

DESCRIPTION

Title of the Invention

GROUND IMPROVEMENT METHOD, AND SYSTEM FOR MANAGING

5 CONSTRUCTION IN GROUND IMPROVEMENT METHOD

Technical Field

[0001]

The present invention relates to a ground improvement method used when
10 improving a soft ground to prepare a solidified body of a block type, a wall type, a lattice
type, a pile type, a layer type, or the like, or an improved ground in the ground, and a
construction control system applied to the ground improvement method.

This application claims priority to and the benefits of Japanese Patent
Application Nos. 2011-118234 and 2011-118235 filed on May 26, 2011, the disclosures
15 of which are incorporated herein by reference.

Background Art

[0002]

As is well known, there is a ground improvement method of: preparing
20 solidification materials such as lime and cement in a slurry form; agitating and mixing
the slurry with soil in the ground to chemically solidify the soil using a chemical
cementation reaction based on a hydration reaction of the solidification material slurry,
an ion exchange action between a hydration product obtained by this hydration reaction
and a clay mineral, or a pozzolanic reaction; and thereby preparing improved piles in the
25 ground to thereby improve the ground (increasing a strength of the ground) or preparing

a solidified body (e.g., see Patent Document 1). This type of ground improvement method is called a deep mixing method.

[0003]

In this ground improvement method, a ground improvement apparatus
5 (treatment machine) 1 based on a pile driving machine and a construction control system as shown in FIG. 8 are used. The treatment machine 1 is configured to cause a base machine 4 to vertically support a screw rod 3 whose tip has agitation blades 2, to cause a driving unit 5 to rotate the screw rod 3 to penetrate into the deepest point of an improvement target range, to inject a cement slurry as a ground improvement material
10 into the ground from an injection outlet formed in the tip of the screw rod 3, to withdraw the screw rod 3 while agitating and mixing the injected cement slurry with soil using the agitation blades 2 during injecting of the cement slurry, and to form an improved pile.

[0004]

Further, when the improved pile is formed by the treatment machine 1, the
15 construction control system includes a slurry flowmeter 6, a shaft revolution counter 7 of the screw rod 3, an ammeter 8 of the driving unit 5, a depth gauge 9 of the screw rod 3, and an elevation speed gauge 10 of the screw rod 3, and is configured to input detected values of these sensors to a control apparatus 11, and to monitor the volume of injection of the cement slurry, and the number of rotation, arrival penetration depth, penetration
20 speed, and withdrawal speed of the screw rod 3 as control items. Among reference numerals, 12 indicates an operation monitor installed on the base machine 4, and 13 indicates a personal computer for data storage.

[0005]

In the ground improvement method using this treatment machine 1, first, the
25 screw rod 3 having the agitation blades 2 is rotated to penetrate into the ground to a given

depth without injecting the ground improvement material. Next, while rotating the screw rod 3 and injecting the ground improvement material from the tip of the screw rod 3, and the screw rod 3 is withdrawn while the ground is agitated and mixed with the ground improvement material by the agitation blades 2. Thereby, the improved pile is prepared by solidifying the soil in the ground in a columnar shape. In this ground improvement method, a blade rotation number per unit depth (1 m) in the ground when the agitation blades 2 are withdrawn (when the ground improvement material is injected) becomes the construction control item.

[0006]

The blade rotation number is influenced by a degree of agitation/mixture between the ground improvement material and the ground. If the blade rotation number is increased, the construction speed is slow, but a mixture condition between the ground improvement material and the ground is improved. If the ground improvement material and the ground are well mixed, the generated ground-improved body develops uniform strength on the whole. As such, the in-situ UCS (unconfined compressing strength of improved body for the site) results in a slight extra increase over the design UCS. Note that this “in-situ UCS” is set to add an extra at a given rate to the design UCS in consideration of a variation in in-situ UCS from improvement body in actual construction.

[0007]

In contrast, if the blade rotation number is reduced, the construction speed increases. However, due to insufficient mixture between the ground improvement material and the ground, a portion at which the in-situ UCS is lowered may develop. As such, in this case, the in-situ UCS needs a great extra increase over the design UCS. What is associated with this extra increase is a coefficient of variation, and the variation

coefficient of the in-situ UCS and the blade rotation number have a given relation.

[0008]

Note that a relational equation between the design UCS, the in-situ UCS, and the variation coefficient of the ground-improved body is as follows:

$$5 \quad Q_f = Q_d / (1 - \alpha \cdot V_c / 100) \dots \dots \dots (1)$$

where:

Q_f ; the average in-situ UCS (kN/m^2)

Q_d ; the design UCS (kN/m^2)

α ; the coefficient ($\alpha=1.3$ when a defect incidence rate of 10% is considered)

10 V_c ; the variation coefficient of in-situ UCS (%)

[0009]

According to Equation (1), for example, when the design UCS $Q_d=1000 \text{ kN/m}^2$, if the variation coefficient of the in-situ UCS $V_c=30\%$, the in-situ UCS $Q_f=1640 \text{ kN/m}^2$, and if the variation coefficient of the in-situ UCS $V_c=15\%$, the in-situ UCS $Q_f=1240$

15 kN/m^2 .

[0010]

To enhance the in-situ UCS Q_f , the amount (volume) of the ground improvement material (cement slurry) composed of water and cement injected into the ground needs to be increased. Since the weight ratio of the water and cement of the ground improvement material is almost the same, to enhance the in-situ UCS Q_f is also to increase the amount of admixture of the cement. Thus, the magnitude of the variation coefficient V_c has influence on the construction cost.

[0011]

Conventionally, the relation between the blade rotation number and the variation

coefficient of the in-situ UCS after the ground improvement material is injected is obtained. The construction control is performed to consider the blade rotation number involved in the construction efficiency and the variation coefficient of the in-situ UCS involved in the construction cost, to obtain the blade rotation number corresponding to a
5 desired variation coefficient of the in-situ UCS, and to make the in-situ blade rotation number equal to this blade rotation number.

[0012]

Regarding the relation between the variation coefficient of the in-situ UCS and the blade rotation number, in the conventional ground improvement method of injecting
10 the ground improvement material into the ground while rotating the screw rod as the screw rod penetrates, and agitating and mixing the ground improvement material and the ground, the blade rotation number is set based on a relationship diagram (semi-log graph) as in FIG. 9. The blade rotation number here is the blade rotation number when the ground improvement material is injected into the ground, and then is agitated and mixed
15 with the ground.

[0013]

On the other hand, in the ground improvement method of: causing the screw rod to penetrate without injecting the ground improvement material; and then simultaneously injecting the ground improvement material and withdrawing the screw rod to agitate and
20 mix the ground improvement material with the ground, the relationship diagram is used even when the blade rotation number during the withdrawal of the screw rod from which the ground improvement material is injected is set from a targeted variation coefficient of the in-situ UCS.

[0014]

25 Further, in the conventional general deep mixing method, a large quantity

(volume) of ground improvement material (cement slurry) is injected into an original ground, and thus the volume of the original ground is inevitably increased. For this reason, there is a possibility that, due to the increase in the volume, the original ground is raised or an adverse influence is exerted on the surrounding ground.

5 [0015]

Thus, as a countermeasure for preventing the adverse influence on the surrounding ground in the deep mixing method as described above, soil equivalent to the discharge volume (injection volume) of the ground improvement material (cement slurry) are removed from the original ground. Thereby, the volume expansion of the original
 10 ground is avoided. Such a soil-removal-type deep mixing method and a construction control system thereof have been proposed by the applicant of the invention (e.g. see Patent Document 1). In this ground improvement method, the important point is that a balance between the discharge volume of the ground improvement material and soil removal volume be maintained. Keeping track of both of these amounts is thus the crux
 15 of the construction control. Here, the discharge volume of the ground improvement material can be measured by a flowmeter. However, it is difficult to know the actual soil-removal volume during construction.

Thus, in Patent Document 1, in an actual measurement test, a measured soil removal volume V_1 and a value of (section area of the screw S) $\times$ (screw pitch P) $\times$
 20 (shaft rotation number N) are obtained, and a soil removal coefficient K is obtained from these results based on $K = V_1 / (S \times P \times N)$. In detail, on Cartesian coordinates adopting $(S \times P \times N)$ as a horizontal axis and V_1 as a vertical axis, several points of the value of V_1 relative to the value of $(S \times P \times N)$ are plotted. A linear approximation equation is obtained from these points. A slope in this linear approximation equation becomes K .

Then, an estimated soil removal volume V in actual construction is obtained by a calculation equation of $V=K \times S \times P \times N$ from the set soil removal coefficient K and measurable values of S , P and N in the following actual construction.

5 Citation List

Patent Document

[0016]

Patent Document 1: Japanese Patent No. 3583307

10 Summary of Invention

Technical Problem

[0017]

However, in the ground improvement method based on the agitation blade, as described above, if the blade rotation number is increased, the mixture condition between the ground improvement material and the ground is improved, but the construction speed is lowered. In contrast, if the blade rotation number is reduced, the construction speed is increased, but there is a possibility of a desired UCS failing to be developed in the ground-improved body.

[0018]

Further, the actual measurement test for obtaining the estimated soil removal volume V should be carried out three times or more on each type of soil in each construction field, and thus takes effort and time. Also, to guarantee reliability, a considerable amount of data is required to some extent, but in the actual measurement test, it is difficult to obtain such a considerable amount of data.

25 [0019]

Accordingly, the present invention was devised in view of the above circumstances, and has as an object the provision of a ground improvement method capable of securing the quality of construction and improving the efficiency of construction.

5 [0020]

Further, another objective of the present invention is to provide a construction control system in the ground improvement method which is capable of speedily calculating the estimated soil removal volume with high reliability.

10 Solution to Problem

[0021]

To solve the above problems, the applicant focused on a blade rotation number that is greatly connected to construction efficiency. Specifically, the applicant completed the present invention by evaluating the blade rotation number when a screw
15 rod penetrates to a given depth without injecting a ground improvement material.

In detail, according to a first aspect of the present invention, there is provided a ground improvement method including: causing a screw rod having agitation blades to penetrate into a ground to a given depth while rotating the screw rod in a state where a ground improvement material is not injected; and withdrawing the screw rod while
20 rotating the screw rod and injecting the ground improvement material from the screw rod to agitate and mix the ground with the ground improvement material using the agitation blades, in which: a sum of a blade rotation number of the agitation blades when the screw rod is caused to penetrate in the state where the ground improvement material is not injected and a blade rotation number of the agitation blades when the screw rod is
25 withdrawn while injecting the ground improvement material is calculated to use the sum

as an adjusted blade rotation number; the adjusted blade rotation number is set from a relation between a preset UCS variation coefficient of a ground-improved body and the adjusted blade rotation number based on a targeted UCS variation coefficient of the ground-improved body; and ground improvement using the set adjusted blade rotation number as a construction control item is performed, thereby reducing the blade rotation number of the agitation blades when the screw rod is withdrawn while injecting the ground improvement material, in comparison with a case in which only the blade rotation number of the agitation blades when the screw rod is withdrawn while injecting the ground improvement material is used as the construction control item while securing the same quality.

[0022]

According to the ground improvement method according to the first aspect, the ground improvement is performed based on the adjusted blade rotation number. Thereby, the ground improvement is improved even if the blade rotation number when the screw rod is withdrawn while injecting the ground improvement material is reduced more than that of the related art. For this reason, the blade rotation number is reduced more than that of the related art, so that the construction efficiency can be enhanced.

Further, with this configuration, in a construction control system that controls a situation of the ground improvement, the construction control can be performed directly using the adjusted blade rotation number. For example, the construction control system of the ground improvement is used to add up the blade rotation number during the penetration of the screw rod and the blade rotation number during the withdrawal of the screw rod at each improvement depth so as to be able to display the result. Thereby, the adjusted blade rotation number is set as the construction control item, so that the construction control can be performed.

[0023]

Further, according to a second aspect of the present invention, there is provided a ground improvement method including: causing a screw rod having agitation blades to penetrate into a ground to a given depth while rotating the screw rod in a state where a
5 ground improvement material is not injected; and withdrawing the screw rod while rotating the screw rod and injecting the ground improvement material from the screw rod to agitate and mix the ground with the ground improvement material using the agitation blades, in which: a sum of a blade rotation number of the agitation blades when the screw rod is caused to penetrate in the state where the ground improvement material is not
10 injected and a blade rotation number of the agitation blades when the screw rod is withdrawn while injecting the ground improvement material is calculated to use the sum as an adjusted blade rotation number; the adjusted blade rotation number is set from a relation between a preset UCS variation coefficient of a ground-improved body and the adjusted blade rotation number based on a targeted UCS variation coefficient of the
15 ground-improved body; and ground improvement using the blade rotation number of the agitation blades when the screw rod is withdrawn, which is obtained by subtracting the blade rotation number of the agitation blades when the screw rod is caused to penetrate from the set adjusted blade rotation number, as a construction control item is performed, thereby reducing the blade rotation number of the agitation blades when the screw rod is
20 withdrawn while injecting the ground improvement material, in comparison with a case in which only the blade rotation number of the agitation blades when the screw rod is withdrawn while injecting the ground improvement material is used as the construction control item while securing the same quality.

[0024]

25 According to the ground improvement method according to the second aspect,

the ground improvement is performed based on the adjusted blade rotation number.

Thereby, the ground improvement is improved even if the blade rotation number when the screw rod is withdrawn while injecting the ground improvement material is reduced more than that of the related art. For this reason, the blade rotation number is reduced
5 more than that of the related art, so that the construction efficiency can be enhanced.

Further, with this configuration, in a construction control system that controls a situation of the ground improvement, even if each of the blade rotation number during the penetration of the screw rod and during the withdrawal of the screw rod can be calculated but the adjusted blade rotation number cannot be calculated and displayed,
10 when there is a system configured such that the blade rotation number during the penetration of the screw rod is almost constant at each improvement depth, the construction control can be performed based on the blade rotation number during the withdrawal of the screw rod.

[0025]

15 Further, according to a third aspect of the present invention, there is provided a ground improvement method includes: causing a screw rod having agitation blades to penetrate into a ground to a given depth while rotating the screw rod in a state where a ground improvement material is not injected; and withdrawing the screw rod while rotating the screw rod and injecting the ground improvement material from the screw rod
20 to agitate and mix the ground with the ground improvement material using the agitation blades, in which: a sum of a blade rotation number of the agitation blades when the screw rod is caused to penetrate in the state where the ground improvement material is not injected and a blade rotation number of the agitation blades when the screw rod is withdrawn while injecting the ground improvement material is calculated to use the sum
25 as an adjusted blade rotation number; a targeted UCS variation coefficient of a

ground-improved body is set from a relation between the preset adjusted blade rotation number and the UCS variation coefficient of the ground-improved body based on the adjusted blade rotation number; and an injected volume of the ground improvement material, which is injected into the ground, is set from the set UCS variation coefficient of the ground-improved body, and the injected volume is injected into the ground, thereby reducing the injected volume of the ground improvement material in comparison with a case of obtaining the UCS variation coefficient of the ground-improved body from only the blade rotation number of the agitation blades when the screw rod is withdrawn while injecting the ground improvement material and of setting the injected volume of the ground improvement material while securing the same quality.

[0026]

According to the ground improvement method according to the third aspect, the ground improvement is performed based on the adjusted blade rotation number. Thereby, although the construction efficiency is kept unchanged from that of the related art, the injected volume of the ground improvement material is reduced, and thus a cost of the ground improvement method can be reduced.

[0027]

Further, according to a fourth aspect of the present invention, in the first to third aspects, water is injected from the screw rod during the penetration of the screw rod into the ground.

[0028]

According to the ground improvement method according to the fourth aspect, the ground can be softened by the water injected into the ground. As a result, the penetration and rotation of the screw rod become smoother, so that a loosening effect caused by the previous blade rotation before the ground improvement material is

discharged is increased.

[0029]

Further, according to a fifth aspect of the present invention, in the fourth aspect,
a volume of the injected water approximates a volume of water obtained from a liquid
5 limit of an improvement target ground.

[0030]

According to the ground improvement method according to the fifth aspect, the
volume of the water injected into the ground is used as a proper amount. Thereby, it is
possible to prevent the strength of the ground-improved body from being reduced by an
10 excess of the volume of water injected into the ground. In other words, the penetration
and rotation of the screw rod become smoother, so that a loosening effect caused by the
previous blade rotation before the ground improvement material is discharged is
increased, and simultaneously the strength of the ground-improved body can be reliably
secured.

15 [0031]

Further, to solve the above problems, according to a sixth aspect of the present
invention, there is provided a construction control system in a ground improvement
method which is applied on carrying out the ground improvement method of: causing a
screw rod, a tip portion of which has agitation blades, to penetrate into a ground;
20 injecting a ground improvement material into the ground via the screw rod; withdrawing
the screw rod while agitating and mixing the ground improvement material with soil by
rotation of the agitation blades; and removing the soil, equivalent to an injected volume
of the ground improvement material, from the ground by the screw rod, and which
detects and monitors a depth, rotation number, penetration speed, and withdrawal speed
25 of the screw rod and the injected volume of the ground improvement material, in which

the system: uses a rate of the injected volume of the ground improvement material slurry with respect to an improvement ground as a ground improvement material admixture rate; sets a soil removal coefficient from a relation between the ground improvement material admixture rate previously obtained for each ground condition and the soil removal coefficient based on the given ground improvement material admixture rate; and computes an estimated soil removal volume caused by the screw rod based on the set soil removal coefficient and the rotation number and monitors the estimated soil removal volume as a control item.

[0032]

10 According to the sixth aspect, the soil removal coefficient can be set based on the ground improvement material admixture rate, and the estimated soil removal volume can be calculated based on the soil removal coefficient. The estimated soil removal volume is used as the control item, so that the estimated soil removal volume can be speedily calculated with high reliability. As a result, the construction control system
15 can contribute to reduction in construction period and cost in the ground improvement method while controlling displacement of the original ground.

[0033]

According to a seventh aspect of the present invention, in the sixth aspect, the construction control system is configured to compare the estimated soil removal volume
20 with the injected volume of the ground improvement material, and to determine whether construction is poor.

[0034]

According the seventh aspect, the estimated soil removal volume is compared with the injected volume of the ground improvement material, thereby determining
25 whether the construction is poor. Thereby, the reliability of the construction can be

sufficiently secured, and the necessity of modified construction becomes clear.

[0035]

The sixth and seventh aspects may be applied when carrying out the ground improvement method of: causing the screw rod having the agitation blades to penetrate
5 into the ground to a given depth while rotating the screw rod in a state where the ground improvement material is not injected; and withdrawing the screw rod while rotating the screw rod and injecting the ground improvement material from the screw rod to agitate and mix the ground with the ground improvement material using the agitation blades.

[0036]

10 In this case, for example, the sixth and seventh aspects may be applied when carrying out the ground improvement method of removing the soil equivalent to the injected volume of the ground improvement material from the ground by the screw rod, the construction control system is applied on carrying out the ground improvement method of: causing the screw rod, the tip portion of which has the agitation blades, to
15 penetrate into the ground while removing the soil equivalent to a plunged mixing tool volume; when the tip portion approaches a deepest point of a ground improvement range, further causing the screw rod to penetrate while injecting the ground improvement material into the ground from a lower injection outlet formed in the tip of the screw rod; and when a most tip of the screw rod arrives at the deepest point of the ground
20 improvement range, withdrawing the screw rod while injecting the ground improvement material into the ground from an upper injection outlet formed above the agitation blades to agitate and mix the ground with the ground improvement material using the agitation blades.

[0037]

25 Further, the sixth and seventh aspects may be applied when carrying out the

ground improvement method of the first to third aspects.

Advantageous Effects of Invention

[0038]

5 According to the ground improvement method of the present invention, the ground improvement is performed based on the adjusted blade rotation number. Thereby, the ground improvement is improved even if the blade rotation number when the screw rod is withdrawn while injecting the ground improvement material is reduced more than that of the related art. For this reason, the blade rotation number is reduced
10 more than that of the related art, so that the construction efficiency can be enhanced. Alternatively, the construction efficiency is kept unchanged from that of the related art, while the injected volume of the ground improvement material is reduced, so that the cost of the ground improvement method can be reduced.

[0039]

15 Further, according to the construction control system in the ground improvement method, the soil removal coefficient can be set based on the ground improvement material admixture rate, and the estimated soil removal volume can be calculated based on the soil removal coefficient. The estimated soil removal volume is used as the control item, so that the estimated soil removal volume can be speedily calculated with
20 high reliability. As a result, the construction control system can contribute to reduction in construction time and cost in the ground improvement method while controlling displacement of the original ground.

Brief Description of Drawings

25 [0040]

FIG. 1 is a view showing an outline of a construction control system used in a ground improvement method of an embodiment of the present invention.

FIG. 2 is a view showing a method of determining a soil removal coefficient (in the case of cohesive soil) used in the construction control system used in the embodiment
5 of the present invention.

FIG. 3 is a graph showing a relation between a blade rotation number and an UCS variation coefficient in the ground improvement method of the embodiment of the present invention.

FIG. 4 is a graph showing a relation between a blade rotation number and an
10 UCS variation coefficient in the ground improvement method of the embodiment of the present invention.

FIG. 5 is a view showing an example of control data in the construction control system used in the embodiment of the present invention.

FIG. 6 is a view showing another example of the control data in the same
15 system.

FIG. 7 is a view showing a method of determining a soil removal coefficient (in the case of sandy soil) used in the same system.

FIG. 8 is a view showing an outline of a treatment machine and construction control system in a conventional deep mixing method.

20 FIG. 9 is a graph showing a relation between a blade rotation number and an UCS variation coefficient in a conventional ground improvement method.

FIG. 10A is a view showing an outline of a treatment machine in a deep mixing method to which the present invention may be applied.

FIG. 10B is an enlarged view of a tip of the screw rod shown in FIG. 10A.

Description of Embodiments

[0041]

Hereinafter, a specific embodiment of a ground improvement method of the present invention will be described with reference to the drawings. The ground
5 improvement method of the present embodiment is applied to, for instance, a soil-removal-type deep mixing method based on a treatment machine 1 shown in FIGS. 10A and 10B.

In short, in the treatment machine 1 shown in FIGS. 10A and 10B, a screw rod 3 having agitation blades 2 is rotated, and simultaneously penetrates into the ground
10 without injecting a cement slurry (a ground improvement material slurry) composed of water and cement. Then, when a tip of the screw rod 3 reaches a length between upper and lower injection outlets 50 and 60 of a given improvement range, the cement slurry is injected from the lower injection outlet 60 formed in the tip of the screw rod 3 into the
15 ground, and the penetration is further performed while blade rotation is performed on the ground by the agitation blades 2. Then, when the most tip of the screw rod 3 reaches the deepest point of the improvement range, the cement slurry is injected from the upper injection outlet 50 formed above the agitation blades 2 into the ground, and the screw rod 3 is withdrawn while the blade rotation is performed by the agitation blades 2.

[0042]

20 In this ground improvement method, soil equivalent to an injected volume of the ground improvement material slurry are removed. Thereby, ground displacement associated with the injection of the ground improvement material slurry is reduced. That is, the construction control system used in the present embodiment is configured to be based on the conventional construction control system shown in FIG. 8, but to add a
25 “soil removal volume,” a calculation method of which is distinguished from that of the

related art, as control items thereof, to monitor the soil removal volume caused by the treatment machine 1, to properly maintain the soil removal volume, and to thereby prevent displacement of the original ground (swelling or adverse influence on the surrounding ground).

5 Furthermore, in the construction control system of the present embodiment, in order to quantitatively ascertain the agitated/mixed state of the cement slurry with soil to properly control it, the “blade rotation number” that takes into consideration the blade rotation number in the event of the penetration of the screw rod is added as the control item.

10 [0043]

That is, as shown by an outline thereof in FIG. 1, the construction control system used in the present embodiment sets: a “material,” “blending,” and “mixture (blade rotation number)” as the control items in view of quality control; a “piling position,” “piling depth,” and “bottom contact” as the control items in view of shape control; and a “soil removal volume” as the control item in view of ground displacement control. Among these control items, the “material,” “blending,” “piling position,” “piling depth,” and “bottom contact” are common to the conventional construction control system shown in FIG. 8. Further, the “mixture (blade rotation number)” and “soil removal volume” are the control items to which contents different from those of the related art are added in the present embodiment.

[0044]

Among the control items common to the related art, the “material” is an item that controls the state (cement amount and water amount) of the cement slurry as the ground improvement material, the “blending” is an item that controls whether or not an injected volume per unit depth is appropriate based on the slurry injected volume

(discharged volume) detected by the slurry flowmeter 6 and the elevation speed of the screw rod 3 detected by the elevation speed gauge 10, the “piling position” is an item that controls a formed position of the improved pile based on measurement made by a transit, the “piling depth” is an item that controls the position of the screw rod 3 detected by the depth gauge 9, and the “bottom contact” is an item that controls whether or not the tip of the screw rod 3 reaches the deepest point of the improvement target range based on the operation state of the driving unit 5 detected by the ammeter 8 and the penetrating speed detected by the elevation speed gauge 10.

[0045]

Further, among the control items added in the present embodiment, the “soil removal volume” is an item that controls an estimated soil removal volume such that the estimated soil removal volume, which is calculated by the rotation number of the screw rod 3 detected by the shaft revolution counter 7, a screw shape, and a soil removal coefficient, is equal to the slurry injected volume.

[0046]

In the present embodiment, the estimated soil removal volume is calculated as follows. The estimated soil removal volume V is a function of a section area of the screw S , a screw pitch P , and a shaft rotation number N , adopts the constant of proportionality thereof as an soil removal coefficient K , and is expressed as follows:

$$V=K \cdot S \cdot P \cdot N \dots\dots\dots (2)$$

where:

V ; the estimated soil removal volume (m^3)

K ; the soil removal coefficient

S ; the section area of the screw (m^2)

P ; the screw pitch (m)

N; the shaft rotation number (rev.s)

In Equation (2), the section area of the screw S and the screw pitch P are specific constants of the treatment machine 1. As such, if a value of the soil removal coefficient K is determined, then the estimated soil removal volume V can be calculated only by measuring the shaft rotation number N from the penetration to the withdrawal.

[0047]

Here, the inventors of the present invention wondered whether a correlation existed between the soil removal coefficient K and the ground improvement material admixture rate x, and checked the correlation between the soil removal coefficient K and the ground improvement material admixture rate x based on a number of construction results (data number n = 99).

[0048]

Here, the inventors of the present invention wondered whether a correlation existed between the soil removal coefficient K and the ground improvement material admixture rate x, and checked the correlation between the soil removal coefficient K and the ground improvement material admixture rate x based on a number of construction results.

As a result, the correlation between the ground improvement material admixture rate x and the soil removal coefficient K is obtained as shown in FIG. 2. FIG. 2 shows the data number n = 99, and the following equation is obtained from the correlation (straight line of FIG. 2, and correlation coefficient $r = 0.81$).

$$K = 0.5116x + 0.0066 \dots \dots \dots (3)$$

where:

x; the ground improvement material admixture rate (%).

Equation (3) is applied to a case in which the ground is cohesive soil, and since

the correlation coefficient $r = 0.81$, the correlation can be said to be strong. A similar correlation expression can be previously obtained for each soil condition of the ground.

[0049]

Further, the ground improvement material admixture rate x is a volume ratio of
 5 the injected volume of the ground improvement material slurry to the original ground for improvement, and can be decided by how high the UCS of the improved ground is set. An added amount (kg) of the ground improvement material added to a unit original ground for improvement (1 m^3) is previously obtained. For example, the added amount of the ground improvement material for each unit of approximately 1 m^3 of original
 10 ground for improvement is 100 kg.

Further, since the ground improvement material is injected as the ground improvement material slurry (cement slurry) in which water is added to cement, and an addition ratio W/C of the water (W) to the cement (C) is also preset in consideration of the performance of construction. The addition ratio W/C is generally set to $W/C \cong 100\%$.
 15 In this case, the ground improvement material slurry corresponding to the added amount of 100 kg of the cement is about 133 liters (specific gravity of the cement is 3). When the ground improvement material slurry of 133 liters is injected and admixed into the 1 m^3 of the original ground for improvement, the ground improvement material admixture rate $x = 0.133$ (13.3%). In this way, the ground improvement material admixture rate x
 20 is previously determined. Then, $x = 0.133$ is substituted into Equation (3), and the soil removal coefficient $K = 0.075$ is calculated.

[0050]

As mentioned above, the soil removal coefficient K , which is previously obtained from Equation (3) based on the given ground improvement material admixture
 25 rate x , is calculated and set. Alternatively, the soil removal coefficient K corresponding

to the ground improvement material admixture rate x may be set on a line obtained by depicting Equation (3) as a straight line on the Cartesian coordinates of the ground improvement material admixture rate x and the soil removal coefficient K (see FIG. 2). Then, if the set soil removal coefficient K , the section area of the screw S , and the screw pitch P are input to the control apparatus 11, the estimated soil removal volume V is computed and calculated according to Equation (2) only by inputting the shaft rotation number N detected by the shaft revolution counter 7 to the control apparatus 11. Output of the shaft rotation number N from the shaft revolution counter 7 may be automatically input to the control apparatus 11. If done in this way, the estimated soil removal volume V is computed and calculated just after the screw rod 3 is withdrawn according to the previously input soil removal coefficient K , section area of the screw S , and screw pitch P . Then, in the construction control system of the present embodiment, whenever one improved pile is constructed, the estimated soil removal volume V thereof is computed. The result is compared with the slurry injected volume detected by the slurry flowmeter 6, thereby determining whether the construction is poor. If the shaft rotation number N is adjusted, the estimated soil removal volume V can be increased or decreased. As such, the shaft rotation number may be controlled every minute such that the estimated soil removal volume V becomes appropriate as needed.

[0051]

Next, the “blade rotation number” that is the control item added in the present embodiment will be described. The blade rotation number is a value that indicates the number of times the blade rotation by a unit length is performed by each agitation blade 2 when the screw rod 3 is withdrawn.

In short, the blade rotation number T (rev.s/m) = (screw rod rotation number n [rev.s/min] $\times$ total agitation blade number M [number]) / (screw rod withdrawal speed v

[m/min]). In this equation, since the total agitation blade number M is the specific constant of the treatment machine, the blade rotation number T can be obtained by the rotation number n detected by the shaft revolution counter 7 and the withdrawal speed v detected by a speed gauge 9. In the control apparatus 11, if the total agitation blade

5 number M is input, the blade rotation number T is automatically computed and calculated, so that it can be checked whether the blade rotation number is within a given control range value.

[0052]

In the actual construction, the ground improvement material in a slurry form is

10 injected while the screw rod 3 is withdrawn. A relation between the blade rotation number T (rev.s/m) when the ground improvement material and the ground are agitated and mixed and the variation coefficient V_c (%) of the UCS of each of the improved bodies A to D taken from them is shown in Table 1. Further, these results are plotted on the conventional relation graph (FIG. 9) by triangular points A1 to D1 of FIG. 3.

15 [0053]

Table 1

Improved body	Blade rotation number T (rev.s/m)	Variation coefficient of UCS V_c (%)
A (A1)	350	17.7
B (B1)	467	15.1
C (C1)	548	14.3
D (D1)	679	11.1

[0054]

Magnitudes of the variation coefficients V_c based on the blade rotation number

T after the ground improvement materials of the triangular points A1 to D1 are injected become values smaller than those of the UCS variation coefficients V_c obtained from the conventional relation graph. In short, the blade rotation number when the screw rod penetrates before the ground improvement material is injected contributes to the UCS variation coefficient. In other words, it can be inferred that to agitate and loosen the ground without injecting the ground improvement material has good influence on a ground agitation effect of injecting the ground improvement material in the future.

[0055]

Then, the blade rotation number when the screw rod penetrates before the ground improvement material is injected and discharged is added to the blade rotation number when the screw rod is withdrawn after the ground improvement material is injected and discharged. The added result is used as a total blade rotation number. A relation between the total blade rotation number and the variation coefficient is shown in Table 2. These are plotted on the conventional relation graph (FIG. 9) by circular points A2 to D2 of FIG. 4.

[0056]

Table 2

Improved body	Total blade rotation number T during penetration and withdrawal (rev.s/m)	Variation coefficient V_c (%)
A (A2)	$136 + 350 = 486$	17.7
B (B2)	$346 + 467 = 813$	15.1
C (C2)	$303 + 548 = 851$	14.3
D (D2)	$544 + 679 = 1135$	11.1

[0057]

As shown in FIG. 4, the circular points A2 to D2 are closer to the conventional relation graph than the triangular points A1 to D1. In short, it can be determined that the evaluation may be done by the total blade rotation number.

5 [0058]

In the four circular points A2 to D2 of FIG. 4, the vicinity of a verification range is represented by a regression expression as follows.

$$V_c = -7.45 \ln(T) + 64.221, \quad r = 0.9345 \dots \dots \dots (4)$$

where:

10 V_c ; the variation coefficient of UCS (%)

T ; the total blade rotation number

r ; the correlation coefficient

$\ln(T)$; the natural logarithm

[0059]

15 In the present embodiment, a targeted variation coefficient V_c is substituted into Equation (4), and thus the total blade rotation number T is calculated and set. The construction control is performed based on the total blade rotation number T . For example, when the construction control system of the ground improvement is configured so that the sum of the blade rotation number when the screw rod penetrates and the blade
20 rotation number when the screw rod is withdrawn is calculated and displayed for each improvement depth, the construction control can be performed by setting the total blade rotation number T as the construction control item. Equation (4) may be a graph of the Cartesian coordinates. In this case, the targeted variation coefficient V_c may be applied to this graph, and the total blade rotation number T corresponding to this may be set.

[0060]

On the other hand, a favorable penetration speed of the screw rod and a favorable rotation number of the screw rod at this penetration speed in a state in which the ground improvement material is not injected depend on classification and hardness of the ground and are found empirically. As such, the blade rotation number when the screw rod penetrates can be determined.

[0061]

When the construction control system of the ground improvement is configured so that the blade rotation number when the screw rod penetrates and is withdrawn are calculated but the total blade rotation number is not allowed to be calculated and displayed, the blade rotation number when the screw rod penetrates may be deducted, i.e. subtracted, from the total blade rotation number T , and the construction control may be performed based on the blade rotation number when the screw rod is withdrawn. The construction control can be performed by any method.

15 [0062]

For example, when the variation coefficient V_c of the UCS of the ground-improved body is set to 15%, the total blade rotation number becomes 740 rev.s/m according to Equation (4). When the blade rotation number in the event of the penetration of the screw rod is set to 300 rev.s/m, the blade rotation number when the screw rod is withdrawn becomes 440 rev.s/m. The blade rotation number when the screw rod is withdrawn is approximated to 1000 rev.s/m in the related art. Thus, in comparison with that of the related art, the blade rotation number is remarkably reduced. Thereby, the withdrawal speed of the screw rod can be greater than that of the related art, and thus the construction efficiency is improved.

25 [0063]

In the actual ground improvement, the ground is improved by performing the construction control of adjusting the screw rod rotation number or the screw rod withdrawal speed such that the total blade rotation number or the blade rotation number when the screw rod is withdrawn, either of which is displayed on the construction control system, does not deviate from a given control value of either the total blade rotation number obtained from the above expression (relation expression between the variation coefficient of the UCS of the ground-improved body and the total blade rotation number) based on a targeted variation coefficient of the UCS of the ground-improved body or the blade rotation number when the screw rod is withdrawn. The relation between the variation coefficient of the UCS of the ground-improved body and the total blade rotation number is not limited to the above expression, but may be changed by accumulation of future construction data.

[0064]

Further, when the sum of the blade rotation number of the agitation blades when the screw rod penetrates without injecting the ground improvement material and the blade rotation number of the agitation blades when the screw rod from which the ground improvement material is injected is withdrawn is used as the total blade rotation number, the blade rotation number when the screw rod penetrates is added at 100% as in the above embodiment. In addition to this case, a case in which a part (e.g. about 70% to 80%) of the blade rotation number when the screw rod penetrates is added, or a case in which a given upper limit value is set to add the blade rotation number when the screw rod penetrates may be considered depending on a difference in the soil condition.

In the present embodiment, the inclusion of the blade rotation number when the screw rod penetrates does not mean only simple addition, and may include: adding a product of a given coefficient; adding a given value as an upper limit; or multiplying the

blade rotation number of the agitation blades when the screw rod from which the ground improvement material is injected is withdrawn by a given coefficient in consideration of the ground loosening effect due to the blade rotation of the agitation blades when the screw rod penetrates without injecting the ground improvement material from the screw
 5 rod

In this sense, the total blade rotation number in the present embodiment includes adjusting and counting the blade rotation number of the agitation blades when the screw rod penetrates, and thus may be called an adjusted blade rotation number. In the aforementioned embodiment in which the blade rotation number during penetration is
 10 subtracted from the total blade rotation number and the construction control is performed by the blade rotation number during withdrawal, when the blade rotation number during penetration is adjusted, the subtracted blade rotation number during penetration is the adjusted blade rotation number during penetration.

[0065]

Each control item is input to the control apparatus (computer) 11 and evaluated, i.e., it is determined whether the construction is poor, and modified construction is performed based on the determination as needed. Then, the construction data is stored in a personal computer 13, and proper control data, for instance a “piling result table” as shown in FIG. 5 or a “daily piling report” as shown in FIG. 6 is printed out as needed.
 15
 20 In the “piling result table” of FIG. 5, the targeted variation coefficient V_c or the total blade rotation number as the control value is not represented. However, the total blade rotation number is calculated and set as the control value by separate computation using Equation (4), and this control value is input to the construction control apparatus.

Otherwise, the regression expression of the variation coefficient V_c and the total
 25 blade rotation number T may be previously programmed for each ground, and the total

blade rotation number T may be calculated and set as the control value by inputting the targeted variation coefficient V_c and the ground classification to the construction control apparatus.

[0066]

5 Further, from another viewpoint, in the case that the blade rotation number of the agitation blades when the screw rod is withdrawn is set to the number of rev.s/m similar to that of the conventional method, the variation coefficient V_c can be set to be less than that of the related art. The variation coefficient V_c being set to be little means that the in-situ UCS of the ground-improved body can be set to be less than that of the
10 related art. In short, the injected volume of the ground improvement material can be set to be less than that of the related art.

With this configuration, the construction efficiency is not different from that of the related art, but the construction cost can be reduced more than that of the related art.

[0067]

15 For example, the blade rotation number when the screw rod is withdrawn after the ground improvement material is injected is set to 500 rev.s/m. In a conventional technical idea, the variation coefficient of the UCS of the ground-improved body in this case becomes 20% from FIG. 9. On the other hand, in the present embodiment, the blade rotation number when the screw rod penetrates without injecting ground
20 improvement material can be counted. As such, if the blade rotation number when the screw rod penetrates is set to 300 rev.s/m, the total blade rotation number becomes 800 rev.s/m. When this is substituted into Equation (4) above, the variation coefficient $V_c=14.3\%$.

[0068]

25 When the design UCS is set to 1000 kN/m^2 , the in-situ UCS of the related art is

set to 1350 kN/m^2 , while the in-situ UCS of the present embodiment is set to 1230 kN/m^2 . Since the in-situ UCS relative to in-lab. blending UCS has a relation of 0.5 to 0.8, when this is set to 0.5, the in-lab. blending UCS is 2700 kN/m^2 relative to the in-situ UCS of 1350 kN/m^2 , and the in-lab. blending UCS is 2460 kN/m^2 relative to the in-situ UCS of 1230 kN/m^2 .

[0069]

The relation between the cement (ground improvement material) added amount and the in-lab. blending UCS is set by performing an in-lab. UCS test. The cement dosage becomes about 165 kg/m^3 relative to the in-lab. blending UCS of 2700 kN/m^2 , and the cement dosage becomes about 150 kg/m^3 relative to the in-lab. blending UCS of 2460 kN/m^2 . The water/cement ratio of the ground improvement material slurry (cement slurry) is frequently set to 100%. As such, when the water/cement ratio is set to 100%, the ground improvement material slurry injected volume becomes 165 l/m^3 relative to the dosage of 165 kg/m^3 , and the ground improvement material slurry injected volume becomes 150 l/m^3 relative to the dosage of 150 kg/m^3 .

[0070]

In the construction, on the basis of a given total blade rotation number (adjusted blade rotation number), a targeted variation coefficient of the UCS of the ground-improved body is calculated and set from the above expression (relation expression between the variation coefficient of the UCS of the ground-improved body and the total blade rotation number), and the ground improvement material slurry injected volume is calculated and set from the set variation coefficient of the UCS of the ground-improved body as described above. Then, the ground improvement material slurry injected volume is managed under control such that an actual ground improvement material slurry injected volume falls into a given range relative to the ground

improvement material slurry volume (150 l/m^3) set above, and thereby the ground improvement is performed. According to the present embodiment, the ground improvement material slurry can be reduced more than that of the related art, and thus the construction cost can be reduced.

5 [0071]

In this way, according to the present embodiment, the blade rotation number is reduced more than that of the related art, so that the construction efficiency can be enhanced. Further, as a separate method, the construction efficiency is kept unchanged from that of the related art, and the ground improvement material slurry injected volume
10 is reduced, so that the construction cost can be reduced. Which of the methods is employed may be decided in consideration of priority in an actual field. Of course, the blade rotation number may be moderately reduced, and simultaneously the ground improvement material slurry injected volume may be moderately reduced. Thereby, both may undergo balanced adjustment so as to moderately improve the construction
15 efficiency and to obtain a moderate cost-saving effect.

[0072]

Further, in the present embodiment, water may be injected and discharged from the ground improvement material slurry injection outlet (in FIG. 8, located at a lower end position of the screw rod 3) of the tip of the screw rod when the screw rod penetrates.
20 With this configuration, it is inferred that, due to the water added to the ground, the ground becomes soft, and the penetration and rotation of the screw rod become smoother, so that the loosening effect caused by the previous blade rotation before the ground improvement material slurry is injected is increased. In this case, an assumed regression line of the variation coefficient and the total blade rotation number is
25 considered to be located at a lower side than that based on the above expression in the

graph shown in FIG. 4.

[0073]

However, if the added water when the screw rod penetration is too much, this is assumed to have influence on reduction in the UCS of the ground-improved body. For this reason, an amount of added water is at most close to an amount of water calculated from a liquid limit of a target ground to be improved, and may be favorable for approximation to the amount of water obtained from this liquid limit. The added water when the screw rod penetrates has a particular effect on the ground higher than an underwater level, and may be applied to the conventional ground improvement method, in which the ground improvement material and the ground are agitated and mixed by the agitation blades, in addition to the present embodiment.

[0074]

Further, the construction control system of the present embodiment which is described above, in addition to being able to perform the quality control and shape control similar to those of the related art when the ground improvement based on the soil-removal type deep mixing method is performed, can speedily estimate the soil removal volume approximate to the actual soil removal volume, and contributes to improvement of the construction efficiency as well as enabling the construction control with high precision.

[0075]

In addition, in the construction control system of the present embodiment, the blade rotation number is controlled so that the degree of the agitation/mixture of the cement slurry and the soil can be quantitatively ascertained. As such, an excellent ground improvement effect can be obtained.

[0076]

Further, for the computation of the soil removal coefficient K , a plurality of correlation expressions may be programmed for each type soil in the construction control system, and if the type of soil is selected and the ground improvement material admixture rate x is input in the construction control system, the soil removal coefficient K may be automatically calculated and set. Alternatively, the soil removal coefficient K may be manually calculated and set using a separate calculator, and a calculated value of the soil removal coefficient K may be input to the construction control system. Afterwards, the method of computing the estimated soil removal volume V from the soil removal coefficient K is as described previously. The “piling result table” of FIG. 5 is an output example of a system that automatically computes the estimated soil removal volume V if the ground improvement material admixture rate x is input.

[0077]

The present invention is not limited to the aforementioned embodiments, and includes various modifications made in the aforementioned embodiments without departing from the spirit and scope of the invention. That is, the specific structures and configurations given in the embodiments are merely given as an example, and thus may be properly modified.

[0078]

For example, in the present embodiment, the calculation expression of the soil removal coefficient when the ground is the cohesive soil has been represented. However, the calculation expression of the soil removal coefficient when the ground is the sandy soil may also be derived similarly to the case in which the ground is the cohesive soil. FIG. 7 is a graph showing a correlation between the ground improvement material admixture rate x and the soil removal coefficient K in the case of the sandy soil. FIG. 7 shows a result when the number of data $n=16$. The following expression

(straight line of FIG. 7) is obtained from this result.

$$K = 0.4935x - 0.0252 \dots\dots\dots (5)$$

In Equation (5), a correlation coefficient $r=0.858$, and thus a correlation can be said to be strong.

5 In this manner, the calculation expression of the soil removal coefficient is previously obtained for each soil condition, or the setting chart is made. Thereby, the estimated soil removal volume can be speedily calculated. However, the correlation expression described in the present embodiment may be changed and obtained by introducing more data in the actual construction.

10 For example, the construction control method based on the total blade rotation number (adjusted blade rotation number) in the present embodiment may also be applied to methods other than the soil-removal-type deep mixing method of removing the soil equivalent to the ground improvement material injected volume. Further, the computation method of the soil removal coefficient of the present embodiment may also
15 be applied to a ground improvement method of injecting and agitating a ground improvement material slurry into the ground when a screw rod penetrates.

[0079]

Furthermore, the ground improvement method and construction control system according to the present invention can be applied to ground improvement methods other
20 than the ground improvement method of injecting the ground improvement material into the ground at a timing set forth in the embodiment as long as the ground improvement method is performed by rotating the screw rod having the agitation blades into the ground, causing the screw rod to penetrate to a given depth without injecting the ground improvement material, rotating the screw rod to inject the ground improvement material
25 from the screw rod, and withdrawing the screw rod while agitating and mixing the

ground with the ground improvement material using the agitation blades during the injection of the ground improvement material.

In this case, the disposition of the screws in the screw rod is not particularly limited. The disposition of the screws may be modified depending on characteristics of the ground. For example, the screws may be not installed on a part of the screw rod. The pitch/interval between the screws may be adjusted to regulate the soil removal volume. Further, the position of each injection outlet in the screw rod is not particularly limited.

10 Industrial Applicability

[0080]

According to the ground improvement method of the present invention, the blade rotation number can be reduced more than the related art, while still enhancing the construction efficiency. Alternatively, the construction efficiency is kept unchanged from the related art, and the injected volume of the ground improvement material can be reduced, so that the construction cost can be reduced.

Also, according to the construction control system in the ground improvement method of the present invention, the estimated soil removal volume can be speedily calculated with high reliability. As a result, the system can contribute to reduction in construction period and cost in the ground improvement method while controlling displacement of the original ground.

Reference Signs List

[0081]

25 1: GROUND IMPROVEMENT APPARATUS (TREATMENT

MACHINE)

	2:	AGITATION BLADE
	3:	SCREW ROD (ROD)
	4:	BASE MACHINE
5	5:	DRIVING UNIT
	6:	SLURRY FLOWMETER
	7:	SHAFT REVOLUTION COUNTER
	8:	AMMETER
	9:	DEPTH GAUGE
10	10:	SPEED GAUGE
	11:	CONTROL APPARATUS
	50:	UPPER INJECTION OUTLET
	60:	LOWER INJECTION OUTLET

CLAIMS

1. A ground improvement method comprising:

causing a screw rod having agitation blades to penetrate into a ground to a given

5 depth while rotating the screw rod in a state where a ground improvement material is not injected; and

withdrawing the screw rod while rotating the screw rod and injecting the ground improvement material from the screw rod to agitate and mix the ground with the ground improvement material using the agitation blades, wherein:

10 a sum of a blade rotation number of the agitation blades when the screw rod is caused to penetrate in the state where the ground improvement material is not injected and a blade rotation number of the agitation blades when the screw rod is withdrawn while injecting the ground improvement material is calculated to use the sum as an adjusted blade rotation number;

15 the adjusted blade rotation number is set from a relation between a preset UCS variation coefficient of a ground-improved body and the adjusted blade rotation number based on a targeted UCS variation coefficient of the ground-improved body; and

ground improvement using the set adjusted blade rotation number as a construction control item is performed, thereby reducing the blade rotation number of the agitation blades when the screw rod is withdrawn while injecting the ground improvement material, in comparison with a case in which only the blade rotation number of the agitation blades when the screw rod is withdrawn while injecting the ground improvement material is used as the construction control item while securing the same quality.

2. A ground improvement method comprising:

causing a screw rod having agitation blades to penetrate into a ground to a given depth while rotating the screw rod in a state where a ground improvement material is not injected; and

5 withdrawing the screw rod while rotating the screw rod and injecting the ground improvement material from the screw rod to agitate and mix the ground with the ground improvement material using the agitation blades, wherein:

a sum of a blade rotation number of the agitation blades when the screw rod is caused to penetrate in the state where the ground improvement material is not injected

10 and a blade rotation number of the agitation blades when the screw rod is withdrawn while injecting the ground improvement material is calculated to use the sum as an adjusted blade rotation number;

the adjusted blade rotation number is set from a relation between a preset UCS variation coefficient of a ground-improved body and the adjusted blade rotation number

15 based on a targeted UCS variation coefficient of the ground-improved body; and

ground improvement using the blade rotation number of the agitation blades when the screw rod is withdrawn, which is obtained by subtracting the blade rotation number of the agitation blades when the screw rod is caused to penetrate from the set adjusted blade rotation number, as a construction control item is performed, thereby

20 reducing the blade rotation number of the agitation blades when the screw rod is withdrawn while injecting the ground improvement material, in comparison with a case in which only the blade rotation number of the agitation blades when the screw rod is withdrawn while injecting the ground improvement material is used as the construction control item while securing the same quality.

3. A ground improvement method, which includes:

causing a screw rod having agitation blades to penetrate into a ground to a given depth while rotating the screw rod in a state where a ground improvement material is not injected; and

5 withdrawing the screw rod while rotating the screw rod and injecting the ground improvement material from the screw rod to agitate and mix the ground with the ground improvement material using the agitation blades, wherein:

a sum of a blade rotation number of the agitation blades when the screw rod is caused to penetrate in the state where the ground improvement material is not injected

10 and a blade rotation number of the agitation blades when the screw rod is withdrawn while injecting the ground improvement material is calculated to use the sum as an adjusted blade rotation number;

a targeted UCS variation coefficient of a ground-improved body is set from a relation between the preset adjusted blade rotation number and the UCS variation

15 coefficient of the ground-improved body based on the adjusted blade rotation number; and

an injected volume of the ground improvement material, which is injected into the ground, is set from the set UCS variation coefficient of the ground-improved body, and the injected volume is injected into the ground, thereby reducing the injected volume

20 of the ground improvement material in comparison with a case of obtaining the UCS variation coefficient of the ground-improved body from only the blade rotation number of the agitation blades when the screw rod is withdrawn while injecting the ground improvement material and of setting the injected volume of the ground improvement material while securing the same quality.

4. The ground improvement method according to any one of claims 1 to 3, wherein water is injected from the screw rod when the screw rod is caused to penetrate into the ground.
- 5 5. The ground improvement method according to claim 4, wherein an amount of the injected water approximates an amount of water obtained from a liquid limit of an improvement target ground.