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(54) **MULTI-FUNCTIONAL APPARATUS FOR GROUNDWORKS**

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APPAREIL MULTIFONCTIONNEL POUR TRAVAUX SOUTERRAINS

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• **NORMAN, Stuart**

Esher, Surrey KT10 9TA (GB)

• **MULHOLLAND, Andrew**

Esher, Surrey KT10 9TA (GB)

• **WALTERS, Jack**

Esher, Surrey KT10 9TA (GB)

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(74) Representative: **Abel & Imray LLP**

Westpoint Building

James Street West

Bath BA1 2DA (GB)

(73) Proprietor: **HIPER Pile Limited**

Esher KT10 9TA (GB)

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(72) Inventors:

• **PELKEN, Paul Michael**

Esher, Surrey KT10 9TA (GB)

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Description

Field of the Invention

[0001] The present disclosure relates to apparatus for use in groundworks and to a method of assembling a modular piling apparatus for use in foundation excavations.

Background of the Invention

[0002] Groundworks includes the work related to formation of the foundations for a building structure (such as commercial buildings, residential buildings, habitable/non-habitable buildings, bridges, and other civil constructions requiring groundworks). Various different types of foundation structures can be used, such as diaphragm walls, and piles. The formation of concrete piles using essentially smooth-sided bores (for example to create a contiguous, interlocking or secant series of piles) is well known.

[0003] Some disclosures have suggested forming impressions in the sides of the bore prior to the casting of the pile. When the concrete is then cast in the bore, it occupies the volume of the impressions. This is thought to improve the strength of the piling by increasing the skin friction at the excavation wall to create a larger pull out resistance and/or by providing a piling structure that better reacts loads into the ground.

[0004] Examples of apparatus for forming impressions in the walls of pile bores are disclosed in US 5908268 and WO2014059537:

US5908268 discloses a piling apparatus that is arranged to be inserted into a pile bore. Pressure is applied to horizontally acting pressers to form impressions in the wall of the bore, and the apparatus is then moved vertically so that a plurality of impressions can be formed within the pile bore.

[0005] WO2014059537 also discloses an apparatus that is inserted into a pile bore. The apparatus forms impressions in the wall of the bore via hydraulically activated rams that extend a predetermined distance outwardly.

[0006] CN 102011389 discloses a rock and soil in-situ testing device comprising a steel pipe having the same shape as a pipe pile. The device has a pressure sensor and one or more side wall friction cylinders arranged along the radial direction of the steel pipe.

[0007] There are two main issues with the state of the art as it stands: Firstly, when forming impressions in the sides of the bore it is thought to be desirable to follow-up with other activities - such as quality control on the impressions formed, or removal of rubble created from the impression-forming process. To do so, the piling apparatus would need to be removed and a specialist piece of apparatus sent down for the desired purpose. This can increase the overall time taken to create the pile. Secondly, the apparatus needed for

each different excavation and/or follow up activity tends to be bespoke to suit the varying requirements of each job. This can increase the overall cost to create the pile and also limits the flexibility of the apparatus for use elsewhere.

[0008] The present invention seeks to mitigate at least some of the above-mentioned problems. The present invention seeks to provide an improved apparatus for groundworks, of the type that forms impressions in a foundation excavation.

Summary of the Invention

[0009] The present invention provides, according to a first aspect, an apparatus for use in groundworks according to claim 1. The apparatus comprises: an impression-forming module having an impression-forming element that is arranged to move between a retracted configuration in which the impression-forming element is retracted such that the module can move along a foundation excavation, and an extended configuration in which the impression-forming element extends outwards to create an impression in the side of the excavation; and wherein the apparatus further comprises: an auxiliary module configured to perform an auxiliary function within the foundation excavation in parallel with operation of the impression-forming module.

[0010] Providing an apparatus with an auxiliary module of this type has been found to be especially beneficial because it enables both the impression-forming function, and the auxiliary function, to be conducted in parallel. This tends to enable time savings. Furthermore, providing an apparatus having a modular construction (i.e. comprising an impression-forming module and an auxiliary module) may enable the overall functionality of the apparatus to be customised to suit the requirements of the project being undertaken. A modular approach may also enable the apparatus to be readily upgraded with future developments without requiring a full overhaul of the apparatus.

[0011] It will be appreciated that parallel operations need not necessarily occur during precisely overlapping time periods; the skilled person will appreciate that parallel operations encompass any operations which may be conducted whilst the impression-forming module is located in the foundation excavation (for example the apparatus may be used to create impressions during lowering of the apparatus into a bore, and to perform auxiliary functions during the subsequent raising from the bore).

[0012] The apparatus may comprise a plurality of impression-forming modules. Each impression forming module may comprise an, and more preferably a plurality of, impression-forming elements that are arranged to move between a retracted configuration in which the impression-forming elements are retracted such that the module can move along the foundation excavation, and an extended configuration in which the impression-

forming elements extend outwards to create an impression in the side of the excavation.

[0013] The impression-forming module comprises an impression forming element. More preferably the impression-forming module comprises a plurality of impression-forming elements. Each impression forming element may take any number of forms, so long as it creates an impression in the side of the excavation. The impressions may be formed sequentially along the excavation as the apparatus is moved in a step-wise fashion. The impressions may be formed continuously as the apparatus moves continuously along the excavation.

[0014] The apparatus may comprise a plurality of auxiliary modules, each of the auxiliary modules being configured to perform an auxiliary function within the foundation excavation in parallel with the operation of the impression-forming module. Embodiments of the invention recognise that by adopting a modular construction of the apparatus, it becomes possible to even perform a plurality of auxiliary functions in parallel with the impression-forming module. In some embodiments, the plurality of auxiliary modules may all perform the same or similar function. In some other embodiments, the plurality of auxiliary modules may all perform different auxiliary functions.

[0015] In embodiments having a plurality of auxiliary modules and/or impression modules, reference herein to any feature of one of the auxiliary and/or impression modules will be understood to also be optionally applicable to any of the other auxiliary and/or impression modules. Equally, reference to a feature of a plurality of the modules will be understood to equally be optionally applicable to the respective auxiliary and/or impression module in embodiments only having one of those modules.

[0016] The, or each, auxiliary module may have a primary, or sole, function. The, or each, auxiliary module may be multi-functional. For example, in some embodiments an auxiliary module may be dedicated to a specific auxiliary function. In other embodiments, an auxiliary module may conduct the auxiliary function, but also have other functionality. The other functionality may be another auxiliary function. The other functionality may include impression-forming. Accordingly, some embodiments of the invention may comprise an impression-forming module, and an auxiliary module that performs both the auxiliary function and also performs an impression-forming function itself. The auxiliary function is not impression-forming.

[0017] In embodiments having a plurality of auxiliary and/or impression modules, the modules may be stacked together. For example, the impression-forming module(s) and the auxiliary module(s) may be stacked together end-to-end. The stacked modules may form a modular string for insertion into a piling bore. In other embodiments, the stacked modules may extend laterally and/or longitudinally to form a modular array, for

example for insertion into a trench.

[0018] In contrast to the prior art, the present invention provides a groundworks apparatus that is modular. Providing a modular arrangement tends to facilitate a flexible apparatus because one auxiliary module may be readily exchanged for another. Accordingly the, or each, module may be detachably connected within the apparatus such that it may be exchanged for a different module. The, or each, auxiliary module is detachably connected to an adjacent impression-forming module or an adjacent auxiliary module. The, or each, impression-forming module may be detachably connected to an adjacent impression-forming module.

[0019] The detachable connection is preferably repeatedly detachable and re-attachable such that the modular apparatus can be repeatedly assembled, disassembled and reassembled, for example in different combinations of modules.

[0020] The detachability of the module(s) provides versatility to the apparatus and enables the provision of an apparatus that can perform a combination of bespoke functions. Moreover, as the technology in the field of the invention advances, and more improved modules are designed, it may be preferable to upgrade the apparatus with newer and different modules. Allowing the modules to be exchangeable anticipates this need. Furthermore, a modular apparatus may be disassembled into separate modules which may then be distributed amongst other apparatus and operated in parallel in different bores.

[0021] Each module (impression-forming module or auxiliary module) may comprise a connection interface for forming a detachable connection to a corresponding connection interface in the apparatus. The corresponding connection interface may be on an adjoining module. The connection interface on a module is preferably compatible with a corresponding connection interface on another module. This does not necessarily mean those connection interfaces are identical - for example they may, respectively, be male and female parts that form a connector.

[0022] A connection interface may be located at one, or both ends of a module. For example, the connection interface may allow the modules to be detachably connected end-to-end. Alternatively or additionally, a connection interface may be located on one or both sides of a module such that the modules can be detachably connected in an array.

[0023] The connection interface may be common to both the impression-forming module(s) and the auxiliary module(s), such that, for example, different auxiliary modules can be exchanged for attachment to the impression-forming module using a common connection interface.

[0024] The, or each, module may be a substantially self-contained unit. The, or each, module may have been preassembled at a remote location. The modules of the apparatus are preferably configured such that the

apparatus is operable with a number of different combinations of module. Each module may be configured such that the apparatus is operable with the module, and without the module (in other words, each module may have its own self-contained functionality).

[0025] The auxiliary module is configured to perform an auxiliary function within the foundation excavation in parallel with operation of the impression-forming module. In principle, the function of the auxiliary module may be one of a number of different functions. The function of the auxiliary module is preferably a support function for the impression-forming module.

[0026] The auxiliary module is preferably a quality-control module, for inspecting and/or monitoring the state of the foundation excavation.

[0027] The auxiliary module may be an image-capture module. The image-capture module may comprise a camera. The image capture module may be configured to obtain fixed images (e.g. photos) and/or moving images (e.g. video). The image-capture module may be arranged to capture images for analysis of the impressions formed in the foundation excavation. Such an auxiliary function has been found to be especially beneficial because it may enable the impression to be inspected shortly after its creation in the side of the foundation excavation.

[0028] The auxiliary module may be a mapping module. The mapping module may comprise a scanner. The scanner may be configured for scanning the sides of the foundation excavation. The mapping module may be arranged to output a data file for rendering a three-dimensional reconstruction of the sides of the excavation foundation, based on measurements from the scanner. Such an auxiliary function has been found to be especially beneficial because it may enable the state of the impression to be accurately logged shortly after its creation in the side of the foundation excavation.

[0029] The auxiliary module may comprise a verticality sensor. The verticality sensor may be configured to provide information on the verticality of the bore. Such an auxiliary function may be particularly useful when the tolerance for verticality error is especially low.

[0030] It will be appreciated that the functionality of the auxiliary module may, in some embodiments, be combined (for example it may be both an image capture and a scanning module).

[0031] The impression-forming module is preferably hydraulically powered. In such embodiments, the apparatus may comprise an interface for receiving a hydraulic feed. The hydraulic feed is preferably an external feed. The apparatus may comprise hydraulic interface module for receiving hydraulic supply lines from an external source.

[0032] The apparatus may comprise a power module. The power module may be an electrical power module. The electrical power module may comprise batteries. The impression forming module may be elec-

trically powered. In such embodiments, the apparatus may comprise an electrical power auxiliary module. The electrical power auxiliary module may comprise an interface for connection to an impression forming module. The electrical power module may be configured to operate a hydraulics module such that there is no requirement for hydraulic supply lines to connect the apparatus to the external source.

[0033] Embodiments of the invention may be applicable to any foundation excavation. For example, the foundation excavation may be a trench (for example for a diaphragm wall). In preferred embodiments, the foundation excavation is a bore for piling. In such embodiments, the apparatus may be a piling apparatus (and accordingly references herein to groundwork apparatus may be replaced with the term 'piling apparatus'). The present invention has been identified as being especially beneficial in the context of piling, because it facilitates a flexible apparatus that may be used in different diameter and different depth bores. The need for quality control has been identified as being especially important in piling, so the ability to conduct auxiliary operations in parallel using embodiments of the present invention is especially beneficial.

[0034] According to a second aspect of the invention there is also provided a method of assembling a modular piling apparatus for use in foundation excavations according to claim 10. The method comprises the steps of: providing an impression-forming module having a plurality of impression-forming elements arranged to move between a retracted configuration in which the impression-forming elements are retracted such that the module can move along the foundation excavation, and an extended configuration in which the impression-forming elements extend outwards to create an impression in the side of the excavation; providing an auxiliary module configured to perform an auxiliary function within the foundation excavation in parallel with operation of the impression-forming module; and detachably connecting the auxiliary module to an end of the impression-forming module to create a modular apparatus having multiple functions.

[0035] By providing a modular arrangement, the apparatus may be readily assembled and disassembled to provide different functionality as required.

[0036] The method may further comprise the steps of: detachably connecting one or more further auxiliary and/or impression forming modules to the modular apparatus. The result of this step may be the formation of a modular string, which may perform a suite of different functions suited to the requirements of the foundation excavation. Combining the different functions into one modular apparatus is advantageous over multiple, discrete pieces of apparatus, because the different functions may be performed in parallel within the excavation, therefore only requiring one device to descend into the excavation once, hence saving time.

[0037] The method may comprise the steps of: ex-

changing an auxiliary module with another auxiliary module by: detaching an auxiliary module from the modular apparatus, and detachably connecting a different auxiliary module in its place. The respective auxiliary modules may have different functionality such that the exchanging of the auxiliary module with the different auxiliary module changes the functionality of the apparatus.

[0038] According to a merely illustrative embodiment there is also provided method of creating foundations, the method comprising the steps of: assembling a modular apparatus for forming impressions in a foundation excavation, the modular apparatus comprising an impression-forming module and at least one auxiliary module; inserting the modular apparatus into the mouth of the foundation excavation; moving the modular apparatus along the foundation excavation and sequentially forming impressions in the foundation excavation using the impression-forming module, and in parallel, performing at least one auxiliary function using the auxiliary module.

[0039] At least one of the auxiliary functions performed in parallel is preferably inspection of the impressions formed by the impression-forming module. Such an approach has been found to improve quality control whilst not unduly adding to the overall time taken to install the piling.

[0040] The output from the inspection of the impressions may be transmitted to a display. The transmission of the output may be transmitted in real-time. The display may be remote from the excavation. The display may be a graphical user interface (GUI). Such an arrangement has been found to be beneficial because the user of the apparatus may then choose to operate the apparatus differently based on the information presented to them. The user may also be better able to spot any defects in the pile at an early stage.

[0041] According to a merely illustrative embodiment there is also provided a kit of parts for use with a groundworks apparatus. The kit comprises:

an impression-forming module having a plurality of impression-forming elements that are arranged to move between a retracted configuration in which the impression-forming elements are retracted such that the module can move along the foundation excavation, and an extended configuration in which the impression-forming elements extend outwards to create an impression in the side of the excavation; and a plurality of auxiliary modules, each auxiliary module being configured for detachable connection to the impression-forming module or to the other auxiliary module(s) and, when so-connected, each auxiliary module being configured to perform an auxiliary function within the foundation excavation in parallel with the operation of the impression-forming module.

[0042] According to another merely illustrative embodiment, there is provided a piling apparatus for use in foundation excavations. The apparatus comprises: a

plurality, and more preferably a multiplicity, of impression-forming modules, each impression forming module having a plurality of impression-forming elements that are arranged to move between a retracted configuration in which the impression-forming elements are retracted such that the module can move along the foundation excavation, and an extended configuration in which the impression-forming elements extend outwards to create an impression in the side of the excavation. The impression forming modules are preferably detachably connected together such that the modules can be arranged or rearranged in different numbers or configurations. This modular approach has been recognised as giving increased flexibility.

[0043] Each of the impression-forming modules may comprise any or all of the features of the impression-forming modules of the other aspects of the invention. For example, the modules preferably comprise a connection interface for detachable connection to adjacent modules.

another merely illustrative embodiment may be a method of assembling a modular piling apparatus for use in foundation excavations, the method comprising the steps of:

providing a first impression-forming module having a plurality of impression-forming elements arranged to move between a retracted configuration in which the impression-forming elements are retracted such that the module can move along the foundation excavation, and an extended configuration in which the impression-forming elements extend outwards to create an impression in the side of the excavation; providing a second impression forming module also having a plurality of impression-forming elements arranged to move between a retracted configuration in which the impression-forming elements are retracted such that the module can move along the foundation excavation, and an extended configuration in which the impression-forming elements extend outwards to create an impression in the side of the excavation; and detachably connecting the impression-forming modules to create a modular apparatus having multiple impression forming modules.

[0044] A further merely illustrative embodiment may comprise a method of creating groundworks for foundation, such as piling, the method comprising the steps of: assembling a modular apparatus for forming impressions in the foundation excavation, the modular apparatus comprising a plurality of impression-forming modules; inserting the modular apparatus into the mouth of a foundation excavation; moving the modular apparatus along the foundation excavation and sequentially forming impressions in the foundation excavation using the impression-forming modules.

[0045] Another merely illustrative embodiment may be a kit of parts for use with a groundworks apparatus, the kit comprising: plurality of impression-forming modules, each having a plurality of impression-forming elements that are arranged to move between a retracted

configuration in which the impression-forming elements are retracted such that the module can move along the foundation excavation, and an extended configuration in which the impression-forming elements extend outwards to create an impression in the side of the excavation, each module being configured for detachable connection to a respective other impression-forming module. The methods of the invention may incorporate any of the features described with reference to the apparatus of the invention and *vice versa*.

Description of the Drawings

[0046] Embodiments of the present invention will now be described by way of example only with reference to the accompanying schematic drawings of which:

- Figures 1a-1d show schematic sides view of a previously-suggested method for forming impressions in a pile bore;
- Figure 2 shows a side view of an apparatus according to a first embodiment of the invention;
- Figure 3a shows a perspective view of an apparatus according to a second embodiment of the invention;
- Figures 3b-3d show selected views of part of the apparatus in Figure 3a;
- Figures 4a-4b show a method for forming impressions in a pile bore, using the apparatus of the second embodiment;
- Figure 5a shows a plan view of a single impression-forming module for forming impressions in a trench according to a third embodiment of the invention;
- Figure 5b-5e shows the modules of Figure 5a being arranged in an array; and
- Figures 6a-6c show a method for using the apparatus of the third embodiment to form impressions in a trench.

Detailed Description

[0047] The invention will be more fully understood and further advantages will become apparent when reference is made to the following detailed description of embodiments of the invention, wherein like reference numerals denote similar elements.

[0048] Figures 1a to 1d schematically show a previously-suggested apparatus and method of forming impressions in pile bores. As is known in conventional piling, a bore 4 was first created using a Kelly Bar fitted with an auger. The auger was then removed and a circular cleaning bucket was fitted to the Kelly Bar and lowered to clean the base of the pile.

[0049] In the suggested arrangement in Figure 1a, an impression-forming apparatus 1 is then connected to a rig 3, which is arranged to lower the impression-forming

apparatus 1 in to the pile bore 4.

[0050] Figure 1b shows the impression-forming apparatus 1 in its descent into the pile bore 4. Figure 1c shows the impression-forming apparatus 1 undergoing radial expansion within the pile bore 4, pressing against the bore wall 2, forming impressions 2a. The apparatus 1 of Figure 1c is a unitary apparatus with a plurality of vertically spaced radially extending rams. For deeper bores, it may be necessary to sequentially translate the apparatus in a vertical direction to create a plurality of impressions 2a in the bore wall 2.

[0051] Although Figures 1a-1c show the apparatus being lowered using a piling rig, it is also possible to lower the apparatus in other ways, such as suspending the apparatus on a cable held by a crane.

[0052] Figure 1d symbolically shows that a camera 5 may be inserted into the bore 2 to inspect the impressions formed. This is done after the apparatus 1 has been removed from the bore 2. This is typically performed by lowering the camera on a cable or bar, and capturing images of the bore wall 2 and impressions 2a. Inspecting the impressions prior to pouring the concrete mix into the bore is beneficial in terms of providing a log of the state of the bore, and quality control more generally. It can, however, be time consuming and requires specialist kit to be available on site at the same time as the piling apparatus is in use.

[0053] Figure 2 shows a side view of a modular piling apparatus 201 according to a first embodiment of the invention. The piling apparatus 201 is formed by string of releasably detachable modules joined end-to-end, as will now be described:

The apparatus 201 is attached to the end of a Kelly Bar (shown schematically by numeral 206). At the top of the apparatus is a hydraulics interface module 207 for receiving hydraulic supply lines (not shown) from a remote hydraulic source (such as from the piling rig). The hydraulic interface module 207 can accommodate numerous supply lines dependent on the number, and the nature of, the modules attached in the remainder of the apparatus below. The interface module neatly channels the hydraulic supply lines (and other conduits such as cabling) into the apparatus.

[0054] The piling apparatus 201 also comprises an impression-forming module 208. An impression-forming module 208 is releasably attached to the hydraulic interface 207 above it, via a male-female connection interface. Specially, the lower end of the hydraulic interface module 207 has a recessed annular rim for mating with a marginally larger diameter annular rim on the top of the impression forming module 208. A series of radially extending bolts pass through holes in both the rims to detachably hold the modules together. For clarity, these connections between modules are shown over-sized in Figure 2 as small rectangles between the modules. It will be appreciated that in other embodiments, different connections may be provided.

[0055] The impression-forming module 208 com-

prises a series of plates 208a spaced around the circumference of the module. Each plate is curved and comprises externally protruding formations 208b designed to create an impression in the bore wall when they are pressed against it: in the first embodiment of the invention the formations are semi-spherical, but other shapes are also possible. By way of example, different shaped formations 208b are shown in some of the auxiliary modules 209, 210 (discussed in more detail below). This is for illustration only, and it will be appreciated that in many embodiments of the invention, the formations will be substantially identical in each and every impression forming module.

[0056] The plates 208a of the impression-forming module 208 are shown in a retracted configuration for the module 208 in Figure 2. In this configuration, the module is able to be moved along the bore (not shown in Figure 2). The plates 208a are also moveable to an extended configuration in which they extend outwardly to create an impression in the side of the bore (this is schematically illustrated in the other modules below - see 209 and 210). The creation of the impressions in the side of the bore tends to improve the strength of the piling compared with a smooth-sided bore.

[0057] The piling apparatus of the first embodiment of the invention is modular and comprises a series of auxiliary modules stacked below the impression-forming module 208, along the length of the apparatus. It is in this sense that the apparatus may be described as a modular string.

[0058] Directly below the impression-forming module 208 is a wireless data transmission module 209. The wireless data transmission module 209 is a self-contained unit that is attached to the impression-forming module 208 in the same manner as the impression-forming module 208 is attached to the hydraulic interface module 207. In other words, the upper ends of each module comprise a substantially identical male connector, and the lower ends of each module comprise a substantially identical female connector.

[0059] The wireless data transmission module 209 comprises a receiver, processor and transmitter (schematically shown as a boxed-cross in Figure 2). The module also includes its own impression-forming element 209a that operates between extended and retracted configurations in the manner described with reference to the impression-forming module 208. The wireless data transmission module is configured to collect data from the impression-forming element 209a such as hydraulic pressure, extension distance, and force applied. The module comprises a transmitter to wirelessly transmit the information in real-time to a receiving unit (not shown) on the surface. In alternative embodiments (not shown), the wireless data transmission module need not necessarily comprise impression-forming plates itself and could instead (or in addition) collect data from other modules comprised in the apparatus (such as the impression-forming module, a

camera module or a scanner module) and transmit the information in real-time to a receiving unit on the surface which may have a display to present the information graphically or pictorially for example. In those embodiments, the wireless data transmission module may comprise data and/or electrical connections for connection to other modules.

[0060] The next module in the apparatus, along the modular string, is a position tracking module 210. The position tracking module 210 comprises sensors (shown schematically with a crossed-box) arranged to determine the verticality of the apparatus 201 so that it is at the same orientation (i.e. angle to the vertical) as the pile bore, and to ensure that the apparatus 201 is maintained at an approximately central position within the pile bore. The position tracking module 210 is also a self-contained unit that is attached to module above and below in the same manner as the other modules (i.e. at connection interfaces at the upper and lower ends). The module also includes its own impression-forming element 210a that operates between extended and retracted configurations in the manner described with reference to the impression-forming module 208 and wireless data module 209.

[0061] The next module along the string is the image capture module 211. The image capture module 211 comprises three cameras arranged 120° apart around longitudinal axis of the apparatus (one of them is not shown), such that they are arranged to capture a full 360° field of view of the bore wall. Rotation of the apparatus 201 is not, therefore, required to view the entirety of the wall. In alternative embodiments (not shown) the camera module 211 may comprise more or fewer cameras. In the alternative embodiments, there may only be one camera that is rotated to view the entire circumference of the bore wall, for example. In further alternative embodiments, there may be more than three cameras, which have overlapping fields of view allowing for the images produced to be stitched together to create a single image representative of the entirety of the bore wall, for example.

[0062] The image capture module is arranged to acquire both still images (pictures) of selected parts of the wall of the bore, as well as video images. In the first embodiment, these images are stored in a memory device for downloading when above ground, but in other embodiments the images may be transmitted to above ground in real time. Either way, the image capture device is able to provide a visual log of the sides of the bore for use in quality control (e.g. checking the correct formation of the impressions, checking for any debris or unexpected features).

[0063] The image capture module 211 is an auxiliary module that is configured to operate in parallel with the impression forming module 208. For example whilst the impression forming module 208 is being actuated to move the impression-forming elements 208a to the extended configuration, the image capture module may

be capturing images of a previously formed impression.

[0064] At the distal end of the apparatus is a bucket 212. As the impression-forming module 208 extends and retracts to form impressions in the bore wall, debris is created and ordinarily falls to the bottom of the pile bore. This creates an uneven, and loose layer of soil in the base of the bore, which would then need to be packed to prevent subsidence of a pile formed within the bore. The bucket 212 is arranged to take up the majority of the diameter of the pile bore, and therefore collect the debris as it falls down the inside of the bore. The inclusion of the bucket 212 therefore reduces the need for packing of the base of the pile bore.

[0065] As will be evident from the description above, the first embodiment of the invention provides a piling apparatus having an impression-forming module 208, along with auxiliary modules such as the image capture module 211, wireless data module 209, and position tracking module 210. Furthermore, the auxiliary modules are configured to provide auxiliary function in parallel with the operation of the impression-forming module. Providing an apparatus with auxiliary modules such as these has been found to be especially beneficial because it enables time savings compared with the conventional thinking of performing the functions sequentially. Furthermore, providing a piling apparatus having a modular construction (i.e. comprising an impression-forming module the auxiliary modules that are releasably detachable) has been found to enable the overall functionality of the apparatus to be readily customised to suit the requirements of the project being undertaken (for example to choose which auxiliary functions are to be included in the apparatus for a particular project, and which auxiliary functions may not be necessary).

[0066] Figure 3a shows a perspective side view of a modular piling apparatus 301 in accordance with a second embodiment of the invention.

[0067] In this embodiment the first module, being the hydraulics interface module 307, is directly connected at one end to a Kelly bar 306. The hydraulics interface module 307 is similar in many respects to the hydraulics interface module 207 of Figure 2. However, in contrast to the first embodiment, the hydraulics module 307 comprises a connection interface on its lower end in the form of a male screw threaded section. This connection interface is arranged to be compatible with a corresponding female screw threaded section on the upper end of the impression-forming module 308 below such that the modules can be assembled end-to-end. The screw-threaded connection interface is held together using a locking arrangement (not shown) but this can be unlocked such that the modules can be detached from each other and replaced or re-ordered in the modular string as needed.

[0068] The modular piling apparatus of the second embodiment of the invention also comprises three additional impression-forming modules connected conse-

cutively (via corresponding screw threaded connections) end-to-end below the first impression-forming module. Although a total of four impression-forming modules are shown in figure 3a, it will be appreciated that any number of impression-forming modules 308 may be used in alternative embodiments of the invention. By providing a modular arrangement of impression-forming modules detachably connected end-to-end, the length of the apparatus can be chosen as appropriate to the foundation excavation. For example in a deep bore, it may be preferable to include a relatively long modular string.

[0069] In the arrangement in Figure 3a, the impression forming modules 308 are alternately offset (by 90 degrees) in their orientation. This means the impression forming elements of adjacent modules extend at 90 degrees to each other. This may be useful in scenarios where it is only necessary to create relatively space-apart impressions along the length of the bore.

[0070] Detachably connected to the underside of the final impression-forming module 308 is an image capture module 311, similar to the image capture module 211 of Figure 2. This module is configured to capture images of the sides of the bore as the modular string is drawn upwards following creation of the impressions (discussed in more detail below with reference to Figures 4a and 4b). The image capture module also comprises a scanner (not shown) to scan the sides of the bore. The scanner is arranged to output a data file for rendering a three-dimensional image of the bore.

[0071] The image capture module 311 is shown in some more detail in Figures 3b (a close-up view from Figure 3a), 3c (a side view taken within the bore) and Figure 3d (an axial view taken through the image capture module). The module comprises three camera 311a having a field of view that encompasses the sides of the bore in which the impression-forming apparatus act.

[0072] Referring now to Figures 4a and 4b, these illustrate a method of using the piling apparatus of the second embodiment of the invention.

[0073] Figure 4a shows the modular apparatus 301 being inserted into the mouth of a pile bore 404. The rig that raises and lowers the apparatus 301 is not shown (it will be appreciated that this could be achieved by a number of known arrangements such as a piling rig or a crane).

[0074] In this embodiment of the invention, the piling apparatus is lowered towards the base of the bore 404. During the lowering of the piling apparatus, it is periodically stopped and the impression-forming modules are actuated to move them to their extended configuration, thereby creating the impressions in the sides of the bore (schematically indicated in Figure 4b).

[0075] Once the piling apparatus has reached the end of the bore, all the impressions have been formed (see Figure 4b). As the piling apparatus is withdrawn from the bore, the image capture module captures

images of the bore sides, and particularly the impressions, and logs the state of the bore. This allows the user of the apparatus to check whether the impressions have been formed correctly, and if necessary, reform the impressions without necessarily removing the modular apparatus 301 from the bore 404. It will be appreciated that the image capture module 311 is therefore an auxiliary module that functions in parallel with the impression forming modules because it functions as the apparatus is being withdrawn from the bore (and it is not necessary to fully withdraw the apparatus and replace it with a separate apparatus to achieve the image capture function).

[0076] Figures 5a to 5e show another embodiment of a groundworks apparatus 501 suitable for alternative types of foundation excavation. The groundworks apparatus 501 comprises several planar impression-forming modules 508, and is suitable for forming impressions in substantially linear foundation excavations: such as trenches, retaining wall foundations, and diaphragm wall foundations for example.

[0077] Figure 5a shows a single module 508 (in top view) and Figures 5b and 5c shows a pair of modules 508 connected side-by-side. Those modules are collated into a five-module wide strip shown in Figure 5d. This strip is attached to a cable 506 via a connector bar 514. As shown in Figure 5e, additional strips are added to the bottom of the first strip to create a three-by-five array of impression-forming modules. By stacking the impression-forming modules into an array in this manner it may be possible to tailor the overall size of the piling apparatus to suit the foundation excavation. For example a larger array would require fewer iterations along/within the trench to create the same number of impressions in the excavation wall, thus reducing the time necessary to create said impressions.

[0078] Figures 6a to 6c show a method for forming impressions in a linear foundation excavation using the groundworks apparatus of Figure 5a-5d. This embodiment of the modular apparatus 508b is the height of three impression-forming modules. Figure 6a shows the piling apparatus being lowered into the excavation 604 (Figure 6d shows this arrangement from a perspective view but only showing one strip of modules for the sake of clarity).

[0079] Figure 6b shows the impression-forming modules 508, comprising extendable impression-forming elements, moving from a retracted configuration to an extended configuration in which the impression-forming elements engage with the bore wall 602. Figure 6c shows the impression-forming elements having moved back to the retracted configuration after creating impressions 602a while in the extended configuration. The modular apparatus 508b is then removed from the excavation 604.

[0080] It will be appreciated that in the embodiment shown in Figures 5a to 6d, the groundworks apparatus does not comprise an auxiliary module, but instead

comprises a multiplicity of impression-forming modules that can be detachably connected together to form a larger modular groundworks apparatus formed from that collection of modules. Such an arrangement has been found to be beneficial in that it can be tailored (for example is size) to meet the requirements of a specific project, and then reassembled in a different form for a different project having different requirements. It therefore enables a more flexible apparatus.

[0081] Whilst the present invention has been described and illustrated with reference to particular embodiments, it will be appreciated by those of ordinary skill in the art that the invention lends itself to many different variations not specifically illustrated herein.

[0082] For example, in some embodiments of the invention (not shown) there may be provided a modular piling apparatus comprising a string of impression-forming modules (without any auxiliary modules). This may be beneficial as the length of the apparatus can be tailored to suit a particular project.

[0083] By way of another example, the groundworks apparatus may be an array similar to Figures 5a to 5d, but also include auxiliary modules (such as image capture modules) to check the impressions in the side of the trench.

[0084] In some embodiments, the impression forming modules may only comprise one impression forming element. Reference should be made to the claims for determining the true scope of the present invention.

Claims

1. An apparatus (301) for use in groundworks, wherein the apparatus comprises:

an impression-forming module (308) having an impression-forming element (208a) that is arranged to move between a retracted configuration in which the impression-forming element is retracted such that the module can move along a foundation excavation, and an extended configuration in which the impression-forming element extends outwards to create an impression in the side of the excavation; and

an auxiliary module (311) configured to perform an auxiliary function within the foundation excavation in parallel with operation of the impression-forming module;

characterised in that

the auxiliary module is detachably connected to an end of the impression-forming module such that the auxiliary module may be exchanged for a different respective module.

2. An apparatus as claimed in claim 1, wherein the

- apparatus comprises a plurality of auxiliary modules, each of the auxiliary modules being configured to perform an auxiliary function within the foundation excavation in parallel with the operation of the impression-forming module. 5
3. An apparatus according to claim 2, wherein each of the auxiliary modules performs a different auxiliary function. 10
4. An apparatus according to any preceding claim, wherein the apparatus comprises a plurality of impression-forming modules (308), each impression-forming module having an impression-forming element that is arranged to move between a retracted configuration in which the impression-forming element is retracted such that the module can move along the foundation excavation, and an extended configuration in which the impression-forming element extends outwards to create an impression in the side of the excavation. 15 20
5. An apparatus as claimed in claims 2 to 4, wherein the modules are stacked to form a modular string. 25
6. An apparatus as claimed in any preceding claim, wherein each module comprises a connection interface for forming a detachable connection to a corresponding connection interface on an adjoining module. 30
7. An apparatus as claimed in claim 6, wherein the connection interface is common to each of the modules, such that different modules can be exchanged for attachment in the apparatus using a common connection interface. 35
8. An apparatus as claimed in any preceding claim, wherein the auxiliary module is an image-capture module comprising a camera (311), and/or is a mapping module comprising a scanner. 40
9. An apparatus according to any preceding claim, wherein the foundation excavation is a bore for receiving a pile, and the apparatus is a piling apparatus. 45
10. A method of assembling a modular piling apparatus (301) for use in foundation excavations, the method comprising the steps of: 50
- providing an impression-forming module (308) having an impression-forming element (208a) arranged to move between a retracted configuration in which the impression-forming element is retracted such that the module can move along the foundation excavation, and an extended configuration in which the impression-forming element extends outwards to create an impression in the side of the excavation; and 55
- providing an auxiliary module (311) configured to perform an auxiliary function within the foundation excavation in parallel with operation of the impression-forming module; **characterised in that** the method comprises detachably connecting the auxiliary module to an end of the impression-forming module such that it may be exchanged for a different respective module, to create a modular apparatus having multiple functions.
11. A method of assembling a modular apparatus as claimed in claim 10, wherein the method further comprises the steps of: detachably connecting one or more further auxiliary modules and/or impression forming modules, to the modular apparatus.
12. A method of assembling a modular apparatus as claimed in claim 10 or claim 11, wherein the method comprises the steps of: exchanging an auxiliary module with another auxiliary module by: detachable connecting an auxiliary module from the modular apparatus, and detachably connecting a different auxiliary module in its place.
13. A method of assembling a modular apparatus as claimed in claim 11 or 12, whereby the respective auxiliary modules have different functionality such that the exchanging of the auxiliary module with the different auxiliary module changes the functionality of the apparatus.

Patentansprüche

1. Vorrichtung (301) zur Verwendung bei Erdarbeiten, wobei die Vorrichtung umfasst:
- ein Abdruckformmodul (308) mit einem Abdruckformelement (208a), das so angeordnet ist, dass es sich zwischen einer zurückgezogenen Konfiguration, in der das Abdruckformelement zurückgezogen ist, sodass sich das Modul entlang einer Fundamentausgrabung bewegen kann, und einer ausgefahrenen Konfiguration, in der sich das Abdruckformelement nach außen erstreckt, um einen Abdruck an der Seite der Ausgrabung zu erzeugen, bewegen kann; und
- ein Zusatzmodul (311), das so konfiguriert ist,

- dass es parallel zum Betrieb des Abdruckformmoduls eine Zusatzfunktion innerhalb der Fundamentausgrabung ausführt;
dadurch gekennzeichnet, dass das Zusatzmodul lösbar mit einem Ende des Abdruckformmoduls verbunden ist, sodass das Zusatzmodul gegen ein anderes entsprechendes Modul ausgetauscht werden kann.
2. Vorrichtung nach Anspruch 1, wobei die Vorrichtung eine Vielzahl von Zusatzmodulen umfasst, wobei jedes der Zusatzmodule so konfiguriert ist, dass es parallel zum Betrieb des Abdruckformmoduls eine Zusatzfunktion innerhalb der Fundamentausgrabung ausführt.
 3. Vorrichtung nach Anspruch 2, wobei jedes der Zusatzmodule eine andere Zusatzfunktion ausführt.
 4. Vorrichtung nach einem der vorstehenden Ansprüche, wobei die Vorrichtung eine Vielzahl von Abdruckformmodulen (308) umfasst, wobei jedes Abdruckformmodul ein Abdruckformelement aufweist, das so angeordnet ist, dass es sich zwischen einer zurückgezogenen Konfiguration, in der das Abdruckformelement zurückgezogen ist, sodass sich das Modul entlang der Fundamentausgrabung bewegen kann, und einer ausgefahrenen Konfiguration, in der sich das Abdruckformelement nach außen erstreckt, um einen Abdruck an der Seite der Ausgrabung zu erzeugen, bewegen kann.
 5. Vorrichtung nach einem der Ansprüche 2 bis 4, wobei die Module zu einer modularen Kette gestapelt sind.
 6. Vorrichtung nach einem der vorstehenden Ansprüche, wobei jedes Modul eine Verbindungsschnittstelle zum Herstellen einer lösbaren Verbindung mit einer entsprechenden Verbindungsschnittstelle an einem angrenzenden Modul umfasst.
 7. Vorrichtung nach Anspruch 6, wobei die Verbindungsschnittstelle allen Modulen gemeinsam ist, sodass verschiedene Module unter Verwendung einer gemeinsamen Verbindungsschnittstelle zur Befestigung in der Vorrichtung ausgetauscht werden können.
 8. Vorrichtung nach einem der vorstehenden Ansprüche, wobei das Zusatzmodul ein Bildaufnahmemodul ist, das eine Kamera (311) umfasst, und/oder ein Kartierungsmodul ist, das einen Scanner umfasst.
 9. Vorrichtung nach einem der vorstehenden Ansprüche, wobei die Fundamentausgrabung eine Bohrung zur Aufnahme eines Pfahls ist und die Vorrichtung eine Pfahlgründungsvorrichtung ist.
 10. Verfahren zum Zusammenbau einer modularen Pfahlgründungsvorrichtung (301) zur Verwendung bei Fundamentausgrabungen, wobei das Verfahren die folgenden Schritte umfasst:
 Bereitstellen eines Abdruckformmoduls (308) mit einem Abdruckformelement (208a), das so angeordnet ist, dass es sich zwischen einer zurückgezogenen Konfiguration, in der das Abdruckformelement zurückgezogen ist, sodass sich das Modul entlang der Fundamentausgrabung bewegen kann, und einer ausgefahrenen Konfiguration, in der sich das Abdruckformelement nach außen erstreckt, um einen Abdruck an der Seite der Ausgrabung zu erzeugen, bewegen kann; und
 Bereitstellen eines Zusatzmoduls (311), das so konfiguriert ist, dass es parallel zum Betrieb des Abdruckformmoduls eine Zusatzfunktion innerhalb der Fundamentausgrabung ausführt;
dadurch gekennzeichnet, dass das Verfahren das lösbare Verbinden des Zusatzmoduls mit einem Ende des Abdruckformmoduls umfasst, sodass es gegen ein anderes entsprechendes Modul ausgetauscht werden kann, um eine modulare Vorrichtung mit mehreren Funktionen zu schaffen.
 11. Verfahren zum Zusammenbau einer modularen Vorrichtung nach Anspruch 10, wobei das Verfahren ferner die folgenden Schritte umfasst:
 lösbares Verbinden eines oder mehrerer weiterer Zusatzmodule und/oder Abdruckformmodule mit der modularen Vorrichtung.
 12. Verfahren zum Zusammenbau einer modularen Vorrichtung nach Anspruch 10 oder Anspruch 11, wobei das Verfahren die folgenden Schritte umfasst:
 Austausch eines Zusatzmoduls gegen ein anderes Zusatzmodul durch:
 Lösen eines Zusatzmoduls von der modularen Vorrichtung und
 lösbares Verbinden eines anderen Zusatzmoduls an dessen Stelle.
 13. Verfahren zum Zusammenbau einer modularen Vorrichtung nach Anspruch 11 oder 12, wobei die jeweiligen Zusatzmodule unterschiedliche Funktionen aufweisen, sodass der Austausch des Zusatzmoduls gegen das andere Zusatzmodul die Funktionalität der Vorrichtung verändert.

Revendications

1. Appareil (301) destiné à être utilisé dans des travaux de terrassement, dans lequel l'appareil comprend :

un module de formation d'empreinte (308) ayant un élément de formation d'empreinte (208a) qui est agencé pour se déplacer entre une configuration rétractée dans laquelle l'élément de formation d'empreinte est rétracté de manière que le module puisse se déplacer le long d'une excavation de fondation, et une configuration déployée dans laquelle l'élément de formation d'empreinte s'étend vers l'extérieur pour créer une empreinte dans le côté de l'excavation ; et

un module auxiliaire (311) configuré pour exécuter une fonction auxiliaire à l'intérieur de l'excavation de fondation en parallèle avec le fonctionnement du module de formation d'empreinte ;

caractérisé en ce que

le module auxiliaire est relié de manière détachable à une extrémité du module de formation d'empreinte de manière que le module auxiliaire puisse être échangé contre un module respectif différent.
2. Appareil selon la revendication 1, dans lequel l'appareil comprend une pluralité de modules auxiliaires, chacun des modules auxiliaires étant configuré pour exécuter une fonction auxiliaire à l'intérieur de l'excavation de fondation en parallèle avec le fonctionnement du module de formation d'empreinte.
3. Appareil selon la revendication 2, dans lequel chacun des modules auxiliaires exécute une fonction auxiliaire différente.
4. Appareil selon l'une quelconque des revendications précédentes, dans lequel l'appareil comprend une pluralité de modules de formation d'empreinte (308), chaque module de formation d'empreinte ayant un élément de formation d'empreinte qui est agencé pour se déplacer entre une configuration rétractée dans laquelle l'élément de formation d'empreinte est rétracté de manière que le module puisse se déplacer le long de l'excavation de fondation, et une configuration déployée dans laquelle l'élément de formation d'empreinte s'étend vers l'extérieur pour créer une empreinte dans le côté de l'excavation.
5. Appareil selon l'une quelconque des revendications 2 à 4, dans lequel les modules sont empilés pour former une chaîne modulaire.
6. Appareil selon l'une quelconque des revendications précédentes, dans lequel chaque module comprend une interface de connexion destinée à former une connexion détachable avec une interface de connexion correspondante sur un module adjacent.
7. Appareil selon la revendication 6, dans lequel l'interface de connexion est commune à chacun des modules, de manière que différents modules puissent être échangés pour être fixés dans l'appareil au moyen d'une interface de connexion commune.
8. Appareil selon l'une quelconque des revendications précédentes, dans lequel le module auxiliaire est un module de capture d'images comprenant une caméra (311), et/ou est un module de cartographie comprenant un scanner.
9. Appareil selon l'une quelconque des revendications précédentes, dans lequel l'excavation de fondation est un forage destiné à recevoir un pieu, et l'appareil est un appareil de battage de pieux.
10. Procédé d'assemblage d'un appareil modulaire de battage de pieux (301) destiné à être utilisé dans des excavations de fondation, le procédé comprenant les étapes consistant à :

fournir un module de formation d'empreinte (308) ayant un élément de formation d'empreinte (208a) agencé pour se déplacer entre une configuration rétractée dans laquelle l'élément de formation d'empreinte est rétracté de manière que le module puisse se déplacer le long de l'excavation de fondation, et une configuration déployée dans laquelle l'élément de formation d'empreinte s'étend vers l'extérieur pour créer une empreinte dans le côté de l'excavation ; et

fournir un module auxiliaire (311) configuré pour exécuter une fonction auxiliaire à l'intérieur de l'excavation de fondation en parallèle avec le fonctionnement du module de formation d'empreinte ;

caractérisé en ce que

le procédé comprend

la connexion détachable du module auxiliaire à une extrémité du module de formation d'empreinte de manière qu'il puisse être échangé contre un module respectif différent, pour créer un appareil modulaire ayant de multiples fonctions.
11. Procédé d'assemblage d'un appareil modulaire selon la revendication 10, dans lequel le procédé comprend en outre les étapes consistant à :

connecter de manière détachable un ou plusieurs

modules auxiliaires supplémentaires et/ou modules de formation d'empreinte, à l'appareil modulaire.

12. Procédé d'assemblage d'un appareil modulaire selon la revendication 10 ou la revendication 11, dans lequel le procédé comprend les étapes consistant à :
- échanger un module auxiliaire avec un autre module auxiliaire en :
- détachant un module auxiliaire de l'appareil modulaire, et
- connectant de manière détachable un module auxiliaire différent à sa place.
13. Procédé d'assemblage d'un appareil modulaire selon la revendication 11 ou 12, dans lequel les modules auxiliaires respectifs ont des fonctionnalités différentes de manière que l'échange du module auxiliaire avec le module auxiliaire différent modifie la fonctionnalité de l'appareil.

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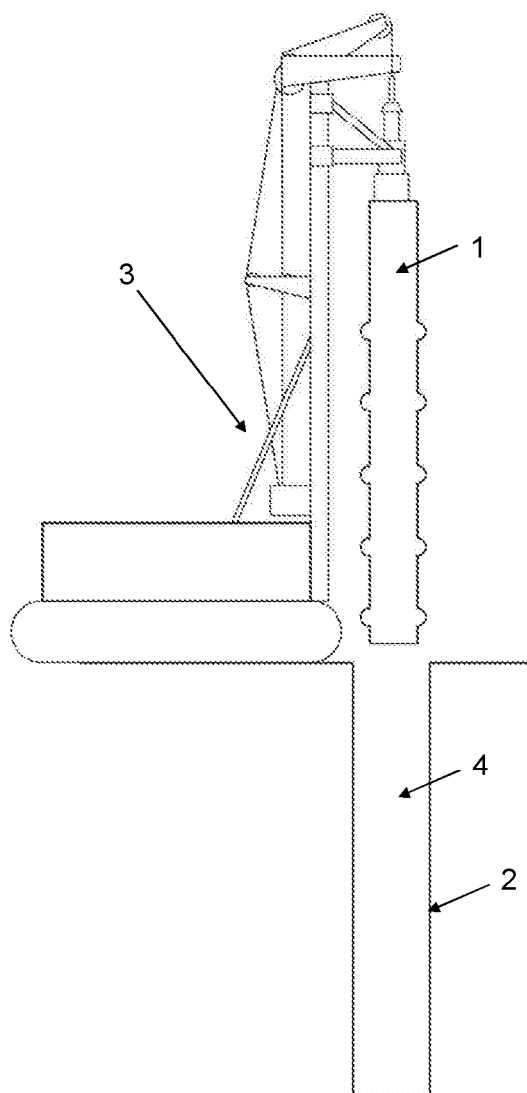


Fig. 1a

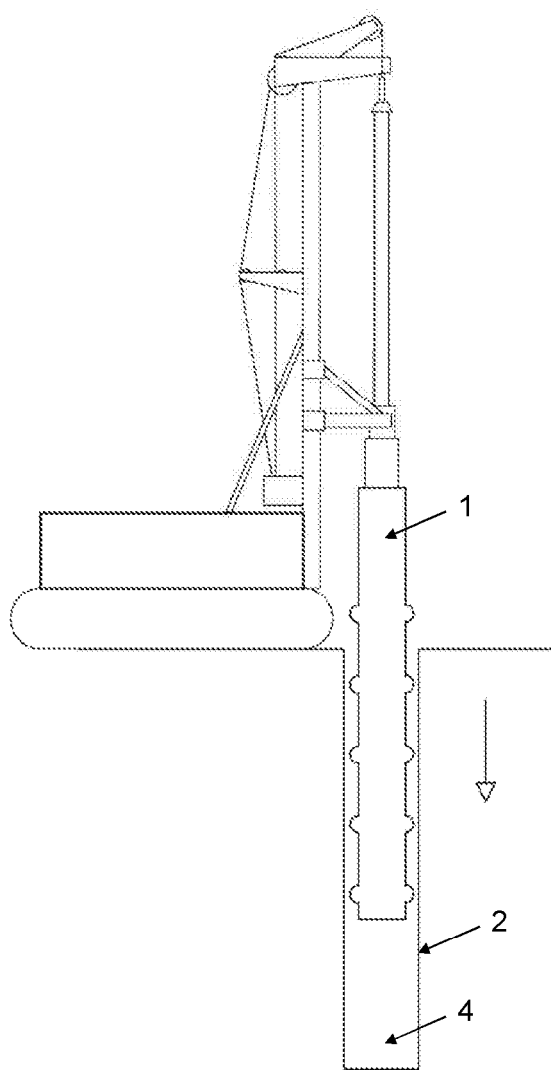


Fig. 1b

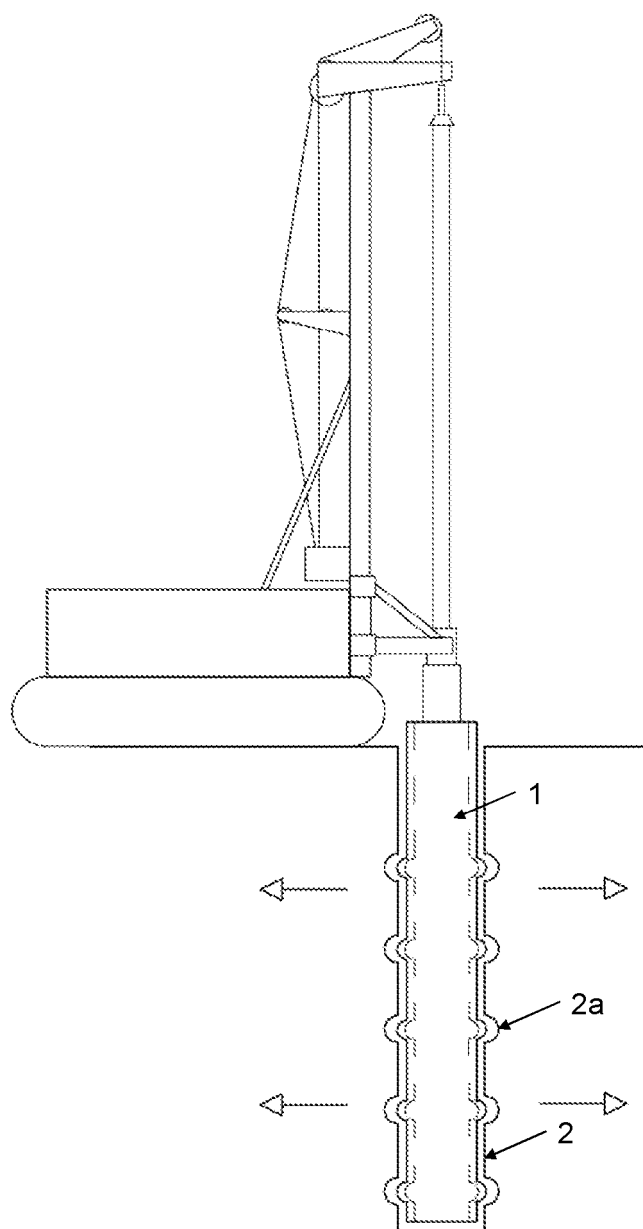


Fig. 1c

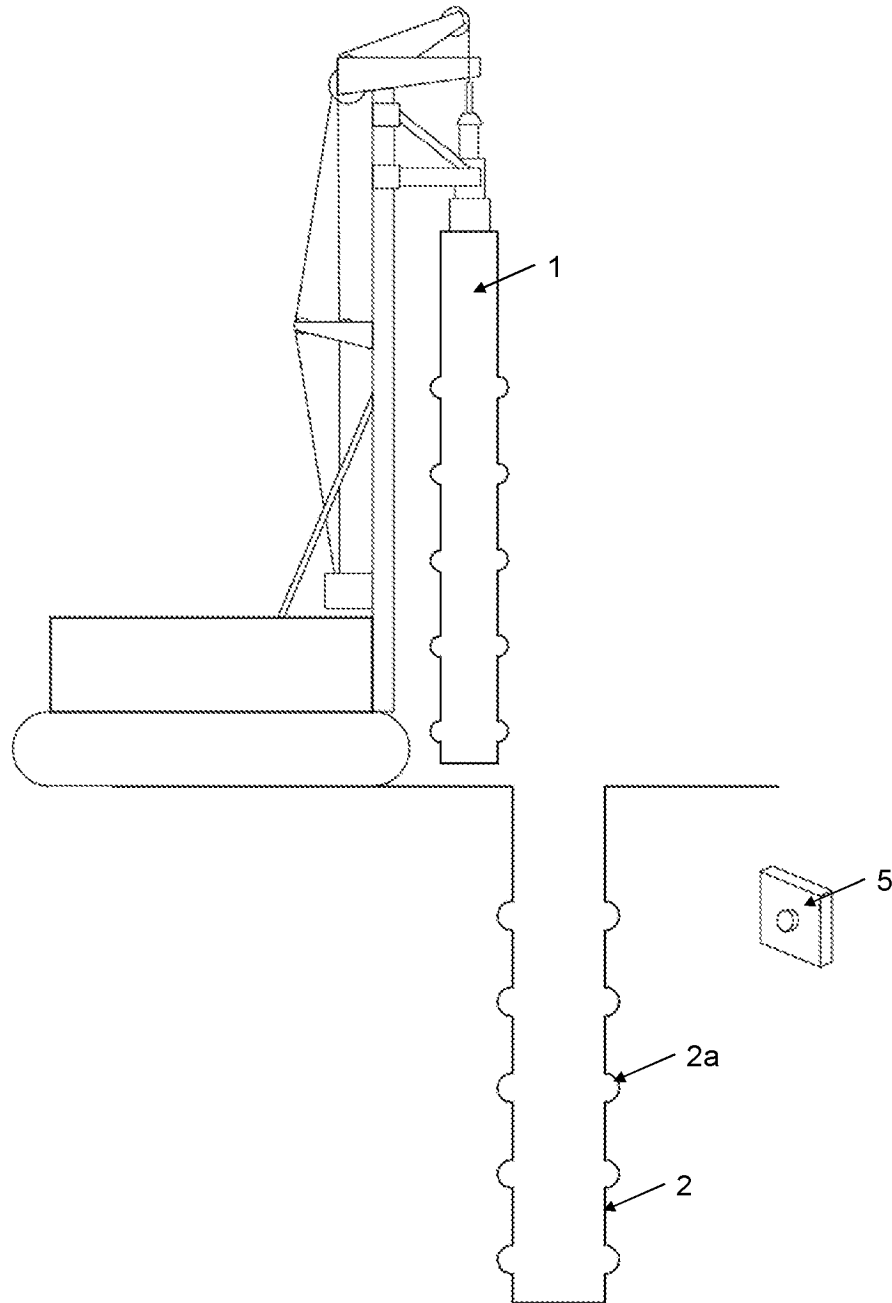


Fig. 1d

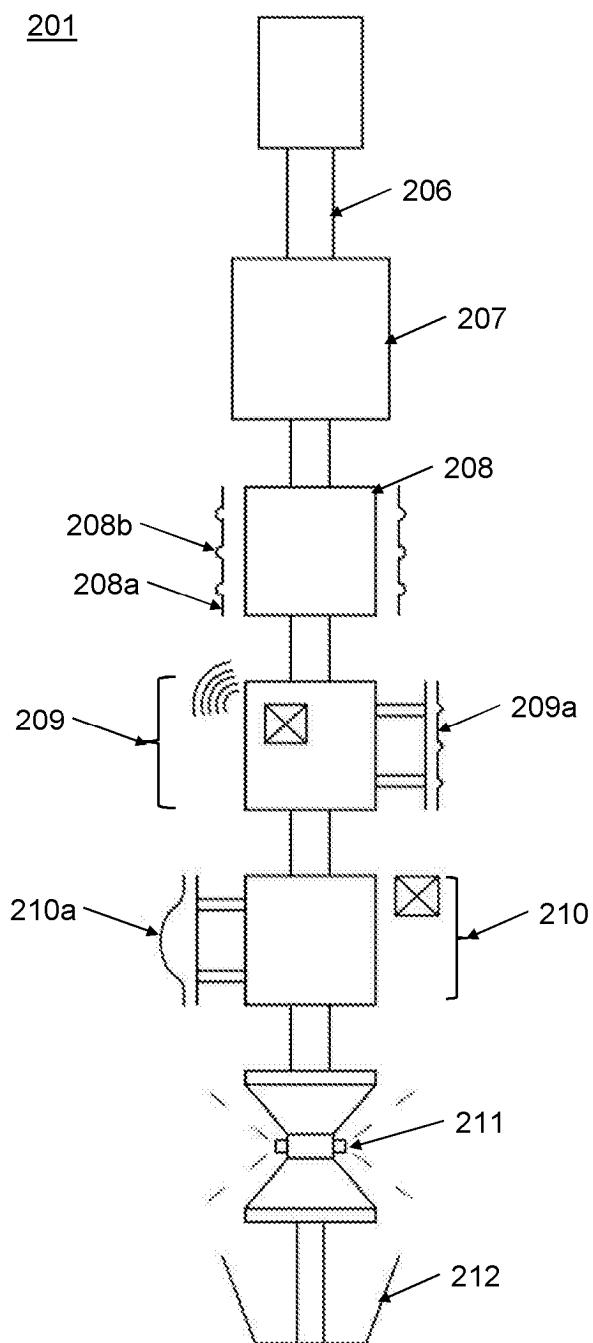


Fig. 2

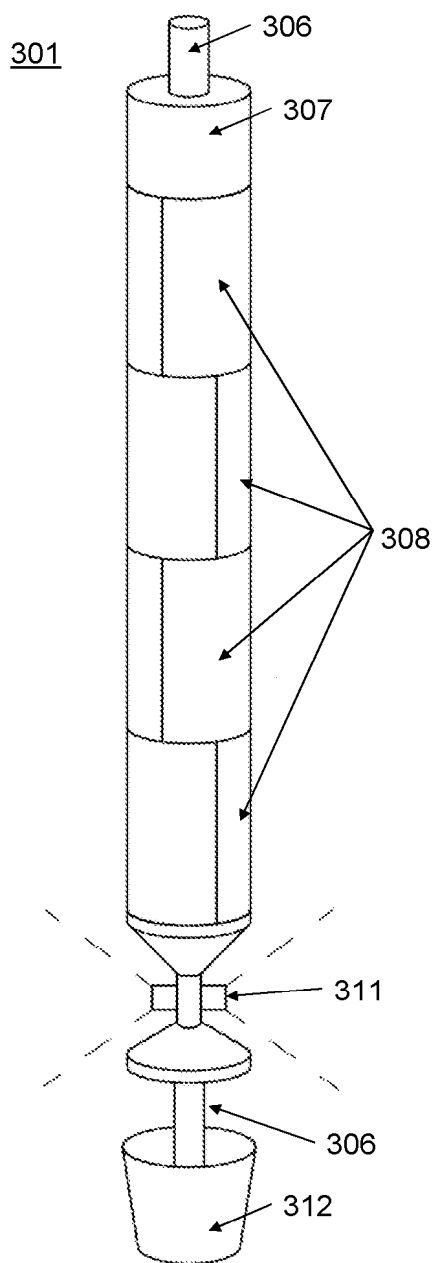


Fig. 3a

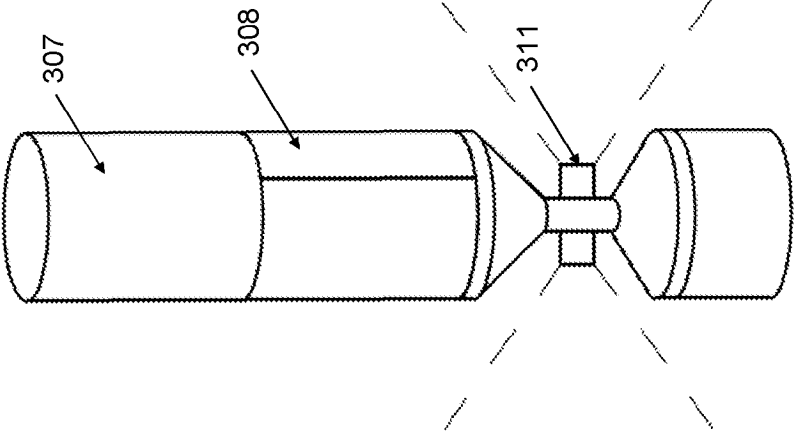


Fig. 3b

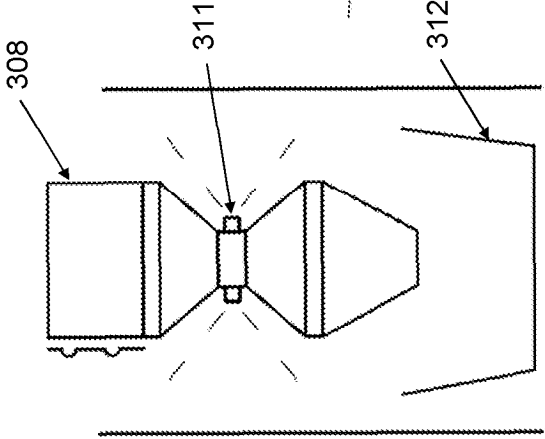


Fig. 3c

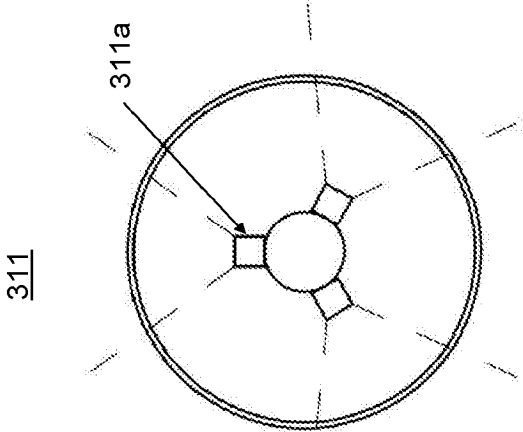


Fig. 3d

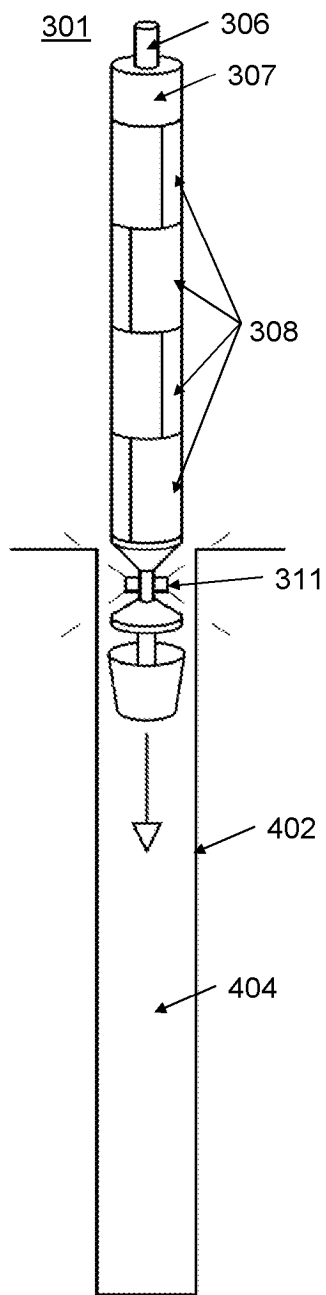


Fig. 4a

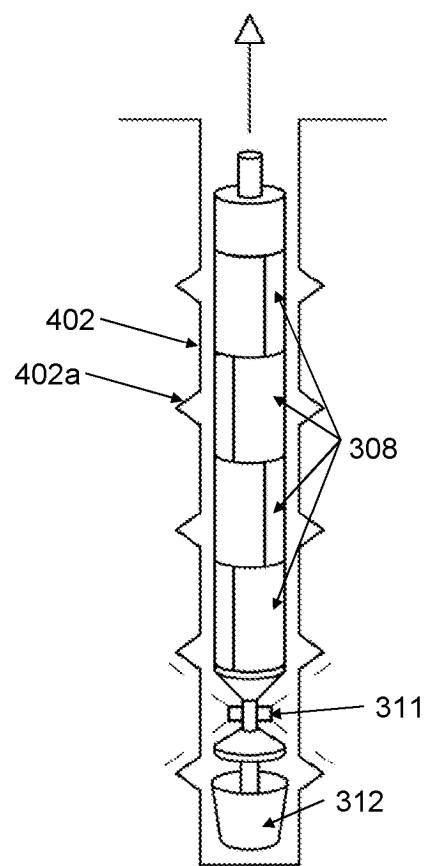


Fig. 4b

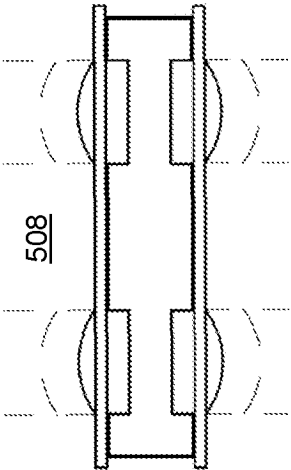


Fig. 5a

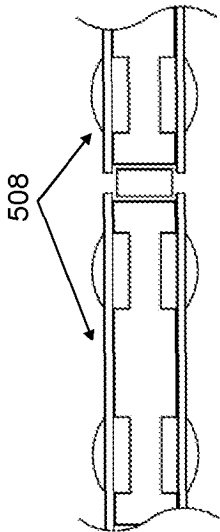


Fig. 5b

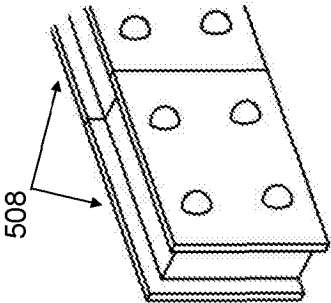


Fig. 5c

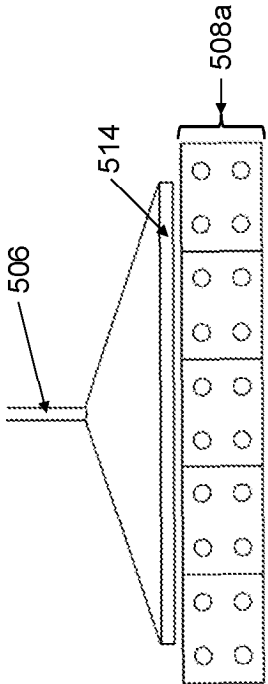


Fig. 5d

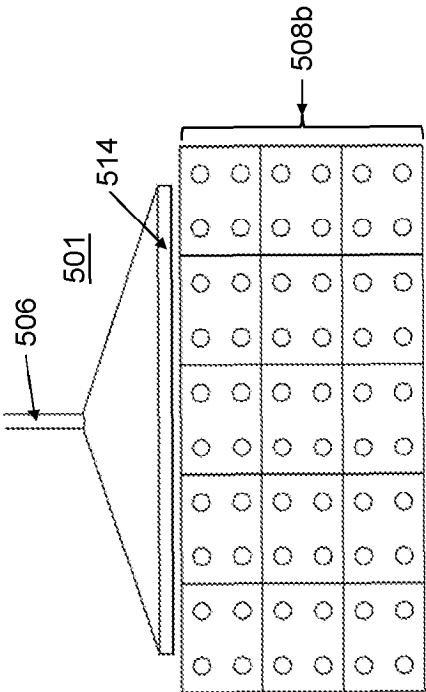


Fig. 5e

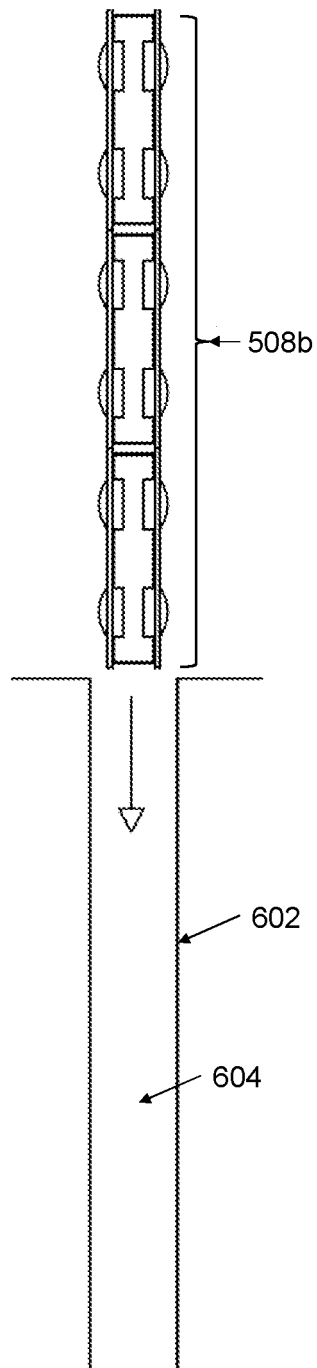


Fig. 6a

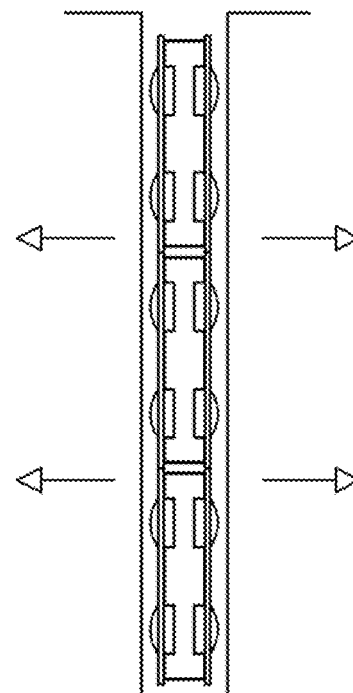


Fig. 6b

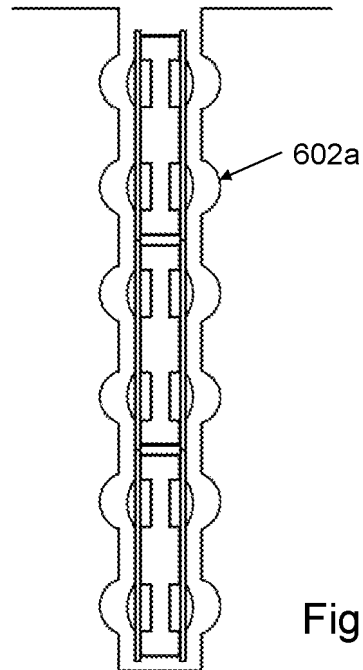


Fig. 6c

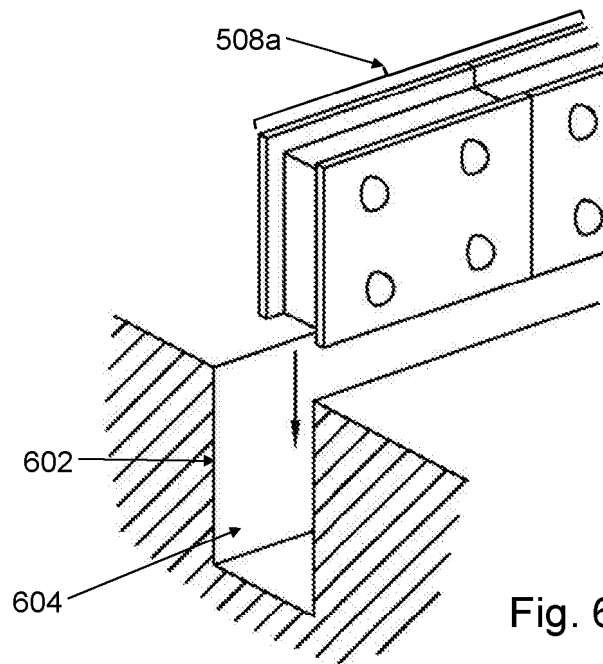


Fig. 6d

REFERENCES CITED IN THE DESCRIPTION

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