



(11) **EP 1 970 494 A2**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
17.09.2008 Bulletin 2008/38

(51) Int Cl.:
E02D 5/46 (2006.01) **E02D 5/48** (2006.01)
E02D 5/56 (2006.01) **E02D 5/80** (2006.01)
E02D 7/22 (2006.01) **E02D 7/26** (2006.01)

(21) Application number: **08250893.8**

(22) Date of filing: **14.03.2008**

(84) Designated Contracting States:
**AT BE BG CH CY CZ DE DK EE ES FI FR GB GR
HR HU IE IS IT LI LT LU LV MC MT NL NO PL PT
RO SE SI SK TR**
Designated Extension States:
AL BA MK RS

(72) Inventor: **Bullivant, Roger Alfred
Burton-on-Trent,
Staffordshire DE15 0SS (GB)**

(74) Representative: **Skinner, Michael Paul
Swindell & Pearson
48 Friar Gate
Derby DE1 1GY (GB)**

(30) Priority: **15.03.2007 GB 0704954**

(71) Applicant: **Roxbury Limited
Gibraltar (GI)**

(54) **Pile formation**

(57) An article is described for use in forming a pile. The article 10 has at least one generally helical flight 12 for driving into the ground. The pitch P of the flight 12 is at least four times the diameter D of the flight.

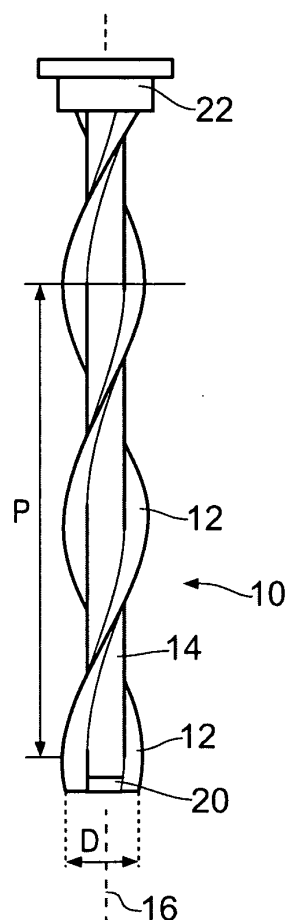


FIG. 1

Description

[0001] The present invention relates to articles for use in forming piles, and methods of forming piles.

[0002] Piles are used in the construction industry for a wide variety of purposes. For example, they may be used to support buildings or other structures on ground which, without preparation, is incapable of supporting the required loads.

[0003] The present invention provides an article for use in forming a pile, the article having at least one generally helical flight for driving into the ground, wherein the pitch of the or each flight is at least four times the diameter of the flight.

[0004] The pitch (p) of the or each flight and the diameter (D) of the flight may be related as $4D \leq p \leq 10D$. The pitch may be substantially six times the diameter.

[0005] The article may have an elongate core around which the or each helical flight extends. The core may be substantially cylindrical. The core may be circular in section. The diameter of the or each flight may be at least twice the diameter of the core.

[0006] The article may have a plurality of flights. The plurality of flights may have substantially the same diameter. The plurality of flights may have substantially the same pitch. The plurality of flights may be substantially equally spaced around the article.

[0007] The article may be a pre-formed pile for embedding in the ground, such as a pre-cast concrete pile.

[0008] The article may be a pile former for forming a void in the ground, for subsequent filling with pile material.

[0009] The invention also provides a method of forming a pile, in which an article as defined above is driven into the ground.

[0010] The article may be driven substantially solely by force applied in the direction of driving. The article may be free to rotate about the driving direction, while being driven. Driving force may be applied by vibration or by a substantially continuous force or by impact.

[0011] Sufficient torque may be applied to the article, while being driven, to overcome frictional resistance without causing driving by threaded engagement between the flight and the ground.

[0012] During at least part of the drive, the article may be turned to cause the flight to auger the surrounding ground. The augered ground may be adjacent the surface. A sleeve may be inserted into the ground, around the augered region.

[0013] The article may be withdrawn after driving, pile material being introduced into the void formed as the article is withdrawn. The pile material may be settable. The pile material may be introduced through a passage provided within the article. Reinforcement may be introduced into the pile material, prior to setting.

[0014] The article may be withdrawn by applying substantially solely a force in the direction of withdrawal. The article may be free to rotate during withdrawal. The withdrawing force may be applied by vibration or may be sub-

stantially continuous or may be applied by impact.

[0015] Sufficient torque may be applied to the article, while being withdrawn, to overcome frictional resistance between the flight and the ground.

[0016] During at least part of the range of withdrawal, the article may be turned to cause the flight to auger the surrounding ground. The augered ground may be adjacent the surface. A sleeve may be inserted into the ground, around the augered region.

[0017] Examples of the present invention will now be described in more detail, by way of example only, and in which:

Fig. 1 illustrates an article for use in forming a pile, and in accordance with the present invention;

Fig. 2 schematically illustrates apparatus for using the article of Fig. 1 for forming a pile;

Figs. 3a to 3d are schematic diagrams of a first example method of forming a pile, and Figs. 4a to 4e similarly illustrate a second example method.

[0018] Fig. 1 illustrates an article 10 for use in forming a pile. In this example, the article 10 has two generally helical flights 12 for driving into the ground, as will be described.

[0019] Each flight is helical and winds around a circular cylindrical core 14. Each flight 12 has a helical pitch p , representing the axial length of a single complete turn of each flight 12, along the axis 16 of the core 14. Each flight 12 has a flight diameter D , being the distance between the outermost extremities of the flight 12, in a direction perpendicular to the axis 16.

[0020] In the example shown, the pitch p and diameter D are chosen so that p is no less than four times the diameter D and no greater than ten times the diameter D . Consequently, the pitch p of each flight and the diameter D of each flight are related as $4D \leq p \leq 10D$. In a particular example, the pitch is substantially six times the diameter.

[0021] In this example, the core 14 may be a hollow pipe around which the flights 12 are formed, for example by bending strip material, such as metal strip. For most purposes, we envisage that the thickness of each flight 12, that is, the thickness of strip material from which the flight is made, will be not less than 25 mm.

[0022] As can be seen from Fig. 1, the two flights 12 each have substantially the same diameter D and substantially the same pitch p . Furthermore, the two flights 12 are substantially equally spaced around the article 10. That is, at any point along the core 14, the flights 12 are 180° apart, when viewed along the axis 16.

[0023] Other arrangements are envisaged. In particular, the number of flights 12 may be varied. One, two or more flights may be used. Where there is a plurality of flights, they may be substantially equally spaced around the article, or spaced irregularly.

[0024] The core 14 is hollow, as noted above, providing a passage along the length of the core 14. Initially, a cap or plug 20 closes the lower end of the core 14. The upper end of the core 14 has a coupling 22 for coupling with apparatus providing driving force.

[0025] Fig. 2 illustrates apparatus for providing driving force. A rig 24 includes a tracked motor unit 26 having a jib 28 on which an actuator 30 is mounted. The actuator is coupled by mating the coupling 22 with a complementary coupling on the actuator 30. The article 10 then hangs below the actuator 30, as illustrated in Fig. 2. The coupling between the actuator 30 and the coupling 22 allows the article 10 to turn about the axis 16.

[0026] The actuator 30 is operable to provide vertical forces to the article 10. These may be by vibration, impact or continuous "crowd" force. The actuator 30 may also be able to apply torque to create rotation of the article 10 about the axis 16, as will be described below.

[0027] The rig 24 and article 10 can be used in a first method of pile forming, as illustrated in Fig. 3, in which details of the rig 24 have been removed, for simplicity, schematically replacing the rig 24 with a drive arrangement 32.

[0028] In the initial stage (Fig. 3a) the article 10 is lowered so that the lowermost point is at the ground 34. The drive 32 is then activated to force the article 10 down against and into the ground 34. As the article 10 penetrates the ground (Fig. 3b), the flights 12 will engage the ground around the article 10. As they do so, further downward movement of the article 10 will result in a twisting of the article 10 about the axis 16, as a result of reaction forces created by engagement between the flights 12 and the ground 34. The article 10 is free to turn in response to this torque, as it is driven further into the ground, as noted above.

[0029] Continued application of downward force results in the article 10 penetrating the ground 34 to the depth required. The required depth may be determined by recording the energy imparted to the article 10, and equating this with the resistance of the ground. Alternatively, the article 10 may be driven to a previously calculated depth.

[0030] The turning induced in the article 10 will result in the flights 12 cutting helical grooves in the ground 34, complementary with the shape and size of the flights 12. It is important to note that in driving the article 10, force is applied substantially solely in the direction of driving, i.e. substantially vertically, while the article 10 is free to rotate. Accordingly, it is the downward (linear) force which creates a torque by reaction with the ground and thus results in the article turning. In many situations, it is envisaged that the article 10 can be driven solely by a linear force, if the coupling with the drive 30 provides sufficiently low turning resistance for the article 10 to turn as it is driven. In other applications, it may be appropriate for the drive 32 to apply a small amount of torque to the article 10, while being driven primarily by a linear force, so that the torque may overcome any frictional resist-

ance, such as that arising between the flights 12 and the surrounding ground, but without causing the article 10 to be driven by threaded engagement between the flights 12 and the ground. In the case of threaded engagement, the torque applied to the article would need to be sufficiently large to overcome any frictional resistance and also to drive the article sufficiently hard to overcome end face resistance at the lowermost point of the article 10. Consequently, much greater torque would be required than is envisaged in accordance with the invention, in which no torque may be necessary, or only a small torque sufficient to overcome frictional resistance.

[0031] Once the article 10 has penetrated to the desired depth to which piling is required, the drive 32 is reversed to provide an upward force to the article 10, tending to withdraw the article 10 from the ground 34. Again, the force may be applied by vibration, substantially continuously or by impact, and is preferably substantially solely applied in linear fashion in the direction of withdrawal, while the article 10 is free to rotate about the axis 16. If necessary, a small torque may be applied to assist the article 10 in overcoming frictional resistance as it is withdrawn.

[0032] As the article 10 is withdrawn, settable material 40, preferably cementitious, such as concrete, is introduced into the top of the article 10. This is schematically illustrated in Fig. 3c as supplying material from a reservoir 36 by means of a pump 38. The settable material 40 flows into the article 10 and down through the core 14 to leave the core 14 at its lowermost end, the plug 20 having been left at the bottom of the void, when withdrawal began. The pump 38 provides sufficient pressure and flow rate to ensure that the void being left behind the retreating article 10 is completely filled by the material 40. Appropriate instrumentation may be used to confirm this. Accordingly, the material 40 will flow into the whole of the void being left as the article 10 withdraws, so that the material 40 is left below the article 10 as a cast-in-situ pile having the same form as the cavity cut by the article 10.

[0033] As the article 10 continues to be withdrawn, the position of Fig. 3d is eventually reached in which the article 10 has been wholly withdrawn from the ground 34 leaving the material 40 forming a complete cast of the article 10 in the ground 34, and with the plug 20 at the bottom of the pile 42 so formed. Prior to the material setting, reinforcement 44 may be introduced into the material 40, such as reinforcing bars, tubes, cages or the like.

[0034] Finally, the pile 42 is left until the material 40 has fully set. Further construction work, using the pile so formed, can then continue.

[0035] In a modified version of the method described in relation to Fig. 3, the article 10 may be a pre-formed pile, such as a pre-cast concrete pile. This can be driven in the same manner described, until embedded to the required depth in the ground 34. Again, the required depth may be determined from the energy imparted, or

may be previously calculated. The drive 32 is then removed and the pile cropped, if necessary, leaving the article 10 embedded in the ground to serve as a pre-cast concrete pile.

[0036] Thus, appropriate choice of materials and design allows the article 10 to be used as a pile former or as a pre-formed pile.

[0037] A further modification of the method of Fig. 3 is illustrated in Fig. 4 and is envisaged for use in ground where heave can take place. Heave refers to vertical movement of the ground, particularly near the surface. Friction between heaving ground and a pile can result in movement of the pile, which can cause damage to buildings or other supported structures. The modifications to be described in relation to Fig. 4 are envisaged to reduce this risk of damage from heave, while retaining advantages of the method and apparatus described above.

[0038] In the first stage (Fig. 4a), the article 10 is brought to the surface of the ground 32 in the same manner as described above in relation to Fig. 3a. Driving then commences. The initial driving uses a downward force (by vibration, continuous or impact forces) sufficient to drive the article 10. This is optionally accompanied with sufficient torque applied to the article 10 to cause the flights 12 to cut into the ground 34 in the region 46, around the article 10, in the manner of an auger. Thus, when auger torque is applied, an augered region 46 is formed at the surface of the ground 34, to a depth a.

[0039] Once the article 10 has penetrated to the depth a (Fig. 4b), the auger torque causing auger action, if any, is removed and further driving continues as described above in relation to Fig. 3, substantially solely by linear force, with a possible small amount of torque to overcome frictional resistance.

[0040] Fig. 4c illustrates the article 10 when nearly fully driven. The result is the same as illustrated in Fig. 3, with the exception of the optional augered region 46, near the surface.

[0041] Once the article 10 has penetrated to the required depth, the drive 32 commences withdrawal, initially in the manner described above in relation to Fig. 3. That is, withdrawal is initially achieved substantially solely by force applied in the direction of withdrawal, either by vibration, continuous force or impact, while the article 10 is free to rotate, or a small torque is applied to overcome frictional resistance. As the article 10 is withdrawn, settable material 40 is pumped down through the core 14 to fill the void formed by withdrawal of the article 10, and leaving the plug 20 at the bottom of the pile 42 being formed.

[0042] When the article 10 has withdrawn to the auger depth a (Fig. 4d), additional torque is applied to the article 10, to cause augering of the region 46, while material 40 continues to be pumped in. This results in the original ground material being augered out to ground level, being replaced by material 40.

[0043] Eventually, the article 10 withdraws fully from the ground 34 (Fig. 4e). This leaves an upper augered

region 46 in the form of a solid, cylindrical body of material 40, above a lower region 48 having the same flighted form as the article 10, and filled with material 40.

[0044] It is envisaged that the auger process may be used as the article 10 initially penetrates the ground, or as the article withdraws, or may be used at only one of these times, such as upon withdrawal.

[0045] A sleeve 50 may be introduced around the augered region 46. Reinforcement such as bars or cages (not shown) may also be introduced into the material 40, before setting.

[0046] The sleeve 50 is formed of a material which eliminates friction between the ground and sleeve, and/or between the sleeve and the set material 40 in the augered region 46. Accordingly, the surface layer of the ground 34 is thereafter free to heave without causing movement of the pile 42.

[0047] In a further alternative, a heave-protected pile may be formed by driving a pre-cast article in the manner described above in relation to Fig. 4, including the initial augering of the upper region 46. After driving to the appropriate depth, the pre-cast article is left in position, and the heave protection is completed, for example by cropping the article 10 to the depth of the augered region 46 and then back filling with additional settable material 40. A sleeve 50 may be installed, if necessary, but in this example, the tensile strength of the pile may be sufficient to overcome heave forces without requiring a sleeve.

[0048] Again, it can be understood that the article 10 may be a pile former or a pre-formed pile.

[0049] The significance of the dimensions and their relationship, as described above, can be seen by further consideration of Fig. 1 in the light of the methods which have now been described. Under compression load (such as from the weight of a building supported by the pile 42), the performance of the pile would depend principally on three factors. These are the end bearing capacity, friction with the surrounding ground, and additional strength provided by the flights. End bearing capacity will depend on the surface area at the lowermost end of the pile, in generally conventional manner. Load bearing capacity arising from friction will also be substantially conventional, subject to the complexity of the shape of the flighted pile. The third factor is affected by the choice of dimensions, particularly the choice that p is four times D , or greater. Under compressive load, this relationship results in neighbouring turns of the pile flights being sufficiently far spaced to remove or significantly reduce the risk of shearing of the ground between consecutive turns (or neighbouring turns of different flights). Rather, compressive load would result in the pile trying to turn, for the same reasons as the article 10 turns while being driven, but this turning will be prevented by the building or other structure to which the pile is connected, and by skin friction between the pile and the surrounding ground. Skin friction is likely to increase as the ground closes in around the pile, after installation is complete. Accordingly, the surface area of the flights will contribute to the load

bearing capacity of the pile in a manner similar to the end face. However, the surface area of the flights can contribute to this load bearing capacity along the whole length of each flight, so that this additional contribution to load bearing capacity is expected to provide significant improvement in load bearing capacity in comparison with known piles of similar dimensions and material content.

[0050] In addition, it is expected to be advantageous that the pile can be constructed in a single operation combining driving, withdrawal and pumping, even if protection against heave is required. Only a single mechanical rig is required, and only on a single occasion. This is expected to provide benefits in terms of speed of pile installation, and consequently in relation to the cost of the operation.

[0051] In each of the examples described above, we envisage that the thickness of the flight or flights will be not less than 25 mm in the finished pile, for most purposes. Thus, a pre-formed pile would be formed with a flight or flights of this thickness. The flight or flights of a pile former may be thinner, but carry an overbreaker of appropriate thickness, on their leading edge, so that a groove of appropriate thickness is cut by the overbreaker and kept open by the rest of the corresponding flight.

[0052] Many variations and modifications can be made to the apparatus described above, particularly in relation to the dimensions, relative dimensions, shapes and forms described and illustrated. Various different materials can be used for constructing the apparatus.

[0053] Whilst endeavouring in the foregoing specification to draw attention to those features of the invention believed to be of particular importance it should be understood that the Applicant claims protection in respect of any patentable feature or combination of features hereinbefore referred to and/or shown in the drawings whether or not particular emphasis has been placed thereon.

Claims

1. An article for use in forming a pile, the article having at least one generally helical flight for driving into the ground, wherein the pitch of the or each flight is at least four times the diameter of the flight.
2. An article according to claim 1, wherein the pitch (p) of the or each flight and the diameter (D) of the flight may be related as $4D \leq p \leq 10D$.
3. An article according to claim 1 or 2, wherein the pitch is substantially six times the diameter.
4. An article according to any preceding claim, having an elongate core around which the or each helical flight extends.
5. An article according to claim 4, wherein the core is substantially cylindrical.
6. An article according to claim 4 or 5, wherein the core is circular in section.
7. An article according to claim 4, 5 or 6, wherein the diameter of the or each flight is at least twice the diameter of the core.
8. An article according to any preceding claim, having a plurality of flights.
9. An article according to claim 8, wherein the plurality of flights have substantially the same diameter.
10. An article according to claim 8 or 9, wherein the plurality of flights have substantially the same pitch.
11. An article according to claim 8, 9 or 10, wherein the plurality of flights are substantially equally spaced around the article.
12. An article according to any preceding claim, the article being a pre-formed pile for embedding in the ground.
13. An article according to claim 12, wherein the article is a pre-cast concrete pile.
14. An article according to any of claims 1 to 11, the article being a pile former for forming a void in the ground, for subsequent filling with pile material.
15. An article for use in forming a pile, substantially as described above, with reference to the accompanying drawings.
16. A method of forming a pile, in which an article as defined above is driven into the ground.
17. A method according to claim 16, wherein the article is driven substantially solely by force applied in the direction of driving.
18. A method according to claim 16 or 17, wherein the article is free to rotate about the driving direction, while being driven.
19. A method according to claim 16, 17 or 18, wherein driving force is applied by vibration or by a substantially continuous force or by impact.
20. A method according to any of claims 16 to 19, wherein sufficient torque is applied to the article, while being driven, to overcome frictional resistance without causing driving by threaded engagement between the flight and the ground.
21. A method according to any of claims 16 to 20, wherein during at least part of the drive, the article is turned

- to cause the flight to auger the surrounding ground.
- 22.** A method according to claim 21, wherein the augered ground is adjacent the surface.
- 23.** A method according to claim 21 or 22, wherein a sleeve is inserted into the ground, around the augered region.
- 24.** A method according to any of claims 16 to 23, wherein the article is withdrawn after driving, pile material being introduced into the void formed as the article is withdrawn. 10
- 25.** A method according to claim 24, wherein the pile material is settable. 15
- 26.** A method according to claim 24 or 25, wherein the pile material is introduced through a passage provided within the article. 20
- 27.** A method according to claim 25, 25 or 26, wherein reinforcement is introduced into the pile material, prior to setting. 25
- 28.** A method according to any of claims 24 to 27, wherein the article is withdrawn by applying substantially solely a force in the direction of withdrawal.
- 29.** A method according to claim 28, wherein the article is free to rotate during withdrawal. 30
- 30.** A method according to claim 28 or 29, wherein the withdrawing force is applied by vibration. 35
- 31.** A method according to claim 28 or 29, wherein the withdrawing force is substantially continuous.
- 32.** A method according to claim 28 or 29, wherein the withdrawing force is applied by impact. 40
- 33.** A method according to any of claims 24 to 32, wherein sufficient torque is applied to the article, while being withdrawn, to overcome frictional resistance between the flight and the ground. 45
- 34.** A method according to any of claims 24 to 32, wherein during at least part of the range of withdrawal, the article is turned to cause the flight to auger the surrounding ground. 50
- 35.** A method according to claim 34, wherein the augered ground is adjacent the surface.
- 36.** A method according to claim 34 or 35, wherein a sleeve is inserted into the ground, around the augered region. 55
- 37.** A method of forming a pile, substantially as described above, with reference to the accompanying drawings.
- 38.** Any novel subject matter or combination including novel subject matter disclosed herein, whether or not within the scope of or relating to the same invention as any of the preceding claims.

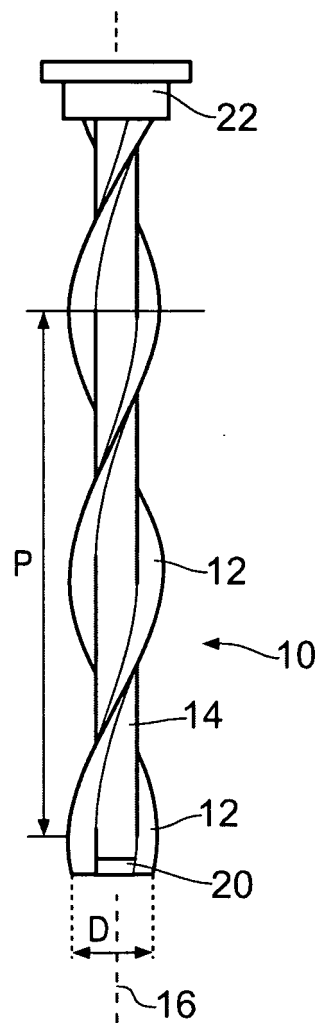


FIG. 1

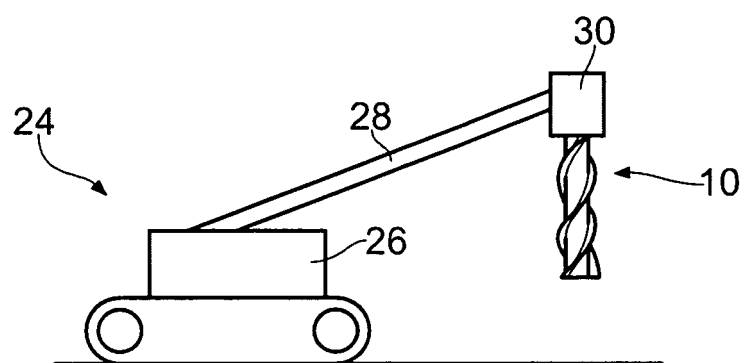


FIG. 2

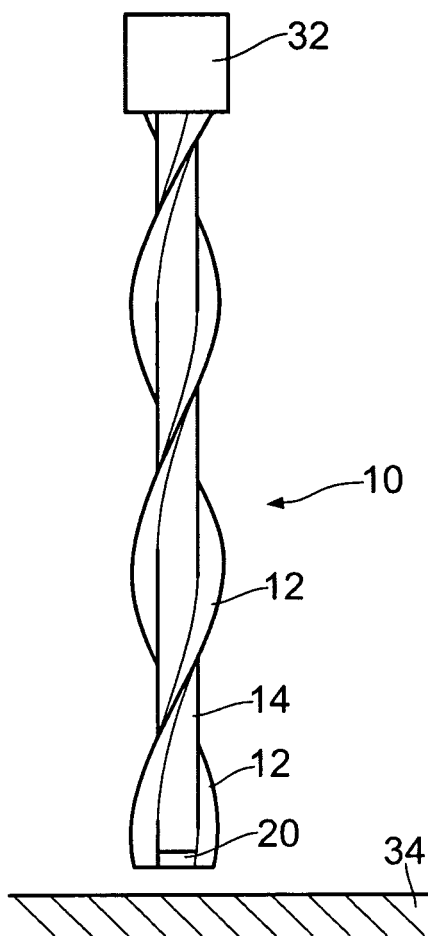


FIG. 3a

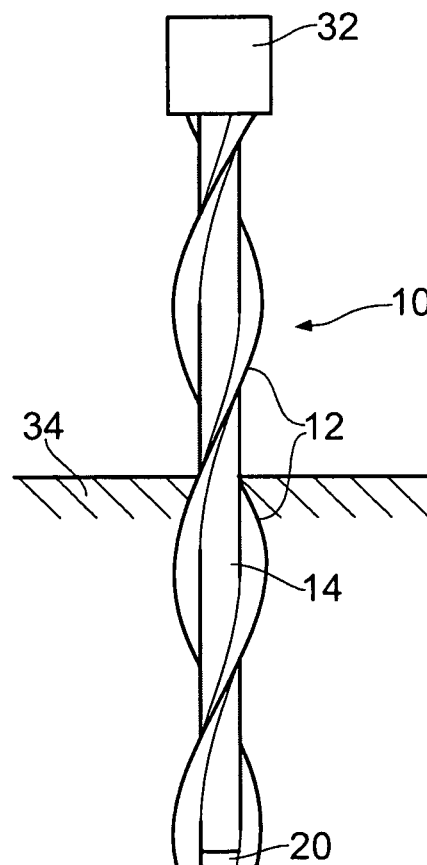


FIG. 3b

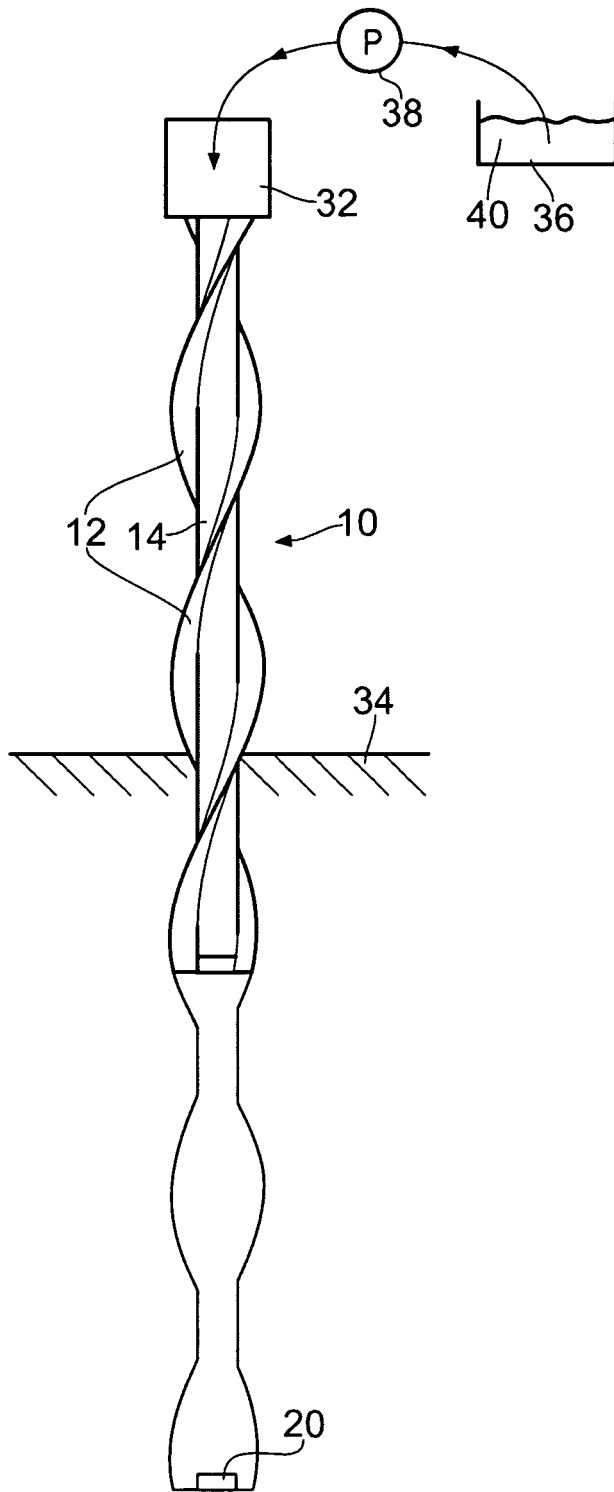


FIG. 3c

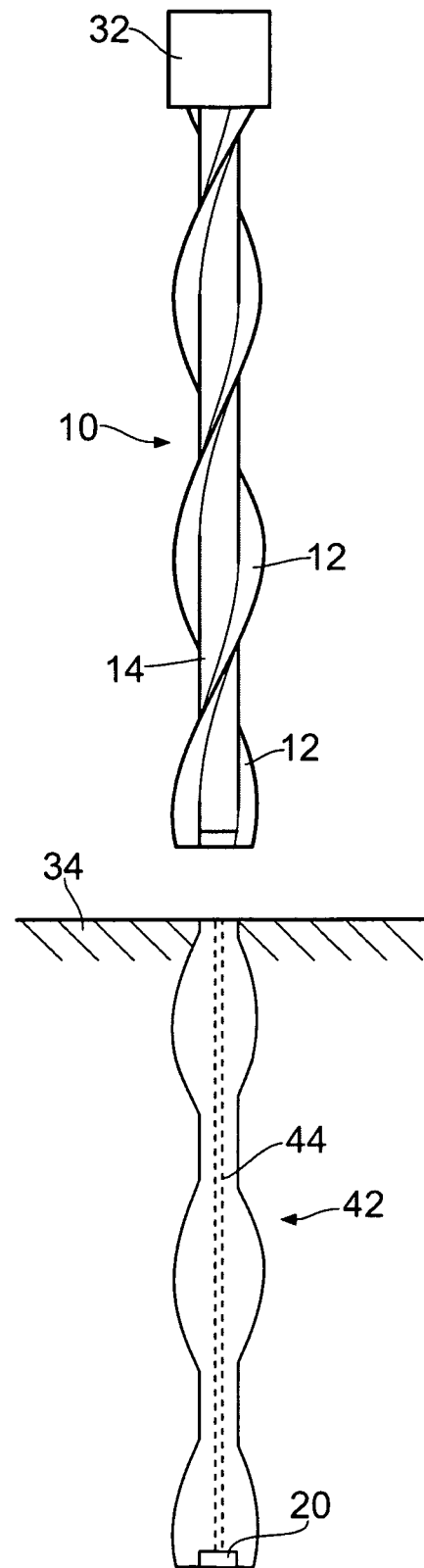


FIG. 3d

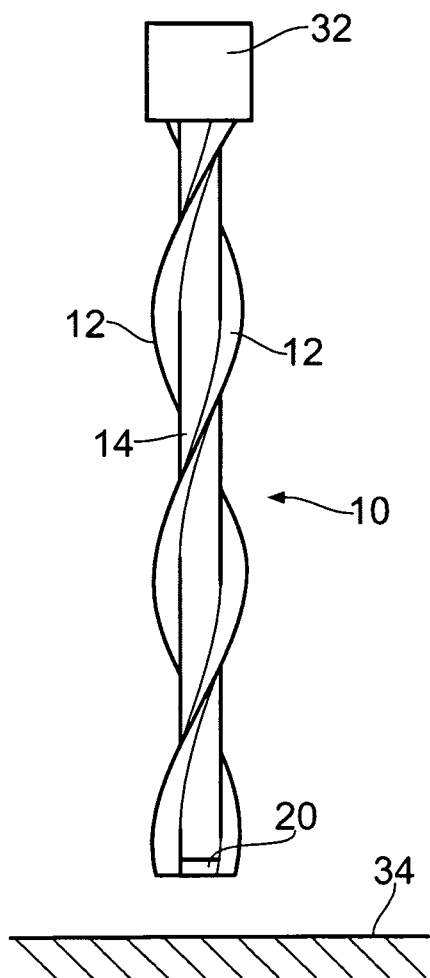


FIG. 4a

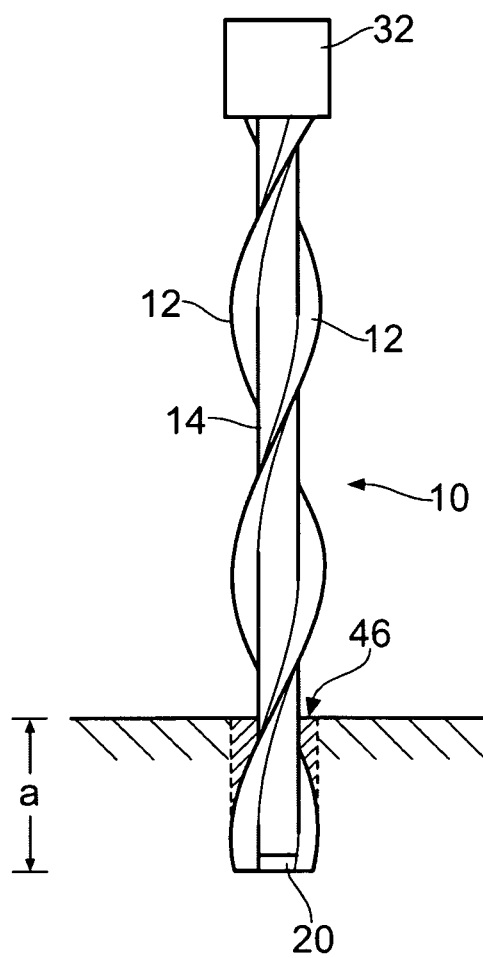


FIG. 4b

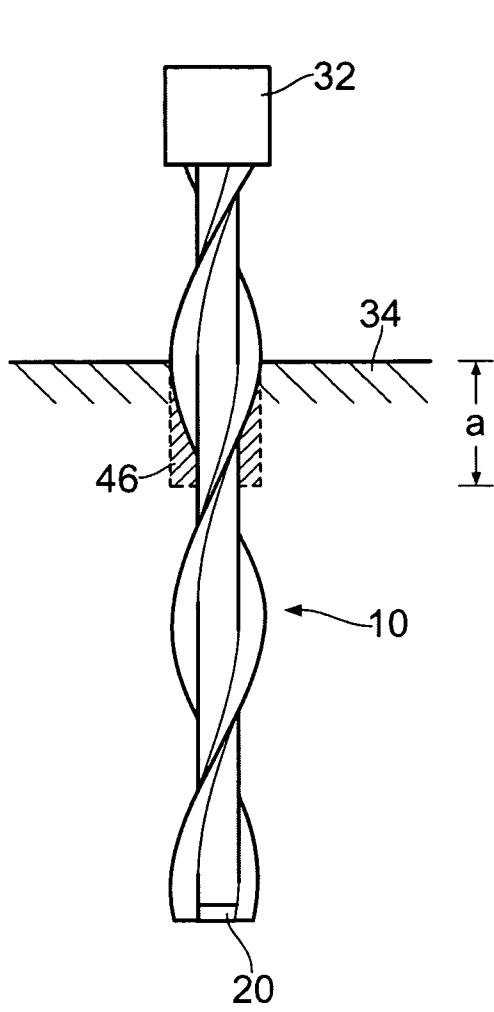


FIG. 4c

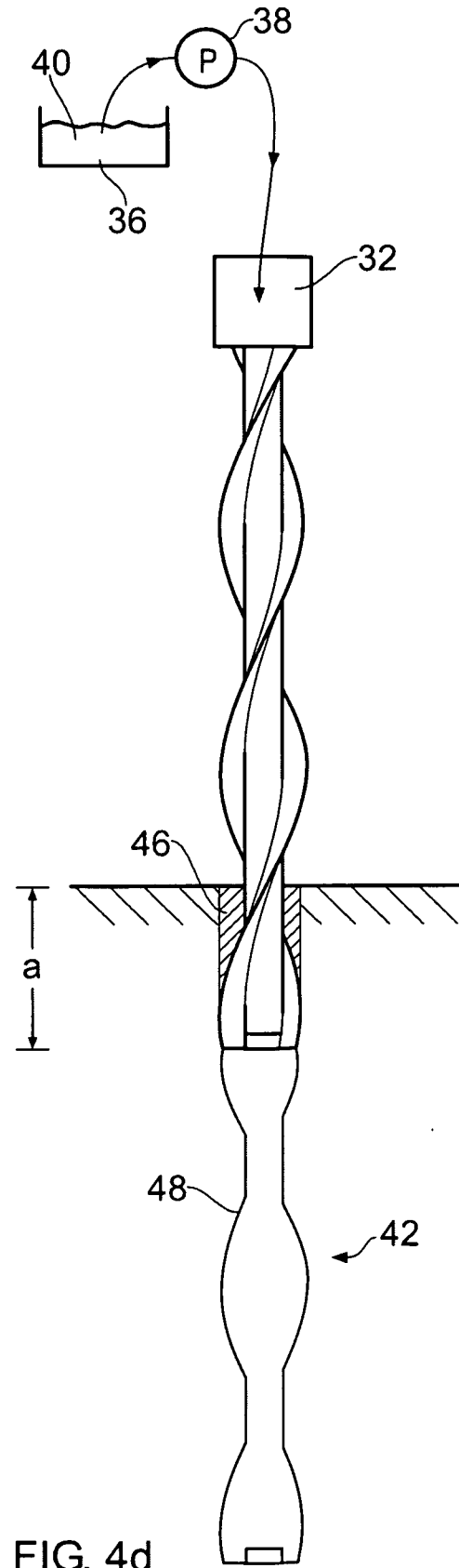


FIG. 4d

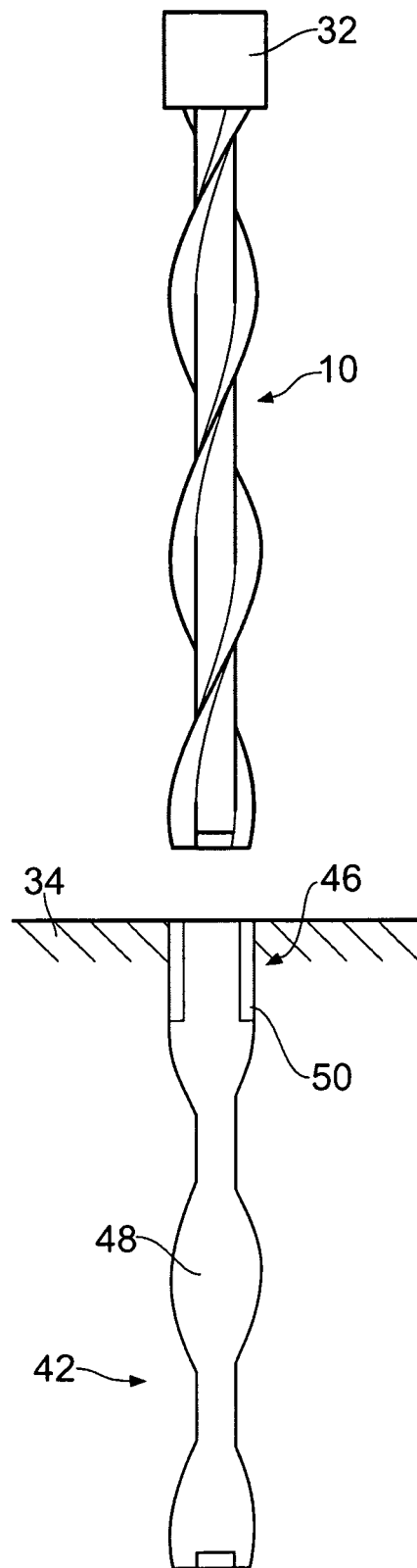


FIG. 4e