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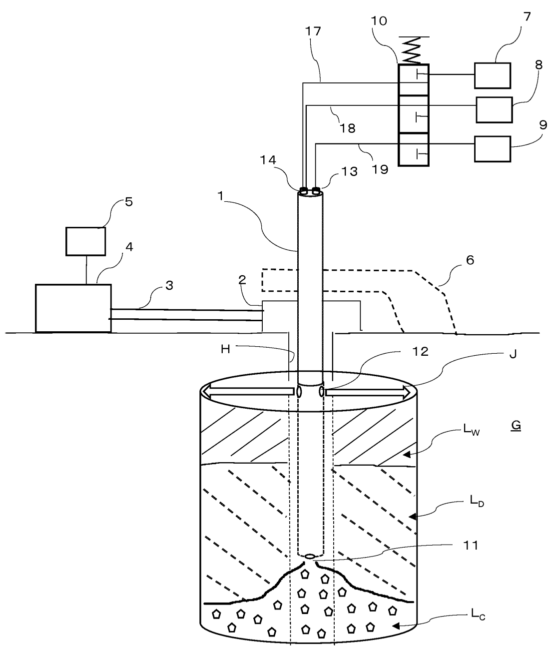
(54) GROUND IMPROVEMENT METHOD

(57) The present invention provides a method for improving ground which is capable of improving the strength or quality of an underground consolidated body formed by reducing the ratio of water to a "rich-mixed" solidification material (a cement) (W/C), assuredly carrying the solidification material from a feed source to a jet device, and reducing the amount of the solidification material treated as an industrial waste in a construction process.

The present invention was accomplished by a method for improving ground including: a step of drilling a drilling hole (H) in a ground to be improved (G);a step of moving (pulling up) a jet device (1) in a vertical direction by rotating the same while the jet device (1) is inserted into the drilling hole(H) and a fluid for cutting the ground(G) (a stable liquid or a partition forming material) is injected from the jet device (1); and a step of injecting a solidification material from the jet device (1).

Fig 1



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Description

TECHNICAL FIELD

[0001] The present invention relates to a ground improvement technology that forms an underground consolidated body by cutting (in-situ) soil in the ground to be improved and mixing water and a solidification material such as cement and agitating a mixture thereof.

BACKGROUND

[0002] A technology for forming an underground consolidated body of a cylindrical shape by drilling a drilling hole in a ground to be improved, moving (pulling up or pushing down) a jet device in a vertical direction by rotating the same while the jet device is inserted into the drilling hole and a high-pressure fluid such as water is injected in an outward radial direction from the jet device to cut an in-situ soil, and by mixing the cut soil and a solidification material such as a cement and agitating a mixture thereof by injecting or delivering the solidification material to the soil has widely been known (e.g. Patent Document 1).

[0003] In order to improve the strength (quality) of an underground consolidated body formed, it is preferable that the ratio of water to a solidification material (a cement) to be fed (W/C) be low, or the solidification material be so called "rich-mixed."

[0004] However, a lower W/C might lead to more viscosity of a mixture of water and a cement, thereby blocking a carrying passage from a cement feed source to a jet device. Thus, it is difficult to carry a solidification material to the jet device.

[0005] In addition, all of a solidification material injected from a jet device is not solidified underground and large amounts of the solidification material are discharged above the ground as a slurry. In fact, such a solidification material must be treated as an industrial waste. Also, if a solidification material is "rich-mixed" with a low W/C, large amounts of the solidification material will be treated as an industrial waste, resulting in an increase in construction costs accordingly.

[0006] From the above described reasons, use of a "lean-mixed" solidification material with a W/C of 100% or more has been essential in a prior art.

PRIOR ART DOCUMENTS

PATENT DOCUMENTS

[0007] Patent Document 1: JP-A-7-331652

SUMMARY OF THE INVENTION

PROBLEM TO BE SOLVED BY THE INVENTION

[0008] The present invention was created in view of the above situation, and has an object to provide a a method for improving ground being capable for improving the strength or quality of an underground consolidated body formed by reducing the ratio of water to a "rich-mixed" solidification material (a cement) (W/C), assuredly carrying the solidification material from a feed source to a jet device, and reducing the amount of the solidification material treated as an industrial waste.

MEANS FOR SOLVING THE PROBLEM

[0009] A method for improving ground of the present invention comprises: a step of drilling a drilling hole (H) in a ground to be improved (G); a step of moving (pulling up) a jet device (1) in a vertical direction by rotating the same while the jet device (1) is inserted into the drilling hole(H) and a fluid for cutting the ground(G) (a stable liquid or a partition forming material)is injected from the jet device (1); and a step of injecting a solidification material from the jet device (1), wherein said step of moving (pulling up) the jet device (1) in a vertical direction by rotating the same while the fluid (the stable liquid or the partition forming material) for cutting the ground(G) is injected from the jet device (1) comprises: a step of cutting the ground(G) by injecting the partition forming material; and a step of injecting a solidification material (C) while the ground(G) is cut by injecting the stable liquid after injecting the partition forming material.

[0010] The method for improving ground of the present invention preferably comprises: a step of collecting a mixture of a stable liquid discharged above the ground and a cut soil (S: slurry) by a slurry collecting structure (2); and a step of carrying the slurry (S) collected by the slurry collecting structure (2) to a slurry treating structure (4) and adding an enzyme (E: a cellulose decomposition enzyme such as "cellulase") from an enzyme feed source (5).

[0011] In addition, the method for improving ground of the present invention can be applied to purify contaminated water, which comprises: a step of drilling a drilling hole (H) in a ground to be improved (G); and a step of moving (pulling up) a jet device (1) in a vertical direction by rotating or pivoting the same while the jet device (1) is inserted into the drilling hole(H) and a fluid (a stable liquid or a partition forming material) for cutting the ground(G) is injected from the jet device (1); the fluid is injected injects zeolite from the jet device (1) in said step of moving the jet device (1) in a vertical direction.

EFFECT OF THE INVENTION

[0012] The method for improving ground of the present invention comprising the above steps can improve the strength(quality)of an underground consolidated body formed from a rich-mixed solidification material whose ratio of water to a cement (W/C) ranges from 26% to 40%, compared to the strength of an underground consolidated body formed with a conventional lean-mixed solidification material.

[0013] Herein, a solidification material (a rich-mixed solidification material whose W/C ranges from 26% to 40%) contains a high fluidity, and an increase in the viscosity of even a rich-mixed solidification material is reduced. Thus, the method for improving ground of the present invention can carry a rich-mixed solidification material by means of a pump for carrying a lean-mixed solidification material used in a prior art.

[0014] According to the present invention, if a partition forming material is injected prior to a step of cutting soil with a stable liquid, a separation layer (L_D) composed of the partition forming material is formed between a layer (L_W) of a mixture of the stable liquid and a cut soil and a layer (L_C) of a rich-mixed solidification material.

[0015] By using the separation layer (L_D: the layer composed of the partition forming material), the rich-mixed solidification material injected underground can reduce contact with the mixture of the stable liquid and the cut soil.

[0016] Therefore, only the mixture of the stable liquid and the cut soil is discharged above the ground as a slurry (S), and the rich-mixed solidification material is scarcely discharged above the ground. Specifically, the layer of the partition forming material(L_D: the separation layer) can reduce discharge of the solidification material injected underground above the ground.

[0017] Since discharge of the solidification material above the ground as a slurry (S) is reduced, the method for improving ground of the present invention can reduce the amount of a solidification material discharged above the ground as a slurry (S) in comparison with a prior art, thereby saving construction costs accordingly.

[0018] The method for improving ground of the present invention can collect a mixture of a stable liquid and a cut soil (S: slurry)ejected above the ground by including a step of collecting the slurry (S) discharged above the ground by a slurry collecting structure (2).Therefore, it is possible to prevent the slurry (S) from dispersing around a construction site and working conditions from deteriorating.

[0019] In addition, by including a step of carrying the slurry (S) collected by the slurry collecting structure (2) to a slurry treating structure (4) and adding an enzyme (E: a cellulose decomposition enzyme such as "cellulase") from an enzyme feed source (5), the slurry (S) as a mixed solution of the stable liquid and the cut soil will turn into a mixed solution of only water and soil after guar gum (a natural water-soluble polymer material) in the stable liquid is degraded by the cellulose decomposition enzyme (E). Herein, since the method for improving ground of the present invention is not required to treat a slurry as an industrial waste, if it is a mixed solution of only water and soil, it is not necessary to transport by land the slurry to a treating facility accordingly, as opposed to a prior art.

[0020] In a step of moving (pulling up) a jet device (1) in a vertical direction by rotating or pivoting the same while a fluid for cutting the ground(G)(a stable liquid or a partition forming material) is injected from the jet device (1) according to the present invention, zeolite is injected from the jet device (1) to form a zeolite layer (L_Z: a zeolite bottom slab)underground.

[0021] When said zeolite bottom slab (L_Z) is placed underground at an outflow (leakage)passage or a diffusion passage of a ground water (W_G)contaminated with a radioactive material in an adjacent facility such as a reactor building (21),the ground water (W_G)contaminated with the radioactive material that flows out or diffuses underground from the reactor building (21) or others comes into said zeolite bottom slab (L_Z) in the process of underground outflow or diffusion and passes (or transmits)said zeolite bottom slab (L_Z).

[0022] In the process of the ground water (W_G) to pass (transmit) the zeolite bottom slab (L_Z), most cesium mainly contained in the radioactive material is adsorbed by zeolite to be removed from the ground water. Consequently, the concentration of the radioactive material in the ground water that passes (transmits) said zeolite bottom slab (L_Z) is significantly reduced to a "standard value" or less. Specifically, the method for improving ground of the present invention also serves as a method for purifying ground water contaminated with a radioactive material.

BRIEF DESCRIPTION OF DRAWINGS

[0023]

Fig. 1 is a schematic view showing an embodiment of the present invention;
Fig. 2 is a process drawing showing a first step for implementing an embodiment;
Fig. 3 is a process drawing showing a step following a step shown in Fig. 2;
Fig. 4 is a cross sectional view of a jet device taken from line A-A of Fig. 3;
Fig. 5 is a process drawing showing a step following a step shown in Fig. 3;
Fig. 6 is process drawing showing a step following a step shown in Fig. 5;
Fig. 7 is a flow chart showing the procedures shown in Figs. 2 to 6;
Fig. 8 is a view showing the problem to be solved by the another embodiment of the present invention;
Fig. 9 is a schematic view showing another embodiment of the present invention; and
Fig. 10 is a process drawing showing a step of another embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0024] An embodiment of the present invention will be described with reference to the drawings.

[0025] First, an apparatus required for implementing an embodiment for the method for improving ground will be described with reference to Fig. 1.

[0026] In Fig. 1, the ground to which the method for improving ground of the present invention is applied is denoted by a symbol G. A rod-shaped jet device 1 is inserted into a drilling hole H drilled in a ground G.

[0027] Herein, a installing mechanism 6 shown by dotted line in Fig. 1 is an apparatus for inserting (installing) the jet device 1 into the drilling hole H.

[0028] The jet device 1 is a double-pipe structure (Fig. 4, not shown in Fig. 1 in detail). In Fig. 4, an inner space of an inner pipe 15 provides a flow passage for feeding a rich-mixed solidification material. An annular space between the inner pipe 15 and an outer pipe 16 provides a flow passage for feeding as table liquid or a partition forming material.

[0029] In Fig. 1, a lower end portion of the jet device 1 is provided with a discharge port 11 (a jetting port) of a solidification material. A portion which is vertically higher than the lower end portion of the jet device 1 is provided with a plurality of jetting ports 12such as nozzles (2 jetting ports in Fig. 1).

[0030] On a horizontal cross section of the jet device 1, a plurality of jetting ports 12 (2 jetting ports in Fig. 1) are disposed so as to be symmetrical with respect to the central axis in a vertical direction (not shown). A plurality of jetting ports 12 are provided to inject the stable liquid or the partition forming material.

[0031] The stable liquid and the partition forming material are not simultaneously injected from a plurality of the jetting ports 12.As shown in Figs. 5 and 6 and later descriptions, the partition forming material is injected from the jetting ports 12 prior to a step of cutting soil by injecting the stable liquid from a plurality of said jetting ports 12.

[0032] As shown in Fig. 1, a separation layer L_D composed of a mixture of the partition forming material and a cut soil is formed between a layer L_W of a mixture of the stable liquid and the cut soil and a layer L_C of a (rich-mixed) solidification material.

[0033] In Fig. 1, the separation layer L_D composed of the partition forming material is formed after a step of forming a separation layer L_D by injecting the partition forming material, and soil is cut by injecting a jet flow J of the stable liquid from the jetting ports 12.Herein, the solidification material is delivered (injected)from the discharge port 11 at a lower end of the jet device 1 to form the layer L_C of the solidification material.

[0034] In an embodiment shown in drawings, a solution containing 5% by weight of a viscosity improver such as guar gum of a natural water-soluble polymer material is injected from the jet device 1 and a plurality of the jetting ports 12 as the stable liquid to drill soil.

[0035] In an embodiment shown in drawings, the partition forming material is a solution containing 5% by weight of a viscosity improver such as guar gum of a natural water-soluble polymer material and 5% by weight of sodium silicate (water glass).The partition forming material is then injected in the soil and mixed with field soil to provide a separation layer L_D.

[0036] The solidification material is a mixture of water and a rich-mixed cement in an embodiment shown in drawings, such as a mixture whose W/C ranges from 26% to 40%.The theoretical value of W/C is determined at 26% and a lower limit. On the other hand, inventors of the present invention experimentally failed to obtain a desired strength (quality) on an underground consolidated body when W/C was over 40%.

[0037] In an embodiment shown in drawings, a high plasticizer is added to the solidification material (W/C ranges from 26% to 40%).Addition of a high plasticizer can reduce an increase in the viscosity of a rich-mixed solidification material whose W/C ranges from 26% to 40%, and it is possible to carry the rich-mixed solidification material (W/C ranges from 26% to 40%) by using a conventional pump for carrying a lean-mixed solidification material.

[0038] In an embodiment shown in drawings, 3to 7% by weight of polycarboxylic acid-based compound (e.g. Product from TAKEMOTO OIL&FAT Co., Ltd. "Chu-poru" series) is added to a cement as a high fluidity. Inventors of the present invention experimentally added 5% by weight of a polycarboxylic acid-based compound to a cement, and found that it is preferable in carrying a solidification material of an underground consolidated body.

[0039] Inventors of the present invention experimentally found that a mixture obtained by mixing 100parts by weight of a cement, 25parts by weight of water and 5parts by weight of a polycarboxylic acid-based compound and agitating a mixture thereof can be carried by using a conventional pump for carrying a lean-mixed solidification material (W/C is 100% or more).

[0040] In Fig. 1, the jet device 1 is connected to a partition forming material feed source 7 via an introduction portion 14 and a feed line 17, and connected to a stable liquid feed source 8 via the introduction portion 14 and a feed line 18. The jet device 1 is connected to a solidification material feed source 9 via the introduction portion 13 and a feed line 19.

[0041] A change-over valve 10 is placed on feed lines17, 18 and 19.By switching the change-over valve 10, the partition forming material, the stable liquid and the solidification material are each fed to the jet device 1 or feeding is quenched.

[0042] As shown in Fig. 1, formation of a separation layer L_D is completed. Soil is cut by injecting the stable liquid, and the solidification material is delivered (injected) to form a layer L_C of the solidification material. Thus, in Fig. 1, while the change-over valve 10 cuts off feeding of the partition forming material from a partition forming material feed source 7 to the jet device 1, the change-over valve 10 is at a switching position for feeding the stable liquid from the stable liquid feed source 8 to the jet device 1 and the solidification material from the solidification material feed source 9 to the jet device 1.

[0043] In place of the change-over valve 10, the partition forming material, the stable liquid and the solidification material can be controlled in feed/feed-quenching by ON-OFF control of a pump of the partition forming material feed source 7 (not shown), a pump of the stable liquid feed source 8 (not shown), a pump of the solidification material feed source 9 (not shown).

[0044] As described above, the jet device is moved(e.g. pulled up)in a vertical direction by rotating the same (i.e. rotating a inject nozzle in a injecting direction) while high-pressure water and a solidification material are injected from the jet device. In this case, a conventional method for improving ground subjects a solidification material to reverse flow above the ground as a slurry of a mixture of water, soil and a solidification material and to discharge above the ground.

[0045] On the other hand, in an embodiment shown in Fig. 1, a layer L_W of a mixture of the stable liquid and the cut soil and a layer L_C of a rich-mixed solidification material are divided by a layer L_D (a separation layer) of a mixture of the partition forming material and the cut soil. Therefore, the layer L_D of the stable liquid for cutting soil hardly mixes with the layer L_C of the rich-mixed solidification material via the separation layer L_D.

[0046] As the rich-mixed solidification material is injected and the size of the solidification material layer L_C in a vertical direction increases (becomes thick), the layer L_D (the separation layer) of the partition forming material will move upward.

[0047] Consequently, the mixture of the stable liquid and the cut soil is discharged above the ground(as a slurry), and excess of the solidification material on the solidification material layer L_C via the separation layer L_D to be discharged above the ground is reduced or removed.

[0048] Specifically, in an embodiment shown in drawings, discharge of the (rich-mixed) solidification material delivered (injected) in the soil by the layer L_D (the separation layer) of the partition forming material above the ground is reduced. Thus, in an embodiment shown in drawings, while a slurry discharged (subjected to reverse flow)above the ground contains the stable liquid and the cut soil, discharge of the solidification material above the ground as a slurry can be reduced.

[0049] Herein, the thickness of the layer L_D(the separation layer) of the partition forming material is equal to a distance L in a vertical direction between the discharge port 11 of the solidification material (the discharge port at a lower end portion of the jet device 1) and the jetting ports 12 for ejecting the stable liquid or the partition forming material (a plurality of jetting ports provided upward from the discharge port 11).

[0050] The vertical distance L between said discharge port 11 and the jetting ports 12 is defined as a thickness (the size in a vertical direction)required for dividing the layer L_W of the mixture of the stable liquid and the cut soil and the layer L_C of the rich-mixed solidification material by the separation layer L_D composed of the partition forming material and preventing the rich-mixed solidification material from mixing with the mixture of the stable liquid and the cut soil.

[0051] In an embodiment shown in drawings, the thickness L (the distance in a vertical direction) is determined at 1m.

[0052] A surface portion of the drilling hole H is provided with a slurry collecting structure 2.

[0053] In Fig. 1, a slurry is ejected above the ground via a sectional annular space between an inner wall surface of the drilling hole H and the jet device 1.

[0054] In Fig. 1, the slurry collecting structure 2 collects slurry discharged above the ground. Thus, dispersion of the slurry around a construction site and deterioration of working conditions can be prevented.

[0055] A known technology may be applied as for the slurry collecting structure 2.

[0056] Slurry collected in the slurry collecting structure 2 is fed to the slurry treating structure 4 via a slurry carrying line 3. An enzyme (a cellulose decomposition enzyme such as "cellulase") is added from an enzyme feed source 5 to the slurry fed to the slurry treating structure 4.

[0057] Herein, since a prior art shows that a slurry discharged above the ground contains a solidification material, the slurry must be treated as an industrial waste. Nevertheless, as described above with reference to Fig. 1, the slurry fed to the slurry treating structure 4 is a mixed solution of the stable liquid and the cut soil to prevent the solidification material from being contained. Therefore, in Fig. 1, when a cellulose decomposition enzyme is added to the slurry fed to a slurry treating structure 4, guar gum (a natural water-soluble polymer material) in the stable liquid is degraded by the cellulose decomposition enzyme and the slurry will turn into a mixed solution of water and soil. This type of solution does not correspond to an industrial waste, and it is thus not necessary to transport the mixed solution to an treating facility as an industrial waste.

[0058] Subsequently, with reference to Figs. 2 to 7, operational processes of the above-mentioned method for improving ground will be described.

[0059] Fig. 2 shows that a drilling hole H is drilled in a ground G to be improved. A jet device 1 is inserted into the drilling hole H.

[0060] In Fig. 2, an internal diameter D_H of the drilling hole H is larger than an external diameter of the jet device 1to be inserted. Herein, when soil of the ground G is cut with a stable liquid, a slurry is discharged (subjected to reverse flow)above the ground via a sectional annular space between an inner wall surface of the drilling hole H and an outer peripheral surface of the jet device 1. The internal diameter D_H of the drilling hole H is determined at a value so that the slurry is smoothly discharged above the ground.

[0061] The depth of the drilling hole H (L_H) is determined according to the depth of the soil to be improved.

[0062] In Fig. 3 showing a step following a step shown in Fig. 2, a rod-shaped jet device 1 is inserted into a drilling hole H. When the jet device 1 is inserted into the drilling hole H, a known installing mechanism 6 is employed.

[0063] Fig. 4 is a cross sectional view showing jetting ports 12 of the jet device 1 taken from line A-A of Fig. 3. Fig. 4 shows only the jet device 1, not a sectional view of the drilling hole H. As shown in Fig. 4, the jet device 1 is a double-pipe structure composed of an inner pipe 15 and an outer pipe 16. A solidification material flows inside the inner pipe 15, and a stable liquid or a partition forming material flows via a space between the inner pipe 15 and the outer pipe 16.

[0064] In fact, the stable liquid or the partition forming material is not simultaneously injected. Either of them is injected according to a corresponding step. An introduction portion 14 of the stable liquid or the partition forming material is connected to a plurality of jetting ports 12 via an annular space (Fig. 4) between the inner pipe 15 and the outer pipe 16 of the jet device 1 and a pipe (not shown).

[0065] Fig. 3 shows that the jet device 1 is inserted into the drilling hole H, and none of the solidification material, the stable liquid or the partition forming material are injected or delivered in the soil.

[0066] Upon injecting of the stable liquid or the partition forming material, in order to pull upwardly the jet device 1 by rotating the same on a central axis in a longitudinal direction, structures (a rotating structure and a lifting structure, not-shown in drawings) are provided in the installing mechanism 6.

[0067] In Fig. 3, a slurry collecting structure 2 provided at a surface portion of the drilling hole H is connected to an annular space between an inner wall surface of the drilling hole H and an outer peripheral surface of the jet device 1 to collect a slurry ejected above the ground. The slurry collecting structure 2 is operated by a drive mechanism (not shown).

[0068] Fig. 5 is a process drawing showing a step following a step shown in Fig. 3 and shows that a partition forming material is injected to cut a ground G. In Figs. 5 and 6, a installing mechanism 6 is not shown.

[0069] In Fig. 5, the partition forming material is introduced at an introduction portion 14 to the jet device 1 from a partition forming material feed source 7 via a change-over valve 10 and a feed line 17.The partition forming material is injected underground from a plurality of jetting ports 12in an outward radial direction as a jet flow J via an annular space (Fig. 4) between an inner pipe 15 and an outer pipe 16.

[0070] Thereafter, the jet device 1 injects the jet flow J of the partition forming material to cut the ground G, and moves (pulls up) in a vertical direction by rotating the same. Consequently, a layer L_D(a separation layer) of a mixture of the partition forming material and a cut soil is formed. As described with reference to Fig. 1, prior to a step of cutting the soil by injecting the stable liquid, the partition forming material is injected to form a separation layer L_D composed of the partition forming material so as not to mix but separate an layer L_W of a mixture of the stable liquid and the cut soil and a layer L_C of a solidification material.

[0071] As shown in Fig. 5, in a step of cutting a ground G by injecting the partition forming material, a change-over valve 10 is opened only in a feed line 17 from a partition forming material feed source 7 to the jet device 1 and closed in feed lines18 and 19 from a stable liquid feed source 8 and a solidification material feed source 9 to the jet device 1.Thus, only the partition forming material is fed to the jet device 1, and the stable liquid and the solidification material are not fed to the jet device 1.

[0072] Herein, in a step of cutting the ground G by injecting the partition forming material, a slurry as a mixture of the partition forming material and a cut soil is generated and subjected to reverse flow above the ground. Slurry subjected to reverse flow above the ground is collected by the slurry collecting structure 2.

[0073] If the jet device 1 is pulled up until the thickness of the layer L_D(the separation layer)of the partition forming material comes to a specific size L (the thickness required for dividing the layer L_W of a mixture of the stable liquid and the cut soil and a rich-mixed layer L_C of the solidification material and reducing mixture with a mixture of the stable liquid and the cut soil by the rich-mixed solidification material: 1 m in an embodiment shown in drawings), a step shown in Fig. 5 will be completed and a step shown in Fig. 6 will be started.

[0074] In a step shown in Fig. 6, the solidification material is injected while the ground G is cut by injecting the stable liquid. In a step shown in Fig. 6, while the change-over valve 10cuts off a feed line L17 from the partition forming material feed source 7 to the jet device 1, it opens a feed line L18 from the stable liquid feed source 8 to the jet device 1 and a feed line L19 from a solidification material feed source 9 to the jet device 1.

[0075] Accordingly, the stable liquid fed via the change-over valve 10 in the feed line 18 from the stable liquid feed source 8 is injected in an outward radial direction in underground from a plurality of jetting ports 12 via an annular space (Fig. 4) between an inner pipe 15 and an outer pipe 16 from an upper introduction portion 14 of the jet device 1. The solidification material is introduced into the jet device 1 from an solidification material introduction portion 13 upward from the jet device 1 via a feed line 19 and the change-over valve 10 from the solidification material feed source 9, and delivered underground from a discharge port 11 via an internal space of the inner pipe 15 (Fig. 4).

[0076] The stable liquid is injected from the jet device 1 as a jet flow J to cut a ground G. The jet device 1 is pulled up in an upward vertical direction by rotating the same.

[0077] Meanwhile, the solidification material is delivered (injected) from the discharge port 11 provided at a lower end of the jet device 1. Thereafter, an in-situ soil and the solidification material are mixed to form an underground consolidated body.

[0078] The stable liquid is injected underground from the jet device 1 to cut and agitate the ground G, and the jet device 1 is pulled up in a vertical direction by rotating the same on an axis of the jet device 1 to form the layer L_W of a mixture of the stable liquid and the cut soil. Then, the solidification material is delivered (injected) underground from the jet device 1 to form the layer L_C of the solidification material (an underground consolidated body).

[0079] As described above, since the separation layer L_D composed of the partition forming material is placed between the layer L_W of a mixture of the stable liquid and the cut soil and the layer L_C of the solidification material, mixture of the layer L_W of a mixture of the stable liquid and the cut soil and the layer L_C of the solidification material are not mixed.

[0080] As the solidification material is continuously delivered (injected) from the jet device 1 and the size of the layer L_C of the solidification material in a vertical direction increases (becomes thick), the layer of the partition forming material (the separation layer L_D) will move upward.

[0081] Thus, a slurry (a mixture of the stable liquid and the cut soil) is discharged above the ground only from an upper region of the separation layer L_D composed of the partition forming material, or the layer L_W of a mixture of the stable liquid and the cut soil. A rich-mixed solidification material in the layer L_C of the solidification material is scarcely discharged above the ground.

[0082] Since the solidification material is not discharged above the ground in a step shown in Fig. 6, a slurry collected by a slurry collecting structure 2 is enzyme-degraded by the slurry treating structure 4, and it will turn into a mixture of soil and water. Accordingly, the trouble of treating the same by using a dedicated treating facility can be saved as an industrial waste.

[0083] The step shown in Fig. 6 is continued until the layer L_C of the solidification material (the underground consolidated body) comes above the ground and a size of an underground consolidated body in a vertical direction reaches a predetermined value.

[0084] Fig. 7 is a flow chart showing steps shown in Figs. 2 to 6.

[0085] With reference to the flow chart in Fig. 7 in particular and Figs. 2 to 6, construction procedures of the embodiment shown in drawings will be described.

[0086] In Fig. 7, in step S1, a change-over valve 10 is switched to open only a feed line 17 from a partition forming material feed source 7 to the jet device 1, and a feed line 18 from a stable liquid feed source 8 and a feed line 19 from a solidification material feed source 9 are closed to feed a partition forming material to the jet device 1.Then, while a partition forming material is injected underground from jetting ports 12, the jet device 1 is pulled up in a vertical direction by rotating the same, thereby forming a separation layer L_D composed of the partition forming material. Thereafter, the process proceeds to step S2.

[0087] In stepS2, whether the thickness of the separation layer L_D composed of the partition forming material reaches a required thickness (a size in a vertical direction L: predetermined size) or not is determined. In other words, in stepS2, whether the amount of pulling up the jet device 1 is a predetermined size L or more or not is determined.

[0088] If the amount of pulling up the jet device 1 (the thickness of the separation layer L_D) is less than the thickness L required for the separation layer L_D(step S2 is determined "NO"), the process will return to step S1 to continue a step of injecting the partition forming material and cutting the ground G to form the separation layer L_D.

[0089] On the other hand, the amount of pulling up the jet device 1 (the thickness of the separation layer L_D)is the thickness L required for the separation layer L_D or more (step S2 is determined "YES"), the process will proceed to step S3.

[0090] In stepS3, the change-over valve 10 is switched to close a feed line 17 from a partition forming material feed source 7 to the jet device 1 and to open a feed line 18 from a stable liquid feed source 8 to the jet device 1 and a feed line 19 from a solidification material feed source 9 to the jet device 1.Accordingly, injecting of the partition forming material is quenched, and the stable liquid is injected in a horizontal direction to deliver a solidification material.

[0091] Thereafter, the jet device 1 is pulled up in a vertical direction by rotating the same while the stable liquid is injected to cut the ground G. At the same time, the solidification material is delivered (injected) from a discharge port 11 provided at a lower end of the jet device 1, and it is mixed with a cut in-situ soil to form an underground consolidated body.

[0092] A slurry (a mixed fluid of the stable liquid and the cut soil) generated in step S3 is collected above the ground by using a collecting structure 2, carried to a slurry treating structure 4 by using a slurry carrying line 3, and an enzyme is added from an enzyme feed source 5 in the slurry treating structure 4 to provide a mixed solution only composed of water and soil. Therefore, it is not necessary to transport the same to a treating facility as an industrial waste.

[0093] Then, the process will proceed to step S4.

[0094] In stepS4, whether a layer L_C of the solidification material reaches above the ground so that the size of an underground consolidated body in a vertical direction is a desired size to complete the formation of an underground consolidated body or not is determined.

[0095] If the layer L_C of the solidification material (the underground consolidated body)does not reach a desired thickness and the formation of the underground consolidated body is not completed (step S4 is determined "NO"), the process will return to step S3 to continue a step of delivering (injecting) the solidification material while the stable liquid is injected to cut the ground G.

[0096] If the layer L_C of the solidification material reaches a desired size in a vertical direction and the formation of the underground consolidated body is completed (step S4 is determined "YES"), the process will proceed to step

S5.

[0097] In stepS5, a change-over valve 10 is switched to close a feed line 18 from a stable liquid feed source 8 to the jet device 1 and a feed line 19 from a solidification material feed source 9 to the jet device 1 to quench the feeding of a stable liquid and a solidification material to the jet device 1.

[0098] In addition, an operation for rotating the jet device 1 and an operation for pulling up the same above the ground at a predetermined speed are quenched.

[0099] Since a passage from the partition forming material feed source 7 to the jet device 1 is closed in step S3, the partition forming material is not fed by the jet device 1 even in step S5.

[0100] Thereafter, operations of a slurry collecting structure 2, a slurry carrying line 3 and a slurry treating structure 4 are quenched, and the process will proceed to step S5 to complete the operations.

[0101] According to the embodiment shown in drawings, use of a rich-mixed solidification material (C) whose ratio of water to a cement (W/C) ranges from 26% to 40% can improve the strength (quality) of an underground consolidated body formed, compared to a solidification material of a conventional lean-mixed solidification material (W/C is 100% or more).

[0102] Herein, since a solidification material (C: a rich-mixed solidification material whose W/C ranges from 26% to 40%) contains a high fluidity, an increase in the viscosity of the solidification material (C) is reduced, and it can be carried by using a conventional solidification material carrying pump (a pump for carrying a lean-mixed solidification material in a prior art).

[0103] In the embodiment shown in drawings, a step S1 for injecting the partition forming material to form a separation layer L_D composed of the partition forming material is implemented prior to step S3 for cutting soil with a stable liquid, a layer L_W of a mixture of the stable liquid and the cut soil and a rich-mixed layer L_C of the solidification material are divided by a separation layer L_D. Accordingly, contact of a rich-mixed solidification material with a mixed fluid of the stable liquid and the cut soil(a mixed liquid comprising a layer L_W) is reduced, and only a mixed fluid of the stable liquid and the cut soil(a mixed liquid composed of a layer L_W) is discharged above the ground as a slurry. Therefore, since the rich-mixed solidification material is scarcely discharged above the ground, consumption of the solidification material can be reduced compared to a conventional level.

[0104] Furthermore, in the embodiment shown in drawings, since a mixture of the stable liquid and the cut soil discharged above the ground is collected by a slurry collecting structure 2, no contamination around a construction site from a slurry ejected above the ground is found.

[0105] The slurry collected by the slurry collecting structure 2 (a mixture of the stable liquid and the cut soil) is carried to a slurry treating structure 4 to add a cellulose decomposition enzyme from an enzyme feed source 5, thereby turning the slurry into a mixed solution of only water and soil as non-industrial waste. Thus, it is not necessary to transport the same to a treating facility, which can save costs for treating a slurry.

[0106] Herein, diffusion of ground water contaminated with a radioactive material (e.g. around a reactor building) has recently become a problem in society. Another embodiment as opposed to the ones described in Figs. 1 to 7 is capable of solving the problem.

[0107] Herein, with reference to Fig. 8, the above described problem (diffusion of ground water contaminated with a radioactive material) will be described.

[0108] In Fig. 8, in cases where a ground water WG1contaminated with a radioactive material from a reactor building 21 (including a storage facility for a radioactive material and ground water: the same as above) flows out (leaks) in the ground G, a continuous wall 22 (e.g. a frozen soil wall) is formed so as to surround the reactor building 21.Specifically, the flow of the ground water WG1 containing a radioactive material subjected to outflow and diffusion underground from the reactor building 21 is cut off by using the continuous wall 22. Accordingly, outflow and diffusion of the ground water WG1contaminated to the outside thereof through the frozen soil wall 22 is prevented.

[0109] A symbol 23 in Fig. 8 represents a device for forming a frozen soil wall.

[0110] However, use of only the continuous wall 22 fails to prevent diffusion of the contaminated ground water WG2 subjected to outflow (leakage) underground in a direction just below the reactor building 21 from the same.

[0111] As obviously shown in Fig. 8, this is because that the flow of the contaminated ground water WG22 running underground more deeply than the continuous wall 22 cannot be prevented.

[0112] An embodiment for solving the problem will be described with reference to Figs. 9 and 10.

[0113] As shown in Fig. 9, according to the construction method of an embodiment shown in Figs. 1 to 7, a layer of zeolite (L_Z: a zeolite bottom slab) extending in a horizontal direction is formed in the ground G and below the reactor building 21.

[0114] The thickness B of the zeolite bottom slab L_Z, while the ground water WG2contaminated with the radioactive material passes (transmits) the zeolite bottom slab L_Z, is determined at a value so that cesium contained in the ground water WG2 can sufficiently be adsorbed by zeolite of the zeolite bottom slab L_Z. The thickness depends on the degree of contamination and several working conditions.

[0115] In addition, the range of the zeolite bottom slab L_Z in a horizontal direction is determined so that passages for outflow and diffusion of the ground water WG2 contaminated with the radioactive material subjected to outflow (leakage) from the from reactor building 21 can assuredly pass the zeolite bottom slab L_Z.

[0116] When the zeolite bottom slab L_Z shown in Fig.

9 is formed, the ground water WG2 subjected to outflow (leakage) and diffusion underground in a direction just beneath the reactor building 21 from the same passes the zeolite bottom slab L_Z to adsorb and remove cesium. This is because zeolite has a chemical property of adsorbing cesium as a main component of the radioactive material. Herein, since cesium is a major component of the radioactive material, and if cesium can be removed, the radioactive material concentration in the ground water WG2 is reduced to a safety value (or a standard value or less).

[0117] The ground water WG1 running upward from the zeolite bottom slab L_Z is cut off by a continuous wall 22, resulting in no diffusion.

[0118] In order to prevent diffusion of the contaminated ground water WG2, the continuous wall 22 and the zeolite bottom slab L_Z are connected to each other.

[0119] According to similar procedures of embodiments shown in Figs. 1 to 7, Fig. 10 shows formation of the zeolite bottom slab L_Z extending in a horizontal direction.

[0120] As shown in Fig. 10, a step of drilling a drilling hole H in the ground G and a step of moving (pulling up) a jet device 1 in a vertical direction by rotating the same while a fluid (a partition forming material) for cutting the ground G is injected from the jet device 1 are the same as those shown in Figs. 1 to 7.

[0121] The jet device 1 injects a jet flow J of the partition forming material to cut the ground G, and pulled up in an upward vertical direction by rotating the same. Like in the embodiments in Figs. 1 to 7, a layer L_D (a separation layer) of a mixture of the partition forming material and a cut soil is formed.

[0122] In a step shown in Fig. 10, zeolite is delivered underground from a discharge port 11 provided at a lower end of the jet device 1, in place of a solidification material according to embodiments shown in Figs. 1 to 7.

[0123] Since the separation layer L_D is placed in this process, the zeolite delivered does not mix with a stable liquid injected from discharge ports12 and a cut soil by a jet flow of a stable liquid to form a zeolite bottom slab L_Z extending in a horizontal direction.

[0124] In other words, by pulling up the jet device 1 in a vertical direction by rotating the same on an axis thereof while the stable liquid is injected underground from the jet device 1 to cut and agitate the ground G, like in the embodiments shown in Figs. 1 to 7, a layer L_W of a mixture of the stable liquid and the cut soil and the layer L_D (the separation layer) of a mixture of the partition forming material and the cut soil are formed. Thereafter, by delivering (injecting) zeolite underground from the jet device 1, a layer L_z of zeolite (a zeolite bottom slab) is formed.

[0125] Since the separation layer L_D composed of the partition forming material is placed between the layer L_W of a mixture of the stable liquid and the cut soil and the layer Lz of the zeolite (the zeolite bottom slab), mixture of the stable liquid of and the cut soil in the layer L_W with the layer L_z of zeolite (the zeolite bottom slab) is reduced, thereby maintaining a separate situation.

[0126] A step shown in Fig. 10 is continued until the layer L_z of zeolite (the zeolite bottom slab) has a predetermined depth at a predetermined position (depth) in a vertical direction underground.

[0127] A cross sectional shape of the layer L_z of zeolite (the zeolite bottom slab) (i.e. the range of the zeolite bottom slab L_Z in a horizontal direction) is circular like in the embodiments shown in Figs. 1 to 7. However, the shape of the zeolite bottom slab L_Z can be non-circular (e.g. a semicircle or a sector) in case contaminated water is diffused.

[0128] It must be stated that the present invention is not restricted by the description of the embodiments shown in drawings. The embodiments shown in drawings are merely examples so that any embodiments composed of substantially the same technical concept as disclosed in the claims of the present invention and expressing a similar effect are included in the technical scope of the present invention.

EXPLANATION OF LETTERS OR NUMERALS

[0129]

1	Jet device
2	Slurry collecting structure
3	Slurry carrying line
4	Slurry treating structure
5	Enzyme feed source
6	Installing mechanism
7	Partition forming material feed source
8	Stable liquid feed source
9	Solidification material feed source
10	Change-over valve
11	Discharge port
12	Jetting port
13	Solidification material introduction portion
14	Stable liquid introduction portion and partition forming material introduction portion
15	Inner pipe (jet device)
16	Outer pipe (jet device)
17	Pipe
G	Ground
H	Drilling hole
L_C	Layer of solidification material
L_D	Layer of partition forming material(separation layer)
L_W	Layer of mixture of stable liquid and cut soil
21	Reactor building
22	Continuous wall
WG1, WG2	Contaminated ground water
L_Z...Layer	of zeolite (zeolite bottom slab)

Claims

1. A method for improving ground comprising:

a step of drilling a drilling hole in a ground to be improved;

a step of moving a jet device in a vertical direction by rotating the same while the jet device is inserted into the drilling hole and a fluid for cutting the ground is injected from the jet device; and

a step of injecting a solidification material from the jet device, wherein said step of moving the jet device in a vertical direction by rotating the same while the fluid for cutting the ground is injected from the jet device comprises:

a step of cutting the ground by injecting the partition forming material; and

a step of injecting a solidification material while the ground is cut by injecting the stable liquid after injecting the partition forming material.

2. The method according to claim 1, wherein the method for improving ground comprising:

a step of collecting a mixture of a stable liquid discharged above the ground and a cut soil by a slurry collecting structure; and

a step of carrying the slurry collected by the slurry collecting structure to a slurry treating structure and adding a decomposition enzyme from an enzyme feed source.

3. A method for improving ground comprising:

a step of drilling a drilling hole in a ground to be improved; and a step of moving a jet device in a vertical direction by rotating the same while the jet device is inserted into the drilling hole and a fluid for cutting the ground is injected from the jet device, wherein said step of moving the jet device in a vertical direction while the fluid is injected injects zeolite from the jet device.

Fig 1

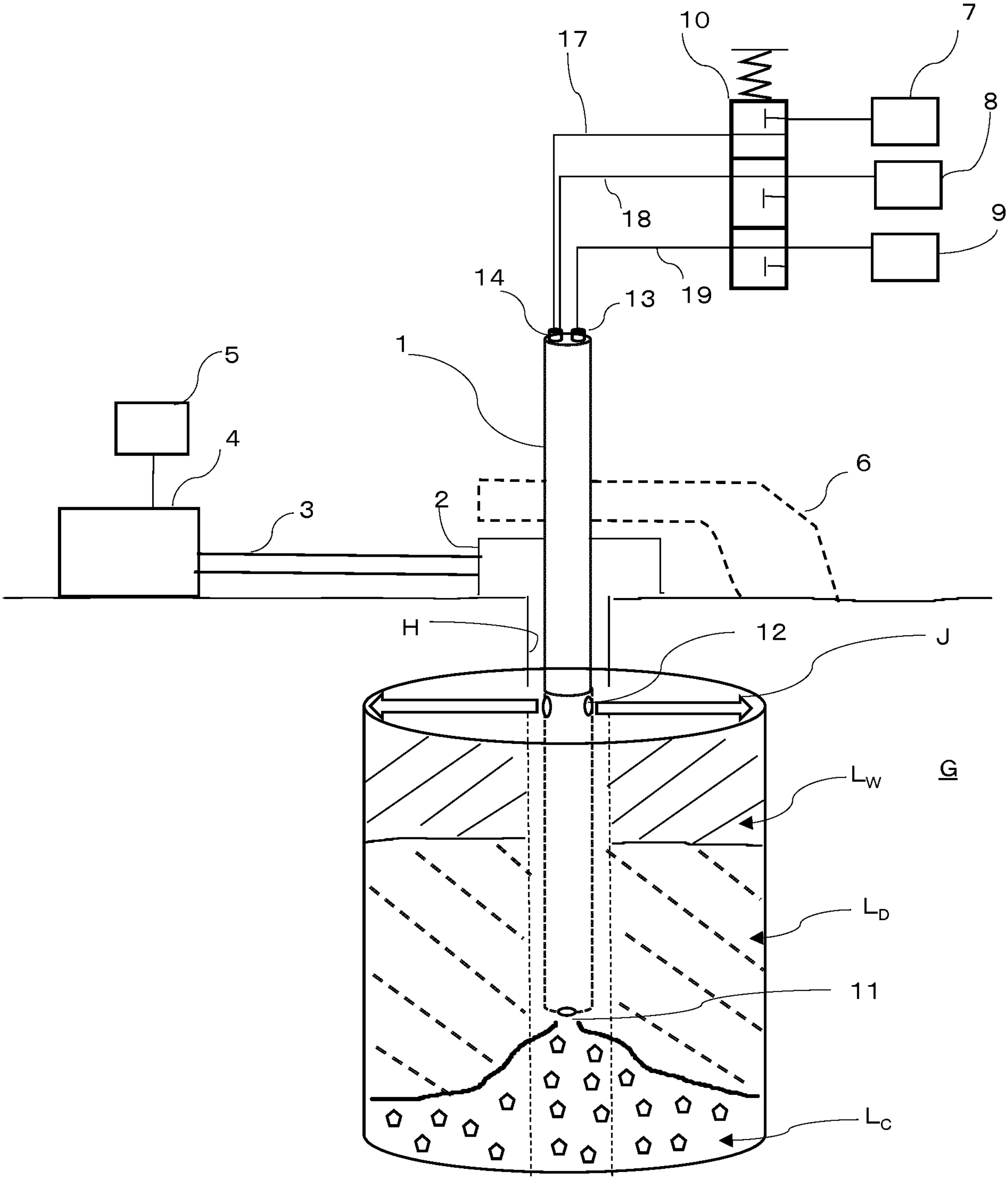


Fig. 2

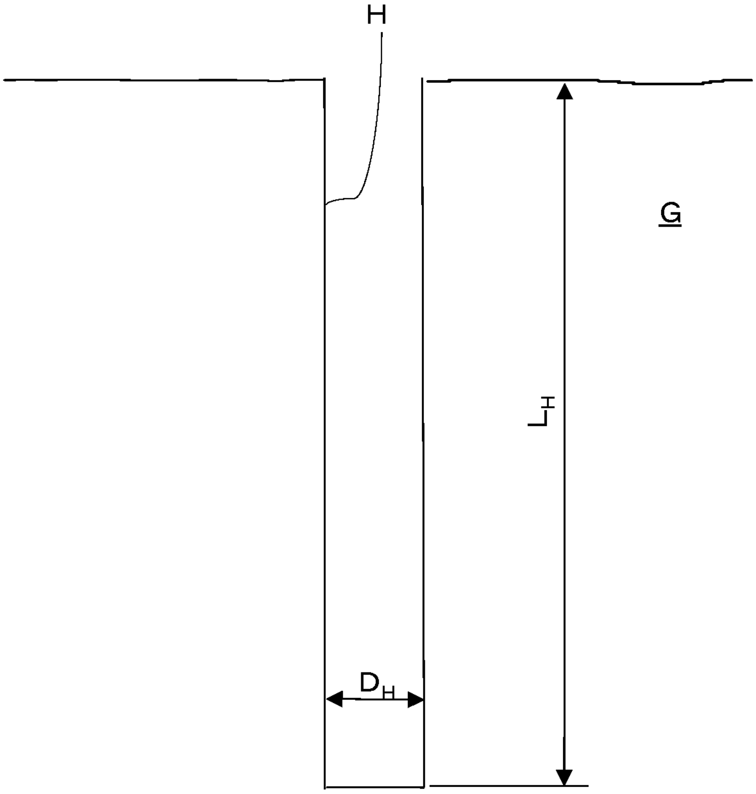


Fig. 4

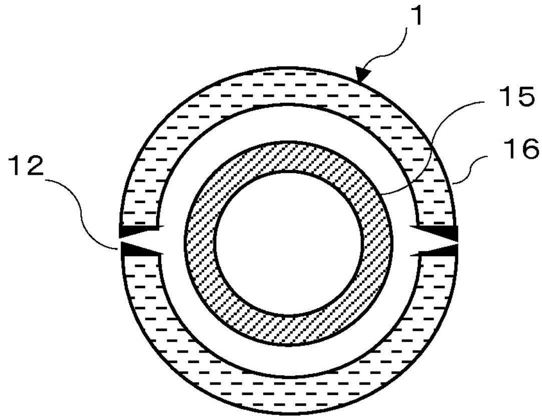


Fig. 3

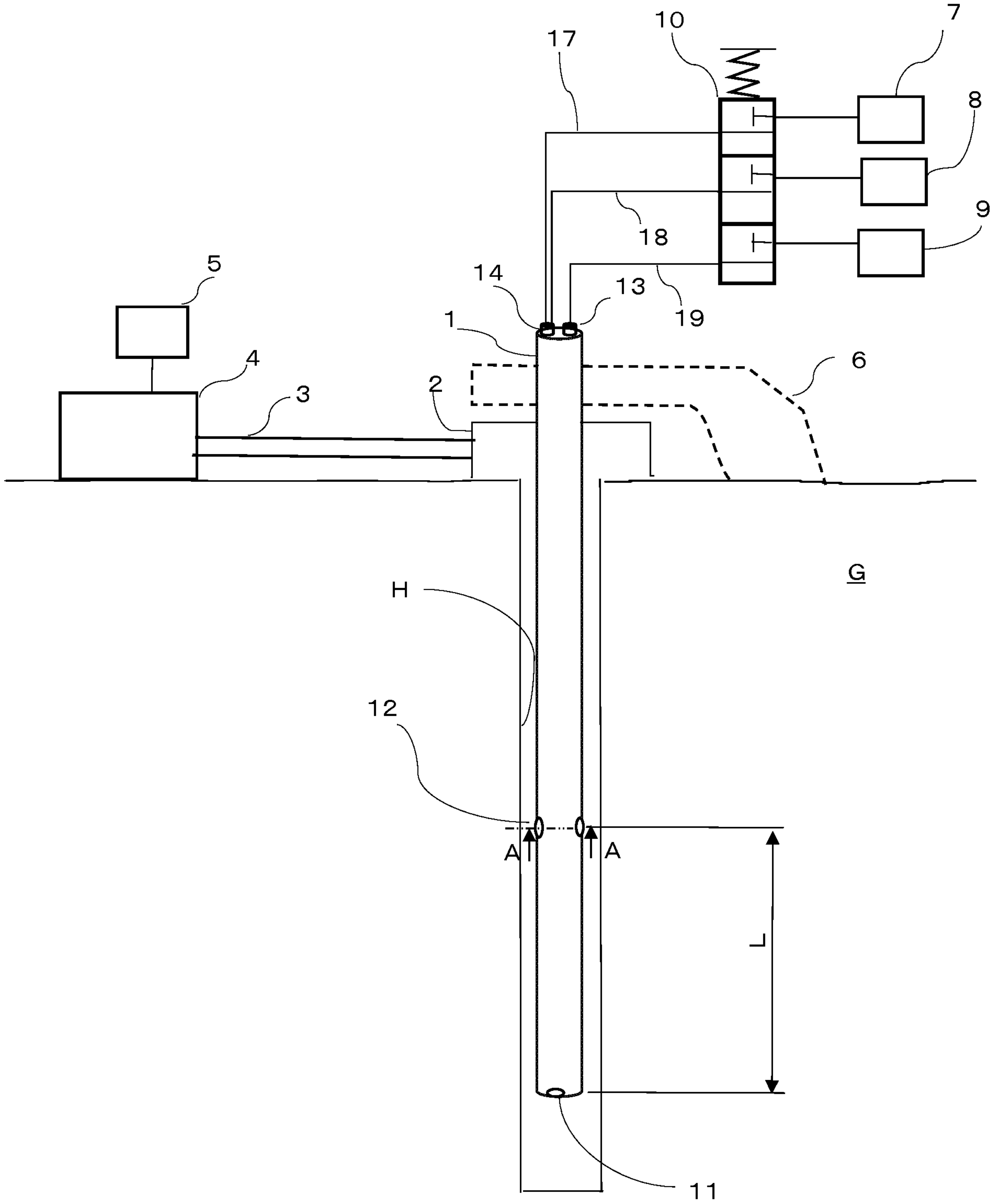


Fig. 5

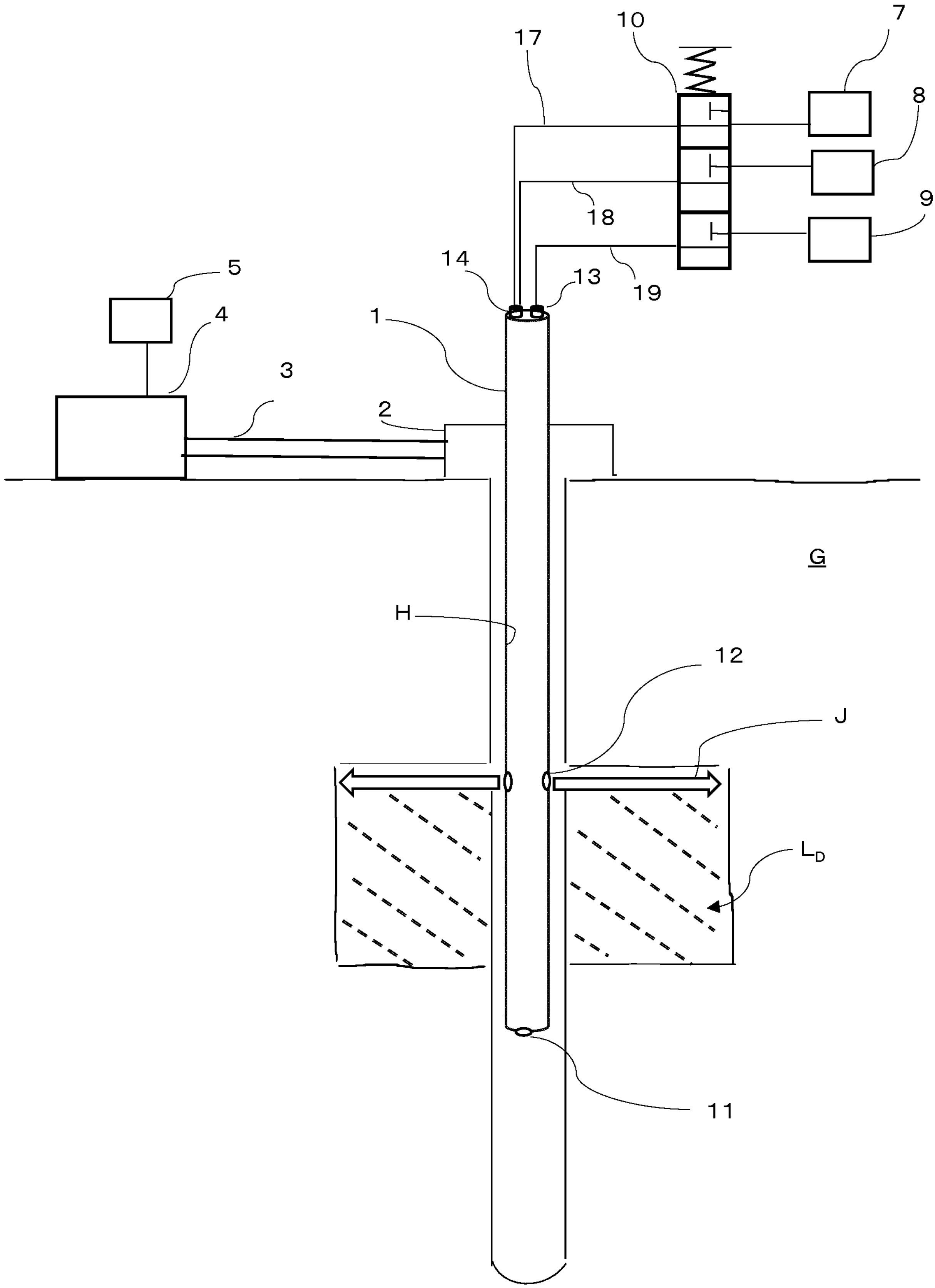


Fig. 6

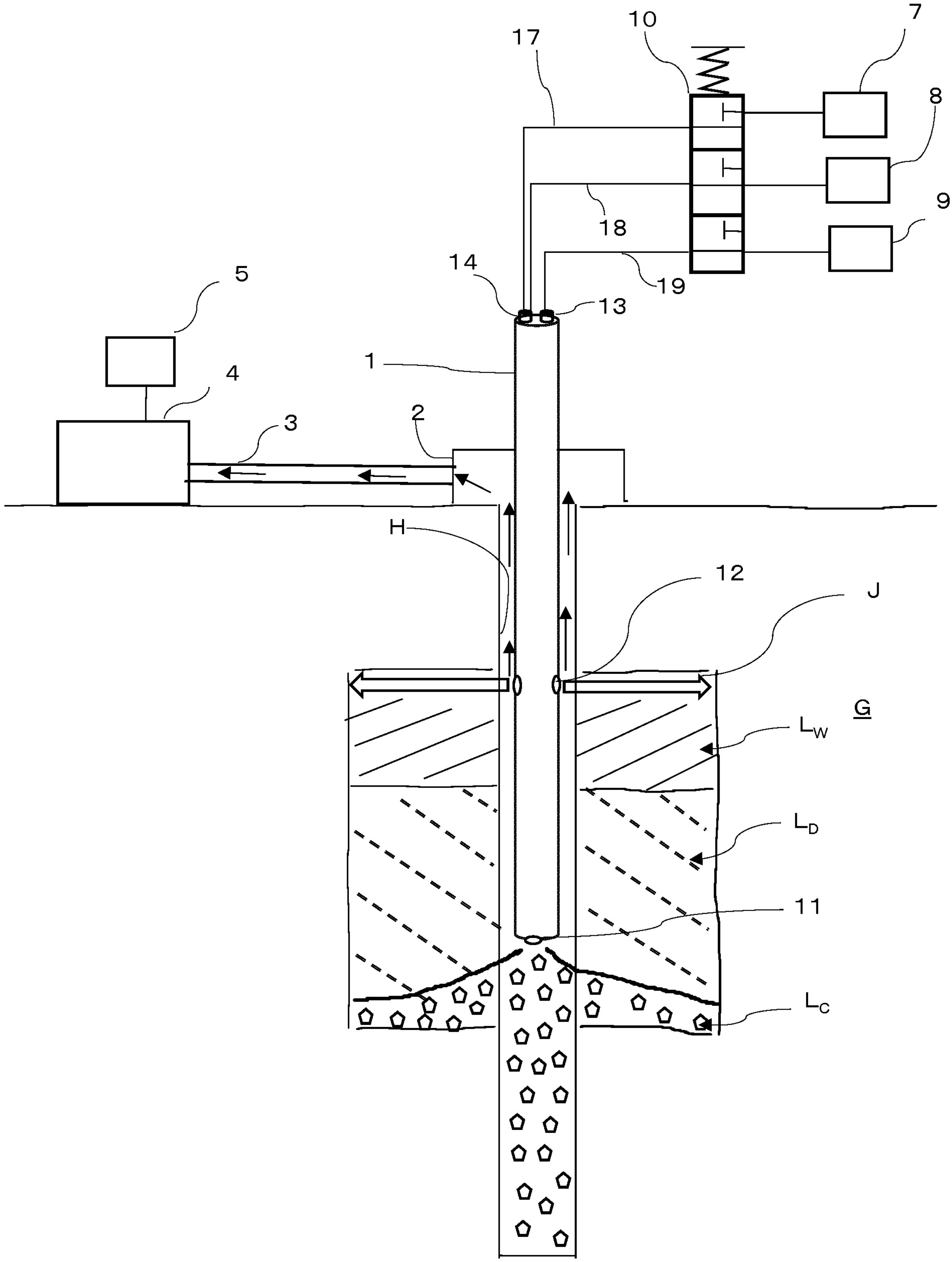


Fig. 7

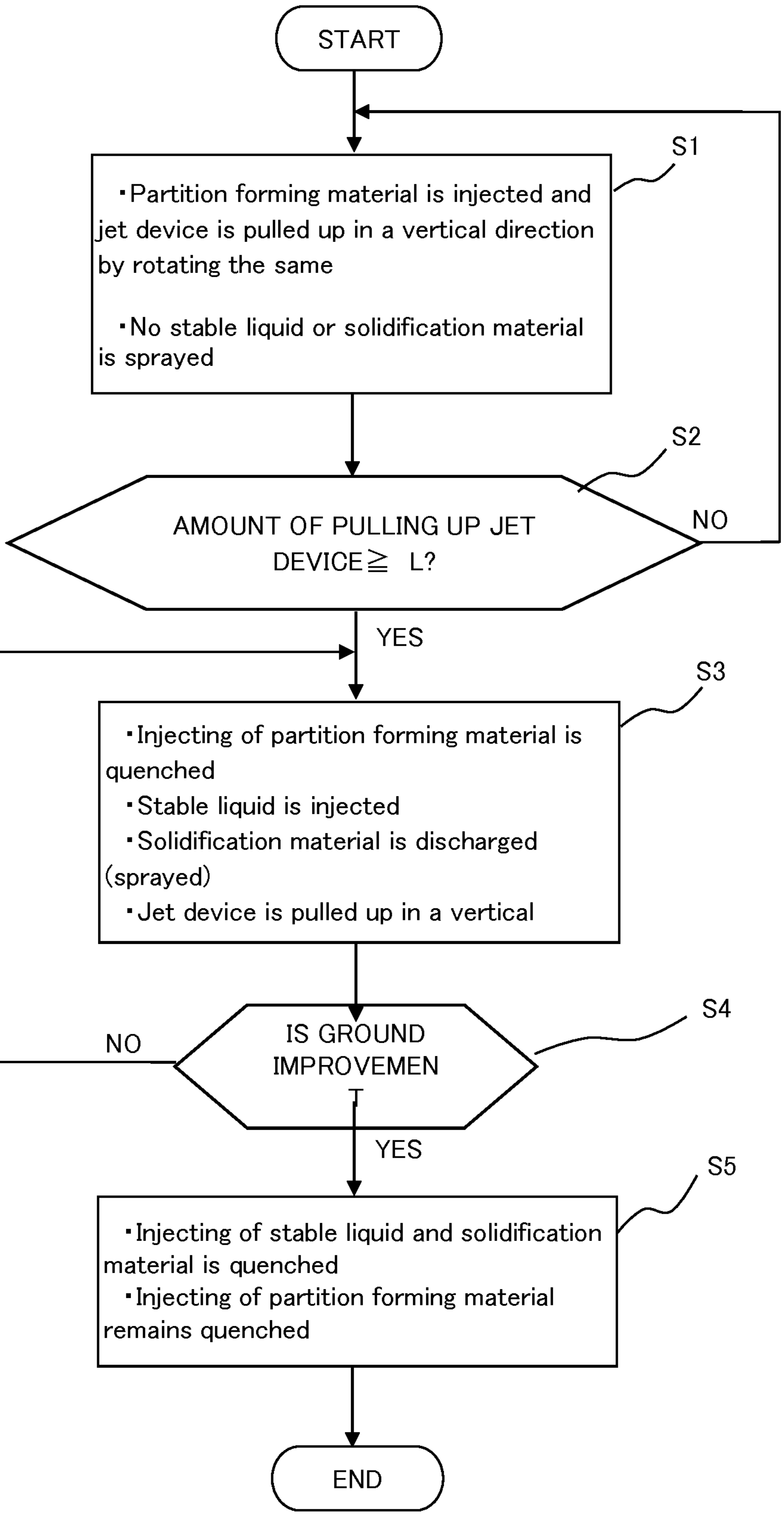

START
S1
・Partition forming material is injected and jet device is pulled up in a vertical direction by rotating the same
・No stable liquid or solidification material is sprayed
S2
AMOUNT OF PULLING UP JET DEVICE≧ L?
NO
YES
S3
・Injecting of partition forming material is quenched
・Stable liquid is injected
・Solidification material is discharged (sprayed)
・Jet device is pulled up in a vertical
S4
IS GROUND IMPROVEMEN T
NO
YES
S5
・Injecting of stable liquid and solidification material is quenched
・Injecting of partition forming material remains quenched
END

Fig. 8

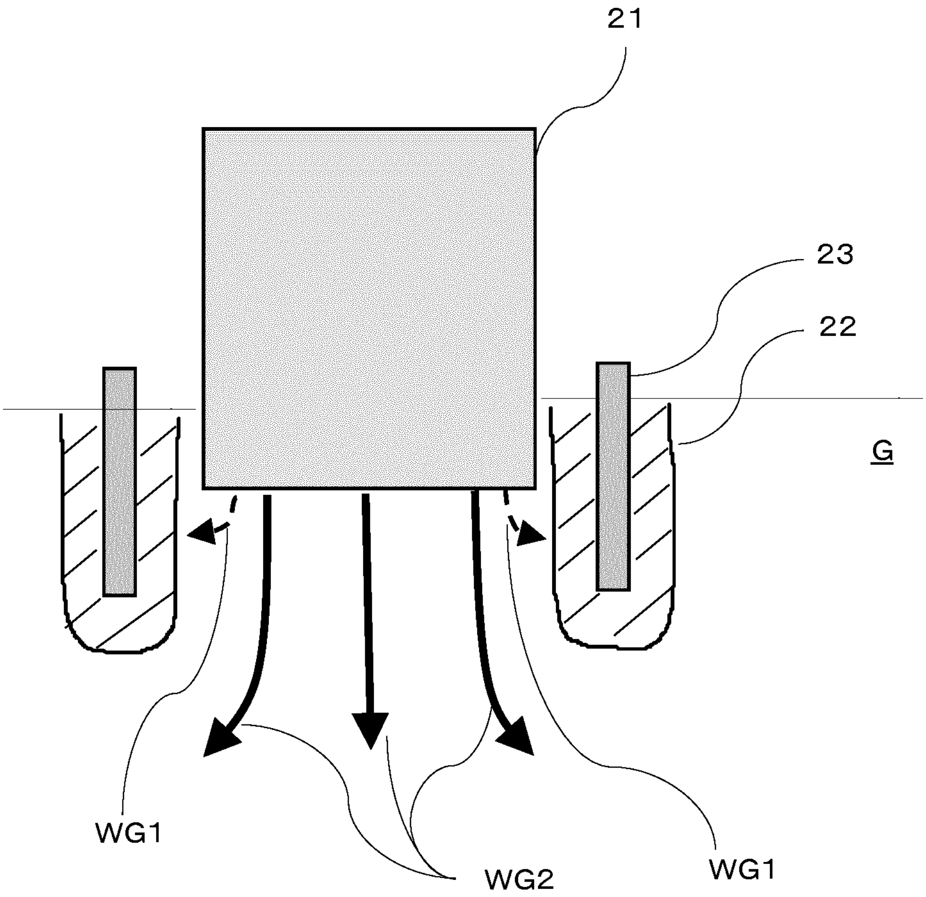


Fig. 9

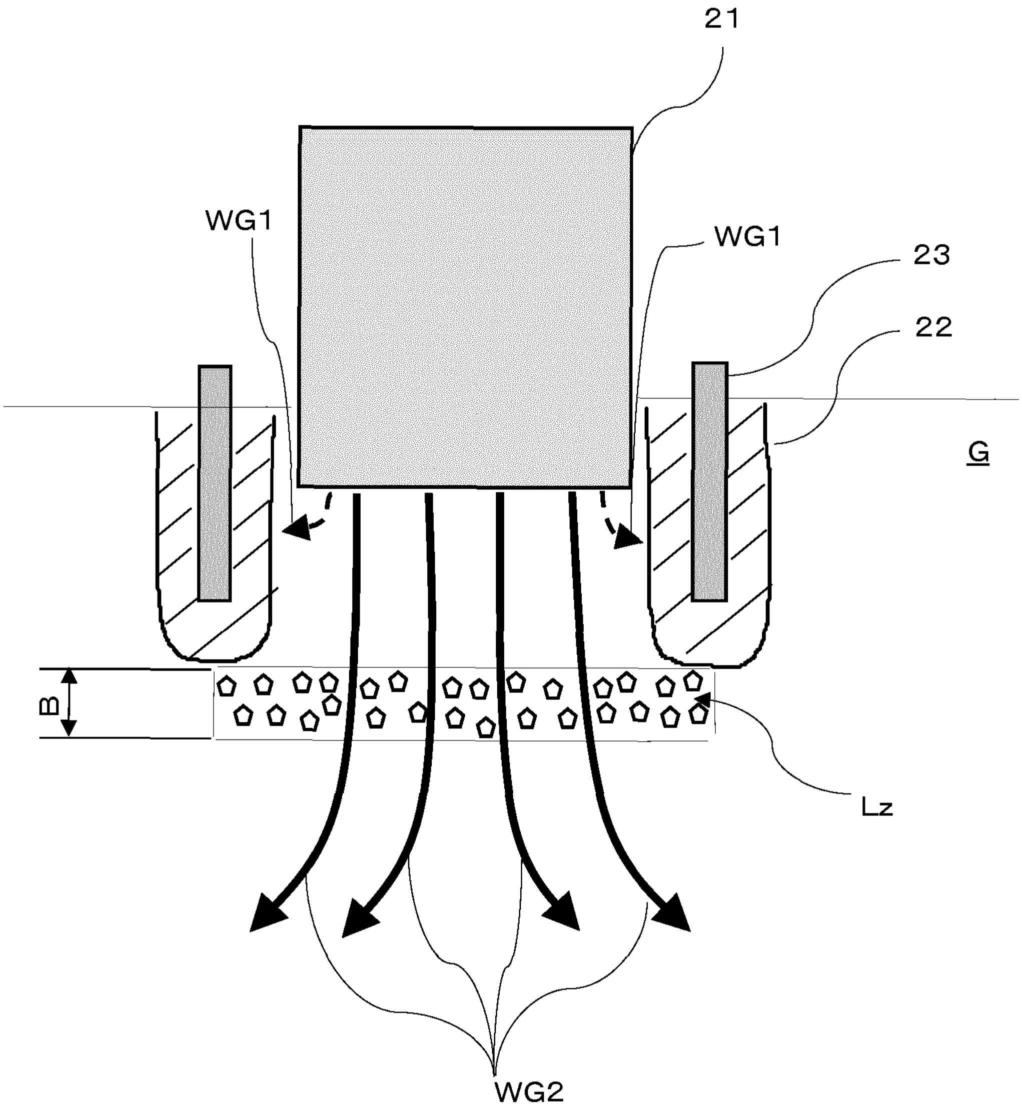
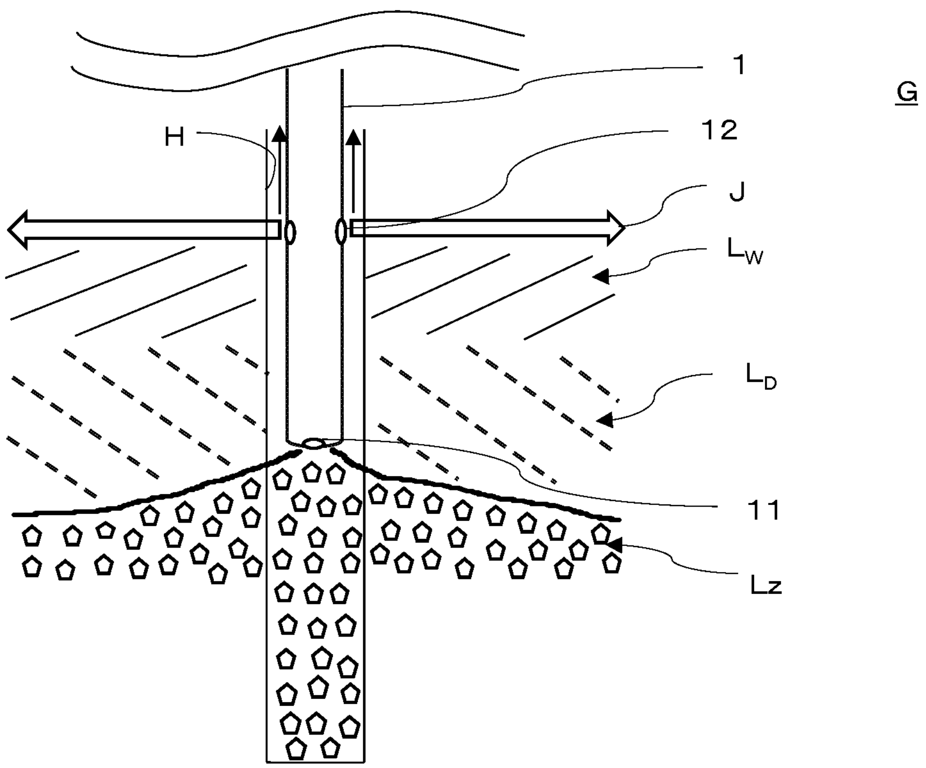


Fig. 10



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2015/065174

A. CLASSIFICATION OF SUBJECT MATTER
E02D3/12(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
E02D3/12

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2015
Kokai Jitsuyo Shinan Koho	1971-2015	Toroku Jitsuyo Shinan Koho	1994-2015

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	JP 2004-195387 A (Toko Corp.), 15 July 2004 (15.07.2004), claims; paragraphs [0009] to [0015] (Family: none)	3 1-2
A	JP 2006-138192 A (Eiko Sangyo Kabushiki Kaisha), 01 June 2006 (01.06.2006), entire text (Family: none)	1-3
A	JP 2000-290991 A (NIT Co., Ltd.), 17 October 2000 (17.10.2000), entire text (Family: none)	1-3

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
18 August 2015 (18.08.15)	01 September 2015 (01.09.15)

Name and mailing address of the ISA/	Authorized officer
Japan Patent Office 3-4-3, Kasumigaseki, Chiyoda-ku, Tokyo 100-8915, Japan	Telephone No.

Form PCT/ISA/210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2015/065174

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2001-232344 A (Kurita Water Industries Ltd.), 28 August 2001 (28.08.2001), entire text (Family: none)	1-3

Form PCT/ISA/210 (continuation of second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2015/065174

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:
See extra sheet.

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☒ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

Form PCT/ISA/210 (continuation of first sheet (2)) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2015/065174

Continuation of Box No.III of continuation of first sheet(2)

Claim 1, claim 2, and claim 3 have a common technical feature, i.e., [a ground improvement method characterized by including: a step of boring a drill hole in the ground to be improved; and a step of inserting an injection device into the drill hole and rotating the injection device so as to move the injection device in a vertical direction while injecting from the injection device a fluid for cutting the ground].

However, the above-said technical feature cannot be considered to be a special technical feature, since the technical feature does not make a contribution over the prior art in the light of the contents disclosed in the document 1.

Further, there is no other same or corresponding special technical feature among these inventions.

Accordingly, claims are classified into two inventions each of which has a special technical feature indicated below.

(Invention 1) claims 1 and 2

[A ground improvement method characterized by including: a step of boring a drill hole in the ground to be improved; a step of inserting an injection device into a drill hole and rotating the injection device so as to move the injection device in a vertical direction while injecting from the injection device a fluid for cutting the ground; and a step of injecting a solidifying material from the injection device, the method wherein the step of rotating the injection device so as to move the injection device in a vertical direction while injecting from the injection device a fluid for cutting the ground further includes: a step of cutting the ground by injecting a partition forming material; and a step of injecting a solidifying material while cutting the ground by injecting a stabilizing liquid after having injected the partition forming material].

(Invention 2) claim 3

[A ground improvement method characterized in that in the step of boring a drill hole in the ground to be improved, the step of inserting the injection device into the drill hole and rotating the injection device so as to move the injection device in a vertical direction while injecting from the injection device a fluid for cutting the ground, and the step of moving the injection device in a vertical direction while injecting the fluid, the injection device injects zeolite].

Claim 3 is not relevant to an invention which involves all of the matters to define the invention in claim 1 and which has a same category.

Further, as a result of the search which has been carried out with respect to claims classified into Invention 1, claim 3 is not relevant to an invention on which it is substantially possible to carry out a search without an additional prior-art search and judgment, and there is no other reason for that it can be considered that it is efficient to carry out a search on claim 3 together with claims 1 and 2, and consequently, it is impossible to classify claim 3 into Invention 1.

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- JP 7331652 A **[0007]**