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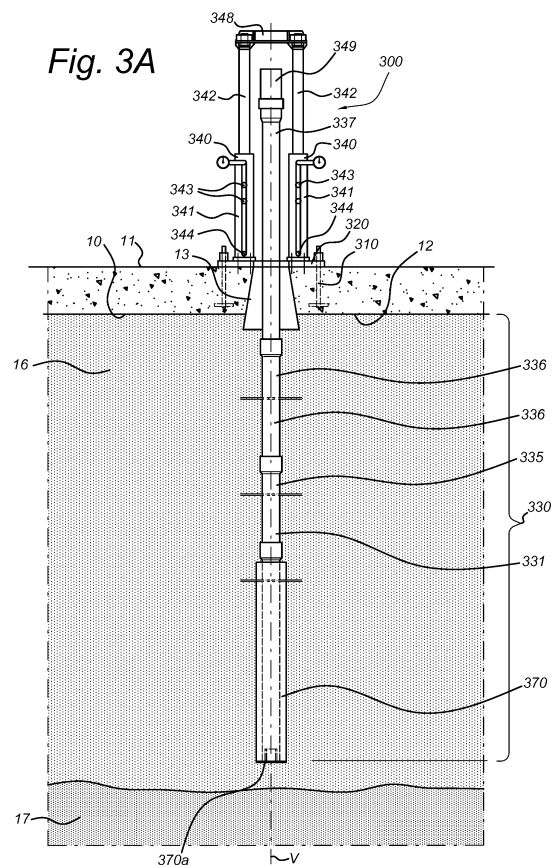
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(54) **APPARATUS AND METHOD FOR STABILIZING A FOUNDATION OF A BUILDING**

(57) The invention relates to an apparatus and method for stabilizing a foundation of a building. The apparatus is adapted to be arranged within said building and comprises: a casing, attachable to the foundation of said building; a jack, attachable to said casing and arranged for pressing hollow pile segments through or adjacent to said casing vertically into the soil to form a substantially vertical hollow pile having a top end and a bottom end and comprising said pile segments; and a percussion device, adapted to be inserted vertically through said hollow pile segments of the pile to a level below the foundation, and adapted for exerting a downward percussive force on the soil at the bottom end of said hollow pile for loosening and/or breaking up said soil.



Description

Field of the invention

[0001] The present invention relates to an apparatus for stabilizing a foundation of a building, wherein said apparatus is adapted to be arranged within said building and comprises: a casing, attachable to the foundation of said building; and a jack, attachable to said casing and arranged for pressing hollow pile segments through or adjacent to said casing vertically into the soil to form a substantially vertical hollow pile having a top end and a bottom end and comprising said pile segments. The present invention further relates to an assembly comprising such an apparatus, and to a method in which use is made of such an apparatus.

Background art

[0002] Such an apparatus is used in the art of restoring the foundation of a building, e.g. by inserting additional piles into the soil when the original piles upon which the foundation rests have been damaged. As the construction of the building is complete, it is generally not possible to use large cranes and/or pile drivers to drive a whole pile into the soil by dropping a weight on the pile from a height. Instead, a pile is build up by sequentially inserting a number of pile sections vertically into the soil. These pile sections typically are formed as hollow cylinders having a flange on one end adapted for accommodating the other end of a cylinder having a same shape. Alternatively, the pile sections may be formed as hollow cylindrical pile sections of which both ends are of a same shape, wherein couplings between two neighbouring pile sections are provided. An apparatus which is adapted for driving pile segments and intermediate couplings into the soil is known from US 4,708,528.

[0003] In order to penetrate different layers of the earth usually different amounts of pressure are exerted on the penetrating end of the pile, as is described in more detail herein with reference to Fig. 2. When the bottom end of the pile encounters stronger or dense soil, the force required for penetrating the soil cannot be provided by the prior art apparatus without risk of the corresponding but oppositely directed force exerted by the apparatus on the foundation causing the foundation to crack and/or the building to be lifted up vertically.

[0004] From US 1,906,136 A a method of driving pile shells is known, wherein in a hollow pile that is provided with a pile-foot at its hollow end, a "monkey" is introduced in the interior of the hollow pile to repeatedly fall upon the inner end of the pile-foot at the same time as, by means of a jack of a suitable construction, the pile is pressed down with the same speed as the monkey can transmit to the pile-foot.

[0005] It is an object of the present invention to provide an apparatus for stabilizing a foundation of a building, which can drive a pile to a specified depth into the soil,

without damaging the foundation of the building and/or the building itself.

[0006] It is a further object to provide such an apparatus which can be carried into a building by hand, in particular without requiring motorized transport such as carts or the like inside the building.

Summary of the invention

[0007] To this end, according to a first aspect, the present invention provides an apparatus for stabilizing a foundation of a building, wherein said apparatus is adapted to be arranged within said building and comprises: a casing, attachable to the foundation of said building; a jack, attachable to said casing and arranged for pressing hollow pile segments through or adjacent to said casing vertically into the soil to form a substantially vertical hollow pile having a top end and a bottom end and comprising said pile segments; wherein said apparatus further comprises: a percussion device, adapted to be inserted vertically through said hollow pile segments of the pile to a level below the foundation, and adapted for exerting a downward percussive force on the soil at the bottom end of said hollow pile. When the penetrating end of the pile is located in a relatively weak layer of soil, e.g. comprising loose sand or the like, the pile segments can usually be pressed into the said layer using only the jack and without the percussion device being inserted in any of the hollow pile segments that have been pressed into the ground. When however the penetrating end of the pile reaches a stronger layer of soil, e.g. which comprises more densely packed sand and/or rock, the percussion device can be let down from the top end of the partially completed hollow pile to a lower end thereof, where it can be activated to loosen and/or break up the soil at the bottom end of the pile. The force for loosening and/or breaking up stronger soil layers is then at least partially provided by the percussion device so that less force has to be exerted by the jack on the top of the partially completed pile. As a result, a corresponding but oppositely directed force exerted by the jack on the foundation and/or the rest of the building can be minimized during penetration of the stronger soil layer by the bottom end of the pile. In general, a downwardly directed percussive force exerted by the percussion device is substantially absorbed by soil at the bottom end of the pile, whereas the oppositely directed reaction force is substantially absorbed by soil that is in contact with substantially the entire pile. The reaction force exerted at the top of the pile and near the foundation is thus substantially less than the downward percussion force at the bottom end of the pile, and damage to the foundation is due to activation of the percussion device is substantially prevented.

[0008] Once the pile has reached a desired depth, the percussion device can be moved upwards along a vertical direction and out of the completed pile. Preferably, the percussion device operates at a rate of between 0 to 1000 strikes per minute, more preferably at a rate of be-

tween 60 to 600 strikes per minute. The pile segments are preferably formed as hollow cylinders having a flange on one end adapted for accommodating the other end of a cylinder having a same shape, though other kinds of pile segments, e.g. as described in US 4,708,528, may be used as well.

[0009] The apparatus of the invention can be constructed in a compact and lightweight fashion, allowing it to be carried into a building and mounted on the foundation thereof, without requiring motorized tools or the like. By compact is meant that the entire apparatus, when mounted, preferably fits within a volume 1 m x 1 m x 2 m. By lightweight is meant that the casing, jack and percussion device preferably each weigh less than 70 kg so that they can be carried two persons, or can be transported by a single person using an unmotorized cart. Such an apparatus is easily portable within the building without requiring motorized transport.

[0010] It is noted that a power supply for the powering the jack and/or percussion device of the apparatus is separate from the apparatus and may be arranged outside of the building. This is particularly convenient when the power supply is a pneumatic or hydraulic power supply.

[0011] Though in principle any kind of pile segment can be used, it is preferable that the pile comprises segments that are formed as metal cylindrical segments having bell at one end and a corresponding spigot at the other end. When the spigot end of one such segment is inserted into the bell end of another such segment that is arranged lower in the pile, preferably a substantially watertight connection is formed therebetween. The water tightness helps prevent soil on the outside of the pile from coming into contact with the interior of the pile, which may be filled in with concrete once all segments of the pile have been pressed into the soil.

[0012] In an embodiment the percussion device is adapted for exerting said downward percussive force while said jack drives the pile into the soil. Thus a combined driving and percussive force is exerted on the soil at the bottom end of the pile, with the driving force pressing the entire pile further into the soil and the percussive force loosening and/or breaking up the soil at the end of the pile which penetrates deepest into the soil.

[0013] In an embodiment the percussion device is adapted for detachably interlocking with an corresponding interlocking pile segment, such that when said percussion device is interlocked with said pile segment a downward percussive force exerted by said percussion device causes a substantially equal upward force on said interlocking pile segment. This prevents the percussion device, when interlocked with the interlocking pile segment and when activated, from bouncing upward in the partially completed pile. The interlocking pile segment may differ from the other segments in the pile in that it is provided with an engagement surface on its interior for detachably interlocking with a corresponding engagement structure on said percussion device. For instance,

the percussion device may be provided with a conical end section adapted for being inserted into an engagement structure in the form of a clamping bush at the end of the pile section that has been driven deepest into the ground. When the conical end section rests on the bush, a few downward strikes by the device are sufficient to lodge it into place with respect to the bush for the remainder of the downward strikes during driving of the pile into the soil. When the end of the pile has reached a required depth the percussion device may be detached from the bush by reversing the direction in which the percussive force is directed, after which the percussion device can be brought to above the foundation again by hauling it in via the fluid supply line. A percussion device of this type may for instance be constructed by taking a conventional pneumatically operated percussion boring apparatus, e.g. as described in US 4,221,157 which is incorporated herein by reference, and placing a cone shaped end over the penetrating end of the apparatus in such a manner that the cone shaped end is stationary relative to a main body of the apparatus.

[0014] Alternatively, the percussion device may be provided with expansion elements which can expand radially with respect to a longitudinal axis of the percussion device, to clamp the device against the inner wall of any pile segment in the pile. In such a case, any pile segment can form the interlocking pile segment.

[0015] In an embodiment said interlocking pile segment is arranged at or near the bottom end of said pile, e.g. the third lowest or second lowest pile segment in the pile, though preferably the interlocking pile segment is the segment at said bottom end. The point where the percussion device is interlocked with the pile is thus close to the bottom end of the pile where the percussion device is to loosen and/or break up the soil.

[0016] In an embodiment said apparatus further comprises a flexible power supply line connectable to said percussion device for powering the percussion device, wherein said flexible power line is adapted for extending from above the soil, through one or more pile segments in the pile, to the percussion device. To this end, the flexible power supply line preferably has a length greater than or equal to the length of the pile when the pile has been driven to a predetermined depth into the ground. The flexible power supply line is preferably also adapted for supporting the weight of the percussion device. For instance, if the percussion device weighs between 60 - 80 kg, then the power supply line should be adapted for supporting at least this weight when suspended therefrom. Alternatively and/or additionally, a separate support line may be used to support suspension of the percussion device in the pile.

[0017] In an embodiment said apparatus further comprises a cap adapted to be arranged between the jack and the top end of the pile and for pressing against the top end of the pile, wherein said cap is provided with an opening for allowing the power supply line to pass there through during said pressing. Additional length of power

supply line can thus be let into the pile as the total length of the pile increases by adding further segments to the top of pile. Besides the cap, no further measures need to be taken in order to be able to supply the percussion device with power when it is inserted in the pile. In particular, the pile segments themselves do not need to be provided with means for powering the percussion device.

[0018] In an embodiment said percussion device is a hydraulically or pneumatically powered device and the power supply line is a pneumatic or hydraulic fluid supply line. The fluid supply line is connectable to a pneumatic or hydraulic power supply which may be arranged either inside or outside of the building. If the jack or jacks of the apparatus are hydraulically or pneumatically powered using a same fluid, e.g. oil or air, then a same power supply may be used for powering the one or more jacks and the percussion device. However, it is preferred that the one or more jacks are powered by means of a hydraulic liquid, such as oil, and that the percussion device is pneumatically powered by means of air. When the percussion device is powered by air, the power supply line may be provided with only a single conduit, and the air used to power to percussion device can escape through the top end of the pile without risk to operators of the device.

[0019] In an embodiment the said casing, jack and percussion device together weigh less than 700 kg, allowing the apparatus to be transported inside a building without requiring motorized transport. Preferably the casing, jack and percussion device together weigh less than 500 kg.

[0020] In an embodiment said jack and said casing together define a maximum length of a pile segment that can be inserted by said apparatus into the soil, and wherein said percussion device has a length smaller than said maximum length, preferably wherein said maximum length is 3 meters or less, more preferably wherein said maximum length is 2 meters or less. This allows the apparatus to be used in existing buildings having ceilings that are spaced apart from the foundation by more than 2 or 3 meters.

[0021] In an embodiment the apparatus further comprises one or more fixing elements adapted for extending through an opening in the foundation and engaging a bottom side of said foundation, wherein said casing is adapted to be fixed to said foundation of the building by connecting to said fixing elements in such a manner that said foundation is clamped between the one or more fixing elements and the casing. As the fixing elements engage the bottom side of the foundation, the force exerted by the jack is distributed over a larger area than if the fixing elements would extend only partially into the foundation.

[0022] According to a second aspect the present invention provides an assembly comprising an apparatus wherein the percussion device is adapted for detachably interlocking with an corresponding interlocking pile segment as described above, said assembly further comprising the interlocking pile segment, and wherein the

interlocking pile segment comprises an interlocking structure on its interior adapted for interlocking with the percussion device

[0023] In an embodiment, said interlocking structure comprises a clamping bush with an opening at an upper end of said bush for receiving a portion of the percussion device therein and supporting said percussion device, wherein said clamping bush is adapted for deforming when said percussion device received therein initially exerts a downwardly directed percussive force, said deforming causing the percussion device to become interlocked with said bush. Thus, when the percussion device has been lowered into the bush it can be lodged therein by deforming the bush during one or more downward directed strikes. Once the bush has been deformed by the initial downward strike or strikes, e.g. by the first 3 or 4 downward strikes on the bush, the percussion device is lodged in the bush and prevented from moving out of the bush during further downward strikes. The bush preferably is a metal bush, e.g. steel, having a deformable edge at the upper end thereof. As the pile segment comprising the bush remains in the soil once the pile is completed, the shape of the bush does not have to be restored to the shape it had initially and prior to being deformed.

[0024] In an alternative embodiment the percussion device, when inserted in said interlocking pile segment, is rotatable around its longitudinal axis between a position in which said percussion device is interlocked with said segment and axial movement therebetween is substantially blocked, to a position in which the entire percussion device can be moved axially out of said segment by pulling it vertically upward, preferably by pulling on the power supply line from a position above the foundation. For instance the percussion device may be provided on its outer surface with engaging elements adapted for engaging a corresponding inner surface of the interlocking pile segment, wherein in a first rotational orientation of the percussion device relative to said segment the percussion device can move freely along its longitudinal axis, and wherein in a second rotational orientation of the percussion device relative to said interlocking segment, the axial position of the percussion device in said segment is substantially fixed. In such an assembly the percussion device, when inserted in the interlocking pile segment, could be rotated by an operator above ground by rotating the power supply line that is connected to the percussion device.

[0025] In an embodiment the percussion device, when interlocked by said interlocking structure, is remotely configurable from a location above the upper end of the pile between a mode for exerting a percussive force in a first direction and a mode for exerting a percussive force in an opposite second direction. Thus, during interlocking of the percussion device in the pile segment as well when loosening and/or breaking up soil at the penetrating end of the pile, the percussion device will generally be configured to a mode for exerting a downward percussion force, while once the pile has reached a required depth

the percussion device will be configured to a mode for exerting an upwardly directed percussion force in order to break the interlocking connection between the device and the pile, allowing the percussion device to be lifted out of the hollow pile.

[0026] In an embodiment the assembly further comprises a guide wheel attachable to or attached to the casing and/or to the jack, and adapted for guiding movement of a flexible power supply line for said percussion device. When the percussion device is to be pulled up by the power supply line and out of the pile, rolling of the guide wheel along with the movement of the power supply line helps to prevent damage to the power supply line.

[0027] According to a third aspect the present invention provides a method for stabilizing a foundation of a building using an apparatus comprising a casing, a jack, attachable to said casing and arranged for driving hollow pile segments through or adjacent to said casing vertically into the soil to form a substantially vertical hollow pile having a top end and a bottom end and comprising said pile segments, and a percussion device adapted to be inserted vertically through said hollow pile segments of the pile to a level below the foundation and adapted for exerting a downward percussive force on the soil at the bottom end of said hollow pile, said method comprising the steps of: -drilling an opening in said foundation for allowing passage there through of said hollow pile segments and said percussion device; -attaching the casing to the foundation of the building to provide a support for the jack, and attaching the jack to the casing; -using said jack to drive one or more hollow pile segments into the soil to form a partially completed vertical hollow pile which extends into the soil to a first depth; -lowering said percussion device, through the foundation and said partially completed hollow pile to a position at or near a lowest segment of the pile; and - activating said percussion device and said jack such that a percussion force is exerted on the soil at the lowest end of the pile while at the same time using said jack to drive one or more further hollow pile segments into the soil to form a completed vertical hollow pile which extends into the soil to a second depth greater than said first depth. The difference between the first and second depth preferably is equal to more than the length of a pile segment in the pile.

[0028] Preferably, once the percussion device has been lowered to the position at or near the lowest segment of the pile, the percussion device is detachably interlocked with a corresponding interlocking pile segment, such that when said percussion device is interlocked with said pile segment a downward percussive force exerted by said percussion device causes a substantially equal upward force on said interlocking pile segment.

[0029] Preferably the percussion device is lowered to and detachably attached to the lowest segment, i.e. to the segment which forms the penetrating end of the pile into the soil, though alternatively the percussion device may be lowered and/or detachably attached to a second or third segment from the lowest end of the pile. When

the percussion device and the jack are activated at the same time, the percussion force exerted by the percussion device can loosen and/or break up the soil on the soil at the lowest end of the pile, allowing the pile to be driven further into the ground by the jack. The percussion device is preferably a percussion device according to the invention as described herein.

[0030] In an embodiment a signal representative of the pressure exerted by the jack on the pile is measured during driving in of the pile segments. When this signal indicates that the pressure exceeds a predetermined threshold, the jack is temporarily stopped and the percussion device is lowered into the pile, preferably to the lowest segment of the pile which comprises the penetrating end of the pile. The predetermined threshold typically depends on national or local building codes and may be equal or lower than a maximum pressure prescribed in such a code. Once the percussion device has been detachably attached to the pile, the percussion device is activated to loosen and/or break up the soil at the penetrating end of the pile, and simultaneously the jack is activated to drive the entire pile further into the soil.

[0031] In an embodiment said step of lowering said percussion device comprises suspending said percussion device from a power supply line, and providing a cap having an opening for said power supply line between said jack and a top pile segment of the pile, preferably wherein said power supply line is a hydraulic fluid supply line.

[0032] In an embodiment, the building is a residential building located within 100 m or less from another residential building. The present invention is especially suitable for use in urban areas where buildings are located close together.

Short description of drawings

[0033] The present invention will be discussed in more detail below, with reference to the attached drawings, in which:

Fig. 1 schematically shows a cross-sectional view of a building in which a prior art apparatus for stabilizing the foundation of the building is arranged,

Fig. 2 shows an example graph of the results of a soil-drilling test using a conventional apparatus for stabilizing a foundation of a building, in which soil depth vs. force required on the penetrating end of the pile is plotted,

Fig. 3A schematically shows a first embodiment of the apparatus according to the invention, driving a hollow pile into relatively soft soil,

Fig. 3B shows the same apparatus while driving the pile through denser soil,

Fig. 3C shows a section III-C of Fig. 3B in greater detail,

Figs. 3D and 3E schematically show respectively a portion of a lower pile end with a percussion device

loosely inserted therein, and with the percussion device lodged therein,

Figs. 4A and 4B respectively illustrate lowering the percussion device into the hollow pile, and pulling the percussion device up from the bottom end of the pile,

Fig. 5 shows another embodiment of the apparatus according to the invention, with the casing arranged in a cut-out portion of a wall of the building and fixed to the foundation of the building.

Description of embodiments

[0034] Figure 1 schematically shows a building 1 comprising a roof 2 which is supported, via walls 3,6,9 on a top side 11 of a foundation 10. The foundation 10 is arranged at about ground level, i.e. the level of the top of the soil 15 which surrounds the foundation, and is with its bottom side 12 at least partially supported on a number of piles 21, 22, 23, 24. The soil comprises a relatively weak, i.e. easily penetrable, top layer 16, on top of which a relatively strong, i.e. less easily penetrable, layer 17 is arranged. In the example shown, the piles 21, 22, 23, 24 are end bearing piles which extend with their penetrating ends into the strong layer 17. Some of these piles may have been damaged and/or have sunk further into the ground than intended and therefore no longer provide sufficient support for the foundation. In order to stabilize the foundation 10 at a location vertically below wall 3, a portion of inner side 4 of the wall 3 has been cut away to form a space 18 for a conventional apparatus 100 for stabilizing the foundation of the building. The apparatus 100 comprises a casing 120 that is fixed to the foundation 10 by means of bolts (not shown for apparatus 100) which extend into the foundation 10. As the casing 120 is placed at least partially within the space between the inner side 4 and outer side 5 of the wall 3, the apparatus 100 can drive a pile 30 vertically into the ground directly below the wall 3. The apparatus comprises a hydraulic jack 140 with a hydraulically powered cylinder that is operable between an extended position, in which a hollow pile segment 39 can be inserted through a cylindrical opening in the casing and subsequently through the foundation, and a retracted position, for driving said hollow pile segment into the ground. The jack 140 is connected via hydraulic fluid supply lines to a hydraulic fluid supply apparatus 150, here shown within the building 1, but which may alternatively be arranged outside of the building.

[0035] The pile 30 is formed by a number of consecutive hollow pile segments 31, 32, 33 ... 39, pressed into the ground using the apparatus 100. When enough pile segments needed to for the pile 30 to reach a predetermined depth d_1 from the ground level have been driven into the ground, the top pile segment 39 is fixed to the wall 3 and/or to the foundation 10, e.g. by welding it to casing 120, to the wall 3, foundation 10 and/or to an iron framework fixed to either of these, so that the pile 30 is immediately loaded and later settlement of the pile due

to subsequently placing a load thereon is minimized. Next, the apparatus 100 is taken out of the space 18, possibly while leaving the casing fixed to the foundation, and concrete is poured into the pile segments after which the space 18 is filled in with masonry. The result is a concrete filled pile which is loaded and stabilizes the foundation 10.

[0036] Fig. 1 further shows another conventional apparatus 100' which is attached to the top side of the foundation 10 and arranged horizontally spaced apart from the walls 3, 6, 9 of the building 1. The apparatus 100', which functions essentially in the same manner as the apparatus 100, comprises a casing 120' which is fixed to the foundation 10 by means of bolts 110' which extend about halfway into the foundation. The apparatus further comprises two hydraulic jacks 140' for driving the pile segments 31' - 39' which form the pile 30' into the ground. The two hydraulic jacks 140' are connected to a hydraulic power supply 150' via hydraulic fluid conduits. When all pile segments needed for the pile 30' to reach the depth d_1 have been driven into the ground, the top pile 39' is fixed to the foundation 10, e.g. by welding it to the casing 120' that is fixed to the foundation, after which the remaining part of the apparatus 100' is detached from the foundation and moved away from the pile 31'. The pile is then filled with concrete, resulting in a concrete filled pile which is loaded and stabilizes the foundation 10.

[0037] Both the apparatuses 100 and 100' are relatively small and light weight, allowing them to be carried inside the building and fixed to the foundation by a human operator 19, without the use of motorized vehicles or cranes or the like.

[0038] Fig. 2 shows an example graph of measured sleeve resistance f_s in MPa (Mega Pascal) and measured cone resistance q_c in MPa of a pile when it is driven into the soil using a conventional apparatus 100 or 100'. Along the vertical axis the depth d in meters to which the penetrating end of the pile is driven into the earth is indicated. As is customary this depth is indicated relative to a specified reference height, e.g. defined as the Dutch reference height denoted "Normaal Amsterdams Peil", or as specified in the European Vertical Reference System 2000. Level line 201 indicates the relative level of the top surface of a foundation on which the apparatus is installed. The graph is an example graph of measurements as may be obtained during driving of a pile into the ground below a building which has a crawl space directly below the foundation. Level line 202 indicates the level of the top surface of the soil below the foundation, and in the present case lies about 1 m below level line 201 due to the presence of the crawl space.

[0039] Line 210 represents measured cone resistance values. The horizontal scale at the top of the graph indicates the scale of the measured cone resistance values which lie in the range of 0 to about 23 MPa. Line 220 represents measured sleeve resistance values. The lower horizontal scale at the bottom of the graph indicates the scale of the measured sleeve resistance values which

lie in the range of 0 to about 0,13 MPa. Though the measured sleeve resistance values and cone resistance values depend to some extent on the shape and dimensions of the pile segments and penetrating end of the pile, changes in the sum of the measured values are best explained by changes in density and material of the soil. For instance, at a depth of about -7 meters relative to the reference height there is a brief spike in the measured values for both the sleeve resistance and the cone resistance, which may be indicative of rock surrounded by relatively softer soil being encountered by the penetrating end of the pile. From a depth of about -7,5 to -15 meters relative to the reference height, both the measured values for f_s and q_c are relatively low, which may be indicative of the soil between these depths being relatively soft. From a depth -15 meters to -23,5 meters it is likely that the penetrating end of the pile encountered a harder soil, e.g. containing rocks and/or more densely packed soil. In order to overcome the resistance by this soil, the apparatus has to exert a pressure on the penetrating end of the pile that is equal to or greater than a sum of the sleeve resistance and the cone resistance. At a depth of -17,5 meters, this pressure exceeds 20 MPa, and an equal but oppositely directed pressure is exerted by the apparatus on the foundation to which it is attached. This may result in the foundation cracking and/or being lifted relative to the reference height.

[0040] Figs. 3A and 3B show side views of an apparatus 300 according to the invention, fixed to the foundation 10 of a building at a position horizontally spaced apart from the walls of the building. The apparatus 300, which may take the place of the apparatus 100' in the building 1 of Fig. 1, comprises a casing 320 fixed to the foundation 10 by bolts 310 which extend partially into the foundation 10. The foundation 10 is shown resting directly on soil layer 16. However, if the apparatus 300 were to be attached to a foundation below which a crawl space is present, the bolts or other fixing elements may extend through completely through the foundation 10 to engage the foundation from its bottom side 12 so that the foundation 10 is clamped between the casing 320 and the fixing elements 310.

[0041] The apparatus 300 further comprises two hydraulic jacks 340, each with a hydraulic cylinder 341 and an arm 342 that is adapted to extend from or retract into its respective cylinder in dependence of hydraulic fluid supplied through hydraulic fluid supply conduits 343, 344. The arms are connected to each other by a bridge 348, so that a pile segment can be placed between the arms and the bridge can exert a force on the top of said pile segment when the arms of the hydraulic cylinders are driven in unison to move the bridge towards the foundation. A removable adapter 349 is arranged between the bridge 348 and the upper side of the top pile segment 339, enabling the apparatus to drive the segment 337 sufficiently deep into the ground along vertical axis V of the pile 330 so that another segment can be arranged on top of said segment when the adapter 349 is removed.

The pile 330 comprises a number of segments 331 - 337 as well as segment 370 which was the first segment of the pile driven into the ground. Distal end 370a of the segment 370 forms the bottom end of the pile 330. When driving pile segments into a weak soil layer, such as weak soil layer 16, the apparatus 300 functions in much the same manner as the conventional apparatus 100'. However, when the penetrating end 370a of the pile encounters more resistance, e.g. when reaching a depth where a stronger soil layer is present, the present invention provides significant advantages over conventional apparatuses.

[0042] Fig. 3B schematically shows the apparatus 300 when two new segments 338 and 339 have been added to the top of the pile 330 and the bottom end 370a of the pile 330 has reached a more dense soil layer 17. In order to penetrate this soil layer without exerting excessive force on the foundation 10, a percussion device 360 of the apparatus 300 has been lowered by a pneumatic fluid supply line 380 connected thereto, from above the foundation 10 through conical opening 13 in the foundation 10 and through the hollow pile 330 to be lodged in the pile section 370 having the penetrating end 370a. Between the bridge 348 and the top segment 339 of the pile, a cylindrical cap 350 is arranged which is provided with a recess 351 at an edge 352. When the pneumatic supply line 380 extends through pile segment 339 and/or through removable adapter 349, the cap 350 may be placed on top thereof on top with the pneumatic fluid supply line 380 passing through the recess 351, as shown in the detail of section III-C in Fig. 3C. The percussion device 360, which was lowered into the pile while suspended from the pneumatic fluid supply line 380, may be pulled up again by pulling on said line.

[0043] Fig. 3D shows a detail of the percussion device 360 with its conical end 361 inserted into the end segment 370 of the pile, wherein the percussion device can still be pulled up simply by pulling on the fluid supply line 380. The end segment 370 comprises a bottom plate 371 to which an outer cylindrical wall 372 and a concentric inner cylindrical wall 373 are welded, with both walls 372, 373 extending perpendicularly from the bottom plate 371. A metal clamping bush 374 which is arranged within the inner cylindrical wall 373 is welded on the plate 371. On its end facing away from the plate the bush 374 has an open end for receiving the conical portion 361 therein. A smallest diameter of the conical portion is smaller than the inner diameter of the opening in the bush, and a largest diameter of the conical portion is larger than said inner diameter.

[0044] Through the partially cutaway section a pneumatically powered reciprocating ram 363 is shown, adapted for impacting a plate 362 which is fixed to the conical end 361. The fluid supply line 380 is attached to a control ring 365 at the top end of the percussion device 360. The direction in which the device exerts the percussive force can be controlled by rotating the control ring 365 relative to the conical end 361 around the longitudinal

axis of the percussion device. When the conical end 361 of the percussion device rests on the top edge 375 of the open end of the bush 374, the direction in which the percussion device exerts the percussive force can thus be reversed by driving rotation of the ring 365 via the fluid supply line, e.g. by manually rotating the fluid supply line from the top of the pile.

[0045] When the device 360 is being lowered into the pile, the direction in which it exerts the percussive force will generally be directed towards the bottom end 370a. Thus, after the percussion device has been lowered onto the bush 374 as shown in Fig. 3D, the ram 363 can be powered to perform downwardly directed strikes. The strike-rate of the percussion device can be set to between 0 and 600 strikes per minute. Usually the strike rate will be set manually while the percussion device is located above the foundation, though alternatively the strike rate may depend on the fluid pressure that is supplied through the fluid supply.

[0046] Fig. 3E shows the percussion device 360 and bush 374 just after the device has been lowered onto the edge 375 of the bush and has performed about three or four downwardly directed strikes. The downward strikes have caused conical end 361 to move a distance H further into the bush, resulting in deformation of the edge 375 so that the inner diameter W3 of the bush is slightly increased by the deformation and the conical end 361 of the device becomes substantially lodged in the bush 374.

[0047] Once the percussion device has reached the end of the pile, it is thus detachably fixed thereto to prevent the percussion device from moving up or even partially out of said pile section 381 when activated to perform further downward strikes. Next, both the jacks 340 of the apparatus 300 as well as the percussion device 360 are activated to simultaneously provide a press-in force on the top pile segment 339 and a percussion force on the penetrating end 370a of the pile section in order to penetrate into the strong layer. Though for the press-in force a similar and oppositely directed force will be exerted on the foundation 10, the distance from the foundation at which the percussion force is exerted on the strong layer, as well as the soil adhering to the pile 330, substantially dampen or even cancel propagation of said percussion force back to the foundation 10. The risk of damage to the foundation - if any - due to the use of the percussion device is thus minimized, as is the risk of damage to surrounding structures, such as surrounding buildings.

[0048] The inner diameter of the W3 of the bush is greater than a smallest outer diameter W1 of the conical end 361 and larger than a largest outer diameter W2 of the conical end 361. The inner wall 373 of the end segment 370, and the inner walls of the other segments of the pile, have an inner diameter W4 which is substantially larger, e.g. at least 30% larger, than the outer diameter W2 of the percussion device. This prevents the percussion device from becoming lodged in any of the other segments of the pile when the device is lowered into the

pile.

[0049] Fig. 4A shows the apparatus 300 when the bottom end of the pile has reached a relatively strong soil layer which cannot be penetrated using the jacks 340 without risking damage to the foundation 10. A hollow top pile segment (not shown) has been driven far enough into the soil so that a next segment 339 can be placed on top thereof, and the arms 341,342 of apparatus 300 are moved to a position which allows the percussion device to be inserted into the hollow top pile segment. With the top and end of the pile in this position an operator 19 places the percussion device 360 into the top pile segment. Subsequently he lowers the percussion device to the bottom of the pile via the pneumatic supply line 380 which is connected to the end of the percussion device until the percussion device reaches the lowest pile segment. The percussion device is then interlocked with the lowest pile segment, for instance as described above. The jacks 340 are subsequently powered by means of hydraulic fluid supplied through hydraulic fluid supply lines 393, 394 for driving the entire pile further into the soil, while at the same time the percussion device is powered by means of pneumatic fluid supplied through the fluid supply line 380 in order to loosen up the soil at the penetrating end of the pile.

[0050] Generally, the percussion device will only need to be activated when the last few segments are to be driven into the soil, e.g. when only 1, 2 or 3 further segments need to be driven into the soil for the pile to reach the desired depth. In this case, before attaching the hydraulic supply line 380 to the percussion device 360, at least the required number of further segments is preferably slid over the fluid supply line 380, so that the fluid supply line can remain connected to both the percussion device 360 and the hydraulic power supply while the pile is being finished.

[0051] Fig. 4B shows the apparatus 300 when the bottom end of the pile has reached an intended depth in the relatively strong soil layer. Again the top pile segment is not shown. The percussion device has been detached from the pile so that it can be pulled up by the two men shown in the figure by hauling in the fluid supply line 380. A guide wheel 395 has been attached to the apparatus 300 so that the fluid supply line can be pulled up in a guided and controlled manner. Generally, the percussion device will be pulled up at a much faster speed than it is lowered down into the pile, so that the guide wheel helps to prevent damage to the fluid supply line during pulling up thereof. The guide wheel 395 shown is detachably attached to the bridge 384, though in other embodiments it may be attached to other portions of the apparatus 300, and may even be fixed to the bridge or other parts of the apparatus.

[0052] Fig. 5 shows an isometric view a second embodiment of the apparatus according to the invention. The apparatus 500 comprises a casing 520 arranged in a cut-out space 518 of a wall 503 of the building and fixed to a foundation 510 of the building. The foundation sup-

ports the wall 503 as well as a floor 580 having a top side 581 and a bottom side 582, wherein at the bottom side a crawlspace 585 of the building is present. It will be clear that an apparatus for stabilizing a foundation of a building should preferably be placed directly above the foundation 510, instead of on a portion of the floor which does not lie directly vertically above the foundation.

[0053] A through opening has been drilled at a position vertically below the wall, through the foundation 510, and a casing tube 590 has been fixed in place in the opening. On top of the casing tube 590, the casing 520 is arranged in such a manner that it is also fixed to the foundation 510 and arranged at least partially between the two opposing sides 504 and 505 of the wall 503. The pile 530 is formed in a manner similar as the pile 330, and a percussion device (not shown) and the jack 540, arm 542 and bridge 548 are adapted for cooperating in the same manner as in the apparatus that is described herein with reference to Figs 3A-3E and 4A and 4B. However, instead of two jacks, the apparatus 500 is provided with a single jack 540 for driving the pile segments into the soil. The jack is used for driving the entire pile further into the ground, and once a stronger soil is encountered by the penetrating end of the pile, the percussion device is inserted through the pile and activated to loosen up the soil at said penetrating end while the jack drives the pile further into the ground.

[0054] Once the pile has been completed, its position is fixed relative to the foundation 510, e.g. by welding it to the casing tube 590. The pile 530 is thus immediately loaded and later settlement of the pile due to subsequently placing a load thereon is substantially prevented. Next, the remainder of the apparatus 500 is removed from the cut-out space 518 in the wall 505, the pile is filled with concrete, and the space 518 is filled in with masonry. The invention thus provides a pile which helps to stabilize the foundation of the building, while the pressure on the foundation during driving of the pile into the soil is reduced.

[0055] In summary, the invention relates to an apparatus and method for stabilizing a foundation of a building. The apparatus is adapted to be arranged within said building and comprises: a casing, attachable to the foundation of said building; a jack, attachable to said casing and arranged for pressing hollow pile segments through or adjacent to said casing vertically into the soil to form a substantially vertical hollow pile having a top end and a bottom end and comprising said pile segments; and a percussion device, adapted to be inserted vertically through said hollow pile segments of the pile to a level below the foundation, and adapted for exerting a downward percussive force on the soil at the bottom end of said hollow pile for loosening and/or breaking up said soil.

[0056] The present invention has been described above with reference to a number of exemplary embodiments as shown in the drawings. Modifications and alternative implementations of some parts or elements are possible, and are included in the scope of protection as

defined in the appended claims. For instance, though in some of the examples the percussion device has been described as pneumatically powered, it will be appreciated that alternatively the percussion device may be powered by any means which allow it to be lowered into the hollow pile. For instance, instead of being pneumatically powered and suspended by a fluid power supply line, the percussion device may be electrically or hydraulically powered and suspended by a rope or cable while being powered by means of an electrical power cable or hydraulic fluid supply line. Moreover, though the apparatus herein has been described as an apparatus that is suitable for stabilizing a foundation of a building and is adapted to be arranged within said building, it will be appreciated that the apparatus is also suitable for driving a pile into the ground outside of a building. For instance, the apparatus may be used to drive piles into the ground close to existing buildings, wherein damage due to vibrations caused by driving the piles into the ground is minimized. In such a case, the casing may still be fixedly attachable to the foundation of a building, though the rest of the building may still be under construction.

Claims

1. Apparatus for stabilizing a foundation of a building, wherein said apparatus is adapted to be arranged within said building and comprises:

a casing, attachable to the foundation of said building;

a jack, attachable to said casing and arranged for pressing hollow pile segments through or adjacent to said casing vertically into the soil to form a substantially vertical hollow pile having a top end and a bottom end and comprising said pile segments;

characterized in that said apparatus further comprises:

a percussion device, adapted to be inserted vertically through said hollow pile segments of the pile to a level below the foundation, and adapted for exerting a downward percussive force on the soil at the bottom end of said hollow pile,

wherein the percussion device is adapted for detachably interlocking with a corresponding interlocking pile segment of the hollow pile, such that when said percussion device is interlocked with said pile segment a downward percussive force exerted by said percussion device causes a substantially equal upward force on said interlocking pile segment.

2. Apparatus according to claim 1, wherein the percus-

sion device is adapted for exerting said downward percussive force while said jack drives said pile into the soil.

3. Apparatus according to claim 1 or 2, wherein said interlocking pile segment is arranged at or near the bottom end of said pile. 5
4. Apparatus according to any one of the preceding claims, wherein said interlocking pile segment is the segment at said bottom end. 10
5. Apparatus according to any one of the preceding claims, further comprising a flexible power supply line connectable to said percussion device for powering the percussion device, wherein said flexible power line is adapted for extending from above the soil, through one or more pile segments in the pile, to the percussion device. 15
6. Apparatus according to claim 5, further comprising a cap adapted to be arranged between the jack and the top end of the pile and for pressing against the top end of the pile, wherein said cap is provided with an opening for allowing the power supply line to pass there through during said pressing. 20 25
7. Apparatus according to claim 5 or 6, wherein said percussion device is a hydraulically or pneumatically powered device and wherein said power supply line is a hydraulic or pneumatic fluid supply line. 30
8. Apparatus according to any one of the preceding claims, wherein said casing, jack and percussion device together weigh less than 700 kg. 35
9. Apparatus according to any one of the preceding claims, wherein said jack and said casing together define a maximum length of a pile segment that can be inserted by said apparatus into the soil, and wherein said percussion device has a length smaller than said maximum length, preferably wherein said maximum length is 3 meters or less. 40
10. Assembly comprising an apparatus according to any one of the preceding claims when dependent on claim 3, further comprising said interlocking pile segment, wherein said interlocking pile segment comprises an interlocking structure on its interior adapted for interlocking with the percussion device. 45 50
11. Assembly according to claim 10, wherein said interlocking structure comprises a clamping bush with an opening at an upper end of said bush for receiving a portion of the percussion device therein and supporting said percussion device, wherein said clamping bush is adapted for deforming when said percussion device received therein first exerts a downward-

ly directed percussive force on said bush, said deforming causing the percussion device to become interlocked with said bush.

12. Assembly according to claim 10 or 11, wherein said percussion device, when interlocked by said interlocking structure, is remotely configurable from a location above the upper end of the pile between a mode for exerting a percussive force in a first direction and a mode for exerting a percussive force in an opposite second direction. 5
13. Assembly according to claim 10, 11 or 12, further comprising a guide wheel attachable to or attached to the casing and/or to the jack, and adapted for guiding movement of a flexible power supply line for said percussion device. 10
14. Method for stabilizing a foundation of a building using an apparatus comprising a casing, a jack, attachable to said casing and arranged for driving hollow pile segments through or adjacent to said casing vertically into the soil to form a substantially vertical hollow pile having a top end and a bottom end and comprising said pile segments, and a percussion device adapted to be inserted vertically through said hollow pile segments of the pile to a level below the foundation and adapted for exerting a downward percussive force on the soil at the bottom end of said hollow pile, said method comprising the steps of: 15 20 25 30 35 40 45 50

drilling an opening in said foundation for allowing passage there through of said hollow pile segments and said percussion device;

attaching the casing to the foundation of the building to provide a support for the jack, and attaching the jack to the casing;

using said jack to drive one or more hollow pile segments into the soil to form a partially completed vertical hollow pile which extends into the soil to a first depth;

lowering said percussion device, through the foundation and said partially completed hollow pile to a position at or near a lowest segment of the pile;

detachably interlocking the percussion device with a corresponding interlocking pile segment, such that when said percussion device is interlocked with said pile segment a downward percussive force exerted by said percussion device causes a substantially equal upward force on said interlocking pile segment; and

activating said percussion device and said jack such that a percussion force is exerted on the soil at the lowest end of the pile while at the same time using said jack to drive one or more further hollow pile segments into the soil to form a completed vertical hollow pile which extends into the

soil to a second depth greater than said first depth.

15. Method according to claim 14, wherein said step of lowering said percussion device comprises sus- 5
pending said percussion device from a power supply
line, and providing a cap having an opening for said
power supply line between said jack and a top pile
segment of the pile, preferably wherein said power 10
supply line is a hydraulic or pneumatic fluid supply
line.

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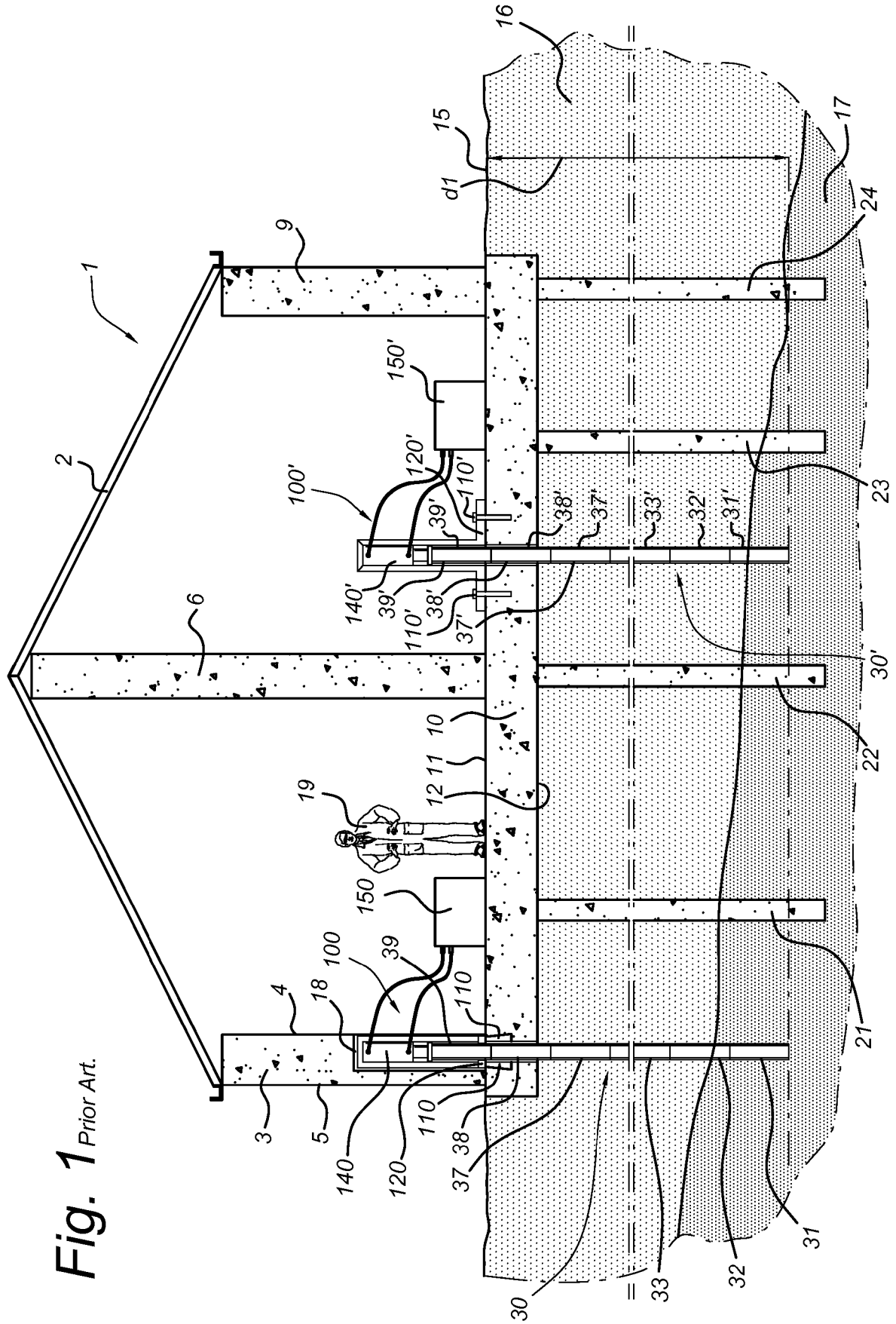


Fig. 2 *Prior Art.*

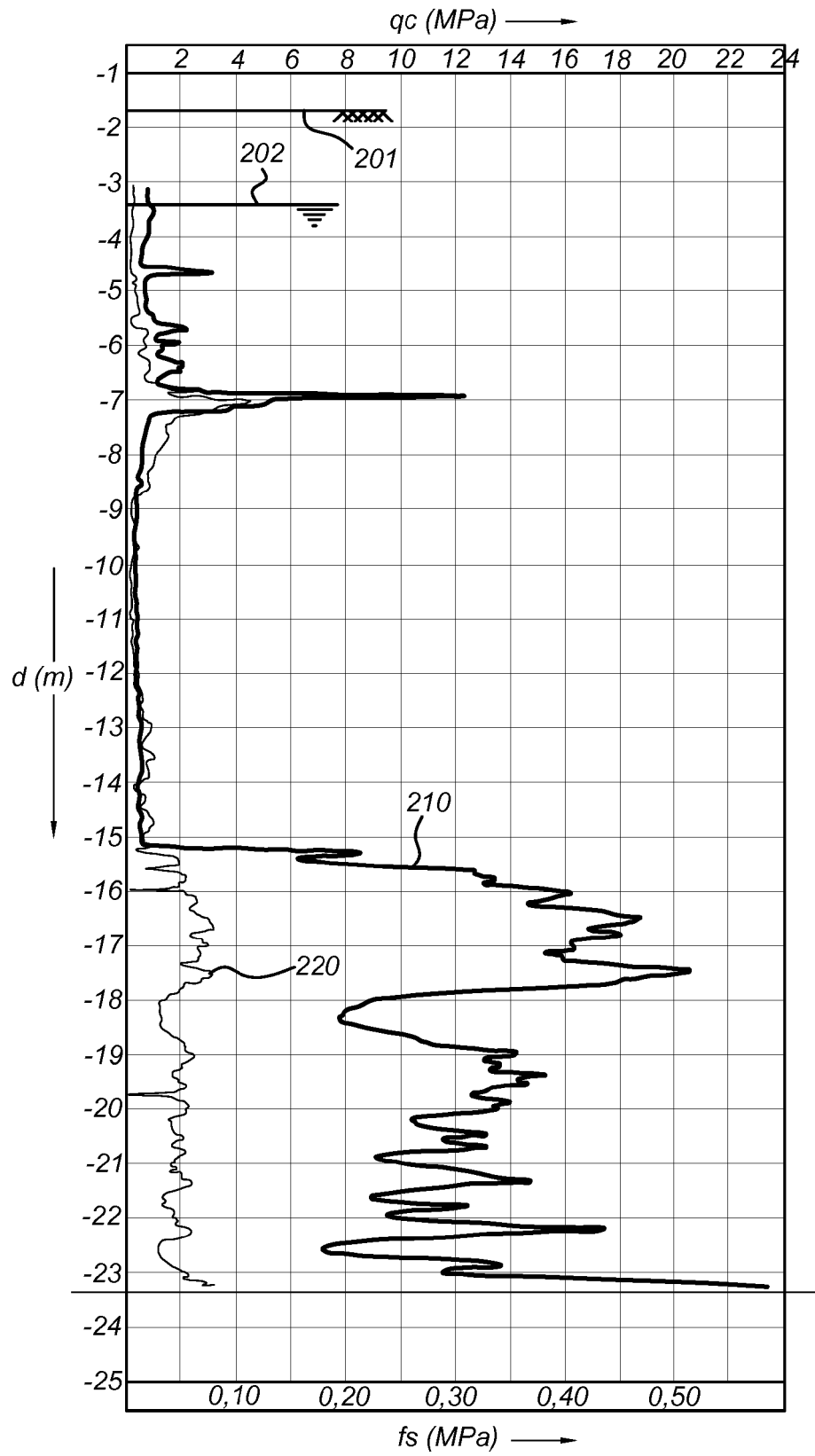


Fig. 3A

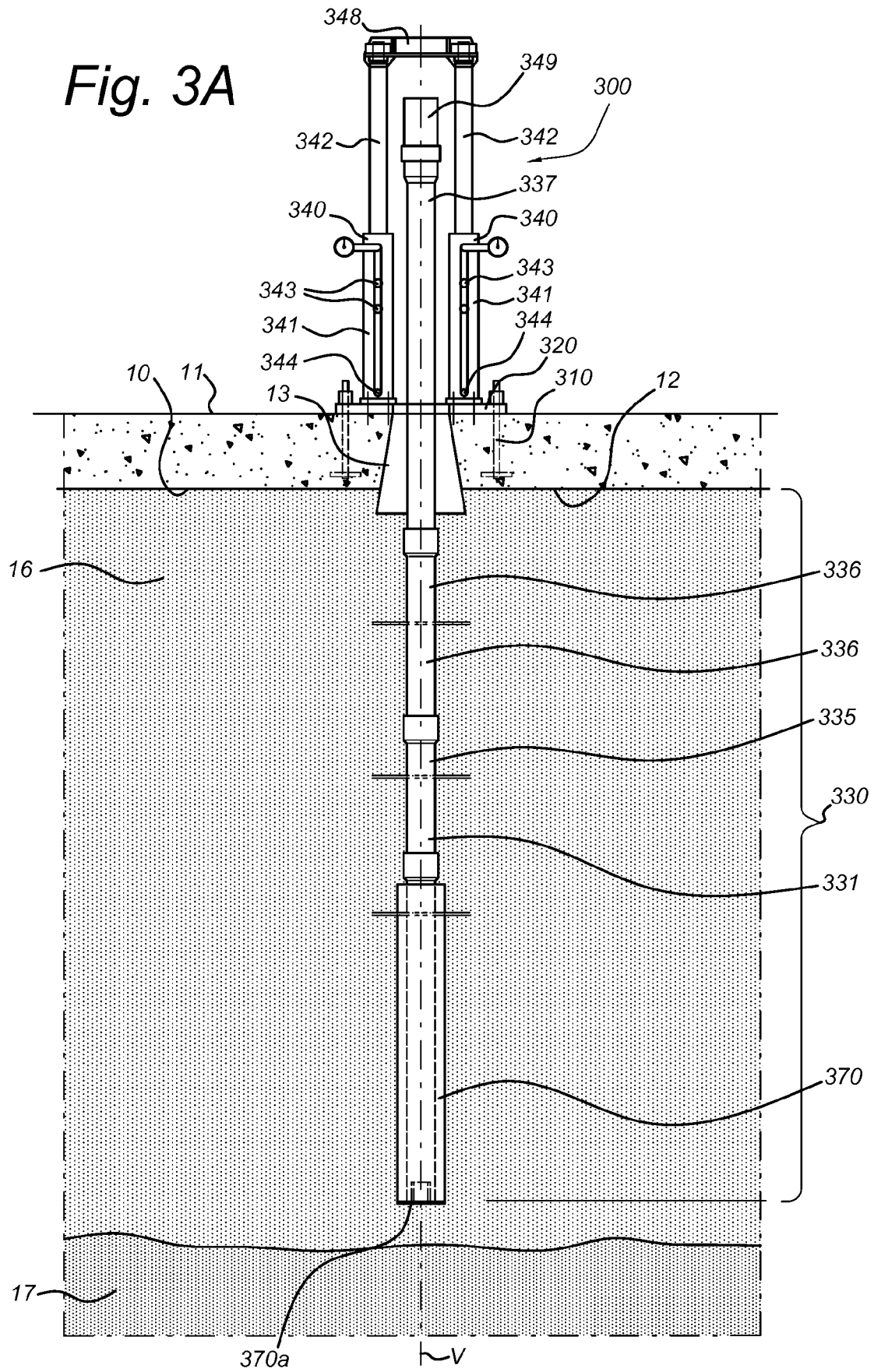


Fig. 3C

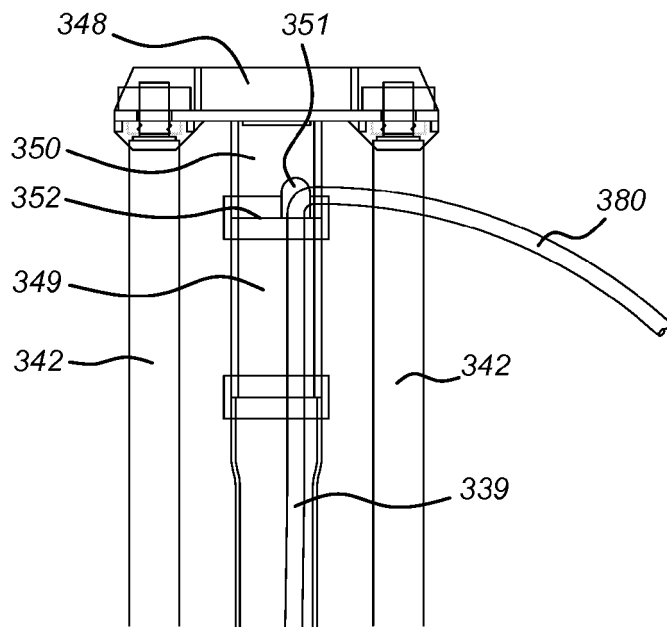


Fig. 3D

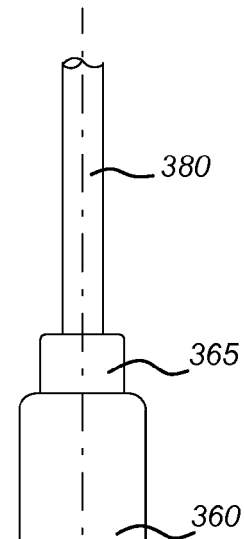


Fig. 3E

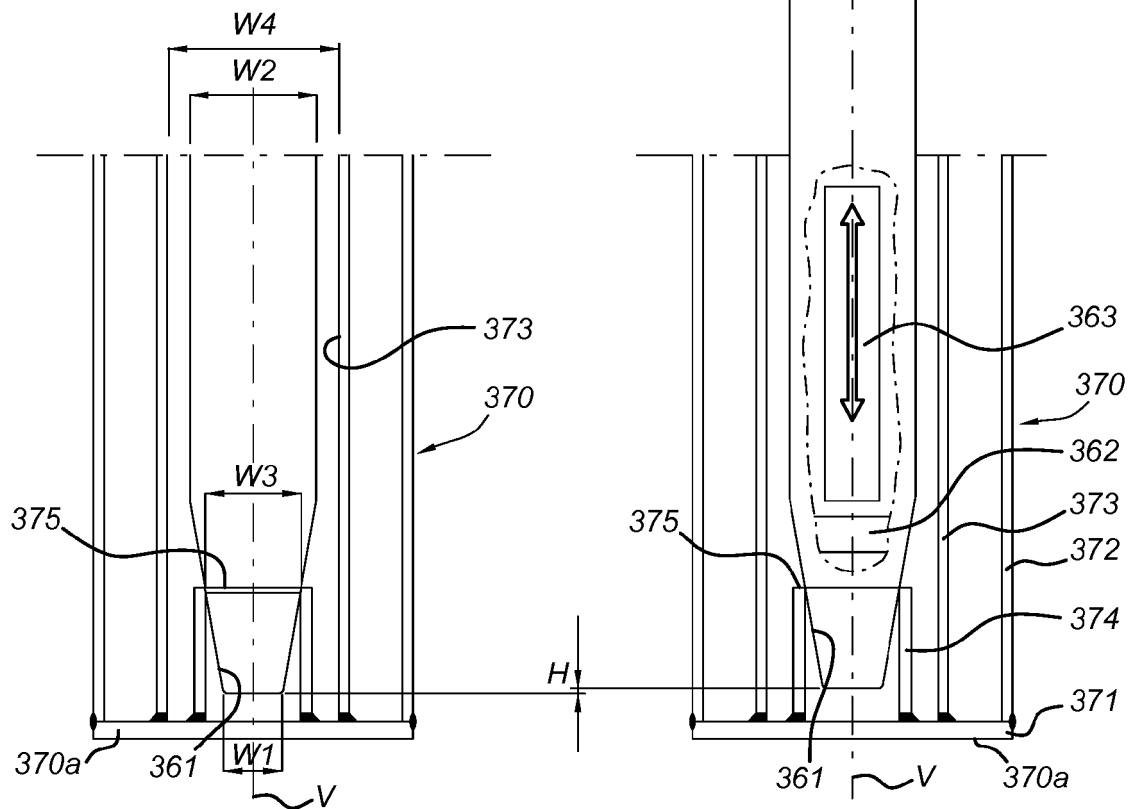


Fig. 4A

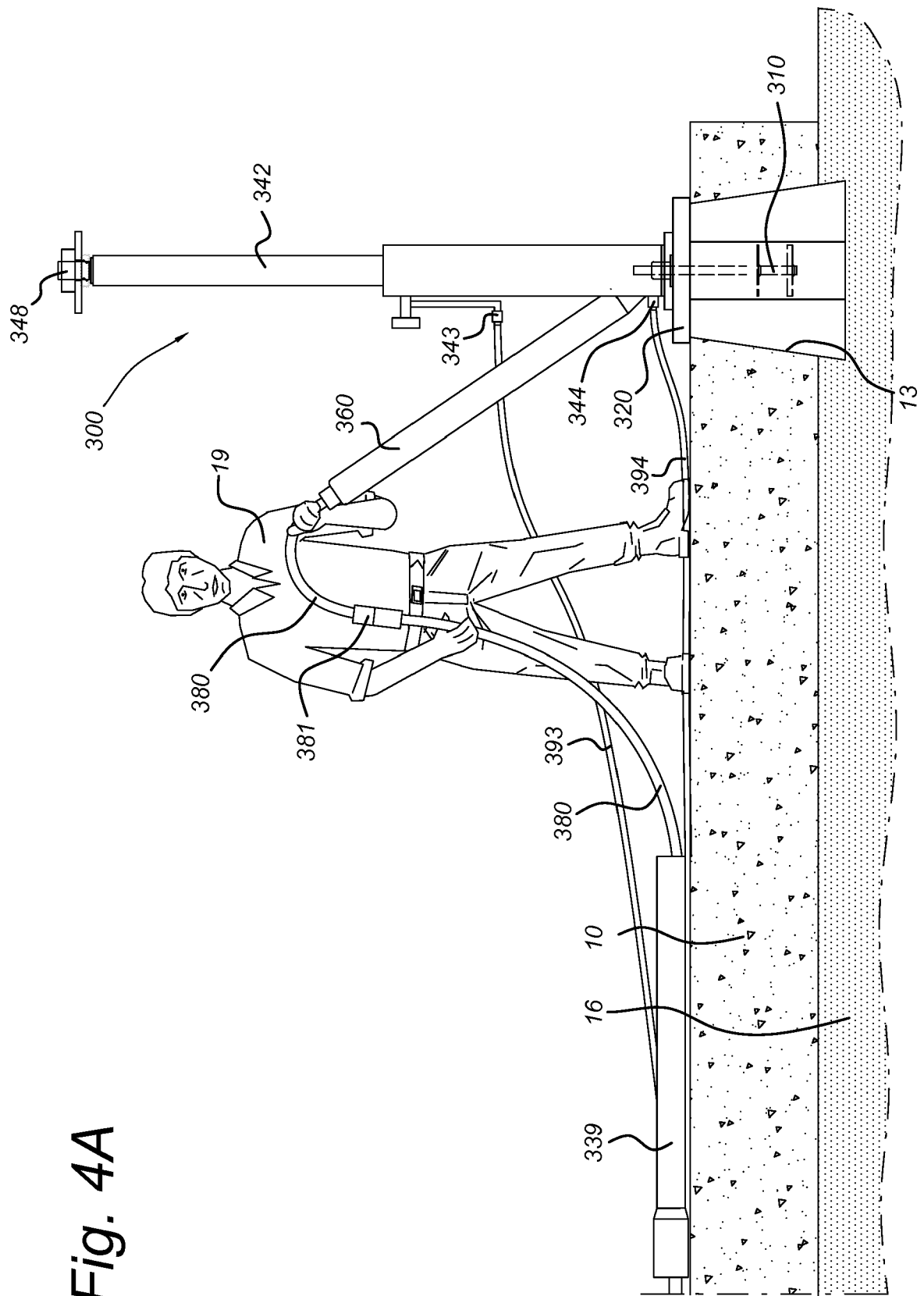


Fig. 4B

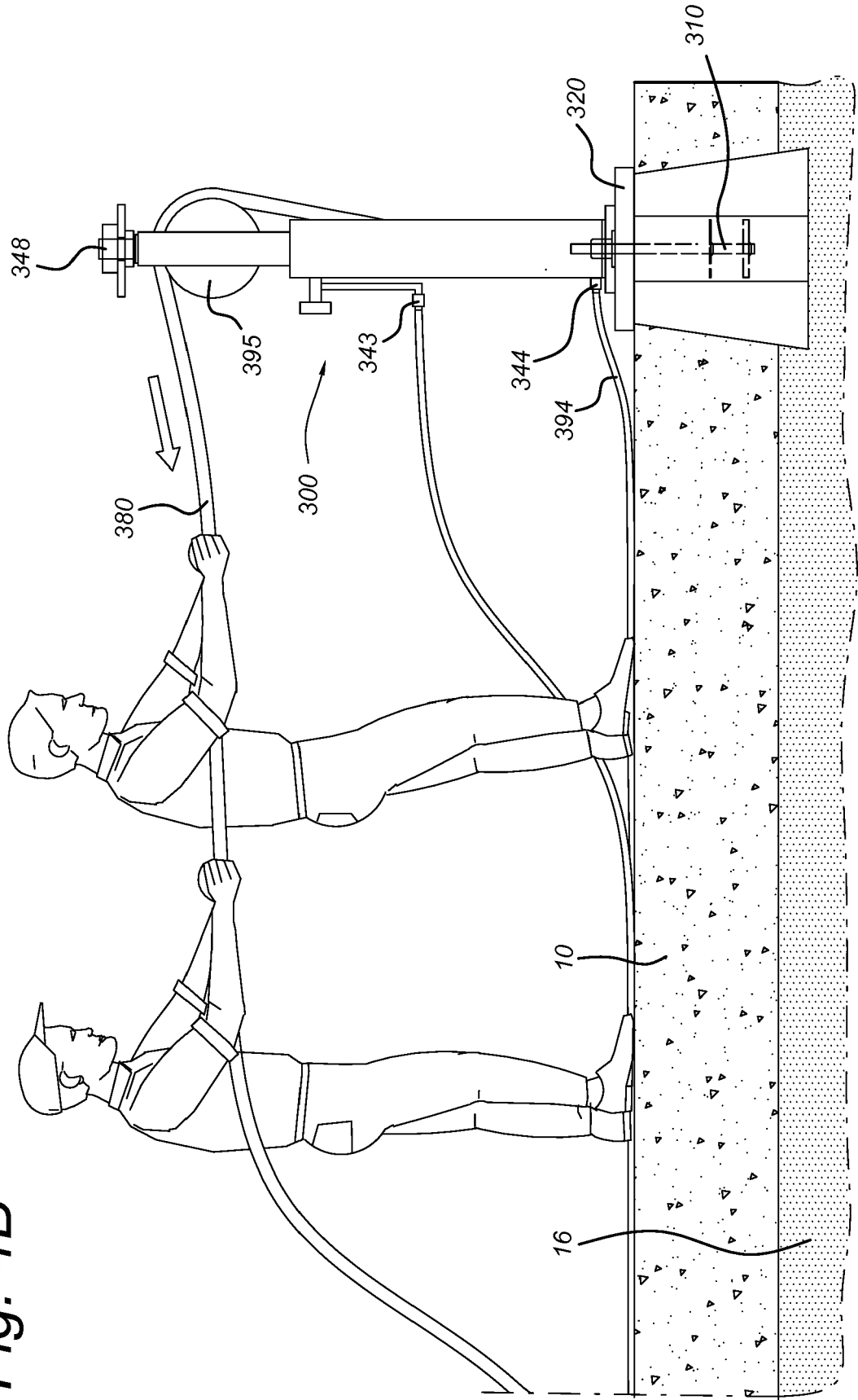
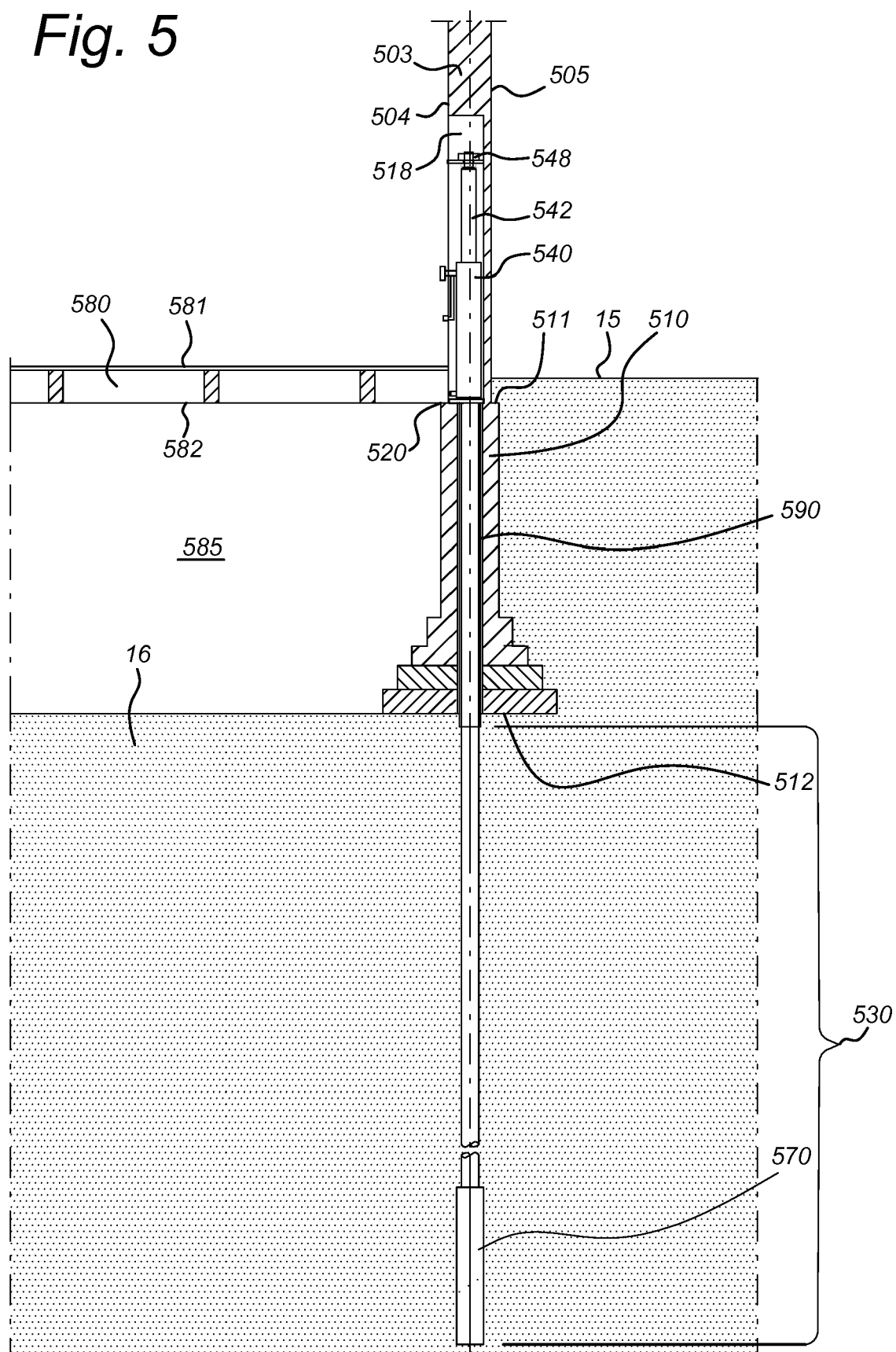


Fig. 5





EUROPEAN SEARCH REPORT

 Application Number
 EP 18 15 2354

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A	EP 0 441 172 A2 (ROEMER HELMUTH [DE]) 14 August 1991 (1991-08-14) * the whole document * -----	1-15	
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			E02D
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 17 May 2018	Examiner Friedrich, Albert
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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The members are as contained in the European Patent Office EDP file on
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17-05-2018

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