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(54) **VOID FORM FOR CONSTRUCTING POST-TENSIONED FOUNDATION PILES**

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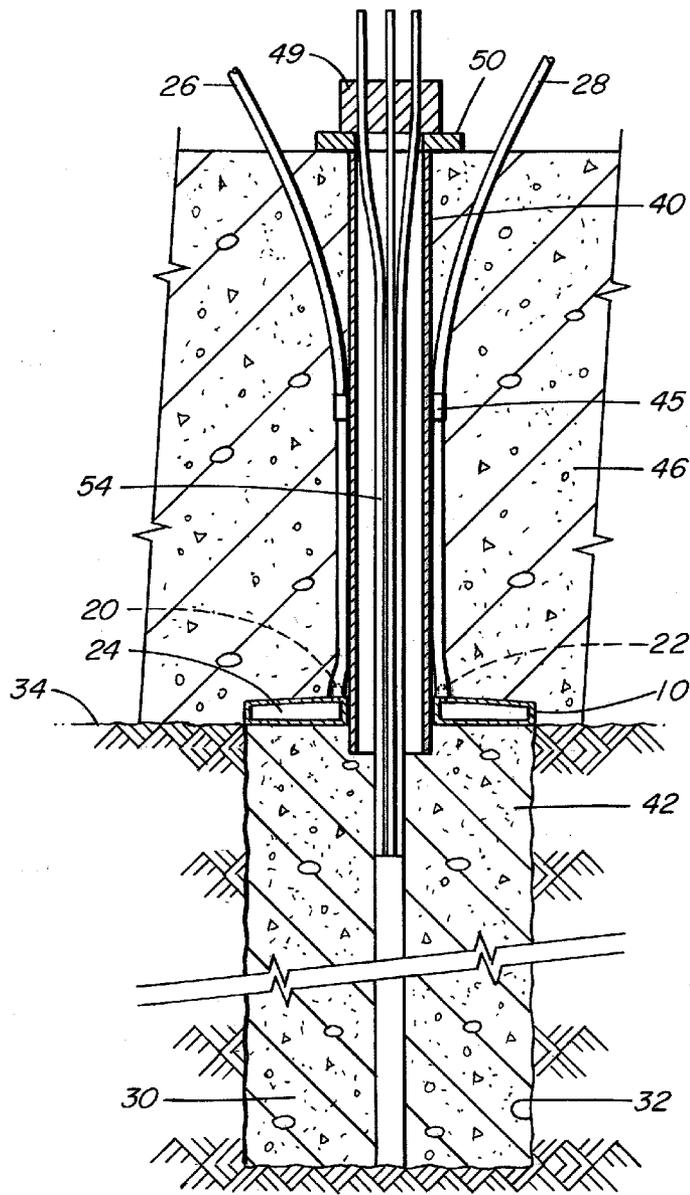
(57) **ABSTRACT**

A void form for use in constructing pile foundations is placed between the pile and the pile cap before the pile is post-tensioned. Once the pile has been tested and tensioned to design load, the void form is filled with a hardenable material to provide continuous vertical support to the foundation.

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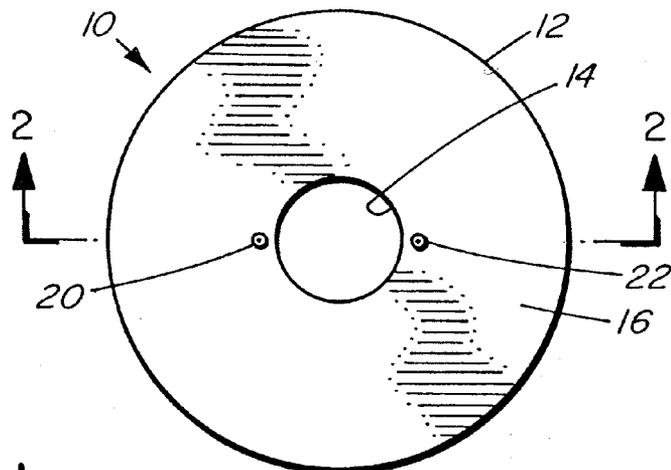


FIG. 1

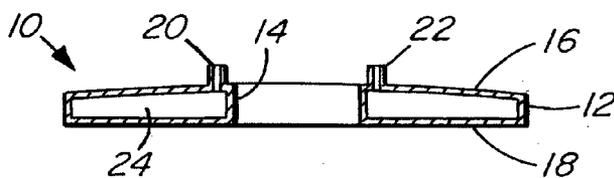


FIG. 2

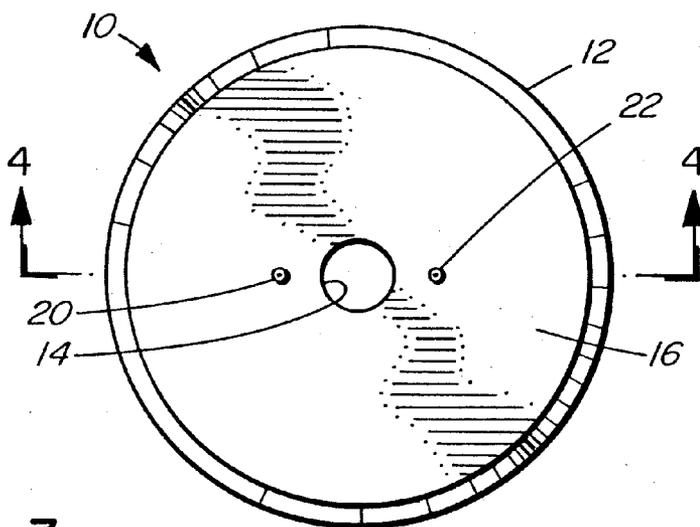


FIG. 3

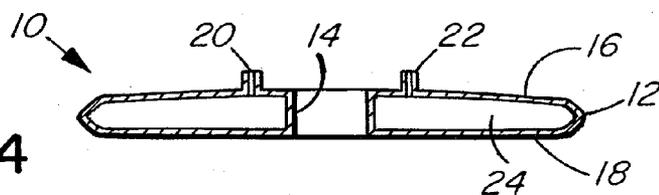
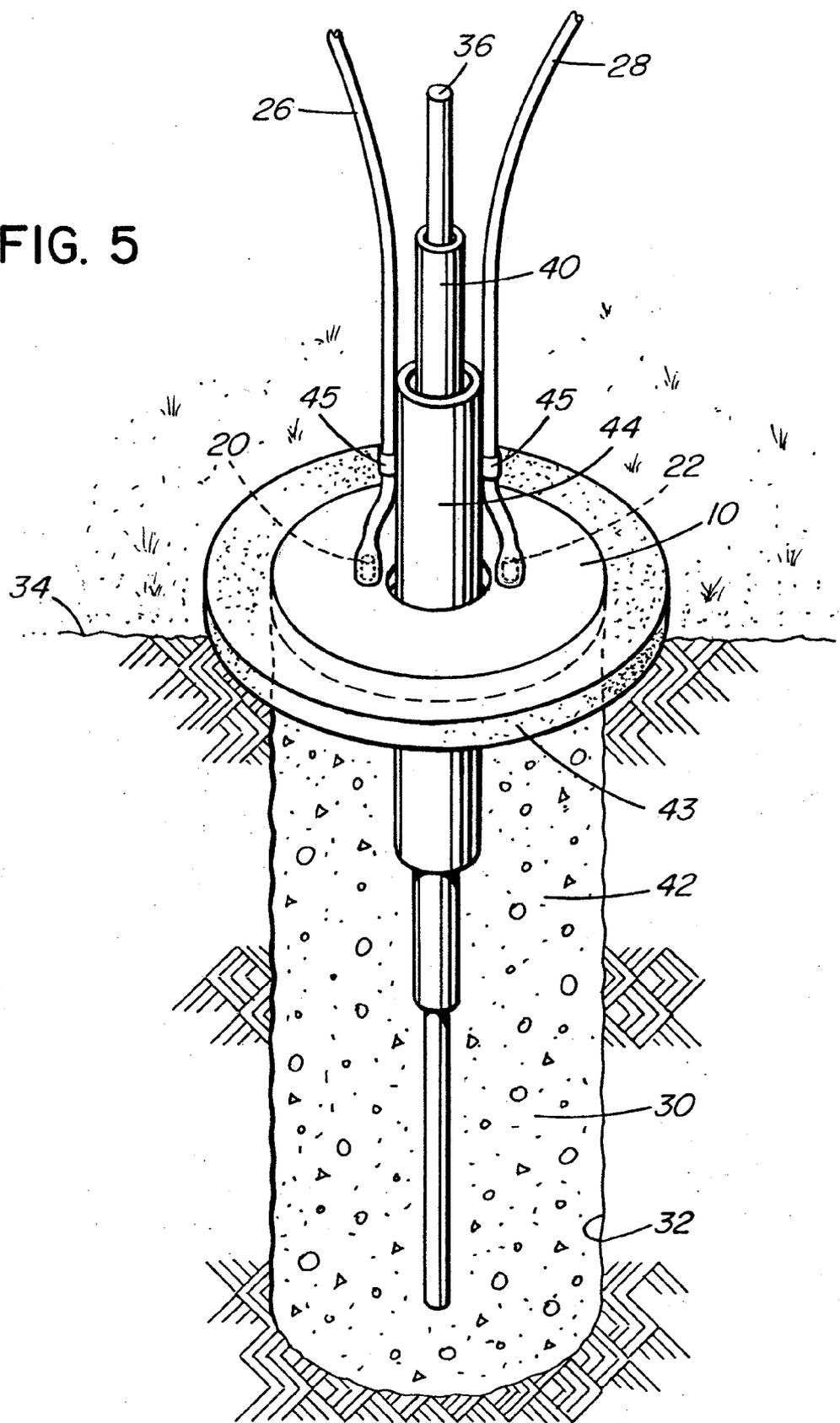


FIG. 4

FIG. 5



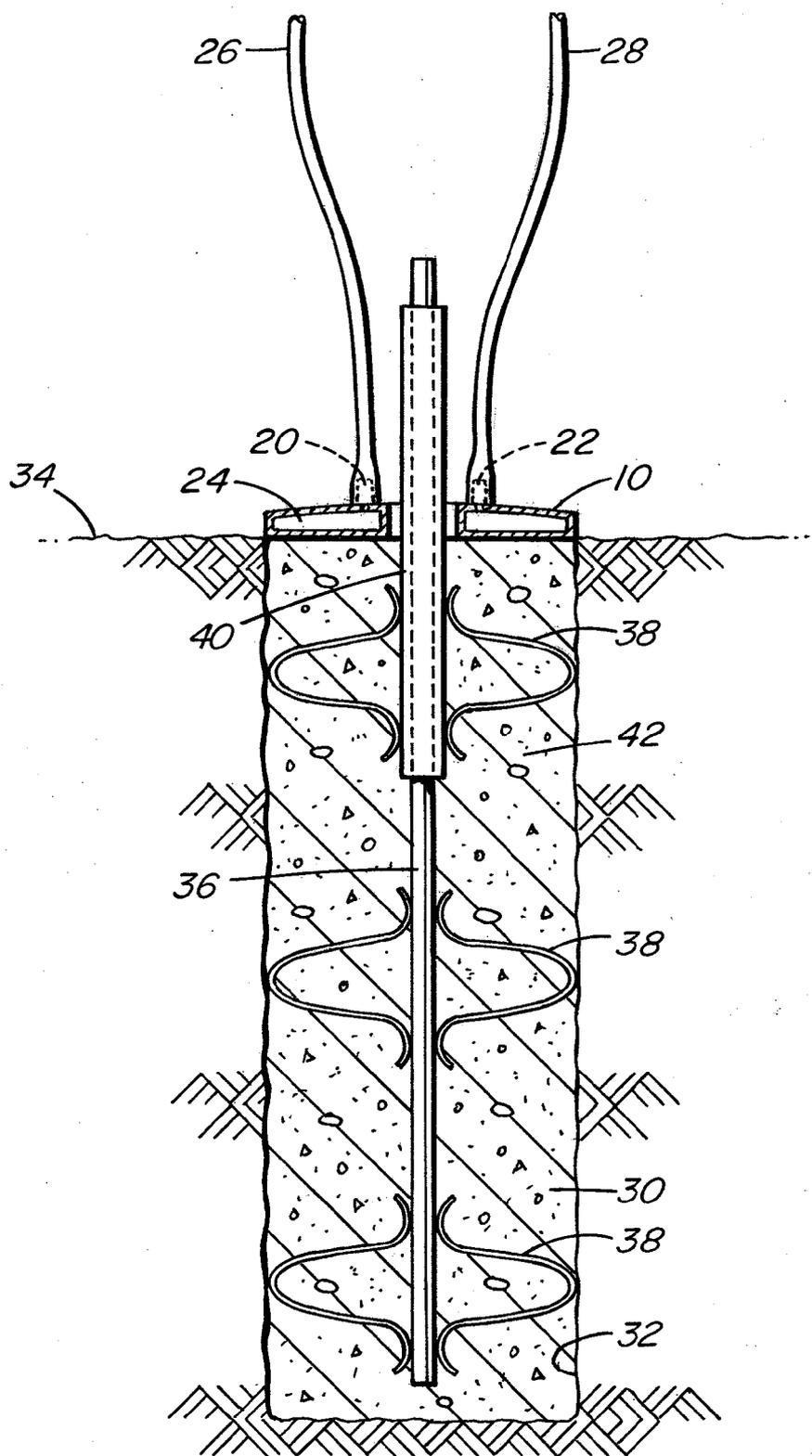


FIG. 6

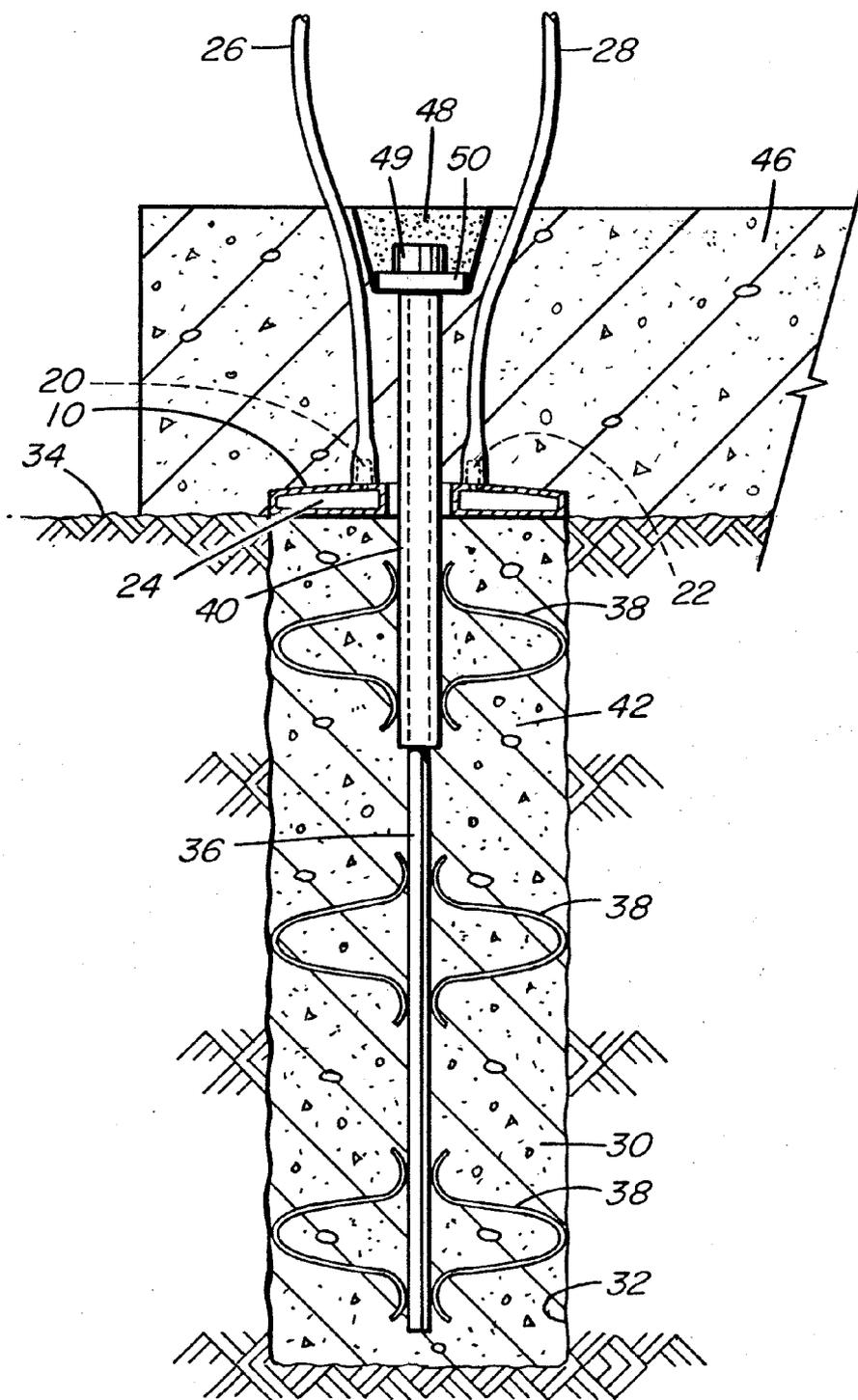


FIG. 7

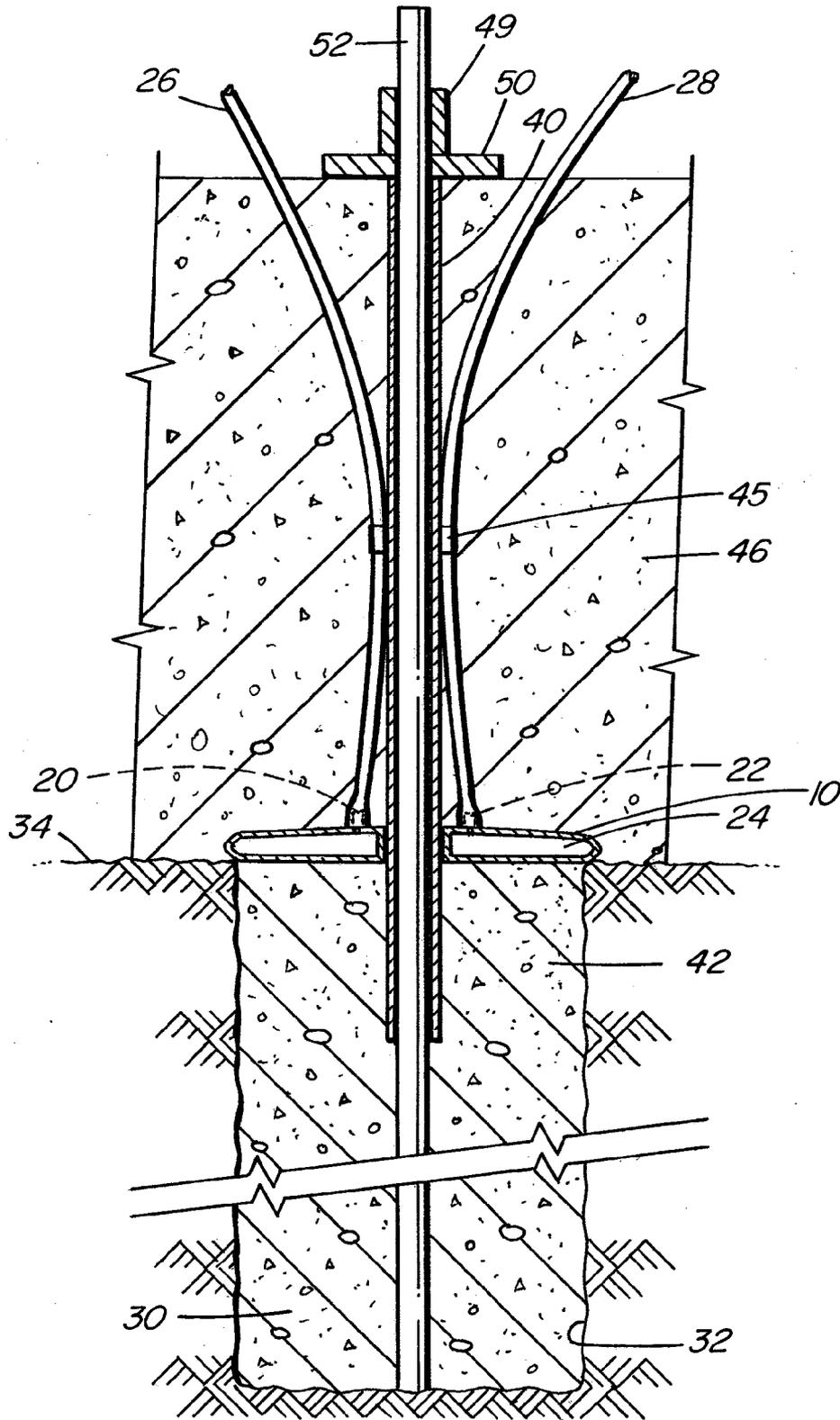


FIG. 8

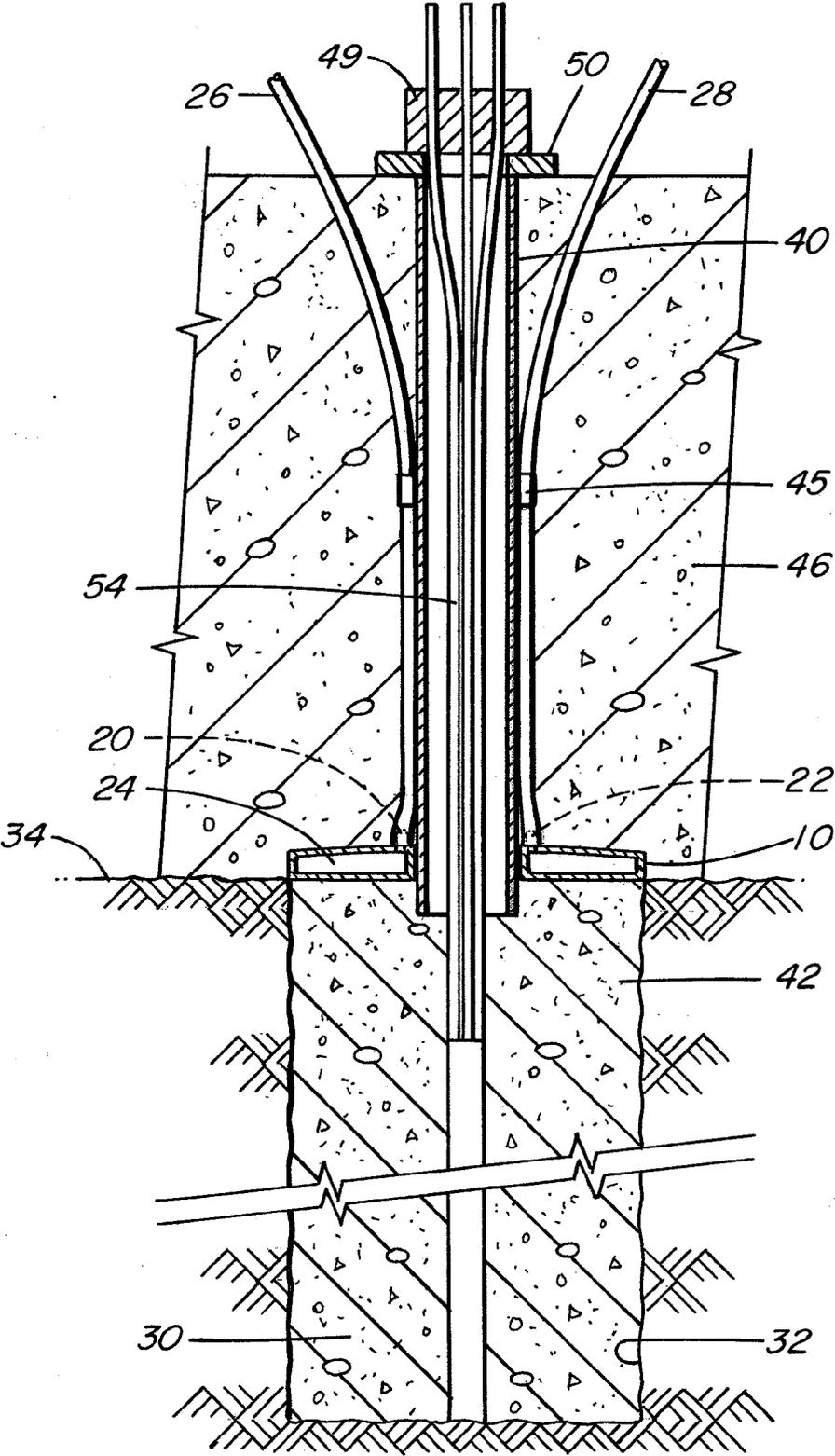


FIG. 9

VOID FORM FOR CONSTRUCTING POST-TENSIONED FOUNDATION PILES

TECHNICAL FIELD OF THE INVENTION

[0001] This invention relates to a void form for constructing a post-tensioned foundation pile with a pile cap, and to a method of constructing a post-tensioned foundation pile with ground anchors and a pile cap, using a void form.

BACKGROUND OF THE INVENTION

[0002] It is known to use foundation piles to support tall or massive structures, to distribute the structure's load to the ground. The foundation material is selected according to factors such as the soil characteristics around the structure, the climate and the groundwater table. An inappropriate foundation may sink or settle, weakening the structure and ruining it for its intended use.

[0003] Taller or broader structures have an additional consideration, in that they are subject to lateral and uplifting forces, such as wind. Such forces, combined with the weight of the structure, impart alternating compressive and tensile stresses on the foundation piles. Some examples of such structures are bridge supports, power lines and wind turbines.

[0004] To support the structure against compressive stresses, concrete foundation piles are commonly used, as concrete is very strong under compression. Anchoring piles support the structure against tensile stresses. Pre-stressed (either pre- or post-tensioned) concrete piles often provide the best combination of strength against alternating compressive and tensile stresses. Steel bar or strand anchors are commonly used to pre-stress a concrete pile. Pile caps may then be installed over the top of the pile or group of piles, to act as a footing for the structure. Continuity between the pile cap and the pile is preferable, to ensure the loading of the structure is distributed evenly to the ground below.

[0005] U.S. Pat. No. 4,043,133 to Yegge discloses a typical method of constructing a post-tensioned foundation pile. A pile hole is drilled into the ground for each pile, and a sheathed tendon is inserted into the hole. Concrete is poured around the sheath to near the top of the hole and is allowed to cure, thus anchoring the bottom of the tendon within the pile hole. The tendon is stressed with a tensioning jack placed on a jacking pad above the top of the pile, leaving some space between the top of the pile and the bottom of the pad. Application of tension to the tendons will compress the soil under the jacking pad and shrink the space between the pad and the pile. Once it has been assured that the entire pile will support the required stresses, the tension on the tendons is released, a concrete pile cap is poured, and the tendon is re-stressed to the design load and anchored to the pile cap. As an alternative embodiment, Yegge contemplates pouring the pile cap before tensioning the tendons, and using the pile cap to support the tensioning jack, instead of the jacking pad. In that case, any voids between top of the pile and the bottom of the pile cap would have to be filled after tensioning. However, Yegge does not disclose any means to do so. In addition, without visual confirmation of the amount and location of any compression of the soil, it would be difficult to ensure the voids are all completely full. Any empty space would tend to weaken the foundation, as the pile cap would be able to further settle or sink onto the top of the pile.

[0006] U.S. Patent Publication No. U.S. 2004/0131428 to Henderson discloses a more complex pile anchor foundation and related construction method. Like Yegge, Henderson contemplates leaving a gap between the top of the pile and the bottom of the pile cap, which may be left empty or filled with a compressible material, such as foam. However, again there is no way to confirm that the void is fully compressed (if left empty) or that the foam fully fills the void and has not shifted during formation of the pile cap or during post-tensioning. Further, under high compressive loads, compressible foam will eventually compress to its minimum size and will be unable to respond to tensile forces. This will eventually cause failure of a structure subject to alternating compressive and tensile loads.

[0007] U.S. Pat. No. 4,060,994 to Chitis discloses a method of constructing a post-tensioned foundation pile, with an additional support footing at the bottom of the pile. A hole is drilled into the ground, into which an anchoring bar is inserted, and concrete is cast in the hole around the anchor. Once the concrete is sufficiently cured, it may be pre-stressed by applying tension to the anchoring bar. Chitis further discloses providing additional support at the base of the pile, in the form of an expandable chamber at the bottom of the anchoring bar. Once the concrete has cured, grout may be injected into the chamber, forcing the chamber to expand into the surrounding soil until it breaks. This releases grout into the ground about the bottom of the pile, compressing the surrounding ground and providing additional support. The chamber may be scavenged and grout re-injected until the chamber breaks again. The process may be repeated until all of the available space about the bottom of the pile is filled with grout. Once the grout is set, it stabilizes the bottom of the pile.

[0008] It is therefore an object of the invention to provide a method of constructing a foundation pile which can be post-tensioned and tested effectively, prior to use.

[0009] It is a further object of the invention to provide a form which will not interfere with the desired movement of the pile cap and pile during post-tensioning, but will still eliminate voids in the post-tensioned pile, thereby providing continuous foundational support for a structure once construction is complete.

[0010] It is a further object of the invention to provide a method of constructing a foundation pile which is stable and supportive of a massive structure which is subject to uplifting or bending forces.

[0011] It is an object of the present invention to provide an improved structure to construct a post tensioned pile cap that overcomes the foregoing disadvantages and limitations.

[0012] These and other objects of the invention will be appreciated by reference to the summary of the invention and to the detailed description of the preferred embodiment that follow.

SUMMARY OF THE INVENTION

[0013] According to one aspect of the invention, there is provided a compressible and fillable hollow chamber or "void form" between the top of a concrete pile and the bottom of a pile cap, thus providing continuity and stability between the cap and the pile, without interfering with the movements of the pile or pile cap while the pile is post-tensioned.

[0014] Hollow tubes extending to the hollow chamber may be used to fill the chamber with grout or any other

flowable, hardenable material. The filled chamber provides a continuous solid surface between the pile and the pile cap, allowing for proper transfer of the loads borne by an overground structure into the ground. The filled chamber also prevents further settlement of the pile cap onto the top of the pile.

[0015] In one aspect, the invention comprises a void form for a post-tensioned pile comprising an upper wall and a lower wall, each having an outer peripheral edge and an inner peripheral edge; an outer wall joining the outer peripheral edges of the upper wall and the lower wall; an inner wall joining the inner peripheral edges of the upper wall and the lower wall; all of the walls defining a chamber; and at least two apertures in the upper wall, each adapted to receive a tube. The outer wall may be perpendicular to the upper and lower walls, or may comprise upper and lower sloped sections meeting at a ridge between the upper and lower walls. The upper wall may be convex.

[0016] In another aspect, the invention comprises a method of constructing a post-tensioned pile, comprising the steps of placing an anchored pile within an anchor hole; placing a void form on top of the anchored pile; placing a pile cap on top of the void form; post-tensioning the anchored pile across the void form and the pile cap to a pre-determined load; and filling the void form with hardenable material, which may be a material such as grout.

[0017] In a further aspect, the invention may comprise the further step of placing a compressible ring around the void form.

[0018] In a further aspect, the invention may comprise the further step of leaving a top portion of an anchor in said anchored pile protruding through said pile cap. A recess may be left in the pile cap about the top portion of the anchor; and the recess may be filled with hardenable material after post-tensioning the anchored pile.

[0019] In yet a further aspect, the method of the invention may be used with a bar anchor or a strand anchor effective for anchoring the anchored pile.

[0020] In another aspect, the invention comprises the use of a void form to construct a post-tensioned pile, comprising the steps of placing an anchored pile within an anchor hole; placing the void form on top of the anchored pile; placing a pile cap on top of the void form; post-tensioning the anchored pile across the void form and the pile cap to a pre-determined load; and filling the void form with hardenable material.

[0021] The foregoing was intended as a broad summary only and of only some of the aspects of the invention. It was not intended to define the limits or requirements of the invention. Other aspects of the invention will be appreciated by reference to the detailed description of the preferred embodiment and to the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022] The preferred embodiment of the invention will be described by reference to the drawings in which:

[0023] FIG. 1 is a plan view of an embodiment of the void form according to the present invention;

[0024] FIG. 2 is a sectional view taken along line 2-2 of FIG. 1;

[0025] FIG. 3 is a plan view of an alternate embodiment of the void form according to the present invention;

[0026] FIG. 4 is a sectional view taken along line 4-4 of FIG. 3;

[0027] FIG. 5 is a perspective view of a pile and the void form according to the present invention;

[0028] FIG. 6 is a sectional view of a pile and the void form according to the present invention;

[0029] FIG. 7 is a sectional view of a pile and the void form according to the present invention, capped with a pile cap;

[0030] FIG. 8 is an enlarged sectional view of the top section of a pile having a bar anchor; and

[0031] FIG. 9 is an enlarged sectional view of the top section of a pile having a strand anchor.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT OF THE INVENTION

[0032] FIGS. 1 and 2 show an embodiment of the void form 10 of the present invention. Void form 10 is preferably made of a compressible material, such as a hard plastic, which can be formed into a hollow chamber that matches the shape of a pile. The exact outer and inner diameter dimensions of the void form 10, defined by outer wall 12 and inner wall 14, are selected based on the size of the pile, and of the anchor which will be used to post-tension the pile. In order to properly fill a void between a pile and a pile cap, void form 10 should have an outer diameter which is at least as large as the outer diameter of the pile. The inner diameter should be selected to closely match the outer diameter of any sheath or casing which is placed around the anchor.

[0033] The void form 10 has upper wall 16, which may be slightly convex, and lower wall 18, which is preferably flat and substantially parallel to upper wall 16. The convex shape of upper wall 16 ensures air initially trapped in the void form 10 may escape as grout fills the hollow chamber 24 of void form 10, as will be discussed later. Upper wall 16 and lower wall 18 may be separated by approximately 2", depending on the diameter of the pile on which the void form will be applied, the type of soil, and the loading conditions. This approximate thickness allows for some compression of the void form 10 during the post-tensioning process, as will be discussed later, while still leaving room for grout. The void form may be thicker than 2", but it is preferable to avoid an excessive amount of grout.

[0034] The void form 10 includes at least one aperture 20, through which grout may be inserted, and a second aperture 22, which through which air trapped in the void form may escape as grout fills the hollow chamber 24 of void form 10. The convex shape of upper wall 16, which allows air to reach the uppermost point at the aperture 22, assists the escape of trapped air. Void form 10 preferably has extending nipples on each of apertures 20, 22, so that tubes 26, 28 (not shown) may be easily and securely connected to void form 10; however, it will be understood that any suitable means to securely connect void form 10 and tubes 26, 28 may be used.

[0035] Void form 10 may be formed with outer wall 12 substantially perpendicular to upper wall 16 and lower wall 18, as shown in FIGS. 1 and 2, or it may have a substantially non-perpendicular outer wall 12. For example, in the alternate embodiment shown in FIGS. 3 and 4, outer wall 12 comprises upper and lower sloped sections meeting at a ridge between upper wall 16 and lower wall 18.

[0036] FIGS. 5 and 6 show the void form 10 in place on a constructed pile 30. The method of constructing the pile 30 is similar to those disclosed in the prior art previously discussed. Essentially, anchor hole 32 is made in the ground 34, such as by drilling, to the desired diameter and depth under the ground 34. Anchor 36 is placed in drill hole 32. Anchor 36 may be a bar or strand anchor, as would be most appropriate for the circumstances. One or more centralizers

38 (shown only in FIG. 6) may be used to ensure anchor **36** is properly placed within anchor hole **32**. Sleeve **40**, of any appropriate material, such as PVC, may be used along any part of anchor **36** to provide a free stress length, which will allow anchor **36** to be properly post-tensioned. The anchor hole **32** is then filled with concrete **42**, preferably to approximately level with ground **34**. If required, a casing **44**, made of a material such as steel pipe, may also be placed around the top of the anchor, to help protect the finished pile against lateral stresses.

[0037] Void form **10** is then placed on top of the concrete. Preferably, void form **10** is placed before concrete **42** sets, to ensure good contact is made between the top surface of concrete **42** and the lower wall **18** of void form **10**. Tubes **26**, **28** may be attached to void form **10** at this point, or may have previously been attached. A ring **43** (shown only in FIG. 5) of compressible material, such as Styrofoam®, may be placed around the void form **10** to compensate for any variation in the diameter of the pile **30** when the anchor hole **32** was excavated. Ring **43** will typically only be used if the pile **30** diameter exceeds the outer diameter of void form **10**, as it will allow movement of the pile **30** during post-tensioning and will still permit proper load transfer about the periphery of the pile **30** once post-tensioning is complete. Attachments **45** (also shown only in FIG. 5), such as cable ties, duct tape or similar wrapping, may be used to fasten tubes **26**, **28** to the outside of anchor **36**, to support tubes **26**, **28**, to keep tubes **26**, **28** free from kinks or bends, and to ensure tubes **26**, **28** can easily be located and used during subsequent stages.

[0038] Referring now to FIG. 7, pile cap **46** may then be placed over pile **30** and void form **10** by any appropriate method. A recess **48** left in pile cap **46** over the top of anchor **36** will permit later post-tensioning of the anchor **36**. The ends of tubes **26**, **28** also protrude through the pile cap **46**. Once pile cap **46** has been placed and finished, the anchor **36** may be tensioned to the desired test load, and locked off at the specified design load. When the anchor has been tensioned, and the pile is therefore properly post-tensioned, grout or other hardenable material may be used to fill recess **48**, securing and protecting the top of anchor **36** from the elements and other stresses.

[0039] During the tensioning process, void form **10** is compressed vertically due to upward forces from the pile **30** and downward forces from the pile cap **46**. Void form **10** may compress as much as 1/2" from each force, and may not compress evenly throughout its area, but the vertical forces do not completely collapse chamber **24**. Nor does void form **10** interfere with the movements of pile **30** and pile cap **46**. It is therefore assured that the pile has been post-tensioned to the desired test and design loads.

[0040] Grout or other strong, hardenable material may then be pumped into void form **10**, through tube **26**, until chamber **24** is filled. Tube **28** allows air to escape, and will also provide visual confirmation when chamber **24** is completely filled with grout. The present invention therefore eliminates any voids in the vertical direction, ensuring continuous support throughout the depth of the pile **30**.

[0041] FIGS. 8 and 9 show the two embodiments of the void form **10** in place in a pile **30**. In either case, the process to construct the pile is the same.

[0042] The void form **10** is versatile and may be used with either a bar anchor **52** (as shown in FIG. 8) or a strand anchor **54** (as shown in FIG. 9). FIGS. 8 and 9 also show a different

method of post-tensioning the anchor. In this embodiment, the anchor head **49** protrudes above the pile cap **46**, and may be post-tensioned by applying force against bearing plate **50** on the top surface of the pile cap **46**. Otherwise, the process for constructing the pile is the same as the embodiment discussed above.

[0043] It will be appreciated by those skilled in the art that other variations to the preferred embodiment described herein may be practised without departing from the scope of the invention, such scope being properly defined by the following claims.

1. A void form for a post-tensioned pile comprising:
 - an upper wall and a lower wall, each having an outer peripheral edge and an inner peripheral edge;
 - an outer wall joining the outer peripheral edges of said upper wall and said lower wall;
 - an inner wall joining the inner peripheral edges of said upper wall and said lower wall;
 - said walls defining a chamber; and
 - at least two apertures in said upper wall, each adapted to receive a tube.
2. The void form of claim 1 wherein said outer wall is perpendicular to said upper and lower walls.
3. The void form of claim 1 wherein said outer wall comprises upper and lower sloped sections meeting at a ridge between said upper and lower walls.
4. The void form of claim 1 wherein said upper wall is convex.
5. A method of constructing a post-tensioned pile, comprising the steps of:
 - placing an anchored pile within an anchor hole;
 - placing a void form on top of said anchored pile;
 - placing a pile cap on top of said void form;
 - post-tensioning said anchored pile across said void form and said pile cap to a pre-determined load; and
 - filling said void form with hardenable material.
6. The method of claim 5, wherein said hardenable material comprises grout.
7. The method of claim 5, comprising the further step of placing a compressible ring around the void form.
8. The method of claim 5, comprising the further step of leaving a top portion of an anchor in said anchored pile protruding through said pile cap.
9. The method of claim 8, comprising the further steps of:
 - leaving a recess in said pile cap around said top portion of said anchor; and
 - filling said recess with hardenable material after post-tensioning said anchored pile.
10. The method of claim 5 comprising the further step of providing a bar anchor effective for anchoring said anchored pile.
11. The method of claim 5 comprising the further step of providing a strand anchor effective for anchoring said anchored pile.
12. Use of a void form to construct a post-tensioned pile, comprising the steps of:
 - placing an anchored pile within an anchor hole;
 - placing said void form on top of said anchored pile;
 - placing a pile cap on top of said void form;
 - post-tensioning said anchored pile said void form and said pile cap to a pre-determined load; and
 - filling said void form with hardenable material.