

DESCRIPTION

TITLE OF INVENTION: CARBONATION ACCELERATOR FOR HYDRAULIC COMPOSITION AND METHOD FOR MANUFACTURING HYDRAULIC COMPOSITION HARDENED BODY

TECHNICAL FIELD

[0001] The present invention relates to a carbonation accelerator for a hydraulic composition and a method for manufacturing a hydraulic composition hardened body. More specifically, it relates to a carbonation accelerator for a hydraulic composition that can accelerate carbonation of the hydraulic composition when added thereto, and a method for manufacturing a hydraulic composition hardened body.

BACKGROUND ART

[0002] In recent years, efforts to achieve a decarbonized society, such as carbon-neutral or carbon-negative, have accelerated around the world. For example, Japan declared in 2020 the realization of "carbon-neutral by 2050", and in 2021, set a target of reducing greenhouse gas emissions by 46% in 2030 compared to 2013.

[0003] Accordingly, for example, the construction industry is also taking measures to reduce carbon dioxide (CO₂) emissions.

[0004] Specifically, concrete is a material that emits a

very large amount of carbon dioxide, since it is manufactured using cement, which emits a large amount of carbon dioxide in the manufacturing process. Therefore, in order to reduce carbon dioxide emissions, low-carbon cement and low-carbon concrete are known in which the used amount of cement is reduced by using industrial by-products such as blast furnace slag fine powder and fly ash.

[0005] In addition, precast concrete is also known that is obtained by hardening a concrete mixture of steelmaking slag powder and Portland cement to which γ -C₂S has been added and subjecting the concrete to carbonation curing after demolding (see, for example, Patent Document 1). This precast concrete is based on a technology in which carbonation due to the absorption of carbon dioxide proceeds at the surface of the concrete, resulting in densification in the surface region and thereby achieving high durability. The γ -C₂S is γ -2CaO·SiO₂ (sometimes called "γ-belite").

[0006] Here, in Patent Document 1, carbonation curing is carried out to densify the concrete and improve its durability, while this technology is the fixation and absorption of carbon dioxide by the concrete. That is, in the entire manufacturing process of the concrete, it can be said that the amount of carbon dioxide emission is reduced by an amount equivalent to the carbon dioxide fixed and absorbed in the concrete during carbonation curing. Thus, γ -C₂S (γ -2CaO·SiO₂) is sometimes used as a technology to reduce, fix, or absorb carbon dioxide (CO₂).

[0007] Similarly, a carbonation accelerator that accelerates carbonation of alkaline earth metal compounds has been reported as one of the efforts to reduce greenhouse gas emissions (see Patent Document 2).

CITATION LIST

Patent Literature

[0008]

Patent Document 1: JP-A-2006-182583

Patent Document 2: JP-A-2023-103807

SUMMARY OF INVENTION

Technical Problem

[0009] However, there is still room for improvement in terms of the amount and rate of carbon dioxide absorption. Therefore, there is a demand for the development of a carbonation accelerator that can further increase the amount of carbon dioxide absorbed and fixed by concrete, improve the rate of carbon dioxide absorption, or achieve both. Increasing the amount of carbon dioxide absorbed by concrete at a given material age shortens the time required for a certain amount of carbon dioxide to be absorbed, and as a result, also shortens the carbonation curing period (shortens the manufacturing time of concrete products).

[0010] In view of the above circumstances, it is an object

of the present invention to provide a carbonation accelerator for a hydraulic composition that can accelerate carbonation of the hydraulic composition when added thereto and can reduce the carbon dioxide balance of the hydraulic composition, and a method for manufacturing a hydraulic composition hardened body. The carbon dioxide balance is the amount of carbon dioxide calculated by the equation: "Amount of CO₂ derived from raw materials constituting concrete (i.e., amount of CO₂ generated in manufacturing of raw materials)" - "Amount of CO₂ absorbed and fixed by carbonation curing or the like". The expression "reduce the carbon dioxide balance" means increasing the amount of carbon dioxide reduction, that is, reducing the value of the carbon dioxide balance calculated by the above equation.

Solution to Problem

[0011] As a result of intensive studies to solve the above problem, the present inventors have found that the above problem can be solved by containing an organic amine compound. According to the present invention, the following carbonation accelerator for a hydraulic composition and a method of manufacturing a hydraulic composition hardened body are provided.

[0012] [1] A carbonation accelerator for a hydraulic composition comprising an organic amine compound.

[0013] [2] The carbonation accelerator for a hydraulic

composition according to [1], wherein the organic amine compound includes at least one selected from alkanolamines and polyamines.

[0014] [3] The carbonation accelerator for a hydraulic composition according to [1] or [2], which is added to a hydraulic composition that becomes a hydraulic composition hardened body after undergoing a carbonation curing step, which is a step of curing in an environment with a carbon dioxide volume concentration of 5% or more.

[0015] [4] The carbonation accelerator for a hydraulic composition according to [1] or [2], which is added to a hydraulic composition containing a binder that contains blast furnace slag fine powder at 40 to 99% by mass, water, and an aggregate.

[0016] [5] The carbonation accelerator for a hydraulic composition according to [1] or [2], wherein the hydraulic composition contains γ -2CaO·SiO₂.

[0017] [6] The carbonation accelerator for a hydraulic composition according to [1] or [2], wherein the hydraulic composition contains at least one selected from the following CO₂-fixed fine powder and the following CO₂-fixed modified recycled fine aggregate.

CO₂-fixed fine powder: including modified concrete powder, which has a 50% particle size of 50μm or less and is a reaction product of recycled concrete powder and carbon dioxide gas, wherein the modified concrete powder contains calcium

carbonate and a siliceous material, wherein the content ratio of the CO₂-fixed fine powder in the hydraulic composition is in the range of 1 to 100% by mass with respect to 100% by mass of the binder.

CO₂-fixed modified recycled fine aggregate: including modified recycled fine aggregate in which all particles have a particle size of 10 mm or less and 85% or more of the particles have a particle size of 5 mm or less, the modified recycled fine aggregate being a dry or wet reaction product of recycled fine aggregate having a water absorption greater than 3.0% and 10% or less and carbon dioxide gas, wherein the modified recycled fine aggregate contains calcium carbonate and silicon dioxide, wherein the content ratio of the CO₂-fixed modified recycled fine aggregate in the hydraulic composition is in the range of 10 to 100% by volume with respect to the total aggregate volume.

[0018] [7] A method for manufacturing a hydraulic composition hardened body, comprising: a preparation step of preparing a hydraulic composition containing a carbonation accelerator for a hydraulic composition according to [1] or [2], a binder containing blast furnace slag fine powder at 40 to 99% by mass, and water; a hardening step of hardening the obtained hydraulic composition to obtain a hydraulic composition hardened body, and a carbonation curing step of curing the obtained hydraulic composition hardened body in an environment with a carbon dioxide volume concentration of 5%

or more to absorb and fix carbon dioxide in the hydraulic composition hardened body.

Effects of the Invention

[0019] The carbonation accelerator for a hydraulic composition of the present invention exhibits an effect that, by being added to a hydraulic composition, it accelerates the carbonation of the hydraulic composition and can reduce the carbon dioxide balance of the hydraulic composition.

[0020] According to the method for manufacturing a hydraulic composition hardened body of the present invention, since a hydraulic composition containing the carbonation accelerator for a hydraulic composition of the present invention is used, it is possible to increase the amount of carbon dioxide reduced in the manufacturing process.

DESCRIPTION OF EMBODIMENTS

[0021] Hereinafter, embodiments of the present invention will be described. However, the present invention is not limited to the following embodiments. Therefore, it should be understood that modifications, improvements, and the like may be made to the following embodiments as appropriate based on the ordinary knowledge of a person skilled in the art without departing from the spirit of the present invention. In the following examples and the like, unless otherwise stated, % means % by mass and part means part by mass.

[0022] (1) Carbonation accelerator for hydraulic composition:

The carbonation accelerator for a hydraulic composition contains an organic amine compound. In the carbonation accelerator for a hydraulic composition, by being added to a hydraulic composition, it can accelerate carbonation of the hydraulic composition and increase the amount of carbon dioxide absorbed by the hydraulic composition (i.e., the amount of carbon dioxide reduction). In other words, the carbon dioxide balance of the hydraulic composition can be reduced.

[0023] By hydration of cement, calcium silicate hydrate (C-S-H), calcium hydroxide (CH), and the like are formed. In addition, in the hydraulic composition, calcium oxide (CaO) and the like are contained as components derived from the raw materials. Then, carbon dioxide can be absorbed and fixed in the hydraulic composition (the hardened body of the hydraulic composition) by carbonation (reaction with carbon dioxide) of these compounds.

[0024] Thermal power plants, for example, release carbon dioxide into the atmosphere as exhaust gas. The carbon dioxide is considered to be one of the causes of global warming; however, by supplying carbon dioxide in exhaust gas to a carbonation curing step, the carbon dioxide can be absorbed into a hydraulic composition, thereby enabling a reduction in carbon dioxide. The hardened body of the hydraulic composition can fix carbon dioxide in the atmosphere not only during the

carbonation curing step but also over a long period of time after being installed at a predetermined location after the step.

[0025] (1-1) Organic amine compound:

The organic amine compound is an organic compound containing one of the following: primary amine, secondary amine, and tertiary amine. The inclusion of the organic amine compound increases the amount of carbon dioxide absorbed by the hardened body of the hydraulic composition (i.e., the amount of carbon dioxide reduction).

[0026] Examples of the organic amine compound include alkanolamines, polyamines, aliphatic amines, aromatic amines, and heterocyclic amines.

[0027] More specific examples of the organic amine compound include monoethanolamine, diethanolamine, triethanolamine, monoisopropanolamine, diisopropanolamine, triisopropanolamine, methylethanolamine, methylisopropanolamine, methyldiethanolamine, methyldiisopropanolamine, diethanolisopropanolamine, diisopropanolethanolamine, tetrahydroxyethylethylenediamine, N,N-bis(2-hydroxyethyl)2-propanolamine, N,N-bis(2-hydroxypropyl)-N-(hydroxyethyl)amine, N,N-bis(2-hydroxyethyl)-N-(2-hydroxypropyl)amine, N,N,N',N'-tetrakis(2-hydroxypropyl)ethylenediamine, tris(2-hydroxybutyl)amine, N,N'-bis(2-hydroxyethyl)ethylenediamine, 2-({2-[(2-aminoethyl)amino]ethyl}amino)ethanol,

trishydroxymethylaminomethane, aminopropanediol, 2-amino-2-ethyl-1,3-propanediol, 2-(dimethylamino)ethanol, 2-methylaminoethanol, 2-(2-aminoethoxy)ethanol, N-phenyldiethanolamine, ethylenediamine, diethylenetriamine, triethylenetetramine, tetraethylenepentamine, pentaethylenehexamine, aminoethylpiperazine, piperazine, 2-aminophenol, glutamine, and morpholine.

[0028] The organic amine compound preferably contains at least one selected from alkanolamines and polyamines. The inclusion of the specific organic amine compound further increases the amount of carbon dioxide absorbed by the hardened body of the hydraulic composition.

[0029] When the organic amine compound contains at least one selected from alkanolamines and polyamines, the total percentage thereof can be 10 to 100% by mass in the organic amine compound.

[0030] As used herein, "alkanolamine" refers to a compound having an alkane skeleton, hydroxy and amino groups.

[0031] As used herein, "polyamine" refers to a compound that is a hydrocarbon having two or more amino groups in the molecule.

[0032] Examples of alkanolamines and polyamines include triisopropanolamine, 1,2-bis{di(hydroxyethyl)amino}ethane, N,N'-bis(2-hydroxyethyl)ethylenediamine, diethanolamine, diisopropanolamine, 2-({2-[(2-aminoethyl)amino]ethyl}amino)ethanol,

trishydroxymethylaminomethane, aminopropanediol, diethylenetriamine, triethylenetetramine, and triethanolamine, and it is preferable that at least one or more of these be contained.

[0033] The content ratio of the organic amine compound is not particularly limited; however, for example, it may be 10 to 100% by mass, preferably 15 to 100% by mass, and more preferably 20 to 100% by mass. That is, the content ratio of components other than the organic amine compound is not particularly limited, but is preferably less than a predetermined ratio. By setting the ratio within such a range, in the case where the "component other than the organic amine compound" is other than water, it is possible to avoid adding too much of "component other than the organic amine compound" when a carbonation accelerator for a hydraulic composition is added to the hydraulic composition. As a result, it is possible to reduce concerns that the "component other than the organic amine compound" may affect various physical properties of the hydraulic composition. In the case where the "component other than the organic amine compound" is water (i.e., when it is an aqueous solution of organic amine compound), the above content ratio makes it easier to maintain the product stability of the carbonation accelerator for a hydraulic composition. It also facilitates the weighing of the carbonation accelerator for a hydraulic composition when they are used. That is, when the carbonation accelerator for a hydraulic composition is added

to a hydraulic composition, the carbonation accelerator for a hydraulic composition is added so that the organic amine compound is at a required concentration. At this time, by setting the content ratio within the above range, the amount of the carbonation accelerator for a hydraulic composition to be added (handling amount) can be reduced, thereby reducing the effort required for weighing.

[0034] (1-2) Other components:

The carbonation accelerator for a hydraulic composition of the present invention may contain other components in addition to the above-described organic amine compound within a range in which the effect is not impaired.

[0035] As other components, for example, water and additives conventionally known to be added to hydraulic compositions can be selected and employed as appropriate.

[0036] The other components may be used singly, or two or more thereof may be used in combination.

[0037] The carbonation accelerator for a hydraulic composition of the present invention is preferably added to the hydraulic composition described below.

[0038] (2) Hydraulic composition:

The carbonation accelerator for a hydraulic composition of the present invention can be added to a hydraulic composition. The hydraulic composition may include, similar to the conventionally known hydraulic compositions, a binder (hydraulic binder), water, and aggregates (fine aggregate and

coarse aggregate).

[0039] The content ratio of the carbonation accelerator for a hydraulic composition of the present invention in the hydraulic composition is not particularly limited and can be appropriately set. For example, the content ratio of the carbonation accelerator for a hydraulic composition of the present invention can be 0.001 to 5% by mass with respect to 100% by mass of the binder.

[0040] Examples of the binder include various Portland cements such as ordinary Portland cement, moderate-heat Portland cement, low-heat Portland cement, high-early strength Portland cement, and sulfate resisting Portland cement, various cements such as blast furnace cement, fly ash cement, and silica fume cement.

[0041] Further, as a binder, various admixtures such as fly ash, blast furnace slag fine powder, limestone fine powder, stone powder, silica fume, expansive material, anhydrous gypsum, hemihydrate gypsum, and dihydrate gypsum may be used in combination with the various cements described above.

[0042] The binder preferably contains blast furnace slag fine powder at 40 to 99% by mass. That is, the hydraulic composition to which the carbonation accelerator for a hydraulic composition of the present invention is added should contain a binder containing blast furnace slag fine powder at 40 to 99% by mass, water, and aggregates. The content ratio of the blast furnace slag fine powder is preferably 50 to 99% by

mass, and more preferably 60 to 99% by mass. In this manner, the carbon dioxide balance of the hydraulic composition can be further reduced.

[0043] Examples of the aggregate include fine aggregate and coarse aggregate.

[0044] Examples of the fine aggregate include river sand, mountain sand, land sand, sea sand, silica sand, crushed sand, various types of slag fine aggregates, and various types of recycled fine aggregates, but may also include fine particulate components such as clay.

[0045] Examples of the coarse aggregate include river gravel, mountain gravel, land gravel, crushed stone, various types of slag coarse aggregates, lightweight aggregate, and various types of recycled coarse aggregates.

[0046] The hydraulic composition preferably contains γ - $2\text{CaO} \cdot \text{SiO}_2$. That is, the carbonation accelerator for a hydraulic composition of the present invention is preferably added to a hydraulic composition containing γ - $2\text{CaO} \cdot \text{SiO}_2$. In this manner, γ - $2\text{CaO} \cdot \text{SiO}_2$ exerts a function of fixing carbon dioxide, thereby making it possible to further increase the amount of carbon dioxide absorbed by the hardened body of the hydraulic composition (i.e., the amount of carbon dioxide reduction). As a result, the carbon dioxide balance of the hydraulic composition can be further reduced. The γ - $2\text{CaO} \cdot \text{SiO}_2$ is a material that hardens by carbonation. The γ - $2\text{CaO} \cdot \text{SiO}_2$ may be added to a hydraulic composition containing a binder that

contains blast furnace slag fine powder at 40 to 99% by mass, water, and aggregates, or to a hydraulic composition that do not contain such a binder and the like.

[0047] The content ratio of γ -2CaO·SiO₂ is not particularly limited; however, for example, it may be a ratio equivalent to 1 to 30% by mass on an internal basis with respect to 100% by mass of the binder.

[0048] The hydraulic composition preferably includes at least one selected from the following CO₂-fixed fine powder and the following CO₂-fixed modified recycled fine aggregate. In this manner, the carbon dioxide balance of the hydraulic composition can be further reduced. Carbon Capture and Utilization (CCU) materials such as CO₂-fixed fine powder and CO₂-fixed modified recycled aggregate (including CO₂-fixed modified recycled fine aggregate) are powders and aggregates produced by previously reacting CO₂ with calcium components derived from waste materials such as waste concrete. The CCU material may be used for carbon neutral or carbon negative concrete. Incidentally, in the hydraulic composition, CO₂-fixed modified recycled coarse aggregate may further be used in addition to CO₂-fixed modified recycled fine aggregate, or CO₂-fixed modified recycled coarse aggregate may be used instead of CO₂-fixed modified fine aggregate.

[0049] (CO₂-fixed fine powder)

The CO₂-fixed fine powder contains modified concrete powder, which has a 50% particle size of 50μm or less and is

a reaction product of recycled concrete powder and carbon dioxide gas, and the modified concrete powder contains calcium carbonate and a siliceous material. The content ratio of the CO₂-fixed fine powder is in the range of 1 to 100% by mass with respect to 100% by mass of the binder.

[0050] The CO₂-fixed fine powder can be produced as follows. That is, a concrete mass is first crushed or grinded to recover recycled concrete fine powder with a median diameter of 100μm or less. The method of performing the crushing or grinding is not particularly limited, and known crushing or grinding devices such as a shot-blast-type crushing device, an impact crusher, and a grinding device of a mechanical rubbing and grinding type that does not involve heating can be used. Next, the recovered recycled concrete fine powder is reacted with carbon dioxide gas with a volume concentration of 5% or more to fix CO₂ to the cement-derived components in the recycled concrete fine powder. The reaction with carbon dioxide gas can be either a dry method in which gaseous carbon dioxide gas is brought into contact, or a wet method in which the recycled concrete fine powder is immersed in a solution such as water, and then carbon dioxide gas is blown into the liquid (dispersion liquid). In this way, CO₂-fixed fine powder can be produced.

[0051] (CO₂-fixed modified recycled aggregate)

The CO₂-fixed modified recycled aggregate is an aggregate produced by previously reacting CO₂ with calcium components

derived from waste materials such as waste concrete, and examples thereof include CO₂-fixed modified recycled fine aggregate and CO₂-fixed modified recycled coarse aggregate. Of these, the use of CO₂-fixed modified recycled fine aggregate is preferable. This is because the CO₂-fixed modified recycled fine aggregate contains more calcium components derived from cements, fixes a larger amount of CO₂ during the production of the CO₂-fixed modified recycled aggregate (that is, the "amount of material-derived carbon dioxide emission" is smaller), and is more effective in reducing the carbon dioxide balance when applied to a hydraulic composition.

[0052] (CO₂-fixed modified recycled fine aggregate)

The CO₂-fixed modified recycled fine aggregate includes modified recycled fine aggregate in which all particles have a particle size of 10 mm or less and 85% or more of the particles have a particle size of 5 mm or less, and the modified recycled fine aggregate is a dry or wet reaction product of recycled fine aggregate having a water absorption of greater than 3.0% and 10% or less and carbon dioxide gas. The modified recycled fine aggregate contains calcium carbonate and silicon dioxide. The content ratio of the CO₂-fixed modified recycled fine aggregate is in the range of 10 to 100% by volume with respect to the total aggregate volume.

[0053] The CO₂-fixed modified recycled fine aggregate can be produced as follows. That is, a concrete mass is first crushed or grinded to obtain recycled fine aggregate. The

method of performing the crushing or grinding is not particularly limited, and known crushing or grinding devices such as a shot-blast-type crushing device, an impact crusher, and a grinding device of a mechanical rubbing and grinding type that does not involve heating can be used. Then, particles are classified so that all particles have a particle size of 10 mm or less, and among these, particles with a water absorption more than 3% and 10% or less are used as recycled fine aggregate. The recycled fine aggregate is then reacted with carbon dioxide gas with a volume concentration of 5% or more to produce CO₂-fixed modified recycled fine aggregate containing calcium carbonate and silicon dioxide. The reaction of recycled fine aggregate with carbon dioxide gas may employ a dry method or a wet method. In this way, CO₂-fixed modified recycled fine aggregate can be produced.

[0054] The content ratio of the CO₂-fixed fine powder can be 1 to 100% by mass, preferably 10 to 90% by mass, and even more preferably 30 to 80% by mass, with respect to 100% by mass of the binder as described above.

[0055] The content ratio of the CO₂-fixed modified recycled fine aggregate can be 10 to 100% by volume, preferably 20 to 100% by volume, and even more preferably 30 to 100% by volume, with respect to the total aggregate volume (more specifically, the aggregate volume using natural aggregates of the original mix) as described above.

[0056] Here, the original mix refers to a mix without CO₂-

fixed modified recycled fine aggregate. Further, natural aggregates refer to aggregates that have not been subjected to CO₂ fixation treatment. Examples of the natural aggregates include, in the case of fine aggregates, river sand, mountain sand, land sand, sea sand, silica sand, crushed sand, and various types of slag fine aggregates, and in the case of coarse aggregates, river gravel, mountain gravel, land gravel, crushed stone, various types of slag coarse aggregates, and lightweight aggregates. That is, "with respect to the aggregate volume using natural aggregates of the original mix" means "with respect to the volume of natural aggregates such as river sand as it has been used in the past". In other words, CO₂-fixed modified recycled fine aggregate may be used in place of aggregates conventionally used as aggregates (100% by volume), or may be used by replacing about 1/5 (i.e., 20% by volume) thereof.

[0057] The hydraulic composition may further contain other constituents as appropriate within a range in which the effect is not impaired. Examples of such other components include a saccharide, a coagulation retardation component made of an oxycarboxylic acid or the like, a component having a dispersing action made of sodium lignin sulfonate or the like, a defoaming agent made of an oxyalkylene-based compound or the like, a shrinkage reducing agent made of a polyoxyalkylene alkyl ether or the like, a thickener made of a cellulose ether-based compound or the like, a preservative made of an

isothiazoline-based compound or the like, and a rust inhibitor made of a nitrite or the like.

[0058] The content ratio of the other components can be, for example, 0 to 5% by mass with respect to 100% by mass of the binder.

[0059] The hydraulic composition may employ any conventionally known ratio as a ratio of water to binder (water/binder ratio) as appropriate; for example, it may be 25 to 70% by mass.

[0060] The hydraulic composition can be hardened to form a hydraulic composition hardened body (specifically, mortar and concrete). When obtaining the hydraulic composition hardened body in this manner, it is preferable to carry out a carbonation curing step, which is a step of curing in an environment with a carbon dioxide volume concentration of 5% or more. By carrying out the carbonation curing step in this manner, a large amount of carbon dioxide can be absorbed and fixed in the hydraulic composition (hydraulic composition hardened body).

[0061] The volume concentration of carbon dioxide in the carbonation curing step is not particularly limited, but can usually be 5 to 100%.

[0062] (3) Method for manufacturing hydraulic composition hardened body:

The method for manufacturing a hydraulic composition hardened body of the present invention includes the following

steps: a preparation step of preparing a hydraulic composition containing a carbonation accelerator for a hydraulic composition of the present invention, a binder containing blast furnace slag fine powder at 40 to 99% by mass, and water; a hardening step of hardening the obtained hydraulic composition to obtain a hydraulic composition hardened body; and a carbonation curing step of curing the obtained hydraulic composition hardened body in an environment with a carbon dioxide volume concentration of 5% or more to absorb and fix carbon dioxide in the hydraulic composition hardened body. According to the method for manufacturing a hydraulic composition hardened body, since a hydraulic composition containing the carbonation accelerator for a hydraulic composition of the present invention is used, the amount of carbon dioxide reduced in the manufacturing process is increased.

[0063] (3-1) Preparation step:

The preparation step is a step of preparing a hydraulic composition containing a carbonation accelerator for a hydraulic composition of the present invention, a binder containing blast furnace slag fine powder at 40 to 99% by mass, and water.

[0064] As described above, blast furnace slag fine powder is contained at 40 to 99% by mass, preferably 50 to 99% by mass, and more preferably 60 to 99% by mass. The above content ratio increases the amount of carbon dioxide reduced in the

manufacturing process of the hydraulic composition hardened body.

[0065] (3-2) Hardening step:

The hardening step is a step of hardening the hydraulic composition obtained in the preparation step to obtain a hydraulic composition hardened body. Conventional known methods for hardening a hydraulic composition can be employed as appropriate.

[0066] (3-3) Carbonation curing step:

The carbonation curing step is a step of curing the hydraulic composition hardened body obtained in the hardening step in an environment with a carbon dioxide volume concentration of 5% or more (carbonation curing) to absorb and fix carbon dioxide in the hydraulic composition hardened body.

[0067] In this step, carbon dioxide in the atmosphere is absorbed into the hydraulic composition hardened body and carbonated and fixed. By using the carbonation accelerator for a hydraulic composition, more carbon dioxide can be absorbed and fixed in the hydraulic composition (hydraulic composition hardened body).

[0068] The volume concentration of carbon dioxide is not particularly limited, but can usually be 5 to 100%.

[0069] If the volume concentration of carbon dioxide is less than 5%, the available amount of carbon dioxide present for absorption is too small, which may result in a prolonged period before reaching a predetermined amount of carbon dioxide

fixation.

Examples

[0070] Hereinafter, the present invention will be described in detail based on examples, but the present invention is not limited to these examples.

[0071] (Examples 1 to 86, Comparative Examples 1 to 9)

(1) Carbonation accelerator for hydraulic composition:

First, carbonation accelerators for a hydraulic composition A-1 to A-22 and RA-1 to RA-2 in Examples and Comparative Examples were prepared in the formulations shown in Table 1 below. In the organic amine compounds A-1 to A-22, organic amine compounds A-1 to A-9 and A-12 to A-19 are alkanolamines, and organic amine compounds A-10 to A-11 are polyamines.

[0072] [Table 1]

Classification	Notation	Compound Name	Manufacturer
Carbonation accelerator	A-1	triisopropanolamine	Tokyo Chemical Industry
	A-2	1,2-bis[di(hydroxyethyl)amino]ethane	-
	A-3	N,N'-bis(2-hydroxyethyl)ethylenediamine	Tokyo Chemical Industry
	A-4	diethanolamine	Tokyo Chemical Industry
	A-5	diisopropanolamine	Tokyo Chemical Industry
	A-6	2-([2-[(2-aminoethyl)amino]ethyl)amino)ethanol	-
	A-7	tris(hydroxymethyl)aminomethane	Tokyo Chemical Industry
	A-8	2-amino-1,3-propanediol	Tokyo Chemical Industry
	A-9	3-amino-1,2-propanediol	Tokyo Chemical Industry
	A-10	diethylenetriamine	Tokyo Chemical Industry
	A-11	triethylenetetramine	Tokyo Chemical Industry
	A-12	triethanolamine	Tokyo Chemical Industry
	A-13	2-aminoethanol (monoethanolamine)	Tokyo Chemical Industry
	A-14	DL-1-amino-2-propanol (isopropanolamine)	Tokyo Chemical Industry
	A-15	2-amino-2-ethyl-1,3-propanediol	Tokyo Chemical Industry
	A-16	2-(dimethylamino)ethanol	Tokyo Chemical Industry
	A-17	2-methylaminoethanol (N-methylethanolamine)	Tokyo Chemical Industry
	A-18	2-(2-aminoethoxy)ethanol (diglycolamine)	Tokyo Chemical Industry
	A-19	N-phenyl diethanolamine	Tokyo Chemical Industry
	A-20	2-aminophenol	Tokyo Chemical Industry
	A-21	L(+)-glutamine	Fujifilm Wako Pure Chemical
	A-22	morpholine	Tokyo Chemical Industry
	RA-1	calcium nitrate tetrahydrate	Fujifilm Wako Pure Chemical
	RA-2	calcium nitrite monohydrate	Kanto Chemical

[0073] The production methods of the carbonation accelerators for a hydraulic composition A-2 and A-6 will be specifically described below. As for the carbonation accelerators for a hydraulic composition other than A-2 and A-6, those manufactured by the above-described manufacturers were used.

[0074] RA-1 in Table 1 is calcium nitrate tetrahydrate, which is a compound conventionally used as a hardening accelerator for a hydraulic composition. RA-2 in Table 1 is calcium nitrite monohydrate, which is a compound conventionally used as a hardening accelerator for a hydraulic composition.

[0075] Organic amine compound A-2:

First, 254.3 g of ethylenediamine was charged in a pressure vessel equipped with a stirrer, pressure gauge, and thermometer. Then, while maintaining the reaction system at $85 \pm 10^\circ\text{C}$, 745.7 g of ethylene oxide was added at a gauge pressure of 0.4 MPa for 4 hours, and the temperature of $85 \pm 10^\circ\text{C}$ was maintained for 2 hours, thereby terminating the reaction. The reaction solution was then filtered to obtain 1,2-bis{di(hydroxyethyl)amino}ethane (organic amine compound A-2).

[0076] Organic amine compound A-6:

First, 701.0 g of diethylenetriamine was charged in a pressure vessel equipped with a stirrer, pressure gauge, and thermometer. Then, while maintaining the reaction system at $85 \pm 10^\circ\text{C}$, 299.0 g of ethylene oxide was added at a gauge pressure

of 0.4 MPa for 4 hours, and the temperature of $85 \pm 10^{\circ}\text{C}$ was maintained for 2 hours, thereby terminating the reaction. The reaction solution was then filtered to obtain 2-({2-[(2-aminoethyl)amino]ethyl}amino)ethanol (organic amine compound A-6).

[0077] (2) Hydraulic composition:

Next, hydraulic compositions (mortars) were prepared by employing Formulations C-1 to C-3 shown in Table 2.

[0078] Specifically, first, ordinary Portland cement, blast furnace slag fine powder #4000, a carbonation admixture LEAF mainly composed of $\gamma\text{-}2\text{CaO}\cdot\text{SiO}_2$, fine aggregate, carbon dioxide (CO_2)-fixed fine powder (CCU fine powder), and carbon dioxide (CO_2)-fixed modified recycled aggregate (CCU recycled fine aggregate) were sequentially charged into a mixer specified in JIS R5201 according to Formulations C-1 to C-3 (mortar formulation) as shown in Table 3, and then dry mixed for 10 seconds. In this case, ordinary Portland cement, blast furnace slag fine powder, and the carbonation admixture were regarded as binders. Ordinary Portland cement has a density of 3.16 g/cm^3 (manufactured by Taiheiyo Cement Corporation). Blast furnace slag fine powder #4000 has a density of 2.89 g/cm^3 (manufactured by Esment Chubu Co., Ltd.). The carbonation admixture LEAF mainly composed of $\gamma\text{-}2\text{CaO}\cdot\text{SiO}_2$ has a density of 3.09 g/cm^3 (manufactured by Denka Company Limited). The fine aggregate has a density of 2.58 g/cm^3 (Oigawa River system land sand). The carbon dioxide (CO_2)-fixed fine powder has a density

of 2.51 g/cm³. The carbon dioxide (CO₂)-fixed modified recycled aggregate has a density of 2.42 g/cm³.

[0079] The following are specific examples of CO₂-fixed fine powder and CO₂-fixed modified recycled aggregate.

[0080] The CO₂-fixed fine powder contains modified concrete powder, which has a 50% particle size of 50μm or less and is a reaction product of recycled concrete powder and carbon dioxide gas, and contains calcium carbonate and a siliceous material.

[0081] The CO₂-fixed fine powder was specifically produced as follows. That is, a concrete mass was crushed and grinded by a known crusher to obtain recycled concrete fine powder with a median diameter of 100μm or less. Then, 1800 kg of water and 200 kg of the obtained recycled concrete fine powder were sequentially charged into a 2m³ capacity vessel and stirred. Furthermore, carbon dioxide gas was injected from the bottom of the vessel at a rate of 150L/min to react the recycled concrete fine powder with CO₂. The above reaction process was continued until the pH of the dispersion liquid was below 6.8, and a reaction product of recycled concrete fine powder and CO₂ was obtained. After the reaction was completed, the obtained reaction product was taken out, excess water was removed with a twill-woven polypropylene filter, and the product was air-dried to obtain CO₂-fixed fine powder.

[0082] The CO₂-fixed modified recycled aggregate (specifically, the CO₂-fixed modified recycled fine aggregate)

includes modified recycled fine aggregate, which is a dry or wet reaction product of recycled fine aggregate with water absorption of greater than 3.0% and 10% or less and carbon dioxide gas, and contains calcium carbonate, silicon dioxide and gypsum.

[0083] The CO₂-fixed modified recycled aggregate was specifically produced as follows. That is, a concrete mass was crushed and grinded by a known crusher, and then classified by a sieve so that all particles had a particle size of 10mm or less, and the particles with water absorption greater than 3% and 10% or less were obtained as recycled fine aggregate. Then, 1800 kg of water and 200 kg of the obtained recycled fine aggregate were sequentially charged into a 2m³ capacity vessel and stirred. Furthermore, carbon dioxide gas was injected from the bottom of the vessel at a rate of 150 L/min to react the recycled fine aggregate with CO₂. The above reaction process was continued until the pH of the dispersion liquid was below 6.8, and a reaction product of recycled fine aggregate and CO₂ was obtained. After the reaction was completed, the obtained reaction product was taken out, excess water was removed with a twill-woven polypropylene filter, and the product was air-dried to obtain CO₂-fixed modified recycled fine aggregate.

[0084] Next, the carbonation accelerator for a hydraulic composition shown in Table 1, a water reducing agent (Chupol NV-80 (trade name), a high-performance water reducing agent manufactured by Takemoto Oil and Fat Co., Ltd.), and a

defoaming agent (AFK-2 (trade name) manufactured by Takemoto Oil and Fat Co., Ltd.) were added to the mixing water. However, the above-described carbonation accelerator, water reducing agent, and defoaming agent were regarded as a part of the mixing water. The mixing water was then charged into the mixer and kneaded for 180 seconds to obtain a hydraulic composition (mortar).

[0085] The carbonation accelerator for a hydraulic composition was added in the range of 0.02 to 0.20% by mass to the binder as shown in Tables 3 to 5. The amount of the water reducing agent added was set to an amount such that the mortar flow was within 205 ± 5 mm in Formulation C-1, set to an amount such that the mortar flow was within 200 ± 5 mm in Formulation C-2, and set to an amount such that the mortar flow was within 275 ± 5 mm in Formulation C-3. The defoaming agent was adjusted and added so that the air content of the kneaded mortar was 2% or less.

[0086] [Table 2]

Form ulat ion type	Water/ binder (%)	Water/ powder (%)	Fine aggreg ate/ binder	Fine aggreg ate/ powder	Amount of each component (upper row: kg/m ³ , lower row: L/m ³)								Amount of material- derived CO ₂ emission (α) (kg/m ³)
					Water	Powder				Oigawa River system land sand	CCU recycled fine aggregate	Total	
						Binder		Carbonation admixture	CCU fine powder				
						Ordinary Portland cement	Blast furnace slag fine powder						
C-1	55.0	55.0	1.78	1.78	342	187	435	0	0	1105	0	2069	154.2
					342	59	151	0	0	428	0	980	
C-2	55.0	55.0	1.78	1.78	343	131	306	187	0	1108	0	2074	131.5
					343	41	106	61	0	429	0	980	
C-3	55.0	36.7	1.28	0.85	335	128	298	183	304	0	777	2025	82.0
					335	40	103	59	121	0	321	980	

[0087] Formulations C-1 to C-3 have the following relationships. Specifically, no carbonation admixture was used in Formulation C-1, while the carbonation admixture was used in Formulations C-2 and C-3. The carbonation admixture is 30% by mass on an internal basis with respect to the binder. Formulation C-3 contains CCU fine powder, and the CCU fine powder is one in which fine aggregate is replaced at 50% by mass on an external basis with respect to the binder. In addition, Formulation C-3 contains CCU recycled fine aggregate, and 100% of the fine aggregate was replaced by the CCU recycled fine aggregate.

[0088] In Table 2, "Amount of material-derived CO₂ emission (α)" was calculated based on the amount of carbon dioxide emission of each component. That is, the amount of carbon dioxide emission of ordinary Portland is 764.3 kg/t, and the amount of carbon dioxide emission of blast furnace slag fine powder is 26.5 kg/t. The amount of carbon dioxide emission of carbonation admixture is 124.5 kg/t, the amount of carbon dioxide emission of CCU recycled fine aggregate is -26.9 kg/t, and the amount of carbon dioxide emission of CCU fine powder is -83.8 kg/t.

[0089] Tables 3 to 5 show the test results (mortar flow (mm), air content (%)) for mortars prepared by employing Formulations C-1 to C-3, respectively, and other results such as carbon dioxide balance. Note that the values in "Amount of material-derived CO₂ emission (α)" in Tables 3 to 5 are the

"Amount of material-derived CO₂ emission (α)" shown in Table 2.

[0090] In Examples 1 to 28 and Comparative Examples 1 and 2 shown in Table 3, the values for "Amount of carbon dioxide reduction" by the carbonation accelerator for a hydraulic composition are obtained by calculating the difference between the carbon dioxide balance of each Example and Comparative Example and the carbon dioxide balance of Comparative Example 3 as a reference. In Examples 29 to 57 and Comparative Examples 4 and 5 shown in Table 4, the values for "Amount of carbon dioxide reduction" by the carbonation accelerator for a hydraulic composition are obtained by calculating the difference between the carbon dioxide balance of each Example and Comparative Example and the carbon dioxide balance of Comparative Example 6 as a reference. In Examples 58 to 86 and Comparative Examples 7 and 8 shown in Table 5, the values for "Amount of carbon dioxide reduction" by the carbonation accelerator for a hydraulic composition are obtained by calculating the difference between the carbon dioxide balance of each Example and Comparative Example and the carbon dioxide balance of Comparative Example 9 as a reference.

[0091] In Comparative Examples 3, 6, and 9, only a water reducing agent is used without using a carbonation accelerator for a hydraulic composition.

[0092] Measurement methods for mortar flow (mm) and air content (%) of the hydraulic composition are shown below.

[0093] (Mortar flow)

The hydraulic composition immediately after mixing was measured in accordance with JIS R5201 in a state without a falling motion.

[0094] (Air volume (% by volume))

The hydraulic composition immediately after mixing was measured in accordance with JIS A1116 using a container for mortar.

[0095] (3) Method for manufacturing hydraulic composition hardened body:

(Hardening step of Mortar)

First, a cylindrical tin-plate concrete specimen molding formwork (product name "Summit Mold", S. C. Cement Co., Ltd, diameter of the bottom of the formwork 50 mm, height of the formwork 100 mm) was prepared, and the formwork was filled with the prepared hydraulic composition (mortar) using the two-layer filling method.

[0096] Next, air curing (20°C) was performed in a room at 20°C. Two hours after the mortar was prepared, the surface of the filled mortar was leveled, covered with polyethylene wrap to prevent moisture from evaporating, and sealed and cured for two days of the material age. A specimen (mortar hardened body) was then obtained.

[0097] (Carbonation curing step of Mortar hardened body (hydraulic composition hardened body))

After sealing and curing, the specimen (mortar hardened

body) was removed from the framework and carbonation curing was performed until a material age of 7 days (curing conditions: 20°C, 60% RH, and a carbon dioxide volume concentration of 60%) in a high concentration accelerated carbonation curing chamber (manufactured by MARUI & Co., Ltd.) capable of controlling temperature, humidity, and carbon dioxide concentration. At this time, carbonation was carried out from the entire surface of the specimen without covering the specimen. The hydraulic composition hardened body was manufactured in this way.

[0098] (Measurement of CO₂ fixation amount)

For the manufactured hydraulic composition hardened body, the amount of carbon dioxide fixed therein was measured as follows.

[0099] (Method of preparing sample for analysis)

After carbonation curing, the specimen (hydraulic composition hardened body) was removed from the curing chamber and promptly moved to a furnace at 105°C for drying treatment for 2 days. After drying, the specimen was entirely crushed and further pulverized with a ball mill to 150µm or less, and used as a sample for analysis.

[0100] (Methods for Measuring total carbon content and Calculating CO₂ fixation amount by carbonation curing)

To confirm the amount of carbon dioxide fixed by carbonation curing (amount of CO₂ fixation), the total carbon content (C (%)) in the sample for analysis was measured using

Total Organic Carbon Analyzer ("TOC-L" and Solid Sample Combustion Unit "SSM-5000A" manufactured by Shimadzu Corporation). The measurement conditions were such that the sample amount was 50 mg and the combustion temperature was 900°C.

[0101] From the obtained total carbon content, the amount of CO₂ fixed in the sample for analysis (%) was calculated using the following formula, and the amount of carbon dioxide fixed by carbonation curing (kg-CO₂/m³) was determined.

Formula: CO₂ (%) = C (%) × 44/12

[0102] The amount of CO₂ fixation is a percentage of the sample weight after heat treatment at 900°C. The amount of CO₂ fixation by carbonation curing is calculated by subtracting the amount of carbon detected as derived from the materials used in the mortar and the components added (water reducing agent, defoaming agent, and carbonation accelerator for a hydraulic composition). The above "materials used in the mortar" are cement, blast furnace slag fine powder, carbonation admixture, carbon dioxide fixed fine powder, fine aggregate, and carbon dioxide fixed modified recycled aggregate (carbon dioxide fixed modified recycled fine aggregate).

[0103] In Tables 3 to 5, "Carbon dioxide balance (α - β)" is the value calculated by the equation: Amount of material-derived CO₂ emissions (α) - Amount of CO₂ fixed by carbonation curing (β). The "Amount of carbon dioxide reduction" is a value calculated by the equation: |"Carbon dioxide balance" in each

Example - "Carbon dioxide balance" of Comparative Examples 3, 6, and 9|. The results of the "Amount of carbon dioxide reduction" indicate that each Example exhibits a superior carbon dioxide absorption effect as compared with the reference Comparative Examples 3, 6, and 9. That is, in each Example, the carbonation of the hydraulic composition is accelerated by the carbonation accelerator for a hydraulic composition.

[0104] [Table 3]

Examples/ Comparative Examples	Form ulat ion type	Water reducing agent		Carbonation accelerator for a hydraulic composition		Mortar flow (mm)	Amount of material- derived CO ₂ emission (α) (kg-CO ₂ /m ³)	Amount of CO ₂ fixed by carbonation curing (β) (kg-CO ₂ /m ³)	Carbon dioxide balance (α-β) (kg- CO ₂ /m ³)	Amount of carbon dioxide reduction *1	
		Type	B× (as- is)	Type	B× (components other than water)					(kg-CO ₂ /m ³)	Eval uati on
Example 1	C-1		0.40	A-1	0.20	208	154.2	143.1	11.1	49.8	S
Example 2	C-1		0.40	A-1	0.10	204	154.2	141.2	13.0	47.9	S
Example 3	C-1		0.40	A-1	0.02	203	154.2	140.8	13.4	47.5	S
Example 4	C-1		0.40	A-2	0.20	206	154.2	145.1	9.1	51.8	S
Example 5	C-1		0.40	A-2	0.10	210	154.2	144.2	10.0	50.9	S
Example 6	C-1		0.40	A-2	0.02	208	154.2	143.8	10.4	50.5	S
Example 7	C-1		0.40	A-3	0.20	207	154.2	144.9	9.3	51.6	S
Example 8	C-1		0.40	A-3	0.02	201	154.2	142.8	11.4	49.5	S
Example 9	C-1		0.40	A-4	0.20	202	154.2	140.2	14.0	46.9	S
Example 10	C-1		0.40	A-5	0.20	207	154.2	145.4	8.8	52.1	S
Example 11	C-1		0.40	A-6	0.20	206	154.2	144.8	9.4	51.5	S
Example 12	C-1		0.40	A-7	0.20	208	154.2	145.1	9.1	51.8	S
Example 13	C-1		0.40	A-8	0.20	205	154.2	140.8	13.4	47.5	S
Example 14	C-1		0.40	A-9	0.20	203	154.2	145.5	8.7	52.2	S
Example 15	C-1		0.40	A-10	0.20	204	154.2	141.8	12.4	48.5	S
Example 16	C-1		0.40	A-11	0.20	206	154.2	145.8	8.4	52.5	S
Example 17	C-1	Chupol	0.40	A-12	0.20	203	154.2	145.2	9.0	51.9	S
Example 18	C-1	NV-80	0.40	A-13	0.20	207	154.2	134.1	20.1	40.8	A
Example 19	C-1		0.40	A-13	0.10	206	154.2	132.9	21.3	39.6	A
Example 20	C-1		0.40	A-14	0.20	205	154.2	132.5	21.7	39.2	A
Example 21	C-1		0.40	A-15	0.20	201	154.2	130.3	23.9	37.0	A
Example 22	C-1		0.40	A-16	0.20	203	154.2	131.4	22.8	38.1	A
Example 23	C-1		0.40	A-17	0.20	208	154.2	132.0	22.2	38.7	A
Example 24	C-1		0.40	A-18	0.20	208	154.2	135.8	18.4	42.5	A
Example 25	C-1		0.40	A-19	0.20	203	154.2	131.4	22.8	38.1	A
Example 26	C-1		0.40	A-20	0.20	210	154.2	120.9	33.3	27.6	B
Example 27	C-1		0.40	A-21	0.20	202	154.2	120.1	34.1	26.8	B
Example 28	C-1		0.40	A-22	0.20	205	154.2	125.4	28.8	32.1	B
Comparative	C-1		0.40	RA-1	0.20	201	154.2	97.0	57.2	3.7	C
Comparative	C-1		0.40	RA-2	0.20	200	154.2	96.3	57.9	3.0	C
Comparative	C-1		0.40	—	0.00	203	154.2	93.3	60.9	0.0	C

*1: a value calculated by the equation: |"Carbon dioxide balance" in each Example - "Carbon dioxide balance" of Comparative Example 3|.

[0105] In Table 3, the following evaluation criteria were used for "Amount of carbon dioxide reduction".

S: Amount of carbon dioxide reduction (kg-CO₂/m³) is 45kg-CO₂/m³ or more

A: Amount of carbon dioxide reduction (kg-CO₂/m³) is 35kg-CO₂/m³

or more and less than $45\text{kg-CO}_2/\text{m}^3$

B: Amount of carbon dioxide reduction ($\text{kg-CO}_2/\text{m}^3$) is $25\text{kg-CO}_2/\text{m}^3$
or more and less than $35\text{kg-CO}_2/\text{m}^3$

C: Amount of carbon dioxide reduction ($\text{kg-CO}_2/\text{m}^3$) is less than
 $25\text{kg-CO}_2/\text{m}^3$

[0106] [Table 4]

Examples/ Comparative Examples	Form ulation type	Water reducing agent		Carbonation accelerator for a hydraulic composition		Mortar flow (mm)	Amount of material- derived CO ₂ emission (α) (kg-CO ₂ /m ³)	Amount of CO ₂ fixed by carbonation curing (β) (kg-CO ₂ /m ³)	Carbon dioxide balance (α-β) (kg- CO ₂ /m ³)	Amount of carbon dioxide reduction *1	
		Type	Bx% (as- is)	Type	Bx% (components other than water)					(kg-CO ₂ /m ³)	Evaluation
Example 29	C-2		0.52	A-1	0.20	198	131.5	160.3	-28.8	44.9	S
Example 30	C-2		0.52	A-1	0.10	202	131.5	159.2	-27.7	43.8	S
Example 31	C-2		0.52	A-1	0.05	203	131.5	158.4	-26.9	43.0	S
Example 32	C-2		0.52	A-2	0.20	198	131.5	157.3	-25.8	41.9	S
Example 33	C-2		0.52	A-2	0.10	196	131.5	156.2	-24.7	40.8	S
Example 34	C-2		0.52	A-2	0.05	197	131.5	155.9	-24.4	40.5	S
Example 35	C-2		0.52	A-3	0.20	204	131.5	159.9	-28.4	44.5	S
Example 36	C-2		0.52	A-4	0.20	197	131.5	158.2	-26.7	42.8	S
Example 37	C-2		0.52	A-4	0.05	205	131.5	157.6	-26.1	42.2	S
Example 38	C-2		0.52	A-5	0.20	195	131.5	156.4	-24.9	41.0	S
Example 39	C-2		0.52	A-5	0.05	196	131.5	155.7	-24.2	40.3	S
Example 40	C-2		0.52	A-6	0.20	203	131.5	159.1	-27.6	43.7	S
Example 41	C-2		0.52	A-6	0.05	198	131.5	157.2	-25.7	41.8	S
Example 42	C-2		0.52	A-7	0.20	195	131.5	158.0	-26.5	42.6	S
Example 43	C-2		0.52	A-8	0.20	204	131.5	155.9	-24.4	40.5	S
Example 44	C-2	Chupol NV-80	0.52	A-9	0.20	196	131.5	159.8	-28.3	44.4	S
Example 45	C-2		0.52	A-10	0.20	200	131.5	158.3	-26.8	42.9	S
Example 46	C-2		0.52	A-11	0.20	199	131.5	156.3	-24.8	40.9	S
Example 47	C-2		0.52	A-12	0.20	205	131.5	155.4	-23.9	40.0	S
Example 48	C-2		0.52	A-13	0.20	204	131.5	150.0	-18.5	34.6	A
Example 49	C-2		0.52	A-14	0.20	196	131.5	148.7	-17.2	33.3	A
Example 50	C-2		0.52	A-15	0.20	196	131.5	149.3	-17.8	33.9	A
Example 51	C-2		0.52	A-16	0.20	203	131.5	146.1	-14.6	30.7	A
Example 52	C-2		0.52	A-17	0.20	199	131.5	146.2	-14.7	30.8	A
Example 53	C-2		0.52	A-18	0.20	205	131.5	145.8	-14.3	30.4	A
Example 54	C-2		0.52	A-19	0.20	201	131.5	149.1	-17.6	33.7	A
Example 55	C-2		0.52	A-20	0.20	195	131.5	140.6	-9.1	25.2	B
Example 56	C-2		0.52	A-21	0.20	195	131.5	138.0	-6.5	22.6	B
Example 57	C-2		0.52	A-22	0.20	199	131.5	140.1	-8.6	24.7	B
Comparative	C-2		0.52	RA-1	0.20	205	131.5	119.5	12.0	4.1	C
Comparative	C-2		0.52	RA-2	0.20	202	131.5	119.1	12.4	3.7	C
Comparative	C-2		0.52	-	0.00	200	131.5	115.4	16.1	0.0	C

*1: a value calculated by the equation: |"Carbon dioxide balance in each Example - "Carbon dioxide balance" of Comparative Example 61|.

[0107] In Table 4, the following evaluation criteria were used for "Amount of carbon dioxide reduction".

S: Amount of carbon dioxide reduction (kg-CO₂/m³) is 40kg-CO₂/m³ or more

A: Amount of carbon dioxide reduction ($\text{kg-CO}_2/\text{m}^3$) is $30\text{kg-CO}_2/\text{m}^3$ or more and less than $40\text{kg-CO}_2/\text{m}^3$

B: Amount of carbon dioxide reduction ($\text{kg-CO}_2/\text{m}^3$) is $20\text{kg-CO}_2/\text{m}^3$ or more and less than $30\text{kg-CO}_2/\text{m}^3$

C: Amount of carbon dioxide reduction ($\text{kg-CO}_2/\text{m}^3$) is less than $20\text{kg-CO}_2/\text{m}^3$

[0108] [Table 5]

Examples/ Comparative Examples	Form ulat ion type	Water reducing agent		Carbonation accelerator for a hydraulic composition		Mortar flow (mm)	Amount of material- derived CO ₂ emission (α) (kg-CO ₂ /m ³)	Amount of CO ₂ fixed by carbonation curing (β) (kg-CO ₂ /m ³)	Carbon dioxide balance (α-β) (kg-CO ₂ /m ³)	Amount of carbon dioxide reduction *1	
		Type	Bx% (as- is)	Type	Bx% (components other than water)					(kg-CO ₂ /m ³)	Eval uati on
Example 58	C-3	Chupol NV-80	1.20	A-1	0.20	278	82.0	99.1	-17.1	31.9	S
Example 59	C-3		1.20	A-1	0.10	277	82.0	98.1	-16.1	30.9	S
Example 60	C-3		1.20	A-1	0.05	276	82.0	97.5	-15.5	30.3	S
Example 61	C-3		1.20	A-2	0.20	279	82.0	98.2	-16.2	31.0	S
Example 62	C-3		1.20	A-2	0.10	275	82.0	98.0	-16.0	30.8	S
Example 63	C-3		1.20	A-2	0.05	270	82.0	97.5	-15.5	30.3	S
Example 64	C-3		1.20	A-3	0.20	278	82.0	99.7	-17.7	32.5	S
Example 65	C-3		1.20	A-4	0.20	276	82.0	100.4	-18.4	33.2	S
Example 66	C-3		1.20	A-5	0.20	275	82.0	98.9	-16.9	31.7	S
Example 67	C-3		1.20	A-6	0.20	271	82.0	99.8	-17.8	32.6	S
Example 68	C-3		1.20	A-7	0.20	272	82.0	100.1	-18.1	32.9	S
Example 69	C-3		1.20	A-7	0.05	270	82.0	99.5	-17.5	32.3	S
Example 70	C-3		1.20	A-8	0.20	277	82.0	100.6	-18.6	33.4	S
Example 71	C-3		1.20	A-8	0.05	270	82.0	99.9	-17.9	32.7	S
Example 72	C-3		1.20	A-9	0.20	276	82.0	99.8	-17.8	32.6	S
Example 73	C-3		1.20	A-9	0.05	278	82.0	98.5	-16.5	31.3	S
Example 74	C-3		1.20	A-10	0.20	276	82.0	97.6	-15.6	30.4	S
Example 75	C-3		1.20	A-11	0.20	277	82.0	98.2	-16.2	31.0	S
Example 76	C-3		1.20	A-12	0.20	279	82.0	98.1	-16.1	30.9	S
Example 77	C-3		1.20	A-13	0.20	276	82.0	91.7	-9.7	24.5	A
Example 78	C-3		1.20	A-14	0.20	273	82.0	90.5	-8.5	23.3	A
Example 79	C-3		1.20	A-15	0.20	272	82.0	90.9	-8.9	23.7	A
Example 80	C-3		1.20	A-16	0.20	280	82.0	92.5	-10.5	25.3	A
Example 81	C-3		1.20	A-17	0.20	273	82.0	90.9	-8.9	23.7	A
Example 82	C-3		1.20	A-18	0.20	280	82.0	92.1	-10.1	24.9	A
Example 83	C-3		1.20	A-19	0.20	280	82.0	93.0	-11.0	25.8	A
Example 84	C-3		1.20	A-20	0.20	276	82.0	86.5	-4.5	19.3	B
Example 85	C-3		1.20	A-21	0.20	270	82.0	86.6	-4.6	19.4	B
Example 86	C-3		1.20	A-22	0.20	280	82.0	86.9	-4.9	19.7	B
Comparative Example 7	C-3		1.20	RA-1	0.20	272	82.0	70.0	12.0	2.8	C
Comparative Example 8	C-3		1.20	RA-2	0.20	271	82.0	69.9	12.1	2.7	C
Comparative Example 9	C-3		1.20	-	0.00	273	82.0	67.2	14.8	0.0	C

*1: a value calculated by the equation: |Carbon dioxide balance" in each Example - "Carbon dioxide balance" of Comparative Example 9|.

[0109] In Table 5, the following evaluation criteria were used for "Amount of carbon dioxide reduction".

S: Amount of carbon dioxide reduction (kg-CO₂/m³) is 30kg-CO₂/m³ or more

A: Amount of carbon dioxide reduction (kg-CO₂/m³) is 20kg-CO₂/m³

or more and less than $30\text{kg-CO}_2/\text{m}^3$

B: Amount of carbon dioxide reduction ($\text{kg-CO}_2/\text{m}^3$) is $10\text{kg-CO}_2/\text{m}^3$ or more and less than $20\text{kg-CO}_2/\text{m}^3$

C: Amount of carbon dioxide reduction ($\text{kg-CO}_2/\text{m}^3$) is less than $10\text{kg-CO}_2/\text{m}^3$

[0110] (Result)

As shown in Tables 3 to 5, it can be seen that the addition of the carbonation accelerator for a hydraulic composition in Examples accelerates carbonation of the hydraulic composition and increases the amount of carbon dioxide reduction by the hydraulic composition (hydraulic composition hardened body). In addition, according to the method for manufacturing a hydraulic composition hardened body in Examples, it is possible to accelerate carbonation of the hydraulic composition and increase the amount of carbon dioxide absorbed by the hydraulic composition hardened body to be manufactured (the amount of carbon dioxide reduction) by using the carbonation accelerator for a hydraulic composition in Examples as a raw material.

Industrial Availability

[0111] The carbonation accelerator for a hydraulic composition of the present invention can be used as a raw material for a hydraulic composition hardened body that reduces carbon dioxide by adding it to a hydraulic composition. The method for manufacturing a hydraulic composition hardened body

of the present invention can be employed as a manufacturing method of a hydraulic composition hardened body that absorbs carbon dioxide.

CLAIMS

1. A carbonation accelerator for a hydraulic composition comprising an organic amine compound.
2. The carbonation accelerator for a hydraulic composition according to claim 1, wherein the organic amine compound contains at least one selected from alkanolamines and polyamines.
3. The carbonation accelerator for a hydraulic composition according to claim 1 or 2, which is added to a hydraulic composition that becomes a hydraulic composition hardened body after undergoing a carbonation curing step, which is a step of curing in an environment with a carbon dioxide volume concentration of 5% or more.
4. The carbonation accelerator for a hydraulic composition according to claim 1 or 2, which is added to a hydraulic composition containing a binder that contains blast furnace slag fine powder at 40 to 99% by mass, water, and an aggregate.
5. The carbonation accelerator for a hydraulic composition according to claim 1 or 2, wherein the hydraulic composition contains γ -2CaO·SiO₂.

6. The carbonation accelerator for a hydraulic composition according to claim 1 or 2, wherein the hydraulic composition contains at least one selected from the following CO₂-fixed fine powder and the following CO₂-fixed modified recycled fine aggregate.

CO₂-fixed fine powder:

including modified concrete powder, which has a 50% particle size of 50μm or less and is a reaction product of recycled concrete powder and carbon dioxide gas,

wherein the modified concrete powder contains calcium carbonate and a siliceous material, and

wherein a content ratio of the CO₂-fixed fine powder in the hydraulic composition is in the range of 1 to 100% by mass with respect to 100% by mass of the binder.

CO₂-fixed modified recycled fine aggregate:

including modified recycled fine aggregate in which all particles have a particle size of 10 mm or less and 85% or more of the particles have a particle size of 5 mm or less, the modified recycled fine aggregate being a dry or wet reaction product of recycled fine aggregate having a water absorption greater than 3.0% and 10% or less and carbon dioxide gas,

wherein the modified recycled fine aggregate contains calcium carbonate and silicon dioxide, and

wherein the content ratio of the CO₂-fixed modified recycled fine aggregate in the hydraulic composition is in the

range of 10 to 100% by volume with respect to the total aggregate volume.

7. A method for manufacturing a hydraulic composition hardened body, comprising:

a preparation step of preparing a hydraulic composition containing a carbonation accelerator for a hydraulic composition according to claim 1 or 2, a binder containing blast furnace slag fine powder at 40 to 99% by mass, and water;

a hardening step of hardening the obtained hydraulic composition to obtain a hydraulic composition hardened body;
and

a carbonation curing step of curing the obtained hydraulic composition hardened body in an environment with a carbon dioxide volume concentration of 5% or more to absorb and fix carbon dioxide in the hydraulic composition hardened body.