

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 grouting method wherein a settable grout is injected in
ground via a rod for the purpose of making soft soil
firmer, and numerous grouts have hitherto been known in
the art. For instance, there is the mention of water
glass-based grouts, special silica-based grouts,
20 polymeric grouts, and suspension grouts such as cements,
clays, and slag. The grouting method using such chemical
compounds has been much field proved because of some
merits of making improvements without disturbing the
ground as much as possible unlike a jet grouting or
25 other similar method in which the ground is disturbed by
high-pressure jets, and using compact installation. The
grouts are generally broken down a solution type and a
suspension type, and the solution type is often 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 long-stand durability problem, 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 durability over an extended period; however, they have had a low penetration problem. Another problem with the suspension grout has been that it contains particles, and immediately at rest, the particles settle down, giving rise to a trouble such as clogging of injection hoses during implementation.

[0003]

Among the suspension grouts known so far in the art, there is a grout composition that comprises fine grained cement clinker and blast-furnace slag to which a polycarboxylic acid-based dispersing agent is added as an essential ingredient (for instance, see Patent Publications 1, 2 and 3). These publications disclose providing a grout composition having penetration capability enhanced by the addition of a specific polycarboxylic acid to it; however, they say nothing about calcium carbonate being contained in the cement and its content, and about the ability to prevent particles from settling down when the grout composition is at rest, nor

do they give any example about durability.

[0004]

For grouts having gelling time, on the other hand, grouts containing water glass, a solidifier and fine
5 grained blast-furnace slag having a Blaine's 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).

[0005]

10 Patent Publication 4 teaches that the combined use of fine grained slag gives a set mass having high gel strength in dozens of seconds to a few minutes, but what is estimated is only strength, and much water glass is contained in it; that is, the composition is composed
15 primarily of water glass. In addition, it is quite silent about the ability to prevent particles from settling down, and penetration capability.

[0006]

Patent Publication 5 is all about the grout
20 comprising 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 specific surface area 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 particles from settling down.

[0007]

What is disclosed in Patent Publication 6 is characterized by comprising a suspension grout containing a mixture of fine grained slag and fine
5 grained cement, wherein the slag and cement have each an average particle diameter of up to 10 μm and a specific surface area 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
10 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 the set mass is estimated in terms of compression strength alone.

[0008]

15 What is set forth in Patent Publication 7 is a suspension type soil improver, characterized by containing water, fine grained, water granulated slag, an alkali stimulator, a dispersing agent, and a polymeric substance that is dissolved or dispersed in
20 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 mass, so one has no understanding
25 of how much the soil is reinforced upon injection and setting.

LISTING OF THE PRIOR ART

PATENT PUBLICATIONS

[0009]

Patent Publication 1: JP(A) 2007-238428

Patent Publication 2: JP(A) 2007-238925

5 Patent Publication 3: JP(A) 2004-175989

Patent Publication 4: JP(A) 02-167848

Patent Publication 5: JP(A) 07-229137

Patent Publication 6: JP(A) 07-286173

Patent Publication 7: JP(A) 2005-344078

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SUMMARY OF THE INVENTION

OBJECTS OF THE INVENTION

[0010]

15 The primary object of the invention is to provide a
hydraulic cement composition for soil injection, which,
upon mixed with water into a suspension or cement milk,
grows high in terms of resistance to settling down of
particles, makes it unlikely for grout ingredients to
flow away even under running water, and is improved in
20 terms of penetration capability and durability, and a
soil improvement method using the same.

MEANS FOR ACCOMPLISHING THE OBJETS

[0011]

25 According to the present invention, the aforesaid
object is accomplishable by the following aspects 1 to 7.

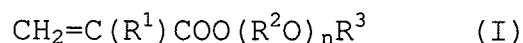
Aspect 1 of the invention provides a hydraulic cement
composition for soil injection, characterized by

comprising 100 parts of fine grained blast-furnace slag having a Blaine's specific surface area of 7,000 to 16,000 cm²/g and a median diameter of 1 to 7 μm, 5 to 30 parts of classified cement capable of satisfying all the following conditions (1), (2) and (3) per 100 parts of the fine grained blast-furnace slag, and 0.1 to 3 parts of a dispersing agent containing a polyacrylic acid-based dispersing agent per a total of 100 parts of the fine grained blast-furnace slag and classified cement:

- (1) classified cement, characterized by containing 6 to 20 parts of calcium carbonate in 100 parts thereof,
- (2) classified cement, characterized by having a Blaine's specific surface area of 7,000 to 16,000 cm²/g, and
- (3) classified cement, characterized by having a median diameter of 1 to 7 μm.

Aspect 2 of the invention provides a hydraulic cement composition for soil injection as recited in Aspect 1, characterized in that the dispersing agent further contains a melamine-based dispersing agent.

Aspect 3 of the invention provides a hydraulic cement composition for soil injection as recited in Aspect 1 or 2, characterized in that the polyacrylic acid-based dispersing agent is a copolymer containing a monomer represented by the following general formula (I):



where R¹ is a hydrogen atom or a methyl group, R²O is an

oxyalkylene group having 2 to 4 carbon atoms, n is an integer of 5 to 40, and R³ is a hydrogen atom or an alkyl group having 1 to 5 carbon atoms.

Aspect 4 of the invention provides a cement milk,
5 characterized in that water is added to and mixed with a hydraulic cement composition for soil injection as recited in any one of Aspects 1, 2 and 3.

Aspect 5 of the invention provides a cement milk as recited in Aspect 4, characterized in that the cement
10 milk obtained by adding and mixing water to and with the hydraulic cement composition for soil injection has a bleeding rate of up to 2% after at rest for 60 minutes.

Aspect 6 of the invention provides a soil improvement method in which a cement milk as recited in Aspect 4 or
15 5 is injected in ground.

Aspect 7 of the invention provides a soil improvement method as recited in Aspect 6, characterized by being used for soil improvement intended to prevent liquefaction.

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

ADVANTAGES OF THE INVENTION

[0012]

25 The hydraulic cement composition for soil injection according to the invention is improved in terms of penetration capability, and is effective for soil improvement, and so on.

MODE FOR CARRYING OUT THE INVENTION

[0013]

The fine grained blast-furnace slag used herein has a Blaine's specific surface area of 7,000 to 16,000 cm²/g and a median diameter of 1 to 7 μm, and is produced by pulverizing steel slag occurring during pig iron production. This slag is now used as an admixture for general blast-furnace cement or concrete. As measured with a Blaine's air permeation apparatus pursuant to JIS R5201, the Blaine's specific surface area should be between 7,000 and 16,000 cm²/g.

As the Blaine's specific surface area of the fine grained blast-furnace slag is less than 7,000 cm²/g, it will cause the bleeding rate to grow high, often resulting in the inability to obtain good enough penetration capability. Exceeding 16,000 cm²/g will be impractical because of incurring too much production cost.

Preferably, the fine grained blast-furnace slag should have a median diameter of 1 to 7 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 more than 7 μm will cause the bleeding rate to grow high, possibly having an adverse influence on penetration capability.

[0014]

The classified cement used herein is regulated in terms of particle sizes with classification equipment. The classified cement contains 6 to 20 parts, preferably 10 to 15 parts of calcium carbonate per 100 parts.

5 If the classified cement contains 6 to 20 parts of calcium carbonate per 100 parts, it is then possible to achieve properties such as the ability to prevent particles from settling down and penetration capability which would apparently be incompatible. At less than 6
10 parts, the sufficient ability to prevent particles from settling down is not achievable, and at greater than 20 parts, viscosity grows high but strength gets low.

 The calcium carbonate contained in the classified cement is of increased reactivity because of being in
15 the form of fine particles through classification. Usually, calcium carbonate is used as a part of sand for the production of cement fillers and concretes. That calcium carbonate is finer than ordinarily used calcium carbonate (fine grained limestone) having a fineness of
20 4,000 to 6,000 cm^2/g ; so it is higher in reactivity, possibly resulting in an increased strength. That calcium carbonate also reacts with calcium aluminate ($3\text{CaO}\cdot\text{Al}_2\text{O}_3$), yielding a mono- or hemi-carbonate. Gypsum reacts with calcium carbonate contained in cement too,
25 yielding ettringite. In the presence of a specific amount of calcium carbonate, the mono-carbonate reaction or the hemi-carbonate reaction prevails so that the reaction of turning the ensuing ettringite into a mono-

sulfate is held back, possibly making it easy to ensure durability.

[0015]

For the classified cement, use may be made of any of
5 Portland cements such as normal Portland cement, early-
strength Portland cement, low-heat Portland cement,
moderate-heat Portland cement, and sulfate-resisting
cement, and any cement may be used if it meets condition
(1) or (2) recited in Aspect 1 of the invention upon
10 classification. 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.

As is the case with the fine grained blast-furnace
slag, the classified cement should have a fineness of
15 7,000 to 16,000 cm^2/g or, preferably, 9,000 to 16,000
 cm^2/g . A fineness of less than 7,000 cm^2/g will cause
the bleeding rate to grow high, often resulting in the
inability to obtain good enough permeation capability,
and a fineness of greater than 16,000 cm^2/g will be
20 impractical because of incurring too much production
cost.

Preferably, the classified cement should have a
median diameter of 1 to 7 μm . For instance, the median
diameter may be measured with a laser diffraction type
25 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 cause the bleeding

rate to grow high, possibly having an adverse influence on penetration capability.

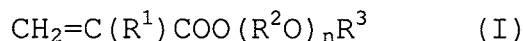
[0016]

The classified cement should be used in an amount of 5 to 30 parts or, preferably 10 to 25 parts, per 100 parts of the fine grained blast-furnace slag. In an amount of less than 5 parts by weight, it will often be unable to contribute to good enough strength, and in an amount of greater than 30 parts by weight, it may have an adverse influence on penetration capability.

[0017]

According to the invention, the dispersing agent contains a polyacrylic acid-based dispersing agent.

The polyacrylic acid-based dispersing agent used herein has a combined effect on preventing particles from settling down in a suspension and imparting penetration capability to the inventive hydraulic cement composition for soil injection. That dispersing agent is characterized by being a copolymer containing a monomer represented by the following general formula (I):



In Formula (I), 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 $-\text{CH}_2\text{CH}_2\text{O}-$, $-\text{CH}_2\text{CH}_2\text{CH}_2\text{O}-$, $-\text{CH}_2\text{CH}(\text{CH}_3)\text{O}-$, $-\text{CH}_2\text{CH}(\text{CH}_2\text{CH}_3)\text{O}-$, and $-\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{O}-$; and n is an integer of 5 to 40 indicative of the number of added moles of the oxyalkylene group or, preferably 7 to 35, and more preferably 9 to 30. As the number of added

moles (n) gets too small, the dispersing power gets insufficient, whereas it gets too large, there will be a difficult-to-handle solid having a high melting point.

R^3 stands for a hydrogen atom or an alkyl group
5 having 1 to 5 carbon atoms such as a methyl, ethyl, propyl or butyl group.

Exemplary monomers, for instance, include polyethylene glycol mono(meth)acrylate, polypropylene glycol mono(meth)acrylate, polybutylene glycol
10 mono(meth)acrylate, methoxy polyethylene glycol (meth)acrylate, methoxy polypropylene glycol (meth)acrylate, methoxy polybutylene glycol (meth)acrylate, ethoxy polyethylene glycol (meth)acrylate, ethoxy polypropylene glycol
15 (meth)acrylate, ethoxy polybutylene glycol (meth)acrylate, and propoxy polyethylene glycol (meth)acrylate, wherein the number of 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
20 the monomer represented by General Formula (I) is contained, use may be made of a copolymer combined with a monomer component having another chemical structure.

Among these, preference is given to a copolymer including methoxy polyethylene glycol (meth)acrylate,
25 and methoxy polypropylene glycol (meth)acrylate in view of the ability to prevent particles from settling down, and penetration capability.

[0018]

In addition to the polyacrylic acid-based dispersing agent, the dispersing agent used herein may contain a melamine-based dispersing agent.

The melamine-based dispersing agent here, for
5 instance, includes a dispersing agent obtained by
sulfonating melamine with a sulfite and formaldehyde,
followed by condensation with formaldehyde. For this,
use may also be made of alkaline metal salts such as
sodium and potassium salts, and alkaline earth salts
10 such as calcium and magnesium salts of melamine
sulfonate-formaldehyde condensates.

The melamine-based dispersing agent of the invention
is used in combination with the polyacrylic acid-based
dispersing agent. In that combined use, the melamine-
15 based dispersing agent is used in an amount of
preferably 10 to 1,000 parts, and more preferably 30 to
600 parts per 100 parts of the polyacrylic acid-based
dispersing agent. In less than 10 parts, there will
often be no effect on synergistic improvements in the
20 ability to prevent particles from settling down, and in
greater than 1,000 parts, there will often be an adverse
effect on the ability to prevent particles from settling
down.

It has now been found that as the polyacrylic acid-
25 based dispersing agent is used in combination with the
melamine-based dispersing agent, it allows the effect on
decreasing the bleeding rate to grow higher from just
after mixing than could be achieved with the sole use of

the polyacrylic acid-based dispersing agent. Accordingly, the dispersibility of particles will be improved over an extended period of time. This will in turn improve the penetration capability of particles through a model

5 ground so that the hydraulic particles will be uniformly dispersed within the ground, making it firmer and more uniform.

[0019]

The dispersing agents are used in an amount of 0.1 to
10 3 parts, and preferably 0.3 to 2 parts per a total of 100 parts of the fine grained blast-furnace slag and classified cement. In less than 0.1 part, there will be neither sufficient ability to prevent particles from settling down nor good enough penetration capability,
15 and in greater than 3 parts, their effect will reach a ceiling.

[0020]

It is here to be noted that inventive hydraulic cement composition for soil injection may be used in
20 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-
25 reducing agents, fluidizers, retarders, early-strength agents, thickeners, waterproof agents (materials), expanding agents (materials), hardening accelerators, shrinkage-reducing agents (materials), rust preventives,

polymer emulsions for cement admixture, and clay minerals.

[0021]

The inventive hydraulic cement composition for soil
5 injection is applied in a milk form with water added to
it. The more the amount of water added, the better the
penetration capability gets, but material separation is
likely to occur, causing the materials to be clogged up
in a pumping hose. As the amount of water added is too
10 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 blast-furnace slag,
15 classified cement and dispersing agent(s). As long as
the amount of water used falls in the aforesaid range,
it is possible to reduce the bleeding rate of the cement
milk after 60 minutes down to 2% or less by the JSCE F-
522 method. As the bleeding rate exceeds 2%, there will
20 be the likelihood of clogging when the pumping of the
grout is shut down for 60 minutes or longer and then
resumed.

Referring here to the time of adding and mixing water
to and with the inventive hydraulic cement composition
25 for soil injection, mixing may be carried out for 1 to 3
minutes after the inventive hydraulic cement composition
for soil impregnation is charged in a grout mixer with a
given amount of water added to it, although the

invention is not limited thereto.

[0022]

The inventive hydraulic cement composition may be applied to everywhere as long as it is used for
5 improving soft grounds. 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,
10 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 permeability, the inventive hydraulic cement composition may also be
15 applied to sandy grounds containing gravel, and effectively work for prevention of liquefaction as well.

[0023]

By way of example but not by way of limitation, the inventive execution method may rely upon execution
20 installations used with ordinary grouts, and carried out pursuant to ordinary grout designs and schemes. For instance, there is the mention 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
25 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 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 modes while commercially available setting accelerators or other admixtures are separately pumped.

Example 1

[0024]

Classified cement was used in such varied amounts as shown in Table 1 per 100 parts of fine grained blast-furnace slag, and 1.0 part of such dispersing agents as shown in Table 1 was added to a total of 100 parts of the fine grained blast-furnace slag and classified cement to prepare hydraulic cement compositions for soil injection. Water was added to each hydraulic cement composition in an amount of 850 parts per 100 parts of the cement composition, and mixing was carried out for 2 minutes in a grout mixer. The obtained cement milks were measured in terms of viscosity, bleeding rate, penetration capability and compression strength. The results are summed up in Table 1.

[0025]

Used Materials

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

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

Dispersing Agent A: Commercially available polyacrylic acid-based dispersing agent (based on methoxy polyethylene glycol methacrylate); in General Formula (I), R¹ is a methyl group, R²O is an oxyethylene group having 2 carbon atoms, and R³ is a methyl group

Dispersing Agent B: Dispersing agent in which 300 parts of a melamine-based dispersing agent made by Sika Ltd. were blended with 100 parts of Dispersing Agent A [0026]

15 Measuring Methods

The viscosity was measured with a B-type rotary viscometer. More specifically, the viscosity was measured just after mixing, and 3 hours and 6 hours after mixing at a temperature of 25°C.

20 The bleeding rate was measured pursuant to JSCE-F522-1999 - Bleeding rate/expansion coefficient testing method for the injected mortar of pre-packed concrete (Polyethylene bag method). Measurements were obtained after 0.5 hour, 1 hour and 2 hours at a temperature of 25°C.

25 The penetration capability was measured pursuant to a sample preparation method for soils stabilized by grouting prescribed by JGS0831-2000. Observation was

made of how cement milk was injected and penetrated at an injection pressure of 0.05 MPa into a model ground in which Toyoura sand was hydraulically filled in an acryl pipe of 50 mm in diameter and 1,000 mm in height.

5 For the compression strength, the acryl pipe subjected to the penetration testing was cut to a height of 100 mm, and the set sand gel was removed from within the acryl pipe to measure its compression strength at a material age of 28 days.

10 [0027]

Table 1

	Ex. No.	Dispersing Agent	Classified Cement e (parts)	Viscosity (mPa·s)		
				0hr*	3hr	6hr
15	1-1	-	0	2.0	2.0	2.0
	1-2	A	5	2.0	2.0	2.0
	1-3	A	10	2.0	2.0	2.5
	1-4	A	15	2.0	2.2	3.0
	1-5	A	25	2.0	2.5	3.6
	1-6	A	30	2.0	2.8	4.5
20	1-7	B	5	1.8	2.0	2.1
	1-8	B	10	1.8	2.0	2.1
	1-9	B	15	1.9	2.1	2.4
	1-10	B	25	2.0	2.2	2.7
	1-11	B	30	2.0	2.4	3.5

25 The parts in the "classified cement" column is per 100 parts of the fine grained blast-furnace slag.

0hr*: just after mixing

Table 1 (continued)

	Ex.	Bleeding (%)			Penetration	Compression	Remarks
	No.	0.5h	1h	2h			
5	1-1	0.3	1.6	2.4	Full	-	Comparative
	1-2	0.3	1.4	2.6	Full	0.3	Inventive
	1-3	0.3	1.5	2.5	Full	0.6	Inventive
	1-4	0.4	1.5	2.4	Full	0.9	Inventive
	1-5	0.4	1.7	2.5	Full	1.1	Inventive
	1-6	0.6	1.7	2.7	Full	1.5	Inventive
10	1-7	0	0	0.5	Full	1.0	Inventive
	1-8	0	0	0.6	Full	1.4	Inventive
	1-9	0	0.3	0.9	Full	1.6	Inventive
	1-10	0	0.7	1.4	Full	2.0	Inventive
	1-11	0	1.0	1.8	Full	2.4	Inventive
15	Full: full penetration						
	[0028]						

From Table 1, it is found that if a specific amount of the classified cement is blended with the fine grained blast-furnace slag of the invention and the polyacrylic acid-based dispersing agent is used in combination with them, it is then possible to produce a grout cement milk having a low bleeding rate, and that the sand gel after penetration produces good enough compression strength too. In particular, it is found that the use of Dispersing Agent B containing both polyacrylic acid-based dispersing agent and the melamine-based dispersing agent contributes more to a further decrease in the bleeding rate, and a more

increased strength.

Example 2

[0029]

Fifteen (15) parts of classified cements varying
5 Blaine's specific surface area were blended with 100
parts of fine grained blast-furnace slag varying in
Blaine's specific surface area, and 1.0 part of
Dispersing Agent A was added to a total of 100 parts of
the fine grained blast-furnace slag and classified
10 cement to prepare hydraulic cement compositions for soil
injection. Water was added to each hydraulic cement
composition for soil injection in an amount of 850 parts
per 100 parts of the cement composition, and mixing was
carried out for 2 minutes in a grout mixer. The obtained
15 cement milks were measured in terms of viscosity,
bleeding rate, penetration capability and compression
strength. The results are summed up in Table 2.

[0030]

Used Materials

20 Fine grained blast-furnace slag b: having a Blaine's
specific surface area of 6,100 cm²/g and a median
diameter of 7.4 μm

Fine grained blast-furnace slag c: having a Blaine's
specific surface area of 8,200 cm²/g and a median
25 diameter of 4.8 μm

Fine grained blast-furnace slag d: having a Blaine's
specific surface area of 15,500 cm²/g and a median
diameter of 1.6 μm

Classified cement f: Classified cement obtained by classification of a mixture of normal Portland cement and calcium carbonate, and having a Blaine's specific surface area of 6,050 cm²/g, a median diameter of 8.6 μm and a calcium carbonate content of 9.9%

Classified cement g: Classified cement obtained by classification of a mixture of normal Portland cement and calcium carbonate, and having a Blaine's specific surface area of 8,300 cm²/g, a median diameter of 6.1 μm and a calcium carbonate content of 9.5%

Classified cement h: Classified cement obtained by classification of a mixture of normal Portland cement and calcium carbonate, and having a Blaine's specific surface area of 15,800 cm²/g, a median diameter of 2.5 μm and a calcium carbonate content of 13.2%.

[0031]

Table 2

Ex. No.	Fine Grained Blast-Furnace Slag	Classified Cement	Viscosity (mPa·s)		
			0hr*	3hr	6hr
20	2-1	b	f	1.8	2.0 2.4
	2-2	b	g	2.0	2.3 2.6
	2-3	b	e	2.0	2.4 2.9
	2-4	b	g	2.2	2.8 3.5
	2-5	c	f	1.9	2.2 2.5
25	2-6	a	f	2.0	2.4 2.8
	2-7	d	f	2.1	2.5 2.9
	1-4	a	e	2.0	2.2 3.0
	2-8	a	g	2.0	2.1 2.4

	2-9	a	h	2.2	2.6	3.7
	2-10	c	e	1.9	2.0	2.4
	2-11	c	g	1.8	2.0	2.5
	2-12	c	h	2.2	2.4	3.5
5	2-13	d	e	2.3	2.7	3.6
	2-14	d	g	2.4	3.0	3.9
	2-15	d	h	2.6	3.5	4.7

0hr*: Just after mixing

10

Table 2 (continued)

	Ex. No.	Bleeding (%)			Penetration	Compression Strength (N/mm ²)	Remarks
		0.5h	1h	2h			
	2-1	1.5	3.1	7.9	45 cm	0.3	Comparative
	2-2	1.4	3.0	7.5	62 cm	0.3	Comparative
15	2-3	1.3	2.8	7.2	72 cm	0.4	Comparative
	2-4	0.5	2.2	6.2	82 cm	0.5	Comparative
	2-5	1.6	3.1	8.2	76 cm	0.4	Comparative
	2-6	1.5	2.7	7.7	85 cm	0.5	Comparative
	2-7	0.6	2.2	7.0	93 cm	0.6	Comparative
20	1-4	0.4	1.5	2.4	Full	0.9	Inventive
	2-8	0.4	1.7	2.5	Full	0.8	Inventive
	2-9	0.2	0.9	2.1	Full	1.0	Inventive
	2-10	0.3	1.6	2.9	Full	0.8	Inventive
	2-11	0.4	1.7	3.1	Full	0.8	Inventive
25	2-12	0.2	0.7	1.7	Full	0.9	Inventive
	2-13	0.3	0.8	1.9	Full	0.9	Inventive
	2-14	0.3	0.8	1.6	Full	1.0	Inventive
	2-15	0.2	0.7	1.2	Full	1.2	Inventive

[0032]

From Table 2, it is found that by use of the fine grained blast-furnace slags and classified cements, each having a Blaine's specific surface area of at least
5 7,000 cm^2/g and a median diameter of up to 7 μm , lower bleeding rates are obtained together with good enough penetration capability and compression strength. As the fine grained blast-furnace slag and/or the classified cement have a Blaine's specific surface area of less
10 than 7,000 cm^2/g or a median diameter of more than 7 μm , it causes the bleeding rate to grow large, the penetration capability to go worse, and the compression strength to get low.

Example 3

15 [0033]

Classified cements varying in the content of calcium carbonate were added to 100 parts of the fine grained blast-furnace slag as shown in Table 3, and 1.0 part of Dispersing Agent A was added to a total of 100 parts
20 of the fine grained blast-furnace slag and classified cement to prepare hydraulic cement compositions for soil injection. Water was added to each hydraulic cement composition in an amount of 850 parts per 100 parts of the cement composition, and mixing was carried out for 2
25 minutes in a grout mixer. For the purpose of comparison, normal Portland cement free from calcium carbonate was classified, and a given amount of calcium carbonate having a Blaine's specific surface area of 5,500 cm^2/g

was added to the classified cement for similar estimation. The obtained cement milks were measured in terms of viscosity, bleeding rate, penetration capability and compression strength. The results are
 5 summed up in Table 3.

[0034]

Used Materials

Calcium carbonate: A commercially available product made by Joetsu Mining Co., Ltd. having a Blaine's specific
 10 surface area of 5,500 cm²/g

[0035]

Table 3

Ex. Calcium Carbonate Viscosity (mPa·s) Bleeding (%)								
	No.	Content (parts)	0hr*	3hr	6hr	0.5h	1h	2h
15	3-1	0	2.0	2.0	2.1	0.7	2.1	4.8
	3-2	5	2.0	2.0	2.2	0.5	2.1	4.0
	3-3	6	2.0	2.0	2.3	0.3	1.7	2.7
	3-4	10	2.0	2.2	2.5	0.3	1.6	2.6
	1-4	11	2.0	2.2	3.0	0.4	1.5	2.4
20	3-5	13	2.0	2.2	2.6	0.3	1.5	2.5
	3-6	15	2.0	2.2	2.6	0.3	1.5	2.4
	3-7	20	2.0	2.3	2.8	0.2	1.3	2.4
	3-8	6	1.9	2.1	2.5	0.6	2.2	4.6
	3-9	13	2.0	2.2	2.4	0.8	2.6	5.2
25	3-10	20	2.1	2.1	2.4	1.0	3.2	6.6

0hr*: Just after mixing

The contents by parts of calcium carbonate are per 100 parts of the classified cement. In Experiment Nos. 3-8, 3-9 and 3-10,

normal Portland cement free from calcium carbonate was classified, and calcium carbonate having a Blaine's specific surface area of 5,500 cm²/g was thereafter added to it. In Experiment Nos. 3-8, 3-9 and 3-10, the contents by parts of calcium carbonate are per a total of 100 parts of the classified cement and calcium carbonate.

Table 3 (continued)

	Ex. No.	Penetration	Compression Strength	Remarks
10			(N/mm ²)	
	3-1	Full	0.2	Comparative
	3-2	Full	0.2	Comparative
	3-3	Full	0.5	Inventive
	3-4	Full	0.6	Inventive
15	1-4	Full	0.9	Inventive
	3-5	Full	1.0	Inventive
	3-6	Full	1.1	Inventive
	3-7	Full	1.0	Inventive
	3-8	Full	0.2	Comparative
20	3-9	Full	0.2	Comparative
	3-10	96 cm	0.2	Comparative

[0036]

From Table 3, it has been found that if calcium carbonate is contained in an amount of 6 to 20 parts (the inventive range) per 100 parts of the classified cement, the bleeding rate remains low and higher strength is produced. When the content of calcium carbonate is less than 6 parts per 100 parts of the

classified cement or when calcium carbonate is added unclassified to the classified cement even though its content comes within the inventive range, on the other hand, it is found to be likely that the bleeding rate grows high and strength gets low, indicating that the reactivity remains low. Thus, the incorporation of a specific amount of fine grained calcium carbonate would appear to contribute to the formation of a firmer set mass, and the set mass would appear to be more durable over an extended period of time.

Example 4

[0037]

Fifteen (15) parts of the classified cement e was added to 100 parts of the fine grained blast-furnace slag a and the dispersing agent was added to a total of 100 parts of the fine grained blast-furnace slag and classified cement as shown in Table 4 to prepare hydraulic cement compositions for soil injection. Water was added to each hydraulic cement composition in an amount of 850 parts per 100 parts of the cement composition, and mixing was carried out for 2 minutes in a grout mixer. The obtained cement milks were measured in terms of viscosity, bleeding rate, penetration capability, and compression strength. The results are summed up in Table 4.

[0038]

Used Materials

Dispersing Agent C: Dispersing agent in which 10 parts

of the melamine-based dispersing agent made by Sika Ltd.
were blended with 100 parts of Dispersing Agent A
Dispersing Agent D: Dispersing agent in which 30 parts
of the melamine-based dispersing agent made by Sika Ltd.
5 were blended with 100 parts of Dispersing Agent A
Dispersing Agent E: Dispersing agent in which 100 parts
of the melamine-based dispersing agent made by Sika Ltd.
were blended with 100 parts of Dispersing Agent A
Dispersing Agent F: Dispersing agent in which 600 parts
10 of the melamine-based dispersing agent made by Sika Ltd.
were blended with 100 parts of Dispersing Agent A
Dispersing Agent G: Dispersing agent in which 1,000
parts of the melamine-based dispersing agent made by
Sika Ltd. were blended with 100 parts of Dispersing
15 Agent A
Dispersing Agent H: Naphthalene sulfonate-based
dispersing agent Cellflow 110P made by DAI-ICHI SEIYAKU
KOGYO Co., Ltd.
Dispersing Agent I: Lignin sulfonate-based dispersing
20 agent Vanilex N made by Nippon Paper Industries Co., Ltd.
Dispersing Agent J: Melamine-based dispersing agent
Sikament FF made by Sika Ltd.

[0039]

Measuring Methods

25 For compression strength variations, sand gel
penetrating through a 1,000 m acryl pipe and set there
was cut to a length of 100 mm to prepare 10 compression
strength testing pieces, which were measured in terms of

compression strength, during which the coefficient of variance was found.

[0040]

Table 4

5	Experiment	Dispersing	Viscosity (mPa·s)			Bleeding (%)		
	No.	Agent (parts)	0hr*	3hr	6hr	0.5h	1h	2h
	4-1	0	7.3	7.8	14.6	15.3	25.6	37.8
	4-2	A0.1	2.8	3.7	4.4	0.9	2.4	4.0
	4-3	A0.3	2.6	2.7	3.6	0.7	1.8	3.3
10	4-4	A0.5	2.1	2.5	2.7	0.4	1.7	3.0
	4-5	A0.8	2.0	2.4	2.7	0.3	1.5	2.7
	1-4	A1.0	2.0	2.2	3.0	0.4	1.5	2.4
	4-6	A1.5	2.0	2.1	2.4	0.3	1.5	2.4
	4-7	A2.0	1.9	2.0	2.2	0.3	1.4	2.2
15	4-8	A2.5	1.8	2.0	2.2	0.2	1.3	2.2
	4-9	A3.0	1.8	2.0	2.2	0.2	1.3	2.0
	4-10	C0.3	2.0	2.1	2.4	0.1	0.7	1.7
	4-11	C1.0	1.9	2.0	2.4	0.1	0.5	1.6
	4-12	C2.0	1.8	1.9	2.2	0.1	0.4	1.4
20	4-13	D0.3	1.9	2.0	2.3	0.1	0.5	1.3
	4-14	D1.0	1.8	2.0	2.2	0.1	0.3	1.1
	4-15	D2.0	1.8	1.9	2.1	0	0.3	0.9
	4-16	E0.3	1.9	2.1	2.3	0.1	0.4	1.1
	4-17	E1.0	1.9	2.1	2.2	0	0.2	0.7
25	4-18	E2.0	1.8	1.9	2.0	0	0.2	0.5
	4-19	B0.3	1.9	2.1	2.2	0.1	0.4	1.0
	1-9	B1.0	1.9	2.1	2.4	0	0.3	0.9
	4-21	B2.0	1.7	1.8	2.0	0	0	0.4

	4-22	F0.3	1.9	2.1	2.2	0.1	0.4	1.0
	4-23	F1.0	1.7	1.9	2.0	0	0	0.4
	4-24	F2.0	1.7	1.8	2.0	0	0	0.3
	4-25	G0.3	2.0	2.3	2.8	0.3	1.0	2.1
5	4-26	G1.0	2.0	2.2	2.6	0.3	0.9	1.5
	4-27	G2.0	1.9	2.2	2.4	0.2	0.7	1.4
	4-28	H1.0	4.8	6.2	8.5	5.2	10.7	26.9
	4-29	I1.0	4.6	7.3	10.8	6.6	12.2	30.4
	4-30	J1.0	3.3	3.6	4.9	0.5	2.2	3.4

10 In the "viscosity" column, 0hr* means just after mixing, and the contents by parts of the dispersing agent are per a total of 100 parts of the fine grained blast-furnace slag and classified cement.

15 Table 4 (continued)

	Ex. No.	Penetration	Compression Strength	Remarks
			(N/mm ²)	
20	4-1	22 cm	0.2	Comparative
	4-2	Full	0.8 (15.3)	Inventive
	4-3	Full	0.9 (14.2)	Inventive
	4-4	Full	0.9 (14.0)	Inventive
	4-5	Full	0.9 (13.1)	Inventive
25	1-4	Full	0.9 (11.8)	Inventive
	4-6	Full	0.9 (10.9)	Inventive
	4-7	Full	0.8 (11.0)	Inventive
	4-8	Full	0.8 (9.6)	Inventive
	4-9	Full	0.7 (9.1)	Inventive
	4-10	Full	0.8 (10.2)	Inventive

	4-11	Full	0.8 (8.6)	Inventive
	4-12	Full	0.9 (7.7)	Inventive
	4-13	Full	0.7 (9.8)	Inventive
	4-14	Full	0.9 (8.1)	Inventive
5	4-15	Full	0.9 (7.5)	Inventive
	4-16	Full	1.0 (9.9)	Inventive
	4-17	Full	1.2 (7.1)	Inventive
	4-18	Full	1.1 (6.8)	Inventive
	4-19	Full	1.5 (9.6)	Inventive
10	1-9	Full	1.6 (7.2)	Inventive
	4-21	Full	1.6 (6.4)	Inventive
	4-22	Full	1.1 (10.3)	Inventive
	4-23	Full	1.3 (6.5)	Inventive
	4-24	Full	1.3 (6.1)	Inventive
15	4-25	Full	0.9 (10.2)	Inventive
	4-26	Full	1.0 (8.5)	Inventive
	4-27	Full	1.0 (8.3)	Inventive
	4-28	41 cm	0.5	Comparative
	4-29	35 cm	0.2	Comparative
20	4-30	69 cm	0.6	Comparative

In the "compression strength" column, the bracketed numerals are indicative of the coefficients of variance (%). Note that in Experiment Nos. 4-1, 4-28, 4-29 and 4-30, no coefficient of variance could be figured out because the permeation distance run short.

[0041]

From Table 4, it has been found that the use of the polyacrylic acid-based dispersing agent enables the

bleeding rate to remain low, making sure good enough penetration capability. In particular, that dispersing agent should preferably be used in combination with the melamine-based dispersing agent. Consequently,

5 differential compression strength due to differential penetration distance gets small, which would appear to result in the ability to obtain a more uniform, improved set mass. When the dispersing agents other than the polyacrylic acid-based dispersing agent (naphthalene

10 sulfonate-based, lignin sulfonate-based, and melamine-based dispersing agents) is used alone, no good penetration capability can be ensured.

Example 5

[0042]

15 Water was added to such hydraulic cement compositions prepared as shown in Table 5 in such amounts per 100 parts of the cement composition as shown in Table 5 to prepare cement milks. Water penetration testing was carried out using those cement milks: they were

20 subjected to water penetration testing with a model ground having a water current in mind. The point to check was whether or not there was an outflow of the cement milk. In addition, the set mass was removed from within the model ground after seven days to observe its

25 shape. When the set mass was in a substantially spherical shape, its diameter was found. The results of testing are summed up in Table 6.

[0043]

Table 5

	Blend	Ex.	Fine Grained Blast-	Classified	Dispersing
	No.	No.	Furnace Slag (parts)	Cement (parts)	Agent (parts)
5	(1)	2-1	100	15	A1.0
	(2)	2-7	100	15	A1.0
	(3)	4-1	100	15	0
	(4)	4-28	100	15	H1.0
	(5)	4-29	100	15	I1.0
10	(6)	4-30	100	15	J1.0
	(7)	-	100	15	A3.5
	(8)	-	100	15	B3.5
	(9)	-	100	15	A1.0
	(10)	1-2	100	5	A1.0
15	(11)	1-4	100	15	A1.0
	(12)	1-6	100	30	A1.0
	(13)	-	100	15	A1.0
	(14)	-	100	15	B1.0
	(15)	1-7	100	5	B1.0
20	(16)	1-9	100	15	B1.0
	(17)	1-11	100	30	B1.0
	(18)	-	100	15	B1.0

The parts in the "classified cement" column are per 100 parts of the fine grained blast-furnace slag, and the parts in the "dispersing agent" column are per a total of 100 parts of the fine grained blast-furnace slag and classified cement.

Table 5 (Continued)

Blend	Water	Remarks
No.	(parts)	
5	(1)	850 Fine grained blast-furnace slag b and Classified cement f
	(2)	850 Fine grained blast-furnace slag d and Classified cement f
	(3)	850 No dispersing agent
10	(4)	850 Naphthalene sulfonate-based dispersing agent
	(5)	850 Lignin sulfonate-based dispersing agent
	(6)	850 Melamine-based dispersing agent
	(7)	850 Addition of excessive dispersing agent
	(8)	850 Addition of excessive dispersing agent
15	(9)	400 The lower limit to the amount of water used
	(10)	850 The lower limit to the classified cement used
	(11)	850 A composition in the more preferable range
	(12)	850 The upper limit to the classified cement used
	(13)	1,500 The upper limit to the amount of water used
	(14)	400 The lower limit to the amount of water used
20	(15)	850 The lower limit to the classified cement used
	(16)	850 A composition in the more preferable range
	(17)	850 The upper limit to the classified cement used
	(18)	<u>1,500 The upper limit to the amount of water used</u>

The parts in the "water" column are per 100 of the hydraulic
 25 cement composition for soil injection.

[0044]

Testing Method

The water penetration testing was carried out pursuant to Water Penetration Testing Method for Soils prescribed in JGS0311-2000. More exactly, a 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 cement milk flowed down. Near the center of the prepared model ground there was a pipe set through which the cement milk was injected. The thus prepared model ground vessel was immersed as a whole in a tank filled up with water, and there was a water level difference of 0.7 cm 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 replacement, 120 cc of the mixed cement milk were injected through the pipe to observe how the cement milk flowed out of the model ground. For the purpose of checking the state of the set cement milk mass remaining in the model ground, the model ground vessel was taken apart after a material age of seven days, 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. The bleeding rate of the grout before injection was measured too.

[0045]

Table 6

Ex.	Blend	Outflow	Shape
No.	No.		
5	5-1 (1)	No outflow	Amorphous shape: no uniform penetration of the grout
	5-2 (2)	No outflow	Amorphous shape: no uniform penetration of the grout
	5-3 (3)	No outflow	Amorphous shape: no uniform penetration of the grout
10	5-4 (4)	Outflow after 60 min.	Substantial sphere
	5-5 (5)	Outflow after 40 min.	No trace of the set mass
	5-6 (6)	No outflow	Amorphous shape: no uniform penetration of the grout
15	5-7 (7)	Outflow after 90 min.	Substantial sphere
	5-8 (8)	Outflow after 90 min.	Substantial sphere
	5-9 (9)	No outflow	Substantial sphere
	5-10 (10)	No outflow	Substantial sphere
	5-11 (11)	No outflow	Substantial sphere
	5-12 (12)	No outflow	Substantial sphere
20	5-13 (13)	No outflow	Substantial sphere
	5-14 (14)	No outflow	Substantial sphere
	5-15 (15)	No outflow	Substantial sphere
	5-16 (16)	No outflow	Substantial sphere
	5-17 (17)	No outflow	Substantial sphere
25	5-18 (18)	No outflow	Substantial sphere

Amorphous shape: the set mass was deformed; so it was indefinite in shape. When 120 cc of the cement milk was rounded, its diameter was 6.1 cm.

Table 6 (Continued)

Ex. No.	Bleeding Rate (%)	Diameter of the Set Mass	Remarks
	1h	(length×width cm)	
5	5-1	3.1	- Comparative
	5-2	2.2	- Comparative
	5-3	25.6	- Comparative
	5-4	10.7	1.5×1.3 Comparative
	5-5	12.2	- Comparative
10	5-6	2.2	- Comparative
	5-7	1.6	3.5×2.8 Comparative
	5-8	0.3	1.8×2.5 Comparative
	5-9	1.6	5.8×6.2 Inventive
	5-10	1.4	5.7×6.0 Inventive
15	5-11	1.5	6.0×5.7 Inventive
	5-12	1.7	6.0×6.2 Inventive
	5-13	1.8	5.9×6.3 Inventive
	5-14	0.6	5.7×6.3 Inventive
	5-15	0	5.6×6.3 Inventive
20	5-16	0.3	5.9×6.1 Inventive
	5-17	1.0	6.1×5.9 Inventive
	5-18	0.7	5.9×6.3 Inventive

[0046]

From Table 6, it has been found that the inventive cement composition for soil injection makes sure the grout remains in the ground with no outflow, even when it is injected into the ground having water currents, providing such a set mass as theoretically expected. The set mass is in a substantially spherical shape, which

indicates that there is uniform penetration and grouting achieved. It also shows that if the amount of water used falls within the range of 400 to 1,500 parts per 100 parts of the hydraulic cement composition for soil injection, bleeding rate changes remain small too.

Example 6

[0047]

The inventive cement composition for soil injection was actually applied to construction work for preventing liquefaction of a seawall foundation. To this end, grout cement milk No. 5-9, 5-11, and 5-16 was adjusted in a grout mixer and injected in the foundation. Those cement milks were each mixed for two minutes, and once it had been passed over to a reservoir, it was pumped and injected by a grout pump via a hose and an injection pipe (a single-pipe rod). During injection, the pressure was managed such that the maximum pressure was set at 0.5 MPa, and the injection rate and amount were set at 40% and 1 m³, respectively. The grout cement milks could all be injected at a pressure below the management pressure. One month later, the ground was turned over to check the set state of the injected cement milk, revealing that the grout cement milk penetrated the ground and was set there. The set masses were all in a nearly spherical shape having a diameter of 45 to 65 cm. Samples were cut out of those set masses to measure their compression strength: 3.5 N/mm² for the set grout mass corresponding to Experiment No. 5-9, 1.4 N/mm² for

Experiment No. 5-11, and 0.4 N/mm² for Experiment No. 5-16, all figures indicating that good enough improvements are achievable.

Example 7

5 [0048]

Using the equipment used for the construction work of Example 6 for preventing liquefaction of the seawall foundation, the inventive cement composition for soil injection was mixed and pumped through a hose, and
10 pumping was interrupted to allow the grout to remain in the hose for 60 minutes. Afterwards, the operation was resumed and how the grout behaved was checked. The blends used were grout cement milks of Experiment Nos. 5-9, 5-11, 5-13, 5-14 and 5-18 (having different water
15 contents), and cement milks of Experiment Nos. 5-1, 5-2, 5-3, 5-4 and 5-6 were used for the purpose of comparison. As a result, there was no or little settling down of particles in the hose with the grouts of Experiment Nos. 5-9, 5-11, 5-13, 5-14 and 5-18, and smooth pumping could
20 be resumed irrespective of the pressure taken for restarting. With the grouts of comparative Experiment Nos. 5-1, 5-2, 5-3, 5-4 and 5-6, on the other hand, there was the settling down of particles in the hose. With Experiment Nos. 5-4 and 5-5 in particular,
25 restarting could not be possible because about half the section of the hose was covered with settled particles. With Experiment Nos. 5-1, 5-2 and 5-3, restarting could be barely possible but about a few minutes after

restarting, a cluster of undispersed particles flowed through the hose due to the pressure taken for restarting, leading to a clogging of the hose.

5 APPLICABILITY TO THE INDUSTRY

[0049]

 The inventive hydraulic cement composition for soil injection is less susceptible to material separation, and excels in penetration capability and the ability to
10 work so that a wide range of improvements are rapidly achievable. In addition, the set mass formed of the specific classified cement, fine grained slag and dispersing agent(s) contributes more to good enough strength and excels more in durability over a long
15 period of time so that it could be applied to reinforcing work for various soft grounds such as the prevention of liquefaction of sandy grounds.

WHAT IS CLAIMED IS:

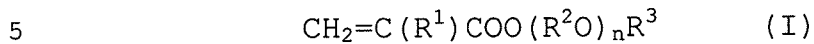
1. A hydraulic cement composition for soil injection, characterized by comprising 100 parts of fine grained
5 blast-furnace slag having a Blaine's specific surface area of 7,000 to 16,000 cm²/g and a median diameter of 1 to 7 μm, 5 to 30 parts of classified cement capable of satisfying all the following conditions (1), (2) and (3) per 100 parts of the fine grained blast-furnace slag,
10 and 0.1 to 3 parts of a dispersing agent containing a polyacrylic acid-based dispersing agent per a total of 100 parts of the fine grained blast-furnace slag and classified cement:

- (1) classified cement, characterized by containing 6
15 to 20 parts of calcium carbonate in 100 parts thereof,
- (2) classified cement, characterized by having a Blaine's specific surface area of 7,000 to 16,000 cm²/g, and
- 20 (3) classified cement, characterized by having a median diameter of 1 to 7 μm.

2. A hydraulic cement composition for soil injection as recited in Claim 1, characterized in that the
25 dispersing agent further contains a melamine-based dispersing agent.

3. A hydraulic cement composition for soil injection

as recited in Claim 1, characterized in that the polyacrylic acid-based dispersing agent is a copolymer containing a monomer represented by the following general formula (I):



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.

10

4. A cement milk, characterized in that water is added to and mixed with a hydraulic cement composition for soil injection as recited in any one of Claims 1, 2 and 3.

15

5. A cement milk as recited in Claim 4, characterized in that the cement milk obtained by adding and mixing water to and with the hydraulic cement composition for soil injection has a bleeding rate of up to 2% after at rest for 60 minutes.

20

6. A soil improvement method in which a cement milk as recited in Claim 4 is injected in a ground.

25

7. A soil improvement method as recited in Claim 6, characterized by being used for soil improvement intended to prevent liquefaction.