

DESCRIPTION

TITLE: GROUND IMPROVEMENT METHOD

TECHNICAL FIELD

[0001] The present invention relates to a ground improvement method for a weak ground by suction of pore water and application of impact.

BACKGROUND ART

[0002] The applicant proposed a ground improvement method that uses the super well point (SWP) in the patent document 1. The SWP is a method for pumping up saturated groundwater by propagating negative pressure.

According to this ground improvement method, a groundwater level lowering device (SWP device) is buried in a target ground. The SWP device includes a strainer pipe that is buried underground, a water-permeable strainer part at the lower end of the strainer pipe, and a filter formed on an outer circumference of the strainer pipe. By evacuating air with a vacuum pump, the groundwater flows into the strainer pipe. The groundwater is then sucked by a drainage pump provided inside the strainer pipe, and drained out to the ground surface through a drainpipe. By suction of pore water in the ground, the groundwater level is lowered, and vacuum evaporation is facilitated, so that the ground is

settled. Further, an air sucking-sending pipe for improving water permeability is installed in the ground to alternately send and suck air into and from the ground.

In the soil particle structures of the target ground, pore water between soil particles is replaced with vacuum evaporated air by evacuation of air with the vacuum pump of the SWP device and drainage of water with the drainage pump and by sending and sucking of air with the air sending-sucking pipe. By adding a surcharge with a planned embankment on the target ground, the soil particle structures are compressed. Thus, the settlement of the ground is facilitated.

CITATION LIST

Patent Document

[0003]

Patent Literature 1: JP6158555B (JP2014-196614A)

SUMMARY of invention

Technical Problem

[0004] The ground improvement method in the patent document 1 can improve the bearing capacity and strength of the ground by facilitating settlement of ground through vacuum evaporation. However, the settlement amount of the ground may be insufficient.

More specifically, after the pump is stopped, the bearing capacity of the ground may decline owing to the

groundwater level recovery. Further, one time of embankment may not sufficiently consolidate the ground.

FIG.6 shows characteristics of the relation between time and settlement amount. With the first consolidation (using the SWP and the air sucking-sending pipe in combination and one time of embankment), the settlement amount may be around 90 % of the target settlement amount, as shown by the obtained characteristic A.

This is considered to result from the remaining main parts of the flocculent structure of soil particles. As shown in FIG.7, in a weak ground, minute soil particles, such as clay and colloids, stick to each other in water to form flocculent structures. The flocculent structures retain a high pore water pressure. Under the first consolidation (combination of the SWP and the air sucking-sending pipe and one time of embankment), the main parts of the flocculent structures remain, as shown in FIG.8, even though the pore water pressure declines through vacuum evaporation.

[0005] The target of the present invention is to further facilitate settlement of the ground by compressing the soil particle structures in the ground in which pore water between soil particles is replaced with vacuum evaporated air through evacuation of air with the vacuum pump of the SWP device and drainage of water with the drainage pump.

Solution to Problem

[0006] To solve the above issue, the invention disclosed in claim 1 is a ground improvement method including: burying, in a target ground, a super well point device that evacuates air with a vacuum pump so that groundwater flows into a strainer pipe buried underground, the strainer pipe including a water-permeable strainer provided at a lower end of the strainer pipe and a filter formed on an outer circumference of the strainer pipe, sucks the groundwater with a drainage pump provided inside the strainer pipe, and drains the groundwater out to a ground surface through a drainpipe; lowering a groundwater level by sucking pore water in the ground; and causing settlement of the ground by facilitating vacuum evaporation, wherein the method further includes applying an impact force to the ground to compress a soil particle structure in the ground so that settlement and consolidation of the ground is facilitated, in which the pore water between soil particles of the soil particle structure is replaced with vacuum evaporated air through the evacuation with the vacuum pump and the drainage with the drainage pump of the super well point device.

[0007] The invention disclosed in claim 2 is the ground improvement method according to claim 1, wherein the applying of the impact force includes: adding a surcharge on the target ground by laying a first embankment on the target ground; and running a vibration roller over the first embankment.

[0008] The invention disclosed in claim 3 is the ground improvement method according to claim 2, wherein the applying of the impact force further includes: further adding a surcharge on the target ground by laying a second embankment on the first embankment; and running the vibration roller over the laid second embankment, whereby the settlement and the consolidation of the ground is secondarily facilitated.

[0009] The invention disclosed in claim 4 is the ground improvement method according to claim 1, wherein the applying of the impact force includes: hammering a casing pipe into the target ground, putting sand into the casing pipe; and vibrating the casing pipe with a vibratory hammer.

[0010] The invention disclosed in claim 5 is the ground improvement method according to claim 4, further including: removing the casing pipe so that a sand pile is formed; and on an upper end of the sand pile, forming a cap layer with a cohesive soil that constitutes the target ground.

Advantageous Effects of Invention

[0011] According to the present invention, the settlement of the ground can be further facilitated by compressing the soil particle structures in the ground in which pore water between soil particles is replaced with vacuum evaporated air through evacuation of air with the vacuum pump of the SWP device and drainage of water with the drainage pump.

BRIEF DESCRIPTION OF DRAWINGS

[0012]

FIG.1 is a schematic long profile showing a configuration of an embodiment to which the ground improvement method according to the present invention is applied.

FIG.2 shows a second embankment and application of impacts to be done after the process of FIG.1.

FIG.3 is a schematic long profile showing a second embodiment.

FIG.4 is a schematic view showing an effect on a flocculent structure according to the present invention.

FIG.5 shows a characteristic of the relation between time and settlement amount according to the present invention.

FIG.6 shows a characteristic of the relation between time and settlement amount.

FIG.7 is a schematic view of the flocculent structure with a high pore water pressure.

FIG.8 is a schematic view of the flocculent structure retaining its main part with a lowered pore water pressure after the first consolidation (combination of the SWP and the air sucking-sending pipe and one time of embankment).

DESCRIPTION OF EMBODIMENTS

[0013] Hereinafter, embodiments of the present invention are described in detail with reference to the

drawings.

[First Embodiment]

FIG.1 shows a schematic configuration of an embodiment to which the ground improvement method according to the present invention is applied. The embodiment includes a target ground 1, a SWP device 2, a planned embankment 3, and a vibration roller 4 (impact application device).

[0014] As shown in the figure, the target ground 1 to which the present invention is applied includes: an improvement target stratum 11 constituted of a cohesive soil; and a water-permeable stratum 12 constituted of a sandy soil under the improvement target stratum 11. Multiple SWP devices 2 that lower the groundwater level are buried in the target ground 1 at intervals.

The planned embankment 3 is laid over the target ground 1, in which the SWP devices 2 are buried at intervals, thereby adding a surcharge to the target ground 1. On the planned embankment 3, the vibration roller 4 as an impact application device is placed.

The stratum below the improvement target stratum 11 may be a hard cohesive soil or a bedrock.

[0015] The SWP device 2 includes: a strainer pipe 21 to be buried in the target ground 1; a strainer part 22, a filter 23, a drainage pump 24, and a drainpipe 25 that are provided to the strainer pipe 21; and a vacuum pump 26 provided on the ground.

[0016] In the target ground 1, the strainer pipe 21 is buried such that the lower end thereof reaches the water-permeable stratum 12 below the improvement target stratum 11. The lower end of the strainer pipe 21 is provided with the water-permeable strainer part 22 having a large number of small apertures. On the outer circumference of the lower part of the strainer 21, the filter 23 is formed.

The drainage pump 24 is arranged inside the lower end part of the strainer pipe 21. The drainage pump 24 drains out the groundwater to the ground surface through the drainpipe 25 that is arranged inside the strainer pipe 21.

The vacuum pump 26 is arranged on the ground and connected to the upper end of the strainer pipe 21 via a hose 27. The vacuum pump 26 performs vacuum suction to evacuate the air in the strainer pipe 21. Accordingly, the groundwater in the improvement target stratum 11 flows into the strainer pipe 21.

[0017] The SWP device 2 as described above evacuates the air in the strainer pipe 21 buried in the target ground 1 with the vacuum pump 26 on the ground, causes the groundwater in the improvement target stratum 11 to flow into the strainer pipe 21 through the strainer part 22 at the lower end and the filter 23 around the strainer pipe 21, sucks the flowing groundwater with the drainage pump 24 provided inside the strainer pipe 21, and drains out the groundwater to the ground surface through the drainpipe 25,

as shown by arrows. The drained water is stored in a water storage tank via a not-illustrated hose.

The SWP device 2 thus constitutes a pore water suction mechanism.

[0018] When the groundwater level falls, pore water between soil particles in the improvement target stratum 11 is replaced with air. When a surcharge, such as an embankment, is placed on the improvement target stratum 11 in which pore water is replaced with air, the soil particle structure is compressed and the ground settlement is facilitated. This increases the strength of the ground.

[0019] The planned embankment 3 as a surcharge is laid over the target ground 1 beforehand, so that the ground settlement can be effectively facilitated. By the suction effect of the SWP device 2, the differential pressure from the atmospheric pressure may also be added to the target ground 1.

Thus, the soil particle structure is compressed by a combination of the groundwater drawdown through suction of pore water and facilitation of the ground settlement with a placed surcharge.

[0020] Further, the vibration roller 4 runs over the planned embankment 3 to apply impacts to the improvement target stratum 11, which is immediately below the planned embankment 3.

Thus, in addition to facilitating settlement of the

ground by placing a surcharge, impacts are applied by the vibration roller 4. As illustrated, the vibrations of impacts applied by the vibration roller 4 are transmitted from the planned embankment 3 to the bottom of the improvement target stratum 11, thereby facilitating consolidation of the soil particle structures.

[0021] As described above, to facilitate the settlement of the target ground 1, the combination of the groundwater drawdown through suction of pore water and placement of a surcharge is employed. To facilitate the consolidation of the target ground 1, impacts are applied. The facilitation of the settlement and consolidation is done in combination for a predetermined necessary period of time, so that compression of the soil particle structures is facilitated. Accordingly, settlement of the target ground 1 is further facilitated.

[0022] FIG.4 shows an effect on the flocculent structure according to the present invention. By applying impacts with the vibration roller 4 in addition to facilitating settlement of the ground with the laid planned embankment 3, the consolidation of the soil particle structures in the improvement target stratum 11 is facilitated.

[0023] FIG.5 shows a characteristic of the relation between time and settlement amount according to the present invention. The characteristic X is obtained by the combination of: groundwater drawdown through suction of pore

water with the SWP device 2; and facilitation of ground settlement with the planned embankment 3. By further applying impacts with the vibration roller 4 in addition to the characteristic X, the ground settlement and consolidation can be facilitated, as shown by the characteristic Y.

[0024] As the characteristic B in FIG.6 shows, the settlement amount can be increased far beyond the target settlement amount L.

[0025] According to the ground improvement method in the embodiment, the SWP device 2 evacuates air with the vacuum pump 26 and drains water with the drainage pump 24, so that pore water between soil particles of the soil particle structures is replaced with vacuum evaporated air in the improvement target stratum 11 of the target ground 1. The soil particle structures in which pore water is replaced vacuum evaporated air are compressed by the planned embankment 3 laid to facilitate the ground settlement and by the impacts applied with the vibration roller 4. Accordingly, the settlement of the target ground 1 can be further facilitated.

[0026] FIG.2 shows a second embankment 5 and application of impacts to be done after the process of FIG.1.

More specifically, the second embankment 5 is laid over the first embankment 3, which is laid over the target ground 1, and the vibration roller 4 runs over the second embankment 5. Accordingly, impacts are applied to the improvement target

stratum 11 immediately below the first embankment 3 and the second embankment 5.

Thus, in addition to facilitating settlement of the ground by placing surcharges with the first embankment 3 and the second embankment 5, impacts are applied by the vibration roller 4. The vibrations of the impacts applied by the vibration roller 4 are transmitted through the second embankment 5 and the first embankment 3 to the bottom of the improvement target stratum 11. This further facilitates consolidation of the soil particle structures.

[0027] In FIG.5, the characteristic Y is obtained in the embodiment shown in FIG.1, which employs the combination of groundwater drawdown with the SWP device 2 sucking pore water and facilitation of ground settlement with the planned embankment 3 and application of impacts with the vibration roller 4. The characteristic Z is obtained by facilitating the ground settlement with the laid second embankment 5 and by applying impacts with the vibration roller 4, in addition to the characteristic Y. As shown by the characteristic Z, settlement and consolidation of the ground can be further facilitated.

[0028]

[Second Embodiment]

FIG.3 shows a second embodiment. The second embodiment includes the target ground 1 and the SWP devices 2 as with the first embodiment, and further includes sand compaction

pile devices 6 (impact application devices).

[0029] As shown in the figure, multiple SWP devices 2 are buried in the target ground 1 at intervals, and multiple sand compaction pile devices 6 as impact application devices are buried in the target ground 1 at intervals.

Each sand compaction pile device 6 includes a casing pipe 61; a vibratory hammer 62 provided at the upper end of the casing pipe 61; and sand 63 that is put into the casing pipe 61.

[0030] More specifically, the vibratory hammer 62 applies impacts to the upper end of the casing pipe 61, thereby hammering the casing pipe 61 into the target ground 1 until the lower end of the casing pipe 61 reaches the water-permeable stratum 12.

The sand 63 is then put into the casing pipe 61, and the casing pipe 61 is pulled up to a certain height.

The vibratory hammer 62 then applies impacts to the casing pipe 61 to hammer the casing pipe 61 into the ground again and vibrate the casing pipe 61, so that the sand 63 forms a sand pile.

[0031] The operation of putting the sand 63 into the casing pipe 61, pulling up the casing pipe 61 to a certain height, and again hammering the casing pipe 61 is repeated. The casing pipe 61 is then removed. Accordingly, the cohesive soil that constitutes the improvement target stratum 11 is replaced with the firm pile of the sand 63.

Thus, in addition to the groundwater drawdown by suction of pore water, the vibratory hammer 62 applies impacts to the casing pipe 61. The vibrations of the impacts on the casing pipe 61 by the vibratory hammer 62 are transmitted from the upper part to the bottom part of the improvement target stratum 11, as shown in the figure. This facilitates consolidation of the soil particle structure.

[0032] The upper end part of each pile of the sand 63 is then filled with a cap layer 64. The cap layer 64 is formed of the cohesive soil that constitutes the improvement target stratum 11.

[0033] By forming piles of the sand 63 with the sand compaction pile devices 6, the cohesive soil around the piles is also hardened. As an advantageous effect, water in the improvement target stratum 11 can be drained out through the piles of the sand 63, as shown by arrows.

[0034] The water can be drained out to the water-permeable stratum 12 through the piles of the sand 63 arranged at intervals, sucked by the SWP devices 2 arranged outside the piles at intervals, and ejected (pumped up) to the ground surface, as shown by arrows.

This can facilitate pump up of water and contribute to lower costs.

[0035] As described above, lowering the groundwater level by sucking pore water in the target ground 1 and facilitating consolidation by applying impacts is employed

in combination for a predetermined necessary period of time. This facilitates compression of the soil particle structures and further facilitates settlement of the target ground 1.

[0036] More specifically, in addition to facilitating settlement of the ground by sucking pore water, impacts are applied by the sand compaction pile devices 6. As a result, consolidation of the soil particle structures in the improvement target stratum 11 is facilitated, as shown in FIG.4.

[0037] In FIG.5, the characteristic X is obtained by lowering the groundwater level through suction of pore water with the SWP device 2 and facilitating settlement of the ground with the planned embankment 3. By further applying impacts with the sand compaction pile devices 6 in addition to the characteristic X, the settlement and consolidation can be facilitated, as shown by the characteristic Y or the characteristic Z.

[0038] As the characteristic B in FIG.6 shows, the settlement amount can be increased far beyond the target settlement amount L.

[0039] As described above, according to the ground improvement method in the second embodiment, the SWP device 2 evacuates air with the vacuum pump 26 and drains water with the drainage pump 24, so that pore water between soil particles of the soil particle structures is replaced with vacuum evaporated air in the improvement target layer 11 of

the target ground 1. The soil particle structures in which pore water is replaced by vacuum evaporated air are compressed by the impacts applied by the soil compaction pile devices 6. Accordingly, the settlement of the target ground 1 can be further facilitated.

[0040]

[Modifications]

Although the above embodiments employ vacuum evaporation with the SWP device and application of impacts, the present invention is not limited to these. Alternate sending and sucking of air through an air sucking-sending pipe buried in the ground may also be employed.

Although multiple SWP devices are buried in the target ground at intervals in the embodiments, a single SWP device may be buried in the target ground.

Further, the number of buried sand compaction piles is not limited. Naturally, other detailed configurations can be appropriately modified.

Industrial Applicability

[0041] According to the present invention, settlement and consolidation of the ground can be facilitated by applying impacts to the target ground and compressing the soil particle structures in which pore water between soil particles is replaced with vacuum evaporated air through evacuation of air with the vacuum pump and drainage of water

with the drainage pump of the SWP device.

Reference Signs List

[0042]

1. Target ground
11. Improvement target stratum (cohesive soil)
2. SWP device
21. Strainer pipe
22. Strainer part
23. Filter
24. Drainage pump
25. Drainpipe
26. Vacuum pump
3. Planned embankment (first embankment)
4. Vibration roller (impact application device)
5. Second embankment
6. Sand compaction pile device (impact application device)
61. Casing pipe
62. Vibratory hammer
63. Sand
64. Cap layer

CLAIMS

1. A ground improvement method comprising:
burying, in a target ground, a super well point device that
evacuates air with a vacuum pump so that groundwater flows into a strainer pipe buried underground, the strainer pipe including a water-permeable strainer provided at a lower end of the strainer pipe and a filter formed on an outer circumference of the strainer pipe,
sucks the groundwater with a drainage pump provided inside the strainer pipe, and
drains the groundwater out to a ground surface through a drainpipe;
lowering a groundwater level by sucking pore water in the ground; and
causing settlement of the ground by facilitating vacuum evaporation, wherein
the method further comprises applying an impact force to the ground to compress a soil particle structure in the ground so that settlement and consolidation of the ground is facilitated, in which the pore water between soil particles of the soil particle structure is replaced with vacuum evaporated air through the evacuation with the vacuum pump and the drainage with the drainage pump of the super well point device.

2. The ground improvement method according to claim 1, wherein the applying of the impact force includes:

adding a surcharge on the target ground by laying a first embankment on the target ground; and

running a vibration roller over the first embankment.

3. The ground improvement method according to claim 2, wherein the applying of the impact force further includes:

further adding a surcharge on the target ground by laying a second embankment on the first embankment; and

running the vibration roller over the laid second embankment,

whereby the settlement and the consolidation of the ground is secondarily facilitated.

4. The ground improvement method according to claim 1, wherein the applying of the impact force includes:

hammering a casing pipe into the target ground,

putting sand into the casing pipe; and

vibrating the casing pipe with a vibratory hammer.

5. The ground improvement method according to claim 4, further comprising:

removing the casing pipe so that a sand pile is formed;

and

on an upper end of the sand pile, forming a cap layer with a cohesive soil that constitutes the target ground.