

## SPECIFICATION

### SAND PILE FORMING METHOD AND APPARATUS

#### TECHNICAL FIELD

The present invention relates to a method of forming a sand pile for improving ground in soft ground and an apparatus for forming the sand pile according to this method.

#### TECHNICAL BACKGROUND

Conventionally, as this type of sand pile forming method and apparatus, there is one disclosed in Japanese Patent No. 2791914.

In the sand pile forming apparatus disclosed in the patent, a downward cylinder 44 driven by supplying pressurized water and a plurality of sand compacting and discharging blades 45 arranged radially and driven vertically by the downward cylinder 44 are provided to a lower portion of a sand pile forming hollow pipe 41 which includes a vibro-hammer 46 at a head portion of the pipe 41 and a hopper 42 for charging sand and a compressed air supply pipe 43 mounted to an upper portion of the pipe 41 as shown in FIG. 15. A reference numeral 47 designates a pressurized water supply pipe for supplying pressurized water to the downward cylinder 44.

A sand pile forming method by using this apparatus is as follows.

First, the hollow pipe 41 is driven into a predetermined depth by using the vibro-hammer 46, the sand is charged from the hopper 42, and compressed air is blown from the compressed air supply pipe 43. At this time, air pressure in the hollow pipe 41 is such a degree that soil around the pipe 41 does not flow into the pipe and must not be such large pressure that the sand charged into the pipe is discharged outside the pipe.

By injecting the pressurized water into the cylinder 44 and vertically moving the discharging blades 45 a plurality of times at a constant speed in this state, almost all sand discharged into the hollow pipe 41 except a part of the sand is forcibly pushed out and discharged below the hollow pipe 41 by contact resistance between the sand and the discharge blades 45. At this time, the hollow pipe 41 is pulled out of the ground by a predetermined length. As a result, the discharged sand is compacted by the discharging blades 45.

If the sand is discharged into the soft ground in the above manner, pressure in the pipe 41 is released, a predetermined amount of sand is charged again from the hopper 42, pressurization in the pipe so as to balance with earth pressure according to a displacement of a lower end of the hollow pipe 41, discharge and compacting of the sand by actuation of the cylinder 44, and pulling out of the hollow pipe 41 by a predetermined length are carried out. After that,

the above operation is repeated to form the sand pile.

A degree of above pressurization is determined based on earth pressure by calculating in advance the earth pressure according to the depth of the lower end of the hollow pipe 41.

As other sand pipe forming apparatuses, there is one disclosed in Japanese Patent Publication No. 8-1060 which was filed before by the present applicant.

As shown in FIG. 16, this is one in which a cylindrical tip end lid case 13' retaining a ball valve 16 having a predetermined specific gravity such that the ball valve 16 can move vertically is mounted to a tip end of a casing pipe 11 provided with a nozzle 21 for introducing compressed air into the pipe 11 and a valve seat portion 14 closed with the ball valve 16 is provided to an opening portion of the tip end (lower end in FIG. 16) of the casing pipe 11. The ball valve 16 closes the tip end of the casing pipe 11 to prevent earth and sand from entering when the casing pipe 11 is driven into ground. The ball valve 16 separates from the valve seat portion 14 due to pressure of the sand and compressed air and a gap for discharging the sand is formed between the ball valve 16 and the tip end lid case 13' when the sand for forming the sand pile is discharged.

In the prior-art sand pile forming apparatus shown in FIG. 15, the sand compacting and discharging blades have to

be provided for vertical movement and the downward cylinder for driving the discharging blades has to be provided on the tip end side in the hollow pipe. The blades and the cylinder may be broken by sand charged into the hollow pipe and pressure generated in fitting in the hollow pipe and may be obstructions in discharging the sand. Furthermore, in this apparatus, because accessory equipment such as the pressurized water supply device for actuating the downward cylinder and a controller of the device is required, the equipment becomes large-scale, which requires extra labor for preparation and operation for the equipment.

In the sand pile forming method by using the apparatus, because it is necessary to repeat the operations of charging the predetermined amount of sand into the hollow pipe, blowing compressed air at predetermined pressure into the pipe, moving the discharging blades vertically in this state to thereby compact the sand, and pulling out the hollow pipe by the predetermined length, operation efficiency is extremely low. Although the air pressure in the hollow pipe is controlled so as to balance with earth pressure according to the displacement of the lower end of the pipe as the hollow pipe is pulled out, the earth pressure is based on a calculated value and therefore, optimal air pressure cannot necessarily be obtained depending on an actual condition of ground and desired operation may not be carried out.

In the apparatus shown in FIG. 16, because the tip end of the casing pipe is closed with the ball valve when the casing pipe is driven in, there is no fear that seawater and argillaceous earth and soil enter the pipe. However, when the sand is discharged, the ball valve becomes an obstruction and discharge of the sand takes time.

It is an object of the present invention to solve the problems of the prior-art sand pile forming methods and apparatuses and to provide a method of reliably and efficiently forming a sand pile having predetermined strength and diameter in various kinds of soft ground with different conditions and an apparatus used for the method.

#### DISCLOSURE OF THE INVENTION

A sand pile forming method of the present invention includes the steps of driving a casing pipe having a tip end lid of a ball valve type into soft ground, charging sand into the casing pipe, and then pulling the casing pipe out while leaving only a sand pile formed of the charged sand in the ground, wherein air pressure in the tip end lid is controlled to be equal to earth pressure measured around the tip end lid when the casing pipe is pulled out of the ground to thereby fill the sand into a cavity formed by the casing pipe without collapsing the cavity.

A sand pile forming method includes the steps of

compacting sand discharged from a casing pipe having a tip end lid and increasing a diameter of the sand simultaneously by intruding the casing pipe again, wherein pressure in intruding the casing pipe again is controlled based on a measurement value of an earth pressure gage provided to a tip end of the casing pipe to thereby form a sand pile having desired strength and diameter.

A sand pile forming apparatus of the invention comprises a casing pipe provided with a nozzle for introducing compressed air into the casing pipe and a tip end lid mounted to a tip end of the casing pipe, wherein the tip end lid is formed of a tip end lid case substantially in a shape of a truncated cone with an expanded tip end, a ball valve housed for vertical movement in the tip end lid case, and a valve seat portion with which the ball valve comes into contact to make the tip end of the casing pipe airtight and the tip end lid case is provided with an earth pressure sensor for measuring earth pressure around the tip end lid case on an outside of the case, a pressure sensor for measuring air pressure in the casing pipe on an inside of the case, and an air supply hole for sending compressed air into the case inside the case.

An earth pressure gage for measuring intrusion pressure of the casing pipe is provided to a tip end of the tip end lid of the apparatus.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a vertical sectional view of an essential portion of an embodiment of a sand pile forming apparatus according to the present invention.

FIG. 2 is a sectional view taken along a line A-A in FIG. 1.

FIG. 3 is a sectional view taken along a line B-B in FIG. 1.

FIG. 4 is a sectional view taken along a line C-C in FIG. 1.

FIG. 5 is a schematic sectional view showing a step of use of the sand pile forming apparatus of the invention.

FIG. 6 is a schematic sectional view showing a step of use of the sand pile forming apparatus of the invention.

FIG. 7 is a schematic sectional view showing a step of use of the sand pile forming apparatus of the invention.

FIG. 8 is a schematic sectional view showing a step of use of the sand pile forming apparatus of the invention.

FIG. 9 is a sectional explanatory view of a sand pile forming method of the invention.

FIG. 10 is a sectional explanatory view of the sand pile forming method of the invention.

FIG. 11 is a simplified sectional view of a state in which a predetermined amount of sand is charged into a

cylindrical case.

FIG. 12 is an explanatory view of stress acting on an inner wall face of the case shown in FIG. 11.

FIG. 13 is a simplified sectional view of a state in which a predetermined amount of sand is charged into a case in a shape of a hollow truncated cone.

FIG. 14 is an explanatory view of stress acting on an inner wall face of the case shown in FIG. 13.

FIG. 15 is a simplified sectional view of a prior-art example of the sand pile forming apparatus.

FIG. 16 is a simplified sectional view of another prior-art example of the sand pile forming apparatus.

#### BEST MODE FOR CARRYING OUT THE INVENTION

In order to more specifically describe the present invention, the invention will be described according to the accompanying drawings. Here, parts having the same functions as those of the prior art are provided with the same reference numerals.

FIG. 1 is a sectional view of a tip end portion of a sand pile forming apparatus of the invention and FIGS. 2, 3, and 4 are respectively sectional views taken along lines A-A, B-B, and C-C in FIG. 1. The sand pile forming apparatus is formed by mounting a tip end lid 12 of a ball valve type to a tip end (a lower end in FIG. 1) of a casing pipe 11 and is

used for forming a sand pile in soft ground in improving the soft ground such as a layer of argillaceous which is a sediment on a sea floor or the like.

The casing pipe 11 is in a tubular shape filled with sand to be poured into the soft ground in a vertical state and having a constant inside diameter. A nozzle portion 21 for spouting a jet of air is provided in the casing pipe 11 to pass through a wall face of the casing pipe 11. The nozzle portion 21 discharges the jet of air downward. At an inner periphery of the tip end of the casing pipe 11, a valve seat portion 14 with which the ball valve (described later) comes in pressure contact is provided.

The valve seat portion 14 has an upper face portion 14a tilting downward as it extends from the inner peripheral face of the casing pipe 11 toward an axial center, an inner peripheral face portion 14b extending downward in parallel to the inner peripheral face of the pipe on an inner periphery side of the upper face portion 14a, and a tapered lower face portion 14c extending from a lower side of the inner peripheral face portion 14b and successively approaching the inner periphery side of the pipe. In other words, the lower face portion 14c projects upward in an arc shape. The valve seat portion 14 is reinforced by a plurality of ribs 14d provided radially around the valve seat portion 14 and is in contact with and fixed to the inner periphery of the casing pipe 11

through the ribs 14d as shown in FIG. 2.

The tip end lid 12 is formed by housing a ball valve 16 in pressure contact with the valve seat portion 14 for vertical movement in a tip end lid case 13 in a shape of a hollow truncated cone. In the tip end lid case 13, a plurality of (four in an illustrated example) ribs 15 are formed on an inner peripheral face of the tip end lid case 13 to extend inward and an upper end of each the rib 15 is in contact with the tip end (lower end in FIG. 1) of the casing pipe 11. An upper half portion of an inner end of each the rib 15 is formed as a vertical portion 15a continuous from the inner peripheral face of the casing pipe 11 in a vertical direction and a lower half portion of the inner end is formed as tilting portions 15b and 15c successively by tilting toward the axial center in two steps as it extends downward.

A reinforcing tube 20 is fitted over an outer peripheral face of a lower end of the tip end lid case 13. Inside the reinforcing tube 20, a pair of reinforcing members 18, 18 in inverted trapezoids are provided in a shape in which the members 18, 18 are assembled into a substantially cross shape in a plan view, a support portion 17 is provided to project upward from a point of intersection of the members 18, 18, and a valve retainer portion 19 having an upper face curved in an arc shape is provided on the support portion 17.

The ball valve 16 is hollow so as to have a smaller

specific gravity than argillaceous earth and sand (silt) and is normally placed on the valve retainer portion 19. If the argillaceous earth and sand enter the tip end lid case 13 in execution of construction, the ball valve 16 floats due to the argillaceous earth and sand and comes into pressure contact with the valve seat portion 14 to thereby close the lower end of the casing pipe 11.

Here, in the sand pile forming apparatus of the invention, an earth pressure sensor S1 for measuring earth pressure around the tip end lid case 13 is provided to an outer side of the tip end lid case 13 formed into the shape of the hollow and substantial truncated cone and a pressure sensor S2 for measuring pressure of an inside of the tip end lid case 13 is provided on an inner side of the tip end lid case 13 and facing the earth pressure sensor S1. An earth pressure gage S3 for measuring intrusion pressure in driving in of the casing pipe 11 is provided to a tip end (lower end in FIG. 1) of the tip end lid 12, i.e., a lower side of the point of intersection of the reinforcing members 18.

Although it is not shown in the drawings, the tip end lid case 13 is provided with an air supply hole for sending compressed air into the tip end lid case 13.

The sand pile forming apparatus of the invention has the above structure.

Next, a sand pile forming method of the invention by

using the sand pile forming apparatus will be described by way of an example of forming a sand pile in soft ground on a sea floor.

First, if a tip end of the sand pile forming apparatus is put into seawater as shown in FIG. 5, the seawater enters the tip end lid case 13 from an opening in the lower end of the case 13. At this time, if the seawater enters to some extent, air pressure in the case 13 increases. Therefore, the seawater does not enter the casing pipe 11 above the valve seat portion 14.

Then, if the apparatus is further moved down, the tip end lid 12 eventually reaches a soft argillaceous earth-and-sand layer 31 and is intruded into the layer 31. If the tip end lid 12 is intruded into the argillaceous earth-and-sand layer 31 in this manner, the argillaceous earth and sand enter from the opening in the lower end of the tip end lid case 13 and the ball valve 16 having the smaller specific gravity than the argillaceous earth and sand is pushed up and comes into pressure contact with the lower face portion of the valve seat portion 14 as shown in FIG. 6. As a result, the lower end of the casing pipe 11 is closed and the argillaceous earth and sand are prevented from entering the casing pipe 11.

At this time, if an intruded amount of the tip end lid 12 into the argillaceous earth-and-sand layer 31 increases,

the ball valve 16 receives a larger buoyant force.

If the tip end lid 12 passes through the argillaceous earth-and-sand layer 31 and is intruded into a hard earth-and-sand layer 32 under the argillaceous sand-and-earth layer 31 as shown in FIG. 7, the ball valve 16 receives a yet larger buoyant force and comes into pressure contact with the valve seat portion 14. Therefore, sand S is charged into the casing pipe 11 in this state. At this time, an amount of the charged sand S is such an amount that the ball valve 16 does not moved down by weight of the sand.

When the sand S is charged into the casing pipe 11 such that the ball valve 16 does not move down, the tip end if further intruded into the hard earth-and-sand layer 32. Thus, a yet larger buoyant force acts on the ball valve 16. Therefore, a state in which sand S can be charged into the casing pipe 11 is obtained and sand S of such an amount that the ball valve 16 does not move down is charged additionally. While repeating charging of the sand S into the casing pipe 11 and intrusion into the hard earth-and-sand layer 32 alternately, the entire apparatus is intruded until the tip end lid 12 reaches ground 33 having predetermined strength under the hard earth-and-sand layer 32 as shown in FIG. 8.

At this time, in the sand pile forming apparatus of the invention, measurement values of the earth pressure sensor S1 and the pressure sensor S2 are contrasted with each other

such that pressure in the tip end lid case 13 corresponds to earth pressure around the apparatus, the earth pressure changing as the apparatus is intruded, and the compressed air is sent into the tip end lid case 13 from the air supply hole (not shown).

Then, if the tip end lid 12 reaches the predetermined ground 33 in the above manner, the entire apparatus is pulled out upward. At this time, because the compressed air is supplied through the air supply hole (not shown) opening into the tip end lid case 13 such that the pressure in the tip end lid case 13 becomes substantially equal to the earth pressure around the apparatus in the sand-pile forming apparatus of the invention, air pressure in a cavity (see a reference numeral 34 in FIG. 9) formed under the tip end lid case 13 due to pulling out is kept equal to the earth pressure around the apparatus and the cavity does not collapse.

Compressed air is introduced into the casing pipe 11 in synchronizaton with the pulling out and a jet of air is spouted from the nozzle portion 21. As a result, the sand S charged into the casing pipe 11 is pressurized downward and the ball valve 16 in pressure contact with the valve seat portion 14 is pushed down. Thus, the lower end of the casing pipe 11 is opened, the sand in the casing pipe 11 passes through a gap between the ball valve 16 and the tip end lid case 13 from the valve seat portion 14 and is discharged into the

cavity 34 under the apparatus as shown by arrows in FIG. 9.

At this time, because the tip end lid case 13 is formed into the shape of the hollow truncated cone with the expanded lower end in the sand pile forming apparatus of the invention, the sand S is discharged smoothly. This is because a gap for passage of the sand and formed between a periphery of the ball valve 16 and an inner face of the tip end lid case 13 is wider than that in a case of a cylindrical tip end case when the ball valve 16 moves down and because there is substantially no friction generated between the sand S and the inner face of the tip end lid case 13.

The reason why there is no friction is as follows.

In the case of the prior-art cylindrical tip end lid case, if the sand S is packed into the case to about a height H as shown in FIG. 11, a horizontal force P expressed as a function of weight of the sand and an angle of internal friction of the sand is generated as shown in FIG. 12. The force P tilts upward through an angle  $\delta$  due to friction between the sand and an inner wall face of the case. If the force P is resolved into forces in a perpendicular direction and a horizontal direction with respect to the wall face, a force  $P_N$  acting perpendicularly on the wall face and a force  $P_L$  acting horizontally on the wall face can be obtained. Then, a friction force  $P_{NF}$  is generated upward and horizontally with respect to the wall face on the force  $P_N$  acting perpendicularly

on the wall face by friction between the sand and the wall face. At this time,  $P_{NF} > P_L$ , in general, and the sand cannot move downward or there is a hindrance to movement of the sand.

In the case of the tip end lid case in the shape of the hollow truncated cone, on the other hand, if the sand S is packed in the case to about a height H as shown in FIG. 13, a horizontal force P expressed as a function of weight of the sand and an angle of internal friction of the sand is generated and the force P similarly tilts upward through an angle  $\delta$  due to friction between the sand and an inner wall face of the case as shown in FIG. 14. However, because the wall face tilts through an angle  $\theta$  with respect to a perpendicular direction, a force  $P_N$  acting perpendicularly to the wall face becomes smaller than that in the case of the cylindrical case and a force  $P_L$  acting in parallel to the wall face becomes larger than that in the case of the cylindrical case by contrast. The friction force  $P_{NF}$  acting horizontally with respect to the wall face due to the friction between the sand and the wall face on the force  $P_N$  acting perpendicularly to the wall face becomes small. This is because there is a tilt angle which causes  $P_{NF} < P_L$  due to a size of the a tilt angle  $\theta$  of the wall face and, as a result, the friction force between the sand and the wall face apparently becomes zero.

The sand pile forming apparatus is pulled out of the hard earth-and-sand layer in the above manner and, as a result,

the sand S charged into the casing pipe 11 is discharged downward through the tip end lid 12 and fills the cavity 34 formed below the tip end lid 12. When the casing pipe 11 is pulled out by a predetermined length, the casing pipe 11 is then pushed down such that the pipe 11 is intruded into the discharged sand. At this time, the ball valve 16 is pushed up by sand which has entered the tip end lid case 13 as shown in FIG. 10 to come in pressure contact with the valve seat portion 14 to close the lower end of the casing pipe 11. Therefore, the sand charged into the cavity formed in the earth-and-sand layer is pressurized with the tip end lid 12 and a diameter of the sand is increased as shown in FIG. 10.

At this time, in the sand pile forming method of the invention, the intrusion pressure of the casing pipe 11 is measured by using the earth pressure sensor S3 mounted to the tip end of the tip end lid 12 and is controlled to be predetermined pressure according to a soil texture. Therefore, the sand pressed by intruding the casing pipe 11 again is formed into a sand pile having a predetermined outside diameter, a predetermined length, and a predetermined pressure density.

By repeating the similar operation, a sand pile SP having a predetermined outside diameter and a predetermined pressure density is formed in the hard earth-and-sand layer 32 and the argillaceous earth-and-sand layer 31 as shown in FIG. 10.

## INDUSTRIAL APPLICABILITY

As described above, according to the sand pile forming method of the invention, it is possible to fill the sand into the cavity formed by using the casing pipe without collapsing the cavity to form the sand pile and it is possible to compact the sand pile to obtain desired strength and diameter. Therefore, the method is useful in improvement of the soft ground such as sea floor ground which is likely to collapse.

According to the sand pile forming apparatus of the invention, in spite of a simple structure, it is possible to reliably form the sand pile and, at this time, the sand can be discharged smoothly. Therefore, efficiency of operation is improved and days required for execution of construction, cost of execution, and labor costs can be reduced and, as a result, there is a possibility that introduction of soil improvement is facilitated in regions where the soil improvement could not be carried out for these reasons.



WHAT IS CLAIMED IS:

1. A sand pile forming method including the steps of driving a casing pipe having a tip end lid of a ball valve type into soft ground, charging sand into said casing pipe, and then pulling said casing pipe out while leaving only a sand pile formed of said charged sand in said ground,

wherein air pressure in said tip end lid is controlled to be equal to earth pressure measured around said tip end lid when said casing pipe is pulled out of said ground to thereby fill said sand into a cavity formed by said casing pipe without collapsing said cavity.

2. A sand pile forming method including the steps of compacting sand discharged from a casing pipe having a tip end lid and increasing a diameter of said sand simultaneously by intruding said casing pipe again,

wherein pressure in intruding said casing pipe again is controlled based on a measurement value of an earth pressure gage provided to said tip end lid to thereby form a sand pile having desired strength and diameter.

3. A sand pile forming apparatus comprising a casing pipe provided with a nozzle for introducing compressed air into said casing pipe and a tip end lid mounted to a tip end of said casing pipe,

wherein said tip end lid is formed of a tip end lid case substantially in a shape of a truncated cone with an expanded



tip end, a ball valve housed for vertical movement in said tip end lid case, and a valve seat portion with which said ball valve comes into contact to make said tip end of said casing pipe airtight and said tip end lid case is provided with an earth pressure sensor for measuring earth pressure around said tip end lid case on an outside of said case, a pressure sensor for measuring air pressure in said tip end lid case on an inside of said case, and an air supply hole for sending compressed air into said case inside said case.

4. The sand pile forming apparatus according to claim 3, wherein an earth pressure gage for measuring intrusion pressure of said casing pipe is provided to a tip end of said tip end lid.