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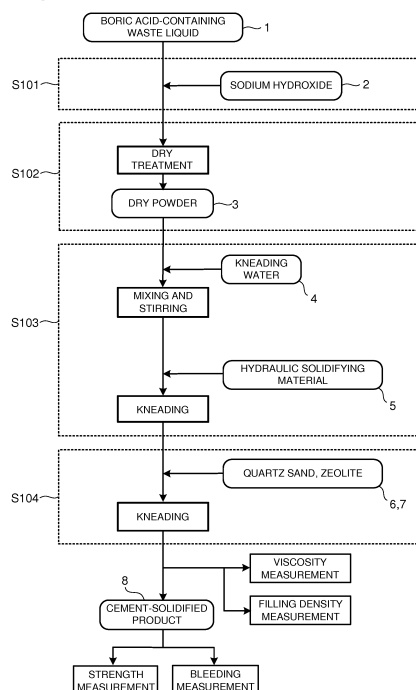
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(54) **CEMENTATION METHOD AND CEMENTATION DEVICE FOR BORIC-ACID-CONTAINING LIQUID WASTE**

(57) A cement-solidification method includes: a volume reduction step of adding a sodium hydroxide 2 to a radioactive boric acid-containing waste liquid 1 and reducing a volume thereof to prepare a matter to be solidified; a first kneading step of kneading the matter to be solidified, a kneading water 4, and a hydraulic solidifying material 5 to prepare a first kneaded product; and a second kneading step of kneading quartz sand 6 and the first kneaded product to prepare a second kneaded product, wherein a weight ratio of the quartz sand 6 to the hydraulic solidifying material 5 (a weight of the quartz sand/a weight of the hydraulic solidifying material) is 1.5 to 3.0. A cement-solidification apparatus 10 includes: a kneader 11; a to-be-solidified matter supply device 12; a kneading water supply device 13; a hydraulic solidifying material supply device 14; and a quartz sand supply device 15.

FIG. 1



Description

FIELD

5 **[0001]** Embodiments described herein relate generally to a cement-solidification method and a cement-solidification apparatus for a boric acid-containing waste liquid.

BACKGROUND

10 **[0002]** In a pressurized water type nuclear power plant, a large amount of boric acid-containing waste liquid which has been used for power adjustment of a nuclear reactor and the like is generated. Further, in a boiling water type nuclear power plant, a boric acid solution to be urgently injected into the nuclear reactor is stored and a boric acid-containing waste liquid is sometimes generated.

15 **[0003]** The boric acid-containing waste liquid is subjected to a neutralization treatment using a sodium hydroxide, a lithium hydroxide or the like, and then solidified with cement or asphalt. In the cement solidification, a boric acid interferes with a setting reaction of cement, resulting in substantial hardening retardation or decrease in strength of a solidified body. Therefore, from the viewpoint of cement-solidifying the boric acid-containing waste liquid while increasing the volume reduction, various kinds of suggestion such as adding a calcium hydroxide or the like as a pretreatment agent for solidification and so on.

20 **[0004]** To avoid hardening retardation due to borate and hydration of sodium borate, there is suggested a method of adding a calcium hydroxide to a radioactive boric acid-containing waste liquid into a dry powder, and then performing compression solidification, solidification with a resin, cement solidification or the like (refer to, for example, Patent Reference 1). In this method which is useful because borate is stabilized and then treated, there is such inconvenience that hardly-soluble waste liquid components may adhere to the inside of piping and the inside of a dryer and the like, and

25 the adhering waste liquid components are difficult to clean and so on.

[0005] As a method of solidifying the radioactive boric acid-containing waste liquid, there is suggested a method of making the boric acid-containing waste liquid into a dry powder, then mixing an alkaline silicate binding agent aqueous solution, and further mixing an auxiliary agent composed of an acidic hardening agent, a hardening retarder, quartz sand or the like for solidification (refer to, for example, Patent Reference 2). This method is for performing solidification using

30 water glass as a main component of a solidifying material and not cement as the main component.

RELEVANT REFERENCES

Patent Reference

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[0006]

Patent Reference 1: JP-A H2-208600

Patent Reference 2: JP-A H4-018640

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SUMMARY

PROBLEMS TO BE SOLVED BY THE INVENTION

45 **[0007]** As described above, the conventional cement-solidification method for a boric acid-containing waste liquid has a problem such as the need for higher volume reduction.

[0008] The present invention has been made to solve the above problem and its object is to provide a cement-solidification method and a cement-solidification apparatus for a boric acid-containing waste liquid, capable of making the boric acid-containing waste liquid into a stable cement-solidified product with high volume reduction.

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MEANS FOR SOLVING THE PROBLEMS

[0009] An aspect of the cement-solidification method for a boric acid-containing waste liquid according to the present invention is a method of cement-solidifying a radioactive boric acid-containing waste liquid, including: a volume reduction step of adding a sodium hydroxide to the boric acid-containing waste liquid and reducing a volume thereof to prepare a matter to be solidified; a first kneading step of kneading the matter to be solidified, a kneading water, and a hydraulic solidifying material to prepare a first kneaded product; and a second kneading step of kneading quartz sand and the first kneaded product to prepare a second kneaded product, wherein a weight ratio of the quartz sand to the hydraulic

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solidifying material (a weight of the quartz sand/a weight of the hydraulic solidifying material) is 1.5 to 3.0.

[0010] An aspect of the cement-solidification apparatus for a boric acid-containing waste liquid according to the present invention is an apparatus for cement-solidifying a radioactive boric acid-containing waste liquid, including: a kneader; a to-be-solidified matter supply device that adds a sodium hydroxide to the boric acid-containing waste liquid and reduces a volume thereof to prepare a matter to be solidified, and supplies the matter to be solidified to the kneader; a kneading water supply device that supplies a kneading water to the kneader; a hydraulic solidifying material supply device that supplies a hydraulic solidifying material to the kneader to prepare a first kneaded product; and a quartz sand supply device that supplies quartz sand to the kneader to prepare a second kneaded product, wherein a weight ratio of the quartz sand to the hydraulic solidifying material (a weight of the quartz sand/a weight of the hydraulic solidifying material) in the quartz sand supply device is 1.5 to 3.0.

EFFECT OF THE INVENTION

[0011] According to the present invention, it is possible to make a boric acid-containing waste liquid into a stable cement-solidified product with high volume reduction.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012]

Fig. 1 is a flowchart illustrating steps of a cement-solidification method for a boric acid-containing waste liquid according to an embodiment of the present invention.

Fig. 2 is a schematic block diagram illustrating a cement-solidification apparatus for a boric acid-containing waste liquid according to an embodiment of the present invention.

Fig. 3 is a graph illustrating the relationship between the value of S/C and the strength of a cement-solidified product in Examples.

DETAILED DESCRIPTION

[0013] Fig. 1 is a flowchart illustrating steps of a cement-solidification method for a boric acid-containing waste liquid according to an embodiment of the present invention. Fig. 2 is a schematic block diagram illustrating a cement-solidification apparatus for a boric acid-containing waste liquid according to an embodiment of the present invention. Hereinafter, an embodiment of the present invention will be described referring to Fig. 1 and Fig. 2.

[0014] The cement-solidification method illustrated in Fig. 1 has: a step (S101) of adding a sodium hydroxide 2 to a boric acid-containing waste liquid 1; a volume reduction step (S102) of drying the boric acid-containing waste liquid 1 with the sodium hydroxide 2 added thereto to prepare a dry powder 3; a first kneading step (S103) of kneading the dry powder 3, a kneading water 4, and a hydraulic solidifying material 5 to prepare a first kneaded product; and a second kneading step (S104) of kneading the first kneaded product and quartz sand 6 to prepare a second kneaded product.

[0015] Besides, a cement-solidification apparatus 10 illustrated in Fig. 2 includes a kneader 11, a to-be-solidified matter supply device 12 that supplies a matter to be solidified to the kneader 11, and a kneading water supply device 13 that supplies the kneading water 4 to the kneader 11. The cement-solidification apparatus 10 further includes a hydraulic solidifying material supply device 14 that supplies the hydraulic solidifying material 5 to the kneader 11, and a quartz sand supply device 15 that supplies the quartz sand 6 to the kneader 11. Further, the to-be-solidified matter supply device 12 includes a volume reduction device (not illustrated) for reducing the volume of the boric acid-containing waste liquid 1 into the matter to be solidified. The matter to be solidified is the dry powder 3 obtained by drying the boric acid-containing waste liquid 1 or a concentrated waste liquid obtained by concentrating the boric acid-containing waste liquid 1. The volume reduction device, for example, heats and dries the boric acid-containing waste liquid 1 into the dry powder 3 or reduces its volume into the concentrated waste liquid. The quartz sand supply device 15 is provided with a quartz sand supply rate adjusting device 16 that adjusts the quartz sand supply rate of the quartz sand supply device 15 to a predetermined rate. A numeral 17 denotes a solidification container that houses therein and solidifies the second kneaded product kneaded by the kneader 11.

(First Step (S101 illustrated in Fig. 1))

[0016] The object of cement solidification in this embodiment is a radioactive waste liquid containing boric acid (boric acid-containing waste liquid 1). The first step in this embodiment is a step of adding the sodium hydroxide 2 to the boric acid-containing waste liquid 1. Thus, the sodium hydroxide 2 reacts with boron in the boric acid-containing waste liquid 1 to generate a sodium borate.

[0017] The amount of the sodium hydroxide 2 is prepared to such an amount that a sodium/boron mole ratio (Na/B mole ratio) is preferably 0.2 or more, more preferably 0.2 to 0.5, and particularly preferably 0.2 to 0.3. This increases the solubility of the sodium borate to water, thereby making it possible to improve the cleaning property for the piping, dryer and so on.

(Second Step (S102 illustrated in Fig. 1))

[0018] The second step in this embodiment is a step of reducing the volume of the boric acid-containing waste liquid 1 so as to solidify a large amount of the boric acid-containing waste liquid 1 with high volume reduction. In the second step in this embodiment, the boric acid-containing waste liquid 1 is supplied to the dryer where a dry treatment is performed to obtain the dry powder 3.

[0019] From the viewpoint of reduction of extraneous matters to the piping and the like, the temperature of the boric acid-containing waste liquid 1 after addition of the sodium hydroxide 2 thereto is adjusted to the deposition temperature of the sodium borate, preferably 60°C or higher, and more preferably about 80°C to 90°C or higher, and then the boric acid-containing waste liquid 1 is supplied to the dryer. In the dryer, the boric acid-containing waste liquid 1 is heated preferably to about 80°C or higher, more preferably about 120 to 180°C, and particularly preferably about 160°C for dry treatment.

[0020] The dryer is not particularly limited, but a centrifugal-film dryer is preferably used. This is because the centrifugal-film dryer has such features that it is high in thermal efficiency and therefore enables downsizing of the apparatus, a powder transfer amount to a gas phase part is small during the dry treatment, the particle size of sodium borate powder to be obtained is stable and so on.

[0021] Note that when reducing the volume of the boric acid-containing waste liquid 1, instead of performing the above-described dry treatment, a concentration treatment or a sedimentation treatment may be performed. Thereby, the concentrated waste liquid can be obtained. In the concentration treatment, for example, the boric acid-containing waste liquid 1 is concentrated by heating and prepared so that the water content in the boric acid-containing waste liquid is about 30% or less by weight ratio. In the sedimentation treatment, an additive is added to the boric acid-containing waste liquid 1 to make the sodium borate to settle down. The settled sodium borate is separated to obtain the concentrated waste liquid. In this embodiment, the same effect can be obtained by performing any of the treatments. Note that the dry powder 3 and the concentrated waste liquid after volume reduction may be cooled down to about room temperature (normal temperature: 25°C) or may be subjected to the next third step without cooling.

(Third Step (S103 illustrated in Fig. 1))

[0022] The third step in this embodiment is a step of kneading the dry powder 3, the kneading water 4, and the hydraulic solidifying material 5 using the kneader to prepare the first kneaded product.

[0023] The sodium borate contained in the dry powder 3 has properties of absorbing water into a salt hydrate. Accordingly, if the dry powder 3 is kneaded into a substance made by kneading cement and the kneading water as in a normal cement mixing procedure, the viscosity of the cement-kneaded product extremely increases due to the salt hydrate and may cause kneading failure and false set. For this reason, at the third step, the dry powder 3 and the kneading water 4 are mixed and stirred in advance, and during the stirring, the salt hydrate is generated in advance. Thereafter, the hydraulic solidifying material 5 such as cement is preferably kneaded. More specifically, it is preferable to knead the dry powder 3 and the kneading water 4, for example, for 10 minutes or longer in consideration of the generation time of the salt hydrate.

[0024] As the hydraulic solidifying material 5, not particularly limited, portland cement is preferably used. When cement-solidifying the boric acid-containing waste liquid 1, calcium contributing to cement solidification tends to decrease because calcium in cement combines with a boric acid. Therefore, portland cement having a large amount of calcium in the hydraulic solidifying material 5 can be preferably used. Further, as the hydraulic solidifying material 5, a mixture of portland cement and blast-furnace slag, a mixture of portland cement and fly ash, or the like may be used.

(Fourth Step (S104 illustrated in Fig. 1))

[0025] The fourth step in this embodiment is a step of kneading the first kneaded product obtained at the third step and the quartz sand 6 to prepare the second kneaded product.

[0026] The boric acid contained in the boric acid-containing waste liquid 1 has an operation of greatly delaying the hardening of cement and an operation of decreasing the strength of a cement-solidified product 8. Adding a calcium hydroxide so as to prevent the operations causes a problem of calcium borate precipitating in the piping and the dryer and adhering thereto. In this embodiment, kneading the quartz sand 6 into the first kneaded product at the fourth step makes it possible to suppress delay of hardening of cement without using calcium and improve the strength of the

cement-solidified product 8 to be finally obtained.

[0027] At the fourth step, the quartz sand 6 is kneaded in such an amount that the weight ratio expressed by the quartz sand 6/the hydraulic solidifying material 5 (hereinafter, called S/C) falls within a range of 1.5 to 3.0. The S/C is preferably 1.7 to 2.6, and particularly preferably about 2.3. Kneading the quartz sand 6 in an amount with which the S/C becomes

1.5 to 3.0 makes it possible to improve the strength of the cement-solidified product 8 and obtain the cement-solidified product 8 excellent in solidification characteristics.

[0028] The particle size of the quartz sand 6 is preferably about 0.026 to 1.18 mm in median diameter.

[0029] In this embodiment, when kneading the quartz sand 6 at the fourth step, it is preferable to replace a part of the full weight of the quartz sand 6 to be added with zeolite 7. The zeolite 7 is a solid acid, and is high in performance of adsorbing radionuclides, and therefore adding the zeolite 7 at a predetermined ratio can drastically improve the radioactivity confining property (distribution coefficient of the radionuclides) of the cement-solidified product 8. Further, the zeolite 7 adsorbs a boron ion and a boron compound that inhibit the progress of cement solidification and therefore can improve the strength of the cement-solidified product 8. The boron ion and the boron compound become more likely to elute under a higher alkaline condition, but the addition of the zeolite 7 in a predetermined amount causes the added boron to adsorb alkali, thereby suppressing an increase in pH of the second kneaded product and the cement-solidified product 8. This can suppress elution of the boron ion, so that the cement-solidified product 8 excellent in solidification characteristics can be obtained.

[0030] The mixed amount of the zeolite 7 is preferably prepared to such an amount that the weight ratio of the zeolite 7 to the total of the zeolite 7 and the quartz sand 6 (the weight of zeolite 7/the total weight of the zeolite 7 and the quartz sand 6) is 0.05 to 0.40, more preferably prepared to 0.05 to 0.25, and particularly preferably prepared to 0.10 to 0.20. Mixing the zeolite 7 in the above-described amount makes it possible to improve the strength and the radioactivity confining property of the cement-solidified product 8. Note that the value of S in the above S/C is the value of the total weight of the quartz sand 6 and the zeolite 7 in this case.

[0031] Further, the particle size of the zeolite 7 is preferably about 770 μm in median diameter. The ion exchange capacity of the zeolite 7 is preferably about 10 to 200 (meq)/100 (g).

[0032] The method of mixing the quartz sand 6 and the zeolite 7 is not particularly limited, and the quartz sand 6 and the zeolite 7 may be mixed together in advance and the mixture may be mixed into the first kneaded product, or the quartz sand 6 and the zeolite 7 may be separately mixed into the first kneaded product. In the case where the quartz sand 6 and the zeolite 7 are separately mixed, the quartz sand 6 and the zeolite 7 may be mixed in any order or at the same time.

[0033] The second kneaded product thus obtained has excellent viscosity characteristics. Therefore, an out-drum mixing method can be used to house the second kneaded product in a solidification container 17 such as a drum from the kneader and form it into the cement-solidified product 8 excellent in solidification characteristics.

[0034] The cement-solidification method in this embodiment may be performed by an in-drum mixing method. More specifically, the kneading of all of the dry powder 3, the kneading water 4, the hydraulic solidifying material 5, the quartz sand 6 and the zeolite 7 may be performed in a radioactive waste solidification container, and the second kneaded product to be obtained may be solidified as it is in this radioactive waste solidification container. In this case, it is possible to further reduce the facility cost and the operating cost.

[0035] The cement-solidification method in this embodiment is excellent in operability because the second kneaded product has excellent viscosity characteristics. Further, the method does not use calcium and therefore causes no problem of adherence of a waste liquid component to the piping and the like. Further, according to the cement-solidification method in this embodiment, mixing the quartz sand 6 at a predetermined ratio makes it possible to obtain the cement-solidified product 8 excellent in solidification characteristics whose strength is further improved.

(Example 1)

[0036] Hereinafter, the result obtained by performing a cement-solidification test for the boric acid-containing waste liquid will be described based on the steps illustrated in Fig. 1. First, the sodium hydroxide was input into an aqueous solution of 12 % by weight of the boric acid heated to about 60°C to adjust a Na/B mole ratio to 0.25 to thereby obtain an aqueous solution of the sodium borate (S101 illustrated in Fig. 1). The sodium borate aqueous solution was regarded as a simulated waste liquid and supplied in a fixed amount into the centrifugal thin film dryer whose heating temperature was set to about 160°C, whereby a sodium borate dry powder was obtained (S102 illustrated in Fig. 1).

[0037] Next, 392 g of the kneading water and 315 g of the sodium borate dry powder produced in the above were put into a 1L plastic cup, and stirred and kneaded for about 60 minutes by a desk-top stirrer, whereby slurry was obtained.

[0038] Into the obtained slurry, 375 g of normal portland cement was mixed, and they were stirred and kneaded for about 10 minutes, whereby the first kneaded product was obtained (S103 illustrated in Fig. 1). Then, 650 g of the quartz sand was mixed (S/C = 1.73) and kneaded for about 60 minutes, whereby the second kneaded product was obtained (S104 illustrated in Fig. 1). The physical properties of the second kneaded product were measured, and then poured

into a formwork of an inner diameter of 50 mm ϕ ×a height of 100 mmH, whereby a cement-solidified product was formed.

[0039] The characteristics of the second kneaded product were excellent rheological characteristics that the viscosity was 9 dPa·s and the filling density was 1.99. The cement-solidified product had a bleeding rate (bleeding from the cement-solidified product) of 0 vol% after 24 hours and a uniaxial compressive strength at a material age of 7 days of 8.9 MPa, and therefore excellent solidification characteristics were also obtained.

(Example 2)

[0040] By adjusting the mixed amounts of the components in Example 1 such that the kneading water was 392 g, the normal portland cement was 375 g, the sodium borate dry powder was 315 g, and the quartz sand was 750 g (S/C = 2.00), the second kneaded product was obtained as in Example 1. Thereafter, a cement-solidified product was produced as in Example 1. Further, the physical properties of the second kneaded product and the cement-solidified product were evaluated as in Example 1.

[0041] The characteristics of the second kneaded product were excellent rheological characteristics that the viscosity was 10 dPa·s and the filling density was 2.02. The cement-solidified product had a bleeding rate of 0 vol% after 24 hours and a uniaxial compressive strength at a material age of 7 days of 9.6 MPa, and therefore excellent solidification characteristics were also obtained.

(Example 3)

[0042] By adjusting the mixed amounts of the components in Example 1 such that the kneading water was 392 g, the normal portland cement was 375 g, the sodium borate dry powder was 315 g, and the quartz sand was 850 g (S/C = 2.27), the second kneaded product was obtained as in Example 1. Thereafter, a cement-solidified product was produced as in Example 1. Further, the physical properties of the second kneaded product and the cement-solidified product were evaluated as in Example 1.

[0043] The characteristics of the second kneaded product were excellent rheological characteristics that the viscosity was 12 dPa·s and the filling density was 2.04. The cement-solidified product had a bleeding rate of 0 vol% after 24 hours and a uniaxial compressive strength at a material age of 7 days of 12.2 MPa, and therefore excellent solidification characteristics were also obtained.

(Example 4)

[0044] By adjusting the mixed amounts of the components in Example 1 such that the kneading water was 392 g, the normal portland cement was 375 g, the sodium borate dry powder was 315 g, and the quartz sand was 950 g (S/C = 2.53), the second kneaded product was obtained as in Example 1. Thereafter, a cement-solidified product was produced as in Example 1. Further, the physical properties of the second kneaded product and the cement-solidified product were evaluated as in Example 1.

[0045] The characteristics of the second kneaded product were excellent rheological characteristics that the viscosity was 100 dPa·s and the filling density was 2.07. The cement-solidified product had a bleeding rate of 0 vol% after 24 hours and a uniaxial compressive strength at a material age of 7 days of 11.9 MPa, and therefore excellent solidification characteristics were also obtained.

(Example 5)

[0046] By adjusting the mixed amounts of the components in Example 1 such that the kneading water was 392 g, the normal portland cement was 375 g, the sodium borate dry powder was 315 g, and the quartz sand was 1125 g (S/C = 3.00), the second kneaded product was obtained as in Example 1. Thereafter, a cement-solidified product was produced as in Example 1. Further, the physical properties of the second kneaded product and the cement-solidified product were evaluated as in Example 1.

[0047] The characteristics of the second kneaded product were excellent rheological characteristics that the viscosity was 100 dPa·s and the filling density was 2.09. The cement-solidified product had a bleeding rate of 0 vol% after 24 hours and a uniaxial compressive strength at a material age of 7 days of 8.7 MPa, and therefore excellent solidification characteristics were also obtained.

[0048] The relationship between the value of S/C and the uniaxial compressive strength in the above Examples 1 to 5 is indicated on a graph in Fig. 3 with the value of S/C plotted on the horizontal axis and the uniaxial compressive strength plotted on the vertical axis.

[0049] Fig. 3 shows that good strength is obtained at an S/C of 1.5 to 3 and the strength is largest at an S/C of 2.27. Therefore, in following Examples 6, 7, a part of the quartz sand was replaced with the zeolite in order to further improve

the radioactivity confining property of the cement-solidified product at the $S/C = 2.27$, and the physical properties of the cement-solidified product were evaluated.

(Example 6)

[0050] By adjusting the mixed amounts of the components in Example 4 such that the kneading water was 390 g, the normal portland cement was 375 g, the sodium borate dry powder was 312 g, the quartz sand was 680 g, and the zeolite was 170 g ($S/C = 2.27$, zeolite/quartz sand (weight ratio) = 20/80), the second kneaded product was obtained as in Example 1. Thereafter, a cement-solidified product was produced as in Example 1. Further, the physical properties of the second kneaded product and the cement-solidified product were evaluated as in Example 1.

[0051] The characteristics of the second kneaded product were excellent rheological characteristics that the viscosity was 70 dPa·s and the filling density was 2.0. The cement-solidified product had a bleeding rate of 0 vol% after 24 hours, a uniaxial compressive strength at a material age of 7 days of 9.6 MPa, and a uniaxial compressive strength at a material age of 28 days of 12 MPa, and therefore excellent solidification characteristics were also obtained.

(Example 7)

[0052] By adjusting the mixed amounts of the quartz sand and the zeolite in Example 6 such that the quartz sand was 765 g and the zeolite was 85 g ($S/C = 2.27$, zeolite/quartz sand (weight ratio) = 10/90), the second kneaded product was prepared as in Example 1 and a cement-solidified product was produced as in Example 1, and their physical properties were evaluated.

[0053] The cement-solidified product had a uniaxial compressive strength at a material age of 28 days of 8.9 MPa, and therefore excellent solidification characteristics could be obtained.

(Comparative Example 1)

[0054] A kneaded product was produced without mixing the quartz sand in Example 1. More specifically, by adjusting the kneading water to 392 g, the normal portland cement to 750 g, and the sodium borate dry powder to 315 g, the kneaded product was obtained as in Example 1. The physical properties of the kneaded product were measured, and then a cement-solidified product was produced as in Example 1 and its physical properties were evaluated.

[0055] The kneaded product had such characteristics that the viscosity was 150 dPa·s and the filling density was 1.95. The cement-solidified product had a bleeding rate of 0 vol% after 24 hours and a uniaxial compressive strength at a material age of 7 days of 2.9 MPa, and it was found that the strength was insufficient.

[0056] The conditions, measurement results and so on of the above-described Examples 1 to 7 and Comparative Example 1 are listed in Table 1.

[Table 1]

	Example 1	Example 2	Example 3	Example 4	Example 5	Example 6	Example 7	Comparative Example 1
Sodium Borate Dry Powder [g]	315	315	315	315	315	312	312	315
Kneading Water [g]	392	392	392	392	392	390	390	392
Normal Portland Cement [g]	375	375	375	375	375	375	375	750
Quartz Sand [g]	650	750	850	950	1125	680	765	0
Zeolite [g]	0	0	0	0	0	170	85	0
S/C	1.73	2.00	2.27	2.53	3.00	2.27	2.27	0
Zeolite/Quartz Sand (Weight Ratio)	-	-	-	-	-	20/80	10/90	-
Kneaded Product Viscosity [dPs•S]	9	10	12	100	100	70	24	150
Kneaded Product Filling Density	1.99	2.02	2.04	2.07	2.09	2	-	1.95
Bleeding Rate [vol%]	0	0	0	0	0	0	0	0
Strength In At Material Age of 7 Days [Mpa]	8.9	9.6	12.2	11.9	8.7	9.6	-	2.9
Strength In At Material Age of 28 Days [Mpa]	-	-	-	-	-	12	8.9	-

[0057] As listed in Table 1, it is found that the strengths of the cement-solidified products were improved in Examples 1 to 7 in which the quartz sand was added as compared with Comparative Example 1 in which the quartz sand was not added.

[0058] While certain embodiments have been described, these embodiments have been presented by way of example only, and are not intended to limit the scope of the inventions. Indeed, the novel embodiments described herein may be embodied in a variety of other forms; furthermore, various omissions, substitutions and changes in the form of the embodiments described herein may be made without departing from the spirit of the inventions. The accompanying claims and their equivalents are intended to cover such forms or modifications as would fall within the scope and spirit of the inventions.

EXPLANATION OF REFERENCE SIGNS

[0059] S101 ... first step, S102 ... second step, S103 ... third step, S104 ... fourth step, 1 ... boric acid-containing waste liquid, 2 ... sodium hydroxide, 3 ... dry powder, 4 ... kneading water, 5 ... hydraulic solidifying material, 6 ... quartz sand, 7 ... zeolite, 8 ... cement-solidified product, 10 ... cement-solidification apparatus, 11 ... kneader, 12 ... to-be-solidified matter supply device, 13 ... kneading water supply device, 14 ... hydraulic solidifying material supply device, 15 ... quartz sand supply device, 16 ... quartz sand supply rate adjusting device, 17 ... solidification container.

Claims

1. A method of cement-solidifying a radioactive boric acid-containing waste liquid, comprising:

a volume reduction step of adding a sodium hydroxide to the boric acid-containing waste liquid and reducing a volume thereof to prepare a matter to be solidified;

a first kneading step of kneading the matter to be solidified, a kneading water, and a hydraulic solidifying material to prepare a first kneaded product; and

a second kneading step of kneading quartz sand and the first kneaded product to prepare a second kneaded product,

wherein a weight ratio of the quartz sand to the hydraulic solidifying material (a weight of the quartz sand/a weight of the hydraulic solidifying material) is 1.5 to 3.0.

2. The cement-solidification method according to claim 1,

wherein in the second kneading step, zeolite is further mixed, and

wherein a weight ratio of a total of the zeolite and the quartz sand to the hydraulic solidifying material (a total weight of the zeolite and the quartz sand/a weight of the hydraulic solidifying material) is 1.5 to 3.0.

3. The cement-solidification method according to claim 1 or 2,

wherein a particle size of the quartz sand is 0.026 to 1.18 mm in median diameter.

4. The cement-solidification method according to claim 2 or 3,

wherein a particle size of the zeolite is 770 μm in median diameter, and an ion exchange capacity of the zeolite is 10 to 200 meq/100 g.

5. The cement-solidification method according to any one of claims 2 to 4,

wherein a weight ratio of the zeolite to a total of the quartz sand and the zeolite (a weight of the zeolite/a total weight of the quartz sand and the zeolite) is 0.05 to 0.40.

6. The cement-solidification method according to any one of claims 2 to 5, wherein a method of mixing the quartz sand

and the zeolite with the first kneaded product in the second kneading step comprises mixing the quartz sand and the zeolite mixed together in advance into the first kneaded product, or mixing the quartz sand and the zeolite separately into the first kneaded product.

7. The cement-solidification method according to any one of claims 1 to 6,

wherein the first kneading step and the second kneading step are performed by an in-drum mixing method or an out-drum mixing method.

8. The cement-solidification method according to any one of claims 1 to 7,

wherein the matter to be solidified is a dry powder obtained by drying the boric acid-containing waste liquid, or a concentrated waste liquid obtained by concentrating the boric acid-containing waste liquid or making sodium borate to settle down.

5 9. The cement-solidification method according to any one of claims 1 to 8,
wherein a temperature of the matter to be solidified obtained in the volume reduction step is normal temperature to 100°C.

10 10. An apparatus for cement-solidifying a radioactive boric acid-containing waste liquid, comprising:

10 a kneader;

a to-be-solidified matter supply device that adds a sodium hydroxide to the boric acid-containing waste liquid and reduces a volume thereof to prepare a matter to be solidified, and supplies the matter to be solidified to the kneader;

15 a kneading water supply device that supplies a kneading water to the kneader;

a hydraulic solidifying material supply device that supplies a hydraulic solidifying material to the kneader to prepare a first kneaded product; and

20 a quartz sand supply device that supplies quartz sand to the kneader to prepare a second kneaded product,
wherein a weight ratio of the quartz sand to the hydraulic solidifying material (a weight of the quartz sand/a weight of the hydraulic solidifying material) in the quartz sand supply device is 1.5 to 3.0.

FIG. 1

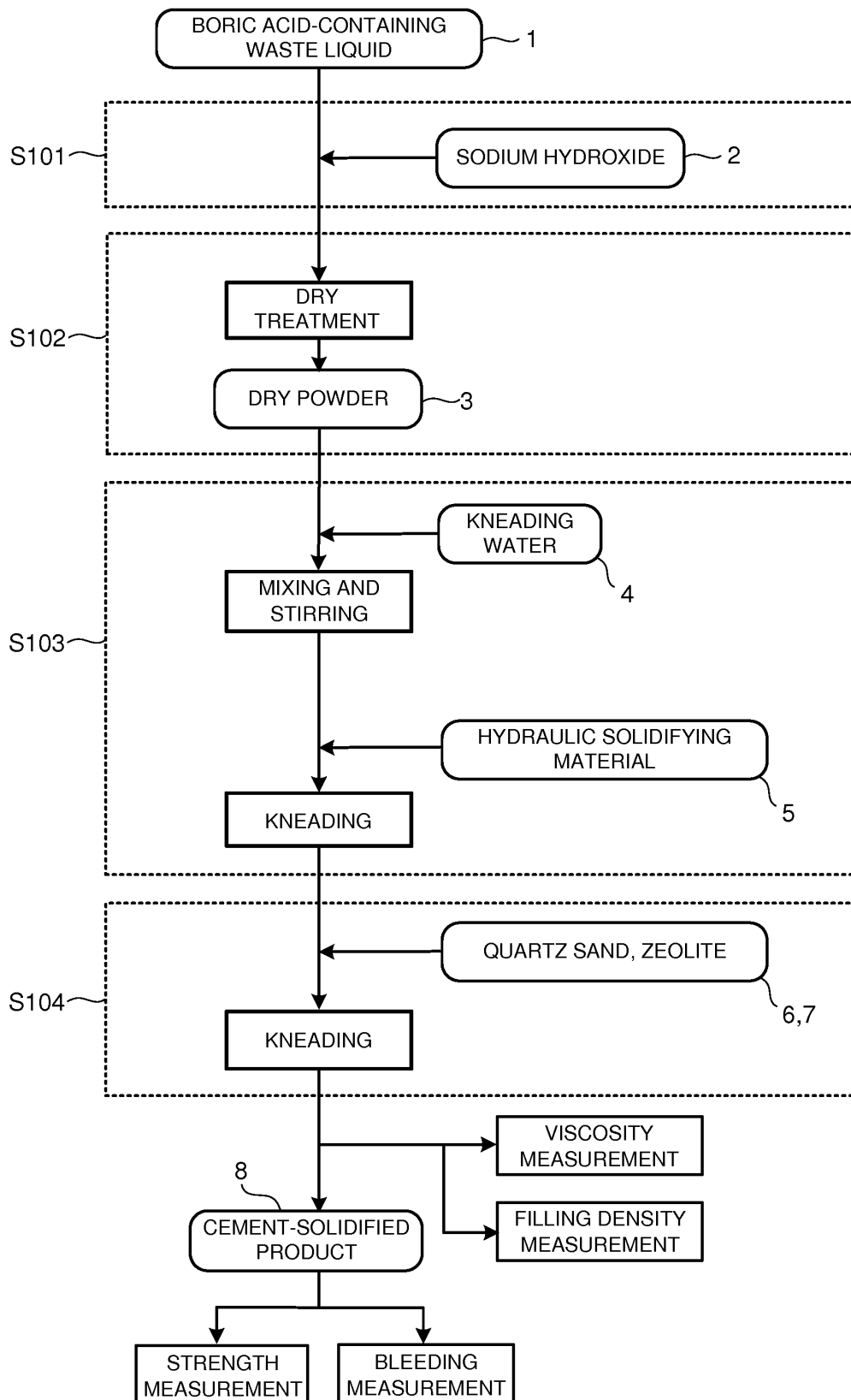


FIG. 2

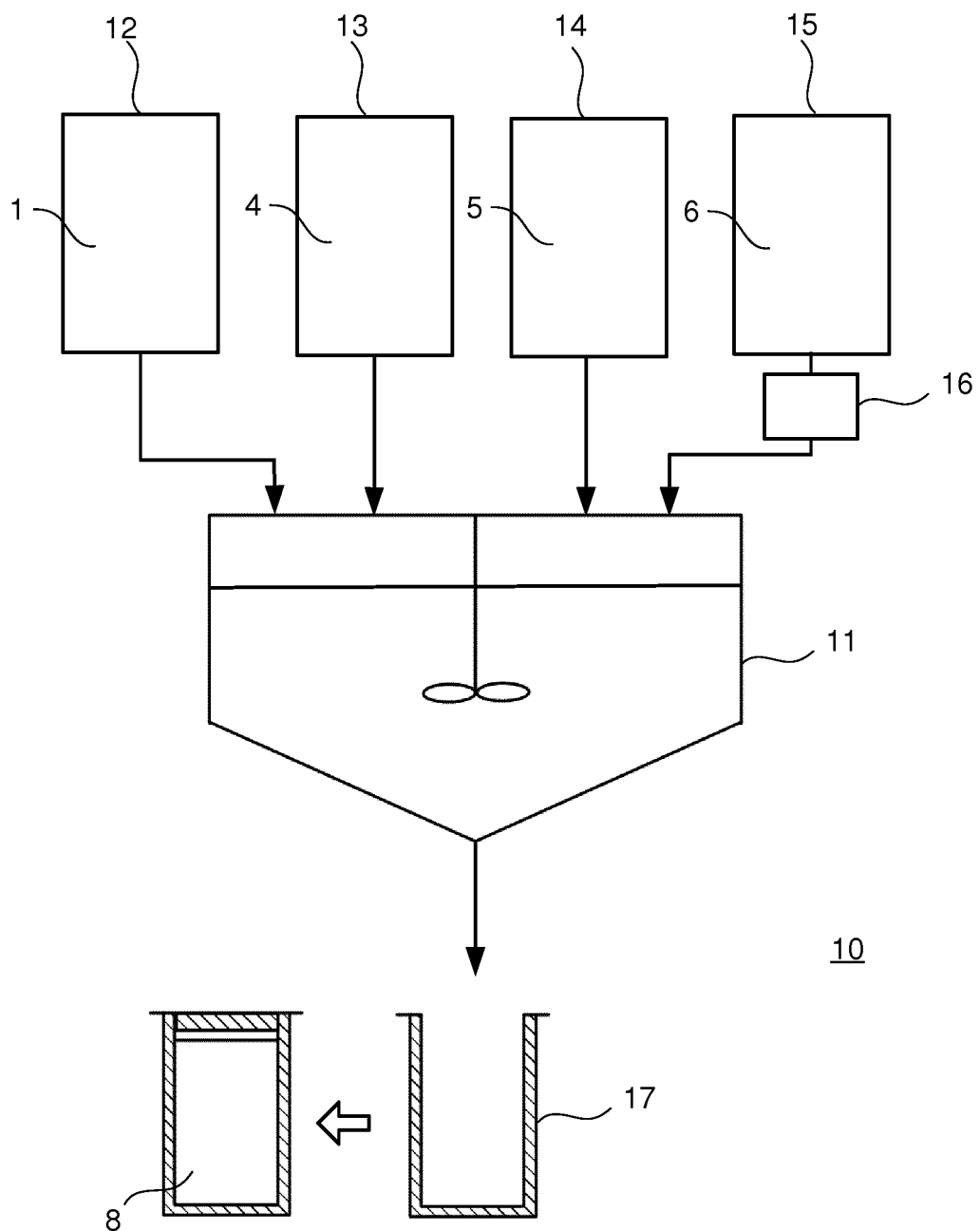
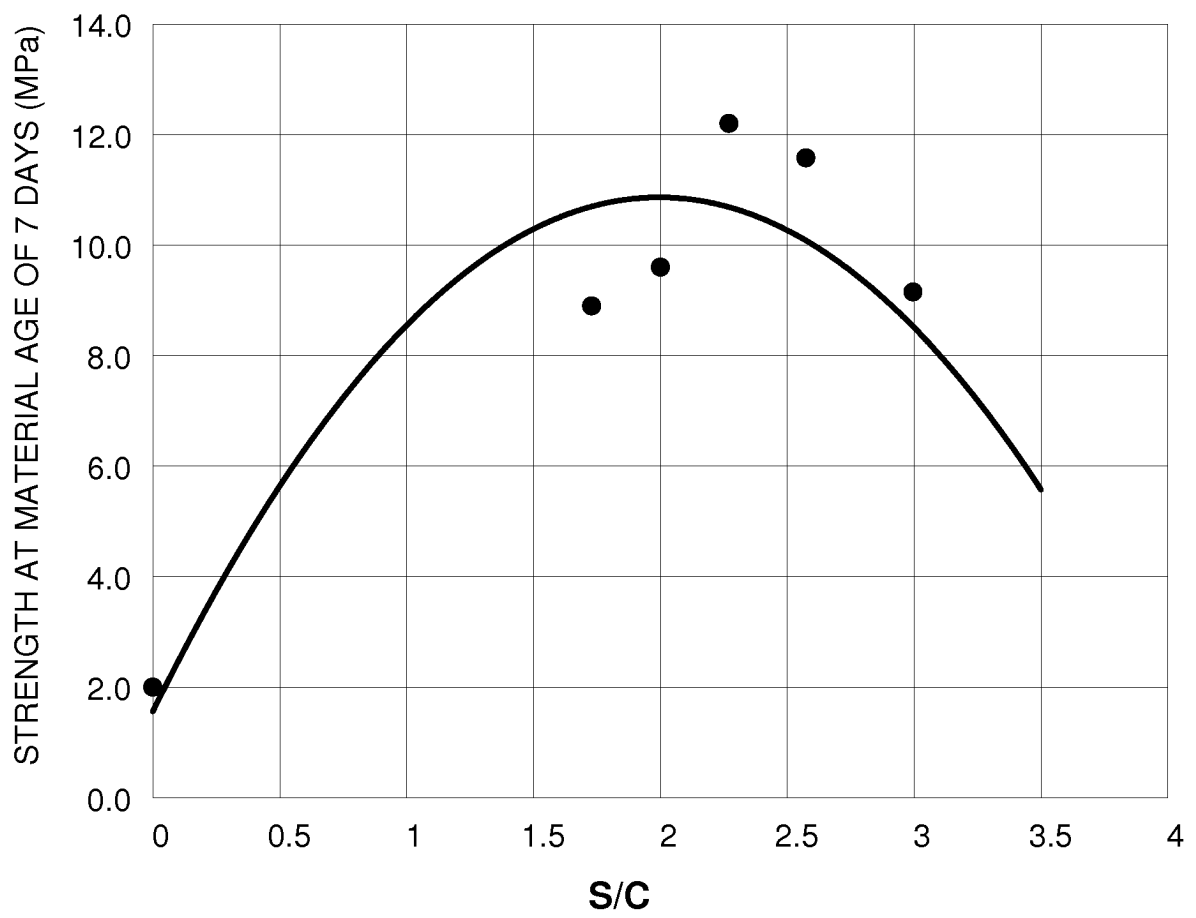


FIG. 3



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2014/003112

A. CLASSIFICATION OF SUBJECT MATTER

G21F9/16(2006.01)i, G21F9/08(2006.01)i, G21F9/12(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

G21F9/16, G21F9/08, G21F9/12

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2014

Kokai Jitsuyo Shinan Koho 1971-2014 Toroku Jitsuyo Shinan Koho 1994-2014

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2010-151487 A (Toshiba Corp.), 08 July 2010 (08.07.2010), claims 5 to 7; paragraphs [0001] to [0003], [0021] to [0045], [0047], [0050] to [0052]; fig. 3 (Family: none)	1-10
A	JP 60-179698 A (Hitachi, Ltd.), 13 September 1985 (13.09.1985), entire text; all drawings (Family: none)	1-10

☐ Further documents are listed in the continuation of Box C.☐ See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search
26 August, 2014 (26.08.14)Date of mailing of the international search report
09 September, 2014 (09.09.14)Name and mailing address of the ISA/
Japanese Patent Office

Authorized officer

Facsimile No.

Telephone No.

Form PCT/ISA/210 (second sheet) (July 2009)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP H2208600 A [0006]
- JP H4018640 A [0006]