

DESCRIPTION

Title of Invention

FILLER FOR REBAR JOINTS

Technical Field

[0001]

The present invention relates to a filler for a reinforcing bar joint.

Background Art

[0002]

Conventionally, as a mortar material used in civil engineering and construction works, a mortar material in which a water-reducing agent is added to cement is generally used. Furthermore, a calcium sulfoaluminate-based expansion material a lime-based expansion material, or a foaming agent such as aluminum powder is added to the mortar material forming a non-shrinkable material, river sand, silica sand or the like is added to the non-shrinkable material, and the obtained product is used as a paste or a mortar. In particular, such materials are widely used for fine voids in concrete structures, voids in reverse construction methods, repairing and reinforcing structures, and construction methods of filling under a base plate of a machine, under a track floor slab and the like, for example.

[0003]

In general, mortar materials applied for filling in civil engineering and construction works are called grouts, and the grouts include PC grouts, prepacked concrete grouts, backfill grouts for tunnels and shields, precast grouts, grouts for repairing and reinforcing structures, reinforcing bar joint grouts, grouts under shoes of bridges, grouts under paved floor slabs, grouts under track floor slabs, and grouts under nuclear power plant containments, for example.

[0004]

In recent years, the quality of concrete used in civil engineering and architectural construction has been improved, and the performance required of mortar materials used as grouts has also been required to be, for example, high in strength, high in fluidity, and low in shrinkage depending on applications.

[0005]

In particular, mortars for filling joints to which reinforcing bars are connected in structures such as reinforced concrete and precast concrete, by requirement of improvement in proof strength of joints such as improvement in strength of joints along with increase in size of

reinforced concrete structures and increase in strength of concrete associated with improvement in earthquake resistance, high fluidity, high strength developability, and low shrinkage of mortars are desired.

[0006]

Patent Literature 1 describes a cement-based grout composition as a steel material joint grout, for example. Patent Literature 1 indicates that in a composition including cement, a fine aggregate, a water-reducing agent, an expansion material, inorganic fine powder, and a foaming substance, the blending amount of the water-reducing agent is 0.05 to 4 parts by mass based on 100 parts by mass of the cement, and 10 to 30 parts by mass of a melamine sulfonate-based water-reducing agent, 55 to 85 parts by mass of a naphthalene sulfonate-based water-reducing agent, and 5 to 20 parts by mass of a lignosulfonate-based water-reducing agent are included in 100 parts by mass of the water-reducing agent. Then, Patent Literature 1 indicates that the expansion material preferably includes free lime, calcium aluminophosphate, and anhydrite as main components.

[0007]

Patent Literature 2 describes a cement composition that can also be used as a filler for a joint. Patent Literature 2 indicates that the cement composition includes belite-rich cement, silica fume, a cement dispersant mainly including a polycarboxylic acid-based polymer compound having a polyalkylene glycol chain, a lime-based mixture material or an organic shrinkage reducing agent, a substance that generates pressure opposing against shrinkage force due to hydration of the belite-rich cement, and a fine aggregate with specific gravity of 3.4 or more and water absorption of 0.5% to 1.5%. Then, Patent Literature 2 indicates that a lime-based expansion material and a product obtained by mixing gypsum and clinker including CaO crystals and pulverizing same are preferable as an expansion material.

[0008]

Patent Literature 3 describes a filler for a reinforcing bar joint and a construction method of filling a reinforcing bar joint using same. Patent Literature 3 indicates that the filler for a reinforcing bar joint includes cement, an expansion material, pozzolan fine powder, a water-reducing agent, and a fine aggregate, the expansion material is a calcium aluminophosphate-based expansion material, the pozzolan fine powder is siliceous fine powder with a silicon dioxide (SiO₂) content of 90% or more and a hydrogen-ion concentration within the acidic region, and the water-reducing agent is a polycarboxylic acid-based water-reducing agent.

Citation List

Patent Literature

[0009]

Patent Literature 1: JP2003-171162 A

Patent Literature 2: JP2003-286064 A

Patent Literature 3: JP2008-94674 A

Summary of Invention

Technical Problem

[0010]

In the current situation in which, for example, skyscrapers are frequently raised, further improvement in performance of reinforcing bar joints is required. In particular, in addition to the technique of Patent Literature 3, it is necessary to satisfy high performance of reinforcing bar joints besides tensile strength and to impart an effect of preventing a mortar surface from settling due to a low bleeding rate. Under such circumstances, a problem of the present invention is to provide a filler for a reinforcing bar joint in which a mortar has high fluidity, a cured body of which has dimensional stability and high strength, and which can prevent cracking due to a low bleeding rate.

Solution to Problem

[0011]

As a result of intensive studies to solve the above problem, the present inventors have found that, by focusing on silica fume, a water-reducing agent, the particle size distribution of a fine aggregate, and the abrasion loss measured by a Los Angeles tester in addition to an expansion material to be used, a filler for a reinforcing bar joint in which a mortar has high fluidity, a cured body of which has dimensional stability and high strength, and which is suitable for achieving prevention of mortar surface settlement, and the present invention has been completed.

[0012]

That is, the present invention is as follows.

[1] A filler for a reinforcing bar joint, including cement, an expansion material, silica fume, a water-reducing agent, and a fine aggregate, in which an abrasion loss of the fine aggregate obtained in an aggregate abrasion test performed by a Los Angeles tester using a 0.09-mm sieve is 3% or less; and based on 100% by mass of the fine aggregate, the content ratio of grains with a grain diameter of 0.3 to 2 mm is 60% to 90% by mass, and the content ratio of grains with a grain diameter of less than 0.3 mm is 10% to 40% by mass.

[2] The filler for a reinforcing bar joint according to [1], in which the content of the

expansion material is 3 parts by mass or more and 20 parts by mass or less based on 100 parts by mass of the cement.

[3] The filler for a reinforcing bar joint according to [1] or [2], in which the content of the silica fume is 3 parts by mass or more and 20 parts by mass or less based on 100 parts by mass of the cement.

[4] The filler for a reinforcing bar joint according to any of [1] to [3], in which the content of the water-reducing agent is 0.05 parts by mass or more and 5 parts by mass or less based on 100 parts by mass of the cement.

[5] The filler for a reinforcing bar joint according to any of [1] to [4], in which the content of the fine aggregate is 50 parts by mass or more and 300 parts by mass or less based on 100 parts by mass of the cement.

[6] The filler for a reinforcing bar joint according to any of [1] to [5], in which the fine aggregate is a heavy aggregate with a density of 2.6 g/cm^3 or more.

[7] The filler for a reinforcing bar joint according to any of [1] to [6], including a foaming agent.

[8] The filler for a reinforcing bar joint according to any of [1] to [7], including a defoaming agent.

Advantageous Effects of Invention

[0013]

According to the present invention, mortar in a filler for a reinforcing bar joint has high fluidity, a cured body thereof has dimensional stability and high strength, and prevention of cracks can be achieved.

Description of Embodiments

[0014]

Hereinafter, the present invention will be described in detail. Specific embodiments described below are merely examples, and the present invention is not limited thereto.

[0015]

Filler for reinforcing bar joint

A filler for a reinforcing bar joint of the present invention includes cement, an expansion material, silica fume, a water-reducing agent, and a fine aggregate. The filler for a reinforcing bar joint of the present invention may further include a foaming agent or a defoaming agent. Hereinafter, a cement composition includes cement, an expansion material, silica fume, and a water-reducing agent.

[0016]

Fine aggregate

The fine aggregate used in the present invention is preferably a heavy aggregate and is not particularly limited as long as, for example, strength is developed and fluidity is maintained. Examples thereof include ferronickel slag, ferrochrome slag, olivine, magnetite, hematite, copper slag, and electric furnace oxide slag, and one kind thereof or a combination of two or more kinds thereof may be used in the present invention. The density of the fine aggregate is preferably 2.6 g/cm³ or more and more preferably 2.9 g/cm³ or more. When the fine aggregate is a heavy aggregate having a density of 2.6 g/cm³ or more, the mortar has good fluidity, and material separation hardly occurs. Dry sand obtained by drying each fine aggregate is preferable for use as a premix product, and with respect to the grain size thereof, the maximum grain size is preferably 2.0 mm from the aspect of fluidity. The density of the fine aggregate can be measured in accordance with the method defined in JIS A 1109:2006 "methods of test for density and water absorption of fine aggregates".

[0017]

The abrasion loss of the fine aggregate on a 0.09-mm sieve is 3% or less when tested in an aggregate abrasion test performed using a Los Angeles tester. The abrasion loss is preferably 2.5% or less and more preferably 2.0% or less. Based on 100% by mass of the fine aggregate, the content ratio of grains with a grain diameter of 0.3 to 2 mm is preferably 60% to 90% by mass and more preferably 70% to 85% by mass, and the content ratio of grains with a grain diameter of less than 0.3 mm is preferably 10% to 40% by mass and more preferably 15% to 30% by mass. In this case, since the fine aggregate has adequate hardness and an adequate grain diameter, when the filler for a reinforcing bar joint uses the fine aggregate, mortar has high fluidity, a cured body thereof has dimensional stability and high strength, and prevention of cracks can be achieved. The content ratio of grains with a grain diameter of 0.3 to 2 mm and the content ratio of grains with a grain diameter of less than 0.3 mm are obtained by separating grains into grains with a grain diameter of 0.3 to 2 mm and grains with a grain diameter of less than 0.3 mm using a 0.3-mm sieve and respectively measuring the mass.

[0018]

The abrasion loss obtained in an aggregate abrasion test performed by a Los Angeles tester using a 0.09-mm sieve is measured in accordance with JIS A 1121:2007 "method of test for resistance to abrasion of coarse aggregate by use of the Los Angeles machine" using the following formula.

$$\text{Abrasion loss (\%)} = (m_1 - m_2)/m_1 \times 100$$

m_1 : Total mass (g) of sample before test

m_2 : Mass (g) of sample remaining on 0.09-mm sieve after test

[0019]

The amount used of the fine aggregate is preferably 50 parts by mass or more and 300 parts by mass or less and more preferably 50 parts by mass or more and 200 parts by mass or less based on 100 parts by mass of the cement. When the amount used of the fine aggregate is 50 to 300 parts by mass based on 100 parts by mass of the cement, shrinkage is small, and strength and fluidity are high.

[0020]

Expansion material

Examples of the expansion material of the present invention include a calcium sulfoaluminate-based expansion material, a calcium aluminophosphate-based expansion material, a lime-based expansion material, and a gypsum-based expansion material, but a calcium sulfoaluminate-based expansion material is preferable among them. When a calcium sulfoaluminate-based expansion material is used, an excellent effect of preventing bleeding is provided, an effect of preventing a mortar surface from settling can be imparted, and dimensional stability can be provided; thus, cracks of a cured body can be effectively prevented.

[0021]

Calcium sulfoaluminate-based expansion materials are produced by mixing a CaO raw material, an Al_2O_3 raw material, a Fe_2O_3 raw material, and a $CaSO_4$ raw material at a predetermined ratio and heat-treating same typically at 1,100°C to 1,600°C using an electric furnace, a rotary kiln, or the like. Expansion performance of an expansion material obtained at a heat treatment temperature of 1,100°C to 1,600°C is sufficient, and anhydrite may decompose at a temperature exceeding 1,600°C.

[0022]

Examples of the CaO raw material include limestone and lime hydrate, examples of the Al_2O_3 raw material include bauxite and residual aluminum ash, examples of the Fe_2O_3 raw material include copper slag and commercially available iron oxide, and examples of the $CaSO_4$ raw material include dihydrate gypsum, hemihydrate gypsum, and anhydrite.

[0023]

Fineness of the expansion material is preferably 4,000 cm^2/g or more and 9,000 cm^2/g or less and more preferably 5,000 cm^2/g or more and 8,000 cm^2/g or less in terms of Blaine value. The content of the expansion material is preferably 3 parts by mass or more and 20 parts by mass or less and more preferably 5 parts by mass or more and 15 parts by mass or less based on 100 parts by mass of the cement. Occurrence of bleeding can be prevented in these ranges.

[0024]

Silica fume

The silica fume used in the present invention is used for good fluidity and prevention of bleeding especially at a low water proportion and for strength development and is obtained as silica fume produced during zirconia production process as a by-product. The silica fume used in the present invention has a primary particle diameter larger than that of conventionally used common silica fume but hardly aggregates. From these viewpoints, the content ratio of silicon dioxide (SiO_2) in the silica fume is preferably 85% or more and more preferably 90% or more. The hydrogen-ion concentration is preferably within the acidic region. The hydrogen-ion concentration herein is a value obtained by putting 20 g of the silica fume into 100 g of pure water, stirring same with a magnetic stirrer for 5 minutes, and subsequently measuring the hydrogen-ion concentration in the suspension with a pH meter.

[0025]

Examples of a silica fume production method include a method of oxidizing metal silicon fine powder in a blaze and a method of melting siliceous raw material fine powder in a blaze at a high temperature, and the silica fume can be produced by adjusting heat treatment conditions for raw material and setting the collection temperature to 550°C or higher in such methods. Silica fume may be produced through collection with a cyclone and subsequent classification when zircon sand is electrically melted in an electric furnace.

[0026]

A preferable specific surface area of zirconia-derived silica fume is preferably 5 to $13 \text{ m}^2/\text{g}$ and more preferably 8 to $12 \text{ m}^2/\text{g}$ in terms of BET specific surface area from the viewpoints of fluidity and strength developability.

[0027]

The average particle diameter of zirconia-derived silica fume grains is larger than an average particle diameter of 0.1 to $0.3 \mu\text{m}$ of heretofore used metal silicon, is larger than an average particle diameter of silica fume collected from exhaust gas generated when ferrosilicon is produced in an arc furnace, and is preferably about $1 \mu\text{m}$ or less.

[0028]

The amount of the silica fume used is preferably 3 parts by mass or more and 20 parts by mass or less and more preferably 5 parts by mass or more and 15 parts by mass or less based on 100 parts by mass of the cement. When the amount of the silica fume used is set to 3 to 20 parts by mass based on 100 parts by mass of the cement, strength development is sufficient, ball bearing effect is exhibited, and a load applied during kneading is reduced, and excellent fluidity is obtained with a predetermined water amount.

[0029]

Water-reducing agent

The water-reducing agent used in the present invention is a general term for those having action of dispersing in cement and air-entraining action, improving fluidity, and increasing strength, and specific examples thereof include a naphthalene sulfonate-based water-reducing agent, a melamine sulfonate-based water-reducing agent, a lignosulfonate-based water-reducing agent, and a polycarboxylic acid-based water-reducing agent. A polycarboxylic acid-based water-reducing agent is preferable in the present invention. Fluidity is maintained well when a polycarboxylic acid-based water-reducing agent is used.

[0030]

The water-reducing agent may be used both in a power form and a liquid form; however, the water-reducing agent is preferably powder when used as a premix product. The content of the water-reducing agent as powder is preferably 0.05 parts by mass or more and 5 parts by mass or less and more preferably 0.1 parts by mass or more and 2 parts by mass or less based on 100 parts by mass of the cement.

[0031]

When the content of the water-reducing agent is 0.05 to 5 parts by mass based on 100 parts by mass of the cement, high fluidity is obtained. A melamine sulfonate-based water-reducing agent and a lignosulfonate-based water-reducing agent can be used in combination within a range not impairing the effects of the present invention.

[0032]

Foaming agent

In the present invention, a foaming agent generating gas when kneaded with water can be used together in order to obtain initial expansion of mortar after kneading. The foaming agent is not particularly limited, and examples thereof include metal powder and a peroxide. Although aluminum powder is particularly preferable from the aspect of the amount added and effect provided, surfaces of aluminum powder are likely to be oxidized, and reactivity decreases when aluminum powder is covered with oxide coating. Therefore, aluminum powder having been surface-treated with a vegetable oil, a mineral oil, stearic acid, or the like is preferable.

[0033]

The amount of the foaming agent used is preferably 0.0001 parts by mass or more and 0.003 parts by mass or less, more preferably 0.0002 parts by mass or more and 0.003 parts by mass or less, and further preferably 0.001 parts by mass or more and 0.002 parts by mass or less based on 100 parts by mass of the cement. When the amount of the foaming agent used is 0.0001 parts or more, a mortar surface can be effectively prevented from settling, and when

the amount of the foaming agent used is 0.003 parts or less, excessive foaming is not caused, and decrease in strength can be prevented.

[0034]

Defoaming agent

A defoaming agent is preferably used in the present invention. The defoaming agent is not particularly limited and examples thereof include a mixture of a particular nonionic surfactant and silica. The amount of the defoaming agent used is preferably 0.3 parts by mass or less and more preferably 0.1 parts by mass or less based on 100 parts by mass of the cement. When the amount of the defoaming agent used is 0.3 parts by mass or less, defoamed foam does not rise in a large quantity to the surface of the cement mortar.

[0035]

Cement

Examples of the cement used in the present invention include various types of Portland cement such as ordinary, high early strength, ultra high early strength, low heat, and moderate heat, various types of mixed cement obtained by mixing these types of Portland cement with blast furnace slag, fly ash, silica, limestone fine powder, or the like and waste utilization cement called eco-cement. Among them, ordinary or high early strength cement is preferable from the aspect of kneading properties and strength development.

[0036]

From the viewpoints of production costs and strength developability, the Blaine value of the cement is preferably 2,500 to 7,000 cm²/g and more preferably 3,000 to 4,500 cm²/g. The Blaine value is obtained in accordance with JIS R 5201:2015 "physical testing methods for cement".

[0037]

Construction method of filling reinforcing bar joint

The filler for a reinforcing bar joint of the present invention is used in a construction method of adding water to the filler for a reinforcing bar joint and kneading same. Specifically, water is firstly added to the filler for a reinforcing bar joint to produce a mortar. Although kneading of the mortar is not particularly limited, a hand mixer with a rotating speed of 900 rpm or more, a common high speed grout mixer, and a biaxial forced mixer are preferably used.

[0038]

Kneading with a hand mixer or a high speed grout mixer is carried out by preliminarily placing a predetermined amount of water in a mixer or a kneading container such as a pail can, and subsequently putting therein the filler for a reinforcing bar joint preliminarily mixed, while rotating the mixer, followed by kneading for two minutes or longer. Kneading with a

forced mixer is carried out by putting, into the mixer, the filler for a reinforcing bar joint preliminarily mixed, and putting a predetermined amount of water while rotating the mixer, followed by kneading for at least two minutes or longer. When the kneading time is two minutes or longer, a mortar with adequate fluidity is easily obtained.

[0039]

After a reinforcing bar is inserted into a joint, the kneaded mortar is applied to fill the joint usually using a diaphragm manual pump, or a squeeze mortar pump. Thereafter, the mortar turns into a cured body, and the reinforcing bar is firmly fixed by the joint.

[0040]

Although the amount of water used for kneading in the present invention is not particularly limited, water is added in an amount of preferably 10 to 30 parts by mass and more preferably 10 to 20 parts by mass based on 100 parts by mass of the filler for a reinforcing bar joint. Fluidity and strength are high within this range.

Examples

[0041]

Experimental Example 1

Cement and an expansion material, silica fume, a water-reducing agent, a fine aggregate, a foaming agent, and a defoaming agent in the amounts shown in Table 2, which were based on 100 parts by mass of the cement, were mixed to prepare a filler for a reinforcing bar joint formed therefrom. Mortar was produced by adding 15 parts by mass of water to 100 parts by mass of the cement composition. The flow, bleeding rate, expansion/shrinkage rate, compression strength, and length change rate of the produced mortar were measured at a temperature of 20°C.

[0042]

Materials used

(a) Cement: ordinary Portland cement, Blaine value of 3,300 cm²/g, commercially available product

(b) Expansion material: calcium sulfoaluminate-based expansion material, Blaine value of 6,000 cm²/g, commercially available product

(c) Silica fume: silica fume including zirconium oxide, zirconium oxide content of 5%, BET specific surface area of 12 m²/g, pH 3.0, commercially available product

(d) Water-reducing agent: polycarboxylic acid-based water-reducing agent, commercially available product

(e) Fine aggregate

The content ratios of the fine aggregate shown below are values rounded off to the

nearest in units of 10% by mass.

(e-1) Fine aggregate A: ferronickel slag aggregate, density of 3.11 g/cm^3 , maximum aggregate diameter of 2.0 mm, aggregate abrasion loss measured by Los Angeles tester (using 0.09-mm sieve) of 1.2%, content ratio of grains with grain diameter of 0.3 to 2 mm of 80% by mass, content ratio of grains with grain diameter of less than 0.3 mm of 20% by mass, commercially available product

(e-2) Fine aggregate B: ferrochrome slag aggregate, density of 3.12 g/cm^3 , maximum aggregate diameter of 2.0 mm, aggregate abrasion loss measured by Los Angeles tester (using 0.09-mm sieve) of 1.4%, content ratio of grains with grain diameter of 0.3 to 2 mm of 80% by mass, content ratio of grains with grain diameter of less than 0.3 mm of 20% by mass, commercially available product

(e-3) Fine aggregate C: olivine aggregate, density of 3.00 g/cm^3 , maximum aggregate diameter of 2.0 mm, aggregate abrasion loss measured by Los Angeles tester (using 0.09-mm sieve) of 0.9%, content ratio of grains with grain diameter of 0.3 to 2 mm of 80% by mass, content ratio of grains with grain diameter of less than 0.3 mm of 20% by mass, commercially available product

(e-4) Fine aggregate D: ferronickel slag aggregate, density of 3.11 g/cm^3 , maximum aggregate diameter of 2.0 mm, aggregate abrasion loss measured by Los Angeles tester (using 0.09-mm sieve) of 1.2%, content ratio of grains with grain diameter of 0.3 to 2 mm of 20% by mass, content ratio of grains with grain diameter of less than 0.3 mm of 80% by mass, commercially available product

(e-5) Fine aggregate E: ferronickel slag aggregate, density of 2.95 g/cm^3 , maximum aggregate diameter of 2.0 mm, aggregate abrasion loss measured by Los Angeles tester (using 0.09-mm sieve) of 3.9%, content ratio of grains with grain diameter of 0.3 to 2 mm of 80% by mass, content ratio of grains with grain diameter of less than 0.3 mm of 20% by mass, commercially available product

(e-6) Fine aggregate F: steel slag aggregate, density of 3.61 g/cm^3 , maximum aggregate diameter of 2.0 mm, aggregate abrasion loss measured by Los Angeles tester (using 0.09-mm sieve) of 2.5%, content ratio of grains with grain diameter of 0.3 to 2 mm of 80% by mass, content ratio of grains with grain diameter of less than 0.3 mm of 20% by mass, commercially available product

(e-7) Fine aggregate G: silica sand, density of 2.60 g/cm^3 , maximum aggregate diameter of 2.0 mm, aggregate abrasion loss measured by Los Angeles tester (using 0.09-mm sieve) of 4.8%, content ratio of grains with grain diameter of 0.3 to 2 mm of 80% by mass, content ratio of grains with grain diameter of less than 0.3 mm of 20% by mass, commercially

available product

(e-8) Fine aggregate H: limestone aggregate, density of 2.60 g/cm^3 , maximum aggregate diameter of 2.0 mm, aggregate abrasion loss measured by Los Angeles tester (using 0.09-mm sieve) of 4.0%, content ratio of grains with grain diameter of 0.3 to 2 mm of 80% by mass, content ratio of grains with grain diameter of less than 0.3 mm of 20% by mass, commercially available product

(e-9) Fine aggregate I: ferrochrome slag aggregate, density of 3.10 g/cm^3 , maximum aggregate diameter of 2.0 mm, aggregate abrasion loss measured by Los Angeles tester (using 0.09-mm sieve) of 4.0%, content ratio of grains with grain diameter of 0.3 to 2 mm of 20% by mass, content ratio of grains with grain diameter of less than 0.3 mm of 80% by mass, commercially available product

(e-10) Fine aggregate J: ferronickel slag aggregate, density of 3.11 g/cm^3 , maximum aggregate diameter of 2.0 mm, aggregate abrasion loss measured by Los Angeles tester (using 0.09-mm sieve) of 1.2%, content ratio of grains with grain diameter of 0.3 to 2 mm of 60% by mass, content ratio of grains with grain diameter of less than 0.3 mm of 40% by mass, commercially available product

(e-11) Fine aggregate K: ferronickel slag aggregate, density of 3.11 g/cm^3 , maximum aggregate diameter of 2.0 mm, aggregate abrasion loss measured by Los Angeles tester (using 0.09-mm sieve) of 1.2%, content ratio of grains with grain diameter of 0.3 to 2 mm of 90% by mass, content ratio of grains with grain diameter of less than 0.3 mm of 10% by mass, commercially available product

(e-12) Fine aggregate L: ferronickel slag aggregate, density of 3.05 g/cm^3 , maximum aggregate diameter of 2.0 mm, aggregate abrasion loss measured by Los Angeles tester (using 0.09-mm sieve) of 3.0%, content ratio of grains with grain diameter of 0.3 to 2 mm of 80% by mass, content ratio of grains with grain diameter of less than 0.3 mm of 20% by mass, commercially available product

(e-13) Fine aggregate M: ferronickel slag aggregate, density of 3.11 g/cm^3 , maximum aggregate diameter of 2.0 mm, aggregate abrasion loss measured by Los Angeles tester (using 0.09-mm sieve) of 1.2%, content ratio of grains with grain diameter of 0.3 to 2 mm of 100% by mass, content ratio of grains with grain diameter of less than 0.3 mm of 0% by mass, commercially available product

(f) Foaming agent: aluminum powder (surface-treated product), commercially available product

(g) Defoaming agent: mixture of particular nonionic surfactant and silica, commercially available product

(h) Water: tap water

Table 1 shows fine aggregates A to M.

[0043]

Table 1

	Type of fine aggregate	Density (g/cm ³)	Maximum aggregate diameter (mm)
Fine aggregate A	Ferronickel slag aggregate	3.11	2.0
Fine aggregate B	Ferrochrome slag aggregate	3.12	2.0
Fine aggregate C	Olivine aggregate	3.00	2.0
Fine aggregate D	Ferronickel slag aggregate	3.11	2.0
Fine aggregate E	Ferronickel slag aggregate	2.95	2.0
Fine aggregate F	Steel slag aggregate	3.61	2.0
Fine aggregate G	Silica sand	2.60	2.0
Fine aggregate H	Limestone aggregate	2.60	2.0
Fine aggregate I	Ferrochrome slag aggregate	3.10	2.0
Fine aggregate J	Ferronickel slag aggregate	3.11	2.0
Fine aggregate K	Ferronickel slag aggregate	3.11	2.0
Fine aggregate L	Ferronickel slag aggregate	3.05	2.0
Fine aggregate M	Ferronickel slag aggregate	3.11	2.0

Table 1 (Continued)

	Aggregate abrasion loss (%) measured by Los Angeles tester	Content ratio of grains with grain diameter of 0.3 to 2 mm (mass%)	Content ratio of grains with grain diameter of less than 0.3 mm (mass%)
Fine aggregate A	1.2	80	20
Fine aggregate B	1.4	80	20
Fine aggregate C	0.9	80	20
Fine aggregate D	1.2	20	80
Fine aggregate E	3.9	80	20
Fine aggregate F	2.5	80	20
Fine aggregate G	4.8	80	20
Fine aggregate H	4.0	80	20
Fine aggregate I	4.0	20	80
Fine aggregate J	1.2	60	40
Fine aggregate K	1.2	90	10
Fine aggregate L	3.0	80	20
Fine aggregate M	1.2	100	0

[0044]

Evaluation method

(1) Flow: measured in accordance with JASS 15 M-103 "self-leveling material quality standard". A vinyl chloride resin pipe with a size of $\varnothing 50 \times 100$ mm was used as a flow container. The pipe was filled with the mortar, and the pipe was pulled up. After the spread

of the mortar was stopped, the diameters in two mutually perpendicular directions were measured, and the average value thereof was taken as a flow value.

(2) Bleeding rate: in accordance with JSCE-F 542-1999, the mortar prepared in each of the Examples and Comparative Examples was collected in a container, bleeding water was collected three hours later, and the ratio of the amount of the bleeding water to the volume of the sample was taken as the bleeding rate.

(3) Expansion/shrinkage rate: in accordance with JSCE-F 542-1999, the mortar prepared in each of the Examples and Comparative Examples was collected in a mold, the depth from the bridge top surface to the glass plate was measured 24 hours later, and the expansion/shrinkage rate was obtained from the difference from the base length.

(4) Compression strength: measured in accordance with JSCE-G 505-1999. The size of the test piece was $\varnothing 50 \text{ mm} \times 100 \text{ mm}$, underwater curing was carried out after demolding over one day, and the test piece at a material age of 28 days was tested to obtain compression strength.

(5) Length change rate: measured in accordance with JIS A 6202:2017, Appendix A, "method for testing expansibility of expansion material using mortar". The test piece was cured under water at a material age of one day, and the length change rate was obtained from the length of the test piece at a material age of seven days.

The results are shown in Table 2.

[0045]

Table 2

No.		1-1	1-2	1-3	1-4	1-5
Amount of expansion material (parts by mass)		5	10	15	10	10
Amount of silica fume (parts by mass)		10	10	10	5	15
Amount of water-reducing agent (parts by mass)		0.5	0.5	0.5	0.5	0.5
Fine aggregate	Type	A	A	A	A	A
	Amount (parts by mass)	110	110	110	110	110
Amount of foaming agent (parts by mass)		0	0	0	0	0
Amount of defoaming agent (parts by mass)		0	0	0	0	0
Flow (mm)		211	206	195	168	211
Bleeding rate (%)		0.8	0.0	0.0	0.2	0.0
Expansion/shrinkage rate (%)		-1.20	-1.00	-0.65	-1.14	-0.95
Compression strength (N/mm ²)		92	90	82	80	93
Length change rate ($\times 10^{-6}$)		163	319	753	327	287
Remarks		Examples	Examples	Examples	Examples	Examples

Table 2 (Continued)

No.		1-6	1-7	1-8	1-9	1-10
Amount of expansion material (parts by mass)		10	10	10	10	10
Amount of silica fume (parts by mass)		10	10	10	10	10
Amount of water-reducing agent (parts by mass)		0.1	2	0.5	0.5	0.5
Fine aggregate	Type	A	A	A	A	A
	Amount (parts by mass)	110	110	70	150	110
Amount of foaming agent (parts by mass)		0	0	0	0	0.0015
Amount of defoaming agent (parts by mass)		0	0	0	0	0.1
Flow (mm)		151	233	210	176	205
Bleeding rate (%)		0.0	0.0	0.0	0.0	0.0
Expansion/shrinkage rate (%)		-0.92	-1.06	-1.22	-0.88	+0.25
Compression strength (N/mm ²)		92	89	95	80	108
Length change rate ($\times 10^{-6}$)		325	303	497	202	317
Remarks		Examples	Examples	Examples	Examples	Examples

Table 2 (Continued)

No.		1-11	1-12	1-13	1-14	1-15
Amount of expansion material (parts by mass)		0	10	10	10	10
Amount of silica fume (parts by mass)		10	0	10	10	10
Amount of water-reducing agent (parts by mass)		0.5	0.5	0	0.5	0.5
Fine aggregate	Type	A	A	A	A	D
	Amount (parts by mass)	110	110	110	0	110
Amount of foaming agent (parts by mass)		0.0015	0.0015	0.0015	0.0015	0.0015
Amount of defoaming agent (parts by mass)		0.1	0.1	0.1	0.1	0.1
Flow (mm)		219	142	55	215	170
Bleeding rate (%)		2.9	0.5	0.0	0.0	0.0
Expansion/shrinkage rate (%)		+0.02	+0.17	+0.14	+0.07	+0.27
Compression strength (N/mm ²)		107	62	68	72	102
Length change rate ($\times 10^{-6}$)		-2	341	328	912	307
Remarks		Comparative Example	Comparative Example	Comparative Example	Comparative Example	Comparative Example

[0046]

It can be seen from Table 2 that the mortars for the filler for a reinforcing bar joint used in the Examples have relatively high flow values and thus provide mortars with high fluidity, have relatively low bleeding rates and thus can prevent mortar surfaces from settling, have relatively low expansion/shrinkage rates and relatively low length change rates and thus impart dimension stability to cured bodies and can prevent cracks of the cured bodies, and have relatively high compression strength and thus provide cured bodies with high strength. With reference to the conditions shown in such Examples and the like, Experimental Example 2 shown below was conducted.

[0047]

Experimental Example 2

A filler for a reinforcing bar joint, including, based on 100 parts by mass of cement, 10 parts by mass of an expansion material, 10 parts by mass of silica fume, 0.5 parts by mass of a water-reducing agent, 0.001 parts by mass of a foaming agent, 0.1 parts by mass of a defoaming agent, and a fine aggregate of the type and in the amount shown in Table 3 was prepared. Mortar was produced by adding 15 parts by mass of water to 100 parts by mass of the cement composition. The materials used for the mortar were identical to those of

Experimental Example 1.

[0048]

The flow, bleeding rate, expansion/shrinkage rate, compression strength, and length change rate of the produced mortar were measured at a temperature of 20°C in the same manner as Experimental Example 1.

Then, a reinforcing bar joint test body was produced using a reinforcing bar (code type: SD490, named D32) defined in JIS G 3112:2010 "steel bars for concrete reinforcement", using S10U/II as a joint, and employing a post-grouting method as follows: after the reinforcing bar was inserted into the joint, the joint is filled with the kneaded mortar using a diaphragm-type hand-actuated pump from an inlet of the joint, and filling of the mortar was stopped after confirming that the mortar was ejected from an air outlet of the joint.

[0049]

The produced reinforcing bar joint test body was cured to a predetermined material age (28 days) in a temperature-controlled room at 20°C and then subjected to a test using the method defined in "standards for determining performance of reinforcing bar joints" described in "Commentary on Structural Regulations of the Building Standard Law of Japan 2007 edition". Evaluation was carried out regarding whether the filler for a reinforcing bar joint after curing at 20°C conformed to A grade performance defined in "standards for determining performance of reinforcing bar joints".

[0050]

Standards for determining performance of reinforcing bar joints

A monoaxial tensile test, a monoaxial cyclic test, an elastic range positive/negative cyclic test, and a plastic range positive/negative cyclic test were performed on the reinforcing bar joint test body to determine tensile strength, stiffness reduction rate, slip amount, and toughness, and whether each of these items satisfied the standards for determining performance of reinforcing bar joints (grade A) was confirmed. Here, ${}_{1c}E$ and ${}_{20c}E$ are the secant stiffnesses of the joined reinforcing bar at a stress of $0.95\delta_{y0}$ on the first application and the twentieth application of force, respectively, ${}_{20c}\delta_s$ and ${}_{4c}\delta_s$ are the slip deformations of the joined reinforcing bar on the twentieth application and the fourth application of force, respectively, ϵ_u is the final strain of the joined reinforcing bar, and ϵ_y is the yield strain of the joined reinforcing bar.

Results are shown in Table 3 together with the standards for determining performance of reinforcing bar joints (grade A).

[0051]

Table 3

No.			Standards for determining performance of reinforcing bar joints (grade A)	2-1	2-2	2-3	2-4	2-5
Fine aggregate	Type		-	A	B	C	D	E
	Amount (parts by mass)		-	110	110	110	110	110
Flow (mm)			-	205	210	195	170	191
Bleeding rate (%)			-	0.0	0.0	0.0	0.0	0.0
Expansion/shrinkage rate (%)			-	+0.25	+0.22	+0.19	+0.27	+0.20
Compression strength (N/mm ²)			-	108	105	97	102	110
Length change rate (×10 ⁻⁶)			-	317	310	322	307	301
Performance of reinforcing bar joint	Tensile strength (N/mm ²)		≥620	746	751	733	711	605
	Stiffness reduction rate (20cE _l /E)		≥0.5	0.85	0.80	0.91	0.79	0.73
	Slip amount	20cδ _s (mm)	≤0.3	0.13	0.11	0.10	0.39	0.22
		4cδ _s (mm)	≤0.6	0.28	0.32	0.25	0.54	0.41
	Toughness	ε _u (%)	≥2	4.0	3.8	4.1	1.8	1.7
		ε _u /ε _y	≥10	19.1	19.6	19.5	9.4	7.5
Remarks			-	Examples	Examples	Examples	Comparative Example	Comparative Example

Table 3 (Continued)

No.			Standards for determining performance of reinforcing bar joints (grade A)	2-6	2-7	2-8	2-9	2-10
Fine aggregate	Type		-	F	G	H	I	J
	Amount (parts by mass)		-	110	110	110	110	110
Flow (mm)			-	216	172	165	208	188
Bleeding rate (%)			-	0.0	0.0	0.0	0.0	0.0
Expansion/shrinkage rate (%)			-	+0.29	+0.33	+0.35	+0.17	+0.26
Compression strength (N/mm ²)			-	106	95	91	102	105
Length change rate (×10 ⁻⁶)			-	305	343	352	323	310
Performance of reinforcing bar joint	Tensile strength (N/mm ²)		≥620	637	603	597	602	738
	Stiffness reduction rate (20cE/1cE)		≥0.5	0.76	0.71	0.63	0.71	0.82
	Slip amount	20cδ _s (mm)	≤0.3	0.20	0.34	0.32	0.25	0.20
		4cδ _s (mm)	≤0.6	0.51	0.55	0.53	0.48	0.35
	Toughness	ε _u (%)	≥2	2.9	1.8	1.5	1.8	3.0
		ε _u /ε _y	≥10	11.1	7.3	7.0	7.7	16.3
Remarks			-	Examples	Comparative Example	Comparative Example	Comparative Example	Examples

Table 3 (Continued)

No.			Standards for determining performance of reinforcing bar joints (grade A)	2-11	2-12	2-13
Fine aggregate	Type		-	K	L	M
	Amount (parts by mass)		-	110	110	110
Flow (mm)			-	219	200	238
Bleeding rate (%)			-	0.0	0.0	0.6
Expansion/shrinkage rate (%)			-	+0.14	+0.27	+0.07
Compression strength (N/mm ²)			-	100	95	87
Length change rate (×10 ⁻⁶)			-	306	318	306
Performance of reinforcing bar joint	Tensile strength (N/mm ²)		≥620	722	629	605
	Stiffness reduction rate (20cE/1cE)		≥0.5	0.83	0.77	0.64
	Slip amount	20cδs (mm)	≤0.3	0.11	0.17	0.25
		4cδs (mm)	≤0.6	0.26	0.37	0.41
	Toughness	εu (%)	≥2	3.7	2.1	1.9
		εu/εy	≥10	18.5	10.9	9.7
Remarks			-	Examples	Examples	Comparative Example

[0052]

From Table 3, the reinforcing bar joint test bodies of the Examples were found to satisfy the standards for determining performance of reinforcing bar joints (grade A). From these results, it can be determined that the filler for a reinforcing bar joint of the present invention can achieve high reinforcing bar joint performance and can sufficiently firmly connect the reinforcing bars by the joint.

CLAIMS

[Claim 1]

A filler for a reinforcing bar joint, comprising cement, an expansion material, silica fume, a water-reducing agent, and a fine aggregate, wherein an abrasion loss of the fine aggregate obtained in an aggregate abrasion test performed by a Los Angeles tester using a 0.09-mm sieve is 3% or less; and based on 100% by mass of the fine aggregate, a content ratio of grains with a grain diameter of 0.3 to 2 mm is 60% to 90% by mass, and a content ratio of grains with a grain diameter of less than 0.3 mm is 10% to 40% by mass.

[Claim 2]

The filler for a reinforcing bar joint according to claim 1, wherein a content of the expansion material is 3 parts by mass or more and 20 parts by mass or less based on 100 parts by mass of the cement.

[Claim 3]

The filler for a reinforcing bar joint according to claim 1 or 2, wherein a content of the silica fume is 3 parts by mass or more and 20 parts by mass or less based on 100 parts by mass of the cement.

[Claim 4]

The filler for a reinforcing bar joint according to any one of claims 1 to 3, wherein a content of the water-reducing agent is 0.05 parts by mass or more and 5 parts by mass or less based on 100 parts by mass of the cement.

[Claim 5]

The filler for a reinforcing bar joint according to any one of claims 1 to 4, wherein a content of the fine aggregate is 50 parts by mass or more and 300 parts by mass or less based on 100 parts by mass of the cement.

[Claim 6]

The filler for a reinforcing bar joint according to any one of claims 1 to 5, wherein the fine aggregate is a heavy aggregate with a density of 2.6 g/cm³ or more.

[Claim 7]

The filler for a reinforcing bar joint according to any one of claims 1 to 6, comprising a foaming agent.

[Claim 8]

The filler for a reinforcing bar joint according to any one of claims 1 to 7, comprising a defoaming agent.