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(54) A METHOD AND A SYSTEM FOR SOIL CONSOLIDATION AND/OR IMPERMEABILISATION

(57) A method for soil consolidation and/or impermeabilisation, comprising the steps of:

i) making a perforation (4) in the soil be means of a drilling rod (2);

ii) dispensing under pressure in the perforation (4), by means of said drilling rod (2):

- a fluid operating material (31) for consolidation and/or impermeabilisation; and
- a fluid accelerating material (32) for accelerating the consolidation and/or impermeabilisation;

iii) performing an extraction of the rod (2) from said perforation (4); the step of dispensing in the perforation (4) by means of said drilling rod (2) the fluid operating material (31) and the fluid accelerating material (32) occurring during the step of performing said extraction and generating a columnar volume of consolidation and/or impermeabilisation of the soil. The step of dispensing in the perforation (4) a fluid operating material (31) and a fluid accelerating material (32) comprises the step of feeding a first and a second dispenser (21, 22) formed on said rod (2) respectively with the fluid operating material (31) and the fluid accelerating material (32); the step of feeding the first and the second dispenser (21, 22) occurring while keeping the fluid operating material (31) and the fluid accelerating material (32) separate.

A system for soil consolidation and/or impermeabilisation is also disclosed.

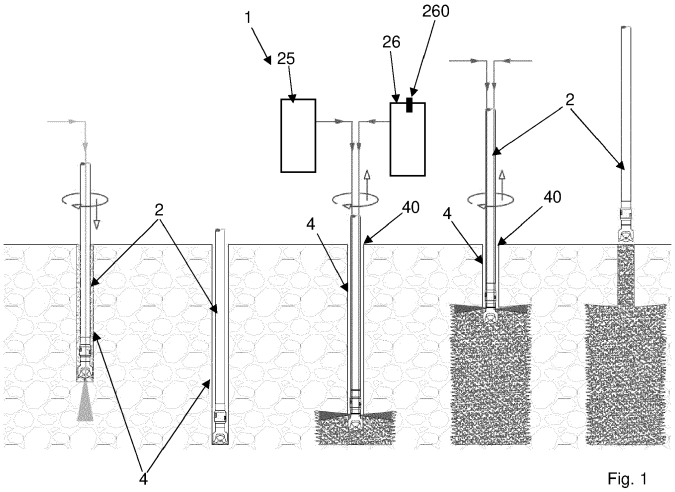

Fig. 1

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Description

[0001] The present invention relates to a method and a plant for soil consolidation and/or impermeabilisation.

[0002] In this regard, making columnar consolidation volumes in soil using the technique known as jet-grouting is well known. It involves making a perforation in the soil by means of a drilling rod and then introducing a high-pressure cement mixture through the latter which mixes with the soil, consolidating it. The dispensing of the cement mixture accompanies the extraction of the drilling rod, thereby generating the columnar volume described above. To obtain an impermeabilisation effect, several columnar volumes are made side by side, generating an envelope which defines an impermeable barrier.

[0003] In soils with abundant moving groundwater, the phenomena of run-off and impoverishment of the cement constituting the fresh column, which has not yet been consolidated, could occur. To reduce this problem, a consolidation accelerant is added to the cement mixture. The mixture thus obtained and integrating the accelerant is then withdrawn from a common tank and dispensed by the drilling rod. However, the quantity of this accelerant must be carefully dosed and cannot be in excess in order to prevent it from solidifying too quickly and blocking the extraction of the rod. An object of the present invention is to provide a method and a plant for soil consolidation and/or impermeabilisation even in soils affected by significant run-off phenomena due to the effect of moving groundwater.

[0004] In particular, an object of the present invention is to solve the technical drawbacks indicated above.

[0005] The stated technical task and specified objects are substantially achieved by a method and a plant for soil consolidation and/or impermeabilisation, comprising the technical features disclosed in one or more of the appended claims.

[0006] Further characteristics and advantages of the present invention will become more apparent from the following indicative and therefore non-limiting description of a method and a plant for soil consolidation and/or impermeabilisation as illustrated in the appended drawings, in which:

- figures 1 shows a schematic succession of five steps from left to right of the method according to the present invention;
- figure 2 shows a detail of figure 1;
- figure 3 shows a graph relating to the method according to the present invention.

[0007] An object of the present invention is a method for soil consolidation and/or impermeabilisation.

[0008] This method comprises the step of making a perforation 4 in the soil by means of a drilling rod 2 (see the first and second images from the left of figure 1).

[0009] This perforation 4 could be substantially vertical (like in figure 1) or have a horizontal extension component which is greater than the vertical component (perhaps extending upwards away from a mouth made on a front that extends between the top and the bottom). For example, to perform the soil consolidation and/or impermeabilisation in areas where tunnels are to be formed, the perforation 4 extends slightly inclined with respect to the horizontal plane.

[0010] The step of making a perforation involves removing material by means of the rod 2 which comprises an end tool (e.g. chisel, three-cone tool, hammer). The step of making a perforation may be accompanied by a dispensing of a fluid (usually air or water) through the rod 2. This facilitates the advancement of the drilling rod 2.

[0011] The method comprises the step of dispensing in the perforation 4 by means of said drilling rod 2 (see the third and fourth images from the left of figure 1):

- a fluid operating material 31 for consolidation and/or impermeabilisation; advantageously the material 31 operates by disintegrating and mixing with the soil to form a columnar volume; advantageously the material 31 is cement grout; and
- a fluid accelerating material 32 for accelerating the consolidation and/or impermeabilisation.

[0012] The fluid accelerating material 32 by reacting with the fluid material 31 facilitates the start of the curing and therefore the consolidation and/or impermeabilisation of the soil with which the material 31 is going to be mixed.

[0013] This fluid material 31 or 32 can be liquid, possibly even dense.

[0014] The dispensing indicated above occurs under pressure (there is therefore a jet for both the fluid operating material 31 and the fluid accelerating material 32).

[0015] The fluid operating material 31 and the fluid accelerating material 32 only come into contact with each other outside the rod 2. In particular, they only come into contact with each other by mixing with the soil.

[0016] The step of dispensing a fluid operating material 31 into the perforation 4 occurs by spraying the fluid material 31 at more than 350 bar (preferably between 400 and 450 bar); this jet exerts an erosive action on the surrounding soil and allows to replace the soil with a mixture of soil, material 31 and material 32. The step of dispensing the fluid accelerating material 32 into the perforation 4 occurs by spraying the fluid accelerating material 32 at a pressure comprised between 20 and 200 bar (preferably between 20 and 80 bar, advantageously at about 50 bar). Advantageously, the step of dispensing the material 31 and the material 32 described above involves rotating said rod 2 around the axis of longitudinal extension thereof. In this way the jet is directed at 360° around the rod 2. The dispensing of the fluid operating material 31 and the fluid accelerating material 32 occurs at least in part at the same time (or rather entirely at the same time).

[0017] In this way the fluid operating material 31 is

mixed with the soil. A structure of longitudinal (columnar) extension is thus formed in which the soil is consolidated and becomes substantially impermeable. The columnar shape is pseudo-cylindrical with a diameter that depends on the consistency of the soil and the dispensing energy (this energy is a function of the pressure, flow rate and dispensing time).

[0018] To obtain an impermeabilisation effect, several columnar volumes are made side by side, generating an envelope which defines an impermeable barrier.

[0019] The fluid operating material 31 typically comprises/is a cement mixture. The material 31 is a mixture comprising cementitious material, water and advantageously pre-hydrated bentonite (whose volume increases in contact with water).

[0020] The fluid accelerating material 32 comprises an active accelerant ingredient and advantageously a diluent/solvent. The diluent is typically water. The active accelerant ingredient is preferably sodium silicate (preferably sodium silicate 38/40 Be) but could be another accelerant of known type.

[0021] The method further comprises the step of performing an extraction of the rod 2 from said perforation 4.

[0022] The dispensing of the fluid operating material 31 and the fluid accelerating material 32 occurs during the step of performing said extraction. Extraction refers to the movement of the rod 2 after the completion of the step of making the perforation 4.

[0023] The step of dispensing in the perforation 4 by means of said drilling rod 2 a fluid operating material 31 and a fluid accelerating material 32 occurs at different distances from a mouth 40 of the perforation 4.

[0024] Preferably, the step of dispensing in the perforation 4 by means of said drilling rod 2 a fluid operating material 31 and a fluid accelerating material 32 occurs continuously during at least a portion of the extraction stroke of the drilling rod 2 from said perforation 4. In one particular exemplary and non-limiting solution, this portion concerns at least 20% of the extraction stroke of the rod 2 (but in some applications it may be lower and in others it may even reach 70%). A last portion of the extraction stroke occurs without dispensing the fluid operating material 31 and the fluid accelerating material 32 (vacuum perforation portion).

[0025] As mentioned above, the dispensing of the fluid operating material 31 and the fluid accelerating material 32 generates a longitudinal (columnar) volume of soil consolidation and/or impermeabilisation. Columnar volume can be understood as a column that extends substantially between the top and bottom, but also a column that extends substantially more horizontally than vertically (as if it were a lying column).

[0026] The step of dispensing in the perforation 4 a fluid operating material 31 and a fluid accelerating material 32 comprises the step of feeding a first and a second dispenser 21, 22 formed on said rod 2 respectively with the fluid operating material 31 and the fluid accelerating material 32.

[0027] The step of feeding the first and the second dispenser 21, 22 occurs while keeping the consolidation and/or impermeabilisation fluid operating material 31 and the fluid accelerating material 32 separate. There are therefore two separate and distinct feeding lines. During the step of performing an extraction of the rod 2, one of these two lines is traversed exclusively by the fluid operating material 31 and the other exclusively by the fluid accelerating material 32.

[0028] The first and the second dispenser 21, 22 dispense the fluid material under pressure. They can therefore be defined nozzles.

[0029] The first and the second dispenser 21, 22 could advantageously be arranged along the same direction and orientated with opposite dispensing directions.

[0030] Advantageously, the first and the second dispenser 21, 22 are located at the same distance from one end of the rod 2. They could be placed at a different distance, but still placed close along the longitudinal extension of the rod 2 (even if orientated along distinct directions). For example, the axial component of the distance between the first and the second dispenser 21, 22 is less than 20 cm (the axial distance is measured along the direction of longitudinal extension of the rod 2).

[0031] In a particular embodiment not illustrated, the rod 2 also comprises an additional dispenser for dispensing the fluid operating material 31. Advantageously this additional dispenser is in a diametrically opposite position with respect to the first dispenser 21. In this way the thrusts of the jets in outflow from the additional dispenser and the first dispenser 21 are compensated at least in part. In this case the second dispenser 22 may be angled at about 90° with respect to the first dispenser 21.

[0032] The method involves varying the percentage of the active accelerant ingredient in the flow rate of the fluid accelerating material 32.

[0033] Figure 3 shows the minutes of injection on the abscissa. The upper graph shows on the ordinate the percentage by volume of diluent (curve A) and active accelerant ingredient (curve B) within the flow rate of the fluid accelerating material 32. The lower graph shows on the ordinate the distance of the first and the second dispenser 21, 22 from the mouth 40.

[0034] The step of dispensing in the perforation 4, by means of said drilling rod 2, the fluid operating material 31 and the fluid accelerating material 32 comprises the sub-step of dispensing within the unit of time a quantity of said active accelerant ingredient that at least in a first position of the rod 2 is less than at least a second position of the rod 2. In particular, the flow rate of the fluid accelerating material 32 has a percentage of said active accelerant ingredient dispensed in the unit of time which is lower in the first position than in the second position. In the second position the drilling rod 2 is more extracted from said perforation 4 than in the first position. In other words, as the drilling rod 2 is extracted, the quantity of active accelerant ingredient dispensed in the unit of time increases with the aim of making the consolidation of the

consolidation and/or impermeabilisation fluid operating material 31 faster. In fact, the more the rod 2 is extracted from the perforation 4, the less time it will still have to remain inside the perforation. Therefore, the solidification time of the material dispensed by the nozzle 21 will be reduced. Instead, when much of the rod 2 is still inside the perforation 4, the rod 2 will remain inside the perforation 4 for a longer amount of time. If the solidification time is excessively reduced when the rod 2 is still very deep inside the perforation, there would be a risk that the material dispensed by the nozzle 21 moves towards the mouth 40, blocking the rod 2 and preventing its extraction. Advantageously, the step of dispensing the fluid operating material 31 and the fluid accelerating material 32 occurs during an extraction stroke of the rod 2 from the perforation 4.

[0035] By way of non-limiting example, the rod 2 assumes the first position at the beginning of said step of dispensing the fluid operating material 31 and the fluid accelerating material 32. The rod 2 assumes the second position at the end of the step of dispensing the fluid operating material 31 and the fluid accelerating material 32.

[0036] The quantity of said active ingredient dispensed in the unit of time in the second position is more than double the quantity of said active ingredient dispensed in the unit of time in the first position (see figure 3).

[0037] The step of dispensing in the perforation 4, by means of said drilling rod 2, the fluid operating material 31 and the fluid accelerating material 32 comprises the step of progressively increasing the quantity of active accelerant ingredient dispensed within the unit of time by the rod 2 during at least a predetermined portion of the extraction of the rod 2. In a particular application (see figure 1) this portion advantageously concerns more than 50% of the extraction stroke, but in alternative solutions it could also be less.

[0038] Advantageously at the beginning of the step of extracting the rod 2 from the perforation, the volume percentage of the active accelerant ingredient is about 20% (preferably between 10% and 30%) of the volumetric flow rate of the fluid accelerating material 32 (advantageously the remainder is the diluent already described above). Advantageously at the end of the step of dispensing the fluid operating material 31, the volume percentage of the active accelerant ingredient is about 60% (preferably between 50% and 70%) of the volumetric flow rate of the fluid accelerating material 32 (advantageously the remainder is the diluent already described above). In the solution exemplified in figure 3, if sodium silicate is 60% of the volumetric flow rate of the fluid accelerating material 32 and water is 40% of the volumetric flow rate of the fluid accelerating material 32, there is still about one minute remaining before the rod 2 risks being blocked.

[0039] Advantageously, the method comprises the step of collecting the fluid operating material 31 from a first tank 25 and conveying it internally to said drilling rod 2 through a first line 23 which feeds the first dispenser 21.

[0040] Advantageously, the method comprises a step of collecting the fluid accelerating material 32 from a second tank 26 and conveying it to the second dispenser 22. During at least a part of the extraction of the rod 2 the method further comprises the step of adding to the fluid accelerating material 32 present in the second tank 26 an additional quantity of the active accelerant ingredient. In this way the volume quantity of the active accelerant ingredient increases inside the dispensed fluid accelerating material 32 (which will advantageously be conveyed internally to said drilling rod 2 through a second line 24 which feeds the second dispenser 22).

[0041] An object of the present invention is also a plant 1 for soil consolidation and/or impermeabilisation. This plant 1 advantageously implements one or more steps of the method described above. This plant 1 comprises a drilling rod 2 in turn comprising a first dispenser 21 and a second dispenser 22. The first dispenser 21 and the second dispenser 22 are advantageously nozzles. The first and the second dispenser 21, 22 are located near an end of said rod (preferably located at the last 15% of the length of the rod 2).

[0042] The first and the second dispenser 21, 22 respectively cause the outflow of the fluid operating material 31 and the fluid accelerating material 32.

[0043] The plant 1 comprises a first tank 25 containing a fluid operating material 31 for soil consolidation and/or impermeabilisation. The first tank 25 is connected to the first dispenser 21. The first tank 25 and the first dispenser 21 are advantageously connected through a first line 23. The first line 23 passes at least in part inside the rod 2. Advantageously, the plant 1 comprises pumping means of the fluid operating material 31 from the first tank 25 to the first dispenser 21.

[0044] The plant 1 further comprises a dosing system of a fluid accelerating material 32 that accelerates the consolidation and/or impermeabilisation. This dosing system is connected to the second dispenser 22. This dosing system comprises a second tank 26 and means 260 for introducing an active accelerant ingredient inside the second tank 26. The means 260 for introducing the active accelerant ingredient thereby allow increasing the quantity of the active accelerant ingredient in the second tank 26. They are operated during the extraction of rod 2. The plant 1 further comprises a second line 24 connecting the dosing system of the fluid accelerating material 32 with the second dispenser 22. This second line 24 passes at least in part inside said rod 2. The plant 1 further comprises second pumping means of the fluid accelerating material 32 to the second dispenser 22. Advantageously the plant 1 may comprise a third feeding line flowing internally to the rod 2. It is used for the transit of water or air that facilitates the making of the perforation 4 by the rod 2 (first image from the left of figure 1).

[0045] The fluid accelerating material 32 and the fluid operating material 31 are of the type described above.

[0046] The present invention achieves important advantages.

[0047] Firstly, it speeds up the consolidation and/or impermeabilisation of the mixture obtained by mixing the first operating fluid 31 with the soil. This allows to reduce the run-off and impoverishment action induced by the groundwater on the cement structure, as well as counteracting the movement of the columnar volume which is being formed. In fact, the sooner the cement structure is able to consolidate, the sooner it is more resistant to the action of groundwater.

[0048] Furthermore, during the extraction of the rod 2 it is important to increase the quantity of active ingredient that accelerates the consolidation action. In this way the consolidation speed is optimised while simultaneously minimising the risk that the rod 2 can remain blocked. This risk would be particularly real if the material 31 were to consolidate too quickly when the rod is still at the bottom of the perforation (since much time must still pass before its complete extraction from the perforation). Consequently, the Applicant has sensed that by increasing the consolidation speed during extraction it is possible, on the one hand, to consolidate the columnar structure as quickly as possible and, on the other hand, to prevent the rod 2 from blocking in the perforation 4.

[0049] The invention as it is conceived is susceptible to numerous modifications and variations, all falling within the scope of the inventive concept characterising it. Furthermore, all the details can be replaced with other technically equivalent elements. In practice, all the materials used, as well as the dimensions, can be any according to requirements.

Claims

1. A method for soil consolidation and/or impermeabilisation, comprising the steps of:

   i) making a perforation (4) in the soil by means of a drilling rod (2);
   ii) dispensing under pressure in the perforation (4), by means of said drilling rod (2):

   - a fluid operating material (31) for consolidation and/or impermeabilisation which operates by disintegrating and mixing with the soil to form a columnar volume; and
   - a fluid accelerating material (32) for accelerating the consolidation and/or impermeabilisation;

   iii) performing an extraction of the rod (2) from said perforation (4); the step of dispensing in the perforation (4) by means of said drilling rod (2) the fluid operating material (31) and the fluid accelerating material (32) occurring during the step of performing said extraction and generating a soil consolidation and/or impermeabilisation;

   characterised in that said step of dispensing in the perforation (4) a fluid operating material (31) and a fluid accelerating material (32) comprises the step of feeding a first and a second dispenser (21, 22) formed on said rod (2) respectively with the fluid operating material (31) and the fluid accelerating material (32); the step of feeding the first and the second dispenser (21, 22) occurring while keeping the fluid operating material (31) and the fluid accelerating material (32) separate.

2. The method according to claim 1, **characterised in that** said fluid accelerating material (32) comprises a mixture comprising a diluent and an active accelerant ingredient; the step of dispensing the fluid operating material (31) and the fluid accelerating material (32) in the perforation (4) by means of said rod (2) comprises the sub-step of dispensing within a unit of time a quantity of said active accelerant ingredient that at least in a first position of the rod (2) is less than at least a second position of the drilling rod (2);
   in said second position the drilling rod (2) being more extracted from said perforation (4) than in the first position.

3. The method according to claim 2, **characterised in that** the step of dispensing the fluid operating material (31) and the fluid accelerating material (32) occurs during an extraction stroke of the rod (2) from the perforation (4); the rod (2) assuming the first position at the beginning of said step of dispensing the fluid operating material (31) and the fluid accelerating material (32); the rod (2) assuming the second position at the end of the step of dispensing the fluid operating material (31) and the fluid accelerating material (32); the amount of said active ingredient dispensed within a unit of time in the second position is more than double the amount of said active ingredient dispensed in the unit of time in the first position.

4. The method according to claim 1, **characterised in that** said fluid accelerating material (32) comprises a mixture comprising a diluent and an active accelerant ingredient; the step of dispensing a fluid operating material (31) and a fluid accelerating material (32) in the perforation (4) through said drilling rod (2) comprises the step of progressively increasing the amount of active accelerant ingredient dispensed within the unit of time by the rod (2) during at least a predetermined portion of the extraction of the rod (2).

5. The method according to claim 2 or 3 or 4, **characterised in that** said active accelerant ingredient is sodium silicate and said fluid operating material (31) is a cementitious material.

6. The method according to any one of the preceding claims, **characterised in that** it comprises a step of:

- collecting said fluid operating material (31) from a first tank (25) and conveying it internally to said drilling rod (2) through a first line (23) which feeds the first dispenser (21);
- collecting said fluid accelerating material (32) from a second tank (26) and conveying it internally to said drilling rod (2) through a second line (24) which feeds the second dispenser (22).

7. The method according to claim 6 when directly or indirectly dependent on claim 2 or 3 or 4 or 5, **characterised in that** it comprises, during at least a part of the extraction of the rod (2), the step of adding to the accelerating material (32) already present in the second tank (26) a further active accelerant ingredient.

8. The method according to claim 6 or 7, **characterised in that** during the step of performing an extraction of the rod (2) from the perforation (4), the first line (23) is traversed exclusively by the fluid operating material (31) and the second line (24) is traversed exclusively by the fluid accelerating material (32); the fluid operating material (31) and the fluid accelerating material (32) coming into mutual communication only downstream of the rod (2) or in output from the rod (2), mixing with the soil surrounding the rod (2).

9. The method according to any one of the preceding claims, **characterised in that** the step of dispensing the fluid operating material (31) in the perforation (4) occurs by spraying said fluid operating material (31) at more than 350 bar; the step of dispensing the fluid accelerating material (32) in the perforation (4) occurring by spraying said fluid accelerating material (32) at a pressure comprised between 20 and 200 bar.

10. A system for soil consolidation and/or impermeabilisation **characterised in that** it comprises:

- a drilling rod (2) comprising a first dispenser (21) and a second dispenser (22);
- a first tank (25) containing a fluid operating material (31) for soil consolidation and/or impermeabilisation; said first tank (25) being connected to said first dispenser (21) through a first line (23);
- a dosing system of a fluid accelerating material (32) for accelerating soil consolidation/impermeabilisation; said dosing system being connected to the second dispenser (22) through a second line (24).

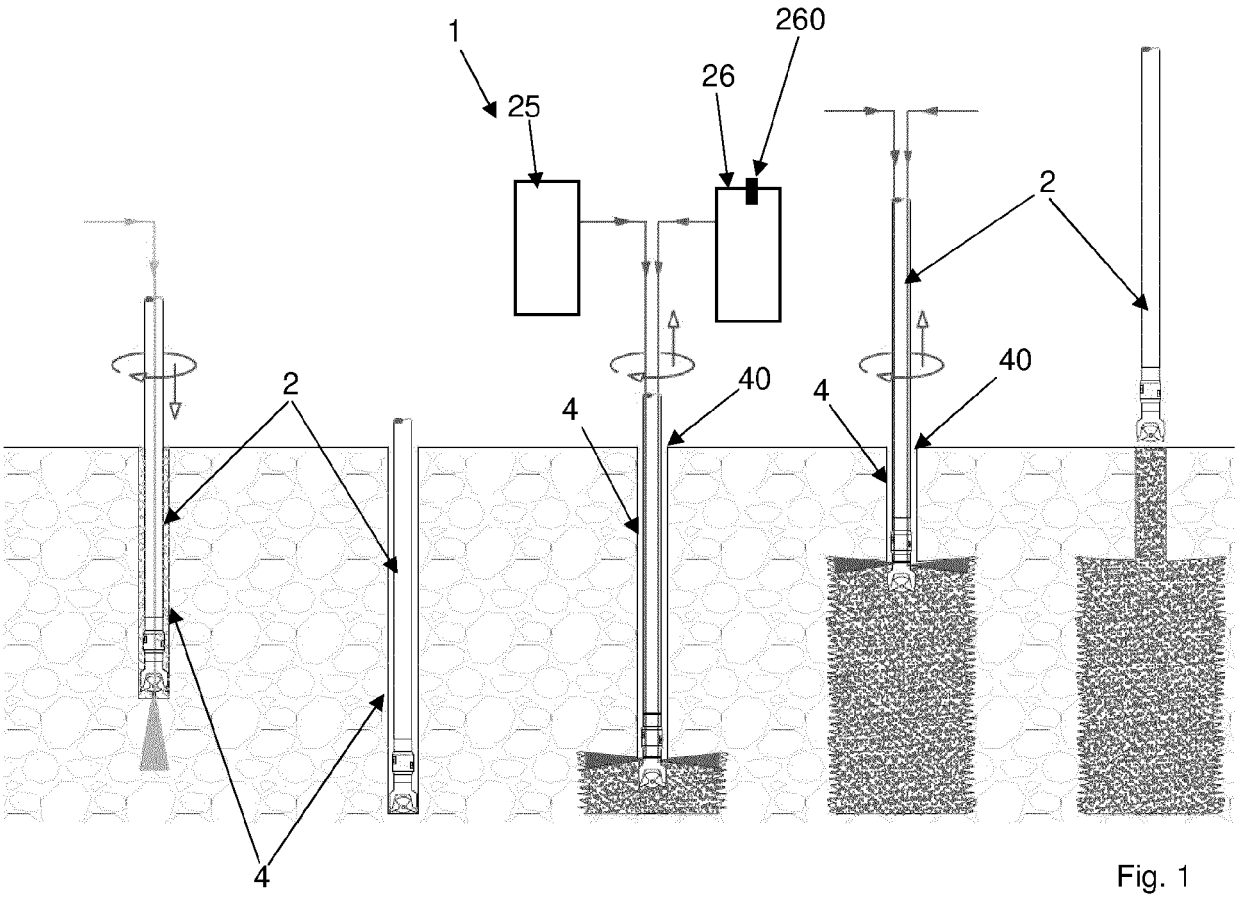

Fig. 1

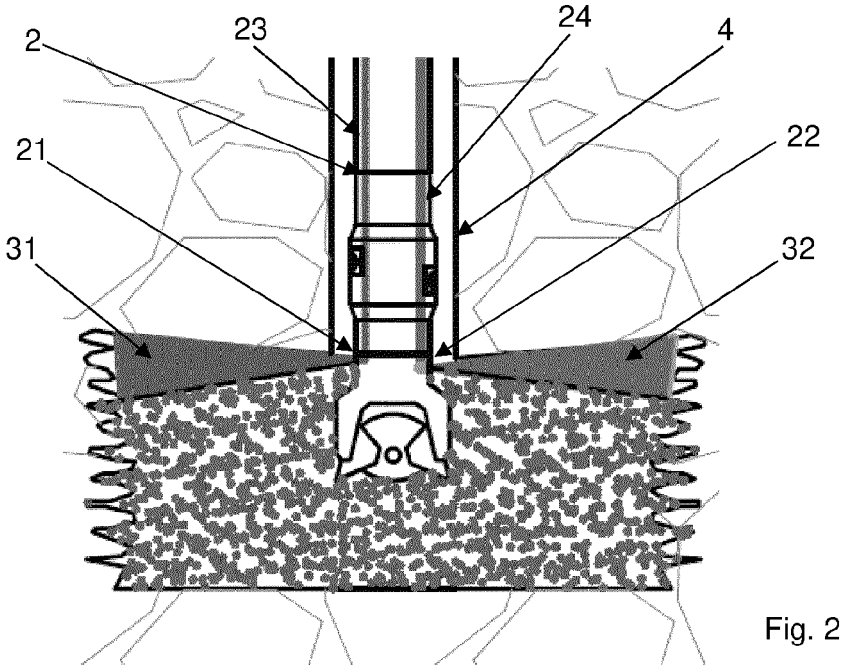

Fig. 2

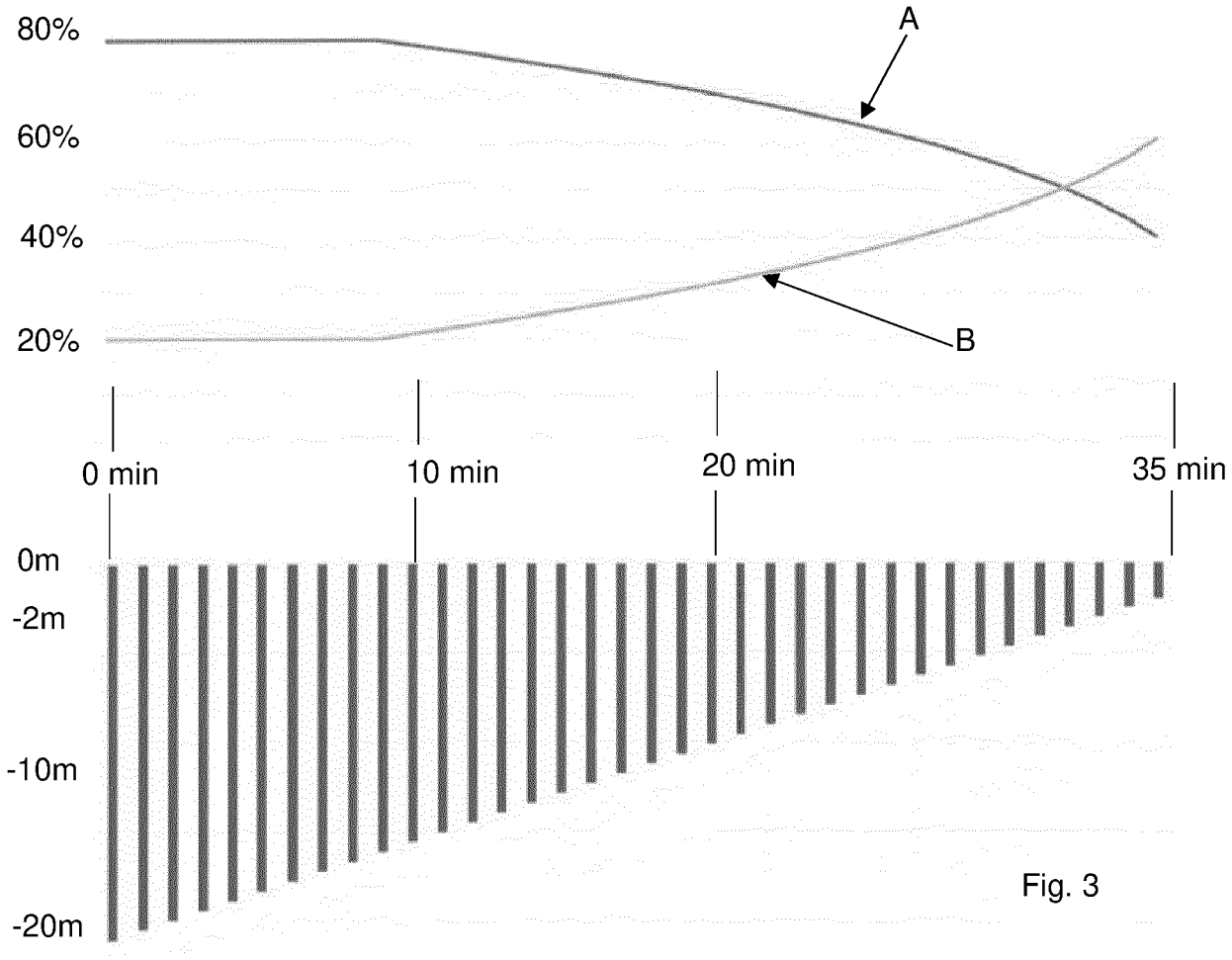

Fig. 3

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EUROPEAN SEARCH REPORT

Application Number
EP 20 17 1537

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	GB 2 062 072 A (SANWA KIZAI CO LTD) 20 May 1981 (1981-05-20)	10	INV. E02D3/12
Y	* page 1, lines 5-7; figures 1,2 * * page 1, lines 55-65 * * page 2, line 37 * * page 2, lines 72-105; claim 1 * -----	1-9	E02D5/46 E02D5/66 C09K17/00
X	WO 2016/208543 A1 (CHIDA ENG INC [JP]) 29 December 2016 (2016-12-29)	10	
Y	* figures 30,31,1,2, 5 * -----	1-9	
X	BR 8 906 248 A (PAOLO MOSIICI [BR]) 14 August 1990 (1990-08-14) * the whole document * -----	10	

TECHNICAL FIELDS SEARCHED (IPC)

E02D
C09K

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	14 September 2020	Klein, A

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 20 17 1537

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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14-09-2020

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