

SPECIFICATION

TITLE OF INVENTION: SEAL MATERIAL

TECHNICAL FIELD

[0001] The present invention pertains to a seal material for use in shield machines and the like for filling a tail clearance in the same.

BACKGROUND ART

[0002] Tail seal structures for shield machines include those indicated in patent documents 1 - 3 and the like. A gap (tail clearance) opens up between a tail seal structure and a segment during performance of an excavation. A seal material for filling tail clearance (tail seal material) is used to prevent water leakage from the ground or leakage of a backfill material that fills the outer-peripheral portion at the rear, via the gap.

[0003] Seal materials prevent water leakage and leakage of backfill materials, and act as a lubricant for shield machines.

Seal materials used in shield machines include materials containing water, calcium soap, mineral oil and polypropylene resin (refer to paragraph 0021 of patent document 4), or materials containing a natural polymer that has guar gum or a modified product thereof, locust bean gum and a galactomannose polymer as main components (refer to paragraph 0015 of patent document 5). Further, seal materials containing mineral-based fibrous substances such as bentonite and montmorillonite (refer to paragraph 0019 of patent document 6) are also proposed as fibrous fillers.

[0004] Patent document 7 also discloses a seal material containing at least one of a water-soluble cellulose ether such as carboxymethyl cellulose or methyl cellulose as a water-soluble polymeric thickener, a natural gum and a man-made gum. The seal material described in patent document 7 does not have oil as a main component thereof; and thus poses little danger of fire and has a low possibility of adversely affecting hardening properties compared to a seal material having oil as a main component thereof, even when mixed with cement milk that is used as a backfill material (refer to paragraph 0035).

PRIOR ART DOCUMENT

PATENT DOCUMENT

- [0005] Patent Document 1: Published Unexamined Patent Application Number 2001-40998
Patent Document 2: Published Unexamined Patent Application Number 2001-355393
Patent Document 3: Published Unexamined Patent Application Number 2011-42938
Patent Document 4: Published Unexamined Patent Application Number 7-109893
Patent Document 5: Patent Number 3235425 (specification)
Patent Document 6: Published Unexamined Patent Application Number 2001-11577
Patent Document 7: Patent Number 2938418 (specification)

SUMMARY OF THE INVENTION

PROBLEM TO BE SOLVED BY THE INVENTION

- [0006] The seal material described in patent document 4, for example, contains oil in a paste-like base thereof, and thus poses a risk of hindering a hardening reaction of cement due to contact with a cement-based backfill material. Further, resin materials such as polypropylene have hardening properties that improve filling properties or adhesive properties of a seal material, but resin materials are hard, posing problems such as resistance when filling a tail clearance, clogging of pipes occurring more easily, and the like.

The seal material described in patent document 5, for example, has poor waterproof properties since it does not contain a fibrous filler. Moreover, the seal material requires use of a natural polymer and a gelling agent, resulting in variances in viscosity due to differences in ground pH levels, causing its properties as a seal material to vary.

- [0007] One of the objectives of the present invention is to provide a seal material that does not contain components that hinder hardening of cement, and that has waterproof properties and lubricity.

MEANS FOR SOLVING THE PROBLEM

- [0008] To solve the problem described above, the seal material of the present invention is characterized by containing water and a seal raw material, wherein the seal raw material contains a water-soluble cellulose-based thickener, a straight-chain nonionic polymer thickener, a fibrous filler that comprises organic fibers, an organic antifoaming agent, a moisturizing agent for retaining moisture, and an inorganic filler that comprises an inorganic compound.

- [0009] Preferably, the fibrous filler contains a first fibrous filler having a length of at least 3 mm, and a second fibrous filler having a length of no more than 2 mm.
- [0010] Preferably, the cellulose-based thickener, the nonionic polymer thickener, the fibrous filler and the antifoaming agent are added to 100 parts by weight of water in a total quantity of between 8.0 and 18.0 (inclusive) parts by weight.
- [0011] Preferably, the inorganic filler is added to 100 parts by weight of water in a quantity of between 5.0 and 15.0 (inclusive) parts by weight.
- [0012] Preferably, the moisturizing agent is added to 100 parts by weight of water in a quantity of at least 2.0 parts by weight.
- [0013] Preferably, the first fibrous filler is added in a quantity that is between 0.875 and 4 (inclusive) times the quantity of the second fibrous filler.

EFFECTS OF THE INVENTION

- [0014] The seal material of the present invention does not contain components that hinder hardening of cement, and has waterproof properties and lubricity.

MODES FOR CARRYING OUT THE INVENTION

- [0015] According to the present invention, a seal material is manufactured by adding a seal raw material to water. The seal raw material contains at least a thickener, a fibrous filler, an antifoaming agent, a moisturizing agent and an inorganic filler.
- [0016] The thickener contains a cellulose-based thickener and a nonionic polymer thickener. A cellulose-based thickener is a water-soluble thickener that contains cellulose. In a cellulose-based thickener, the viscosity of 1 wt% of an aqueous solution is measured by use of a viscometer under the conditions 25°C / 2000 rpm; of this cellulose-based thickener, the part having a viscosity of between 2500 and 4500 mPa (inclusive) is used. This cellulose-based thickener has properties of increasing the viscosity of water by being combined with the water. By inclusion of this cellulose-based thickener, viscosity of water increases, and in seal materials, compliance within a clearance space is improved.
- [0017] A nonionic polymer thickener is a polymer material in which carbon atoms bond in a straight chain, and is water-soluble, in which ionization due to a functional group showing hydrophilic properties such as a hydroxyl group being bonded to any of the carbon atoms does not occur, and which is a polymer material having a molecular weight of between 10,000 and 1,000,000 (inclusive) for industrial use, for example.

Polyvinyl alcohol, polyethylene oxide and the like can be given as examples of nonionic polymer thickeners.

[0018] The fibrous filler comprises organic fibers including natural fibers such as cellulose-based fibers, or synthetic fibers such as acrylic fibers, polyester fibers and polyethylene fibers.

[0019] The fibrous filler is classified into a first fibrous filler and a second fibrous filler according to its length. The first fibrous filler has a length of at least 3 mm. The second fibrous filler has a length of no more than 2 mm. The fibrous filler contains the first fibrous filler and the second fibrous filler.

An acceptable diameter or thickness of each of the first fibrous filler and second fibrous filler is no more than 2 mm. Inclusion of the two types of fibrous fillers improves the waterproof properties of the seal material in a tail clearance.

[0020] Antifoaming agents include silicon-based and oil-based antifoaming agents, but here, an organic antifoaming agent is used. By including this antifoaming agent, the seal material prevents air from being introduced when a filler with is combined with water, when a shield machine moves within a clearance, or the like, and suppresses a decrease in waterproof properties due to introduction of air.

[0021] A moisturizing agent retains moisture and prevents a seal material from drying out. Moisturizing agents include urea, a water-absorbing resin and the like, for example. Water-absorbing resins include polyacrylate crosslinking agents and the like.

[0022] An inorganic filler is a substance for improving compatibility of a thickener and a fibrous filler. At least 90 % of the inorganic filler consists of a granular inorganic compound that passes through an aperture of 250 μm , the official aperture of the test sieve of JISZ8801-1, namely, ASTM mesh no. 60, but does not pass through a test sieve having apertures of 150 μm , that is, ASTM mesh no. 100.

[0023] Inorganic fillers include calcium silicate, mica, wollastonite and the like, for example.

[0024] It was discovered that a seal material obtained by adding water to a seal raw material that contains a water-soluble cellulose-based thickener, a straight-chain nonionic polymer thickener, a fibrous filler that comprises organic fibers, an organic antifoaming agent, a moisturizing agent for retaining moisture, and an inorganic filler that comprises an inorganic compound, does not hinder hardening of cement, and has suitable waterproof properties and lubricity.

EXAMPLES

[0025] (1) Materials Used in Samples

A water-soluble cellulose-based thickener, a straight-chain nonionic polymer thickener, a fibrous filler, an antifoaming agent, a moisturizing agent and an inorganic filler were combined to create the seal raw materials for samples 1 - 25.

Methyl cellulose manufactured by Kanto Chemical Co., Inc. (CAS number: 9004-67-5) was used as the cellulose-based thickener.

Polyvinyl alcohol (PVA, manufactured by Kuraray Co., Ltd.) was used as the nonionic polymer thickener.

[0026] For the fibrous filler, an acrylic filler was used as the first fibrous filler, and a cellulose-based filler was used as the second fibrous filler.

An acrylic yarn having a thickness of approximately 1 mm and length of approximately 5 - 10 mm was used as the acrylic filler. This is one example of the first fibrous filler that has a length of at least 3 mm.

Waste paper having cellulose as a main component thereof, which was formed into a fibrous state that has a thickness of approximately 0.1 mm and a length of approximately 1 mm, was used as the cellulose-based filler. This is one example of the second fibrous filler that has a length of no more than 2 mm.

[0027] A polyether-based antifoaming agent (medical sample) manufactured by Kanto Chemical Co., Inc. was used as the antifoaming agent.

Urea (manufactured by Kanto Chemical Co., Inc., medical sample) was used as the moisturizing agent.

Calcium silicate was used as the inorganic filler.

[0028] (2) Testing

(A) Fluidity Test 1

Samples 1 - 5, in which each material is added to 100 parts by weight of water in the quantities shown in Table 1, were created. Principle 1 below was applied to determine the ratio of quantities to be added. In samples 1 - 5, the total quantity of thickener, fibrous filler and antifoaming agent added to 100 parts by weight of water, 2 parts by weight of a moisturizing agent and 10 parts by weight of an inorganic filler was modified from 3 parts by weight to 23 parts by weight.

<Principle 1>

Cellulose-based thickener : nonionic polymer thickener : antifoaming agent = 15.4 : 1 : 0.924.

First fibrous filler : second fibrous filler = 9.5 : 5.5

(Thickener + antifoaming agent) : fibrous filler = 4.5 : 7.5

[Table 1]

Components		Quantities added to 100 parts by weight of water				
		Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Thickener	Cellulose-based thickener	1	2.67	4.33	6	7.67
	Nonionic polymer thickener	0.06	0.17	0.28	0.39	0.5
Fibrous filler	First fibrous filler	1.19	3.17	5.15	7.13	9.1
	Second fibrous filler	0.69	1.83	2.98	4.13	5.27
Antifoaming agent		0.06	0.16	0.26	0.36	0.46
Moisturizing agent		2	2	2	2	2
Inorganic filler		10	10	10	10	10

[0029] A pump pressure-feed test was performed on samples 1 - 5. The pump pressure-feed test was judged on whether the samples were continuously pushed out of the exit port after pushing 20 liters of each of samples 1 - 5 into the entry port of a 2 cm pipe by use of a grease pump over a length of 2 meters. The results are as shown in Table 2.

[Table 2]

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Total quantity of thickener, fibrous filler and antifoaming agent	3	8	13	18	23
Results of fluidity test	Not acceptable	Good	Good	Good	Not acceptable

[0030] The results were evaluated as “good” for samples that were pushed out of the exit port, and as “not acceptable” for samples that were not.

[0031] From the results of fluidity test 1, it was discovered that if the total quantity of thickener, fibrous filler and antifoaming agent added to 100 parts by weight of water increases to 23 parts by weight, viscosity becomes too high, thereby remarkably decreasing fluidity. It was also discovered that, if this total quantity is reduced to 3 parts by weight, separation of the materials occurs, preventing the samples from being pushed out continuously and clogging the pipe.

[0032] Accordingly, it was confirmed that a seal material in which a thickener (cellulose-based thickener and nonionic polymer thickener), fibrous filler and antifoaming agent are added to 100 parts by weight of water in a total quantity of between 8.0 and 18.0 parts by weight (inclusive) shows

suitable fluidity.

[0033] (B) Waterproof Test 1

Samples 6 – 10, in which each of the materials is added to 100 parts by weight of water in the quantities shown in Table 3, were created.

Principle 1 below was applied to determine the ratio of quantities to be added. In samples 6 - 10, the total quantity of thickener, fibrous filler and antifoaming agent added to 100 parts by weight of water and 2.50 parts by weight of moisturizing agent was fixed at 10.0 parts by weight, and the quantity of inorganic filler was modified from 0 to 20 parts by weight.

[Table 3]

Components		Quantities added to 100 parts by weight of water				
		Sample 6	Sample 7	Sample 8	Sample 9	Sample 10
Thickener	Cellulose-based thickener	3.33	3.33	3.33	3.33	3.33
	Nonionic polymer thickener	0.22	0.22	0.22	0.22	0.22
Fibrous filler	First fibrous filler	3.96	3.96	3.96	3.96	3.96
	Second fibrous filler	2.29	2.29	2.29	2.29	2.29
Antifoaming agent		0.2	0.2	0.2	0.2	0.2
Moisturizing agent		2.5	2.5	2.5	2.5	2.5
Inorganic filler		0	5	10	15	20

[0034] Waterproof test 1 was performed on samples 6 - 10. Waterproof test 1 was judged on whether water leakage occurred after the pressure applied to the samples was changed from 0.1 MPa to 4.0 MPa. The results were as shown in Table 4.

[Table 4]

Pressures	Sample 6	Sample 7	Sample 8	Sample 9	Sample 10
0.1MPa	Not acceptable	Good	Good	Good	Good
0.5MPa	—	Good	Good	Good	Good
1.0MPa	—	Good	Good	Good	Good
2.0MPa	—	Good	Good	Good	Good
3.0MPa	—	Good	Good	Good	Good
4.0MPa	—	Good	Good	Good	Good

[0035] The results were evaluated as “good” for samples for which no water leakage occurred, and as “not acceptable” for samples for which water

leakage did occur. Testing at increased pressure was not performed on the samples for which water leakage occurred at a low pressure, since it was naturally predicted that water leakage would occur. The results in such a case were marked as “-”.

[0036] From the results of waterproof test 1, it was discovered that when the quantity of inorganic filler added to 100 parts by weight of water is 0 parts by weight, the waterproof properties are not sufficient, but sufficient waterproof properties can be obtained at 5 parts by weight or more.

[0037] (C) Fluidity Test 2

Samples 11 – 15, in which each of the materials is added to 100 parts by weight of water in the quantities shown in Table 5, were created. Principle 1 described above was applied to determine the ratio of quantities to be added. In samples 11 - 15, the total quantity of thickener, fibrous filler and antifoaming agent added to 100 parts by weight of water and 10 parts by weight of moisturizing agent was fixed at 20 parts by weight, and the quantity of inorganic filler was modified from 5 to 25 parts by weight.

[Table 5]

Components		Quantities added to 100 parts by weight of water				
		Sample 11	Sample 12	Sample 13	Sample 14	Sample 15
Thickener	Cellulose-based thickener	6	6	6	6	6
	Nonionic polymer thickener	0.39	0.39	0.39	0.39	0.39
Fibrous filler	First fibrous filler	7.13	7.13	7.13	7.13	7.13
	Second fibrous filler	4.13	4.13	4.13	4.13	4.13
Antifoaming agent		0.36	0.36	0.36	0.36	0.36
Moisturizing agent		10	10	10	10	10
Inorganic filler		5	10	15	20	25

[0038] The above-described pump pressure-feed test was performed on samples 11 - 15. The results were as shown in Table 6.

[Table 6]

	Sample 11	Sample 12	Sample 13	Sample 14	Sample 15
Results of fluidity test	Good	Good	Good	Not acceptable	Not acceptable

[0039] The results were evaluated as “good” for samples that were pushed out

of the exit port, and as “not acceptable” for samples that were not.

[0040] From the results of fluidity test 2, it was discovered that if the total quantity of thickener, fibrous filler and antifoaming agent added to 100 parts by weight of water is 20 parts by weight, fluidity decreases remarkably when the quantity of inorganic filler added is increased to 20 parts by weight or more. The cause thereof is presumed to be the effects of the filler.

[0041] Accordingly, the results of waterproof test 1 and fluidity test 2 confirmed that a seal material in which an inorganic filler is added to 100 parts by weight of water in a quantity of between 5.0 and 15.0 parts by weight (inclusive) shows suitable waterproof properties and fluidity.

[0042] (D) Moisture Retention Test

Samples 16 – 20, in which each of the materials is added to 100 parts by weight of water in the quantities shown in Table 7, were created. Principle 1 described above was applied to determine the ratio of quantities to be added. In samples 16 - 20, the total quantity of thickener, fibrous filler and antifoaming agent added to 100 parts by weight of water and 10 parts by weight of inorganic filler was fixed at 15 parts by weight, and the quantity of moisturizing agent was modified from 0 to 20 parts by weight.

[Table 7]

Components		Quantities added to 100 parts by weight of water				
		Sample 16	Sample 17	Sample 18	Sample 19	Sample 20
Thickener	Cellulose-based thickener	5	5	5	5	5
	Nonionic polymer thickener	0.32	0.32	0.32	0.32	0.32
Fibrous filler	First fibrous filler	5.94	5.94	5.94	5.94	5.94
	Second fibrous filler	3.44	3.44	3.44	3.44	3.44
Antifoaming agent		0.3	0.3	0.3	0.3	0.3
Moisturizing agent		0	2	10	15	20
Inorganic filler		10	10	10	10	10

[0043] A moisture retention test was performed on samples 16 - 20. The moisture retention test was judged by confirming whether a great change occurred in the feel of the samples when the samples were re-stirred one hour after the samples were created. The results were as shown in Table 8.

[Table 8]

	Sample 16	Sample 17	Sample 18	Sample 19	Sample 20
Results of moisture retention test	Not acceptable	Good	Good	Good	Good

[0044] The results were evaluated as “good” for samples for which water leakage did not occur, and as “not acceptable” for samples that caused a person to sense dehydration when touching by hand or for which water leakage occurred. Testing at increased pressure was not performed on the samples for which water leakage occurred at a low pressure, since it was naturally predicted that water leakage would occur. The results in such a case were marked as “-”.

[0045] From the results of the moisture retention test, it was discovered that when the quantity of moisturizing agent added to 100 parts by weight of water is 0 parts by weight, the moisture retention properties are not sufficient, but sufficient moisture retention properties can be obtained at 2.0 parts by weight or more.

[0046] (E) Waterproof Test 2

Samples 21 – 25, in which each of the materials is added to 100 parts by weight of water in the quantities shown in Table 9, were created. Principle 2 below was applied to determine the ratio of quantities to be added. In samples 21 - 25, the total quantity of thickener, fibrous filler and antifoaming agent added to 100 parts by weight of water, 5 parts by weight of moisturizing agent and 10 parts by weight of inorganic filler was fixed at 12 parts by weight, and the ratio of the quantities added was modified in the first fibrous filler and the second fibrous filler.

<Principle 2>

Cellulose-based thickener : nonionic polymer thickener : antifoaming agent = 15.4 : 1 : 0.924.

(Thickener + antifoaming agent) : fibrous filler = 4.5 : 7.5.

[Table 9]

Components		Quantities added to 100 parts by weight of water				
		Sample 21	Sample 22	Sample 23	Sample 24	Sample 25
Thickener	Cellulose-based thickener	4	4	4	4	4
	Nonionic polymer thickener	0.26	0.26	0.26	0.26	0.26
Fibrous filler	First fibrous filler	7.5	6	3.5	1	0
	Second fibrous filler	0	1.5	4	6.5	7.5
Antifoaming agent		0.24	0.24	0.24	0.24	0.24
Moisturizing agent		5	5	5	5	5
Inorganic filler		10	10	10	10	10

[0047] Waterproof test 2 was performed on samples 21 - 25. Waterproof test 2 was judged on whether water leakage occurred for each of the samples when pressure applied to the samples was modified from 0.1 MPa to 4.0 MPa. The results were as shown in Table 10.

[Table 10]

Pressures	Sample 21	Sample 22	Sample 23	Sample 24	Sample 25
0.1MPa	Good	Good	Good	Good	Acceptable
0.5MPa	Acceptable	Good	Good	Good	—
1.0MPa	—	Good	Good	Acceptable	—
2.0MPa	—	Good	Good	—	—
3.0MPa	—	Good	Good	—	—
4.0MPa	—	Good	Good	—	—

[0048] The results were evaluated as “good” for samples for which water leakage did not occur, and as “acceptable” for samples that were not unusable as seal materials but for which water leakage occurred. Testing at increased pressure was not performed on the samples for which water leakage occurred at a low pressure, since it was naturally predicted that water leakage would occur. The results in such a case were marked as “—”.

[0049] From the results of waterproof test 2, it was discovered that when the quantity of fibrous filler is fixed at 7.5 parts by weight with respect to 100 parts by weight of water, the waterproof properties are not sufficient if the quantity of the first fibrous filler or the second fibrous filler added is 0 parts by weight, but sufficient waterproof properties can be obtained if at least 3.5 parts by weight of the first fibrous filler and at least 1.5

parts by weight of the second fibrous filler are added. That is, desirably the seal material would contain a first fibrous filler having a length of at least 3 mm, and a second fibrous filler having a length of no more than 2 mm.

[0050] Further, it was discovered that sufficient waterproof properties can be obtained when the first fibrous filler is added in a quantity that is between 0.875 ($=3.5/4$) and 4 ($=6/1.5$) (inclusive) times the quantity of the second fibrous filler.

CLAIMS

- [Claim 1] A seal material characterized by containing water and a seal raw material, wherein
- the seal raw material contains
 - a water-soluble cellulose-based thickener,
 - a straight-chain nonionic polymer thickener,
 - a fibrous filler that comprises organic fibers,
 - an organic antifoaming agent,
 - a moisturizing agent for retaining moisture, and
 - an inorganic filler that comprises an inorganic compound.
- [Claim 2] A seal material as set forth in claim 1, characterized in that
- the fibrous filler contains a first fibrous filler having a length of at least 3 mm, and a second fibrous filler having a length of no more than 2 mm.
- [Claim 3] A seal material as set forth in claim 1 or claim 2, characterized in that
- the cellulose-based thickener, the nonionic polymer thickener, the fibrous filler and the antifoaming agent are added to 100 parts by weight of water in a total quantity in a range from 8.0 to 18.0 parts by weight.
- [Claim 4] A seal material as set forth in any one of claims 1 - 3, characterized in that
- the inorganic filler is added to 100 parts by weight of water in a quantity in a range from 5.0 to 15.0 parts by weight.
- [Claim 5] A seal material as set forth in any one of claims 1 - 4, characterized in that
- the moisturizing agent is added to 100 parts by weight of water in a quantity of at least 2.0 parts by weight.
- [Claim 6] A seal material as set forth in claim 2, characterized in that
- the first fibrous filler is added in a quantity in a range from 0.875 to 4 times the quantity of the second fibrous filler.