(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 2 319 992 A2

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
11.05.2011 Bulletin 2011/19

(51) Int Cl.:
E02D 7/26 *(2006.01)* ***E02D 7/28*** *(2006.01)*

(21) Application number: **11155948.0**

(22) Date of filing: **04.04.2003**

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IT LI LU MC NL PT RO SE SI SK TR

(30) Priority: **04.04.2002 NL 1020304**
24.07.2002 NL 1021143

(62) Document number(s) of the earlier application(s) in accordance with Art. 76 EPC:
03723499.4 / 1 497 503

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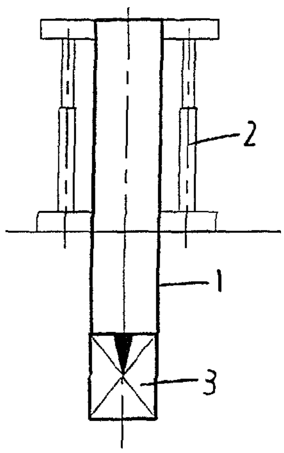
Remarks:
This application was filed on 25-02-2011 as a divisional application to the application mentioned under INID code 62.

(54) Method and system for placing at least one foundation element in the ground

(57) Method for forming at least one foundation pile or deep wall in the ground, comprising the step of sinking one or more hollow foundation elements (1) into the ground with a substantially vertical orientation. The sinking of the foundation element (1) into the ground takes place during driving of a removable drilling head (3), which drilling head (3), during the sinking of the foundation element (1), extends at least partially below a bottom part of the foundation element (1), by means of excavating members, which can rotate with respect to the foundation element (1) and have radial dimensions which in particular are greater than or equal to external dimensions of the foundation element (1), in which the excavation members, at the same time as the foundation element (1) is being sunk, drills out earth beneath the said bottom part of the foundation element (1), and in which at least the drilling head (3), after the foundation element (1) has been sunk, is removed again from the ground.

Fig. 2



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Description

[0001] The invention relates to a method for forming at least one foundation element in the ground in accordance with the preamble of claim 1.

[0002] A number of variants for positioning a foundation pile or deep wall of this type are known from the prior art. For example, it is known to drive foundation piles or deep wall elements into the ground using a pile-driver or to vibrate them into the ground using a vibrating machine. The deep walls to be put in place generally lie below the groundwater level, in which case they have to be substantially impervious to groundwater.

[0003] One drawback in this respect is that the pile-driver or vibrating machines take up a large amount of space and cause high levels of noise pollution during operation. Moreover, high forces occur and are transmitted via the earth to at least the immediate vicinity, which may cause damage to, for example, buildings or other existing structures.

[0004] One of the more recent developments involves using a rotary movement to twist pipes composed of hollow pipe segments into the ground. In this case, a first pipe segment is twisted into the ground, after which a following segment is welded to it, and then the two segments are twisted further into the ground, etc. Grout bodies have to be injected between adjacent pipes in order to obtain a substantially watertight deep wall.

[0005] A drawback of this arrangement is that it is necessary to overcome considerable forces to enable the pipes to be twisted into the ground. In this case, in particular, insurmountable problems may arise if great depths have to be covered. The machine required to do this is expensive to produce and also expensive to use. The fitting of the grout bodies between the tubes is complex, and, depending on the soil composition, relatively unpredictable and unreliable, with the result that it is difficult to ensure that the arrangement will be impervious to groundwater.

[0006] It is an object of the present invention to at least partially overcome the abovementioned drawbacks and/or to provide a usable alternative. In particular, it is an object of the invention to provide a relatively inexpensive, environmentally-friendly, safe and reliable method and system for positioning a foundation element which takes up only a small amount of machinery space and can be used at any desired location without damaging the immediate vicinity.

[0007] This object is achieved by a method according to claim 1. According to the method, a hollow foundation element is introduced into the ground in a substantially upright position. At the same time as it is being introduced into the ground, a removable drilling head is active beneath the bottom part of the foundation element. The drilling head drills out the earth which the foundation element would otherwise come into contact with while it is being sunk into the ground. For this purpose, the drilling head is provided with at least one excavating member which can rotate about a drive shaft of the drilling head and has radial dimensions which in particular are greater than or equal to the external dimensions of the foundation element. The earth which has been drilled out can then be discharged to outside the foundation element in a suitable way. It has been found that the foundation element can therefore be introduced into the ground relatively easily and that considerable penetration depths of more than 66 metres can be achieved without a heavy press installation, pile-driving device, vibratory unit or the like being required directly for that purpose. The method can advantageously be used at working locations where only a low working height is available. The minimum working space height required is in this case substantially determined by the length of the foundation elements to be introduced. In this context, it is advantageously possible to use a plurality of segments which can be joined to one another and together serve to form one foundation element and which, by way of example, are in each case welded to one another.

[0008] In a first, more particular preferred embodiment, the progress of introducing the foundation element into the ground is monitored and, in the event of a deviation from the intended direction of introduction of the foundation element being observed, the position of the drive shaft with excavating member is adjusted accordingly with respect to the bottom part of the foundation element. The adjustment may involve displacement of the drive shaft with excavating member in the horizontal plane and/or tilting of the drive shaft with excavating member with respect to the vertical. The new position leads to the excavating member starting to dig out more earth on one side and less earth on the other side beneath the bottom part of the foundation element. As a result, the foundation element is subject to less resistance on one side and more resistance on the other side as it penetrates into the earth, and will begin to straighten itself out. This possibility of controlling the drilling head advantageously allows the intended direction of introduction to be monitored in a reliable way and adjusted if desired.

[0009] This form of control works well in particular in combination with a foundation element of which the bottom part is provided with a tapering peripheral wall part. Moreover, the tapering peripheral wall part reduces the initial resistance to penetration by the foundation element.

[0010] In a second, more particular preferred embodiment, during the introduction into the ground, a downward force is exerted on the foundation element with the aid of a press installation. The press installation is in this case of the hydraulic type which comprises a frame which is supported on the ground next to the foundation element. The frame can be anchored to the ground by means of anchoring elements, for example threaded anchors, but may also be held against the ground with the aid of counterweights. As a result, the foundation element can be pressed uniformly into the ground, with simultaneous driving of the drilling head, by means of a relatively light press installation, without the surrounding area being adversely affected. The press installation may advantageously be designed with a limited overall height, in particular a height of less than 3 metres, and generates little noise and is free of vibrations. Moreover, it is safe for workers on the construction site.

[0011] The required introduction force can be reduced further by filling the cavity in the foundation element with liquid while it is being introduced into the ground.

[0012] The press installation is provided with engagement means which can be moved up and down by hydraulic means with respect to the frame. The engagement means are preferably also laterally adjustable. This makes it possible to adjust the direction in which the foundation element is introduced slightly if desired. This is important in particular when the bottom part of the foundation element starts to be introduced into the ground, since the above-described adjustment with the aid of the drilling head is at that stage not yet fully functional.

[0013] In a more particular, third preferred embodiment, earth which is drilled out by the excavating member passes via introduction openings into a flushing chamber which is delimited by housing walls of the drilling head and is located above the excavating member. The earth which has been drilled out is in this case forced continuously into the flushing chamber via the introduction openings by the excavating member and the drilling head which moves downwards together with the foundation element. A stream of liquid supplied via a feed line is passed through the flushing chamber. In this way, the earth which has been released can mix with the flushing liquid in the flushing chamber and can easily be discharged via a discharge line. In this case, it is possible for the flushing liquid together with the earth which has been drilled out to be discharged via a suitable system of lines to well away from the immediate working location, for example to a sludge repository. Making use of a flushing chamber of this type has demonstrated that water, for example water from a lake or river in the vicinity, without further additives for increasing the viscosity, can be used very effectively as a flushing liquid. Furthermore, it is advantageous that the discharge of the earth which has been drilled out does not have to lead to contamination of the remainder of the drilling head, of the cavity in the foundation element and of the working area above the ground.

[0014] The pressure of the flushing liquid fed into the flushing chamber is preferably set to a slight excess pressure with respect to a prevailing groundwater pressure in the surrounding ground. In particular, the excess pressure is in this case approximately 0.1-0.3 bar. This excess pressure ensures that the ground can be discharged in a controlled manner at the location of the excavating member. This reduces the risk of undesirable disturbances to the surrounding ground, and therefore also the risk of erosion and subsidence. The rate at which the earth mixture is discharged can be accurately matched to the desired penetration rate as a result of the use of the flushing chamber with a slight excess pressure.

[0015] The introduction openings are advantageously provided in a base plate which delimits the flushing chamber on the underside and is fixed to the housing in such a manner that it can move up and down in a controllable manner in the drilling head. If a fault is detected which is related to an accumulation of pieces of earth which are too large for the introduction openings, this fault can be overcome by, as it were, breaking up the pieces of earth between the base plate and excavating member by means of the base plate being moved downwards with a certain force.

[0016] In a more particular, fourth preferred embodiment, the drilling head is designed in such a manner that the excavating member can be retracted with respect to the drive shaft substantially in a plane which is perpendicular to the direction of introduction, into an at-rest position, in which the maximum dimension of the entire drilling head is then smaller than internal dimensions of the cavity in the foundation element. The direction of movement of the excavating member in the plane which is substantially perpendicular to the drilling direction advantageously ensures that the drilling head can be used immediately as soon as the excavating member emerges beneath the foundation element. This also allows improved control of the drilling head. After the foundation element has been sunk or in the event of problems in the meantime, the drilling head can then be retracted upwards through the cavity. As a result, the drilling head is not lost and can in each case be re-used and/or repaired. It is also possible for the drilling head to be temporarily retracted in order for impenetrable obstacles which it may encounter to be removed by other means before drilling is then recommenced.

[0017] In a variant, the excavating member is provided with a part which can be folded down. This fold-down part preferably extends from the free end of the excavating member to just inside the internal dimensions of the cavity in the foundation element. The fold-down part can then be folded out during the first revolution of the excavating member about the drive shaft and/or folded in prior to or during the retraction of the drilling head in the upwards direction through the foundation element.

[0018] At the same time as the drilling head is being drawn upwards, it is possible for a settable material to be injected into the foundation element. In this way, a strong, robust foundation pile, which is surrounded by the foundation element is formed. It is also possible for the drilling head and the foundation element which has been sunk to depth to be removed into the upwards direction substantially together, while, at the same time, a settable material is being injected into the cavity left behind. In this case too, a reliable, robust foundation pile is advantageously formed. After the material has set, this pile then consists exclusively of set injected material. It is then possible to re-use not just the drilling head but also the foundation element itself.

[0019] In another variant, the foundation element is left in the ground and, after the drilling head has been removed, is at least partially filled with foundation material. If necessary, the foundation element can be filled with liquid, for example a bentonite-containing liquid, in an intermediate step. This prevents the foundation element from undesirably filling up with earth or contaminated groundwater. The foundation material used can then once again be a settable material, but also, for example, a foundation material which is tipped in as a loose material, such as earth or rocks. In the event of the foundation element being partially filled with rocks, it has proven advantageous for the foundation element to be provided, at least in its bottom wall part, with a profile, such as ribs.

[0020] The abovementioned method makes it possible to form both free-standing foundation piles and deep walls (bored pile walls) which comprise a plurality of foundation elements which have been formed in accordance with the invention.

[0021] When the deep walls are being used, the foundation elements can be fitted such that they adjoin one another and also such that a space is left between them, in which, for example, sealing bodies can be arranged. The sealing bodies can then be forced into the ground using the same press installation.

[0022] Drilling has not proven necessary for this operation.

[0023] In particular, the tubes are provided on the outer side with connecting pieces which extend in the longitudinal direction. It is then possible for the sealing bodies, such as sheet pile planks, to be arranged between the connecting pieces. The result is a combination deep wall, comprising hollow foundation elements and sheet pile planks with reliable properties such as water tightness and strength. The provision of a connecting piece on the outer side of the foundation element is advantageously possible through the fact that the foundation element is introduced into the ground in a substantially upright position without having to be rotated about its longitudinal axis. After all, in the event of rotation, a connecting piece of this type would present considerable additional resistance. The sheet pile planks can be coupled to the foundation elements in segments which can be connected to one another.

[0024] More particularly, the foundation elements are in this case provided with a profiled connecting piece which is designed to engage on a profiled edge part of the sealing body by means of a sliding movement in the abovementioned longitudinal direction.

[0025] Further preferred embodiments of the invention are defined in the subclaims.

[0026] The invention also relates to a system for using the method according to one of claims 17-43 and to a drilling head according to claim 44 and to a foundation pile according to claim 45 and to a deep wall according to claim 46.

[0027] The invention will be explained in more detail with reference to the appended drawing, in which:

Fig. 1-4 diagrammatically depict successive method steps in accordance with the invention;

Fig. 5 shows a cross-sectional view on line V-V in Fig. 4;

Fig. 6 shows a view, on an enlarged scale, of details X, Y and Z from Fig. 5;

Fig. 7 shows a cross-sectional view through an embodiment of a drilling head which is positioned in a segment of a foundation element;

Fig. 8 shows a view from below of Fig. 7 with excavating members positioned in a drilling position;

Fig. 9 shows a view corresponding to that shown in Fig. 8, with excavating members positioned in an at-rest position;

Fig. 10 shows a diagrammatic cross-sectional view through a system with an anchored press installation;

Fig. 11 shows a transverse sectional view of Fig. 10;

Fig. 12 shows a view corresponding to that shown in Fig. 10 during the placing of the foundation element;

Fig. 13 shows a view corresponding to Fig. 10 during the retraction of the drilling head;

Fig. 14 shows a view corresponding to that shown in Fig. 10 with a plurality of foundation piles formed next to one another;

Fig. 15a-f shows six steps involved in forming a deep wall with overlapping piles;

Fig 16 shows a cross section through a variant of a deep wall which has been formed;

Fig. 17 shows a perspective view of a variant of a drilling head positioned in a bottom part of a foundation element;

Fig. 18 shows a view corresponding to that shown in Fig. 17, seen more from above;

Fig. 19 shows a diagrammatic longitudinal section through Fig. 17 with laterally adjusted excavating members;

Fig. 20 shows a view of Fig. 19 from below;

Fig. 21 shows a diagrammatic longitudinal section view of a further variant; and

Fig. 22 shows a cross section on line XXII-XXII in Fig. 21.

[0028] It can be seen from Fig. 1 how a hollow tube 1 has been positioned in a hydraulic press device 2 and is ready to be forced into the ground as a foundation element. A drilling head 3 is arranged in a bottom part of the tube 1. The drilling head 3 has an external diameter which is less than or equal to the internal diameter of the tube 1. During operation, the hydraulic press device 2 and the drilling head 3 are driven simultaneously, i.e. the drilling head 3 drills out earth which the front part of the tube 1 meets at the same time as the tube 1 is advancing (Fig. 2). The drilling head 3 is equipped with a flushing section. During the drilling, the earth which has been drilled out is discharged by means of a flow of water which is passed through the flushing section. The flow of water is in this case controlled in such a manner that there is never too much earth discharged. The flow of water together with the earth which is released is tipped into a sludge repository at a distance from the working location.

[0029] The drilling head 3 is advantageously provided with a control system making it possible to correct any deviations in the penetration direction during drilling.

[0030] After the tube 1 has been sunk (Fig. 3), the drilling head 3 is retracted upwards through the tube 1. Before the drilling head 3 is retracted, the tube 1 can be filled with water, so that it is impossible for any earth to enter from the underside. After the drilling head 3 has been retracted, the tubes 1 can be filled with earth, concrete or the like.

[0031] An injection line is advantageously carried along during the operation of forcing the tube into the ground. The injection line can be used to add lubricant around the tube 1 in order to further reduce the friction. The lubricant may, for example, comprise bentonite lubrication. The lubrication can also be used to make it possible to carry out corrections to the penetration direction of the tube 1.

[0032] After a number of tubes 1 have been put in place, a sheet pile plank 4 is pressed between the tubes 1 (Fig. 4). The same press device 2 can be used for this purpose. Suitably profiled connecting pieces 6 have been welded, bolted or connected in some other way to the tubes 1 beforehand to match the sheet pile planks 4 (Fig. 6), and longitudinal edges 7 with a complementary profile of the sheet pile planks 4 can be pushed into these connecting pieces.

[0033] After the sheet pile planks 4 have been sunk, the abovementioned injection pipes can be used to deliver a settable material, for example a grout mixture. As a result of a material of this type being pressed in from the underside of the tubes 1, firstly the tubes 1 are bonded to the earth and secondly the connecting pieces 6 and the longitudinal edges 7 of the sheet pile planks 4 are also provided with a cladding. This cladding enhances the water barrier function.

[0034] To enable further absorption of compressive forces on the deep wall, it is also possible to fit tie rod anchors. The tie rod anchors are advantageously formed by threaded injection anchors. The tie rod anchors can be positioned, for example, from the space inside the hollow tubes 1.

[0035] If the tubes 1 are to extend over great depths and/or if it is necessary to work from a working space with a limited working height available, it is advantageously possible to select to use tube segments which can be connected to one another. In each case after a tube segment has been sunk into the ground using the internal drilling, a subsequent tube segment is attached to the top of it, for example by welding. The combined pressing and drilling process can then be continued until this tube segment too has been sunk. In this case, it is advantageously possible to alternate between two tubes. Components of the installation which are not in use while a new tube segment is being connected to a first tube, for example a drive unit for the drilling head, can then be transferred to another tube and drive the drilling head located there during the pressing operation. In this way, various components can be utilized efficiently, and in particular the time required to join the tube segments to one another is optimally utilized.

[0036] The method is suitable in particular for placing tubes with a relatively large cross section, in particular larger than one and a half metres, in the ground. The tube is composed in particular of tube segments with a height of approximately two metres.

[0037] Before the tube or a first tube segment of the tube is pressed into the ground, it is preferable first of all for a housing of approximately one metre to be pressed into the ground. This housing is used to prevent material from being flushed out during the initial part of the drilling and pressing process.

[0038] In Fig. 7, a drilling head 9 comprises a rotatable excavator wheel with adjustable excavating members 10. Above the excavator wheel there is a flushing chamber 11 with rock crusher. The flushing chamber 11 is connected to flushing lines 13. Furthermore, the drilling head 9 comprises a hydraulic drive 12 for rotating the excavator wheel during introduction of a tube segment 14. Controllable clamping means 15 with seals 16 which engage in a sealing manner with the inner peripheral wall of the tube segment 14 are provided along the peripheral wall of the drilling head 9. With the aid of control cylinders 17, the drilling head 9 can be accurately oriented with respect to the tube segment 14 during the introduction operation. With this, a part of the drilling head 9 in which the excavator wheel with excavating members 10 and a drive shaft of the excavator wheel are mounted tilts.

[0039] A downwardly tapering peripheral wall part 18, which merges into a cylindrical part 19, is provided on the outer peripheral wall of the tube segment 14. The cylindrical part 19 forms an overlap with respect to that part of the outer peripheral wall of the tube segment 14 which is located above it. The overlap has the advantage that during the advancing movement space is left clear behind it. This space can advantageously be used for the abovementioned supply of lubricant along the outer peripheral wall of the foundation element. For this purpose, the overlap is preferably a few centimetres. The space can also be used to supply a particularly slow-setting material which, after it has set, bonds the earth to the foundation element. In the case of a combination, in a first phase of penetration a lubricant is supplied, and in a second phase, after the foundation element starts to approach or has reached its final depth, this lubricant is expelled by the settable material, in particular cement.

[0040] The excavating members 10 can be displaced in the radial direction between a drilling position (Figs. 7 and 8) and an at-rest position (Fig. 9). In the drilling position, the excavating members 10 extend beyond the outer peripheral wall of the tube segment 14. In the at-rest position, the drilling head 9 as a whole has a cross-sectional dimension which is smaller than the inner peripheral wall of the tube segment 14.

[0041] In Figs. 10 and 11, the drilling head 9, together with the first tube segment 14 from Fig. 7 are positioned beneath a press installation 20. The press installation 20 comprises a frame which is anchored to the ground 22 by anchors 21. The installation 20 comprises a hydraulic press section 24 which is designed to engage on the tube segment 14 and to press it downwards into the ground 22 with the excavator wheel of the drilling head 9 being driven.

[0042] Fig. 12 shows a number of steps further in the drilling introduction of the tube, in which a plurality of tube segments 14, which are connected to one another, have already been pressed into the ground with, at the same time, the earth located beneath the front part of the tube segment 14 which was introduced first being drilled out at the same time. This procedure can be continued until a desired depth has been reached. The press section 24 is in this case in a raised position, so that a new tube segment can be placed beneath it.

[0043] Fig. 13 shows a tube which has been sunk and in which the drilling head 9 is being removed upwards through the interior of the tube. The tube which is being introduced in this way can already form a foundation pile. It is preferable for the tube to be at least partially filled with foundation material, in particular settable material.

[0044] Fig. 14 shows the situation in which a plurality of filled foundation piles 26 of this type have been formed next to one another beneath the press installation 20. It is clearly apparent that the press section 24 can be displaced sideways along the frame, so that the plurality of piles 26 can be formed in succession without the installation 20 having to be moved along every time.

[0045] As a result of the piles adjoining one another, it is advantageously possible to form a deep wall. They can be made to adjoin one another with separate sealing elements positioned between them, as in Fig. 1-6, but it is also possible to have the piles adjoining one another with a slight overlap. Fig. 15a-f show a preferred method for forming a deep wall in this way. First of all, tubes 30 are introduced into the ground at positions 1, 2 and 3 (Fig. 15a). Then, with simultaneous injection of settable material 31 into the tubular cavity which has been released, they are pulled back out of the ground together with the used drilling head (Fig. 15b). Reinforcing bars 32 are arranged in the as yet unset material 31 (Fig. 15c). Then, tubes 34 are introduced into the ground at the intervening positions 4, 5 and 6. During the introduction, the drilling head drills out a small proportion of the piles 35 which have been formed previously (Fig. 15d). The tubes 34 are then also, with simultaneous injection of settable material 36 into the tubular cavity released, pulled back out of the ground together with the used drilling head (Fig. 15e). Reinforcing bars 37 are placed in the as yet unset material 36 (Fig. 15f). This forms a very strong deep wall, of which the piles which have been formed in accordance with the invention adjoin one another in a reliably watertight and successful way. The material 36 can bond to the previously injected material 31 very well during the injection, while the reinforcing bars 32, 37 contribute to the rigidity and strength of the deep wall.

[0046] Fig. 16 shows a deep wall of which the tubes 40 are arranged in a zigzag shape. This contributes to a further reinforcement of the deep wall and can advantageously be produced using the method according to the invention.

[0047] Fig. 17-20 show a variant of a bottom part or segment of a tubular foundation element 50. This includes upper and lower positioning lugs 51 as well as a clamping wall part 52 which is set back inwards. The outer peripheral wall comprises a downwardly tapering peripheral wall part 53 which at the top merges into a cylindrical wall part 54 with a thickness which is greater than that of the part of the outer peripheral wall of the foundation element 50 which is located above it.

[0048] A drilling head 55 has been lowered into the inside of the foundation element 50. In the process, the drilling head 55 is automatically centred between the positioning lugs 51. An upper edge 56 of the clamping wall part 52 is in this case used as a stop edge for delimiting the drilling head 55 downwardly.

[0049] The drilling head 55 comprises controllable clamping means 60 which clamp securely on to the clamping wall part 52. In this case, the clamping means 60 are formed by inflatable strips. These have the advantage of simultaneously clamping and forming a seal. Connection nozzles 61 for the clamping means 60, which are intended to be connected to pneumatic or hydraulic control lines are provided in the drilling head 55.

[0050] In the drilling head 55 there is a plate 62 which is fixedly connected to an outer peripheral wall 63 of the drilling head 55. Above this plate 62 there is a mounting flange 64 on which a drive 65 is mounted for driving an excavator wheel with excavating members 71 which is mounted on a drive shaft 70 (the excavator wheel with excavating members is only shown in Figs. 19 and 20). The drive 65 is in this case formed by a plurality of hydraulic motors which engage on the drive shaft 70 by means of planetary gear mechanisms. The hydraulic motors have the advantage of taking up little space and being able to supply a high power while not being sensitive to dirt and moisture. The hydraulic motors are provided on their top sides with openings which are intended to be connected to hydraulic supply lines. A plurality of control members 74 are distributed over the periphery between the plate 62 and the mounting flange 64 and are in this case formed by actuable cylinders. The control members 74 are provided with connection nozzles to be connected to pneumatic or hydraulic control lines and are designed to adjust the position of the drive shaft 70 with respect to the tapering peripheral wall part 53 of the foundation element 50 in the plane which is perpendicular to the drive shaft 70. Figs. 19 and 20 show a position in which the drive shaft 70 with drive members 71 has been displaced a few centimetres to the left from the centre. As a result, the penetration direction of the bottom part of the foundation element 50 will turn slightly to the right during further movement.

[0051] The control members 74 may be actuated manually or in automated fashion; it is preferable to use measuring means to determine the direction of advance of the foundation element 50. The measuring means may be provided in or on the drilling head and/or may interact therewith and are formed, for example, by inclinometers in the drilling head or a laser beam which interacts with a sight or a plumb-line whose position is determined. The plumb-line may advantageously also serve as a proximity sensor and/or a velocity-measuring device.

[0052] Beneath the plate 62 there is a base plate 78 which is provided with a large number of introduction openings 79. A flushing chamber 80 is delimited between the two plates 62, 78. A feed line 81 for supplying a flushing liquid under a slight excess pressure and a discharge line 82 are connected to the flushing chamber 80. While earth is being drilled out by the excavating members 71 and, at the same time, the drilling head 55 is advancing downwards into the ground together with the foundation element 50, the earth which is drilled out is automatically forced into the flushing chamber 80 via the introduction openings 79. There, the earth mixes with the flushing liquid, and this mixture is guided up out of the foundation element 50 via the discharge line 82. The flushing liquid enters the flushing chamber 80 via the feed line 81, comes into contact with the base plate 78 and then sprays up on all sides. The turbulence which results advantageously ensures intimate mixing of the flushing liquid and the earth.

[0053] The introduction openings 79 are preferably designed in such a manner that they widen towards the top. As a result, earth which enters the introduction openings will relief by the time it enters the flushing chamber 80.

[0054] A plurality of displacement members 84, which in this case are formed by actuable cylinders, are provided distributed over the periphery between the plate 62 and the base plate 78. The displacement members 84 are provided with connection nozzles for connection to pneumatic or hydraulic control lines and are designed to be able to move the base plate 78 up and down in the axial direction in the direction of the excavating members 71. In this way, it is possible to execute a type of crushing movement if a blockage occurs between the excavating members 71 and the base plate 78.

[0055] It is possible to switch the feed and discharge lines in terms of their functions in order to flush blockages out of the flushing chamber 80. This switching may advantageously take place above ground outside the foundation element 50. Furthermore, a bypass 90, in which there is an actuable valve, is also provided between the feed line 81 and the discharge line 82. Actuable valves are also accommodated in the feed and discharge lines 81, 82. The lines can be flushed efficiently by actuating these valves in a suitable way.

[0056] Fig. 21 and 22 show another variant, in which a bottom part of a foundation element is composed of a section 100 which is, or can be, fixedly connected to the other part of the foundation element and a section 101 which is movably connected to this section 100. In this case, the section 101 is connected to the section 100, which is of slightly smaller dimensions, by means of chains 102, and the section 101 is of double-walled design. In the sections there is secured a drilling head, of which excavating members 106, which are mounted on a excavator wheel in such a manner that they can be folded over, project beneath the section 101. The drilling head comprises an upper part 107, which is pivotably connected, in a manner which can be controlled by means of control members 108, to a lower part 109. The drilling head part 107 is in this case accommodated in a sealing manner in the section 100 while the drilling head part 109 is accommodated in the section 101. This creates a control option by suitable actuation of the control members 108. The position of the drilling head part 109 with a drive shaft with the excavator wheel and the excavating members 106 inside it can be adjusted with respect to the drilling head part 107 and as a result with respect to the section 100 of the foundation element. During further drilling introduction, the section 100 will, as it were, be pulled along behind the adjusted section 101.

[0057] The drilling head part 109 in this case comprises an electric drive 110 for driving the excavator wheel with excavating members 106. A flushing chamber 112, in which a flushing line 113 opens out, is diagrammatically indicated above the excavator wheel with excavating members 106. Furthermore, there is a direction indicator with a camera 115 directed at it, the direction indicator acting between the two drilling head parts 107, 109. To provide improved visibility, lighting may be provided in the drilling head. An injection line 116 for supplying filling medium, lubricant and/or foundation material is mounted on the outer side of the drilling head.

[0058] The drilling head part 107 may extend to above the ground and if desired may in each case be lengthened at the same time as the foundation element. In this way, the inner side of the drilling head can be kept dry, which is important in particular for the drive and the measuring means. During operation, liquid can be placed between the drilling head part 107 and the section 100, in order to offer a counterpressure to the groundwater pressure.

[0059] In addition to the embodiments described above, numerous variants are possible and/or it is possible to produce combinations between the embodiments. In addition to tubular foundation elements it is also possible to introduce other forms of foundation elements provided with a cavity. The foundation elements may also comprise two or more longitudinal parts which adjoin one another. This has the advantage that these longitudinal parts can each be placed around the feed and control lines without the latter having to be uncoupled. As an alternative to sheet pile planks, it is also possible for complete bodies made from a settable material, for example a grout material, to be fitted between the foundation elements by means of injection. As an alternative to being welded to one another, the segments may also be coupled to one another in other ways. It is also possible for the foundation elements themselves to be provided with suitably profiled shaped connecting pieces which are designed to be received slideably in complementary connecting pieces on foundation elements which have already been put in place. As an alternative to a separate base plate, the flushing chamber may also be delimited on the underside by a excavator wheel provided with introduction openings and/or by the rotating excavating members themselves.

[0060] During introduction of a foundation element, the majority of the drilling head is preferably located inside the bottom part of the foundation element. It is preferable for only part of the drive shaft and the excavating members to be located beneath the foundation element. Since the drilling head can be clamped securely into the foundation element and is provided with its own drive unit, the drilling head can advantageously be kept very compact, in particular with a height of less than approximately two metres. The compact drilling head merely has to be powered and/or actuated via preferably flexible lines. This ensures that the drilling head can be removed again from a foundation element which has been put in place even in small working spaces with a limited available height. Furthermore, the drilling head is provided with significant protection against damage from the outside, and accurate positioning and control are possible without having to use rigid connecting and drive means which have to extend above ground.

[0061] Therefore, the invention creates an efficient and reliable method and a system for carrying out a method of this type which can highly advantageously be used for difficult projects, for example in the vicinity of fragile constructions, such as a building of historic value, or from limited working spaces, for example from an existing tunnel below the ground, in which case the possibility of counteracting the prevailing water pressure counts as an additional benefit.

[0062] The present invention also relates to one or more of the following clauses:

1. Method for forming at least one foundation pile or deep wall in the ground, comprising the step of sinking one or more hollow foundation elements (50) into the ground with a substantially vertical orientation, <u>characterized in that</u> the sinking of the hollow foundation element (50) into the ground takes place during driving of a removable drilling head (55), which drilling head (55), during the sinking of the foundation element (50), is in a drilling position in which the drilling head (55) extends at least partially below a bottom part of the foundation element (50) by means of at least one excavating member (71) which rotates about a drive shaft (70) and has radial dimensions which are in particular greater than or equal to external dimensions of the foundation element (50), in which the excavating member (71), at the same time as the foundation element (50) is being sunk, drills out earth beneath the said bottom part of the foundation element (50), and in which at least the drilling head (55), after the foundation element (50) has been sunk, is removed again from the ground.

2. Method according to clause 1, in which, if the foundation element (50), while it is being sunk, starts to deviate from the intended direction of introduction, the position of at least the drive shaft (70), together with the excavating member (71) of the drilling head (55) is adjusted with respect to the foundation element (50).

3. Method according to clause 1 or 2, in which, during the sinking of the foundation element (1), a downwardly directed compressive force is exerted on the foundation element (1), with the aid of a pressing installation (2) which is supported on the ground by means of a frame and in particular is anchored to the ground.

4. Method according to one of the preceding clauses, in which earth which is drilled out by the excavating member (71) passes, via introduction openings (79) into a flushing chamber (80), which is located above the excavating member (71), where it is mixed with a flushing liquid, which is introduced into the flushing chamber (80) under pressure via at least one feed line (81), before then being discharged upwards to outside the foundation element (50), together with the flushing liquid, via at least one discharge line (82).

5. Method according to clause 4, in which the pressure of the flushing liquid supplied is set to a value which is higher than the groundwater pressure prevailing in the surrounding ground, in particular an excess pressure of approximately 0.1-0.3 bar.

6. Method according to clause 4 or 5, in which a base plate (78), which is provided with the introduction openings (79) and delimits the underside of the flushing chamber (80), is moved substantially up and down in the direction of the excavating member (71) in the event of a problem being detected.

7. Method according to one of the preceding clauses, in which the drilling head (55), while the foundation element (50) is being sunk, is positioned in such a manner with respect to the foundation element (50) that the drilling head (55) is located partly inside the foundation element (50), while the remaining part is located below the bottom part of the foundation element (50).

8. Method according to clause 7, in which the drilling

head (55), during the drilling, is fixed to an inner peripheral wall part (52) of the bottom part of the foundation element (50) with the aid of controllable clamping means (60).

9. Method according to one of the preceding clauses, in which the excavating member (10) can be displaced with respect to the drive shaft, substantially in a plane which is perpendicular to the direction of introduction, and after the foundation element (14) has been sunk, the excavating member (10) is moved from the drilling position into an at-rest position, in which the excavating member (10) has radial dimensions which are smaller than internal dimensions of the foundation element (14), after which the drilling head (9) is retracted upwards through the interior of the foundation element (14).

10. Method according to one of the preceding clauses, in which, before the drilling head (3) is retracted upwards, the foundation element (1) is filled with liquid.

11. Method according to one of the preceding clauses, in which, after the drilling head (9) has been retracted, the foundation element (14) is at least partially filled with a foundation material (26).

12. Method according to one of the preceding clauses, in which, after the foundation element (30) has been sunk, the drilling head and/or the foundation element (30) are pulled back upwards, with simultaneous injection of a foundation material (31), in particular a settable foundation material.

13. Method according to one of the preceding clauses, in which, during the sinking operation, one or more injection lines are entrained for the purpose of supplying foundation material after the foundation element has been sunk.

14. Method according to one of the preceding clauses, in which, during the sinking operation, one or more injection lines are entrained for the purpose of supplying lubricant around the foundation element while it is being introduced into the ground.

15. Method according to one of the preceding clauses, in which each foundation element (1) is composed of segments, in particular with a height of less than 2 metres, which can be joined to one another, in particular by welding.

16. Method according to one of the preceding clauses, in which the foundation element, in the section above the drilling head, while it is being sunk is filled with liquid, in particular water.

17. System in particular for using the method according to one of clauses 1-16, comprising:

- at least one hollow foundation element (1);
- an installation (2) designed to exert a substantially vertically oriented force on the foundation element (1); and
- a drilling head (3) which can be lowered into the foundation element and has at least one excavating member which can rotate about a drive shaft and, in a drilling position, while the foundation element (1) is being sunk into the ground, has radial dimensions which in particular are greater than or equal to external dimensions of the foundation element (1).

18. System according to clause 17, in which control members (74) are provided in the drilling head (55) for adjusting the position of the drive shaft (70) with the excavating member (71) with respect to a bottom part of the foundation element (50).

19. System according to clause 18, in which the control members (74) comprise hydraulically actuable control cylinders.

20. System according to clause 18 or 19, in which the control members (74) are active between a mounting flange (64) in which the drive shaft (70) is mounted and a housing part (62) of the drilling head (55), which, during drilling, can be fixed in position with respect to the bottom part of the foundation element (55).

21. System according to one of clauses 18-20, in which the control members (74) act so as to adjust the position of the drive shaft (70) together with the excavating member (71) with respect to the bottom part of the foundation element (55) in a direction which is substantially perpendicular to the drive shaft (70).

22. System according to one of clauses 18-20, in which the control members (17) act so as to tilt the angular position of the drive shaft together with the excavating member (10) with respect to the bottom part of the foundation element (14).

23. System according to one of clauses 17-22, in which the bottom part of the foundation element (55) is provided with a downwardly tapering peripheral wall part (53).

24. System according to one of clauses 17-23, in which there are measuring means for determining the direction of introduction of the foundation element, which measuring means interact with and/or are provided on the drilling head.

25. System according to one of clauses 17-24, in which the drilling head (55) incorporates a drive unit (65) for driving the drive shaft (70), in particular a hydraulic motor.

26. System according to clause 25, in which planetary gear mechanisms are provided as transmission between the drive unit (65) and the drive shaft (70).

27. System according to one of clauses 17-26, in which the installation is a press installation (20) which comprises a frame which can be supported on the ground, in particular can be anchored to the ground, and which is provided with engagement means, which can move up and down by hydraulic means with respect to the frame, for exerting a downwardly directed compressive force on the foundation element (14).

28. System according to clause 27, in which the engagement means can also be controllably adjusted with respect to the frame in a direction which is substantially perpendicular to the downward pressing direction.

29. System according to one of clauses 17-28, in which the drill head (54) comprises a flushing chamber (80), which is located above the excavating member (71) and on the underside comprises introduction openings (79) provided in particular in a base plate (78), to which flushing chamber (80) at least one feed line (81) for introducing a flushing liquid into the flushing chamber (80) under pressure is connected, and to which flushing chamber at least one discharge line (82) for discharging the flushing liquid mixed with earth which has been drilled out from the flushing chamber (80).

30. System according to clause 29, in which the introduction openings (79) widen in the upwards direction.

31. Method according to clause 29 or 30, in which displacement members (84) are provided in the drilling head (55) for moving the base plate (78) substantially up and down in the direction of the excavating member (71).

32. System according to clause 31, in which the displacement members (84) comprise hydraulically actuable displacement cylinders.

33. System according to clause 31 or 32, in which the displacement members (84) act between the base plate (78) and a housing part (62) of the drilling head (55), which, during drilling, can be fixed in position with respect to the foundation element (50).

34. System according to one of clauses 17-33, in which the drilling head (55) comprises controllable clamping means (60) for clamping it securely on to an inner peripheral wall part (52) of a bottom part of the foundation element (50).

35. System according to one of clauses 17-34, in which a bottom part of the foundation element (50) is provided, along its inner peripheral wall, with a stop edge (56) for delimiting the drilling head (55) downwardly.

36. System according to one of clauses 17-35, in which a bottom part of the foundation element (50) is provided, along its inner peripheral wall, with positioning lugs (51) for positioning the drilling head (55).

37. System according to one of clauses 17-36, in which the excavating member (10) can be displaced with respect to the drive shaft substantially in a plane which is perpendicular to the drive shaft, between the drilling position and an at-rest position in which the excavating member (10) has radial dimensions which are smaller than internal dimensions of the foundation element (14).

38. System according to one of clauses 17-37, in which there are one or more injection lines for supplying foundation material after the foundation element has been sunk.

39. System according to one of clauses 17-38, in which there are one or more injection lines for supplying lubricant around the foundation element while it is being introduced into the ground.

40. System according to clause 39, in which the injection line opens out behind an overlap in the peripheral wall of a bottom part of the foundation element.

41. System according to one of clauses 17-40, in which each foundation element (14) comprises segments, in particular with a height of less than 2 metres, and in which there are means for connecting the segments to one another.

42. System according to clause 41, in which the drilling head (55) has a total height which is less than the height of a segment of the foundation element (50).

43. System according to one of clauses 17-42, in which the drilling head (55) has a total height which is less than 2 metres.

44. Drilling head for use in a system according to

one of clauses 17-43.

45. Foundation pile formed using a system according to one of clauses 17-43.

46. Deep wall comprising a plurality of foundation elements positioned next to one another in the ground, formed using a system according to one of clauses 17-43.

Claims

1. Method for forming at least one foundation pile or deep wall in the ground, comprising the step of sinking one or more hollow foundation elements (50) into the ground with a substantially vertical orientation, **characterized in that** the sinking of the hollow foundation element (50) into the ground takes place during driving of a removable drilling head (55), which drilling head (55), during the sinking of the foundation element (50), is in a drilling position in which the drilling head (55) drills out earth by means of at least one excavating member (71) which rotates about a drive shaft (70), in which the excavating member (71), at the same time as the foundation element (50) is being sunk, drills out earth, and in which at least the drilling head (55), after the foundation element (50) has been sunk, is removed again from the ground.

2. Method according to claim 1, in which the drilling head (55), while the foundation element (50) is being sunk, is positioned in such a manner with respect to the foundation element (50) that the drilling head (55) is located partly inside the foundation element (50), while the remaining part is located below a bottom part of the foundation element (50).

3. Method according to claim 1 or 2, in which the drilling head (55), during the drilling, is fixed to an inner peripheral wall part (52) of the bottom part of the foundation element (50) with the aid of controllable clamping means (60).

4. Method according to one of the preceding claims, in which the excavating member (10) can be displaced with respect to the drive shaft, substantially in a plane which is perpendicular to the direction of introduction, and after the foundation element (14) has been sunk, the excavating member (10) is moved from the drilling position into an at-rest position, in which the excavating member (10) has radial dimensions which are smaller than internal dimensions of the foundation element (14), after which the drilling head (9) is retracted upwards through the interior of the foundation element (14).

5. Method according to one of the preceding claims, in which, after the drilling head (9) has been retracted, the foundation element (14) is at least partially filled with a foundation material (26).

6. Method according to one of the preceding claims, in which, after the foundation element (30) has been sunk, the drilling head and/or the foundation element (30) are pulled back upwards, with simultaneous injection of a foundation material (31), in particular a settable foundation material.

7. Method according to one of the preceding claims, in which, during the sinking operation, one or more injection lines are entrained for the purpose of supplying foundation material after the foundation element has been sunk.

8. System in particular for using the method according to one of claims 1-7, comprising:

- at least one hollow foundation element (1); and
- a drilling head (3) which can be lowered into the foundation element and has at least one excavating member which can rotate about a drive shaft.

9. System according to claim 8, in which the drilling head (55) incorporates a drive unit (65) for driving the drive shaft (70), in particular a hydraulic motor.

10. System according to claim 9, in which planetary gear mechanisms are provided as transmission between the drive unit (65) and the drive shaft (70).

11. System according to one of claims 8-10, in which the drilling head (55) comprises controllable clamping means (60) for clamping it securely on to an inner peripheral wall part (52) of a bottom part of the foundation element (50).

12. System according to one of claims 8-11, in which the excavating member (10) can be displaced with respect to the drive shaft substantially in a plane which is perpendicular to the drive shaft, between the drilling position and an at-rest position in which the excavating member (10) has radial dimensions which are smaller than internal dimensions of the foundation element (14).

13. Drilling head for use in a system according to one of claims 8-12.

14. Foundation pile formed using a system according to one of claims 8-12.

15. Deep wall comprising a plurality of foundation elements positioned next to one another in the ground, formed using a system according to one of claims 8-12.

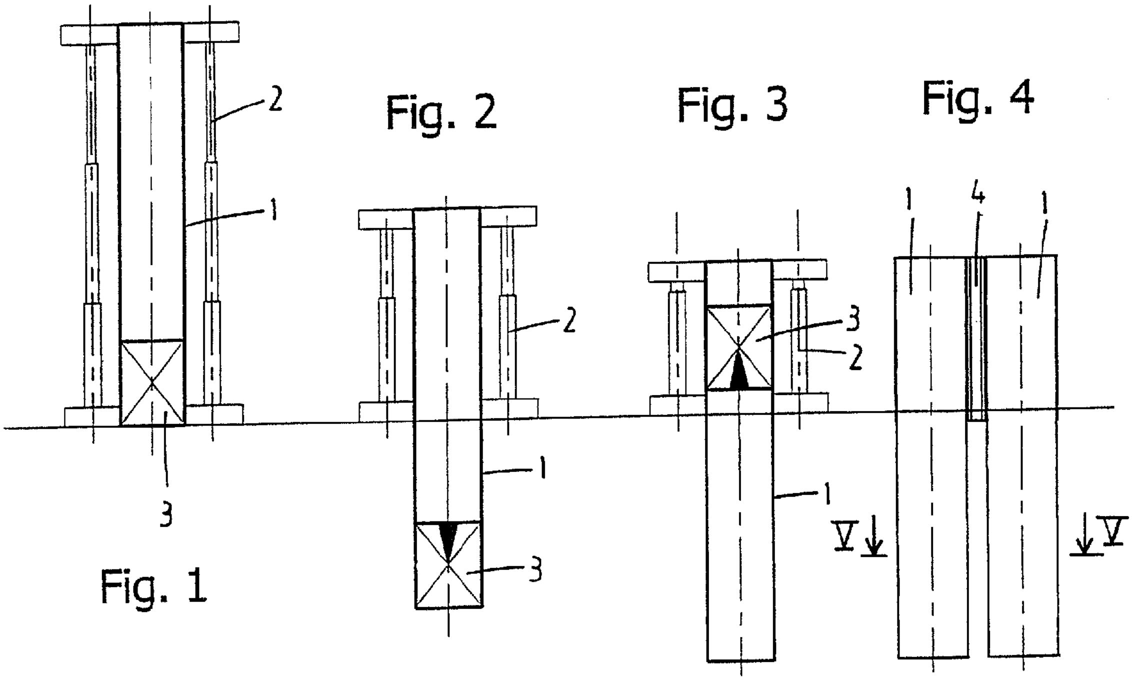

Fig. 1

Fig. 2

Fig. 3

Fig. 4

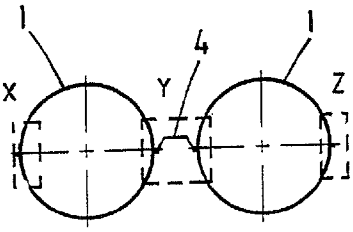

Fig. 5

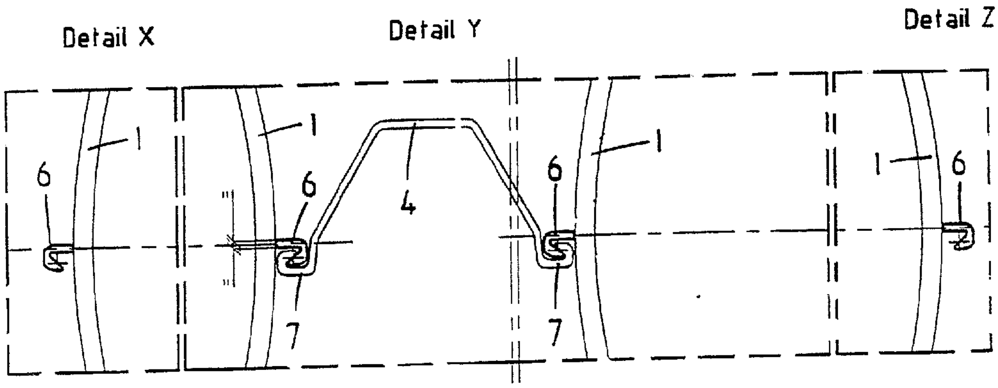

Fig. 6

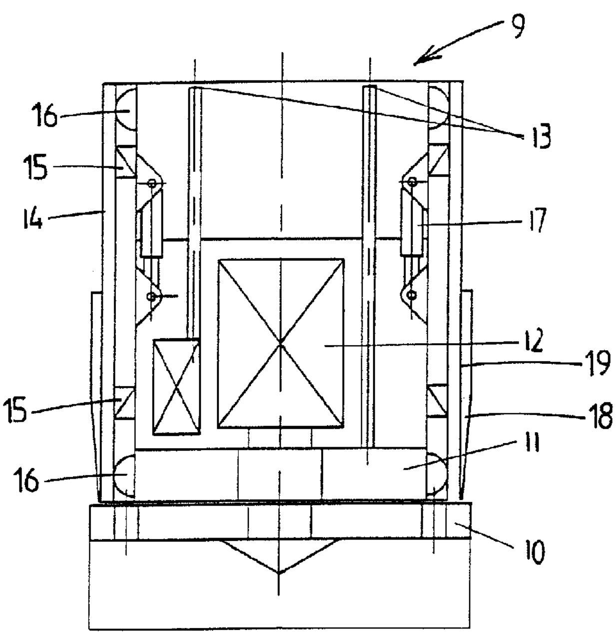

Fig. 7

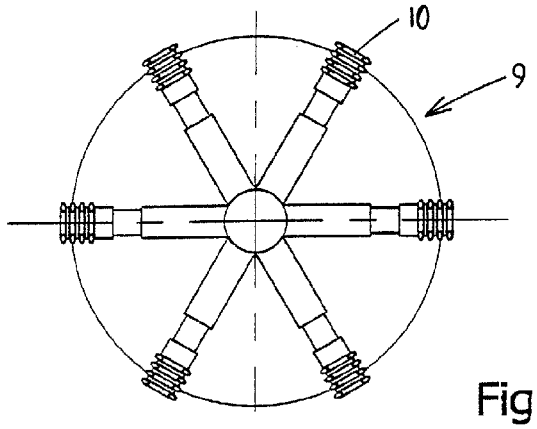

Fig. 8

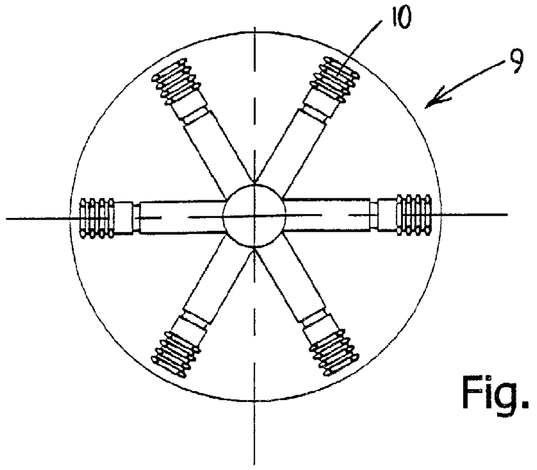

Fig. 9

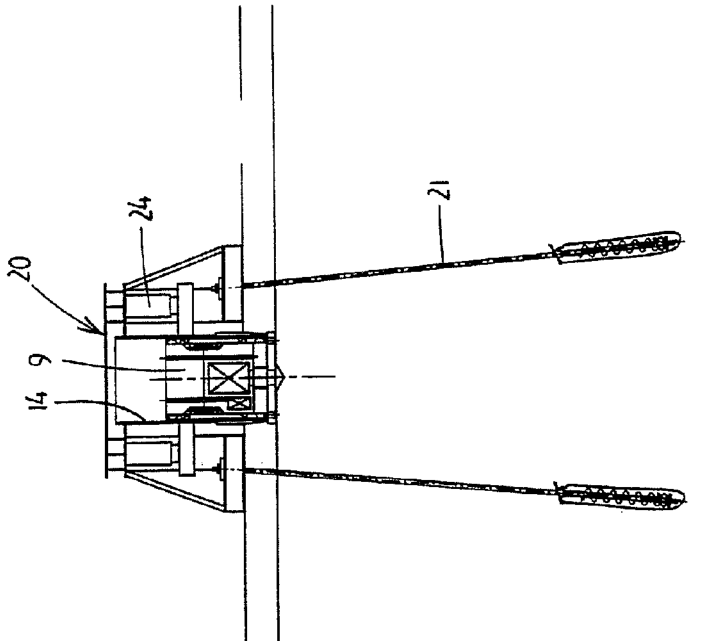

Fig.11

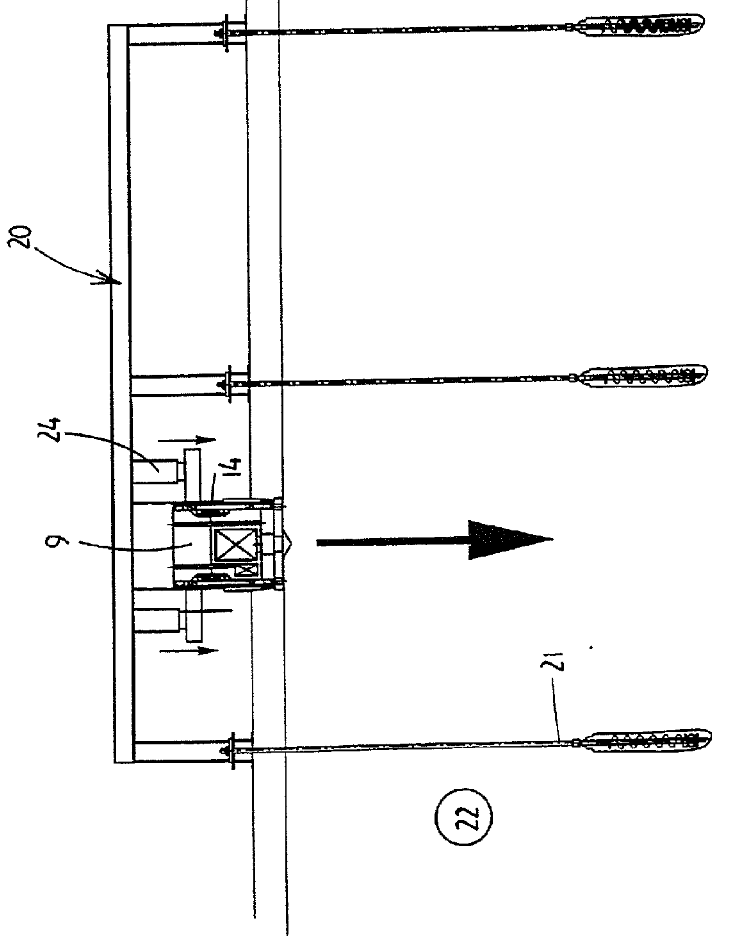

Fig.10

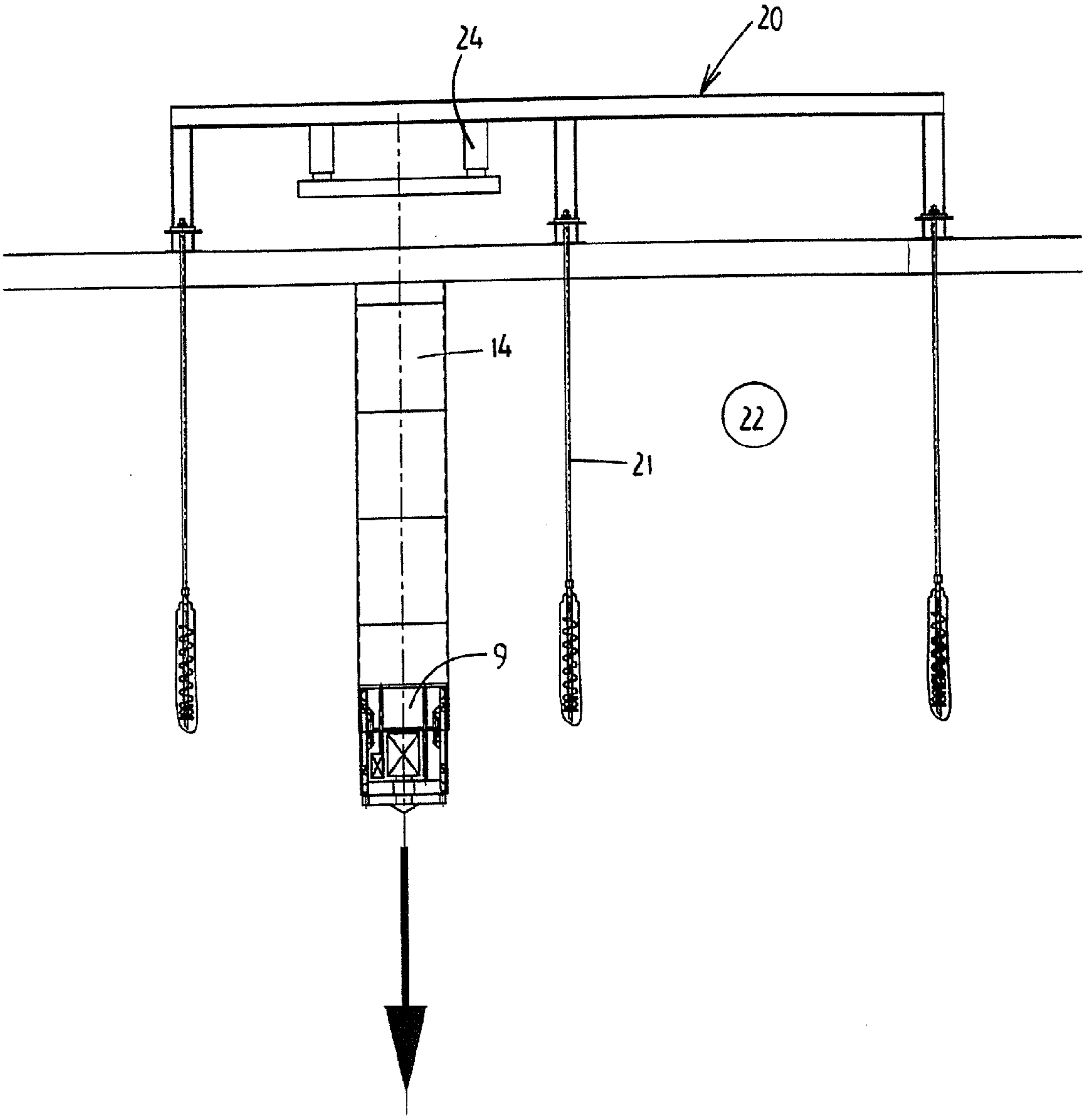

Fig.12

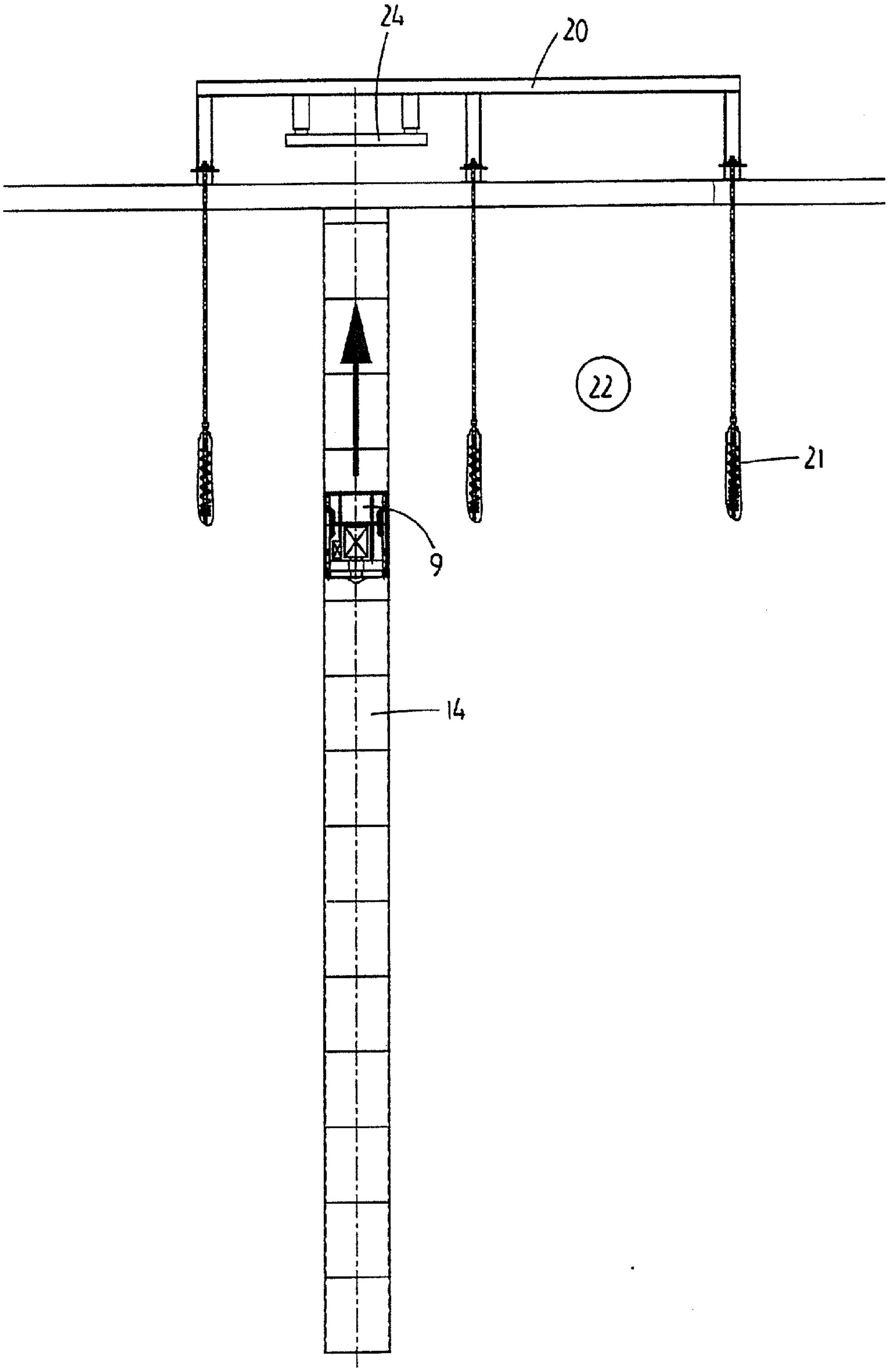

Fig.13

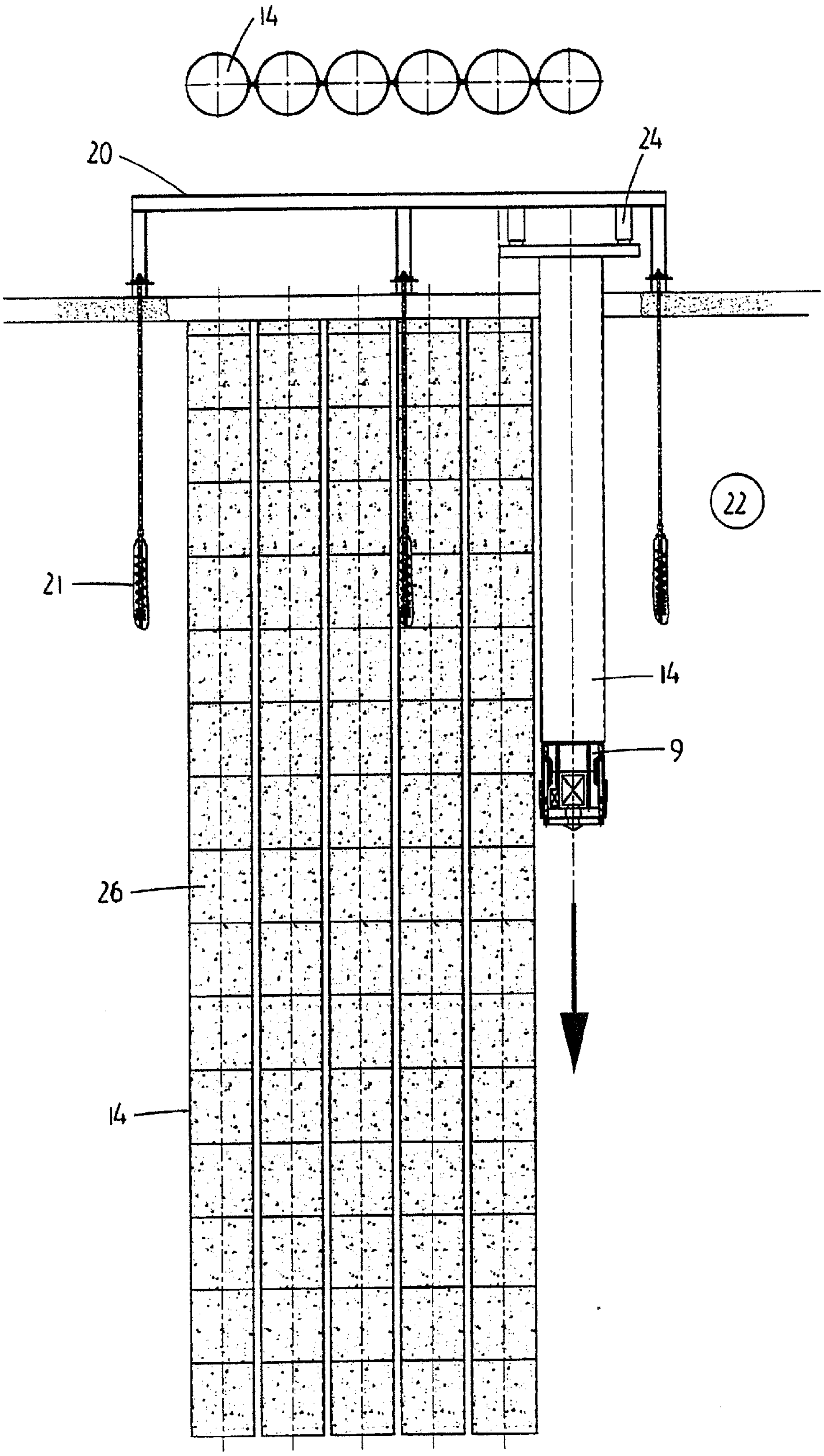

Fig. 14

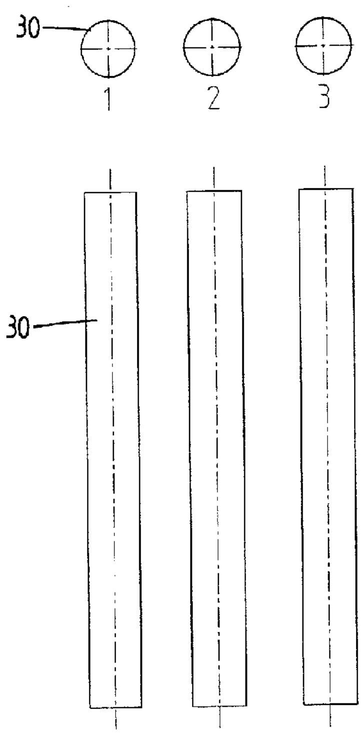

Fig. 15a

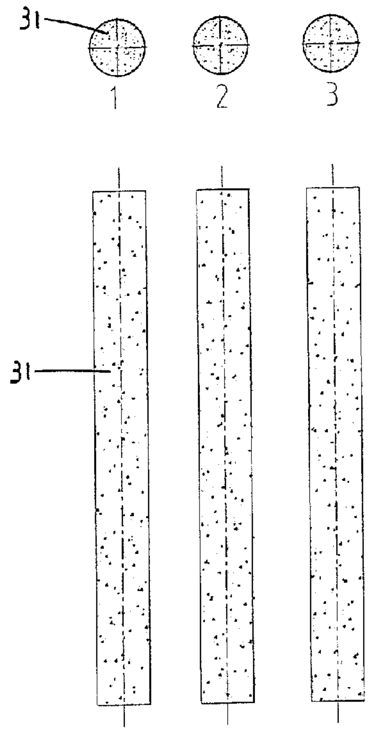

Fig. 15b

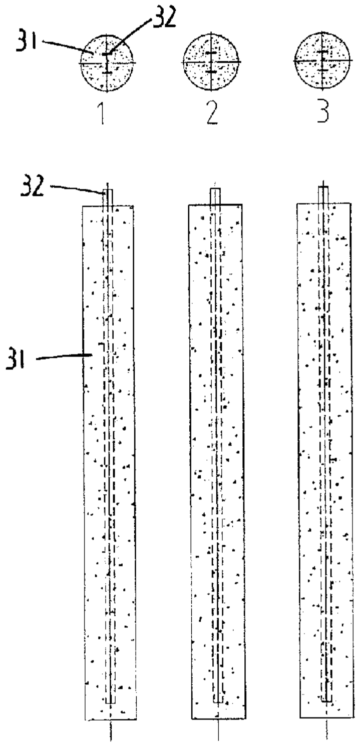

Fig. 15c

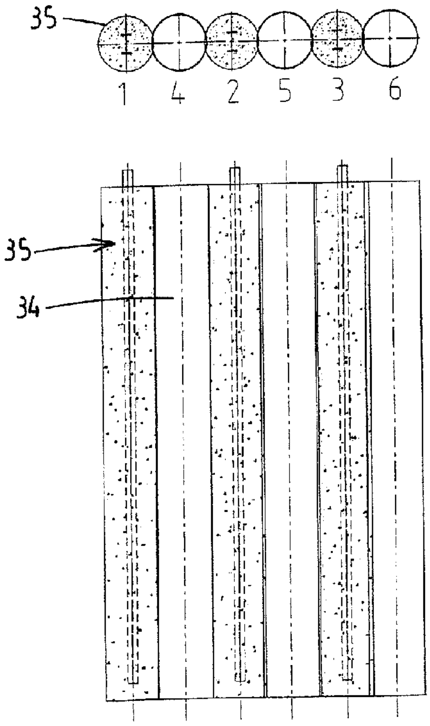

Fig. 15d

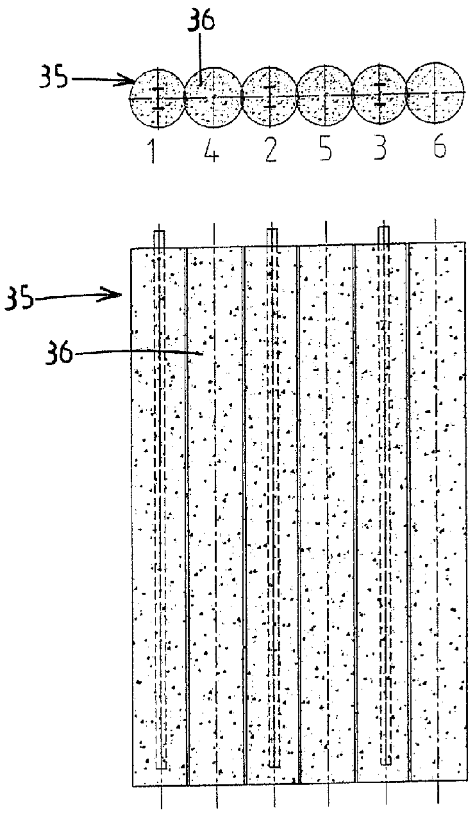

Fig.15E

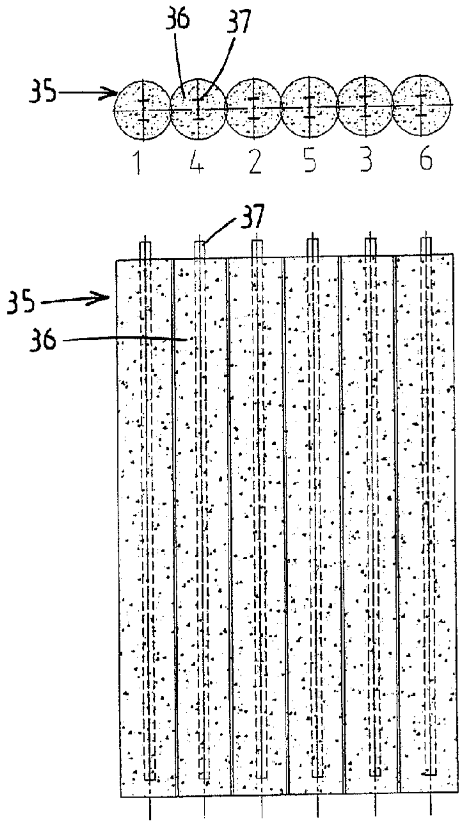

Fig.15F

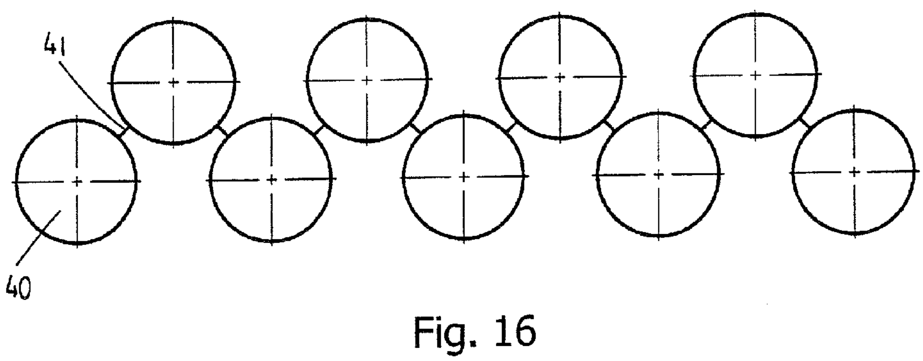

Fig. 16

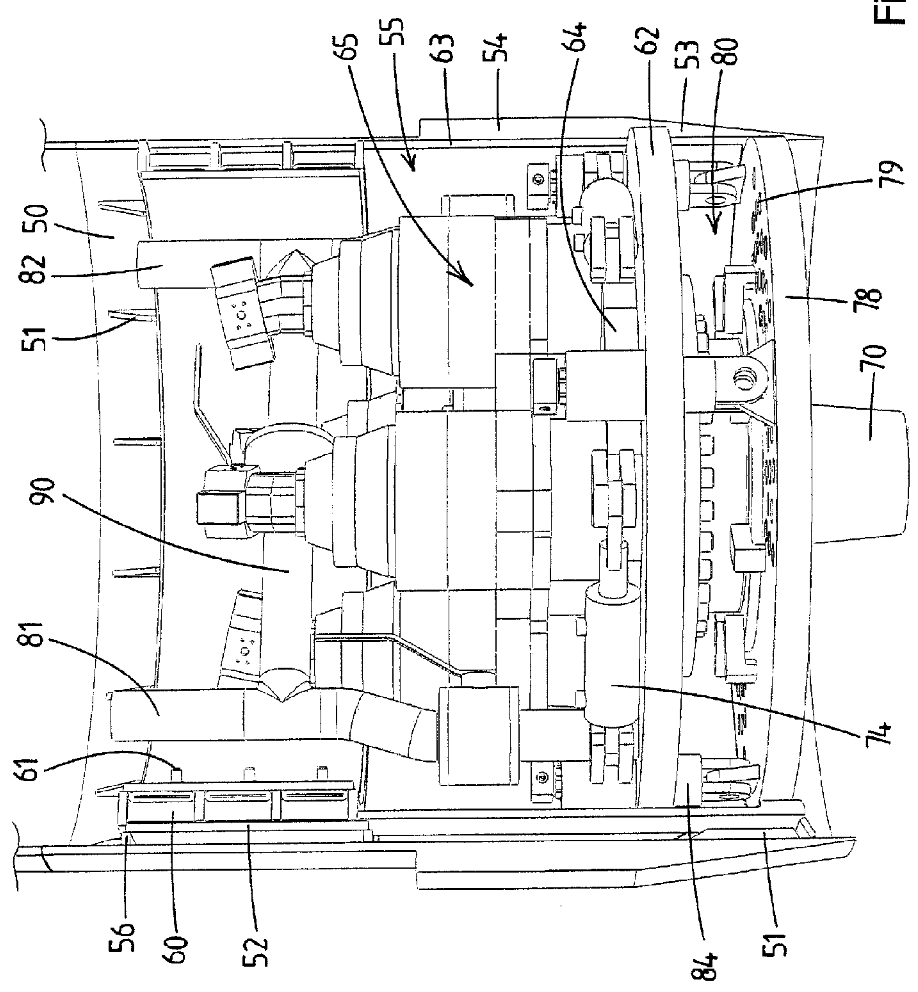

Fig.17

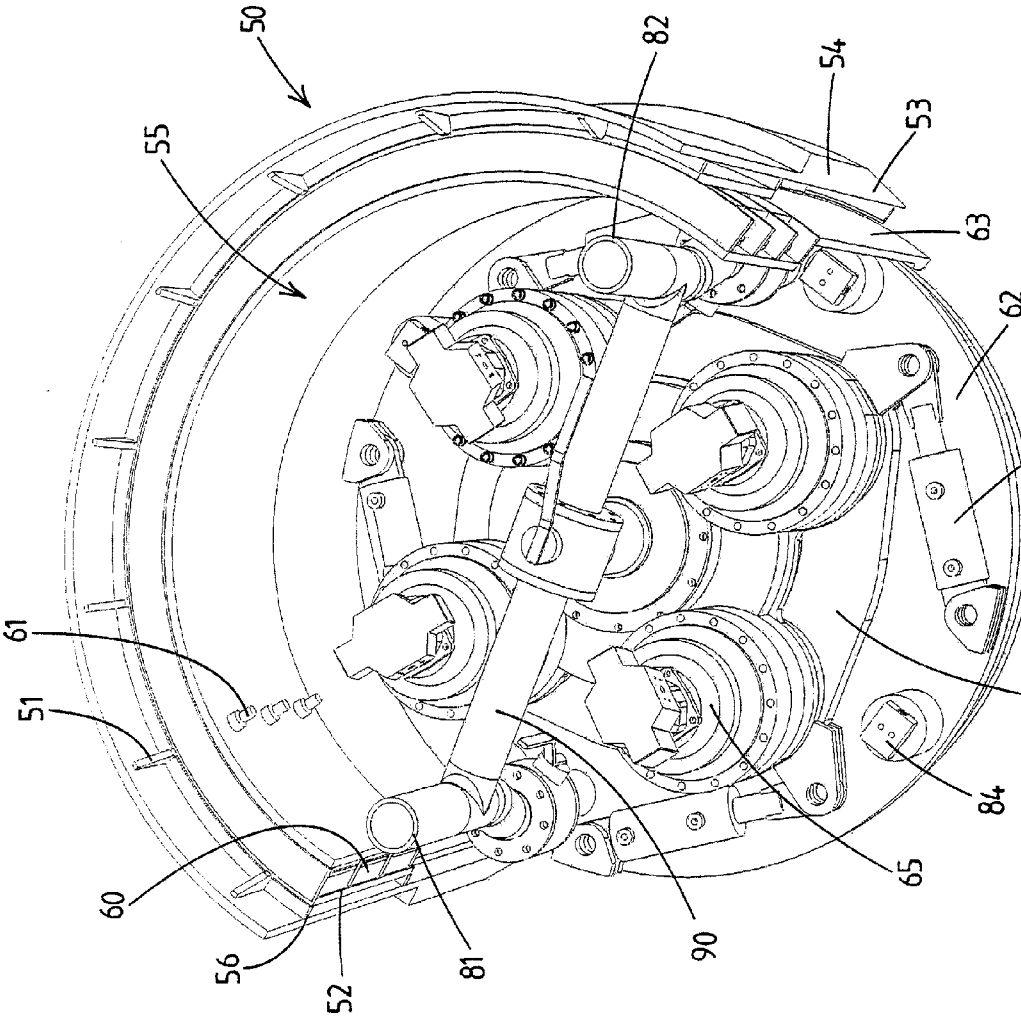

Fig.18

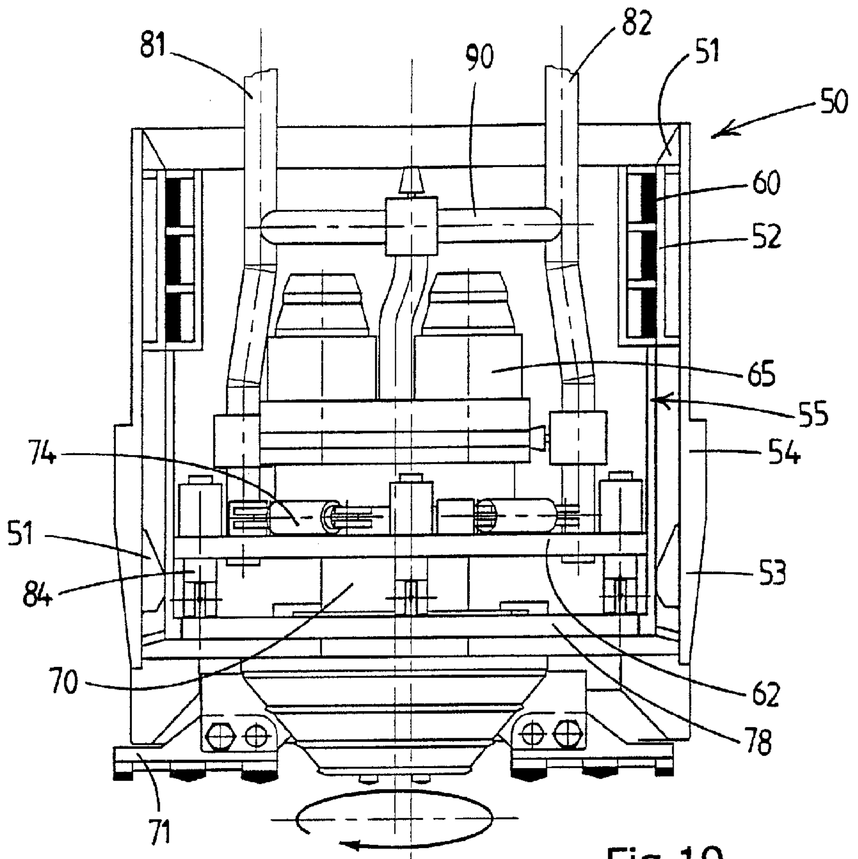

Fig.19

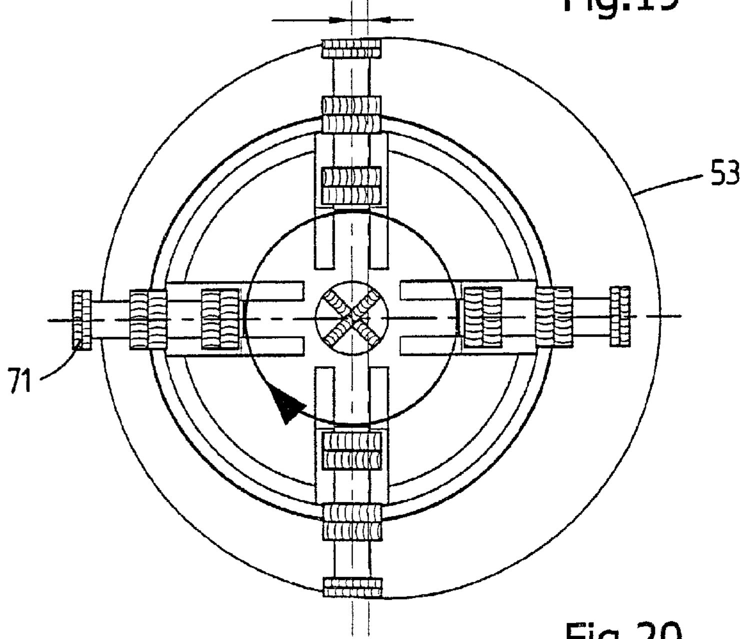

Fig.20

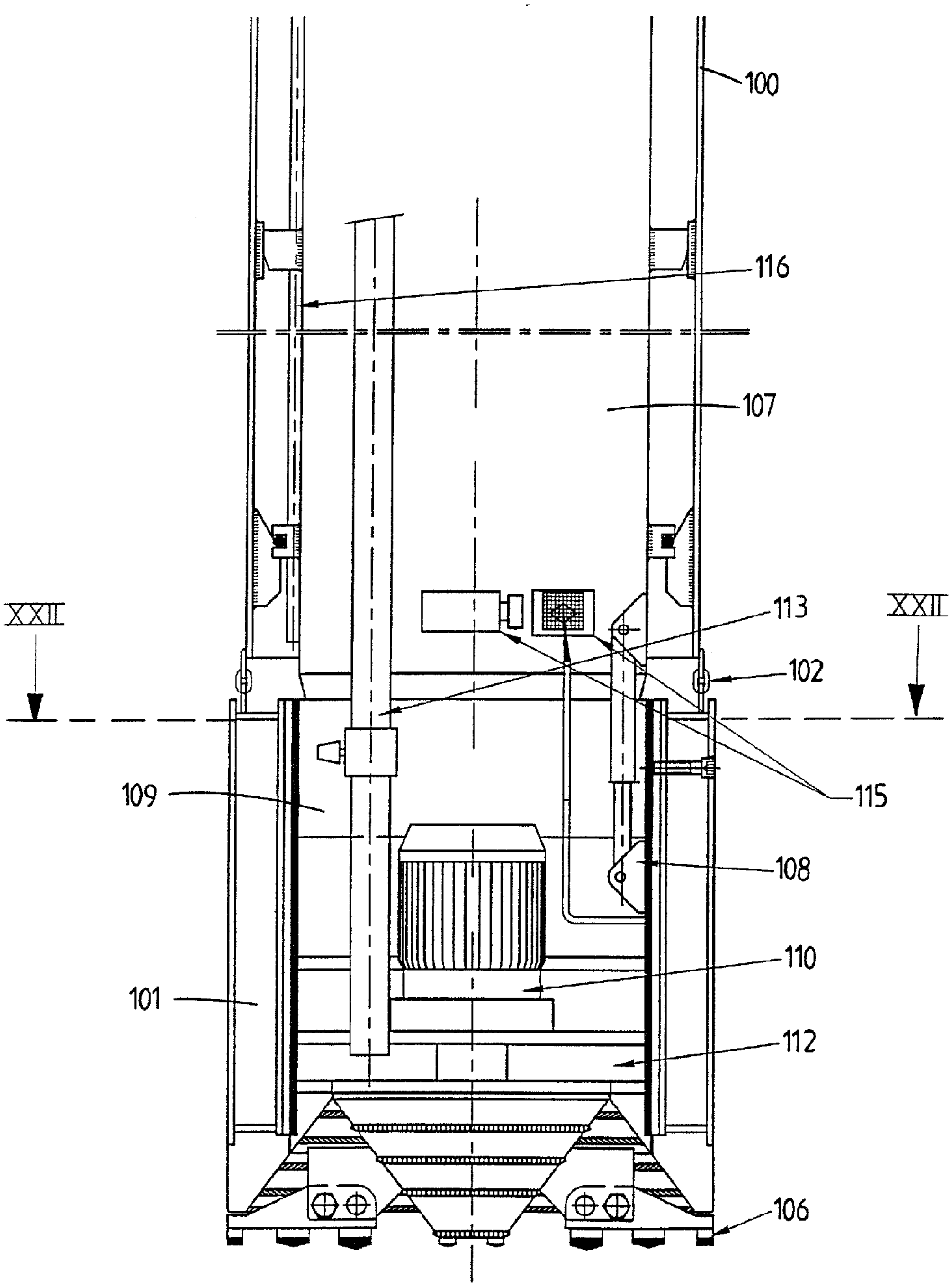

Fig.21

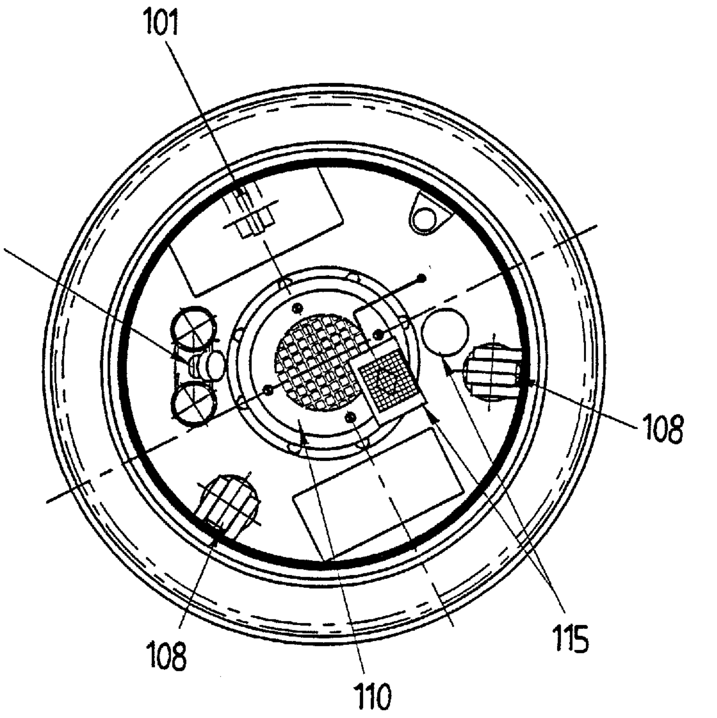

Fig.22