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(54) PROCESS FOR CONSOLIDATION OF SOILS AND/OR BUILDING STRUCTURES IN CONTACT WITH THEM, AND RELATED DEVICE

(57) The process allows soils (20) and/or building structures (22) to be consolidated and consists of: producing in the soil (20), by means of drilling, at least one hole using a drill rod (10) with a drill bit (18) of single use type, the drill rod (10) comprising several hollow drill bars (12) arranged consecutively and connected to one another by means of coaxial sleeves (14), at least one of the sleeves (14) being provided with at least one lateral through opening (16) that places the inside of the sleeve (14) in communication with the outside, this opening (16) being closed by a check valve adapted to open when the pressure inside the sleeve (14) exceeds a predetermined value; leaving the drill rod (10) in the hole bored in the soil, so as to act as reinforcement; injecting into the drill rod (10), through the outer end thereof, at a pressure that causes opening of the check valves provided in the holes (16) of the sleeves (14), an expanding substance adapted to consolidate the surrounding soil and to constrain thereto the drill rod (10) acting as reinforcement.

The device comprises the above drill rod.

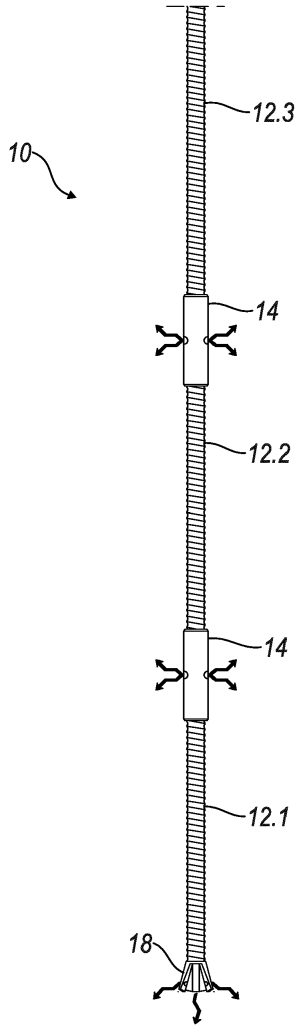

Fig. 1

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Description

[0001] The present invention relates to a process for consolidation of soils and/or building structures in contact with soils, as well as a relevant device used in said process.

[0002] The soils, but also the building structures of civil, industrial or monumental buildings, as well as the building structures consisting of retaining walls of embankments or slopes, may be ravelled, in particular as a result of ground failures or seismic events, which may cause instability and damages, even serious ones, to the relevant building structures.

[0003] The consolidation of said soils and of the building structures in contact with them, which may also be performed by way of prevention (in particular, antiseismic prevention), is traditionally performed in two ways:

- through the so-called micropiles, reinforced with steel pipes, having such a length as to allow a suitable (according to the indications inferred from on-site surveys and from a geotechnical site characterization) underlying soil to be reached. The use of micropiles normally involves the use of extremely bulky machinery and the accomplishment of significantly invasive excavations and also entails the accomplishment of reinforced concrete curbs connecting the micropile heads.
- through the reclamation of the existing soil by injecting polyurethane resins or eco-friendly expansive cement mortars allowing the soil to be consolidated, however with limited results, which may be insufficient.

[0004] Italian patent IT 1383319 describes a process for consolidating building structures and the relevant device to implement said process, basically combining the micropile technology with soil consolidation through expanding substances. In particular, the process consists of:

producing at least one hole having a first section which extends in the building structure and a second section which extends in the adjacent soil;
inserting into each hole a reinforcement which extends in both the first section and the second section;
injecting at least in the second section, between the reinforcement and the wall of each hole, an expanding resin which, once cured, is adapted to consolidate the soil and to constrain the reinforcement thereto.

[0005] However, IT 1383319 also provides the possibility to constrain the reinforcement in each hole to the building structure by injecting in said first section of the hole, according to a particular technique, a fluid other than said resin and suitable to harden after curing.

[0006] In this manner, micropiles are implemented in particular under the foundations of a building structure and, in addition, the soil around each micropile and more generally under the building structure is consolidated, all this in order to make sure that the underlying soil and the overall building structure are consolidated as desired.

[0007] However, the solution offered by IT 1383319 has some drawbacks. In particular, once the above hole has been drilled, in yielding soils it may turn out hard or even impossible to insert the relevant reinforcement in the hole, because the soil surrounding the hole collapses, clogging it.

[0008] Furthermore, it is necessary to have availability of two different machine-tools, namely a drill and a machine for injecting the expanding resin.

[0009] The present invention sets the goal to implement a process for consolidation of soils and, if present, also of the building structures in contact with said soils, as well as a device usable in said process, so that the drawbacks described above do not arise.

[0010] Said goal is achieved and the relevant technical problem is solved by the consolidation process and the relevant device disclosed in the appended claims.

[0011] The invention will be more easily understandable from the following description of a form of embodiment of the process and device according to the invention. In said description reference will be made to the appended drawings, wherein:

fig. 1 is a side view of a form of embodiment of the device according to the invention, to be used for implementing a process according to the invention, the process allowing soils and/or building structures in contact with said soils to be consolidated;
fig. 2 is an enlarged view of one of the sleeves which are a part of the device of fig. 1;
fig. 3 is a side view of the same sleeve as shown in fig. 2, but rotated by 90° degrees around its own axis;
fig. 4 is a top view thereof;
fig. 5 is an axial cross-section according to the dashed line 5-5 of fig. 3;
fig. 6 is a cross-section thereof according to the dashed line 6-6 of fig. 5;
fig. 7 shows the device of fig. 1 as mounted in situ as a result of the implementation of the process according to the invention, the device having been used to consolidate a soil having a level surface;
fig. 8 shows the use of several devices according to the invention for consolidating the soil underlying a mat foundation of a building structure, the devices being constrained to said foundation;
fig. 9 shows the use of devices such as those of fig. 1 for consolidating a stone building structure of a traditional type as well as the underlying soil;
fig. 10 shows how it possible to consolidate the soil under a traditional stone building structure and at the same time to constrain the device according to the invention to said structure without any drilling concerning the building structure directly;

fig. 11 shows an alternative way to connect a traditional stone building structure with the devices according to the invention;
fig. 12 shows how it is possible to consolidate an embankment and the relevant building structure consisting of a traditional stone containment wall;
fig. 13 shows how it is possible to consolidate and contain an embankment or a slope.

[0012] Examining fig. 1 it can be seen that the device 10 comprises a series of conventional self-drilling hollow bars 12 (in the specific case three bars, marked with 12.1, 12.2 and 12.3), made of steel (such as S 355 steel or a steel with enhanced performance), of the type with improved adhesion, the side surface of said bars having a helical rib allowing a connection to be made between them through sleeves 14, the enlargement of one of which is shown in figures 2-6.

[0013] As can be seen in particular in figures 5 and 6, the sleeve 14 is internally threaded so that the corresponding ends of two consecutive bars 12 can be screwed thereinto, implementing the connection between the two bars 12. In particular, fig. 6 shows that the two hollow bars 12 which are screwed to refusal into the sleeve 14 do not reach the through side openings 16 obtained in the sleeve 14 in diametrically opposed positions. It should be remarked that the number of openings 16 can be other than two (although the availability of two openings arranged like openings 16 is preferential) and the openings can even not be lying on the same transverse plane, their number ranging from a single opening to a number not far higher than two, for obvious reasons. The openings 16, if more than one, are conveniently arranged at an angle and are equally spaced. Check valves (non shown for the sake of simplicity), opening when a certain pressure is achieved inside the sleeve, are inserted in the openings 16.

[0014] Again with reference to fig. 1, it can be seen that a conventional single-use drill bit 18 is fastened in a conventional way to the lower end of the bar 12.1. The assembly formed by the self-drilling bars 12.1, 12.2 and 12.3, by the two connecting sleeves 14 and by the drill bit 18 forms a drill rod 10 which is used, by means of special machines, in the process according to the present invention.

[0015] The length of the drill rod 10 can be varied within certain ranges, using an appropriate number of bars 12 and sleeves 14, the bars being available on the market in different lengths and diameters. In particular, bars of the self-drilling type having an outer diameter of 32 mm, 38 mm and 51 mm, respectively, and a thickness of 5.2 mm for 32 and 38 mm bars and a thickness 9.4 mm for 51 mm bars can be retrieved.

[0016] The connecting sleeves 14, preferably made of S 355 steel or a steel with enhanced features, are made so as to be adapted to the diameter of the bars 12 which must be connected.

[0017] The two through openings 16 provided in the sleeves 14 have in this specific case a diameter of 16 mm. The relevant check valves (as pointed out, not shown for the sake of simplicity) are conveniently of the type applicable by pressing them into the relevant openings 16 and can be set, for example, to 10 bar or to 20 bar opening or to other pressure values, depending on the requirements.

[0018] As regards the single-use drill bits 18, they are retrievable on the market as kits for the aforesaid self-drilling bars and they can be provided with bits for holes in the rock or in walls, or else they can be three-blade drilling bits for drilling in soils of any nature. Said single-use bits are provided with through openings allowing the environment outside the bit and the inside of the hollow drill rod 10 to communicate with each other.

[0019] The hole which is obtained by drilling with drill rods 10 provided with the drill bits 18 has a diameter ranging from 60 to 100 mm, depending on the diameter of the bar 12 and hence of the drill bit 18 in use.

[0020] Some applications of the process and of the device according to the present invention will now be described, referring to figures 7-14.

[0021] The drill rod 10 represented in fig. 1 can be used to simply consolidate the soil, for example the soil marked with 20 in fig. 7. In this case, after accurate geotechnical surveys, a design will be drafted, providing a certain number of drillings with drill rods 10 of a certain length and consisting of a certain number of self-drilling bars 12, having a certain diameter and a suitable single-use drilling bit 18.

[0022] Once a drilling to reach the desired depth (for example to reach a soil layer with better features or to have an anchorage of sufficient length) has been made and once the relevant hole has accordingly been bored in the soil 20, the drill rod 10 is left in the hole, so as to act as reinforcement.

[0023] Through an injection pipe 19 connected with the outer end of the drill-reinforcement rod 10, an expanding fluid substance (for example a proper polyurethane resin of the type used for consolidating soils, or else a mortar based on expanding cement, of the type which is already used for this purpose) is now injected inside the latter. The injection occurs at a pressure which causes the opening of the check valves provided in the openings 16 of the sleeves 14, so that the expanding substance flows out of the openings 16 and out of the openings (not shown) which are present in the bit 18, fills the hole portion which is not occupied by the drill rod 10 and also infiltrates the surrounding soil. Once said expanding substance is cured, the situation is as represented in fig. 7, wherein the area marked as a whole with 21 is the soil portion concerned by said substance one expanded, so that the soil is consolidated on account of the presence of the above expanded substance and of the relevant reinforcement consisting of the drill rod 10.

[0024] Repeating the above process for the required number of times, a soil with any surface extension may be consolidated.

[0025] The process according to the present invention can also be used to consolidate a soil on which a building structure is already existing (in particular, a pre-existing building structure in a seismic area), which is in its turn consolidated. Fig. 8 shows a building structure 22.1 (represented very schematically), in particular a reinforced concrete structure, whose foundation 24.1 rests on the soil 20.

[0026] Using such a process as described above with reference to fig. 7, it is possible to achieve the situation represented in fig. 8, wherein the soil 20 under the foundation 24.1 is consolidated through the use of a series of drill-reinforcement rods 10 and relevant soil areas 21 concerned by the expanding substance, but in this case the drilling also concerns the building structure 22.1 and in particular its foundation 24.1, a ring gasket 26 fitted on each drill rod 10 prevents the expanding fluid substance from climbing again to the hole beyond said gasket and the hole section remaining free from the drill rod 10 above the gasket 26 is injected, through a second injection pipe 23, with a fluid substance (for example an epoxy mortar with large-size gravel and/or rapid-setting, shrink-proof rheoplastic mortar), thus implementing a connecting means, marked with 27, adapted to make the relevant section of the drill-reinforcement rod 10 integral with the foundation 24.1 of the structure 22.1.

[0027] Fig. 9 represents a situation wherein the drill-reinforcement rods 10 are also constrained to the building structure 22.2, which is of the traditional type made of stone, and in particular to its foundation 24.2, since the drilling has been performed through said foundation as well. Highlighting that identical or similar elements in figures 8 and 9 have been marked with the same reference numbers (this applies also to the remaining figures), it should be remarked that in fig. 9 the two visible drill-reinforcement rods 10, to be regarded as not lying on the same vertical plane, have an opposed tilting and might belong to a sequence of rod pairs such as the one in fig. 9, a sequence which concerns the whole length of the structure 22.2 perpendicularly to the sheet plane.

[0028] Fig. 10 represents a building structure 22.2 similar to the one of fig. 9, the only difference being that the two drill-reinforcement rods 10 do not cross the building structure and are inserted directly into the soil (as is the case of fig. 7), but are slightly tilted in the opposite direction and with one of the two rods 10 (the one on the right) being connected to the building structure 22.2 by a connecting means, marked as a whole with 27.1, comprising a section of the steel L-profile 30.1, which is connected both to the relevant rod 10 by a special threaded sleeve 28 and to the building structure 22.2 through screws 29 conventionally inserted in the foundation of the building structure 22.2.

[0029] Fig. 11 represents another situation wherein the two drill-reinforcement rods 10, in this case arranged vertically, do not cross the stone building structure 22.2: they are both connected to the structure 22.2 by a connecting means, marked as a whole with 27.2, comprising a metal profile 30.2 arranged across the foundation of the building structure 22.2 and buried in a concrete casting, with the two ends of the profile 30.2 being welded to the head of the relevant rods 10 and embodied in their respective reinforced concrete grade beams extending parallel to the foundation of the building structure 22.2 and containing the same.

[0030] Fig. 12 shows how the process and the device according to the present invention allow an embankment 20 supported by a building structure 22.3 consisting of a traditional stone containment wall to be consolidated. The drill-reinforcement rod 10 inserted into the embankment crosses also the wall 22.3 and is connected thereto by the connecting means 27 used in figures 8 and 9; however, a steel match plate 33 fastened to the rod 10 by a threaded sleeve 28 similar to the one used in fig. 10 to fasten the rod 10 to the L-profile 30 is also provided. Obviously, in the case of fig. 12 several drill-reinforcement rods 10 might be provided and the containment wall might be made of reinforced concrete instead of stone.

[0031] Fig. 13 illustrates the case wherein an embankment 20 (originating for example from excavations), not supported by a containment wall, is stabilised by means of the drill-reinforcement rods 10, whose outer end is fastened to plates 33 such as those of figures 12 and 13, the plates matching an electrowelded steel net 34, between the latter and the embankment a geonetwork 35 being available to prevent the embankment from collapsing.

[0032] As can be understood from the foregoing, the process and the device according to the present invention are usable for consolidation of soils and/or building structures in the most varied situations and are adjustable to the specific requirements which may arise, particularly for the consolidation of soils and building structures existing in seismic areas, but also simply for the consolidation of soils (for example liquefied as a result of an earthquake) and/or for increasing the load-carrying capacity thereof in view of the construction of new building structures upon them.

[0033] It is also highlighted that in order to implement the process according to the present invention a single machine-tool can be used to perform both the drilling and the injection.

Claims

1. Process for consolidating soils (20) and/or building structures (22) in contact with these soils, comprising the following steps:

   - producing in the soil (20) to be consolidated, by means of drilling, at least one hole using a drill rod (10) with a drill bit (18) of single use type, the drill rod (10) comprising several hollow drill bars (12) arranged consecutively and connected to one another by means of coaxial sleeves

(14) to obtain a rotating coupling that allows drilling, at least one of the sleeves (14) being provided with at least one lateral through opening (16) that places the inside of the sleeve (14) in communication with the outside, this opening (16) being closed by a check valve adapted to open when the pressure inside the sleeve (14) exceeds a predetermined value;
- leaving the drill rod (10) in the hole bored in the soil, so as to act as reinforcement;
- injecting into the drill rod (10), through the outer end thereof, at a pressure that causes opening of the check valves provided in the holes (16) of the sleeves (14), an expanding substance adapted, once cured, to consolidate the surrounding soil and to constrain thereto the drill rod (10) acting as reinforcement.

2. Process according to claim 1, wherein the expanding substance is a two-component polyurethane resin having this characteristic.

3. Process according to claim 1, wherein the expanding substance is a premixed cement-based mortar having this characteristic.

4. Process according to claim 1, wherein, if a building structure (22) is present on the soil (20) to be consolidated, there are provided means (27) to connect the outermost length of the drill rod (10) left in situ with a part of the building structure (22).

5. Process according to claim 4, wherein the means (27) for connecting the outermost length of the drill rod (10) with a part of the building structure (22) are obtained by boring, by means of the same drill rod (10), a first part of the hole in the building structure (22), and then inserting into the first part of the hole, between the drill rod (10) left in situ and the wall of the hole, an annular gasket (26) that, when injection is carried out, prevents the expanding resin from rising substantially into the first part of the hole that involves the building structure (22), the drill rod (10) not having the aforesaid sleeves (14) provided with check valves in the first part of the hole;
subsequently, after the expanding substance has been injected, injecting into the hole bored in the structure, between drill rod (10) and wall of this hole, a fluid substance adapted to unify the related length of the drill rod (10) with the building structure (22).

6. Process according to claim 5, wherein the fluid substance adapted to unify the related length of the drill rod with the building structure (22) is an epoxy mortar and/or a quick setting shrinkage-compensated rheoplastic mortar.

7. Process according to claim 4, wherein the means for connecting the outermost length of the drill rod with the part of the building structure comprise metal elements (30) and/or reinforced concrete elements (31) fastened both to the outermost length of the drill rod (10) and to the building structure (22).

8. Device for consolidating soils (20) and/or building structures (22) in contact with these soils, consisting of a drill rod (10) comprising several hollow drill bars (12) arranged consecutively and connected to one another by means of coaxial sleeves (14) to obtain a rotating coupling between the bars (12) that allows drilling, at least one of the sleeves (14) being provided with at least one lateral through opening (16) that places the inside of the sleeve (14) in communication with the outside, this opening (16) being closed by a check valve adapted to open when the pressure inside the sleeve (14) exceeds a predetermined value.

9. Device according to claim 8, wherein the drill bars (12) are of the self-drilling type with external helical ribs, the sleeves (14) being internally threaded so that the related end of the corresponding bar (12) can be screwed, for a given length, until the end of its travel, into each of the two ends of the sleeves (14).

10. Device according to claim 8, wherein the drill bars (10) and the connecting sleeves (14) are made of S355 steel.

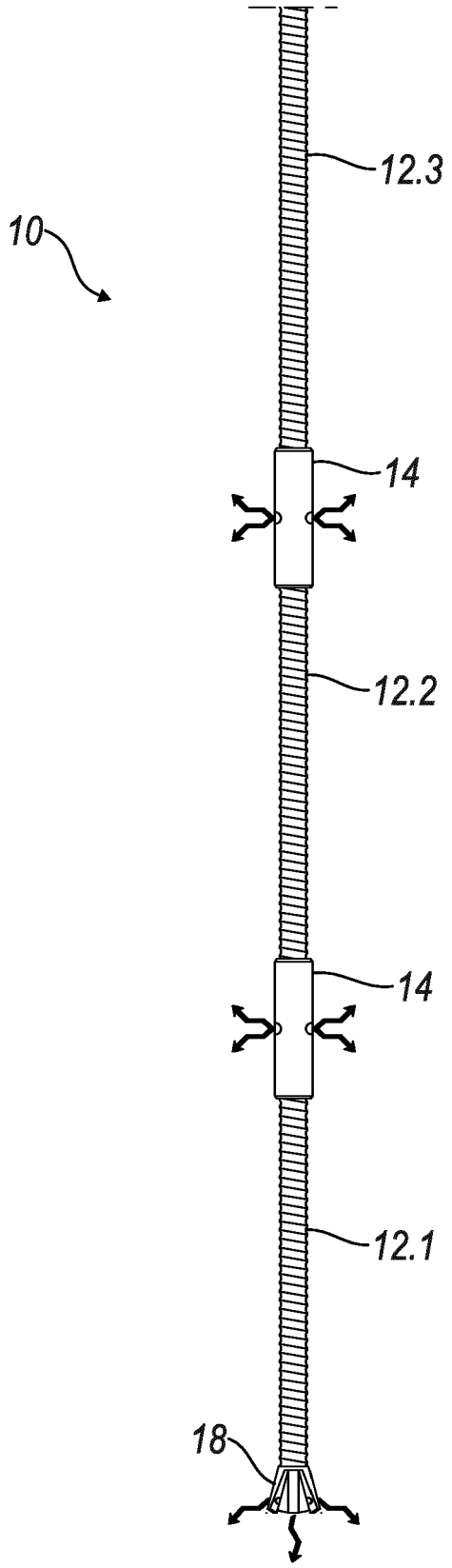

Fig. 1

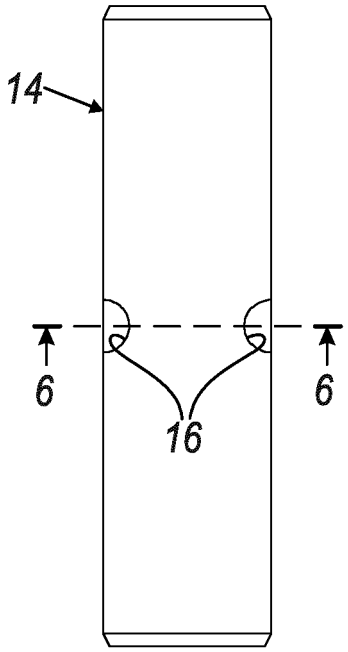

Fig. 2

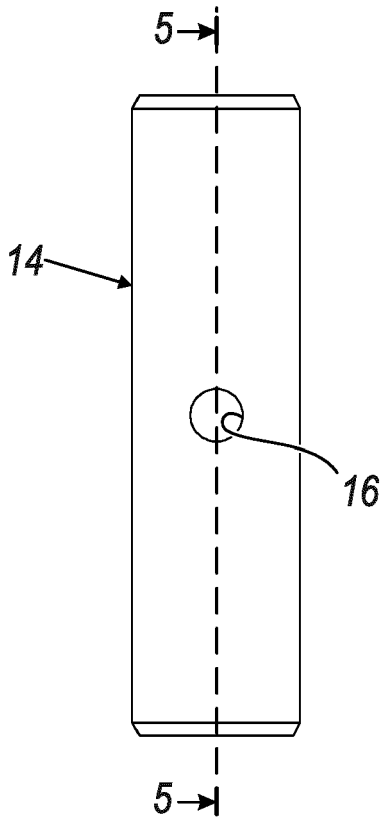

Fig. 3

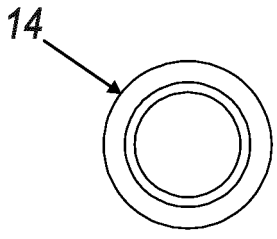

Fig. 4

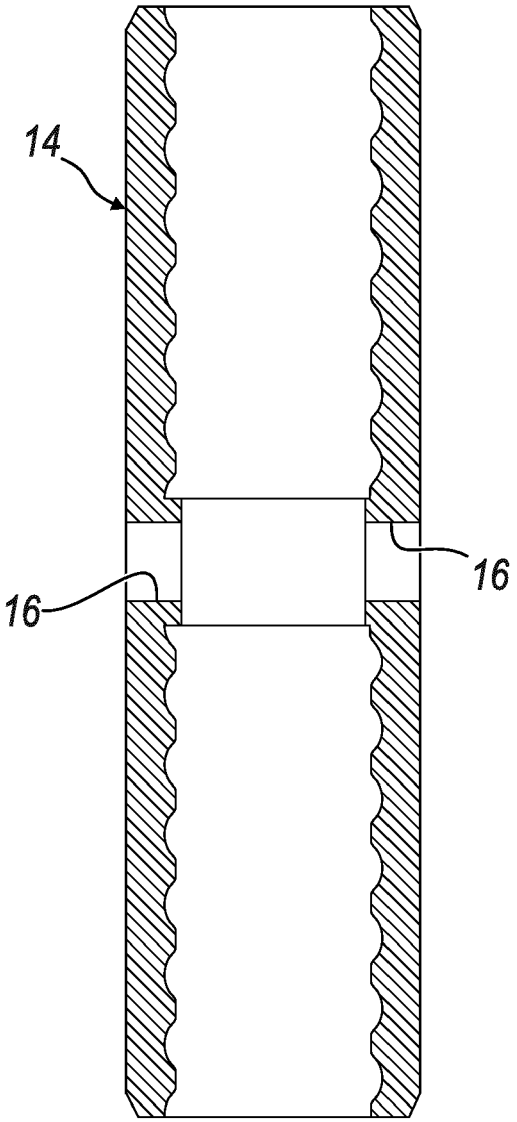

Fig. 5

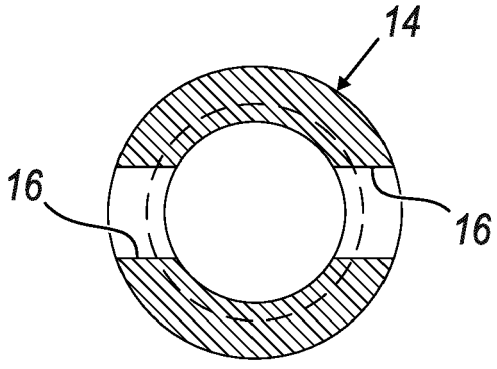

Fig. 6

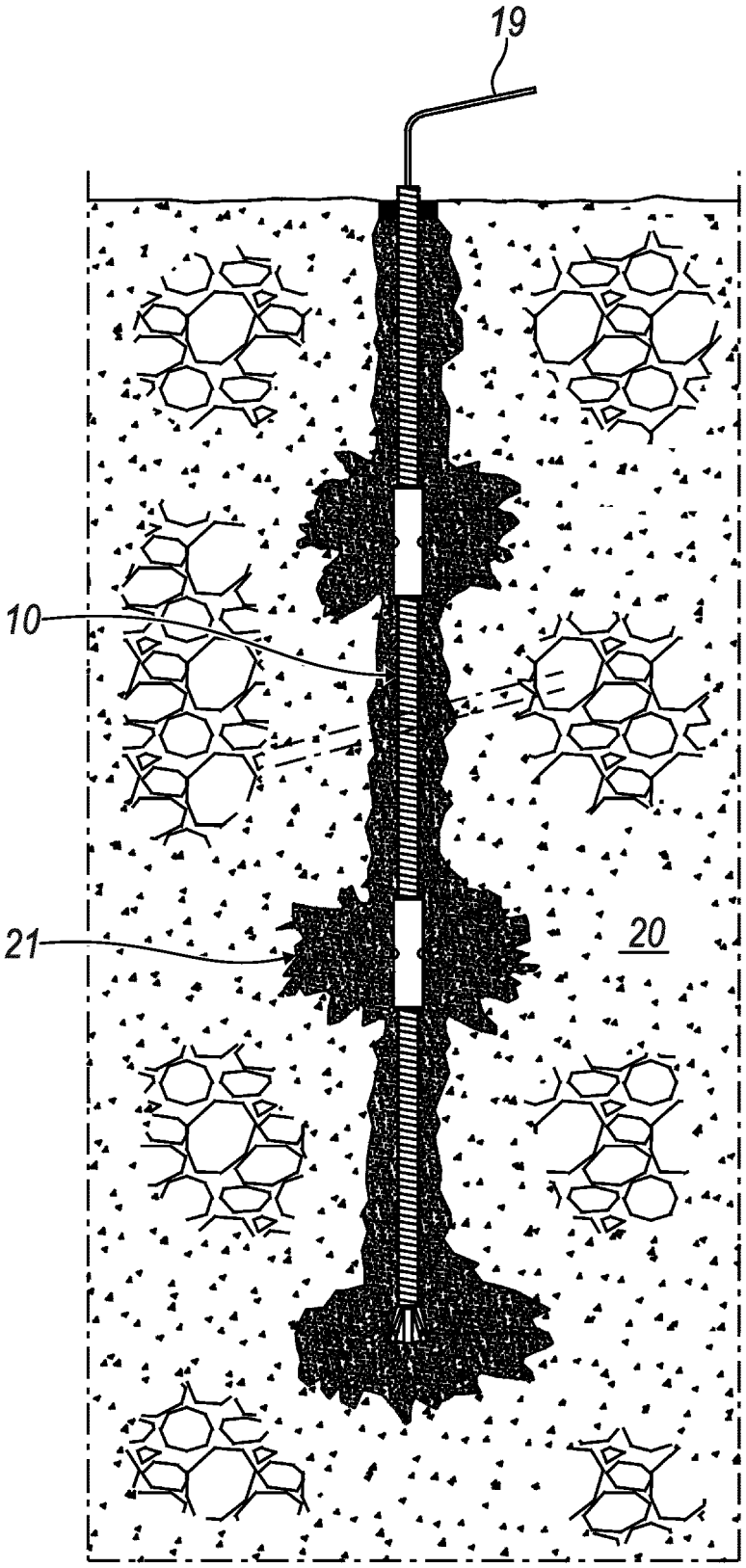

Fig. 7

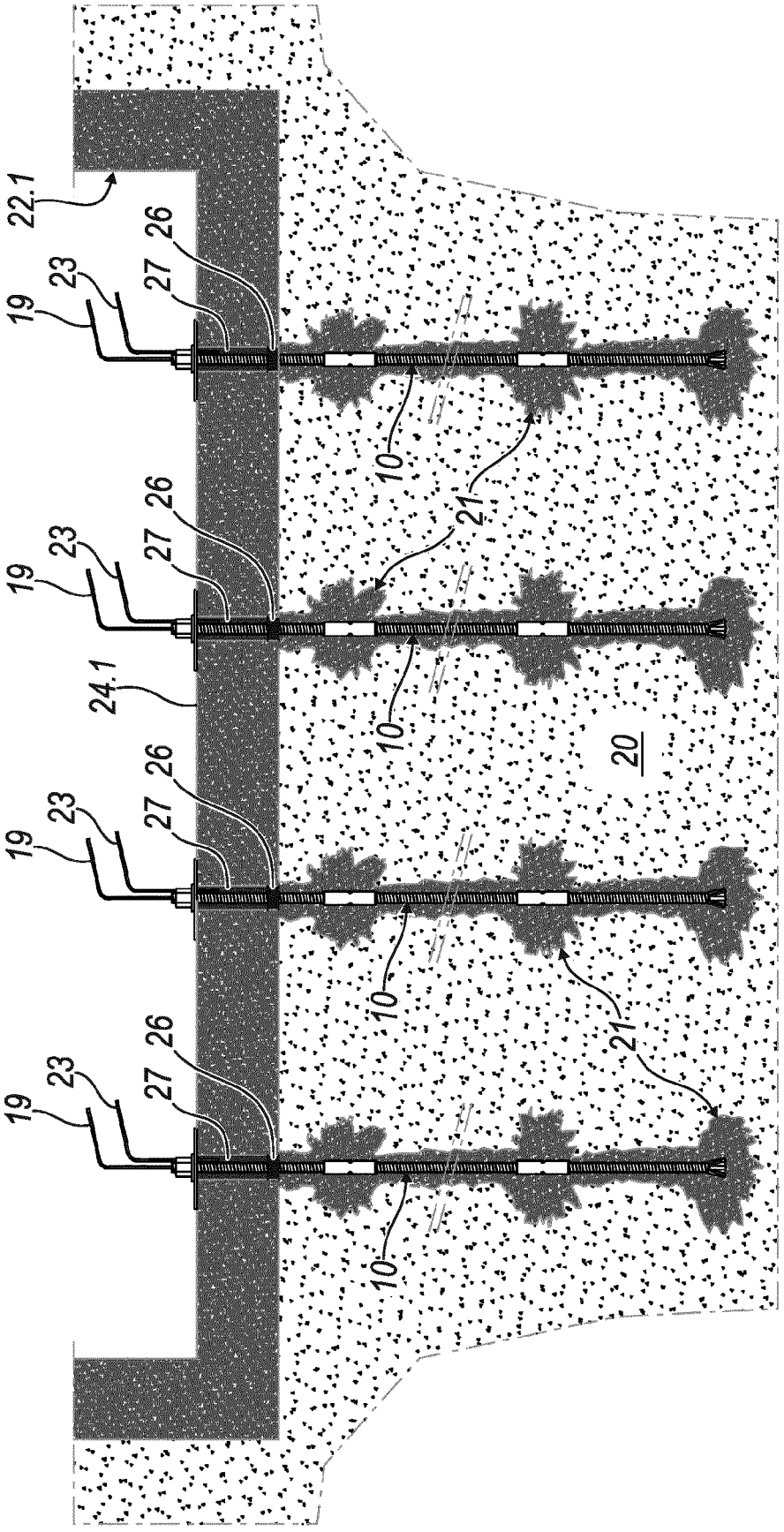

Fig. 8

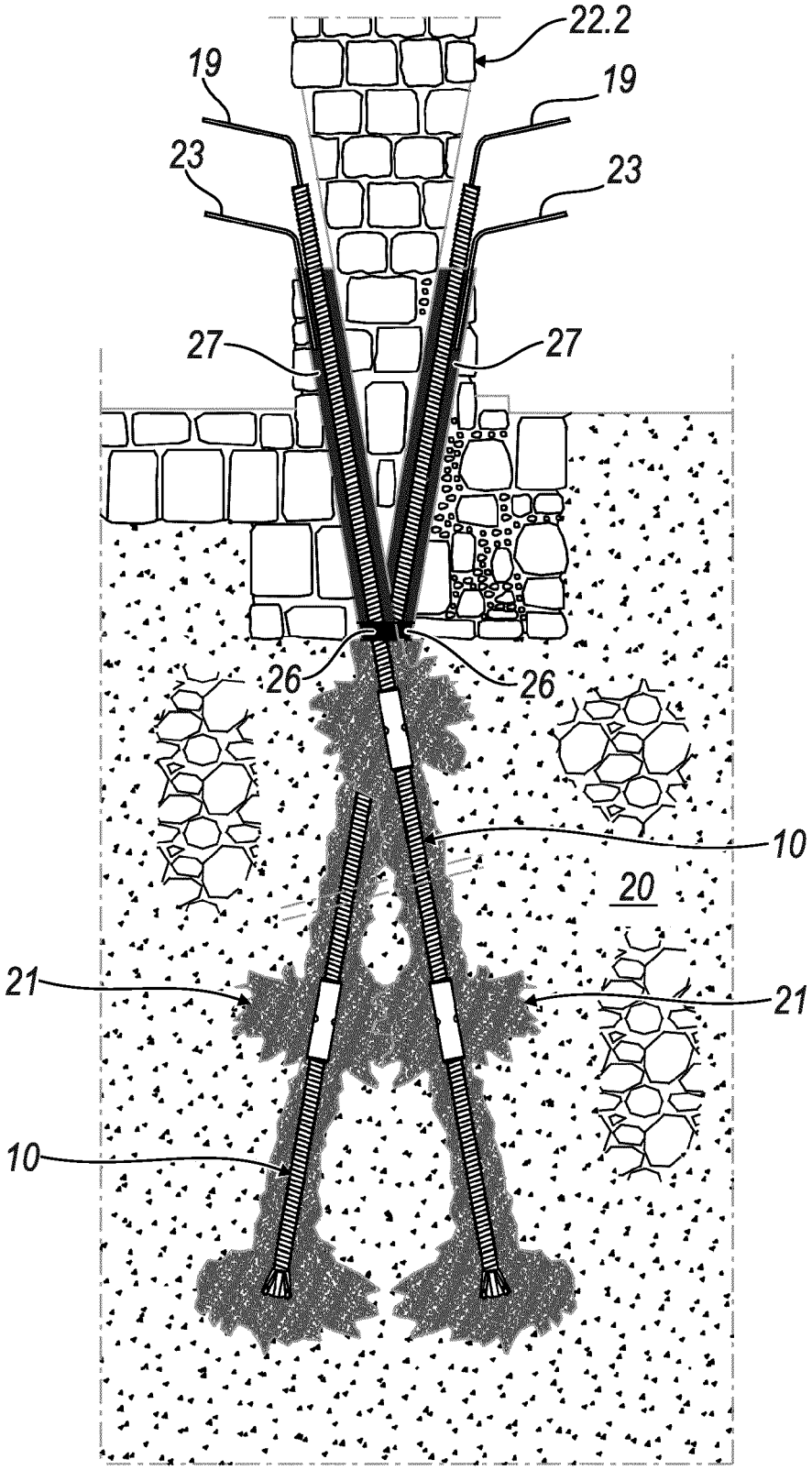

Fig. 9

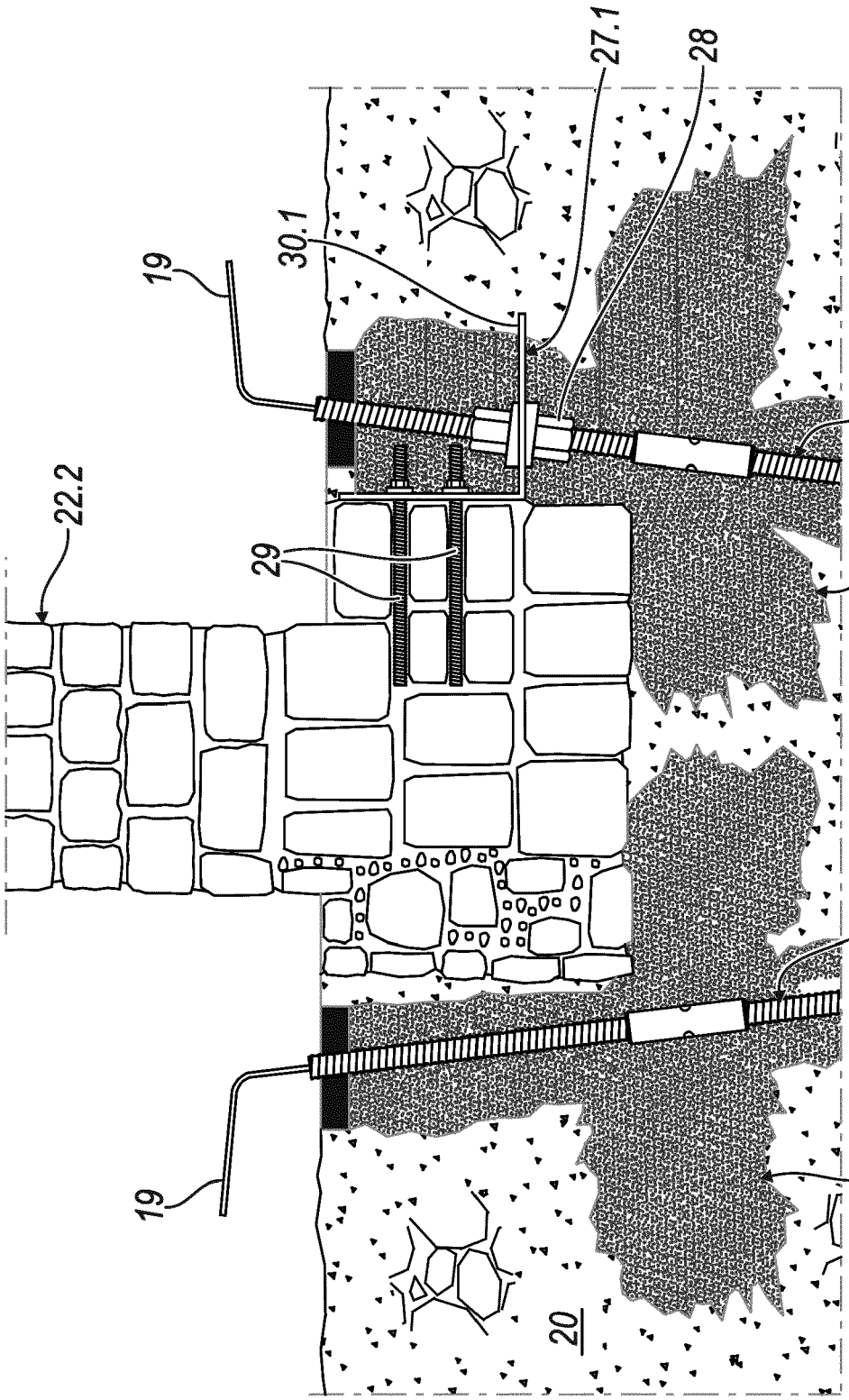

Fig. 10

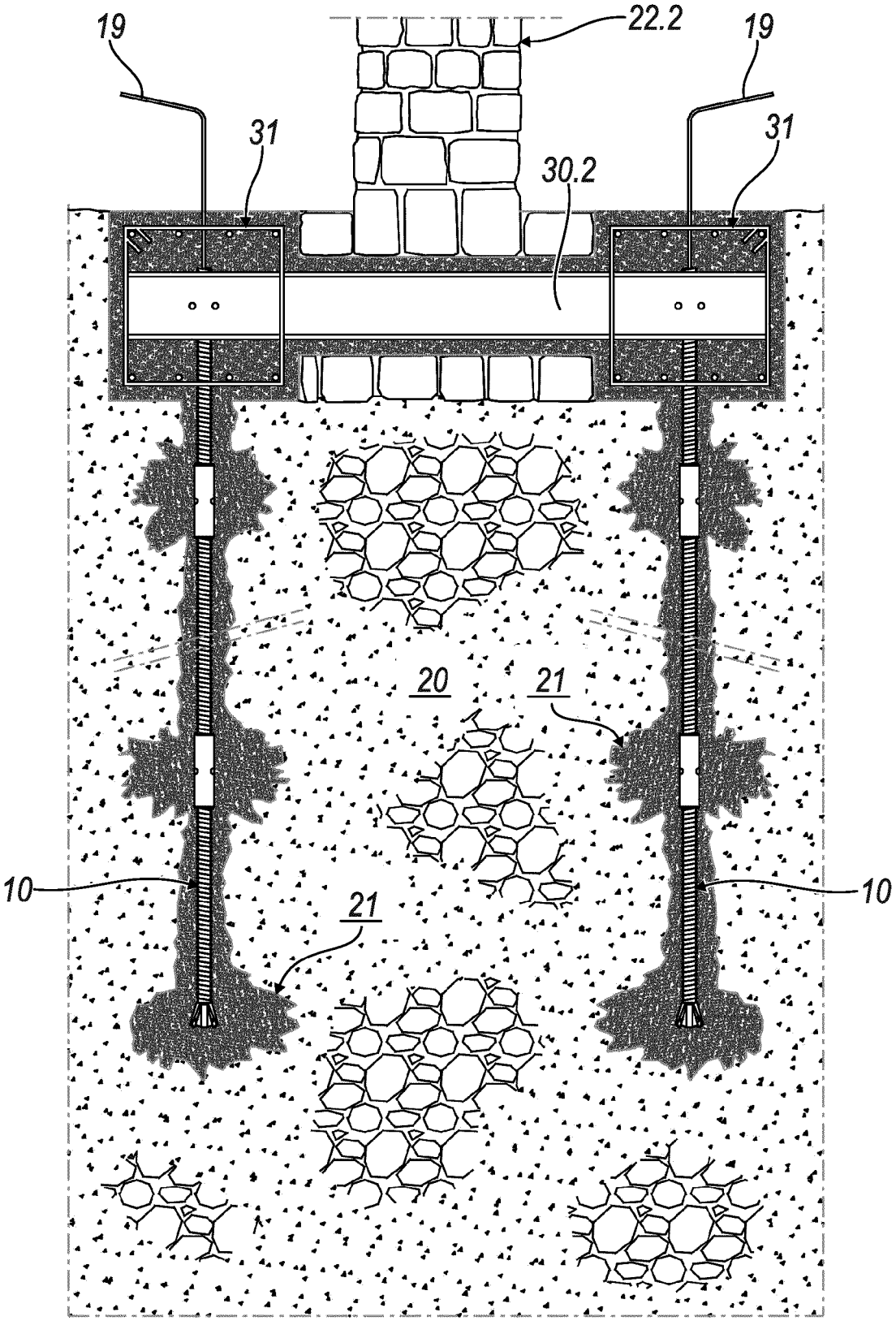

Fig. 11

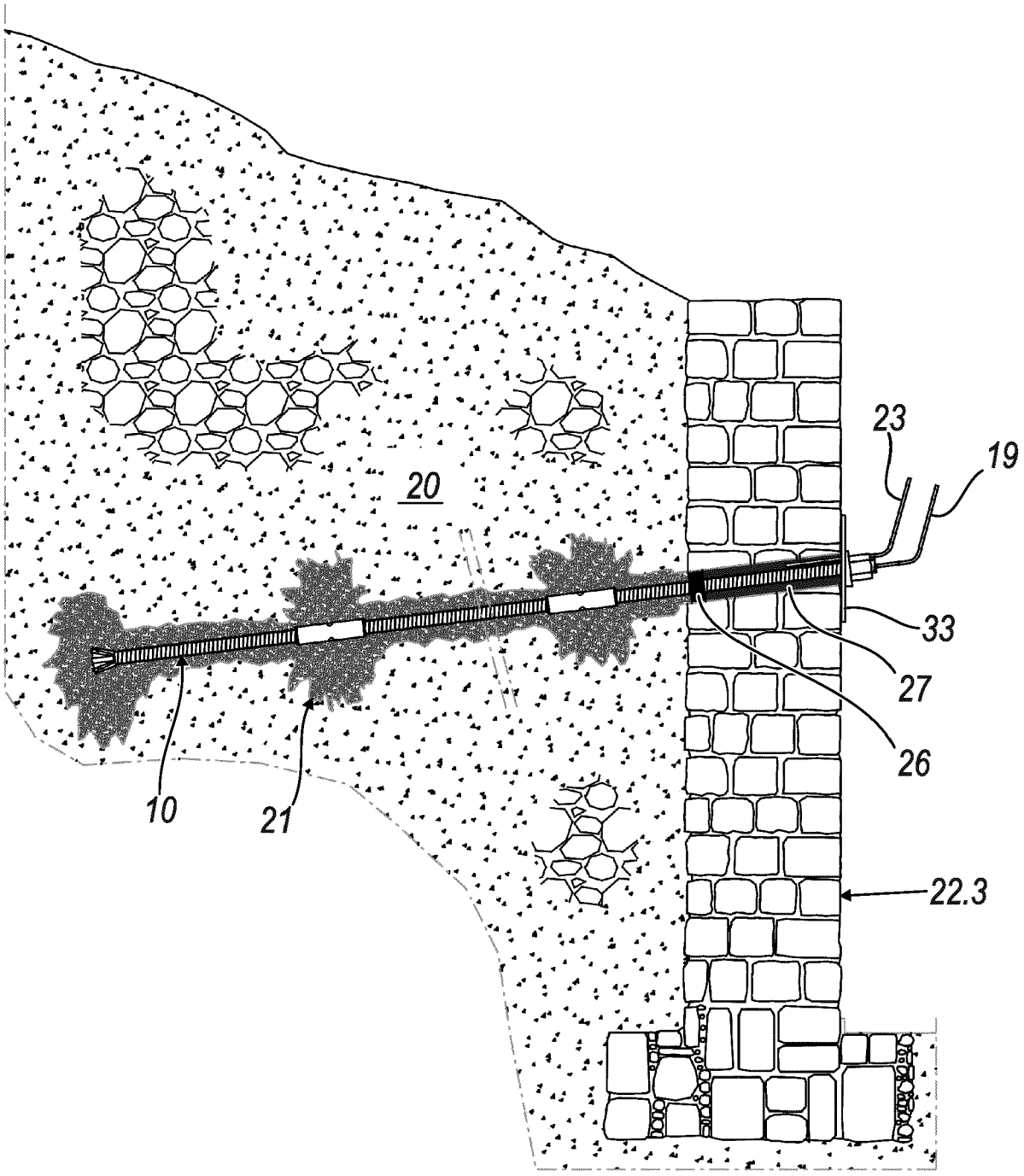

Fig. 12

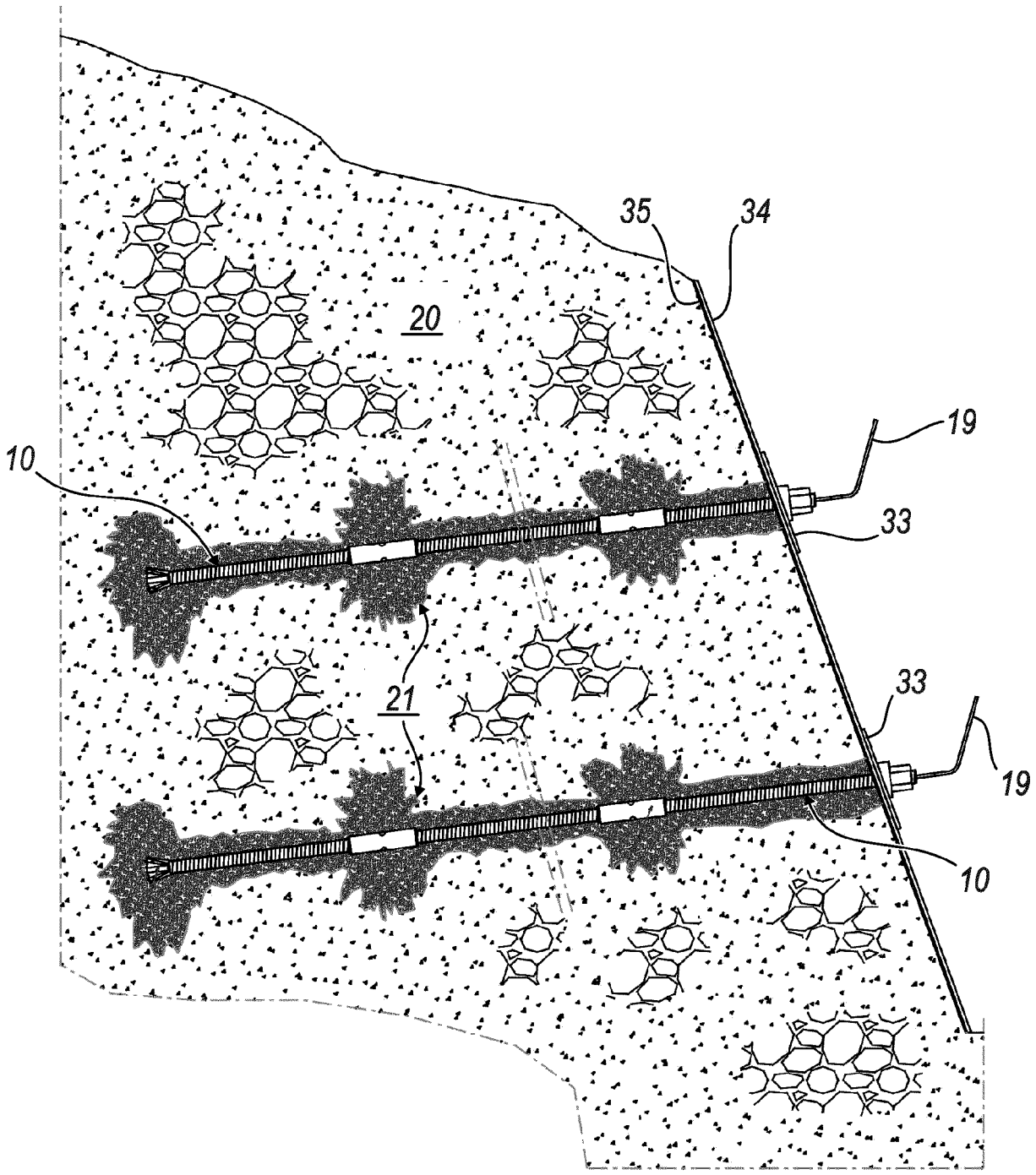

Fig. 13

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EUROPEAN SEARCH REPORT

Application Number
EP 15 20 1468

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	EP 1 719 841 A1 (MELEGARI CESARE [IT]) 8 November 2006 (2006-11-08) * the whole document * -----	1-10	INV. E02D3/12 E02D5/46 E02D15/04
A	US 6 050 337 A (MELEGARI CESARE [IT]) 18 April 2000 (2000-04-18) * the whole document * -----	1-10	

TECHNICAL FIELDS SEARCHED (IPC)

E02D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	27 April 2016	Friedrich, Albert

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 15 20 1468

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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27-04-2016

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 1719841 A1	08-11-2006	NONE	
US 6050337 A	18-04-2000	IT PC970024 A1	12-03-1999
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EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

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Patent documents cited in the description

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