

TITLE OF THE INVENTION

**HYDRAULIC CEMENT COMPOSITION FOR INJECTION INTO SOIL, AND
METHOD FOR IMPROVEMENT IN SOIL USING SAME**

5

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

[0001]

The present invention relates to a hydraulic cement composition for soil injection, and a soil improvement
10 method using the same.

DESCRIPTION OF THE PRIOR ART

[0002]

As a sort of soil improvements, there has been a
15 chemical grout-injection method in which a settable
chemical grout is injected in ground via a rod for the
purpose of making soft soil firmer, and numerous chemical
grouts have hitherto been known in the art. For instance,
there is the mention of water glass-based grouts, special
20 silica-based grouts, polymeric grouts, and suspending
grouts such as cements, clays, and slag. The grouting
method using such chemical grouts has been much field
proved because of some merits of making improvements
without disturbing the ground as much as possible unlike
25 a jet grouting or other similar method in which the
ground is disturbed by high-pressure jets, and using a
compact installation.

The grouts are generally broken down into a chemical

type and a suspension type, and the chemical grouts have often been used in applications where high penetration capability is in need. With the chemical grout, however, it has been found that although there is high penetration capability, yet there may be a problem with long-term durability, because the set soil is of low strength in itself and undergoes some considerable shrinkage. Some suspension grouts having hydraulic cement, slag or other components, on the other hand, have merits of making it likely to produce relatively high strength and making sure long-term durability; however, they have had a low penetration problem. Accordingly, the suspension grouts now under development have focused on improvements in penetration capability. With soil improvements at harbors and coastal areas, however, there has still been an either-or situation problem: the higher the penetration capability of the suspension grout, the more likely it is to flow away with the tides.

[0003]

The suspension grouts known so far in the art include a grout composition comprising fine grained cement clinker and blast-furnace slag and containing as an essential ingredient a polycarboxylic acid-based dispersing agent (for instance, see Patent Publications 1, 2 and 3). These publications provide a grout composition having its penetration capability improved by the use of a specific polycarboxylic acid-based dispersing agent, but say nothing about the ability to prevent the grout

composition from flowing away and fail to provide any example about durability.

[0004]

Referring to grouts having gelling time, on the other
5 hand, grouts containing water glass, a solidifier and fine grained blast-furnace slag having a Blaine's surface area value of 8,000 cm²/g or higher, and the like have also been known in the art (for instance, see Patent Publications 4, 5 and 6).

10 [0005]

Patent Publication 4 teaches that the combined use of fine grained slag gives a set soil having high gel strength in dozens of seconds to a few minutes, but what is estimated is only strength, there is nothing set forth
15 about penetration capability, and much water glass is contained in it; that is, the composition is composed primarily of water glass.

[0006]

Patent Publication 5 is all about a grout comprising
20 water glass having a molar ratio of 2.8 to 4.0 and fine grained slag having an average particle diameter of up to 10 μm and a Blaine's specific surface area value of at least 5,000 cm²/g or, preferably, at least 8,000 cm²/g, and optionally containing cement. Water glass being used
25 in large amounts, that publication refers to compression strength and penetration capability, but is quite silent about the ability to prevent the grout to flow away.

[0007]

What is disclosed in Patent Publication 6 is characterized by comprising a suspension grout containing a mixture of fine grained slag and fine grained cement, wherein the slag and cement have each an average particle diameter of up to 10 μm and a Blaine's specific surface area value of at least 5,000 cm^2/g , and the cement is mixed at a mixing rate of up to 50%, and further characterized in that water glass and/or an alkali material are contained in it. In that publication, too, water glass is used in large amounts, so there is the mention of penetration capability, but there is nothing said about the ability to prevent the grout from flowing away, and the set soil is estimated in terms of compression strength alone.

[0008]

What is set forth in Patent Publication 7 is a suspension type soil improver that contains water, fine grained, water granulated slag, an alkali stimulator, a dispersing agent, and a polymeric substance that is dissolved or dispersed in water to bring about viscosity, with or without a consolidation improver. That publication refers to penetration capability and the ability to prevent particles from settling down, but says nothing about the properties of the set soil, so one has no understanding of how much the soil is reinforced upon injection, and how much the group is prevented from flowing away.

[0009]

Patent Publication 8 discloses a grout that contains wet pulverized slag, a polyacrylic acid-based dispersing agent, and sodium silicate. This publication refers to injection capability and improvements in compression strength, but says nothing about penetration capability and the ability to prevent the grout from flowing away.

LISTING OF THE PRIOR ART

PATENT PUBLICATIONS

10 [0010]

Patent Publication 1: JP(A) 2007-238428

Patent Publication 2: JP(A) 2007-238925

Patent Publication 3: JP(A) 2004-175989

Patent Publication 4: JP(A) 02-167848

15 Patent Publication 5: JP(A) 07-229137

Patent Publication 6: JP(A) 07-286173

Patent Publication 7: JP(A) 2005-344078

Patent Publication 8: JP(A) 2002-212556

20 SUMMARY OF THE INVENTION

OBJECTS OF THE INVENTION

[0011]

The primary object of the invention made with such problems in mind is to provide a hydraulic cement composition for soil injection, which is improved in terms of penetration capability and the ability to prevent a grout from flowing away, produces good enough strength, and is improved in terms of long-term

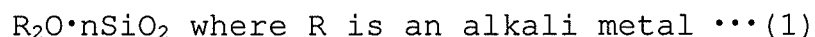
durability, and a soil improvement method using the same.

MEANS FOR ACCOMPLISHING THE OBJETS

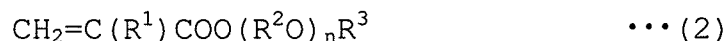
[0012]

5 According to the present invention, the aforesaid object is accomplishable by the following aspects 1 to 5.

Aspect 1 of the invention provides a hydraulic cement composition for soil injection, characterized by containing fine grained blast-furnace slag, classified
10 cement, a polyacrylic acid-based dispersing agent and an alkali metal silicate salt acting as an agent for preventing a grout from flowing away, wherein the alkaline metal silicate salt is used in a molar rate n of at least 3.5 in the following general formula (1), and in
15 an amount of 0.2 to 7 parts per a total of 100 parts of the blast-furnace slag and classified cement:



Aspect 2 of the invention provides a hydraulic cement composition for soil injection as recited in Aspect 1,
20 characterized in that the polyacrylic acid-based dispersing agent is a copolymer that contains a monomer represented by the following general formula (2):



where R^1 is a hydrogen atom or a methyl group, R^2O is an
25 oxyalkylene group having 2 to 4 carbon atoms, n is an integer of 5 to 40, and R^3 is a hydrogen atom or an alkyl group having 1 to 5 carbon atoms.

Aspect 3 of the invention provides a hydraulic cement

composition for soil injection as recited in Aspect 1 or 2, characterized in that the fine grained blast-furnace slag and the classified cement have each a Blaine's specific surface area value of 7,000 to 16,000 cm²/g and
5 a median diameter of 1 to 7 μ m.

Aspect 4 of the invention provides a soil improvement method in which a hydraulic cement composition for soil injection as recited in any one of Aspects 1, 2 and 3 is injected in ground.

10 Aspect 5 of the invention provides a soil improvement method as recited in Aspect 4 of the invention, characterized by being used for soil improvement intended to prevent liquefaction.

It is here noted that unless otherwise stated, the
15 part and % are given on a mass basis.

ADVANTAGES OF THE INVENTION

[0013]

The hydraulic cement composition for soil injection
20 according to the invention is improved in terms of penetration capability and the ability to prevent a grout from flowing away, so it is effective for soil improvement, and so on.

25 MODE FOR CARRYING OUT THE INVENTION

[0014]

The inventive hydraulic cement composition for soil injection is comprised of fine grained blast-furnace slag,

classified cement, a polyacrylic acid-based dispersing agent and an alkali metal silicate salt acting as an agent for preventing a grout from flowing away. The fine grained blast-furnace slag and classified cement are used
5 for the purpose of producing high strength, long-term durability, and high penetration capability.

[0015]

The fine grained blast-furnace slag is produced by the pulverization of steel slag occurring upon pig iron
10 production, and used as an admixture for general blast-furnace cement or concrete.

The fine grained blast-furnace slag used herein has a fineness represented by a Blaine's specific surface area value (hereinafter called the Blaine's value) of
15 preferably at least 7,000 cm²/g, more preferably 7,000 to 16,000 cm²/g, and most preferably 9,000 to 13,000 cm²/g. A Blaine's value of less than 7,000 cm²/g will often result in no sufficient penetration capability, and a Blaine's value of greater than 16,000 cm²/g will be
20 impractical because of incurring too much production cost. The Blaine's value is measured with a JIS R5201 Blaine's air penetration apparatus.

Preferably, the fine grained blast-furnace slag should have a median diameter of preferably 1 to 7 μm,
25 and more preferably 2 to 5 μm. For instance, the median diameter may be measured with a laser diffraction type particle size distribution measuring apparatus. A median diameter of less than 1 μm will be impractical because of

incurring too much production cost, and a median diameter of greater than 7 μm will possibly have an adverse influence on penetration capability.

[0016]

5 The classified cement used herein is the one that is regulated in terms of particle sizes with classification equipment. The cement to be classified includes Portland cements such as normal Portland cement, early-strength Portland cement, low-heat Portland cement, moderate-heat
10 Portland cement, and sulfate-resisting cement. The same also holds for mixed cements such as fly ash cement, and silica cement as well as for refractory cement such as alumina cement.

15 In addition to the cement ingredient, the classified cement may contain gypsum dihydrate and calcium carbonate added in the cement production process. Some classified cement allowed to contain finer calcium carbonate particles through classification may work more in favor of strength.

20 As is the case with the fine grained blast-furnace cement, the classified cement should have a fineness represented by a Blaine's value of preferably at least 7,000 cm^2/g , more preferably 7,000 to 16,000 cm^2/g , and most preferably 9,000 to 13,000 cm^2/g . A Blaine's value
25 of less than 7,000 cm^2/g will often fail to make sure good enough penetration capability, and a Blaine's value of greater than 16,000 cm^2/g will be impractical because of incurring too much production cost.

The classified cement should have a median diameter of preferably 1 to 7 μm , and more preferably 2 to 5 μm . For instance, the median diameter may be measured with a laser diffraction type particle size distribution

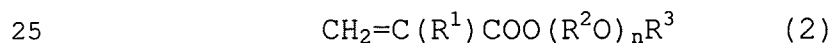
5 measuring apparatus. A median diameter of less than 1 μm will be impractical because of incurring too much production cost, and a median diameter of greater than 7 μm will possibly have an adverse influence on penetration capability.

10 [0017]

The classified cement content should be preferably 5 to 30 parts, and more preferably 10 to 25 parts per 100 parts of the fine grained blast-furnace slag. A content of less than 5 parts will possibly contribute to strength, and a content of greater than 30 parts will possibly have an adverse influence on penetration capability.

[0018]

In the invention, the polyacrylic acid-based dispersing agent is used. The polyacrylic acid-based dispersing has a combined effect on preventing particles from settling down in a suspension form and imparting penetration capability to it. That dispersing agent is characterized by being a copolymer represented by the following general formula (2):



In Formula (2), R^1 stands for a hydrogen atom or a methyl group, R^2O is indicative of an oxyalkylene group having 2 to 4 carbon atoms such as $-\text{CH}_2\text{CH}_2\text{O}-$, $-\text{CH}_2\text{CH}_2\text{CH}_2\text{O}-$,

-CH₂CH(CH₃)O-, -CH₂CH(CH₂CH₃)O-, and -CH₂CH₂CH₂CH₂O-; and n is an integer of 5 to 40 indicative of the number of added moles of the oxyalkylene group. As the number of added moles (n) gets too small, the dispersing power gets
 5 insufficient, whereas it gets too large, there will be a difficult-to-handle solid having a high melting point.

R³ stands for a hydrogen atom or an alkyl group having 1 to 5 carbon atoms such as a methyl, ethyl, propyl or butyl group.

10 Exemplary monomers, for instance, include polyethylene glycol mono(meth)acrylate, polypropylene glycol mono(meth)acrylate, polybutylene glycol mono(meth)acrylate, methoxy polyethylene glycol (meth)acrylate, methoxy polypropylene glycol
 15 (meth)acrylate, methoxy polybutylene glycol (meth)acrylate, ethoxy polyethylene glycol (meth)acrylate, ethoxy polypropylene glycol (meth)acrylate, ethoxy polybutylene glycol (meth)acrylate, and propoxy polyethylene glycol (meth)acrylate, wherein the number of
 20 added moles of alkylene oxide is 5 to 40 moles. These monomers may be used alone or in combination of two or more. As long as the monomer represented by General Formula (2) is contained, use may be made of a copolymer combined with a monomer component having another chemical
 25 structure.

Among these, preference is given to a copolymer including methoxy polyethylene glycol (meth)acrylate, and methoxy polypropylene glycol (meth)acrylate in view of

the ability to prevent particles from settling down, and penetration capability.

The polyacrylic acid-based dispersing agent should have a mass average molecular weight of preferably 5,000 to 100,000, and more preferably 20,000 to 80,000.

By way of example but not by way of limitation, the polyacrylic acid-based dispersing agent should be used in an amount of preferably 0.1 to 3 parts, and more preferably 0.3 to 2 parts per a total of 100 parts of the fine grained blast-furnace slag and the classified cement.

In the invention, the polyacrylic acid-based dispersing agent may be used in combination with a melamine-based dispersing agent.

[0019]

The alkali metal silicate salt imparts to the hydraulic cement composition for soil injection the ability to prevent it from flowing away. This ability to prevent the composition from flowing away is achievable by making it thixotropic.

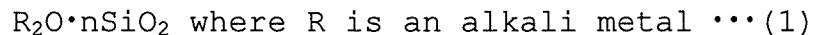
Note here that "thixotropy" refers to the property of a certain gel or fluid that is at first difficult to fluidize like a solid, but gets fluidized like a liquid with the application of force and behaves like a solid with removal of that force. When it comes to a grouting method, the thixotropic hydraulic cement composition of the invention is allowed to have high fluidization by injection pressure on injection, thereby having high penetration capability so that it can easily penetrate

ground. After the injection, the fluidity goes down due to no pressure load, so the grout does not flow away even when there is a hydraulic gradient on the order of the tides.

5 The tighter the hydraulic gradient (water pressure per unit distance in a water flowing direction: hydraulic gradient = water level difference/water flowing distance), the more likely the grout is to flow away; when there is no alkali metal silicate salt, the grout will often flow
10 away at a hydraulic gradient of 0.1 or greater. By combined use of a specific amount of the alkali metal silicate salt, however, the grout does not flow away even at a hydraulic gradient of 0.1 or greater.

[0020]

15 The alkali metal silicate salt used with the inventive hydraulic cement composition for soil injection is represented by the following general formula (1) where the molar ratio n is at least 3.5.



20 The alkali metal silicate salt includes sodium silicate, potassium silicate, and lithium silicate, among which sodium silicate is most preferred in view of stable supply and price. The alkali metal silicate salt exists in aqueous solution and powder forms, and there is a
25 wider selection of aqueous solutions commercially available; so those aqueous solutions go the mainstream of the alkali metal silicate salt when used with grouts, because they are of good workability too.

Referring to the molar ratio n , the ability to prevent the grout from flowing away will go down at less than 3.5, and too much alkali content may possibly lead to concern that the hydration reaction of cement is held
5 back, resulting in decreased strengths. Accordingly, the molar ratio n must be at least 3.5, and preferably 3.7 to 5.0. A molar ratio n of at least 3.5 causes the alkali content of the alkali metal silicate salt to get low, easing loads on the environment.

10 [0021]

The content of the alkali metal silicate salt should be 0.2 to 7 parts (in the case of an aqueous solution, 0.2 to 7 as calculated on a solid basis) per a total of 100 parts of the fine grained blast-furnace slag and
15 classified cement, and preferably 1 to 4.5 parts. At less than 0.2 parts, the ability to prevent the grout from flowing away will diminish. At greater than 7 parts, on the other hand, the viscosity will decrease and the ability to prevent the grout from flowing away will again
20 diminish. In addition, the alkali metal silicate salt and the cement will come together into a coagulation, resulting in a decrease in penetration capability.

[0022]

It is here to be noted that inventive hydraulic
25 cement composition for soil injection may be used in combination with known cement admixture agents (materials) unless its own performance is otherwise affected. For instance, there is the mention of AE

agents, AE water-reducing agents, high-performance water-reducing agents, high-performance AE water-reducing agents, fluidizers, retarders, early-strength agents, defoamers, thickeners, waterproof agents (materials),
5 expanding agents (materials), hardening accelerators, shrinkage-reducing agents (materials), rust preventives, polymer emulsions for cement admixture, and clay minerals.
[0023]

The inventive hydraulic cement composition for soil
10 injection is applied in a milk form with water added to it. The more the amount of water added, the better the penetration capability becomes, but the more likely material separation is to occur, causing the cement milk to be clogged up in a pumping hose. As the amount of
15 water added is too small, it will cause the viscosity of the cement milk to grow too high for penetration capability. The optimum range of the water used is preferably 400 to 1,500 parts, and more preferably 700 to 1,200 parts, per a total of 100 parts of the fine grained
20 blast-furnace slag, classified cement and polyacrylic acid-based dispersing agent.

[0024]

The inventive soil improvement method may be applied to everywhere as long as it is used for soft ground
25 improvement. For instance, it may be applied just only to grounds having various structures located thereon, typically harbors, river and shore banks, airports, and municipal and mountainous soft grounds but also for the

purpose of cut-off or shield-off grouts, heaving prevention grouts, subsidence prevention grouts, blow prevention grouts, soil pressure-reducing grouts, support power-increasing grouts, suction prevention grouts and the like. Because of having good penetration capability, the inventive hydraulic cement composition may also be applied to sandy grounds containing gravel, and effectively work for prevention of liquefaction as well. [0025]

10 By way of example but not by way of limitation, the inventive execution method may rely upon execution installations used with ordinary chemical grouting and carried out pursuant to ordinary chemical grouting designs and schemes. For instance, there is the mention
15 of a method of pumping cement milk prepared in a mixer via a hose, and injecting it in ground via an underground rod. By way of example but not by way of limitation, the rod used here includes a single-pipe rod, a single-pipe strainer rod, a double-pipe rod, and double-packer mode
20 rod of a double-pipe.

Basically, the inventive hydraulic cement composition for soil injection may be injected in a one-shot mode; however, depending on the state of the ground applied or the purposes, it may be injected in 1.5 shot or 2 shot
25 modes while commercially available setting accelerators or other admixtures are separately pumped.

EXAMPLES

[0026]

The present invention will now be explained more specifically with reference to some examples.

[0027]

Experimental Example 1

5 Fine grained blast-furnace slag, 20 parts of
classified cement per 100 parts of the fine grained
blast-furnace slag, 1 part of the polyacrylic acid-based
dispersing agent per a total of 100 parts of the fine
grained blast-furnace slag and classified cement, and
10 water shown in Table 1 were mixed together for 1 minute
in a grout mixer into a mixture. Then, sodium silicate A
was added in such solid matter amounts as shown in Table
1 to a total 100 parts of the fine grained blast-furnace
slag and classified cement, and mixed for 1 minute in a
15 grout mixer to prepare a grout comprising the inventive
hydraulic cement composition for soil injection.

Shown in Table 1 are the viscosity, compression
strength, penetration capability, outflow (that is an
index to the estimation of the ability to prevent the
20 grout from flowing away) and shape of the grout as well
as the result of water penetration testing for measuring
the diameter of the set mass.

For comparative purposes, in the absence of sodium
silicate A, 20 parts of the classified cement were added
25 to 100 parts of the fine grained blast-furnace slag and
1.0 part of the polyacrylic acid-based dispersing agent
was added to a total of 100 parts of the fine grained
blast-furnace slag and classified cement. Then, 966

parts of water were added to 100 parts of the resulting mixture for a two-minute mixing in a grout mixer, thereby preparing a grout composed of a comparative hydraulic cement composition for soil injection, and similar testing was carried out. The results are also shown in Table 1.

[0028]

Used Materials

Fine grained blast-furnace slag: Commercially available, fine grained blast-furnace slag having a Blaine's value of 10,500 cm²/g and a median diameter of 3.6 μm

Classified cement: Classified cement obtained by classification of normal Portland cement, and having a Blaine's value of 9,700 cm²/g, a median diameter of 4.1 μm and a calcium carbonate content of 11.3%

Polyacrylic acid-based dispersing agent: Commercially available polyacrylic acid-based dispersing agent (based on methoxy polyethylene glycol methacrylate); in General Formula (2), R¹ is a methyl group, R²O is an oxyethylene group having 2 carbon atoms, R³ is a methyl group, and n = 23), with a mass average molecular weight of 42,000 as measured by the GPC method (with a standard substance consisting of a sodium polystyrene sulfonate/water system)

Water: Fresh water

Sodium silicate A: Aqueous solution having a molar ratio n of 3.97 and composed of 23.38% SiO₂ and 6.07% Na₂O with a SiO₂+Na₂O concentration of 29.45%

Potassium silicate: Aqueous solution having a molar ratio of 3.69 and having a SiO_2 concentration of 21.2%, a K_2O concentration of 9.0%, and a $\text{SiO}_2+\text{K}_2\text{O}$ concentration of 30.2%

5 [0029]

Testing Methods

The viscosity was measured with a B-type rotary viscometer just after mixing and at a temperature of 25°C.

For the compression strength, 80 ml of grout were
10 weighed in a form of 100 mm in height, after which 306 g of #5 silica sand were charged in that form. The viscosity was measured at a material age of 28 days.

The penetration capability was measured pursuant to the sample preparation method for soils stabilized by
15 grouting prescribed by JGS0831-2000. Observation was made of how the grout made its way into a model ground at an injection pressure of 0.05 MPa, which model ground was prepared by hydraulically filling #5 silica sand up in an acryl pipe of 50 mm in diameter and 1,000 mm in height.

20 Water Penetration Testing: Outflow, Shape, and Diameter of the Set Mass

The water penetration testing was carried out pursuant to the water penetration testing method for soils prescribed in JGS0311-2000. More exactly, a
25 transparent acryl vessel of $\phi 10 \times 23$ cm was packed with #5 silica sand at a porosity of 40.5% to prepare a model ground. Note here that the acryl vessel for preparing the model ground was provided at its bottom with a filter

out of which water and the grout flowed down. Near the center of the prepared model ground there was a pipe set through which the grout was injected. The thus prepared model ground vessel was immersed as a whole in a tank
 5 filled up with water, and there was a water level difference of 3.5 cm (the hydraulic gradient = 0.152) maintained between the upper end of the model ground vessel and the tank filled up with water. Under such conditions that water was constantly fed for water
 10 replacement, 120 ml of the grout were injected through the pipe to observe how the grout flowed out of the model ground. For the purpose of checking the state of the set grout remaining in the model ground, the model ground vessel was taken apart after a material age of seven days,
 15 and the set mass was removed from within to observe its shape. When the set mass was in a substantially spherical shape, its diameter was found. Note here that when the set of 120 ml of grout was rounded, the diameter of the set mass was 6.1 cm.

20 [0030]

Table 1

Ex. No.	Sodium Silicate	Water	Viscosity (mPa·s)	Compression Strength (N/mm ²)	Penetration
1-1	- 0	966	4	0.5	Full
25 1-2	A 0.2	665	29	1.0	Full
1-3	A 0.5	664	34	1.1	Full
1-4	A 1.0	663	38	1.4	Full
1-5	A 1.5	962	33	0.7	Full

	1-6	A 3.0	957	42	0.6	Full
	1-7	A 4.5	954	45	0.6	Full
	1-8	A 7.0	947	52	0.6	Full
	1-9	A 8.0	944	5	0.4	760mm
5	1-10	* 1.5	962	35	0.8	Full

In the "penetration" column, the full means full penetration, and the shape of Experiment No. 1-9 is amorphous due to no penetration of the grout, and * in Experiment No. 1-10 shows that potassium silicate is used instead of sodium silicate.

10

Table 1(continued)

Ex.	Outflow	Shape	Diameter of the	Remarks
No.	Set Mass (Length×Width cm)			
15	1-1 Outflow after 5 min.	No trace of of the set mass	-	Comparative
	1-2 No outflow	Substantial sphere	6.1×5.8	Inventive
	1-3 No outflow	Sphere	6.0×5.9	Inventive
	1-4 No outflow	Sphere	5.9×6.0	Inventive
	1-5 No outflow	Substantial sphere	5.8×6.1	Inventive
20	1-6 No outflow	Substantial sphere	6.0×5.8	Inventive
	1-7 No outflow	Substantial sphere	6.0×5.8	Inventive
	1-8 No outflow	Substantial sphere	6.1×5.8	Inventive
	1-9 Outflow after 10 min.	Amorphous	Immeasurable	Comparative
25	1-10 No outflow	Substantial sphere	5.8×6.1	Inventive

[0031]

As can be seen from Table 1, the viscosity just after

mixing was 29 to 52 mPa·s in Experiment Nos. 1-2 to 1-8 wherein the amount of sodium silicate was 0.2 to 7 parts. On the other hand, the viscosity was 4 mPa·s in Experiment No. 1-1 free from sodium silicate, and 5 mPa·s in Experiment No. 1-9 using 8 parts of sodium silicate, both lower than the figures obtained in the inventive examples.

The compression strength was 0.6 to 1.4 N/mm² in Experiment Nos. 1-2 to 1-8. On the other hand, the compression strength was 0.5 N/mm² in Experiment No. 1-1 (comparative), and 0.4 N/mm² in Experiment No. 1-9 (comparative).

Referring to the penetration capability, the grout penetrated full down the 1,000 mm-height acryl pipe in Experiment Nos. 1-2 to 1-8 (inventive) and Experiment No. 1-1 (comparative). In Experiment No. 1-9 (comparative), on the other hand, the grout did not penetrate full down: it penetrated just 760 mm.

[0032]

In Experiment No. 1-9 (comparative) wherein the sodium silicate content was 8 parts, more than 0.2 to 7 parts, per a total of 100 parts of the fine grained blast-furnace slag and classified cement, the penetration capability and compression strength were somewhat lower than those obtained in Experiment No. 1-5, and in the water penetration testing, the grout flowed out of the acryl pipe only 10 minutes after injection: an amorphous set mass was found due to no uniform penetration of the

grout.

In Experiment No. 1-1 (comparative) free from sodium silicate, the penetration capability was similar to that of Experiment No. 1-5, but the compression strength was
5 somewhat lower. In the water penetration testing, the grout flowed out of the acryl pipe 5 minutes after injection, leaving no trace of the set mass: there was no effect on soil improvement (reinforcement) at all.

[0033]

10 Experimental Example 2

Experimental Example 1 was repeated with the exception that the sodium silicates shown in Table 2 were used in an amount of 1.5 parts as calculated on a solid basis per a total of 100 parts of the fine grained blast-
15 furnace slag and classified cement. The results are shown in Table 2.

[0034]

Used Materials

Sodium silicate B: Aqueous solution having a molar ratio
20 n of 4.96, a SiO_2 concentration of 19.56% and a Na_2O concentration of 4.07% with a $\text{SiO}_2+\text{Na}_2\text{O}$ concentration of 23.63%

Sodium silicate C: Aqueous solution having a molar ratio
n of 3.74, a SiO_2 concentration of 24.00% and a Na_2O
25 concentration of 6.62% with a $\text{SiO}_2+\text{Na}_2\text{O}$ concentration of 30.62%

Sodium silicate D: Aqueous solution having a molar ratio
n of 3.5, a SiO_2 concentration of 25.61% and a Na_2O

concentration of 7.55% with a $\text{SiO}_2+\text{Na}_2\text{O}$ concentration of 33.16%

Sodium silicate E: Aqueous solution having a molar ratio n of 3.16, a SiO_2 concentration of 28.84% and a Na_2O

5 concentration of 9.43% with a $\text{SiO}_2+\text{Na}_2\text{O}$ concentration of 38.27%

[0035]

Table 2

10	Ex. Sodium Silicate		Water Viscosity		Compression Penetration	
	No.	Type Molar Ratio	(mPa·s)	Strength (N/mm ²)		
	2-1	E 3.16	963	8	0.4	Full
	2-2	D 3.5	922	25	0.5	Full
	2-3	C 3.74	962	28	0.6	Full
	1-5	A 3.97	962	33	0.7	Full
15	2-4	B 4.96	960	41	0.8	Full

Table 2(continued)

20	Ex. Outflow		Shape	Diameter of the		Remarks
	No.			Set Mass (Length×Width cm)		
	2-1	Outflow	Amorphous	Immeasurable		Comparative
		after 10 min.				
	2-2	No outflow	Substantial sphere	5.6×6.0		Inventive
	2-3	No outflow	Substantial sphere	5.7×5.9		Inventive
	1-5	No outflow	Substantial sphere	5.8×6.1		Inventive
25	2-4	No outflow	Substantial sphere	5.7×6.2		Inventive

[0036]

From Table 2, it has been found that the grouts of

Experiment Nos. 1-5 and 2-2 to 2-4 wherein the alkali metal silicate salts are used in an amount of 1.5 parts as calculated on a solid basis per a total of 100 parts of the fine grained blast-furnace slag and classified
5 cement have a viscosity of as high as 25 to 41 mPa·s just after mixing and a compression strength of as high as 0.5 to 0.8 N/mm² at a material age of 28 days; so they are improved in terms of penetration capability, and there is no outflow of the grouts in the water penetration testing
10 wherein the hydraulic gradient was relatively tightly set, with the set mass kept in a substantially spherical shape, indicating that the grouts are improved in terms of the ability to prevent them from flowing away.

In Experiment No. 2-1 wherein the molar ratio n of
15 sodium silicate was 3.16 less than 3.5, the penetration capability was similar to that in Experiment No. 1-5, but the compression strength was somewhat lower, and the grout flowed out of the acryl pipe 10 minutes after injection in the water penetration testing, resulting in
20 an amorphous set mass.

[0037]

Experimental Example 3

Experimental Example 2 was repeated with the exception that sodium silicate A was used in an amount of
25 1.5 parts as calculated on a solid basis per a total of 100 parts of the fine grained blast-furnace slag and classified cement, and the polyacrylic acid-based dispersing agent shown in Table 3 was used. The results

are shown in Table 3.

[0038]

Table 3

Ex. Polyacrylic Acid- Water Viscosity Compression Penetration						
5	No.	Dispersing Agent	(mPa·s)	Strength (N/mm ²)		
	3-1	0.0	962	63	0.7	500 mm
	3-2	0.1	962	58	0.7	900 mm
	3-3	0.3	962	45	0.7	Full
	1-5	1	962	33	0.7	Full
10	3-4	2	962	28	0.5	Full
	3-5	3	962	26	0.4	Full

Table 3 (continued)

	Ex.	Outflow	Shape	Diameter of the	Remarks
15	No.	Set Mass (Length×Width cm)			
	3-1	No outflow	Sphere	5.0×5.0	Comparative
	3-2	No outflow	Sphere	5.1×5.2	Inventive
	3-3	No outflow	Sphere	5.5×5.7	Inventive
	1-5	No outflow	Substantial Sphere	5.8×6.1	Inventive
20	3-4	No outflow	Substantial Sphere	6.2×5.9	Inventive
	3-5	A little	Substantial Sphere	6.3×5.7	Inventive

[0039]

With the grout of Experiment No. 3-1 wherein no polyacrylic acid-based dispersing agent was used, there was no outflow of the grout in the water penetration testing, but there was barely 500 mm penetration in the penetration testing.

[0040]

Experimental Example 4

Experimental Example 2 was repeated with the exception that sodium silicate A was used in an amount of 1.5 parts as calculated on a solid basis per a total of 100 parts of the fine grained blast-furnace slag and classified cement, and the fine grained blast-furnace slag and classified cement shown in Table 4 were used. The results are shown in Table 4.

[0041]

10

Table 4

Ex. Fine Grained Blast-Furnace Slag		Classified Cement	
No.	Blaine's Value	Median Diameter	Blaine's Value Median Diameter
4-1	7,300	6.3	9,700 4.1
1-5	10,500	3.6	9,700 4.1
4-2	15,700	1.3	9,700 4.1
4-3	10,500	3.6	7,500 6.8
4-4	10,500	3.6	15,500 1.6

15

Table 4 (continued)

Ex. No.	Water	Viscosity	Compression Strength	Penetration
		(mPa·s)	(N/mm ²)	
4-1	962	29	0.5	900 mm
1-5	962	33	0.7	Full
4-2	962	38	0.8	Full
4-3	962	32	0.6	Full
4-4	962	35	0.7	Full

25

Table 4 (continued)

Ex. No.	Outflow	Shape	Diameter of the	Remarks
			Set Mass (Length×Width cm)	
4-1	No outflow	Substantial Sphere	5.7×6.0	Inventive
5 1-5	No outflow	Substantial Sphere	5.8×6.1	Inventive
4-2	No outflow	Substantial Sphere	6.1×5.9	Inventive
4-3	No outflow	Substantial Sphere	5.7×6.1	Inventive
4-4	No outflow	Substantial Sphere	5.8×6.1	Inventive

10 [0042]

The grout obtained using the fine grained blast-furnace slag having a Blaine's value of 7,300 cm²/g and a median diameter of 6.3 μm and the classified cement having a Blaine's value of 9,700 cm²/g and a median diameter of 4.1 μm penetrated 900 mm: there was no full penetration achievable.

[0043]

Experimental Example 5

Experimental Example 2 was repeated with the exception that sodium silicate A was used in an amount of 1.5 parts as calculated on a solid basis per a total of 100 parts of the fine grained blast-furnace slag and classified cement, and the classified cement was used in such amounts as shown in Table 5 per 100 parts of the fine grained blast-furnace slag. The results are shown in Table 5.

[0044]

Table 5

Ex.	Classified	Water	Viscosity	Compression	Permeation	
No.	Cement		(mPa·s)	Strength (N/mm ²)		
	5-1	0	962	5	0	Full
5	5-2	5	962	12	0.4	Full
	5-3	10	962	28	0.5	Full
	1-5	20	962	33	0.7	Full
	5-4	25	962	35	0.8	Full
	5-5	30	962	38	1.0	900 mm

10 The parts of the classified cement were per 100 parts of the fine grained blast-furnace slag.

Table 5(continued)

	Ex.	Outflow	Shape	Diameter of the	Remarks
15	No.	Set Mass (Length×Width cm)			
	5-1	Outflow	No trace of	Immeasurable	Comparative
		after 5 min.	the set mass		
	5-2	A little	Substantial sphere	6.3×5.6	Inventive
	5-3	No outflow	Substantial sphere	6.1×6.0	Inventive
20	1-5	No outflow	Substantial sphere	5.8×6.1	Inventive
	5-4	No outflow	Substantial sphere	5.8×6.2	Inventive
	5-5	No outflow	Substantial sphere	5.8×6.1	Inventive

[0045]

Referring to Experiment No. 5-1 using none of the
 25 classified cement, the grout penetrated full down the
 acryl pipe in the penetration testing, but in the water
 penetration testing, the grout flowed out of the acryl
 pipe 5 minutes after injection, leaving no trace of any

set mass, indicating that there is no effect on ground improvement (reinforcement) at all.

[0046]

From the aforesaid results, it has been found that
5 the inventive hydraulic cement composition for soil
injection - which contains fine grained blast-furnace
slag, classified cement, a polyacrylic acid-based
dispersing agent and an alkali metal silicate salt acting
as an agent for preventing a grout from flowing away,
10 wherein the alkaline metal silicate salt is used in a
molar rate n of at least 3.5 in General Formula (1), and
in an amount of 0.2 to 7 parts per a total of 100 parts
of the blast-furnace slag and classified cement - is
improved in terms of penetration capability and the
15 ability to prevent grouts from flowing away, and
contributes more to sufficient strength and long-term
durability.

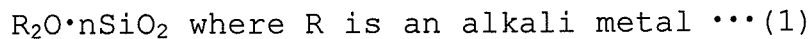
APPLICABILITY TO THE INDUSTRY

20 [0047]

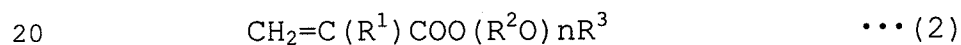
Being improved in terms of penetration capability and
the ability to prevent grouts from flowing away, and
contributing more to sufficient strength and long-term
durability, the inventive hydraulic cement composition
25 for soil injection could be applied to reinforcement
construction for a variety of soft soils such as
prevention of liquefaction of sandy soils at harbors,
coastal areas, and so on.

WHAT IS CLAIMED IS:

1. A hydraulic cement composition for soil injection, characterized by containing fine grained blast-furnace slag, classified cement, a polyacrylic acid-based dispersing agent and an alkali metal silicate salt acting as an agent for preventing a grout from flowing away, wherein the alkaline metal silicate salt is used in a molar rate n of at least 3.5 in the following general formula (1), and in an amount of 0.2 to 7 parts per a total of 100 parts of the fine grained blast-furnace slag and classified cement:



2. A hydraulic cement composition for soil injection as recited in claim 1, characterized in that the polyacrylic acid-based dispersing agent is a copolymer that contains a monomer represented by the following general formula (2):



where R^1 is a hydrogen atom or a methyl group, R^2O is an oxyalkylene group having 2 to 4 carbon atoms, n is an integer of 5 to 40, and R^3 is a hydrogen atom or an alkyl group having 1 to 5 carbon atoms.

25

3. A hydraulic cement composition for soil injection as recited in claim 1, characterized in that the fine grained blast-furnace slag and the classified cement have

each a Blaine's specific surface area value of 7,000 to 16,000 cm²/g and a median diameter of 1 to 7 μ m.

4. A soil improvement method in which a hydraulic
5 cement composition for soil injection as recited in any
one of claims 1, 2 and 3 is injected in ground.

5. A soil improvement method as recited in claim 4,
characterized by being used for soil improvement intended
10 to prevent liquefaction.