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(54) **SOIL DISPLACEMENT PILE ASSEMBLY AND METHOD OF FORMING FOUNDATION PILE**

(71) Applicant: **Hubbell Incorporated**, Shelton, CT (US)

(72) Inventors: **Jason Wayne Herron**, Centralia, MO (US); **Benjamin Lehman Jennings**, Centralia, MO (US); **Joseph Reed Brown**, Ava, MO (US)

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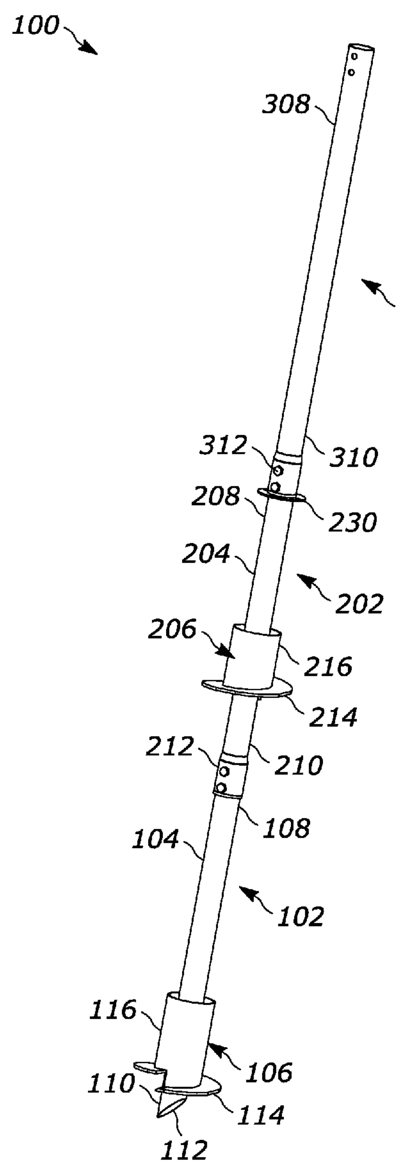
(57) **ABSTRACT**

A soil displacement pile includes a lead shaft having a lead end and a lead head. A lead soil displacement assembly is connected to the lead shaft. The lead soil displacement assembly includes a helical plate and a canister. The helical plate extends at least partially around the lead shaft. The canister includes an outer wall extending around the lead shaft defining an interior and an opening in the outer wall to permit the ingress of soil.



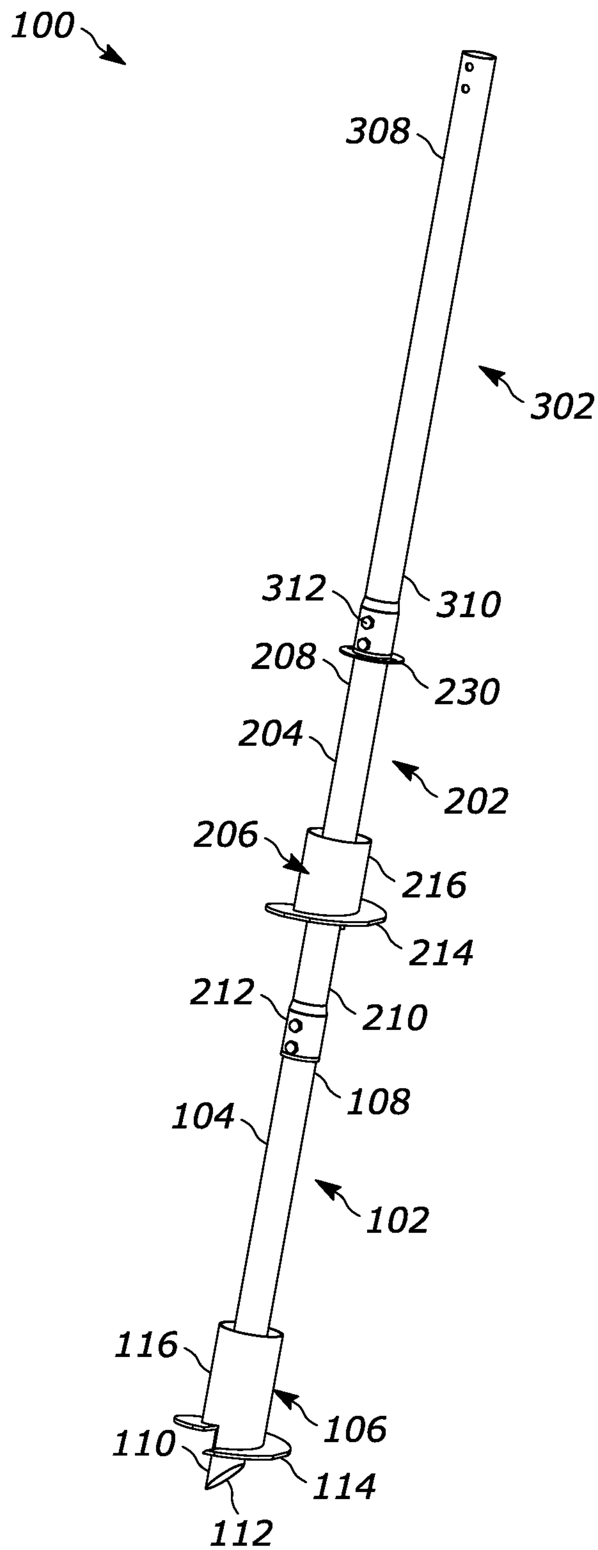

100
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FIG. 1

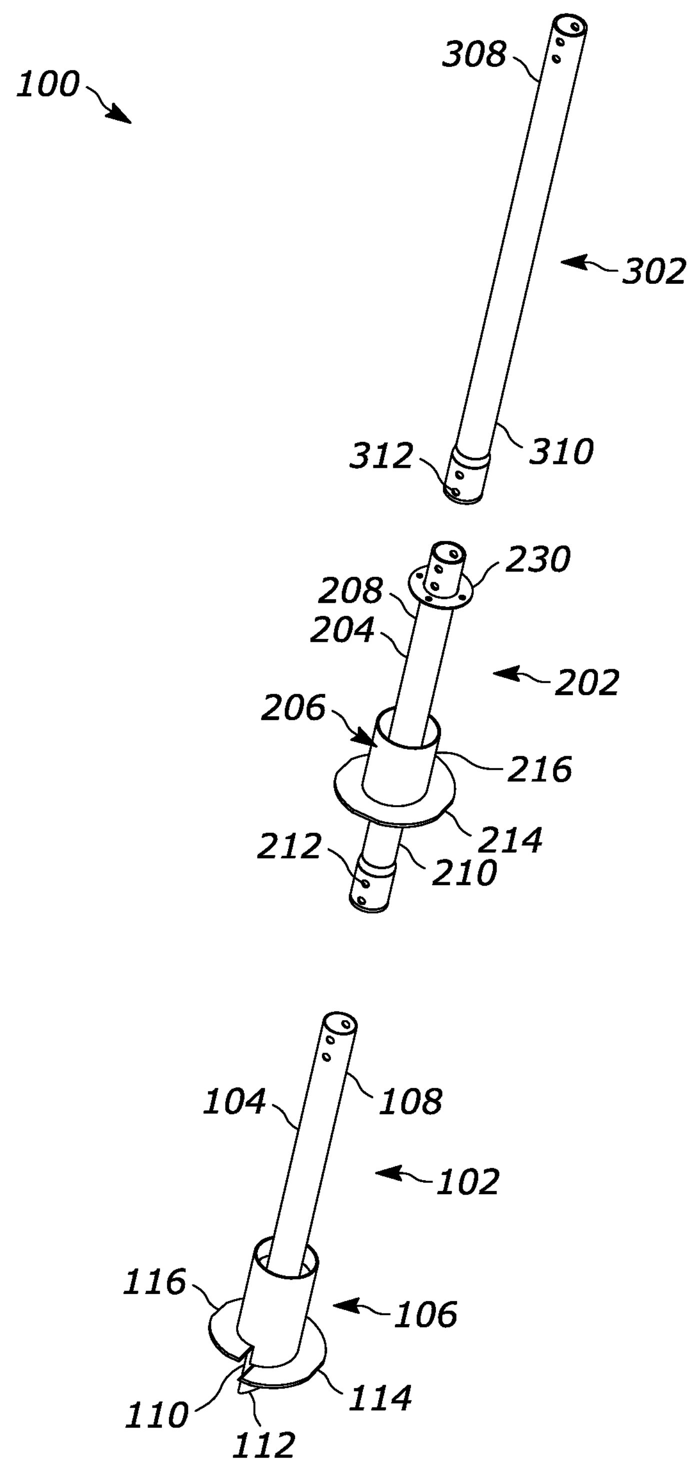
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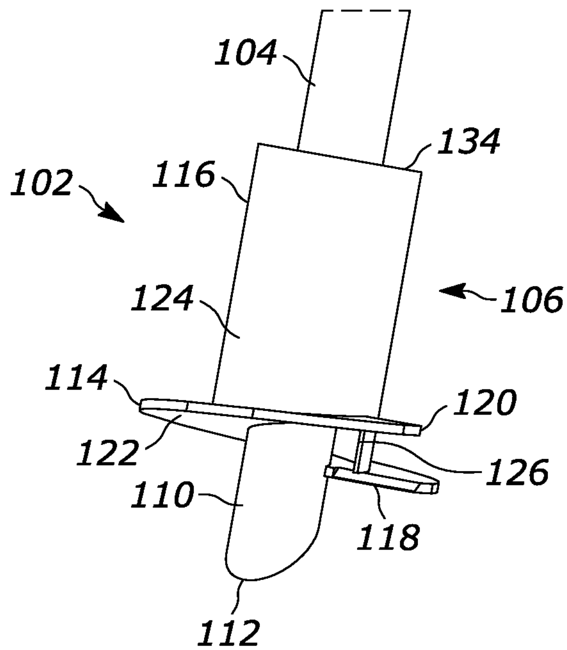
FIG. 2


104
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112

FIG. 3

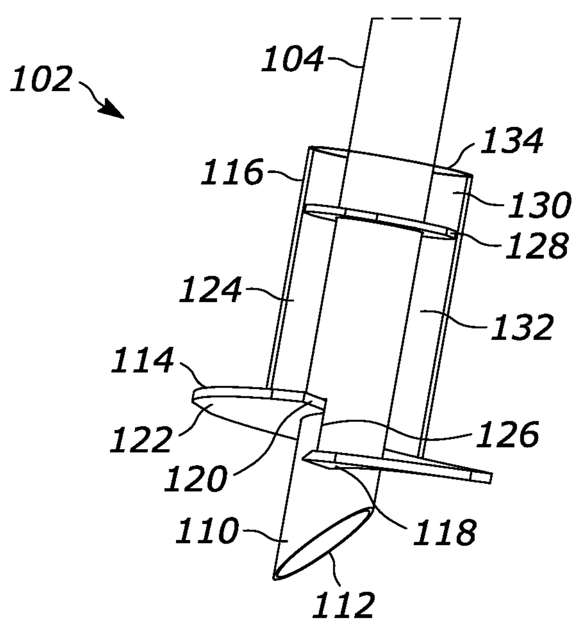
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FIG. 4

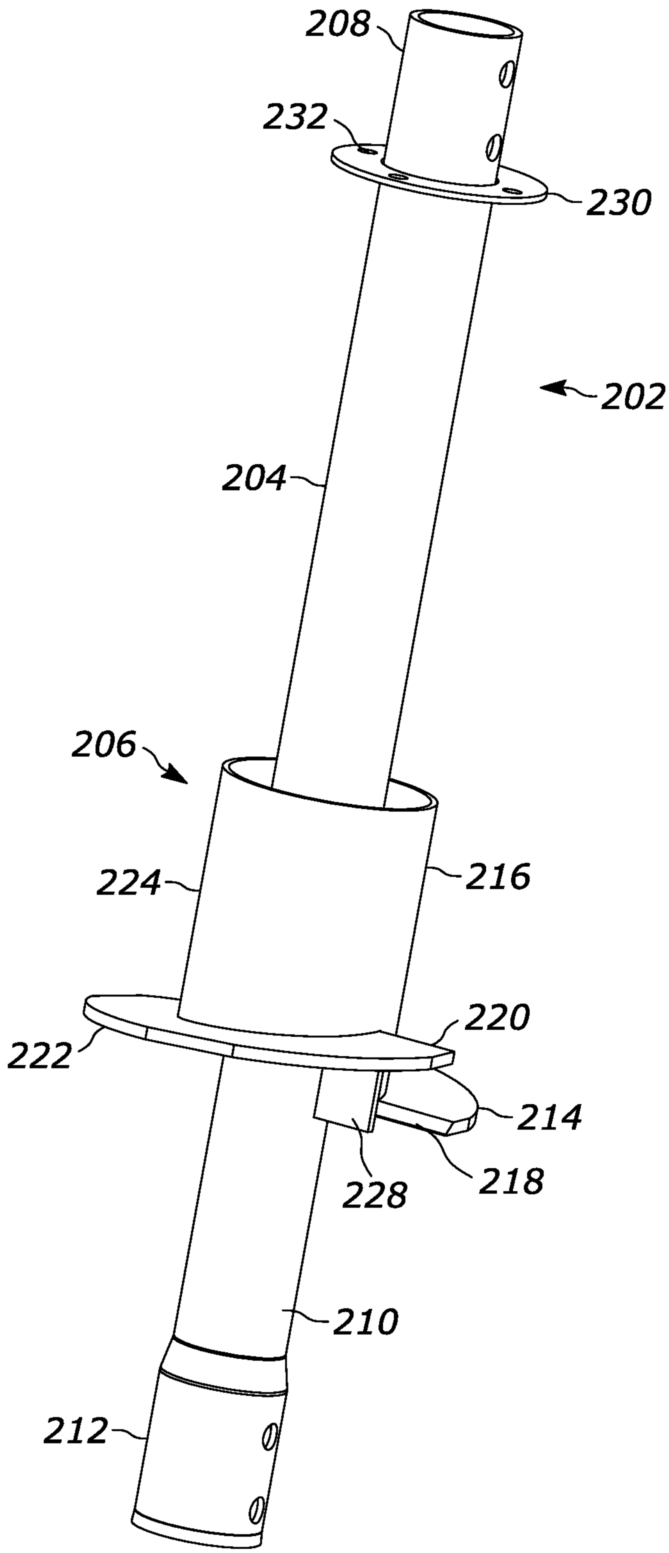

FIG. 5

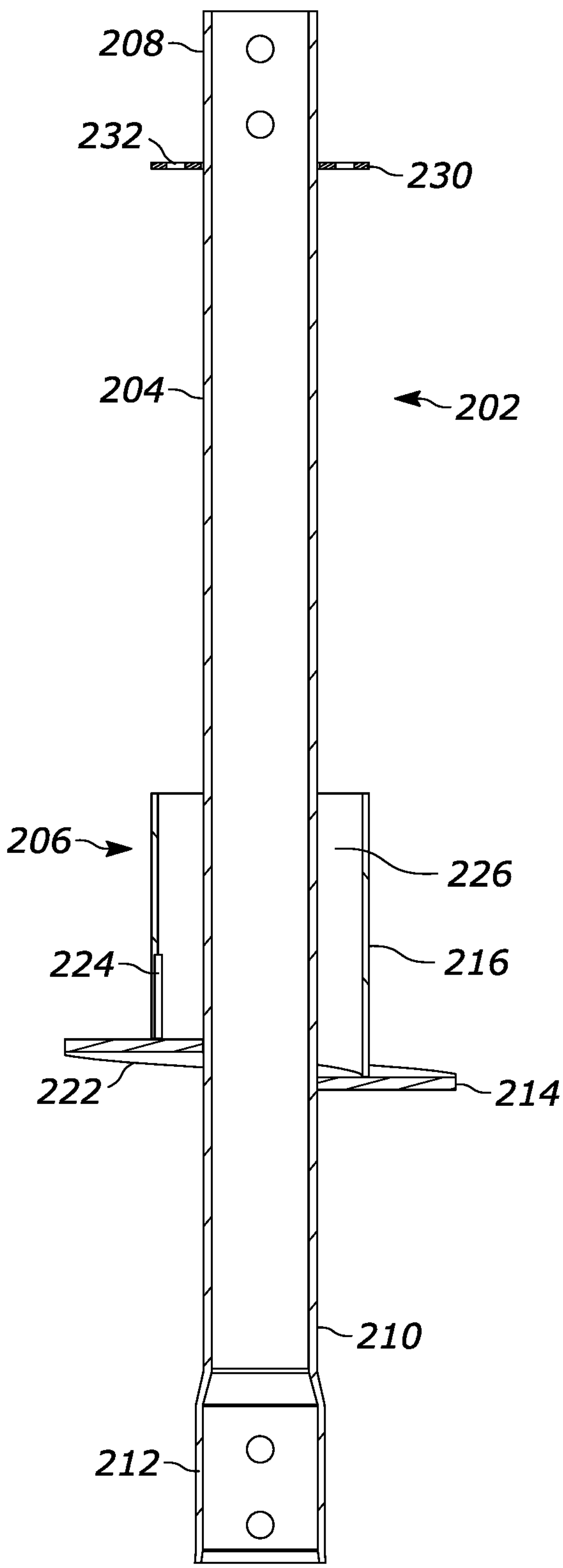

FIG. 6

SOIL DISPLACEMENT PILE ASSEMBLY AND METHOD OF FORMING FOUNDATION PILE

RELATED APPLICATION(S)

[0001] This application claims priority to U.S. Provisional Application Ser. No. 63/454,376, filed Mar. 24, 2023, the disclosure of which is incorporated herein by reference in its entirety.

FIELD

[0002] Various exemplary embodiments relate to pile leads and extensions with soil displacement assemblies for forming composite pile columns.

BACKGROUND

[0003] Piles are used to support structures where surface soil is weak by penetrating the ground to a depth where a competent load-bearing stratum is found. Piles are often required to be placed into the ground for providing support for foundations or other structures. It is desirable to install such piles quickly and efficiently so as to reduce construction costs. Often it is beneficial to form the piles in place, i.e., at the job site.

[0004] One conventional method for forming piles at the job site involves rotating a shaft having a lower end screw section and a disc into the ground. The disk clears a cylindrical region around the shaft. The cylindrical region is filled with grout to encapsulate the shaft. Another conventional method for forming piles at the job site involves placing a helical pile that has an elongated pipe with a central chamber in the soil. The pipe has a helical blade with an opening in the trailing edge of the blade where grout is extruded. The grout fills the portions of the soil disturbed by the blade. A helical pile typically is made of relatively small galvanized steel shafts sequentially joined together, with a lead section having helical plates. The pile is installed by applying torque to the shaft at the pile head, which causes the plates to screw into the ground with minimal soil disruption.

SUMMARY

[0005] In certain configurations, a soil displacement pile includes a lead shaft having a lead end and a lead head. A lead soil displacement assembly is connected to the lead shaft. The lead soil displacement assembly includes a helical plate and a canister. The helical plate extends at least partially around the lead shaft. The canister includes an outer wall extending around the lead shaft defining an interior and an opening in the outer wall to permit the ingress of soil.

[0006] In certain configurations, a soil displacement pile includes a lead shaft having a lead end and a lead head. A lead soil displacement assembly is connected to the lead shaft. The lead soil displacement assembly includes a helical plate and a canister. The helical plate extends at least partially around the lead shaft. The canister includes an outer wall extending around the lead shaft defining an interior and a divider plate is positioned in the canister to separate the interior into an upper section and a lower section.

[0007] In certain configurations, a soil displacement pile includes a lead shaft having a lead end and a lead head. A lead soil displacement assembly is connected to the lead shaft. The lead soil displacement assembly including a first helical plate and a first canister. An extension shaft has an extension end and an extension head. An extension soil displacement assembly connected to the extension shaft. The extension soil displacement assembly includes a second helical plate and a second canister. The first helical plate extends at least partially around the lead shaft. The first canister includes an outer wall extending around the lead shaft defining a first interior and a divider plate is positioned in the first canister to separate the first interior into an upper section and a lower section.

[0008] A method of forming a composite pile column can include positioning a lead shaft for ground insertion. The lead shaft has a lead end, a lead head, and a lead soil displacement assembly. The lead soil displacement assembly includes a helical plate and a canister having an open top. The lead shaft and lead soil displacement assembly are rotated to rotate the helical plate and canister and cause displacement of soil. A cavity is formed in the ground by displacement of soil by the lead shaft and lead soil displacement assembly. Filler is inserted into the cavity and at least a portion of the filler is introduced into the canister through the open top.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] The aspects and features of various exemplary embodiments will be more apparent from the description of those exemplary embodiments taken with reference to the accompanying drawings.

[0010] FIG. **1** is a perspective view of an exemplary configuration of a soil displacement pile.

[0011] FIG. **2** is a perspective, partially exploded view of the soil displacement pile of FIG. **1**.

[0012] FIG. **3** is a perspective, partial view of the lead section of the soil displacement pile of FIG. **1**.

[0013] FIG. **4** is a perspective view of the lead section of FIG. **3** with a portion of the canister wall removed to show the interior.

[0014] FIG. **5** is a perspective view of the extension section of the soil displacement pile of FIG. **1**.

[0015] FIG. **6** is a cross-sectional view of the extension section of FIG. **5**.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

[0016] Certain configurations include piles and systems and methods of forming piles used as support columns in construction. Examples of piles are described in: U.S. Pat. Nos. 9,115,478; 9,416,513; and 10,865,539, the disclosures of which are hereby incorporated by reference in their entirety.

[0017] In certain implementations, piles are rotated into the ground by a machine to displace soil and form a cylindrical cavity. The piles can be left in the ground to form part of the support column. Filler can be poured in the open cavity around the pile to form the support column. The filler can include grout, cement, concrete, or other suitable material that can be poured into the cavity and hardened to form a composited pile column.

[0018] FIG. **1** shows an exemplary configuration of a soil displacement pile **100**. The soil displacement pile **100** has a lead **102**. The lead **102** comprises a lead shaft **104** and at least one lead soil displacement assembly **106**. The lead shaft **104** extends along a longitudinal axis. The exemplary configuration of the lead shaft **104** is shown with a cylindrical body, although other curvilinear and rectilinear shapes can be used. For example, the lead shaft **104** can be of varying diameter or standard round corner square bar with diameter ranging from 1¼ inches to 2¼ inches. The lead shaft **104**, which is the bottom most shaft of a soil displacement pile **100**, has a lead head portion **108** and a lead end portion **110**. The lead end portion **110** is configured to first penetrate the soil, and terminates at its distal end with a tapered tip **112**.

[0019] One or more extensions **202** can be connected to the lead **102**. The one or more extensions **202** can include an extension shaft **204**. The extension shafts **204** can extend along the longitudinal axis coaxially with the lead shaft **104**. In certain configurations, the extension **202** can have at least one extension soil displacement assembly **206**. In other configurations, a plain shaft **204** can be used or the extension **202** can include other features. The exemplary configuration of the extension shaft **204** is shown with a cylindrical body, although other curvilinear and rectilinear shapes can be used. For example, the extension shaft **204** can be of varying diameter or standard round corner square bar with diameter ranging from 1¼ inches to 2¼ inches. The size and shape of the extension shaft **204** can be identical to the lead shaft **104** or be different.

[0020] The extension shaft **204** can include an extension head portion **208** and an extension end portion **210**. The first extension **202** added to the soil displacement pile **100** is secured to the lead **102** where the extension end portion **210** is mated with the lead head portion **108** using one or more fasteners, for example a nut and bolt assembly. Subsequent extensions **202** may be sequentially joined together where the extension end portion **210** of the next in line extension **202** is mated with the extension head portion **208** of the previous extension **202**. The lead shaft **104** and the extension shaft **204** can be hollow or solid, and the shafts **104**, **204** can be made of metal, e.g., steel or galvanized steel, or carbon fiber, or other suitable material known in the art.

[0021] The extensions **202** are optional such that the lead **102** may comprise the soil displacement pile **100** and a pile drive system head is used to rotate the lead **102** into the soil. If one or more extensions **202** are added to the lead **102** then the lead **102** and the one or more extensions **202** form the soil displacement pile **100**, and the pile drive system head is used to first rotate the lead **104** into the soil and then each extension **202** successively into the soil.

[0022] In certain configurations, one or more lead soil displacement assemblies **106** are secured directly or indirectly to the lead shaft **104**. The lead soil displacement assembly **106** can be secured directly to the lead shaft **104** by a direct connection between the respective shaft **104** and the soil displacement assembly **106**, such as by welding or mechanical fasteners. Securing the lead soil displacement assembly **106** indirectly to the lead shaft **104** can include an indirect connection between the respective shaft and the soil displacement assembly, such as by using a coupler to join the respective shaft and the lead soil displacement assembly and securing the coupler to the shaft, or by mating the soil displacement assembly with a coupling already on the respective shaft. In the configuration of FIG. **1**, the lead **102** has one lead soil displacement assembly **106**, although more than one lead soil displacement assembly **106** can be used.

[0023] As best shown in FIGS. **3** and **4**, the lead soil displacement assembly **106** can include a helical plate **114** and a canister **116**. The illustrated embodiment shows the soil displacement assembly **106** positioned toward the lower end of the lead shaft **104**, although other configurations can have the soil displacement assembly **106** positioned closer to the head **108**. The helical plate **114** is positioned below the canister **116** and extends at least substantially around the shaft **104**. The canister **116** extends around the shaft **104** and above the helical plate **114** toward the lead head **108**. The helical plate **114** and the canister **116** can be jointly or separately directly or indirectly connected to the shaft **104**. The configuration (e.g., size and shape) can be varied as desired based on the size and type of pile to be formed.

[0024] As best shown in FIGS. **3** and **4**, the helical plate **114** can have a first end **118**, a second end **120**, and a helical body **122** extending between the first and second ends **118**, **120**. The first end **118** is positioned below the second end **120** along the longitudinal axis based on the pitch of the helical plate **114**. The first end **118** can also be spaced circumferential from the second end **120**. The first and second ends **118**, **120** can taper to form a cutting blade to help displace the soil. The helical body **122** can extend at least partially around the lead shaft **104** with some configurations extending entirely around the lead shaft **104**.

[0025] In certain configurations, the diameter of the helical plate **114** can range from between about 6 inches to about 30 inches depending upon the size of the cavity to be created by the lead soil displacing assembly **106** and thus the size of the pile column created by the cured filler (e.g. grout) and soil displacement pile **100**. Smaller or larger sizes may be used as needed dependent on the operational requirements, such as load requirements and soil type.

[0026] The exemplary canister **116** has a substantially solid outer wall **124** defining a substantially hollow interior. The canister **116** is shown having a cylindrical shape with a curved outer wall **124** having a diameter less than the diameter of the helical plate **114**. In other configurations, different sizes and shapes of the canister **116** can be used. As best shown in FIG. **3**, an opening **126** can be provided in the outer wall **124**. The opening **126** can be positioned between the first end **118** and the second end **120** of the helical plate **114**. The opening **126** can extend from the shaft **104** to the outer wall **124**.

[0027] A divider **128** can be positioned inside of the canister **116**. The divider **128** can extend from the shaft **104** to the outer wall **124** to separate the canister **116** into an upper section **130** and a lower section **132**. In other configurations, one or more portions of the interior of the canister **116** can be solid. The divider **128** is positioned below an upper edge **134** of the canister **116**, forming an opening so that the upper section **130** can receive filler during installation. The divider **128** is shown as a substantially flat plate, although other configurations may be used depending on the application and the shape of the canister **116**.

[0028] The outer wall **124** can help to push back soil during installation of the lead **102** and the opening **126** can allow soil to enter the canister **116**. Allowing the soil to enter the canister **116** can help to bite out more soil which can help increase the stability of the pile **100** and decrease installation time. The divider **128** is positioned in the canister **116** to limit that amount of soil and maintain a relatively clear upper section **130**. This allows the upper section **130** to receive filler during installation, helping to form and maintain a stronger pile **100** than can be achieved with just a helical plate or a combination of helical plate and paddle design.

[0029] As shown in FIG. **1**, one or more extensions **202** can be connected to the lead **102** as the pile **100** is formed. One configuration of a first extension **202** can include a collar **212** configured to fit over the head **108** of the lead shaft **104**. The collar **212** can have one or more openings to receive fasteners to connect the extension **202** to the lead **102**. As best shown in FIGS. **5** and **6**, the first extension **202** can include an extension soil displacement assembly **206** having a helical plate **214** and a canister **216**. The illustrated embodiment shows the extension soil displacement assembly **206** positioned toward the lower end of the extension shaft **204**, although other configurations can have it positioned closer to the head **208**.

[0030] The helical plate **214** is positioned below the canister **216** and extends substantially around the shaft **204**. The canister **216** extends around the shaft **204** and above the helical plate **216** toward the head **208** of the extension **202**. The helical plate **214** and the canister **216** can be jointly or separately directly or indirectly connected to the shaft **204**. The configuration (e.g., size and shape) can be varied as desired based on the size and type of helical pile to be formed.

[0031] The helical plate **214** and the canister **216** of the extension soil displacement assembly **206** can having substantially the same configuration of the lead soil displacement assembly **106**. The helical plate has a first end **218**, a second end **220**, and a body **222** extending between the first and second ends **218**, **220**. The canister **216** can have an outer wall **224** defining an interior **226**. In certain configurations, the interior of the canister **216** is substantially hollow and no plate is positioned in the canister **216**. This allows filler to flow into the entire interior **226** of the canister **216**. In certain configurations, the canister **216** does not have an opening as with the lead soil displacement assembly **106**. In the illustrated embodiment, a cover **228** extends between the first end **218** and the second end **220** of the helical plate to cover the opening. The cover **228** can be directly or indirectly connected to the shaft **204**, helical plate **214**, or the canister **216**. This allows the same type of canister **216** to be used for both the lead soil displacement assembly **106** and the extension soil displacement assembly **206**.

[0032] An upper plate **230** can also be connected to the extension shaft **204**. In the illustrated embodiment, the upper plate **230** is positioned above the extension soil displacement assembly **206** closer to the head **208** of the extension shaft **204**. The upper plate **230** can have one or more through holes **232**, allowing filler to flow through the upper plate **230**. The upper plate **230** can be directly or indirectly connected to the extension shaft **204**. One or more upper plates **230** can be used or no upper plates **230** can be used depending on the application.

[0033] FIGS. **1** and **2** also show a second extension **302** that can be connected to the first extension **202** as the pile **100** is formed. The second extension **302** can include a shaft **304** having a head **308** and an end **310**. A collar **312** configured to fit over the head **208** of the first extension shaft **204**. The collar **312** can have one or more openings to receive fasteners to connect the second extension **302** to the first extension **202**. Different numbers of first extensions **202** and second extensions **302** can be optionally used depending on the size and depth of pile to be formed. Certain piles can omit both extensions **202**, **302** or can include multiple units of either extension **202**, **302** in any combination.

[0034] An example of an operation to form a pile can include connecting the lead **102** to a foundation pile drilling machine or other industrial machine capable of rotating the lead **102** into the ground. The shaft **104** of the lead **102** is rotated so that the helical plate **114** grips the soil to start pulling the lead **102** into the ground. As the lead **102** rotates the soil will enter the canister **116** and the canister **116** outer wall **124** can displace the soil, forming an opening in the ground to provide a cavity in which filler is poured. The canister **116** helps to compact the soil around the cavity, which helps create a stronger, more repeatable column in different soil types. The open top of the canister **116** allows filler to flow into the upper section **130**, reducing the amount of soil mixed in with the initial filler around the lead **102**, allowing better filler intake as the pile **100** is being formed.

[0035] After the lead **102** is rotated to a sufficient depth, the first extension **202** can be connected to the lead **102** and the two are rotated together. The extension soil displacement assembly **206** will outwardly displace any soil that may have entered the column and further compact the soil along the outer perimeter of the column. Depending on the depth and load requirements of the pile **100**, multiple first extensions **202** can be used, and/or he plain second extensions **302** can be used to achieve the desired column.

[0036] In certain operations, the pile **100** can be installed at a constant rate, which is not repeatedly achievable with other types of piles. Moving at a constant rate allows torque to be measured so that torque to capacity ratios can be determined and used to calculate load bearing capacity in different soil types.

[0037] The present disclosure describes a way of displacing soil for the purpose of creating a pile column with an embedded soil displacement pile. The one or more soil displacement assemblies displace soil so that filler may be poured into a cavity created by the one or more soil displacement assemblies around the soil displacement pile forming a pile column at the job site. The soil displacement assembly of the present disclosure permits the use of larger diameter shafts and helical plates for the lead and/or extensions which facilitates displacement of more soil and results in the formation of pile columns having larger diameters and therefore improved load capacity.

[0038] The soil displacement pile and soil displacement assembly of the present disclosure can be adapted to form any size pile column needed for a particular job. For example, the soil displacement pile and soil displacement assembly of the present disclosure can easily form pile columns that are greater than eight inches in diameter.

[0039] While illustrative embodiments have been described and illustrated above, it should be understood that these are exemplary and are not to be considered as limiting. Additions, deletions, substitutions, and other modifications can be made without departing from the spirit or scope of the present disclosure. Accordingly, the invention is not to be considered as limited by the foregoing description.

[0040] The foregoing detailed description of the certain exemplary embodiments has been provided for the purpose of explaining the general principles and practical application, thereby enabling others skilled in the art to understand the disclosure for various embodiments and with various modifications as are suited to the particular use contemplated. This description is not necessarily intended to be exhaustive or to limit the disclosure to the exemplary embodiments disclosed. Any of the embodiments and/or elements disclosed herein may be combined with one another to form various additional embodiments not specifically disclosed. Accordingly, additional embodiments are possible and are intended to be encompassed within this specification and the scope of the appended claims. The specification describes specific examples to accomplish a more general goal that may be accomplished in another way.

[0041] As used in this application, the terms "front," "rear," "upper," "lower," "upwardly," "downwardly," and other orientational descriptors are intended to facilitate the description of the exemplary embodiments of the present disclosure, and are not intended to limit the structure of the exemplary embodiments of the present disclosure to any particular position or orientation. Terms of degree, such as "substantially" or "approximately" are understood by those of ordinary skill to refer to reasonable ranges outside of the given value, for example, general tolerances associated with manufacturing, assembly, and use of the described embodiments. Unless specified or limited otherwise, the terms "mounted," "connected," "supported," and "coupled" and variations thereof are used broadly and encompass both direct and indirect mountings, connections, supports, and couplings.

What is claimed:

1. A soil displacement pile comprising:
- a lead shaft having a lead end and a lead head;
- a lead soil displacement assembly connected to the lead shaft, the lead soil displacement assembly including a helical plate and a canister,
- wherein the helical plate extends at least partially around the lead shaft, and
- wherein the canister includes an outer wall extending around the lead shaft defining an interior and an opening in the outer wall to permit the ingress of soil.

2. The soil displacement pile of claim **1**, wherein a divider is positioned in the canister to separate the interior between an upper section and a lower section.

3. The soil displacement pile of claim **2**, wherein the canister includes an open top in communication with the upper section.

4. The soil displacement pile of claim **1**, wherein the helical plate includes a first end and a second end, and the canister opening extends between the first end and the second end.

5. The soil displacement pile of claim **1**, wherein the canister is cylindrical.

6. The soil displacement pile of claim **1**, wherein the lead shaft has a hollow cylindrical configuration.

7. The soil displacement pile of claim **1**, further comprising an extension shaft connected to the lead shaft. and an extension soil displacement assembly connected to the extension shaft.

8. The soil displacement pile of claim **7**, wherein the extension shaft includes an extensions soil displacement assembly connected to the extensions shaft.

9. The soil displacement pile of claim **8**, wherein the extension soil displacement assembly includes an extension canister defining a second interior and wherein the extensions canister includes an open top in communication with the second interior.

10. A soil displacement pile comprising:
- a lead shaft having a lead end and a lead head;
- a lead soil displacement assembly connected to the lead shaft, the lead soil displacement assembly including a helical plate and a canister,
- wherein the helical plate extends at least partially around the lead shaft, and
- wherein the canister includes an outer wall extending around the lead shaft defining an interior and a divider plate is positioned in the canister to separate the interior into an upper section and a lower section.

11. The soil displacement pile of claim **10**, wherein the canister includes an open top in communication with the upper section.

12. The soil displacement pile of claim **10**, wherein the canister includes an opening in the outer wall to permit the ingress of soil into the lower section.

13. The soil displacement pile of claim **12**, wherein the helical plate includes a first end and a second end, and the canister opening extends between the first end and the second end.

14. The soil displacement pile of claim **10**, wherein the helical plate has a first outer diameter and the canister has a second outer diameter less than the first outer diameter.

15. The soil displacement pile of claim **10**, wherein the canister extends above the helical plate toward the lead head.

16. The soil displacement pile of claim **10**, further comprising an extension shaft connected to the lead shaft and an extension soil displacement assembly connected to the extension shaft.

17. The soil displacement pile of claim **16**, wherein the extension soil displacement assembly includes an extension canister defining a second interior and wherein the extensions canister includes an open top in communication with the second interior.

18. The soil displacement pile of claim **16**, wherein an upper plate is connected to the extension shaft.

19. A method of forming a composite pile column comprising:
- positioning a lead shaft for ground insertion, the lead shaft having a lead end, a lead head, and a lead soil displacement assembly, wherein the lead soil displacement assembly includes a helical plate and a canister having an open top;
- rotating the lead shaft and lead soil displacement assembly to rotate the helical plate and canister and cause displacement of soil;
- forming a cavity in the ground by displacement of soil by the lead shaft and lead soil displacement assembly;
- inserting filler into the cavity, wherein at least a portion of the filler is introduced into the canister through the open top.

20. The method of claim **20**, further comprising connecting an extension shaft to the lead shaft and rotating the extension shaft and lead shaft to insert the extension shaft into the cavity.

* * * * *