.

[0048] In another aspect, a method using a hydraulic system for driving a support structure into a solid base may account for the fact that a solid base may be highly heterogeneous. For example, when driving a pile into the ground, the helicoidal portion at the end of its stem may encounter rocks and similar obstacles that create transient resistance to a progression of the pile. As the helicoidal portion of the pile moves a rock to the side of the pile, this transient resistance may disappear. Optionally, measurements such as those obtained as per the above described operations 120, 220, 230, or in similar manners, may be filtered so that effects from irrelevant transients on the resulting profile of the solid base are reduced or eliminated. In this context, filtering of measurement results may be understood as any mechanical, logical or mathematical function capable of attenuating or rejecting erratic measurements.

[0049] In a further aspect, it may be desirable to determine a profile of
the ground along a vertical axis. However, piles may sometimes be inserted at an angle relative to a true vertical axis. In a variation from the sequence of Figure 3, a tilt angle of the stem, relative to a vertical axis, may be measured. Determining a profile of the ground may comprise calculating a vertical penetration of the stem based measured penetration depth values and on the tilt angle. The following Figures will describe an apparatus for driving piles into the ground; such apparatus may comprise, *inter alia*, a sensor for measuring a tilt of a pile being inserted into the ground.

[0050] Figure 4 is an example of a screwable pile according to an embodiment. A pile 400 comprises an elongated stem 410, a helicoidal portion 420 at one end of the elongated stem 410, a top end 430 at an opposite end of the elongated stem 410, and may also comprise a jacket 440. The stem 410, the helicoidal portion 420 and the top end 430 may be made of strong metal, such as for example steel, stainless steel or galvanized steel. The stem 410 may be a solid shaft or may be formed a hollow cylinder. The helicoidal portion 420 may be formed by soldering plate material around the stem 410, while conferring a spiral shape to the plate material, as shown on Figure 4. The helicoidal portion 420 may have a wide diameter to confer a large load-bearing capacity of the ground where the pile 400 is inserted. The stem 410, the helicoidal portion 420 and the top end 430 may be assembled by welding, screwing, bolting, or any other similar method. Driving equipment (shown on later Figures) may apply a rotating force at the top end 430 to insert the pile 400 into the ground. For applications where an extended pile length is required, an extension stem (not shown) may be attached to the top end 430 when the pile 400 has been fully driven into the ground, if it is desired to drive the pile 400 further into the ground. The extended stem has a lower end configured to attach to the top end 430 of the pile 400, and an opposite extremity, which is similar to the top 430 in order to be capable of connecting to the same driving equipment.

[0051] The jacket 440 may or may not be present. When present, it is
loosely inserted over the stem 410. When the pile 400 is inserted into the ground, some layers of the ground may move, for example due to freezing and thawing cycles. Generally, the helicoidal portion 420 will be inserted below the freezing line. Movements of the ground due to freezing and thawing may be transmitted to the jacket 440 without directly affecting the stem 410. Consequently, the pile 400 is generally unmoved by natural movements of the ground above a level of the helicoidal portion 420.

[0052] Variants of the pile 400 comprise two helicoidal portions, similar to the helicoidal portion 420. In such a pile, a second helicoidal portion is positioned on the stem 410, above the helicoidal portion 420 shown on Figure 4. The present disclosure applies to piles having one or more helicoidal portions.

[0053] Figure 5 is an example of an apparatus for driving a support structure into a solid base according to an embodiment. An apparatus 500 may be used for driving a support structure, having a helicoidal portion attached to one end of a stem, into a solid base, for example for driving into the ground the pile 400 introduced in the foregoing description of Figure 4. Though the apparatus 500 will now be described in relation to a pile 400 for insertion into the ground, variations of the apparatus 500 may be applied for driving other types of support structures into other types of solid bases. Therefore, the present description of the apparatus 500 as shown on Figure 5 is illustrative and not limiting. The apparatus 500 comprises an actuator 510 for applying a rotating force to the support structure, for example on the top end 430 of the pile 400. The apparatus 500 is generally controlled by a controller 520. The controller 520 may be connected to a user interface, for example to a computer, a PDA or a smartphone, using a wired or a wireless connection, for example via Bluetooth™. The controller 520 or the computer, PDA or smartphone, or a combination of these devices, may comprise software implementing some of the features and functions presented in relation to Figures 1, 2 and 3.
A measuring unit 560 may be mounted on the actuator 510. The measuring unit 560 includes a distance sensor (not explicitly shown) and may further comprise a tilt sensor (not explicitly shown). Variants of the measuring unit may be located in other positions on the apparatus 500. Other variants may comprise a measuring unit that is in communication with the apparatus 500, for example communicating with the controller 520 via a wireless link while not being physically connected to the apparatus 500. The distance sensor is used for measuring a penetration depth of the pile 400 into the ground or, more generally, a penetration depth of a support structure into a solid base. For applications in which the support structure is to be inserted vertically into the ground, as in the case of the pile 400 of Figure 5, the distance sensor may be construed as a height sensor. The distance sensor may for example comprise a laser sensor capable of detecting a distance (or height) from the actuator 510 to the ground. Other types of distance sensors may be used, including an optical measurement tool, an acoustic measurement tool including a sonar, a mechanical measurement tool including an analog mechanism using a ruler, and the like. For other applications, a penetration depth of a support structure into a solid base may not be normal to the solid base. The tilt sensor may provide a value of a relative angle of the pile 400 in relation to a true vertical axis, or relative to a normal angle to another solid base. The controller 520 may obtain an actual normal depth of the pile by multiplying penetration depth values of the pile 400 by the cosine of this relative angle (of by the sine of an angle measured against a surface of the solid base). Tilt sensors are well-known in the art and need not be described herein further.

As the apparatus 500 drives the pile 400 into the ground, measurements are taken of rotating force values and of penetration depth values. These measurements may be taken in real-time, in continuous fashion, at predetermined depth intervals, or at predetermined time intervals, as required by the application. Penetration depth values are provided by the distance sensor or calculated from intermediate measurements obtained from
the distance sensor. The controller 520 comprises a determiner (not explicitly shown) of a profile of the solid base based on a correspondence between a plurality of rotating force values and a plurality of penetration depth values. The controller 520 may also comprise a memory (not explicitly shown) operably connected to the determiner for recording rotating force values in relation to the corresponding penetration depth values. The determiner may read, from the memory, the rotating force values, the penetration depth values and the profile, which are based on real-time measurements. The determiner may further calculate a load-bearing capacity of the solid base based on the profile. In an aspect, software within the controller 520 may comprise a filtering function for attenuating or eliminating transients in the measured rotating forces so that effects from erratic measurements due to heterogeneities in the solid base are reduced or eliminated from the profile.

[0056] As shown, the apparatus 500 also comprises a frame 530 for holding the actuator 510 and for maintaining the stem generally perpendicular to the solid base. The frame 530 is movable and extendable and further comprises a first cylinder 532 for adjusting its length and a second cylinder 534 for raising or lowering the frame 530. The frame 530 may be attached to a vehicle 540.

[0057] The apparatus 500 may further comprise a hydraulic system 550 for applying the rotating force. The hydraulic system 550 as shown comprises a hydraulic pump 552 providing a fluid pressure, several hoses 554 for distributing the fluid pressure to various components of the apparatus 500, and a fluid pressure monitor 556 for measuring a fluid pressure applied at the actuator 510. In the controller 520, the determiner may calculate the values of the rotating force based on fluid pressure values obtained from the fluid pressure monitor 556. Software within the controller 520 may optionally filter the fluid pressure values in order to eliminate transients. In the embodiment of Figure 5, some of the hoses 554 provide fluid pressure to the first cylinder 532 and to the second cylinder 534 for positioning elements of the frame 530.
Instead of the hydraulic system 550, a variant of the apparatus 500 may use other types of motors for applying the rotating force onto the actuator 510, for example an electric motor.

[0058] In some applications, a length of the stem 410 of the pile 400 may not be sufficient to provide a desired load-bearing capacity. The length of the stem 410 is also limited by the configuration of the apparatus 500, more specifically by a maximum height of the actuator 510. When the stem 410 has been fully inserted into the ground, the top end 430 may be disconnected from the actuator 510, which may be raised freely. An extension stem may be attached to the top end 430, for example by bolting or welding the extension stem to the top end 430. Generally, the extension stem will have a top end, similar to the top end 430, for compatible attachment to the actuator 510. An input interface (not shown) operably connected to the determiner, for example via Bluetooth™, may be used by an operator for providing to the determiner an indication that a stem extension has been added to the support structure. Based on readings from the height sensor obtained before disconnecting from the top end 430 of the pile 400 and after connecting again to the top of the stem extension, the determiner may determine a length of the stem extension. The determiner may then factor the length of the stem extension into a calculation of the penetration depth of the support structure.

[0059] The controller 520 may contain a global positioning system (GPS) receiver, or be communicatively coupled with a GPS receiver, in order to allow recording geographical coordinates of insertion sites for the piles 400. These coordinates and profiles of the ground at specific insertion sites may be used, in real-time or off-line, to produce a broader geographical profile of terrain profiles. The resulting geographical profile may help preliminary analysis of future construction sites and help determining in advance a number and size of piles to be inserted on such sites.

[0060] Figure 6 is an alternative example of an apparatus for driving a support structure into a solid base according to another embodiment. An
apparatus 600 generally comprises equivalent components to those of the apparatus 500.

[0061] Of course, the apparatuses as shown on Figures 5 and 6 further comprise components having functions not directly related to the act of driving support structures, for example wheels 560 for providing mobility to the apparatuses and stabilizers 570 for maintaining the apparatuses in position. Simpler and or smaller apparatuses may comprise a lesser number of components sufficient for driving piles, or other types of support structures besides piles, into the ground or into other types of solid bases. The apparatuses of Figures 5 and 6 are thus shown for illustration purposes without limiting the present disclosure.

[0062] Those of ordinary skill in the art will realize that the description of the method and apparatus for driving support structures into solid bases are illustrative only and are not intended to be in any way limiting. Other embodiments will readily suggest themselves to such persons with ordinary skill in the art having the benefit of the present disclosure. Furthermore, the disclosed method and apparatus may be customized to offer valuable solutions to existing needs and problems of installing support structures.

[0063] In the interest of clarity, not all of the routine features of the implementations of the method and apparatus for driving support structures into solid bases are shown and described. It will, of course, be appreciated that in the development of any such actual implementation of the method and apparatus for driving support structures into solid bases, numerous implementation-specific decisions may need to be made in order to achieve the developer's specific goals, such as compliance with application-, system-, and business-related constraints, and that these specific goals will vary from one implementation to another and from one developer to another. Moreover, it will be appreciated that a development effort might be complex and time-consuming, but would nevertheless be a routine undertaking of engineering for those of ordinary skill in the field having the benefit of the present disclosure.
[0064] Although the present disclosure has been described hereinabove by way of non-restrictive, illustrative embodiments thereof, these embodiments may be modified at will within the scope of the appended claims without departing from the spirit and nature of the present disclosure.
WHAT IS CLAIMED IS:

1. A method of driving into a solid base a support structure having a helicoidal portion attached to one end of a stem, comprising:
   applying a rotating force to the support structure, whereby the helicoidal portion penetrates into the solid base;
   measuring a plurality of rotating force values and a plurality of corresponding penetration depth values of the support structure; and
   determining a profile of the solid base based on a correspondence between the plurality of rotating force values and the penetration depth values.

2. The method of claim 1, wherein the support structure is a pile for driving into the ground.

3. The method of claim 2, comprising:
   measuring a tilt angle of the stem;
   wherein determining a profile of the ground comprises calculating a vertical penetration of the stem based on the tilt angle.

4. The method of claim 1, comprising applying the rotating force at an end of the stem opposite from the helicoidal portion.

5. The method of claim 4, comprising:
   stopping application of the rotating force upon reaching a preset penetration depth value;
   attaching one end of a stem extension to the end of the stem opposite from the helicoidal portion; and
   resuming application of the rotating force at another end of the stem extension.
6. The method of claim 1, comprising recording the rotating force values and the penetration depth values in real-time.

7. The method of claim 1, comprising stopping application of the rotating force when a value of the rotating force reaches a predetermined threshold.

8. The method of claim 1, comprising stopping application of the rotating force when a rate of increase of the rotating force, for increasing penetration depths, reaches a predetermined threshold.

9. The method of claim 1, comprising:
   applying the rotating force using a hydraulic system; and
   measuring a fluid pressure of the hydraulic system;
   wherein the rotating force values are calculated based on fluid pressure values.

10. The method of claim 1, comprising determining a load-bearing capacity of the solid base based on the profile.
11. An apparatus for driving into a solid base a support structure having a helicoidal portion attached to one end of a stem, comprising:
   an actuator for applying a rotating force to the support structure;
   a sensor for measuring a penetration depth of the support structure; and
   a determiner of a profile of the solid base based on a correspondence between a plurality of rotating force values and a plurality of penetration depth values.

12. The apparatus of claim 11, comprising a frame for holding the actuator and for maintaining the stem generally perpendicular to the solid base.

13. The apparatus of claim 11, comprising:
   an input interface operably connected to the determiner for receiving an indication that a stem extension is added to the support structure;
   wherein the determiner is capable of factoring a length of the stem extension into a calculation of the penetration depth of the support structure.

14. The apparatus of claim 13, wherein:
   the sensor is attached to the actuator for measuring a distance from the actuator to the solid base; and
   the determiner is capable of calculating the length of the stem extension based on a change of distance from the actuator to the solid base.
15. The apparatus of claim 14, wherein the sensor is selected from a laser sensor, an optical measurement tool, an acoustic measurement tool and a mechanical measurement tool.

16. The apparatus of claim 11, comprising a motor operably connected to the actuator for applying the rotating force to the support structure.

17. The apparatus of claim 11, comprising:
   
   a hydraulic system for applying the rotating force;
   
   a monitor of a fluid pressure in the hydraulic system;
   
   wherein the determiner is capable of calculating the rotating force values based on fluid pressure values.

18. The apparatus of claim 11, wherein the determiner is capable of calculating a load-bearing capacity of the solid base based on the profile.

19. The apparatus of claim 11, comprising software for attenuating transients in the plurality of rotating force values.

20. The apparatus of claim 11, comprising a memory operably connected to the determiner for recording the plurality of rotating force values in relation to the corresponding penetration depth values.
Apply a rotating force to a support structure for driving the support structure into a solid base

Measure a plurality of rotating force values and a plurality of corresponding penetration depth values of the support structure

 Determine a profile of the solid base based on a correspondence between the plurality of rotating force values and the penetration depth values

Stop application of the rotating force upon reaching a preset penetration depth value

Attach one end of a stem extension to the end of the stem opposite from the helicoidal portion

Resume application of the rotating force at another end of the stem extension

Determine a load-bearing capacity of the solid base based on the profile

Figure 1
Use a hydraulic system to apply a rotating force to a support structure for driving the support structure into a solid base

Measure a fluid pressure of the hydraulic system

Calculate values of the rotating force based on fluid pressure values

Determine a profile of the solid base based on a correspondence between a plurality of rotating force values and a plurality of penetration depth values

Figure 2
Apply a rotating force to a pile for driving the pile into the ground

Measure a plurality of rotating force values and a plurality of corresponding penetration depth values of the pile

Determine a profile of the ground based on a correspondence between the plurality of rotating force values and the penetration depth values

Stop application of the rotating force when a value of the rotating force reaches a predetermined threshold

Figure 3
Figure 4
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

IPC: E02D 7/06 (2006.01), E02D 7/02 (2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
E021) 7/06, E02D 7/02, E02DS/56, E02DS/80, E02D7/22, E02D27/50. (2006.01).

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic database(s) consulted during the international search (name of database(s) and, where practicable, search terms used)
LexisNexis Totalpatent, Espacenet, Intellect; keywords: helix, helicoid, screw, coil, rotate, turn, twist, spin, measure, monitor, determine, ascertain, appraise, assess, evaluate, read, pile, graph.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
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<td>j figure 4; [0019], but factoring in a extension length lacking j</td>
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<td>EP 2348159 A1 (SCHOKKTNG, F.) 27 July 201 1 (27-07-201 1)</td>
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<td>A</td>
<td>US 5791820 A (REMPLE, J.) 11 August 1998 (11-08-1998)</td>
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[X] See patent family annex.

Further documents are listed in the continuation of Box C.

[X] Date of the actual completion of the international search: 3 April 2013 (03-04-2013)

Date of mailing of the international search report: 10 April 2013 (10-04-2013)

Name and mailing address of the ISA/CA
Canadian Intellectual Property Office
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Gatineau, Quebec K1A 0C9
Facsimile No.: 001-819-953-2476

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Edward Dabrowski (819) 953-1378

Form PCT/ISA/210 (second sheet) (July 2009)
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