

DESCRIPTION

TITLE OF THE INVENTION:

SOIL IMPROVEMENT METHOD

TECHNICAL FIELD

[0001]

The present invention relates to a method of improving soft ground by vacuum evaporation facilitation.

BACKGROUND ART

[0002]

The applicant has proposed a soil improvement method in Patent document 1.

This method uses the SWP (super well point) to pump up saturated groundwater by negative pressure propagation, and thereby locally lowers water level in a specific target area to generate an unsaturated zone. Thereafter, the method facilitates vacuum evaporation in a range of the unsaturated zone by using an SWP vacuum pump or a vortex pump to remove water and volatile components such as VOCs (volatile organic compounds) and oil content from the ground, and thereby facilitates the ground improvement and soil purification.

PRIOR ART DOCUMENTS

PATENT DOCUMENTS

[0003]

[Patent document 1]

Japanese Patent Application Laid Open Publication No.
2007-303095 (Japanese Patent No. 4114944)

DISCLOSURE OF THE INVENTION

PROBLEMS TO BE SOLVED BY THE INVENTION

[0004]

An object of the present invention is to provide a method which is used for assisting a soft ground improvement method and a soil purification method by vacuum evaporation facilitation, the method being an assistant method for facilitating even and rapid improvement and purification of an entire target area to be improved.

Also, another object of the present invention is to improve apparent hydraulic conductivity and to reduce well loss (difference in water level between a well and the ground) by using, as supplementary to large-scale wells associated with the SWP method, small wells having diameters of approximately 40 to 50 mm to pneumatically provide water passages.

MEANS FOR SOLVING THE PROBLEM

[0005]

In order to achieve the above objects, the invention described in claim 1 is a soil improvement method, including: providing two wells at a predetermined interval in a ground;

feeding water and air under pressure from one of the wells into the ground through a strainer at a lower position of the one well; and sucking water and air in the ground from the other well through a strainer at a lower position of the other well.

[0006]

The invention described in claim 2 is the soil improvement method according to claim 1, wherein a water pump feeds the water and a compressor feeds the air into the one well, and a lifting pump pumps up the water and a vacuum pump sucks the air from the other well.

[0007]

The invention described in claim 3 is the soil improvement method according to claim 1, wherein the feeding of the water and the air under pressure from the one well into the ground and the sucking of the water and the air in the ground from the other well are repeatedly performed.

[0008]

The invention described in claim 4 is a soil improvement method, including: providing a large well in a ground and a plurality of small wells at predetermined intervals around the large well in the ground; feeding air under pressure from lower portions of the small wells into the ground; and sucking water and air in the ground from the large well through a strainer at a lower position of the large well.

[0009]

The invention described in claim 5 is the soil improvement

method according to claim 4, wherein a compressor or a plunger pump feeds the air to each of the small wells, and a lifting pump pumps up the water and a vacuum pump sucks the air from the large well.

[0010]

The invention described in claim 6 is the soil improvement method according to claim 4, wherein, while the small wells are stepwise moved up, the feeding of the air under pressure from the lower portions of the small wells into the ground and the sucking of the water and the air in the ground from the large well are repeatedly performed.

[0011]

The invention described in claim 7 is the soil improvement method according to claim 4, wherein a boring machine bores with a bore channel by a predetermined depth to establish each of the small wells.

[0012]

The invention described in claim 8 is the soil improvement method according to claim 5, further including: providing air feed holes at predetermined depth intervals in the small wells; installing air feed channels in the small wells; and feeding the air under pressure into the ground through the air feed holes while stepwise moving up the air feed channels.

[0013]

The invention described in claim 9 is a soil improvement method, including: providing two small wells at a predetermined

interval in a ground; feeding air under pressure from one of the small wells into the ground; and sucking air in the ground from the other small well.

[0014]

The invention described in claim 10 is the soil improvement method according to claim 9, wherein air suction holes are provided at predetermined depth intervals in the other small well, and a vortex pump sucks the air into the other small well.

[0015]

The invention described in claim 11 is a soil improvement method, including: providing a large well and a small well at a predetermined interval in a ground; sucking water and air in the ground from the large well through a strainer at a lower position of the large well and sucking air from a periphery of the strainer; and sucking air in the ground through a lower portion of the small well.

[0016]

The invention described in claim 12 is the soil improvement method according to claim 11, wherein a lifting pump pumps up the water and a vacuum pump sucks the air from the large well, and a vortex blower sucks the air from the periphery of the strainer and from the small well.

[0017]

The invention described in claim 13 is the soil improvement method according to claim 12, wherein a gas-liquid

separation apparatus is provided in an air suction path from the small well to the vortex blower.

[0018]

The invention described in claim 14 is the soil improvement method according to claim 13, wherein water separated by the gas-liquid separation apparatus is fed into a water lifting path from the large well to the lifting pump.

EFFECTS OF THE INVENTION

[0019]

The method according to the present invention can facilitate even and rapid improvement and purification of an entire target area to be improved as assistant in soft ground improvement and soil purification by vacuum evaporation facilitation.

Furthermore, the present invention can improve the apparent hydraulic conductivity and reduce well loss by using small wells having diameters of about 40 to 50 mm and providing pneumatically water passages as supplementary to a large-scale well associated with the SWP method.

BRIEF DESCRIPTION OF DRAWINGS

[0020]

FIG. 1 is a cross-sectional view illustrating a method according to a first embodiment of the present invention.

FIG. 2A is a plan view illustrating a method according

to a second embodiment of the present invention.

FIG. 2B is a cross-sectional view illustrating the method according to the second embodiment of the present invention.

FIG. 3 is a cross-sectional view illustrating a method according to a third embodiment of the present invention.

FIG. 4 is a cross-sectional view illustrating a method according to a fourth embodiment of the present invention.

FIG. 5 is a cross-sectional view illustrating a method according to a fifth embodiment of the present invention.

FIG. 6 is a cross-sectional view illustrating a method according to a sixth embodiment of the present invention.

FIG. 7 is an enlarged view illustrating ground facilities in FIG. 6.

EMBODIMENTS FOR CARRYING OUT THE INVENTION

[0021]

Hereinafter, embodiments for carrying out the present invention will be described in detail with reference to the accompanying drawings.

<First Aspect>

A first aspect of the present invention provides a method which is used for assisting soft ground improvement and soil purification by vacuum evaporation facilitation, the method facilitating even and rapid improvement and purification of an entire target area to be improved.

[0022]

"Cleaning by Interactive Pressure Feeding and Suction"

By using two large-scale wells associated with the SWP method, one of which is for vacuum suction and the other of which is for purification and providing water passages by pressure feeding with a large compressor, improvement in the hydraulic conductivity K' and purification are facilitated.

[0023]

(First Embodiment)

FIG. 1 illustrates a method according to a first embodiment of the present invention. Reference numeral 1 denotes a well for feeding water and compressed air, 10 denotes a strainer, 11 denotes a water tank, 12 denotes a water pump, 13 denotes a water pipe, 15 denotes a large compressor, 16 denotes an air feed channel, 2 denotes a well for water lifting and air suction, 20 denotes a strainer, 21 denotes a lifting pump, 22 denotes an inner channel, 23 denotes a lifting pipe, 25 denotes a vacuum pump, and 26 denotes a suction channel.

[0024]

As illustrated in the drawing, the two SWP wells 1 and 2 are installed at a predetermined interval in a target area of the ground.

[0025]

The well 1 for feeding water and compressed air is connected to the water pipe 13 which is connected to the water pump 12 installed in the water tank 11 on the ground, and the well 1 is also connected to the air feed channel 16 which is

connected to the large compressor 15 on the ground.

Water and air are fed to the well 1 by the water pump 12 and the large compressor 15 respectively, and fed under pressure into the ground through the strainer 10 at a lower position of the well.

[0026]

As for the well 2 for water lifting and air suction, the lifting pipe 23 is connected to the inner channel 22 connected to the lifting pump 21 provided at the bottom of the well 2, and the well 2 is also connected to the suction channel 26 which is connected to the vacuum pump 25 on the ground.

Water and air in the ground are sucked into the well 2 through the strainer 20 at a lower position by the lifting pump 21 and the vacuum pump 25.

[0027]

The above-described pressure feeding of water and air into the ground through the well 1 and suction of water and air in the ground through the well 2 are repeatedly performed.

[0028]

By repeatedly performing the pressure feeding and the suction respectively through the interactive wells 1 and 2 in this manner, negative pressure suction is enhanced, hydraulic conductivity between the SWP wells 1 and 2 is substantially improved, water level lowering is enhanced, and a well loss is substantially reduced.

[0029]

<Second Aspect>

A second aspect of the present invention provides improvement in apparent hydraulic conductivity and reduction in well loss with small wells having diameters of approximately 40 to 50 mm to pneumatically provide water passages, without providing many large-scale wells associated with the SWP method.

[0030]

"Cleaning by Ring Type Pressure Feeding and Suction"

One of the wells associated with the SWP method still adopts vacuum suction, while a boring machine bores by a predetermined depth and then a large compressor continuously sends compressed air therethrough in a back step manner by about 0.5 m each step, to facilitate improvement in the hydraulic conductivity, reduction in well loss, and purification.

[0031]

(Second Embodiment)

FIGS. 2A and 2B illustrate a method according to a second embodiment of the present invention. The reference numeral 3 denotes a large well, 30 denotes a strainer, 31 denotes a lifting pump, 32 denotes an inner channel, 4 denotes a small well, 45 denotes a large compressor, 46 denotes an air feed channel, and 5 denotes a boring machine.

[0032]

As illustrated in the drawing, one large well 3 associated with the SWP method is installed in a target area of the ground,

and multiple (four, in the illustrated example) small wells 4 are circularly provided at predetermined regular intervals around the large well 3.

[0033]

A lifting pipe (not shown in the drawings) on the ground is connected to the inner channel 32 which is connected to the lifting pump 31 provided at the bottom of the large well 3, and a suction pipe connected to a vacuum pump (not shown in the drawings) on the ground is also connected to the large well 3.

Water and air in the ground are sucked into the large well 3 by the lifting pump 31 and the vacuum pump through the strainers 30 which are respectively provided at a lower and a middle position of the well.

[0034]

Each of the small wells 4 is connected to the air feed channel 46 connected to the large compressor 45 on the ground.

Air is fed into each of the small wells 4 by the large compressor 45 and the air is fed under pressure through the lower end into the ground.

[0035]

The small well 4 is, specifically, a bore channel held by the boring machine 5, and bores down by a predetermined depth by the boring machine 5 and then continuously feeds compressed air by the large compressor 45.

Thereafter, as indicated by an arrow, the boring machine 5 slides up the small well 4 by approximately 0.5 m each step,

while the compressor continuously feeds air in a back step manner.

[0036]

The above described pressure feeding of air into the ground through the multiple (four, in the illustrated example) small wells 4 circularly provided at predetermined regular intervals and the suction of water and air in the ground through the large well 3 located in the center are repeatedly performed, and the small wells 4 are moved upward in a stepwise manner while feeding air into the ground.

[0037]

In this manner, the small wells 4 for compressed air can achieve reduction in well loss L and lowering of a water level as illustrated in the drawing.

[0038]

<Third Aspect>

A third aspect of the present invention uses air pressure generated by a compressor for the compaction of soft ground.

Furthermore, the above well is also used as an air suction channel for assisting the process described in Patent document 1, to produce the same effects as those brought about by many large wells such as SWP wells, leading to effects such as facilitation of uniform vacuum evaporation in an entire target area.

Moreover, since effects can be expected without providing many large wells such as wells associated with the SWP method,

substantial cost reduction can be expected.

In this method, with a single small well, both of air feeding and suction can be performed.

[0039]

"Installation of Small Wells"

A small well is typically a rod used to dig to a predetermined depth, that is, the rod itself is used as a small well after digging.

The materials of the well include a boring rod and a steel pipe such as a gas tube having a similar shape and processed into a single purpose rod.

The tip of the well is provided with a cemented carbide bit, which leads to boring with the nearly same diameter (ϕ is approximately equal to 40 to 50 mm).

As a result, in pressure feeding and suction of air, a packer (blow-preventing material) and such like are not necessary since there is no clearance between the well and the natural ground, leading to easy installment and high cost performance.

Furthermore, after boring, the rod itself can be used as a channel for pressure feeding and air suction, and thus time and cost can be reduced.

[0040]

"Installation of Mobile Small Wells"

(Third Embodiment)

FIG. 3 illustrates a method according to a third

embodiment of the present invention. Reference numeral 6 denotes a small well (boring rod), 61 denotes a cemented carbide bit, 65 denotes a plunger pump, 66 denotes an air/water feed channel, and 7 denotes a boring machine.

[0041]

As illustrated in the drawing, multiple (two, in the illustrated example) small wells are provided by the boring rods 6 in place of the small wells 4 of the second embodiment.

That is, each of the boring rods 6 is hollow and has a cemented carbide bit 61 at its lower end (tip). The rod 6 is held by the boring machine 7 and is extended by screw joints, depending on the progress of boring.

[0042]

The multiple boring rods 6 are respectively connected to the air/water feed channels 66 connected to the plunger pump 65 on the ground.

Air and water are fed by the plunger pump 65 into the small wells 6 consisting of the multiple boring rods, and sent under pressure into the ground through the lower ends of the wells.

[0043]

As described above, similarly to the second embodiment, the boring machine 7 bores by a predetermined depth with the multiple small wells (boring rods) 6, and then the plunger pump 65 continuously feeds compressed air and water. Thereafter, the boring machine 7 slides up the small wells (boring rods) 6 by approximately 0.5 m each step, while air and water are

continuously fed in a back step manner.

[0044]

"Installation of Stationary Small Wells"

A stationary small well described below, which is installed in the same manner as in the above mobile well, can also provide stepwise pressure feeding using inner channels after the installment.

[0045]

(Fourth Embodiment)

FIG. 4 illustrates a method according to a fourth embodiment of the present invention. Reference numeral 8 denotes a small well, 81 denotes an air vent, 85 denotes a large compressor, and 86 denotes an air feed channel.

[0046]

As illustrated in the drawing, the small well 8 is installed in place of the small wells 4 of the second embodiment.

The small well 8 has multiple air vents 81 provided at each depth stage and includes multiple (two, in the illustrated example) air feed channels 86 therein connected to the large compressor 85 on the ground.

Air is fed under pressure into the ground through the air vents 81 which are located under the lower end of the air feed channels 86.

[0047]

As described above, similarly to the second embodiment, the multiple air feed channels 86 in the small well 8 are moved

upward in a stepwise manner, while air is continuously fed under pressure into the ground through the air vents 81 under the lower end of the air feed channels 86.

[0048]

"Air Suction with Stationary Small Well"

The well performs air suction as a whole in an air suction mode.

[0049]

(Fifth Embodiment)

FIG. 5 illustrates a method according to a fifth embodiment of the present invention. Reference numeral 9 denotes a small well, 90 denotes a filter, 91 denotes an air vent, 95 denotes a vortex pump, 96 denotes an air suction channel, and 97 denotes a cover.

[0050]

As illustrated in the drawing, the small well 9 is installed in place of the large well 3 of the second embodiment.

The small well 9 includes the 3D (three-dimensional) filter 90 at a bottom aperture and multiple air vents 91 provided at each depth stage, and the upper end of the small well 9 is closed with the top cover 97 which is connected to the air suction channels 96 connected to the vortex pump 95 on the ground.

[0051]

The three-dimensional filter 90 at the bottom aperture of the small well 9 allows for water feeding during the boring and for prevention of inflow of earth and sand even during the

suction.

Each of the air vents 91 has a pore size of approximately 1.5 to 3.5 mm in diameter for the prevention of sand inflow.

[0052]

As described above, similarly to the second embodiment, with the small well 9, water and air in the ground are continuously sucked through the three-dimensional filter 90 at the bottom aperture and the multiple air vents 91 provided at each depth stage.

[0053]

The functional effects by the small well will now be described.

[0054]

"Use of Small Well for Suction Evaporation"

Without using a large well for vacuum evaporation facilitation, the small well allows sufficient air to be sucked to create a vacuum, resulting in substantial cost reduction.

Furthermore, a large number of such small wells installed in an entire area can prevent unevenness of vacuum drying and purification.

[0055]

"Use of Compressed Air as Preload"

By the pressure feeding of air from the compressor into cohesive soil and a sand stratum under the soil, the residual pressure remains in the ground, though some air blow would reach the ground surface.

The residual pressure P is as much as 3.0 to 7.0 kg/cm², comparable to an embankment loading WP of 30 to 70 t/m² and also to an embankment height H of a loaded embankment which is approximately 18 to 41 m, resulting in considerable and effective compression stress.

The pore water pressure of vacuum evaporated soil is slight, which leads to ready compaction.

Furthermore, the stepwise compression can lead to tight compaction.

Although an embankment generates great loading stress at the ground surface, the stress decreases with an increasing distance from the surface due to a dispersed load.

In addition, direct air blow can be made at the area, achieving rapid and even purification.

[0056]

"Effective for Liquefaction Prevention"

1) At the sand stratum, vacuum evaporation and the following compressed air feeding generates trapped air occupying 5% or more of the interstices, which is effective for liquefaction prevention.

2) According to the above operations, the relative density of sand is increased by cleaning effect, which is effective for liquefaction prevention.

The cohesive soil is also strengthened for the effect by the process in Patent document 1, which is effective for liquefaction prevention.

[0057]

"Disadvantage"

The unsaturated ground caused by the SWP method lowering a water level includes pore water and attached water; hence, the suction by a vortex blower, an oil vacuum pump and such like through suction holes (underground suction pipes) causes cavitation in the vortex blower and such like by the water evaporated to be sucked, resulting in failure of the vortex blower and vacuum pump due to a heated pump and a swelled and locked rotary fan. Thereafter, suction cannot be performed.

[0058]

(Sixth Embodiment)

FIG. 6 illustrates a method according to a sixth embodiment of the present invention, while FIG. 7 is an enlarged view of ground facilities in FIG. 6. Reference numeral 101 denotes a large well, 102 denotes a strainer, 103 denotes a lifting pump, 104 denotes an inner channel, 105 denotes an air suction channel, 106 denotes a vacuum pump, 107 denotes a suction channel, 108 denotes an air suction channel, 109 denotes a vortex blower, 111 denotes a small well, 112 denotes a suction channel, 113 denotes a gas-liquid separation apparatus, 114 denotes a gas-liquid separation filter, 115 denotes an air suction channel, and 116 denotes a water feed channel.

[0059]

As illustrated in the drawing, one large well 101 associated with the SWP method and one small well 111 are

installed at a predetermined distance in a target area of the ground.

[0060]

The large well 101 includes an inner channel 104 which has strainers 102 respectively provided at a lower and a middle positions and a lifting pump 103 at a bottom position and a suction channel 107 along the inner channel 104.

The inner channel 104 is connected to a water lifting channel (not shown in the drawings) on the ground and to the vacuum pump 106 via the air suction channel 105.

Water and air in the ground are sucked into the large well 3 by the lifting pump 103 and the vacuum pump 106, respectively, through the lower and middle strainers 102.

[0061]

The suction channel 107 is connected to the vortex blower 109 via the air suction channel 108 on the ground. The vortex blower 109 sucks only air.

[0062]

The small well 111 is connected to the gas-liquid separation apparatus 113 via the suction channel 112 on the ground. The gas-liquid separation apparatus 113 includes the gas-liquid separation filter 114 therein.

In addition, the top of the gas-liquid separation apparatus 113 is connected to the vortex blower 109 via the air suction channel 115, while the bottom is connected to the inner channel 104 via the water feed channel 116.

[0063]

"Suction from Periphery of Large Well (SWP) 101"

The suction channel 107, which is preliminarily provided along the large well (SWP) 101 for gas-liquid separation, puts the inside of well filters (strainers 102) under negative pressure; hence, air suction through the filters (strainers 102) by the vortex blower 109 can facilitate the vacuum evaporation of an unsaturated zone of the ground.

The vacuum degree in the SWP well is as high as approximately $P_v = -0.04$ to -0.085 MPa, so that water is sucked through the well, while the vacuum degree in the vortex is as low as $P_v = -0.02$ to -0.035 MPa. This difference in pressure allows the vortex blower 109 to suck mainly air in large amounts, facilitating vacuum evaporation.

[0064]

"Suction System of Small Well 111"

Direct suction from an unsaturated zone in the ground with the suction channel 107 and the small well 111 would suck water vapor as described above, resulting in failure of the vortex blower 109 and such like.

For this reason, the gas-liquid separation apparatus 113 is provided between the small well 111 and the vortex blower 109 so as to allow for continuous suction of air into the vortex blower 109 and water into the SWP well and into the vacuum pump 106.

[0065]

An ordinary gas-liquid separation apparatus directly sucks water with a pump when the water level rises in the tank.

In contrast, in the gas-liquid separation apparatus 113, despite the suction of water through pinholes with high negative pressure on the bottom of the tank, the negative pressure has no influence on the negative pressure of the vortex blower 109 because the amount of water suction is small.

[0066]

As described above, according to the sixth embodiment, the vortex blower 109 applies vacuum (negative pressure) to the top of a sand stratum and cohesive soil with the suction channel 107 and the small well 111.

This lowers the boiling point of water, resulting in the expansion of the pore water into water vapor, which is then sucked to be emitted to the ground surface through the suction channel 107 and the small well 111, leading to dry of the ground.

The pore water pressure at this time is negative pressure; hence, excess pore pressure is prevented in the event of earthquake, which can contribute to liquefaction prevention.

INDUSTRIAL APPLICABILITY

[0067]

The present invention can be used for assisting soft ground improvement and soil purification by vacuum evaporation facilitation and can be utilized to facilitate even and rapid improvement and purification of an entire target area to be

improved.

EXPLANATION OF REFERENCE NUMERALS

[0068]

- | | |
|----|---|
| 1 | well for feeding water and compressed air |
| 10 | strainer |
| 11 | water tank |
| 12 | water pump |
| 13 | water pipe |
| 15 | large compressor |
| 16 | air feed channel |
| 2 | well for water lifting and air suction |
| 20 | strainer |
| 21 | lifting pump |
| 22 | inner channel |
| 23 | lifting pipe |
| 25 | vacuum pump |
| 26 | suction channel |
| 3 | large well |
| 30 | strainer |
| 31 | lifting pump |
| 32 | inner channel |
| 4 | small well |
| 45 | large compressor |
| 46 | air feed channel |
| 5 | boring machine |

6	small well (boring rod)
61	cemented carbide bit
65	plunger pump
66	air/water feed channel
7	boring machine
8	small well
81	air vent
85	large compressor
86	air feed channel
9	small well
90	filter
91	air vent
95	vortex pump
96	air suction channel
97	cover
101	large well
102	strainer
103	lifting pump
104	inner channel
105	air suction channel
106	vacuum pump
107	suction channel
108	air suction channel
109	vortex blower
111	small well
112	suction channel

- 113 gas-liquid separation apparatus
- 114 gas-liquid separation filter
- 115 air suction channel
- 116 water feed channel

CLAIMS

1. A soil improvement method, comprising:

providing a large well in a ground and a plurality of small wells at predetermined intervals around the large well in the ground;

feeding air under pressure from lower portions of the small wells into the ground;

sucking water and air in the ground from the large well through a strainer at a lower position of the large well, wherein while the small wells are stepwise moved up, the feeding of the air under pressure from the lower portions of the small wells into the ground and the sucking of the water and the air in the ground from the large well are repeatedly performed.

2. The soil improvement method according to claim 1, wherein a compressor or a plunger pump feeds the air to each of the small wells, and a lifting pump pumps up the water and a vacuum pump sucks the air from the large well.

3. The soil improvement method according to claim 1, wherein a boring machine bores with a bore channel by a predetermined depth to establish each of the small wells.

4. A soil improvement method, comprising:

providing a large well in a ground and plurality of small wells at predetermined intervals around the large well in the ground;

feeding air under pressure from lower portions of the small wells into the ground;

sucking water and air in the ground from the large well through a strainer at a lower position of the large well,

providing air feed holes at predetermined depth intervals in the small wells;

installing air feed channels in the small wells; and

feeding the air under pressure into the ground through the air feed holes while stepwise moving up the air feed channels.

5. A soil improvement method, comprising:

providing two small wells at a predetermined interval in a ground;

feeding air under pressure from one of the small wells into the ground; and

sucking air in the ground from the other small well, wherein air suction holes are provided at predetermined depth intervals in the other small well, and a vortex pump sucks the air into the other small well.

6. A soil improvement method, comprising:

providing a large well and a small well at a predetermined interval in a ground;

sucking water and air in the ground from the large well, through a strainer at a lower position of the large well and sucking air from a periphery of the strainer; and

sucking air in the ground through a lower portion of the small well.

7. The soil improvement method according to claim 6, wherein a lifting pump pumps up the water and a vacuum pump sucks the air from the large well, and

a vortex blower sucks the air from the periphery of the strainer and from the small well.

8. The soil improvement method according to claim 7, wherein a gas-liquid separation apparatus is provided in an air suction path from the small well to the vortex blower.

9. The soil improvement method according to claim 8, wherein water separated by the gas-liquid separation apparatus is fed into a water lifting path from the large well to the lifting pump.