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(54) Apparatus and method for producing a high pressure grouted foundation pile

(57) This invention relates to device for constructing a foundation pile, the device comprising a driving for rotating and displacing a drill head (2) into the ground, the drill head (2) comprising at least one hole (4) for ejecting a liquid into the ground surrounding the drill head (2), the at least one hole (4) being connected to a supply for the liquid, the drill head (2) being connectable to a pipe (3), wherein the drill head (2) comprises at least one high pressure ejection nozzle (4) for ejecting a viscous, settable liquid into the ground surrounding the drill head to cut the ground, the pipe (3) having a hollow inner space connected to a high pressure device for supplying the viscous liquid at a pressure of at least 50 bar towards and through the inner space towards the at least one ejection nozzle (4).

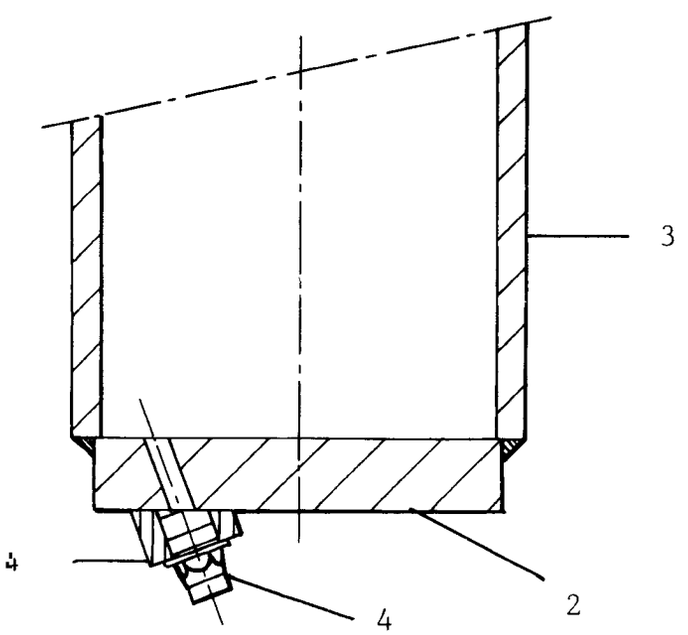

Fig. 5

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Description

[0001] The present invention relates to a device for constructing an foundation pile through jet-grouting as disclosed in the preamble of the first claim.

[0002] From DE-C-3828335 a drilling device is known comprising a threaded shaft to the front end of which a drill head is mounted. The drill head comprises three cutting elements mounted on a carrier for cutting the ground to be drilled and a hollow body which is mounted on the back side of the drill head and surrounds the shaft to provide a space around the shaft for removing drilled ground and rinsing liquid. The hollow body further functions to stabilise the channel wall in the vicinity of the drill head to prevent collapsing of the channel and rolling of the drill head. Rinsing liquid, for withdrawing drilled away ground and rock, is supplied towards at least one radial channel in the drill head through a shaft. The rinsing liquid forces the drilled ground to flow through a first hollow housing mounted behind the drill head around the shaft and a second hollow housing mounted around the shaft at a distance from the first housing. In sandy grounds, the hollow housing functions as a means to prevent collapsing of the channel wall and to condense the ground around the channel, so as to allow that a cement layer with a constant thickness can be build between the outer wall of the shaft and the channel wall. Cutting elements are mounted on the drill head to assist the drilling action.

[0003] The drilling device disclosed in DE-C-38 28 335 however has an important disadvantage in case of converging grounds. In converging grounds there is a risk that the in the course of the drilling operation which may take some time, at the position where the channel wall is not supported by the hollow body the channel wall starts converging. As this convergation can be hardly controlled, the support pile will have a varying diameter, which does not correspond to the intended diameter.

[0004] Another technique for constructing foundation piles or underground grout columns is the very high pressure grout technique in which a fluid (mostly cement grout) is injected into the ground at high pressure through a drill shaft with ejection nozzles for the fluid, to cut and loosen the ground in an area surrounding the drill shaft. The simultaneous rotation of the drill shaft and slow retraction of the shaft leads to a mixing of the ground surrounding the drill shaft with the fluid, the excess of ground and fluid being forced upwards along the space between the drill shaft and the cut ground. Reinforcing steel armatures are drilled into the grout mixture after the drill head has been retracted.

[0005] This technique has as a main disadvantage that the position of the reinforcing steel armatures can be hardly controlled as they are often inserted while the grout mixture is still fluid to a certain extent. In case the armature is located at the rim of the foundation pile in stead of in the middle thereof, there is an increased risk to the occurrence of corrosion as the armature is not protected by a surrounding hardened grout mixture.

[0006] It is the aim of the present invention to provide a device for the production of foundation piles with a controllable diameter.

[0007] This is achieved in the present invention with the technical features of the characterising part of the first claim.

[0008] The device of this invention comprises a driving for rotating the drill head and at least one pipe connected to the drill head and for holding the head and the at least one pipe. The drill head comprises at least one high pressure ejection nozzle for ejecting a viscous fluid, which may be hardened, into the ground surrounding the drill head at a pressure of at least 50 bar, for cutting ground in the vicinity of the drill head over a diameter which is approximately equal to or larger than the diameter of the drill head. The simultaneous rotation of the drill head and ejection of the fluid jets into the ground results in

(1) a loosening and cutting of the ground surrounding the drill head, as a consequence of which the drill head and the at least one pipe connected to it is moved into the ground, preferably in downward direction. Simultaneously the penetrability of the ground for the fluid is improved.

(2) an instant mixing of the loosened ground with the fluid mixture, so that simultaneously with the drilling of the required diameter, the material for forming the foundation pile is injected in the area around the reinforcement pipe.

(3) the speed with which the drill head is moved in downward direction can take place in a controlled manner, as the driving is also responsible for holding the drill head and the at least one pipe coupled to it.

[0009] As a result of the uncoupling of the driving for rotating the drill head and the high pressure device, with which the drill head is forced into the ground, the high pressure device may be located at a distance from the driving of the shaft part. As a result of this uncoupling also foundation piles may be constructed at locations where space is limited, which are not accessible to the high pressure device and would not be accessible to known driving devices for drill heads. Also, by using the high pressure device reinforced foundation piles with larger depths may be made, as well as reinforced foundation piles with larger diameters than could be achieved up to now with the device known from the art.

[0010] The at least one pipe which is coupled to the drill head and all subsequent pipes coupled thereto are left in the ground so that an improved positioning of the at least one reinforcement pipe within the foundation pile may be obtained thus minimising the risk to corrosion of parts of the pipe that are not surrounded by the grout mixture. Also the risk that a positioning of the reinforcement would not be possible because the grout mixture

has hardened too much at the time the reinforcement is introduced may be minimised. The uncoupling of the driving for rotating the drill head and the high pressure device furthermore makes it possible to reduce noise annoyance and vibrations of the ground to a minimum.

[0011] With the device of this invention, due to the presence of the high pressure fluid ejection nozzles, foundation piles may be constructed the diameter of which is larger than the diameter of the reinforcing pipe. As a consequence, the diameter of the drill shaft can be maintained rather small so that the couple needed to rotate the drill head can be kept small, thus limiting the dimensions of the device for rotating the drill head. Also due to the uncoupling, the production of foundation piles may be interrupted and extracted at any time, in a way that the soil in place is left almost undisturbed.

[0012] The pressure, and thus the flow rate, with which the fluid is ejected from the ejection nozzles is preferably adjustable to allow the diameter of the drilled ground part and thus the diameter of the foundation pile to be varied as required by the circumstances. This is of particular importance when constructing foundation piles the diameter of which is larger than the diameter of the drill shaft. Preferably this pressure is adjustable between approximately 50 bar and 450 bar if it is desired to make piles with large diameters. Existing techniques are limited to approximately 200 bar, which seriously limits the diameter of the foundation piles that may be constructed. The pressure will in general be adapted to the type of soil that needs to be cut and to the fluid flow rate to be delivered.

[0013] Preferably, the device for rotating the drill head is also provided for supplying additional pipes and coupling additional pipes to the last pipe that has been inserted into the soil. Thereto, preferably each pipe comprises an extremity for coupling to a subsequent pipe. The coupling of additional pipes, and driving of the additional pipes into the ground allows using pipes the length of which may be adapted to the circumstances pertaining at the yard. In case foundation piles need to be constructed in a space with a limited height, the height of the pipes can be limited accordingly by increasing the number of pipes connected to each other and inserted in the ground.

[0014] The drill head of the device of this invention has a top and a side wall. Along opposite sides of the side wall preferably cutting edges extend. The cutting edges preferably have the shape of a wedge with an inclined edge to improve cutting of the ground and facilitate evacuation of the cut ground and direction of the cut ground along the shaft.

[0015] The cutting edge preferably also extends over the top face of the drill head, high pressure ejection nozzles being located on both sides of the cutting edge. This positioning ensures an even distribution of the ejected fluid, assists in controlling the position and movement of the drill head, and allows to maintain inclination of the piles with respect to the device.

[0016] The invention also relates to a method for constructing an underground foundation pile, the method comprising the steps of

a) driving a drill head to which at least one pipe is coupled into the ground to a first depth h1, by rotating the drill head and the at least one pipe and by simultaneously supplying a viscous fluid which may be hardened through the pipe to the drill head, ejecting the fluid from the drill head at a pressure of at least 50 bar to cut an area of ground with a first diameter d1. Preferably the drill head and the at least one pipe coupled to it are held, to allow the velocity with which the drill head and pipe are moved into the ground, to be controlled.

b) as the drill head has reached depth h1, increasing the pressure to at least 200 bar, preferably at least 250 or even 270 bar, to cut an area of ground with a second diameter d2 > d1

c) evacuating the excess of drilled ground,

d) filling the shaft part with the viscous fluid and hardening the fluid to form a reinforced underground column.

[0017] In a preferred embodiment at least part of the evacuated ground is mixed with the viscous fluid and returned to the drill shaft and ejected from the drill head, if it is desired to produce a foundation pile the composition of which resembles as much as possible the composition of the surrounding soil. If so desired, it is also possible in a first stage to use water as the fluid for cutting the upper part of the ground, and to use the settable fluid only in a second stage. Usually an excess of fluid to be hardened is used, so that the water/ground mixture in the upper part of the pile will be replaced by the raising fluid/ground mixture produced as the drill head proceeds deeper in the ground.

[0018] The invention is further elucidated in the appending figures and description thereof.

[0019] Figure 1 shows in cross section the method of this invention.

[0020] Figure 2 is a top view to the drill head of the device of this invention.

[0021] Figure 3, 4 and 5 show the drill head of figure 2 in cross section, the cutting edge being omitted.

[0022] Figure 6 is a cross section of a foundation pile obtainable with the method of this invention.

[0023] The device of this invention can be described as a jet grouting device, which is a technique suitable for constructing deeper foundations than the existing ones, constructing horizontal or vertical sealing layers, constructing anchoring elements etc.

[0024] The device of this invention comprises a driving with which the drill head 2 is rotated and displaced into the ground. The driving is also responsible for supplying and coupling a pipe 3 to the drill head 2, and for supplying and coupling additional pipes 3. The driving is further responsible for holding the drill head 2 and the

pipes 3 coupled to it back, to allow the rate with which they are displaced in the ground to be controlled.

[0025] The device of this invention comprises a high pressure liquid supply for supplying a viscous fluid, preferably a fluid which hardens, at high pressure to the pipe 3 and from there to the drill head 2. As can be seen from figure 2-5, the drill head 2 comprises at least one hole or high pressure ejection nozzle 4 for ejecting the viscous fluid at high pressure into the ground. The device preferably comprises means for controlling the pressure with which the fluid is ejected to allow controlling the diameter of the ground into which the fluid is injected, and thus the diameter of the foundation pile that is constructed. The at least one hole 4 is connected to a supply for the fluid.

[0026] As can be seen from figure 2, a cutting edge extends over the top of the drill head 2 and along at least part of opposing sides of the side wall to facilitate loosening of the ground to be penetrated by the drill head 2. To ensure an even penetration of the fluid, to allow the advancing of the drill head 2 to be controlled in an improved manner and to counteract rolling of the drill head 2, the ejection nozzles 4 are mounted on both sides of the cutting edge.

[0027] The diameter of ground around the drill head which is influenced by the fluid leaving the ejection nozzles is determined by

- the pressure of the fluid when leaving the ejection nozzle
- the diameter of the fluid jet
- the residence time of the fluid jet as this determines to some extent the penetration of the ground by the jet and the cement content of the foundation pile
- the density and resistance of the ground into which the fluid is supposed to penetrate

[0028] With the device and method of this invention, foundation piles can be constructed with large diameters, which would be difficult with the known techniques. This can be done because the ground in which the foundation pile is to be constructed, is first loosened and cut by the fluid emerging from the ejection nozzles on the rotating drill. As higher pressures may be used than in the devices known from the art, larger diameters may be cut.

[0029] The drill head 2 is connected to a pipe 3. Each pipe 3 is preferably connected to a subsequent pipe 3 as is shown in figure 1a-1b. As the pipes are left in the drilled part, a reinforcement of the desired height may be created Each pipe 3 has a hollow inner space 8. The inner space 8 is connected to a high pressure device for supplying the viscous liquid at a pressure of at least 50 bar towards and through the inner space of the shaft towards the one ejection nozzle 6. As the pipes are left in the drilled part to form a reinforcement for the foundation pile, the positioning of the reinforcement within the column can be well controlled.

[0030] The fluid that is ejected from the ejection nozzle 4 is preferably a fluid which is capable of penetrating the soil into which the pile needs to be constructed and hardening. Suitable examples of viscous fluid are viscous mixtures of cement or mortar or any other fluid capable of hardening. It is however also possible to start the process with water as a fluid and to use the cement or mortar mixture only after a certain depth has been reached. As the excess of cut ground and viscous fluid will move to the surface, the water/ground mixture will automatically be replaced by the viscous fluid/ground mixture. Immediately surrounding the pipe with the settable fluid as it is advanced into the ground may be of special importance in case foundation piles with large depth have to be constructed in an area where the composition, constitution and quality of the ground varies with depth and some of the layers are weak. In that way foundation piles may be obtained the properties of which are independent of the constitution of the surrounding ground, so that a load that can be absorbed and supported by the column, in particular by the reinforcing interconnected shaft parts of the columns, is independent of the constitution of the ground. Because the shaft part has a hollow inner space, also the inner space can be filled with the viscous fluid.

[0031] The method of this invention is illustrated in figure 1a-1c and can be summarised as follows. The method of this invention comprises the steps of coupling a pipe 3 to the drill head 2 by means of the thereto provided device and rotating the drill head 2 to facilitate its displacement into the ground. Supplying the viscous fluid from the high pressure device to the rotating pipe 3 and drill head 2, ejecting the fluid at high pressure from the ejection nozzles 4 so that the ground surrounding the drill head 2 is cut by the jets and the drill head 2 and pipe 3 are moved into the ground. The pressure is adjusted so that an area with a desired diameter is cut by the fluid. Simultaneously the drill head 2 and pipe 3 are held back to prevent that they penetrate the ground with a too high velocity. As fluid is ejected, the ground surrounding the drill head is mixed with the fluid so that an intimate mixture of cement or mortar and ground is obtained. As soon as the first pipe 3 has been inserted in the ground to a predetermined depth, a second pipe 3 is supplied, the fluid supply is interrupted, the second pipe 3 is coupled to the end 6 of the first pipe and fluid supply is restarted. Additional pipes 3 are added in a similar manner until a pile of the desired depth is obtained. The soil/fluid mixture 9 is allowed to harden.

[0032] If so desired, the pressure with which the fluid is ejected from the ejection nozzles 4 may be varied with depth. In that way for example a pile can be constructed the top of which has a first diameter, the body of which has a second diameter smaller than the first, and the bottom of which has a third diameter larger than the second. Of course other possibilities exist.

Claims

1. A device for constructing a foundation pile (1), the device comprising a driving for rotating and displacing a drill head (2) into the ground, the drill head (2) comprising at least one hole (4) for ejecting a liquid into the ground surrounding the drill head (2), the at least one hole (4) being connected to a supply (5) for the liquid, the drill head (2) being connectable to a pipe (3), characterised in that the drill head (2) comprises at least one high pressure ejection nozzle (4) for ejecting a viscous, settable liquid into the ground (7) surrounding the drill head to cut the ground, the pipe (3) having a hollow inner space (8) connected to a high pressure device for supplying the viscous liquid at a pressure of at least 50 bar towards and through the inner space (8) towards the at least one ejection nozzle (4).

2. A device as claimed in claim 1, characterised in that the device comprises means for adjusting the pressure with which the fluid is ejected from the ejection nozzle (4).

3. A device as claimed in claim 1 or 2, characterised in that the device comprises means for holding the drill head (2) and pipe (3) and controlling the speed with which the drill head (2) is advanced in the ground.

4. A device as claimed in any one of claims 1-3, characterised in that the device comprises a supply for supplying additional pipes (3) and coupling an additional pipe to a previous one.

5. A device as claimed in any one of claims 1-4, characterised in that the drill head has a top and a side wall, cutting edges (6) extending along the side wall of the drill head, the cutting edges (6) being wedge shaped.

6. A device as claimed in claim 1 or 2, characterised in that each pipe (3) comprises an extremity which is connectable to a subsequent pipe.

7. A device as claimed in claim 5 or 6, characterised in that the drill head comprises three high pressure ejection nozzles, mounted on both sides of the cutting edge (6).

8. A device as claimed in any one of claims 2-7, characterised in that the high pressure device is provided for ejecting the fluid with a pressure of between approximately 50 and 450 bar.

9. A method for constructing a foundation pile, the method comprising the steps of rotating a drill head mounted onto a pipe, supplying a liquid to the drill head and ejecting the liquid from the drill head at a pressure of at least 50 bar to cut the ground over a first diameter d1 until a first depth h1 has been reached, the diameter d1 being larger than the diameter of the shaft part, after the first depth has been reached changing the pressure to at least 250 bar to cut the ground over a second diameter d2 > d1 to a second depth h2, evacuating at least part of the drilled ground, hardening the fluid to form the reinforced underground column.

10. A method as claimed in claim 9, characterised in that as a fluid use is made of a water/mortar or a water/cement mixture.

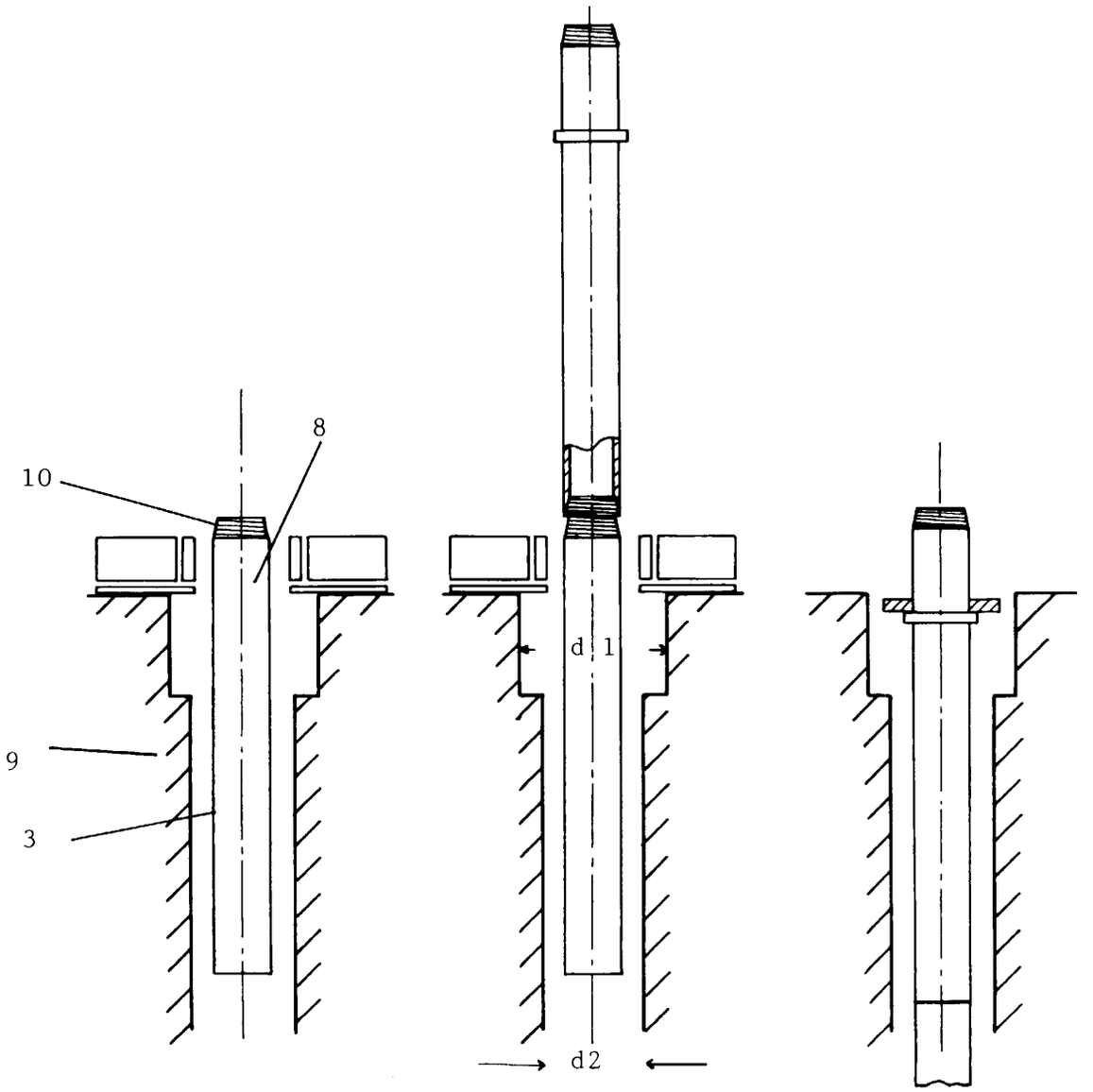
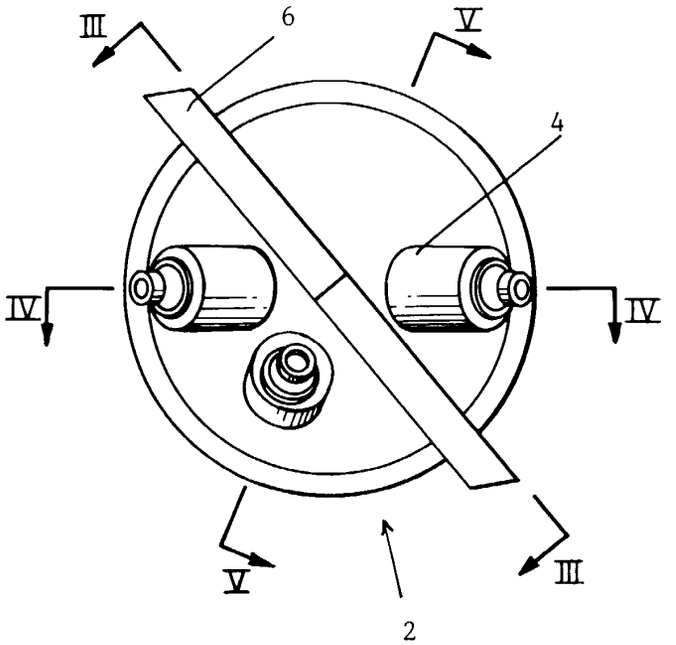


Fig. 1a Fig. 1b Fig. 1c

Fig. 2



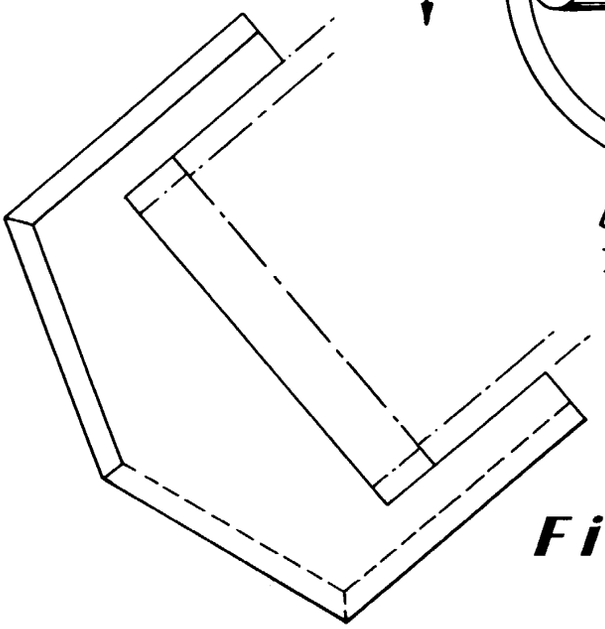


Fig. 3

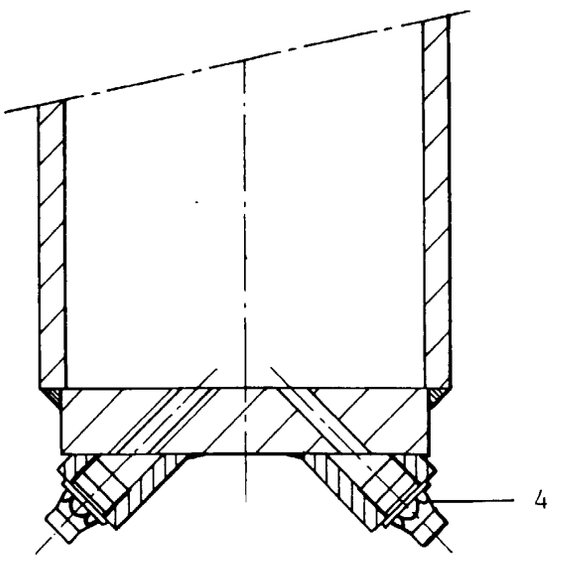


Fig. 4

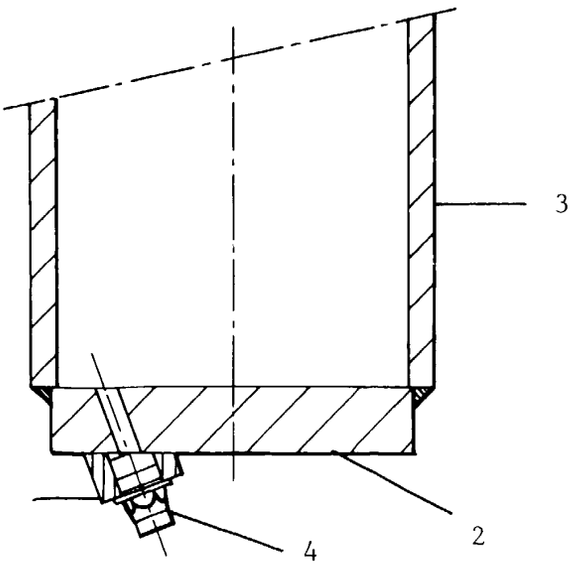


Fig. 5

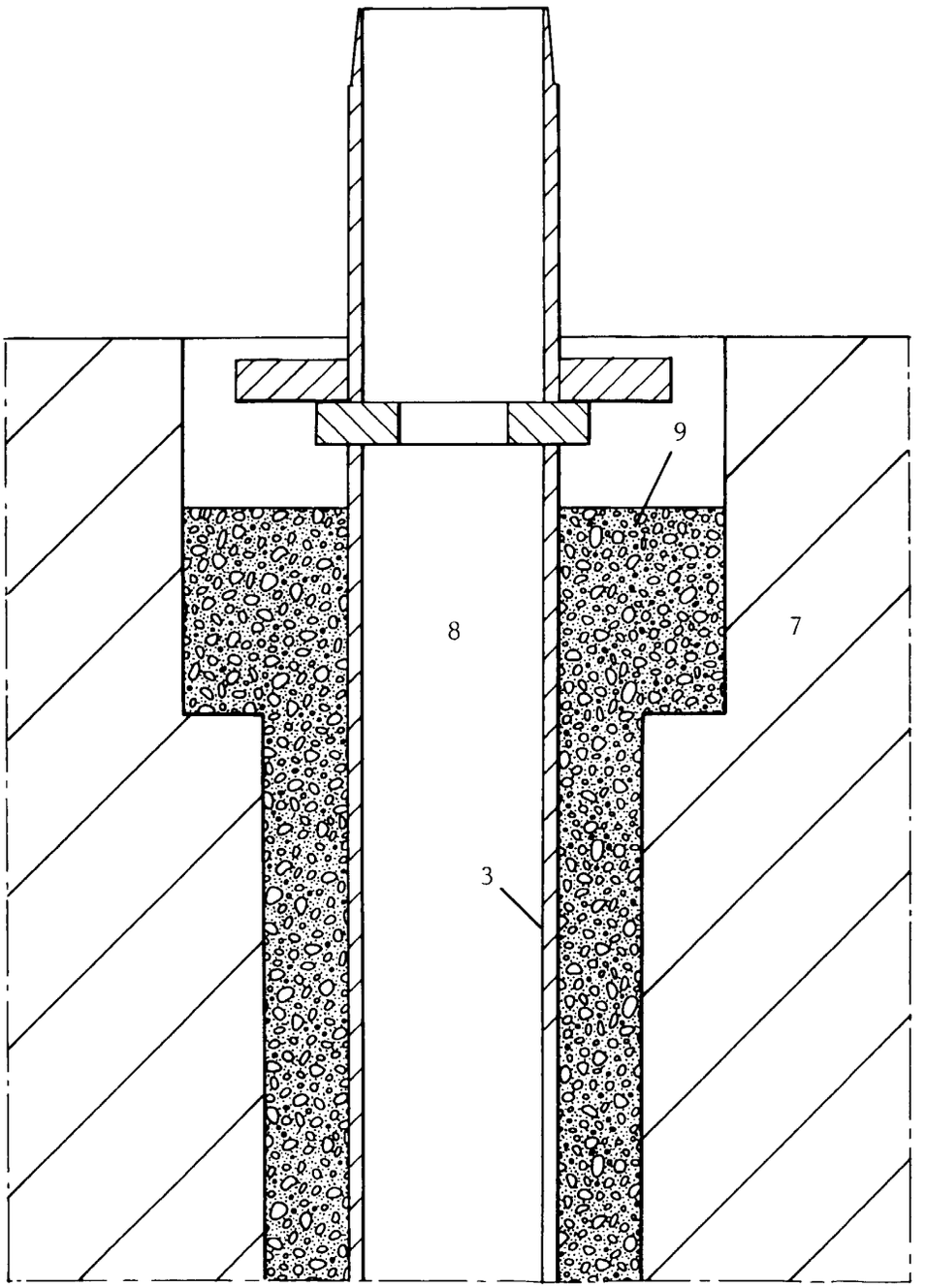


Fig. 6