

GROUND SETTLEMENT AMOUNT MEASUREMENT METHOD AND GROUND SETTLEMENT AMOUNT MEASUREMENT SYSTEM

Technical Field

[0001] The present invention relates to a ground settlement amount measurement method and a ground settlement amount measurement system for a site of water-area land reclamation.

Background Art

[0002] In water-area land reclamation, if the original ground is soft, the original ground will settle due to the load of a land reclamation material. In order to make the finished shape of the land reclamation location into a designed finished shape, the settlement amount of the original ground of the region in which land reclamation is performed needs to be measured.

[0003] The method disclosed in Patent Document 1 is an example of a method for measuring the settlement amount of the original ground in a water area. In this method, a flexible net-like body that can deform in conformity with the settlement shape of the original ground is laid on the original ground on which a land reclamation material such as rubble is to be provided in land reclamation construction, and a protective tube containing a pore water pressure gauge is attached below the net-like body. The protective tube is a flexible or rigid tube with openings at both ends. The protective tube contains the pore water pressure gauge and sand that fills the interior so as to cover the pore water pressure gauge. A flexible double-layered protective tube is connected to one end of the protective tube. A communication cable with one end connected to the pore water pressure gauge is arranged inside of the protective tube on the inner side of the double-layered protective tube. The double-layered protective tube is arranged in a horizontal direction along the net-like body so as to reach an area in which the land reclamation material is not arranged. The

communication cable with one end connected to the pore water pressure gauge extends into the water from the opening portion at the other end of the double-layered protective tube, and thereafter extends upward and is connected to a float on the water. The float transmits the measurement value transmitted from the pore water pressure gauge via the communication cable to a management apparatus on a boat or on land wirelessly or by wire.

Citation List

Patent Literature

[0004] Patent Document 1: JP 2005-147735A

Summary of Invention

Technical Problem

[0005] If the original ground in the water-area land reclamation is ground with low water-permeability, such as clay or silt, excessive water pressure (excessive pore water pressure) occurs in the ground due to the load of the land reclamation material acting on the original ground. However, if the land reclamation material is soil material with high water permeability, such as gravel or sand, the excessive pore water pressure that occurs in the original ground easily dissipates. On the other hand, if the land reclamation material is soil material with low water permeability, such as clay or silt, excessive pore water pressure that occurs in the land reclamation material and the original ground will take a long time to dissipate, for example, several years. Accordingly, if the settlement amount of the original ground at a specific position is to be calculated, by merely arranging the pore water pressure gauge at that specific position, the excessive pore water pressure will act on the pore water pressure gauge when the land reclamation material accumulates on the original ground. As a result, there is a problem in that an accurate settlement amount cannot be calculated based

on a measurement value of the pore water pressure gauge since a genuine hydrostatic pressure cannot be measured by the pore water pressure gauge.

[0006] In the case of using the invention disclosed in Patent Document 1, the pore water pressure gauge is in contact with the movement path of the water passing through the bottom portion of the water area outside of the land reclamation region via the protective tube that extends in the horizontal direction, and the pore water pressure gauge measures only the hydrostatic pressure. In general, unlike construction in which a base mound or the like is constructed on the bottom of the water area, in land reclamation construction, the region in which the protective tube in the invention disclosed in Patent Document 1 is to be installed (entire land reclamation region) often extends over a wide area.

[0007] However, in the invention disclosed in Patent Document 1, the protective tube is arranged so as to extend from the pore water pressure gauge in the horizontal direction until reaching outside of the land reclamation region, and therefore the installation extension of the protective tube per pore water pressure gauge is longer. If the installation extension of the protective tube extending horizontally in the land reclamation region increases in length, the friction resistance of the inner surface of the protective tube and the resistance of the sand filling the protective tube will increase. As a result, a long period of time is required for excessive pore water pressure to dissipate, and therefore an accurate settlement amount cannot be measured. Also, if multiple pore water pressure gauges are arranged, the total installation extension of the protective tube becomes very long, and maintenance during construction also becomes complicated. Furthermore, since it is difficult to remove the embedded protective tube, a large amount of unnecessary items are left in the land reclamation region after land reclamation construction is complete, and thus it may not be possible to obtain approval for protective pipe installation from a construction client or the like in some cases. Accordingly, in common land

reclamation construction, it is not necessarily practical to employ the invention disclosed in Patent Document 1.

[0008] In view of the above-described background, the present invention provides a means for, in water-area land reclamation, enabling measurement of an accurate settlement amount of original ground based on a measurement value of a pore water pressure gauge arranged on the upper surface of the original ground, even if the original ground and land reclamation material have low water-permeability.

Solution to the Problem

[0009] In order to solve the above-described problem, the present invention provides, as a first aspect, a ground settlement amount measurement method for measuring a ground settlement amount at a site of water-area land reclamation, the method including: a first step of arranging a pore water pressure gauge covered by a water-permeable filter material on an upper surface of original ground; a second step of arranging a water-permeable drain material such that one end portion of the drain material is inserted into the filter material and the drain material extends vertically upward from the filter material, thereby entering a state in which only hydrostatic pressure acts on the pore water pressure gauge; a third step of dumping soil material into water at the site; and a fourth step of calculating a settlement amount of original ground at a position at which the pore water pressure gauge is arranged, based on water pressure measured by the pore water pressure gauge.

[0010] According to the measurement method of the first aspect, in water-area land reclamation over a wide range, it is possible to calculate an accurate ground settlement amount based on the measurement value of the pore water pressure gauge arranged on the upper surface of the original ground, even if the original ground and the land reclamation material have low water-permeability.

[0011] In the ground settlement amount calculation method according to the first aspect, it is also possible to employ, as a second aspect, a configuration in which the second step includes a step of arranging a floating body such that a second end portion of the drain material, which is coupled to the floating body, is kept at a higher position than a top end of the soil material dumped into water at the site and accumulated in water.

[0012] According to the ground settlement amount measurement method according to aspect 2, by using a floating body, a drain material can be put in a state of extending in the vertically upward direction from the filter material and reaching a position higher than the top end of the soil material dumped into water and accumulated in water.

[0013] Also, the present invention provides, as a third aspect, a ground settlement amount measurement system for, at a site of water-area land reclamation, calculating a settlement amount of original ground at a specific position, based on water pressure measured at the specific position, the ground settlement amount measurement system including: a pore water pressure gauge arranged on an upper surface of original ground; a water-permeable filter material arranged so as to cover the pore water pressure gauge; a water-permeable drain material that has one end portion inserted into the filter material and extends vertically upward from the filter material, thereby being in a state in which only hydrostatic pressure acts on the pore water pressure gauge; a floating body that is coupled with the drain material and is arranged such that a second end portion of the drain material is kept at a higher position than a top end of soil material dumped into water at the site and accumulated in water; a communication cable for transmitting measurement data of the pore water pressure gauge to a relay apparatus on water; and a wireless apparatus configured to transmit the measurement data of the pore water pressure gauge from the relay apparatus to a data processing apparatus.

[0014] According to the ground settlement amount measurement system of

the third aspect, in water-area land reclamation over a wide range, it is possible to calculate an accurate settlement amount of original ground based on a measurement value of a pore water pressure gauge arranged on the original ground, even if the original ground and the soil material used for filling have low water-permeability.

Brief Description of the Drawings

[0015] FIG. 1 is a diagram showing a configuration of a ground settlement amount measurement system according to an embodiment.

FIG. 2 is a diagram showing a structure of an example of a drain material included in the ground settlement amount measurement system according to the embodiment.

FIG. 3 is a diagram for illustrating a method of arranging the ground settlement amount measurement system according to the embodiment.

FIG. 4 is a diagram for illustrating a method of arranging the ground settlement amount measurement system according to the embodiment.

FIG. 5 is a diagram for illustrating a method of arranging the ground settlement amount measurement system according to the embodiment.

FIG. 6 is a diagram for illustrating a method of arranging the ground settlement amount measurement system according to the embodiment.

FIG. 7 is a diagram showing a ground settlement amount measurement system according to a modified example.

FIG. 8 is a diagram showing the ground settlement amount measurement system according to the modified example.

FIGS. 9(A) to 9(D) are diagrams showing a state in which a drain material of the ground settlement amount measurement system according to the modified example is extended.

Detailed Description of the Invention

Embodiment

[0016] Ground settlement amount measurement system 1 according to an embodiment of the present invention will be described hereinafter. Ground settlement amount measurement system 1 is used to measure a ground settlement amount at a site of water-area land reclamation.

[0017] FIG. 1 is a diagram showing a configuration of ground settlement amount measurement system 1. Ground settlement amount measurement system 1 includes: sandbag 10, which contains pore water pressure gauge 11 and filter material 12; communication cable 21; drain material 22; buoy 30, which contains processing apparatus 31 and battery 32; and buoy 40. Note that in FIG. 1, ground settlement amount measurement system 1 is provided at only one location in the land reclamation region in order to prevent the diagram from becoming complicated, but ground settlement amount measurement system 1 may also be arranged at multiple locations in the land reclamation region, and ground settlement amount measurement of original ground G at each of the multiple locations may also be performed.

[0018] Sandbag 10 is arranged on the upper surface of original ground G.

[0019] Sandbag 10 contains pore water pressure gauge 11 and filter material 12, which is water-permeable. Filter material 12 is, for example, sand, crushed stone, or a combination of sand and crushed stone. However, the type of the filter material is not limited, as long as it has high water-permeability and can rapidly dissipate excessive pore water pressure, which will be described later. Pore water pressure gauge 11 is a measurement device covered by filter material 12, and measures the pore water pressure inside filter material 12. Upon acquiring a command instructing measurement, pore water pressure gauge 11 measures the pore water pressure and outputs the measurement result.

[0020] One end (first end portion) of drain material 22, which is water-permeable, is inserted into filter material 12 in sandbag 10. In general, the drain material is a band-shaped or string-shaped member, internally includes a movement path for water, and has a structure that

allows water to enter while preventing entrance of the soil material (clay or silt, etc.) through the side surface. For this reason, the drain material has a function of draining water with the excess water pressure (excess pore water pressure) in the ground into the water or the air when part of the drain material is embedded in the ground and part of the drain material is arranged in the water or in the air.

[0021] The drain material has several types, such as a drain material made of plastic, a drain material made of fiber, and a sand drain using sand. Drain material 22 included in ground settlement amount measurement system 1 needs to be lightweight such that it extends vertically upward from filter material 12 due to the buoyancy of buoy 40 coupled to drain material 22, in a state in which one end (first end portion) of drain material 22 is inserted into filter material 12. Accordingly, for example, a sand drain or the like is not suitable as drain material 22.

[0022] FIG. 2 is a diagram showing a configuration of an example of drain material 22 (drain made of plastic). Drain material 22 having the structure shown in FIG. 2 includes: core material 221 with a grid-shaped cross section orthogonal to the longitudinal direction (X direction in FIG. 2); and filter sheets 222 that cover both side surfaces of the core material 221 (in FIG. 2, the upper surface and lower surface of core material 221). Core material 221 is synthetic resin, for example, and fulfills a role of forming movement paths for water in drain material 22. The coefficient of permeability in the longitudinal direction (X direction in FIG. 2) of drain material 22 is about 1×10^{-2} m/sec, for example. Filter sheet 222 is, for example, non-woven cloth, prevents soil material from entering the interior, and substantially does not prevent water from entering the interior. The coefficient of permeability in the direction (Y direction in FIG. 2) orthogonal to the longitudinal direction of drain material 22 is about 1×10^{-3} m/sec, for example.

[0023] Since drain material 22 is usually left in the land reclamation region after the land reclamation construction is complete, the raw material of

drain material 22 is preferably highly biodegradable. For example, biodegradable plastic is preferably used as the raw material in core material 221 and filter sheet 222. Also, as drain material 22, it is also possible to use a drain material made of fibers, in which natural fibers such as palm rope are used in the core material and natural cloth such as jute cloth is used in the filter sheet.

[0024] Note that in general, drain material 22 is a material that prompts consolidation at a time of ground improvement, but in the present embodiment, drain material 22 is used as a means for causing excessive pore water pressure that occurs inside sandbag 10 to rapidly dissipate.

[0025] Buoy 40 is coupled to drain material 22 in the vicinity of the end portion (second end portion) that is not the end portion inserted into filter material 12 (first end portion), of the two end portions of drain material 22. Due to the buoyancy of buoy 40, as shown in FIG. 1, drain material 22 extends in the vertically upward direction from sandbag 10. In the example shown in FIG. 1, the second end portion of drain material 22 is located in the water, but the second end portion of drain material 22 may also protrude above water surface W.

[0026] Buoy 30 is a floating body that floats on water surface W and contains processing apparatus 31 and battery 32. Battery 32 is a power source of processing apparatus 31. Processing apparatus 31 is connected to pore water pressure gauge 11 by communication cable 21, which extends vertically upward from inside of sandbag 10. The length of communication cable 21 is a length that exceeds the distance from water surface W at full tide to original ground G. Processing apparatus 31, which is a wireless communication apparatus including a wireless communication function, acquires the measurement result of pore water pressure gauge 11, and transmits the acquired measurement result to external apparatus 100, which is installed on ship 50, through wireless communication. Note that processing apparatus 31 may also transmit a measurement result to external

apparatus 100, which is installed on land, via a mobile communication network, for example.

[0027] For example, when a predetermined date and time are reached, processing apparatus 31 transmits a command instructing measurement to pore water pressure gauge 11. Processing apparatus 31 acquires the measurement result transmitted from pore water pressure gauge 11 in response to the transmitted command. Processing apparatus 31 transmits the acquired measurement result to external apparatus 100 through wireless communication.

[0028] Next, a method for arranging ground settlement amount measurement system 1 and a method for measuring the settlement amount of original ground G will be described. FIGS. 3 to 5 are diagrams for illustrating the method for arranging ground settlement amount measurement system 1.

[0029] First, after inserting pore water pressure gauge 11, which is connected to one end of communication cable 21, into sandbag 10, a worker inserts filter material 12 into sandbag 10 so that pore water pressure gauge 11 is covered by filter material 12. The worker pulls the other end of communication cable 21 upward and connects it to processing apparatus 31, which is inside of buoy 30. The worker arranges sandbag 10, which contains pore water pressure gauge 11 and filter material 12, on the upper surface of original ground G as shown in FIG. 3 and floats buoy 30 on water surface W.

[0030] The worker inserts one end (first end portion) of drain material 22 into sandbag 10 arranged on the upper surface of original ground G, pulls the other end (second end portion) vertically upward, and couples the buoy 40 to it in the vicinity of the other end. Due to buoy 40 being coupled to drain material 22 in the vicinity of the other end of drain material 22, as shown in FIG. 4, drain material 22 extends vertically upward from inside of sandbag 10 and the other end is kept in the water.

[0031] In the state shown in FIG. 4, the water around pore water pressure gauge 11 communicates with the water around sandbag 10 via the water movement paths formed inside of filter material 12. Accordingly, only hydrostatic pressure acts on pore water pressure gauge 11.

[0032] Next, the worker dumps soil material E into the water at the site of land reclamation construction. Soil material E is, for example, clay or silt. Due to soil material E being dumped into the water, as shown in FIG. 5, sandbag 10 is covered by soil material E. If there were no drain material 22, excessive water pressure (excessive pore water pressure) would occur in sandbag 10 due to the load of soil material E. However, in ground settlement amount measurement system 1, drain material 22, which forms the water movement paths between filter material 12 and the water above soil material E, is arranged, and therefore the water in sandbag 10, on which the excessive pore water pressure acts, is rapidly drained through drain material 22 and the excessive pore water pressure in sandbag 10 is rapidly dissipated. Accordingly, the state in which only hydrostatic pressure substantially acts on pore water pressure gauge 11 is maintained, and pore water pressure gauge 11 can measure the hydrostatic pressure at the arranged position.

[0033] When a predetermined date and time are reached, processing apparatus 31 transmits a command instructing measurement to pore water pressure gauge 11. Pore water pressure gauge 11 measures the pore water pressure in response to the command transmitted from processing apparatus 31 and transmits the measurement result to processing apparatus 31. Processing apparatus 31 receives the measurement result transmitted from pore water pressure gauge 11 and transmits the received measurement result to external apparatus 100 on ship 50 through wireless communication.

[0034] Upon receiving the measurement result transmitted by processing apparatus 31, external apparatus 100 calculates the settlement amount of original ground G. FIG. 6 is a diagram for illustrating a procedure by which

external apparatus 100 calculates the settlement amount of original ground G. For example, upon receiving the measurement result transmitted by processing apparatus 31, external apparatus 100 calculates distance d1 from original ground G to water surface W at a time before the start of settlement of original ground G, based on the tide level at the date and time when pore water pressure gauge 11 performed measurement. Also, external apparatus 100 calculates distance d2 from original ground G to water surface W at that time at the position at which pore water pressure gauge 11 is arranged, based on the water pressure indicated by the received measurement result. External apparatus 100 calculates the result of subtracting distance d1 from distance d2 as the settlement amount of original ground G at that time at the position at which pore water pressure gauge 11 is arranged.

Modified Examples

[0035] The above-described embodiment can be modified in various ways. Examples of these modifications will be given hereinafter. Note that the above-described embodiment and the modified examples disclosed hereinafter may also be combined as appropriate.

[0036] (1) If it is difficult to keep communication cable 21 pulled up to water surface W with only buoy 30 or the like, one or more intermediate buoys may be coupled to communication cable 21, and these intermediate buoys may be arranged on water surface W or in the water. Also, if the second end portion of drain material 22 cannot be kept at a higher position than the top end of soil material E that was dumped into water and accumulated in water with only buoy 40 or the like, one or more intermediate buoys may be coupled to drain material 22, and these intermediate buoys may be arranged on water surface W or in the water. FIG. 8 shows an example in which multiple intermediate buoys 33 are coupled to communication cable 21 and multiple intermediate buoys 41 are coupled to drain material 22.

[0037] (2) Drain material 22 may also be coupled to buoy 30 via communication cable 21 without providing buoy 40, or may be coupled to buoy 30 directly, without using communication cable 21. FIG. 7 shows a configuration in which communication cable 21 and drain material 22 are coupled near the second end portion of drain material 22 via coupling tool 23, and drain material 22 is coupled indirectly to buoy 30. The configuration shown in FIG. 7 may also be employed.

[0038] (3) In the above-described embodiment, communication cable 21 is arranged outside of drain material 22, but communication cable 21 may also be arranged inside of drain material 22.

[0039] (4) In the above-described embodiment, processing apparatus 31 transmits the measurement result of pore water pressure gauge 11 to external apparatus 100 through wireless communication, but processing apparatus 31 and external apparatus 100 may also be connected by a communication cable and the measurement result may also be transmitted to external apparatus 100 via the communication cable.

[0040] (5) In the above-described embodiment, processing apparatus 31 transmits the measurement result of pore water pressure gauge 11 to external apparatus 100, but processing apparatus 31 need not necessarily transmit the measurement result of pore water pressure gauge 11 to external apparatus 100. For example, a configuration may also be employed in which processing apparatus 31 includes a detachable non-volatile memory (SD memory card, etc.) and the measurement results of the pore water pressure are accumulated in the non-volatile memory. In this case, for example, a worker removes the non-volatile memory from processing apparatus 31 and moves the measurement results of pore water pressure gauge 11 accumulated in the non-volatile memory to a computer, using a card reader/writer connected to the computer, and thus the worker can use the measurement results of the pore water pressure gauge 11 in the computer.

[0041] (6) It is also possible to use a configuration in which buoy 30 is provided with a mechanism for automatically performing winding and unwinding of communication cable 21, and the length of communication cable 21 is automatically adjusted according to the change in tide level. According to this configuration, the length of communication cable 21 is automatically adjusted according to the change in tide level.

[0042] (7) Drain material 22 may also be extended according to the progression of land reclamation construction. FIGS. 9(A) to 9(D) are diagrams showing a state in which drain material 22 is extended during land reclamation construction. Note that in FIGS. 9(A) to 9(D), pore water pressure gauge 11, processing apparatus 31, and battery 32, which are included in ground settlement amount measurement system 1, are omitted. FIG. 9(A) shows a state prior to when introduction of soil material E into the water is started. In the example shown in FIG. 9(A), the height of the upper end portion (second end portion) of drain material 22 is higher than the planned top end at the time of completing the land reclamation construction.

[0043] FIG. 9(B) shows a state in which soil material E is dumped into the water and first layer E1 of soil material E is formed above original ground G. In the state shown in FIG. 9(B), the upper end portion of drain material 22 is kept at a higher position than the top end of soil material dumped into water and accumulated in water, and therefore pore water pressure gauge 11 can measure the accurate hydrostatic pressure. However, if the dumping of the soil material E into the water is continued as-is, the upper end portion of drain material 22 is buried by soil material E and pore water pressure gauge 11 can no longer measure the accurate hydrostatic pressure.

[0044] In view of this, a worker extends drain material 22 by adding new drain material of the same type to the existing drain material. FIG. 9(C) shows a state in which drain material 22 has been extended. FIG. 9(D) shows a state thereafter, in which soil material E is introduced into the water and second layer E2 of soil material E is formed above first layer E1

formed in advance.

[0045] As described above, the position of the second end portion of drain material 22 may also be changed as appropriate, as long as it is kept at a higher position than the top end of soil material introduced into water and accumulated in water.

[0046] (8) In the above-described embodiment, a task of inserting drain material 22 into filter material 12 in sandbag 10 is performed in the water. Instead of this, drain material 22 may also be inserted into filter material 12 in sandbag 10 before sandbag 10 is introduced into the water, and sandbag 10, which is coupled to drain material 22, may be arranged on original ground G.

[0047] (9) In the above-described embodiment, external apparatus 100 calculates the ground settlement amount of original ground G. Instead of this, processing apparatus 31 may also calculate the ground settlement amount and transmit the calculated ground settlement amount to external apparatus 100.

[0048] (10) In the above-described embodiment, processing apparatus 31 acquires the measurement result from pore water pressure gauge 11 via communication cable 21. Instead of this, the measurement result of pore water pressure gauge 11 may also be acquired through acoustic communication. In the case of using this configuration, sandbag 10 contains a measurement unit including pore water pressure gauge 11, an acoustic communication unit, and a battery. Also, the acoustic communication unit is also provided in external apparatus 100. The acoustic communication unit in sandbag 10 performs communication with the acoustic communication unit provided in external apparatus 100 using an acoustic signal, and the measurement result of pore water pressure gauge 11 is transmitted to external apparatus 100.

Reference Signs List

[0049] 1 ... Ground settlement amount measurement system. 10 ... Sandbag. 11 ... Pore water pressure gauge. 12 ... Filter material. 21 ... Communication cable. 22 ... Drain material. 23 ... Coupling tool. 30 ... Buoy. 31 ... Processing apparatus. 32 ... Battery. 40 ... Buoy. 50 ... Ship. 100 ... External apparatus. 221 ... Core material. 222 ... Filter sheet.

What is Claimed is:

1. A ground settlement amount measurement method for measuring a ground settlement amount at a site of water-area land reclamation, the method comprising:

a first step of arranging a pore water pressure gauge covered by a water-permeable filter material on an upper surface of original ground;

a second step of arranging a water-permeable drain material such that one end portion of the drain material is inserted into the filter material and the drain material extends vertically upward from the filter material, thereby entering a state in which only hydrostatic pressure acts on the pore water pressure gauge;

a third step of dumping soil material into water at the site; and

a fourth step of calculating a settlement amount of original ground at a position at which the pore water pressure gauge is arranged, based on water pressure measured by the pore water pressure gauge.

2. The ground settlement amount calculation method according to claim 1, wherein

the second step includes a step of arranging a floating body such that a second end portion of the drain material, which is coupled to the floating body, is kept at a higher position than a top end of the soil material dumped into water at the site and accumulated in water.

3. A ground settlement amount measurement system for, at a site of water-area land reclamation, calculating a settlement amount of original ground at a specific position, based on water pressure measured at the specific position, the ground settlement amount measurement system comprising:

a pore water pressure gauge arranged on an upper surface of original

ground;

a water-permeable filter material arranged so as to cover the pore water pressure gauge;

a water-permeable drain material that has one end portion inserted into the filter material and extends vertically upward from the filter material, thereby being in a state in which only hydrostatic pressure acts on the pore water pressure gauge;

a floating body that is coupled with the drain material and is arranged such that a second end portion of the drain material is kept at a higher position than a top end of soil material dumped into water at the site and accumulated in water;

a communication cable for transmitting measurement data of the pore water pressure gauge to a relay apparatus on water; and

a wireless apparatus configured to transmit the measurement data of the pore water pressure gauge from the relay apparatus to a data processing apparatus.