

Method and Apparatus to Improve Sandy Ground

BACKGROUND OF THE INVENTION

Field of the Invention:

This invention relates to a method and an apparatus used to improve supporting force of the sandy ground and or to enhance liquefaction resistance.

Description of the Prior Art:

Heretofore has been provided such a method of improving soft ground as pumping by disposing a deep well at every required interval on the soft ground, supplying compressed air into the soft ground by inserting an air tube between adjacent deep wells, and forcibly catching moisture content in the soft ground by the deep wells (Japanese Patent Appln. Public Disclosure No. 54-1908).

According to this conventional method of improvement, water in soil rapidly decreases due to the catchment by pumping and the catchment by air injection, so that, when a saturated state of the moisture content in the soil exists no longer, the buoyancy of soil particles in the water is released, increasing the weight of the soil per volume, whereby the soil is consolidated by its own weight (lines 2 - 7, lower left column, p. 2 of the Official Gazette).

Compressed air, when supplied to the soft ground, mixes with the earth and sand of the soft ground to stir the earth and sand. In such a stirred state, the earth and sand cannot be consolidated. Consequently, a consolidating effect by the compressed air can not be obtained by only supplying the compressed air to the ground such as in the conventional method of improvement except for only a little catchment effect. On the other hand, it has been confirmed that, by supplying the compressed air intermittently to the ground, the stirred soil is reaccumulated during suspension of the supply of the compressed air, and thereby a consolidation effect can be obtained.

An object of the present invention lies in providing a method and an apparatus to improve ground, effectively utilizing high-pressure fluid discharged in the ground.

SUMMARY OF THE INVENTION



The method of improving the ground relative to this invention comprises inserting a supply tube for the compressed air and a suction tube for the ground water and air, intermittently supplying the compressed air through the supplying tube to the sandy ground to give an impact load to the sandy ground, and sucking the ground water and the air through the sucking tube out of the sandy ground while the compressed air is intermittently supplied or after the supply thereof is suspended.

When the compressed air is intermittently supplied, the time for supply is shortened so that an impact load may be applied to the sandy ground. In the ground subjected to the impact load, particles of the sand and earth are disconnected in a moment, and particles of the sand and earth shaken by the impact load are tightly connected with each other and reaccumulated.

Since the compressed air is not only intermittently supplied but it is supplied in a short time and the impact load obtained thereby is utilized, a great load is exerted to the particles of the earth and sand, shaking them greatly and positively sucking the ground water and the air, the particles of the sand and earth of the ground are reaccumulated in a tightly connected state, and a high compacting effect of the ground can be obtained. In place of the compressed air, high-pressure water can be used as squirt fluid. Also, since the impact load of the air is utilized, a great loss due to pipeline resistance in case of obtaining a similar effect by an impact load of water can be avoided, and since the compressed air expands when supplied to the ground, thereby transmitting the impact load over a wide range, a high effect can be obtained with a little waste of energy.

The supply tube is preferably provided with a check valve. By this, the earth and sand of the sandy ground can be prevented from being sucked due to the negative pressure generated in the supply tube by the suspension of supplying the compressed air.

When the supply of the compressed air is suddenly suspended, a negative pressure may be generated to the interior of the supply tube depending on the length of the supply tube. By providing a check valve, the earth and sand is



prevented from being sucked into the supply tube from the ambient ground, and a cause for clogging of the supply tube can be removed.

Further, another method of improvement relative to the present invention is performed by disposing a hollow body capable of varying its capacity in the sandy ground and thereafter supplying high-pressure fluid into the hollow body, thereby rapidly increasing the capacity of the hollow body. It is possible to alternate supplying of high-pressure fluid into the hollow body and discharging of the fluid from the hollow body. Preferably, during the supply of the high-pressure fluid, the ground water is sucked from around the hollow body.

According to the present invention, when the capacity of the hollow body is rapidly increased by the supply of the high-pressure fluid into the hollow body disposed in the ground, the hollow body hits the ambient ground, exerting impact force to the ambient ground. Upon receipt of the impact force, the ambient ground shakes, whereby the accumulation density of the soil particles in the ambient ground is increased, to consolidate the ambient ground. According to the present invention, the high-pressure fluid exerts an impact action to the ambient ground indirectly through the hollow body. Therefore, there is no immersion of the high-pressure fluid into the ambient ground nor lowering in consolidation of the ambient ground accompanying therewith. Consequently, the sandy ground can be further improved by effectively utilizing the high-pressure fluid.

By alternating supplying and discharging of the high-pressure fluid into the hollow body and discharging, impact actions are exerted to the ambient ground a number of times to enhance the degree of consolidation. Also, since upon receipt of an impact action, the ground water pressure of the saturated sandy ground sometimes rises to become plastic. Therefore, by sucking the ground water from the neighborhood of the hollow body during the supply of the high-pressure fluid, the sandy ground with a high ratio of water content can be prevented from transferring to a plastic state, thereby compacting the ground.

Such a method of improvement can be performed by using an apparatus which comprises a tube member having at least one hole connected to a high-pressure fluid



supply source and a sheet member attached to the tube member and defining, in cooperation with the tube member, a hollow portion communicating to the hole in the circumference of part of the tube member. The tube member should further have at least one hole connected a negative pressure source and communicating to the hollow portion. Furthermore, the tube member can have at least one hole opening in the periphery of the tube member outside the hollow portion and connected to the negative pressure source or another negative pressure source.

In this apparatus for improving the ground, when used, a sheet member defining the hollow portion in the circumference of part of the tube member can be disposed in the sandy ground by inserting the tube member into the sandy ground. The hollow portion is in a state of a small volume due to the ground water pressure of the ambient ground, and can suddenly change into a state of a great volume by introduction of high-pressure fluid from the high-pressure fluid supply source through the hole of the tube member. The rapid change in volume of the hollow portion makes the sheet member hit the ambient ground to exert an impact action. The fluid inside the hollow portion can be discharged through another hole of the tube connected to the negative pressure source. It is also possible to suck the ground water from the ambient ground through a hole provided in the tube member and opening in the outside of the hollow portion.

BRIEF DESCRIPTION OF THE DRAWING

Fig. 1 is a schematic diagram showing an embodiment of the method of improving the ground relative to this invention.

Fig. 2 is a schematic diagram showing an embodiment for performing on an upper level the method of improving the ground relative to the invention as shown in Fig. 1.

Fig. 3 is a schematic diagram showing another embodiment of the method of improving the ground relative to this invention.

Fig. 4 is a schematic diagram showing still another embodiment of the method of improving the ground relative to this invention.

Fig. 5 is a schematic diagram showing still another embodiment for performing

the method of improving the ground relative to the invention.

Fig. 6 is a schematic diagram showing still another embodiment of the method of improving ground relative to this invention, in which (a) and (b) respectively show examples of disposing check valves in different positions.

Fig. 7 is a time chart showing a negative pressure temporarily generating in the supply tube.

Fig. 8 is a schematic diagram showing a method of improvement by which an effect similar to the method of improving the ground relative to this invention can be anticipated.

Fig. 9 is a perspective view showing a soil tank used for an experiment to confirm the effect of the method of improving the ground relative to this invention.

Fig. 10 shows a result of the experiment according to the present invention, in which (a) is a contour showing the relation between the depth of the ground and the horizontal distance from the nozzle, and (b) is a graph showing cone penetration resistance values by color variation.

Fig. 11 shows a result of the experiment according to the present invention, in which (a) is a contour showing the relation between the depth of the ground and the horizontal distance from the nozzle, and (b) is a graph showing cone penetration resistance values by color variation.

Fig. 12 shows a result of a comparative experiment, in which (a) is a contour showing the relation between the depth of the ground and the horizontal distance from the nozzle, and (b) shows cone penetration resistance values by color variation.

Fig. 13 is a schematic diagram showing a gap generated in the ground when a supply of the compressed air is continued for a long time.

Fig. 14 is a schematic illustration of the apparatus for improving the ground installed in the ground.

Fig. 15 is a schematic illustration of the apparatus for improving the ground under improvement.

Fig. 16 is a partly enlarged perspective view of the apparatus for improving the ground.

Fig. 17 is an exploded view of elements forming the hollow portion of the apparatus for improving the ground.

DETAILED DESCRIPTION OF THE INVENTION

In the embodiments shown in Figs. 1 through 6, the same reference numerals indicate the parts of the same function and superfluous explanations are omitted.

As shown in Fig. 1, the supply tube 20 for the compressed air and the suction tube 22 for the ground water and air are inserted into the sandy ground 24. The insertion of these tube members 20, 22 into the sandy ground 24 is preferably made through a common tube member 26. The supply tube 20 and the suction tube 22 are inside and secured to the tube member 26. The tube member 26 is provided with a plurality of squirt holes 21 communicating to the supply tube 20 and a plurality of inlet ports 23 communicating to the suction tube 22. The squirt holes 21 and the inlet ports 23 are respectively arranged at intervals in the circumferential direction. The tube member 26 can be inserted into the sandy ground 24 by inserting or other well-known methods, or by loading a weight (not shown) on the upper end of the tube member 26 while dropping water from the lower end thereof onto the sandy ground 24, or while squirting water jet from the lower end onto the sandy ground 24 below the lower end. By using the tube member 26, clogging of the earth and sand at the front ends respectively of the supply tube 20 and the suction tube 22 at the time of inserting into the sandy ground 24 can be avoided, and the relative position of the supply tube 20 and the suction tube 22 can be maintained to be constant. The supply tube 20 is connected to a compressed air generator 28, and the suction tube 22 is connected to a pump 30.

Through the supply tube 20, the compressed air is intermittently supplied to the sandy ground 24 from the squirt holes 21 formed like a nozzle, to give an impact load to the sandy ground 24. The impact load is generated by opening and closing for a short time an electromagnetic switching valve 32 incorporated into the supply tube 20. The switching time to turn on and off the electromagnetic switching valve 32 should be 0.1 second or less. The impact load becomes an impact wave 34 and propagates through the sandy ground 24 to disconnect the earth and sand of the

sandy ground for an instant. The earth and sand are shaken by the impact wave 34 and reaccumulated densely. The impact is a violent collision between two articles such as to cause an obvious change in momentum of a system, i.e., impulsive or transient motion or force continuing for about 1/1000 seconds to 1/10 seconds which can cause a mechanical resonance such as an impact wind due to explosion, so that the switching time of such a range as mentioned above is appropriate.

What is important is to fix the time from the start of supplying the compressed air till the suspension of supply to be within the above-mentioned range (1/1000 seconds to 1/10 seconds), and the time from the suspension of supply to the following start of supply does not matter. The latter time can be determined on the basis of such factors as the time required for preparation of compressed air for the following supply, the degree of required compacting of the ground, the range of the ground, the period of construction. While the pressure of the compressed air is also an important factor, as apparent from the relation that a change in momentum equals to an impulse, the amount of force is determined relative to the time during which the force is exerted on an object. Since the time in this case has a certain range as mentioned above, the amount of pressure is not univocally determined. It is recommendable to determine to give the impact load to the ground in relation to the time for supplying the compact air. For example, in case the compact air is supplied from supply holes of the same size, similar effects can be anticipated in case of supplying for 1/100 seconds under pressure of 10kgf/cm² and in case of supplying for 1/200 seconds under pressure of 20kgf/cm².

The ground water and air in the sandy ground is sucked out through the suction tube 22. This sucking can be performed continuously from the time while the compressed air is being supplied or after the supply of the compressed air is suspended. Filters (not shown) are mounted on the inlet ports 23 in advance. By sucking in the ground water and air as shown by arrows 25 and exhausting onto the ground, the earth and sand of the sandy ground becomes further dense. It is also preferable that the sucking of the ground water and air be also intermittent.

By repeating intermittent supply of the compressed air and sucking of the

ground water and air, the compacted improved ground 36 over a certain range can be obtained as shown in Fig. 2. Then, pulling and moving upward the tube member 26 within the sandy ground 24, intermittent supply of the compressed air and sucking of the ground water and the air are repeated. It is preferable that the tube member 26 be provided with slits (not shown) extending downward from the upper end through which hoses respectively connected to the supply tube 20 and the suction tube 22 can pass with the movement of the tube member so that the hoses can enter the slits, and it is also preferable that each hose is previously mounted detachably on a strut 38.

As shown in Fig. 3, it is also possible to secure a supply tube 20 to a tube member 40 and the suction tube 22 to a tube member 42 so that they can enter the sandy ground 24 separately. According to this embodiment, the ground water and air can be sucked at a position at an interval in the horizontal direction from a supply portion of the compressed air or at a position at an interval in the horizontal and the vertical directions.

As shown in Fig. 4, since it is also possible to insert the tube member 26 diagonally into the sandy ground 24, the ground directly under an existing building 41 and the ground in the neighborhood of a structure can be compacted.

As in the embodiment shown in Fig. 5, in case the sandy ground 24 to be improved is below the surface layer ground 43 which needs no improvement, the tube member 26 can be disposed on the sandy ground to be improved and compacted. In this point, in comparison with, for example, compacting by the use of a conventional shaking compacting apparatus which also shakes even the surface layer ground 43, further energy saving can be intended.

As shown in Fig. 7, the pressure within the supply tube is a positive pressure at A when the compressed air is supplied by the supply tube, but it becomes a negative pressure at B temporarily when the supply is suspended. So, as shown in Fig. 6, the supply tube 20 is preferably provided with a check valve 44. The check valve 44 permits the air flow from the supply tube 20 toward the sandy ground 24 but checks the ground water flow and the air flow from the sandy ground 24 toward

the supply tube 20. In the embodiment of Fig. 6(a), the check valve 44 is positioned above away from the nozzle, i.e., the squirt hole 21 of the supply tube 20, and acts for all the nozzles in common. On the other hand, in the embodiment of Fig. 6(b), the check valve 44 is positioned adjacent to each nozzle 21, which is provided with one check valve.

As shown in Fig. 8, an effect similar to the case of the compressed air can be obtained by inserting an explosive 50 and a suction tube 52 for a gas generated by an explosion and the ground water into the sandy ground 24 and applying an impact load to the sandy ground 24 by exploding the explosive 50. In such a case, continuously from during the explosion or after the explosion, the ground water and the gas are sucked from the sandy ground 24 through the suction tube 52 as shown by an arrow 53 and exhausted onto the ground. A plurality of explosives 50 are previously mounted on a bar 54 at intervals, and the bar 54 is inserted into a hole 56 opened in the sandy ground 24. The explosive 50 at the bottom is first exploded, and the ground water and the gas generated by the explosion are exhausted by the suction tube 52. Thereafter, the suction tube 52 is pulled up by a predetermined distance, and then the explosive 50 at the second from the bottom is exploded and the ground water and the gas generated by the explosion are sucked by the suction tube 52.

A soil tank 60 having the dimension as shown in Fig. 9 and filled with sand was prepared and a supply tube 62 was inserted into a corner of the soil tank 60. A cycle of squirting the compressed air 64 of 10kgf/cm^2 for 0.03 seconds from a nozzle 63 provided at the lower end of a supply tube 62 and then continuing a one-second suspension of the squirting is performed for 120 seconds, and suction 66 of the water and the air was continued during the squirting of the compressed air. This is called Experiment A. Experiment B was conducted under the same condition except the supply of the compressed air for 0.08 seconds. Incidentally, the nozzle 63 had the inner diameter of 13 mm and was provided a tone portion of the supply tube 62, the level of the nozzle 63 being 75 cm.

Fig. 10(a) is a contour obtained by Experiment A, showing the relation between

the depth of the ground and the horizontal distance from the nozzle, while (b) indicates cone penetration resistance values shown by the shading of the contour. Also, Figs. 11(a) and (b) are a contour and cone penetration resistance values obtained by Experiment B. Figs. 12(a) and (b) are a contour and cone penetration resistance values of Comparative Experiment C in which the compressed air of 10kgf/cm² is squirted for 2 seconds, then a 2-second suspension of squirting is continued, and otherwise under the same condition as mentioned above. In Fig. 10, there are white or nearly white portions close to the nozzle, which indicates that the cone penetration resistance values in these portions are particularly great. In Fig. 11, the view is similar to that of Experiment A, while in a portion above the 75 cm level of the nozzle, the cone penetration resistance values are smaller in comparison with Experiment A in Fig. 10. On the other hand, there is no white or nearly white portion in Fig. 12, and the cone penetration resistance values are smaller in comparison with Figs. 10 and 11. When the compressed air is supplied to the sandy ground, air bubbles mix with the earth and sand to cause a so-called boiling phenomenon which stirs the earth and sand, causing pores 70 in the ground 72 as shown in Fig. 13. The longer the supply of the compressed air, the more these pores 70. The fact that in Fig. 12 the cone penetration resistance values are small in the portion above the 75 cm level of the nozzle indicates that compacting is difficult because of many pores. According to experiments in the present invention, since the compressed air is supplied only for such a short time as an impact load can be obtained, it is considered that a boiling phenomenon has not substantially occurred.

Results of the examples of experiments and the examples of comparative experiments are shown in the following Table, in which the relative density D_r can be given by the following equation:

$$D_r = \{(e_{\max} - e)/(e_{\max} - e_{\min})\} \times 100 (\%)$$

where e is the ratio of gaps in sand, $e_{\max}$ is the ratio of gaps of the sand in the least dense state, and $e_{\min}$ is the ratio of gaps of the sand in the densest state.



		Before testing		After testing	
Experi- ment No.	Squirt- ing Time (sec.)	Relative Density (%)	Average cone penetration resistance value of entire soil tank (Kg/cm ²)	Relative Density (%)	Average cone penetration resistance value of entire soil tank (Kg/cm ²)
A	0.03	36.9	1.40	54.0	7.48
B	0.08	36.9	1.47	50.7	6.55
C	2.00	36.9	1.48	49.2	5.47

As seen from the Table, in Experiments A and B according to the present invention, the relative densities are improved in comparison with Comparative Experiment C and the average cone penetration resistance values of the entire ground are greater.

The improving method of the present invention can be performed by applying high-pressure water instead of the compressed air, similarly to the case of using the compressed air.

In the following, another method of improvement relative to the present invention and the ground improving apparatus 80 for performing it are explained with reference to Figs. 14 and 15.

The ground improving apparatus 80 comprises a tube member 82 similar to the tube member 26 shown in Fig. 1 and a sheet member 84 mounted on the tube member 82.

The illustrated tube member 82 has a lower end portion 86 and an open upper end portion 88. The tube member 82 can be penetrated into the sandy ground 24 from its lower end portion 86, whereby the ground improving apparatus 80 can be disposed in the ground. The lower end portion 86 of the tube member is set to have a tapered configuration to make the intrusion resistance small. Also, it is blocked so as to prevent the earth and sand from entering the tube member 82 while



inserting or intruding. The intrusion of the tube member 82 into the sandy ground 24 can be performed, as in the case of the tube member 26, by loading a weight (not shown) on the upper end portion 88 of the tube member 82, or further by dripping water on the sandy ground 24 from the lower end portion 86, or by squirting water jet on the sandy ground 24 further downward from the lower end portion 86.

The tube member 82 is provided with a plurality of holes 90 similar to the holes 21 in Fig. 1, the holes opening on the peripheral surface, and a plurality of holes 92, 94 similar to the holes 23. The plurality of holes 90 are respectively at the same height portion, and there is one hole 92 below these holes 90. There are provided at least one each of the holes 90, 92, 94. The holes 90, 92, 94, as a set, can be provided at an arbitrary height position of the tube member 82, and each of the holes 90, 92, 94 can be disposed at an arbitrary height position of the tube member 82. The former two holes 90, 92 are, however, disposed at positions to be covered by a sheet member 84 fully mentioned later, while the latter hole 94 is disposed at a position not to be covered by the sheet member 84. It is desirable to cover the holes 92 and 94, such as the holes 23 in Fig. 1, with a filter 97 for preventing foreign substances such as earth and sand or dust from entering.

Each hole 90 at the highest position is connected to a high pressure fluid supply source 100 such as a high-pressure water compressor or an air compressor installed on the ground, through a flexible capillary tube 98. By actuating the high-pressure fluid supply source 100, high-pressure fluid such as high-pressure water or high-pressure air can be squirted into the outside of the tube member 82 from each hole 90.

One hole 92 directly below each hole 90 is connected to a negative pressure source (not shown) such as a storage pump or a vacuum apparatus installed on the ground, through a flexible tube 102 similarly extending upward and downward within the tube member 82. By actuating the negative pressure source, a negative pressure action can be exerted from the hole 92 to the environment outside the tube member 82.

In place of the illustrated embodiment for providing both of the holes 90 and

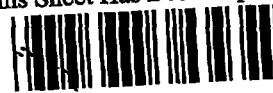


the holes 92, it is possible to provide either of the holes 90 or the holes 92, using them as common holes for squirting the high-pressure fluid and applying a negative pressure. One or a plurality of the common holes can be connected to both of the high pressure fluid supply source 100 and the negative pressure source through a tube similar to the one mentioned above and a valve means (not shown) such as a two-way valve. The squirt of the high-pressure fluid and the application of the negative pressure can be alternately made by operating the valve means.

The holes 94 positioned in the neighborhood of the lower end portion 86 of the tube member 82 are connected to the negative pressure source similarly through a flexible tube 104 extending in the vertical direction within the tube member 82 and through valve means (not shown) such as a two-way valve, or independently thereof, to another negative pressure source (not shown) disposed on the ground. By actuating the negative pressure source, a negative pressure action can be applied to the environment outside each hole 94 and suck the ground water from the sandy ground 24.

The sheet member 84 surrounds the periphery of part of the tube member 82, defining a hollow portion 106 presenting an annular configuration as a whole. The holes 90 and 92 are covered by the sheet member 84 which is a hollow body, and are communicated to the hollow portion 106. In place of the illustrated embodiment in which one hollow portion 106 is provided, a plurality of hollow portions 106 defined by a plurality of sheet members 84 can be disposed on multiple stages in the longitudinal direction of the tube member 82. In such a case, it is preferable to dispose holes similar to the holes 94 for sucking the ground water between the hollow portions 106.

The sheet members 84 are selected so as to have a property not to pass any liquid such as water or any gas such as air and such a strength as not to be cracked by contact with gravel, earth and sand in the ground 24 when intruding into the ground. As those suited to such a property, there are, for example, a rubber sheet material, sheet materials such as a fabric made of aramid, high strength polyethylene fiber (such as, for example, ダイニーマ (pronounced like "dainiima")



produced by Toyo Boseki Kabushiki Kaisha). As a fabric made of the above-mentioned ダイニーマ, a fabric, for example, having a thickness of 0.36 mm may be selected. A resin coating is applied to the fabric, if necessary, for ensuring liquid tightness and air tightness.

Since the sheet material 84 is foldable and transformable, the capacity of the hollow portion 106 is varied with transformations of the sheet member 84. In the sandy ground 24, due to the earth and water pressure applied from the periphery, the sheet member 84 in its major portion is brought into contact with the peripheral surface of the tube member 82, and the capacity of the hollow portion 106 at this time is small. The maximum size of the capacity, the length of the sheet member 84 in the axial direction of the tube member 82, the maximum diameter of the sheet member 84, etc. can be arbitrarily determined.

As fully shown in respective examples in Figs. 16 and 17, in order to form the hollow portion 106 defining a sealed space, a hole 90 of the tube member 82 to be covered by the sheet 84 and the portion 108 (Fig. 17) for disposing a hole 92 are set to have larger diameters than another portion 110. In the vicinity of the large diameter portion 108, a rubber band 112 is wound at each small diameter portion 110. Each rubber band 112 and the periphery of the large diameter portion 108 are surrounded by the cylindrical sheet member 84. Each end portion of the cylindrical sheet member 84 is narrowed, surrounded by another rubber band 114 which is further surrounded by a stainless fastening band 116. Each fastening band 116 has an inner diameter smaller than the outer shape of the inner rubber band 114, and has both end portions opposite to each other at an interval in the peripheral direction. Each end portion of the sheet member 84 is mounted liquid-tightly or air-tightly on each small diameter portion 110 of the tube member 82 through both rubber bands 112, 114 by fastening of a bolt and nut assembly 118 which penetrates both end portions opposite to each other of each fastening band 116.

As shown in Fig. 15, the improvement of the sandy ground is carried out by supplying high-pressure fluid into the hollow portion 106 from the high-pressure fluid supply source 100 through the tube 98 and the holes 90. The sheet member



84 is rapidly expanded by an increase of the internal pressure following the supply of the high pressure fluid. It is desirable to supply such an amount of the high-pressure fluid as causes no elongation to the sheet member 84, that is, less than the maximum capacity of the hollow portion 106. The supply time and the supply pressure of the high-pressure fluid can be set respectively at 0.1 ~ 0.01 second and 10 ~ 100 Kg/cm², for example.

As a result of the rapid expansion of the sheet member 84, the peripheral ground is subjected to impact force and shakes. Due to this shake, the state of accumulation of the earth and sand of the peripheral ground varies and is consolidated, compacting the peripheral ground. The high pressure fluid can be supplied repeatedly. In such a case, the high-pressure fluid is supplied preferably after the total amount of the previously supplied fluid is discharged from the hole 92. The fluid is discharged by applying negative pressure action to the hole 92 by actuating the negative pressure source and sucking the fluid from the hollow portion 106. By repeating the impact action to the peripheral ground, the degree of consolidation of the peripheral ground can be further enhanced. Also, according to the example to dispose a plurality of hollow portions 106 in multistages, the ground can be compacted in a wide range in the depth direction of the ground. The supply of the high-pressure fluid to the multistage hollow portions 106 can be made to all the hollow portions 106 temporarily or at intervals in time.

Preferably, during the application of the impact force, that is, during the supply of the high pressure fluid into the hollow portion 106, the ground water is sucked from the vicinity of the hollow portion 106. The sucking of the ground water is done by actuating the negative pressure source and applying negative pressure to the holes 94 near the lower end portion 86 of the tube member 82.

When the sandy ground 24 under improvement, more particularly, the peripheral ground is in a saturated state, the impact action sometimes raises the ground water pressure inside the peripheral ground to bring the peripheral ground to a plastic state, while sucking of the ground water prevents the peripheral ground having a great percentage of water content from transferring to a plastic state, so

that the peripheral ground can be compacted well.

The improvement of the sandy ground 24 by using the improving device 80 can be done step by step from a deep position to a shallow position similarly to one described above by intermittently pulling up the improving device 80. Also, the improvement of the ground by using the improving device can be done with the tube member 82 tilted, not in a vertical state. The ground under a building can, therefore, be improved as described above, for example, by intruding the tube member 82 diagonally toward directly under the building from the periphery of the building on the sandy ground.

**WHAT IS CLAIMED IS:**

1. A method of improving the ground comprising:
inserting a supply tube for the compressed air and a suction tube for the ground water and air into sandy ground;
applying an impact load to the sandy ground by intermittently supplying the compressed air through the supply tube; and
sucking the ground water and air from the sandy ground continuously from during the supply of the compressed air or after suspension of the supply of the compressed air through the sucking tube.
2. A method of improving the ground according to claim 1, wherein said supply tube includes a check valve and prevents sucking of earth and sand of the sandy ground by a negative pressure generated in said supply tube by suspending the supply of the compressed air.
3. A method of improving the ground comprising:
inserting a supply tube for high-pressure water and a suction tube for the ground water into sandy ground;
applying an impact load to the sandy ground by intermittently supplying the high-pressure water through the supply tube; and
sucking the ground water from the sandy ground continuously from during the supply of the high-pressure water or after suspension of the supply of the high-pressure water through the sucking tube.
4. A method of improving the ground, wherein after a hollow body capable of varying the capacity is disposed in the sandy ground, a high pressure fluid is supplied into said hollow body to rapidly increase the capacity of said hollow body.
5. A method of improving the ground, wherein after the hollow body is disposed in the sandy ground capable of varying the capacity, a supply of a high-pressure fluid into said hollow body to rapidly increase the capacity of said hollow body and a discharge thereof from said hollow body are alternated.
6. A method as described in claim 4, wherein while said high-pressure fluid is supplied, the ground water is sucked from the vicinity of said hollow body.





7. A method as described in claim 5, wherein while said high-pressure fluid is supplied, the ground water is sucked from the vicinity of said hollow body.

8. An apparatus for improving the ground comprising a tube member disposed in the sandy ground for improvement of said sandy ground and having at least one hole connected to the high pressure fluid supply source, and a sheet member mounted on said tube member and defining a hollow portion communicated with the periphery of part of the tube member.

9. An apparatus as described in claim 8, wherein said tube member is further provided with at least one hole connected to a negative pressure source and communicating with said hollow portion.

10. An apparatus as described in claim 8, wherein said tube member has at least one hole opening on the peripheral surface of said tube member outside said hollow member and connected to the negative source.