

SPECIFICATION

Title of Invention

CONCRETE COMPOSITION AND METHOD FOR MANUFACTURING CONCRETE

5 COMPOSITION

Technical Field

[0001]

The present invention relates to a concrete composition
10 and a method of manufacturing a concrete composition.

Background Art

[0002]

The performances required for concrete are roughly
15 classified into workability, strength, and durability. Among
indices indicating the performances of concrete, slump or slump
flow pertaining to workability, or compressive strength
pertaining to strength is a representative and general index.
In addition, the compressive strength of concrete largely
20 depends on water-cement ratio. Therefore, by appropriately
setting the compressive strength, durability that largely
depends on water-cement ratio is also secured. In a case where
satisfactory durability cannot be obtained with only
water-cement ratio, the kind of cement can also be selected
25 according to required performance.

Slump or slump flow is excessively used as a representative and general index indicating workability, and thus workability may be determined based on only a numerical value of slump or slump flow. Actually, material separation resistance and/or impact deformation resistance pertaining to workability is an important index indicating the performance of concrete.

Material separation resistance and/or impact deformation resistance largely relates to the viscosity of concrete. In a case where fluidity is excessively increased in order to improve workability, material separation resistance and/or impact deformation resistance deteriorates. In a case where material separation, which is a phenomenon in which a coarse aggregate is separated from mortar, occurs, strength and durability deteriorate. In addition, the degree of deformation of a concrete composition by impact increases, material separation resistance deteriorates. That is, material separation resistance and/or impact deformation resistance relates not only to workability but also to improvement of strength and durability.

[0003]

In order to secure material separation resistance and/or impact deformation resistance of concrete, it is necessary to examine materials used and compositions thereof. One measure to secure material separation resistance and/or impact deformation resistance is to use fine powder such as cement as

much as possible. Another measure is to use fine particles such as a fine aggregate as much as possible within an allowable range.

However, the amount of powder or fine particles used is limited, and a necessary amount of powder or fine particles for securing material separation resistance and/or impact deformation resistance may not be used. Therefore, in a case where material separation resistance and/or impact deformation resistance is not sufficiently secured with powder or fine particles, an admixture such as blast furnace slag fine powder, limestone fine powder, fly ash, or silica fume may be used.

In this way, in order to improve material separation resistance of concrete, a technique of mixing materials containing powder, fine particles, and an admixture with a good balance as concrete materials is disclosed (for example, refer to Patent Literature No. 1). On the other hand, a technique of improving material separation resistance by chemically imparting viscosity using a special admixture such as a thickener or an underwater-inseparable admixture is also disclosed (for example, refer to Patent Literature No. 2).

Prior art Literature

Patent Literature

[0004]

[Patent Literature No. 1] Japanese Laid-open Patent

Publication No. 2014-114176 A

[Patent Literature No. 2] Japanese Laid-open Patent
Publication No. 2005-281088 A

Summary of Invention

5 Problems to be solved

[0005]

As described above, basic means for securing material separation resistance and/or impact deformation resistance of concrete is to add appropriate amounts of powder and fine
10 particles. However, improvement of material separation resistance and/or impact deformation resistance using powder and fine particles may lead to deterioration in workability due to an increase in viscosity. In addition, in a case where material separation resistance and/or impact deformation
15 resistance is improved while securing the amount of cement, there may be problems of thermal cracking or an increase in autogenous shrinkage due to an increase in the amount of cement.

Therefore, a means to solve the problems is to add an admixture such as silica fume and a special admixture such as
20 a thickener or an underwater-inseparable admixture. However, the admixture and the special admixture are extremely expensive materials. Therefore, in a case where the admixture and the special admixture are added only to secure material separation resistance and/or impact deformation resistance, there is a
25 problem in that cost-effectiveness is low.

[0006]

An object of the present invention is to provide a concrete composition in which cost-effectiveness and environmental load reduction are superior, material separation resistance and/or impact deformation resistance is secured at a high level, and workability is superior.

Solution to Problems

[0007]

The present inventors performed a thorough investigation in order to achieve the object and found that, by adding crushed fly ash obtained by crushing fly ash raw powder to have specific physical properties in consideration of cost-effectiveness and environmental load reduction, a concrete composition in which material separation resistance and/or impact deformation resistance is secured at a high level and in which workability is superior can be provided, thereby conceiving the present invention. That is, the present invention is as follows.

[0008]

[1] A concrete composition comprising:
cement; and

crushed fly ash that is obtained by crushing fly ash raw powder,

in which the crushed fly ash satisfies a condition that a JA funnel flow time of fly ash paste containing 50 parts by

mass of water with respect to 100 parts by mass of the crushed fly ash is in a range of 17 ~ 27 seconds.

[2] A concrete composition comprising:

cement; and

5 crushed fly ash that is obtained by crushing fly ash raw powder,

in which when a mixture of the crushed fly ash and water is agitated by "9.2.3 Mixer for Mechanical Mixing" of JIS R5201, a water-powder mass ratio of the mixture at which a current
10 flowing through the mixer for mechanical mixing is maximum, is 23 ~ 27%.

[3] A concrete composition comprising:

cement; and

crushed fly ash that is obtained by crushing fly ash raw
15 powder,

in which for the crushed fly ash, a bulk specific gravity after crushing increases by 1.5% or higher and 3.0% or lower relative to a bulk specific gravity before crushing.

[4] The concrete composition according to any one of [1]
20 to [3],

in which an ignition loss of the crushed fly ash is 3 mass% or higher and 10 mass% or lower.

[5] The concrete composition according to any one of [1]
to [4],

25 in which a content of the crushed fly ash is 20 kg or more

and 150 kg or less per 1 m³ volume of the concrete composition.

[6] The concrete composition according to any one of [1] to [5], further comprising at least one selected from the group consisting of an admixture and a special admixture.

5 [7] The concrete composition according to any one of [1] to [6],

in which the cement is at least one selected from the group consisting of normal Portland cement, high early strength Portland cement, moderate heat Portland cement, and low-heat
10 Portland cement.

[8] A method of manufacturing a concrete composition containing cement and crushed fly ash that is obtained by crushing fly ash raw powder, the method comprising:

a step of obtaining the crushed fly ash by crushing the
15 fly ash raw powder such that a bulk specific gravity after crushing increases by 1.5% or higher and 3.0% or lower relative to a bulk specific gravity before crushing; and

a step of mixing the cement and the crushed fly ash.

[9] The method of manufacturing a concrete composition
20 according to [8],

in which an ignition loss of the fly ash raw powder is 3 mass% or higher and 10 mass% or lower.

Effects of Invention

25 [0009]

According to the present invention, it is possible to provide a concrete composition in which cost-effectiveness and environmental load reduction are superior, material separation resistance and/or impact deformation resistance is secured at
5 a high level, and workability is superior.

Mode for carrying out the Invention

[0010]

A concrete composition of an embodiment of the present
10 invention comprises: cement; and crushed fly ash that is obtained by crushing fly ash raw powder, in which the crushed fly ash satisfies a condition that a JA funnel flow time of fly ash paste containing 50 parts by mass of water with respect to 100 parts by mass of the crushed fly ash is in a range of 17 ~ 27 seconds.

15 In this specification, the JA funnel flow time refers to a flow time measured by a grout flow cone MIC-363-0-03 according to JSCE-F531 "Test Method for Fluidity of PC Grout".

In this specification, the JA funnel flow time of fly ash paste containing 50 parts by mass of water with respect to 100
20 parts by mass of the crushed fly ash will also be referred to as "JA funnel flow time" or "JA funnel flow time of fly ash paste".

[0011]

In this specification, "crushed fly ash" refers to fly ash obtained by crushing the fly ash raw powder. The crushed fly
25 ash may satisfy JIS standards. In this specification, in order

to obtain the crushed fly ash, all the particles in the fly ash raw powder are not necessarily crushed into fine particles. Fly ash which is obtained by crushing the fly ash raw powder but still contains some non-crushed particles even after crushing is also called crushed fly ash.

As a crusher for crushing, a ball mill or a vibration mill (that refines powder by applying vibration to a container and transmitting the vibration to media (balls and rods) in the container) can be used. The crushed fly ash obtained by crushing the fly ash raw powder satisfies the condition that the JA funnel flow time of fly ash paste containing 50 parts by mass of water with respect to 100 parts by mass of the crushed fly ash is in a range of 17 ~ 27 seconds.

[0012]

In a case where the crushed fly ash contained in the concrete composition satisfies the condition that the JA funnel flow time of the fly ash paste is in a range of 17 ~ 27 seconds, the concrete composition containing the crushed fly ash has superior fluidity and appropriate viscosity and can improve workability. In a case where the crushed fly ash contained in the concrete composition satisfies the condition that the JA funnel flow time of the fly ash paste is in a range of 17 ~ 27 seconds, high material separation resistance can be secured due to appropriate fluidity. Material separation resistance can be indirectly evaluated based on a rebound reducing effect, and

the impact deformation resistance of the concrete composition can be evaluated based on the rebound reducing effect. As the number of times for spread measured by a test method described below in Examples increases, the rebound reducing effect is high, and material separation resistance and/or impact deformation resistance can be evaluated to be superior. In a case where the crushed fly ash satisfies the condition that the JA funnel flow time of the fly ash paste is shorter than 17 seconds, the fluidity of the concrete composition containing the crushed fly ash increases, the viscosity excessively decreases, and the workability may deteriorate. On the other hand, in a case where the crushed fly ash satisfies the condition that the JA funnel flow time of the fly ash paste is longer than 27 seconds, the fluidity deteriorates, and the workability may not be improved.

[0013]

Regarding the crushed fly ash that satisfies the condition that the JA funnel flow time of the fly ash paste containing 50 parts by mass of water with respect to 100 parts by mass of the crushed fly ash is in a range of 17 ~ 27 seconds, from the viewpoints of improving workability and securing high material separation resistance, is preferable that, when a mixture of the crushed fly ash and water is agitated by "9.2.3 Mixer for Mechanical Mixing" of JIS R5201, a water-powder mass ratio of the mixture at which a current flowing through the mixer for mechanical mixing is maximum, is 23 ~ 27%.

In addition, the crushed fly ash that satisfies the condition that the JA funnel flow time of the fly ash paste containing 50 parts by mass of water with respect to 100 parts by mass of the crushed fly ash is in a range of 17 ~ 27 seconds, from the viewpoints of improving workability and securing high material separation resistance, is preferable that a bulk specific gravity after crushing increases by 1.5% or higher and 3.0% or lower relative to a bulk specific gravity before crushing.

[0014]

A concrete composition of an embodiment of the present invention comprises: cement; and crushed fly ash that is obtained by crushing fly ash raw powder, in which when a mixture of the crushed fly ash and water is agitated by "9.2.3 Mixer for Mechanical Mixing" of JIS R5201, a water-powder mass ratio of the mixture at which a current flowing through the mixer for mechanical mixing is maximum is 23 ~ 27%.

[0015]

When the mixture is agitated by "9.2.3 Mixer for Mechanical Mixing" of JIS R5201 while changing the ratio of water to 1000 g of the crushed fly ash, a current value flowing through the mixer for mechanical mixing is measured. In this case, in a case where the addition amount of water is fixed with respect to 1000 g of the crushed fly ash, the current value flowing through the mixer for mechanical mixing is maximum. In this case, a ratio

of the mass of water to the mass of the crushed fly ash in the mixture at which the current value flowing through the mixer for mechanical mixing is maximum, will also be referred to as "water-powder mass ratio at the maximum current value".

5 [0016]

The water-powder mass ratio at the maximum current value is a numerical value specific to powder as a target. The water-powder mass ratio at the maximum current value can be defined as a bound water ratio and is recognized as a numerical
10 value specific to powder. The bound water ratio represents the mass of water bound in powder. In a case where the current value flowing through "9.2.3 Mixer for Mechanical Mixing" of JIS R5201 is maximum, the current value does not depend on the kind of an agitator and the operation condition (low speed or high speed)
15 of an agitator. In a case where the mixture is agitated while slowly adding water to the powder, the current value flowing through the mixer for mechanical mixing is measured, and the measured current value shows a peak at a given water-powder mass ratio. At this time, the operation of a paddle does not change
20 in the mixer for mechanical mixing, and the water-powder mass ratio is not recognizable by visual inspection. A water-powder mass ratio at which an agitation torque is maximum, is recognizable based on only a change in current value.

[0017]

25 When the crushed fly ash and water are mixed and agitated

by "9.2.3 Mixer for Mechanical Mixing" of JIS R5201, in a case where a water-powder mass ratio of the mixture at which a current value flowing through the mixer for mechanical mixing is maximum, is 23% ~ 27%, the crushed fly ash appropriately adsorbs water, and the concrete composition containing the crushed fly ash has superior fluidity and appropriate viscosity and can improve workability. When the crushed fly ash and water are mixed and agitated, in a case where the water-powder mass ratio at which the agitation torque is maximum, is 23% ~ 27%, the crushed fly ash appropriately adsorbs water. Therefore, the concrete composition containing the fly ash can secure high material separation resistance and/or impact deformation resistance. When the crushed fly ash and water are mixed and agitated by the mixer for mechanical mixing, in a case where the water-powder mass ratio at which the current value flowing through the mixer for mechanical mixing is maximum is lower than 23%, the amount of water bound in the crushed fly ash is small. For example, in spray concrete, the amount of rebound increases, and the rebound reducing effect tends to decrease. When the crushed fly ash and water are mixed and agitated by the mixer for mechanical mixing, when the crushed fly ash and water are mixed and agitated by the mixer for mechanical mixing, in a case where the water-powder mass ratio at which the current value flowing through the mixer for mechanical mixing is maximum, is higher than 27%, the amount of water bound in the crushed fly ash is

large, the fluidity in the fresh state at the start of agitation deteriorates, and the viscosity increases. On the other hand, an excessively large amount of water is absorbed. Therefore, the amount of rebound increases, and impact deformation resistance required to reduce rebound deteriorates.

[0018]

The crushed fly ash that satisfies the condition that, when the crushed fly ash and water are mixed and agitated by "9.2.3 Mixer for Mechanical Mixing" of JIS R5201, a water-powder mass ratio of the mixture at which a current flowing through the mixer for mechanical mixing is maximum, is 23% ~ 27%, it is preferable that the JA funnel flow time of the fly ash paste is in a range of 17 ~ 27 seconds from the viewpoints of improving workability and securing high material separation resistance and/or impact deformation resistance.

When the crushed fly ash and water are mixed and agitated by the mixer for mechanical mixing, in a case where a water-powder mass ratio of the mixture at which a current flowing through the mixer for mechanical mixing is maximum, is 23 ~ 27%, it is preferable that a bulk specific gravity after crushing increases by 1.5% or higher and 3.0% or lower relative to a bulk specific gravity before crushing from the viewpoints of improving workability and securing high material separation resistance and/or impact deformation resistance.

[0019]

A concrete composition of an embodiment of the present invention comprises: cement; and crushed fly ash that is obtained by crushing fly ash raw powder, for which in the crushed fly ash, a bulk specific gravity after crushing increases by 1.5% or higher and 3.0% or lower relative to a bulk specific gravity before crushing. In this specification, an increase rate of the bulk specific gravity of the fly ash after crushing with respect to the bulk specific gravity of the fly ash before crushing will also be referred to as "increase rate of the bulk specific gravity".

[0020]

In a case where the increase rate of the bulk specific gravity in the crushed fly ash is lower than 1.5%, sufficient material separation resistance and/or impact deformation resistance cannot be secured. In addition, in a case where the increase rate of the bulk specific gravity in the crushed fly ash is higher than 3.0%, fluidity and workability deteriorate. From the above-described points, it is preferable that for the crushed fly ash, the bulk specific gravity after crushing increases by preferably 1.6% or higher and 2.9% or lower, more preferably 1.7% or higher and 2.8% or lower, and still more preferably 1.8% or higher and 2.7% or lower relative to the bulk specific gravity before crushing.

In this specification, "bulk specific gravity" refers to the apparent density of powder which is measured when an iron

container having a volume of 400 cm³ or higher and 410 cm³ or lower is filled with the powder as a measurement target and then a falling motion using a flow table defined in JIS R5201:2015 is applied to the powder for 70 times.

5 [0021]

The crushed fly ash, which has the bulk specific gravity after crushing increased by 1.5% or higher and 3.0% or lower—relative to the bulk specific gravity before crushing, from the viewpoints of improving workability and securing high material separation resistance and/or impact deformation resistance, is preferable that the JA funnel flow time of the fly ash paste is in a range of 17 ~ 27 seconds.

The crushed fly ash which has the bulk specific gravity after crushing increased by 1.5% or higher and 3.0% or lower relative to the bulk specific gravity before crushing in the crushed fly ash, from the viewpoints of improving workability and securing high material separation resistance and/or impact deformation resistance, is preferable that, when the crushed fly ash and water are mixed and agitated by “9.2.3 Mixer for Mechanical Mixing” of JIS R5201, a water-powder mass ratio of the mixture at which a current value flowing through the mixer for mechanical mixing is maximum is 23% or higher and 27% or lower.

[0022]

25 It is preferable that the bulk specific gravity of the

crushed fly ash is $1.12 \text{ g/cm}^3 \sim 1.13 \text{ g/cm}^3$. In a case where the bulk specific gravity of the crushed fly ash is $1.12 \text{ g/cm}^3 \sim 1.13 \text{ g/cm}^3$, the concrete composition containing the crushed fly ash has superior fluidity and an appropriate viscosity, can improve workability, and can secure high material separation resistance and/or impact deformation resistance.

[0023]

From the viewpoint of securing sufficient workability, it is preferable that an ignition loss of the crushed fly ash is preferably 3 mass% or higher and 10 mass% or lower. The ignition loss of the crushed fly ash is more preferably 3 mass% or higher and 9 mass% or lower and still more preferably 3 mass% or higher and 8 mass% or lower. The ignition loss can be measured by a method described below in Examples. The mechanism in which the ignition loss of the crushed fly ash contributes to workability is not clear. However, in a case where the ignition loss of the crushed fly ash is 3 mass% or higher and 10 mass% or lower, appropriate viscosity is applied to the concrete composition-containing the crushed fly ash and the cement, and sufficient workability can be obtained.

[0024]

The kind of the cement contained in the concrete composition is not particularly limited, and is preferably at least one selected from the group consisting of normal Portland cement, high early strength Portland cement, moderate heat

Portland cement, and low-heat Portland cement.

The mixing amount of the cement in the concrete composition is preferably 300 kg or more and 420 kg or less, more preferably 320 kg or more and 400 kg or less, and still more preferably 340 kg or more and 380 kg or less per 1m^3 volume of the concrete composition.

[0025]

For example, the concrete composition may further contain water, a fine aggregate, a coarse aggregate, or an admixture as a constituent material. The fine aggregate is an aggregate having a particle diameter of 5 mm or less. For example, a well-known fine aggregate such as river sand, mountain sand, land sand, crushed sand, sea sand, or silica sand can be used. The coarse aggregate is an aggregate having a particle diameter of more than 5 mm. For example, a well-known coarse aggregate such as gravel or crushed sandstone can be used.

The mixing amount of the fine aggregate in the concrete composition is preferably 850 kg or more and 1050 kg or less, more preferably 875 kg or more and 1025 kg or less, and still more preferably 900 kg or more and 1000 kg or less per 1m^3 volume of the concrete composition.

The mixing amount of the coarse aggregate in the concrete composition is preferably 600 kg or more and 900 kg or less, more preferably 650 kg or more and 850 kg or less, and still more preferably 700 kg or more and 800 kg or less per 1m^3 volume

of the concrete composition.

[0026]

It is preferable that the concrete composition further contains at least one selected from the group consisting of an admixture and a special admixture. It is preferable that the concrete composition contains the admixture and the special admixture in consideration of cost-effectiveness and environmental load reduction.

Examples of the admixture are blast furnace slag fine powder, limestone fine powder, and silica fume.

Examples of the special admixture are a thickener and an underwater-inseparable admixture.

Examples of the thickener are: a cellulose thickener such as methyl cellulose; a biopolymer thickener such as a water-soluble polysaccharide; and an acrylic thickener such as an acrylic polymer.

Examples of the underwater-inseparable admixture are: a cellulose admixture of a cellulose water-soluble polymer as a major component; and an acrylic admixture containing a polyacrylamide water-soluble polymer as a major component.

[0027]

From the viewpoints of securing high material separation resistance and/or impact deformation resistance and sufficient workability, the mixing amount of the crushed fly ash in the concrete composition is preferably 20 kg or more and 150 kg or

less per 1 m³ volume of the concrete composition. The content of the crushed fly ash is more preferably 30 kg or more and 140 kg or less and still more preferably 40 kg or more and 130 kg or less.

5 [0028]

From the viewpoint of securing sufficient workability, it is preferable that an ignition loss of the fly ash raw powder is preferably 3 mass% or higher and 10 mass% or lower. The ignition loss of the fly ash raw powder is more preferably 3 mass% or higher and 9 mass% or lower and still more preferably 3 mass% or higher and 8 mass% or lower. The ignition loss can be measured by a method described below in Examples. The mechanism in which the ignition loss of the crushed fly ash contributes to workability is not clear. However, in a case where the ignition loss of the crushed fly ash is 3 mass% or higher and 10 mass% or lower, appropriate viscosity is applied to the concrete composition containing the crushed fly ash and the cement, and sufficient workability can be obtained.

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[0029]

The fly ash raw powder in which the ignition loss is in the above-described range is, for example, ash discharged from a coal-fired power plant, and is produced by burning pulverized coal. The fly ash raw powder are: fly ash that is collected from combustion gas of a combustion boiler when the combustion gas falls and passes through an air preheater or an economizer; fly

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ash that is collected by an electrical dust collector; and ash that falls to a furnace bottom of a combustion boiler.

[0030]

The concrete composition of the embodiment of the present invention is preferably used as spray concrete. Spray concrete refers to concrete used in a construction method of feeding concrete containing a concrete composition and water and spraying the concrete from a nozzle tip to a predetermined position by compressed air to be cured. In the spray construction method of concrete, a phenomenon in which aggregates in sprayed concrete rebound due to the impact, a designed amount of concrete is not sprayed, and there is loss in the amount of concrete is called rebound. The rebound reducing effect is that sprayed concrete endures impact, aggregates do not rebound, a designed amount of cement can be sprayed, and there is no loss in the amount of concrete. In the concrete composition having the rebound reducing agent, aggregates and components (for example, cement or fly ash) other than aggregates are not likely to be separated from each other, that is, material separation resistance is high. In addition, in the concrete composition having the rebound reducing effect, aggregates do not rebound, and impact deformation resistance is high. By checking superiority and inferiority of the rebound reducing effect of the spray concrete, superiority and inferiority of material separation resistance or impact

deformation resistance can be indirectly evaluated.

[0031]

A method of manufacturing a concrete composition of an embodiment of the present invention is a method of manufacturing a concrete composition containing cement and crushed fly ash that is obtained by crushing fly ash raw powder. This method-comprises: a step of obtaining the crushed fly ash by crushing the fly ash raw powder such that a bulk specific gravity after crushing increases by 1.5% or higher and 3.0% or lower relative to a bulk specific gravity before crushing; and a step of mixing the cement and the crushed fly ash.

[0032]

In the step of obtaining the crushed fly ash by crushing fly ash raw powder, various crushing methods for adjusting the bulk specific gravity of the crushed fly ash to be in the above-described range can be adopted.

As a crusher for preparing the crushed fly ash, a ball mill or a vibration mill (that refines powder by applying vibration to a container and transmitting the vibration to media (balls and rods) in the container) can be used.

In a case where a ball mill is used as the crusher, the rotating speed of the ball mill is preferably 45 rpm or higher and 75 rpm or lower, more preferably 50 rpm or higher and 70 rpm or lower, and still more preferably 55 rpm or higher and 65 rpm or lower. In addition, in a case where a ball mill is

used, the crushing time is preferably 3 minutes or longer and 15 minutes or shorter, more preferably 3 minutes or longer and 12 minutes or shorter, and still more preferably 3 minutes or longer and 10 minutes or shorter.

5 [0033]

In the step of mixing the cement and the crushed fly ash, the concrete composition can be prepared by adding the cement, the crushed fly ash, and other constituent materials at a mixing ratio and mixing the components by a mixer or the like.

10 [0034]

The concrete composition of the embodiment of the present invention is prepared by mixing solids contained in the concrete composition and water to manufacture a concrete mixture.

Solids-contained in the concrete composition may be prepared
15 in advance and then mixed with water to prepare a concrete mixture, or all the source materials including respective solids contained in the concrete composition and water may be mixed at the same time to prepare a concrete mixture. The mixing method is not particularly limited as long as the components can be
20 uniformly mixed.

The amount of water used for mixing can vary depending on the kind and composition of materials to be used and thus cannot be unambiguously determined. However, the water-cement ratio is preferably 50 mass% or higher and 70 mass% or lower and more
25 preferably 55 mass% or higher and 65 mass% or lower.

In addition, mixing conditions, the kind of a mixer, and the like are not particularly limited, and a common mixer can be used.

The obtained concrete mixture can be cured by, for example,
5 steam curing or water curing to obtain concrete.

[0035]

For the concrete composition of the present invention, by adding the crushed fly ash obtained by crushing the fly ash raw powder to have specific physical properties, material
10 separation resistance can be secured at a high level. Since the material separation resistance of the concrete composition is high, the workability of the concrete composition is superior, and the work efficiency can be improved.

Examples

15 [0036]

Hereinafter, the present invention will be described in more detail with Examples but is not limited to the Examples.

[0037]

(Materials Used)

20 ·Cement: normal Portland cement (manufactured by Sumitomo Osaka Cement Co., Ltd.)

·Water: tap water

·Fine aggregate: mountain sand

·Coarse aggregate: crushed sandstone

·Fly ash (FA): the following (1) to (10)

(1) Type II ash (product (classified product) conforming to Type II of JIS A 6201: 2015 "Fly Ash for use in Concrete", ignition loss: 2.75 mass%)

5 (2) Raw powder (fly ash raw powder, produced from a domestic coal-fired power plant, ignition loss: 6.21 mass%)

(3) 1-minute crushed FA (crushed fly ash produced from a domestic coal-fired power plant, ignition loss: 6.21 mass%)

10 (4) 2-minute crushed FA (crushed fly ash produced from a domestic coal-fired power plant, ignition loss: 6.21 mass%)

(5) 3-minute crushed FA (crushed fly ash produced from a domestic coal-fired power plant, ignition loss: 6.21 mass%)

(6) 4-minute crushed FA (crushed fly ash produced from a domestic coal-fired power plant, ignition loss: 6.21 mass%)

15 (7) 5-minute crushed FA (crushed fly ash produced from a domestic coal-fired power plant, ignition loss: 6.21 mass%)

(8) 10-minute crushed FA (crushed fly ash produced from a domestic coal-fired power plant, ignition loss: 6.21 mass%)

20 (9) 20-minute crushed FA (crushed fly ash produced from a domestic coal-fired power plant, ignition loss: 6.21 mass%)

(10) 30-minute crushed FA (crushed fly ash produced from a domestic coal-fired power plant, ignition loss: 6.21 mass%)

[0038]

25 The ignition losses of the fly ash raw powder and the crushed fly ash were obtained according to JIS A 6201: 2015 "Fly

Ash for use in Concrete" (ignition at 975°C for 15 minutes).

[0039]

(Crushing of Fly Ash Raw Powder)

In order to crush the fly ash raw powder, a tilting ball
5 mill with a drum having a capacity of 100 liters was used. As
balls to be put, $\phi 10$ mm chromium steel balls (about 3.5 kg/piece)
are used. The balls were put into the fly ash raw powder in the
drum (weight ratio=100 kg of the balls with respect to 10 kg
of the fly ash raw powder at most). After putting the balls,
10 the tilting ball mill was horizontally positioned and was
operated at a rotating speed of 60 rpm for the predetermined
time to crush the fly ash raw powder.

[0040]

Regarding each of (1) the type II ash, (2) the fly ash raw
15 powder, and (3) to (10) of the respective crushed fly ashes,
the following measurement was performed.

[0041]

(Measurement of Bulk Specific Gravity)

An iron container having a volume of 400 cm³ or higher and
20 410 cm³ or lower was filled with the fly ash as a measurement
target, and a falling motion using a flow table defined in "12.2
Measurement of Flow Value" of JIS R5201:2015 "Physical Testing
Methods for Cement" is applied to the fly ash for 70 times. Next,
the apparent density (bulk density) of the fly ash was measured
25 as the bulk specific gravity.

[0042]

(Increase Rate of Bulk Specific Gravity)

In a case where the bulk specific gravity of the crushed fly ash before crushing was represented by d_1 and the bulk specific gravity of the fly ash raw powder after crushing was represented by d_2 , an increase rate of the bulk specific gravity of the crushed fly ash with respect to the bulk specific gravity of the fly ash raw powder was measured based on the following Expression (1). Increase Rate (%) of Bulk Specific Gravity of

10 Crushed Fly Ash = $(d_2 - d_1) / d_1 \times 100$ (1)

[0043]

(JA Funnel Flow Time)

1500 g of the fly ash as a measurement target and 750 g of water (50 parts by mass of water with respect to 100 parts by mass of the fly ash) were mixed and agitated to prepare fly ash paste. The fly ash and water were mixed according to "9.4.1 Mixing of Cement Paste" of JIS R5201:2015 "Physical Testing Methods for Cement". The flow time of the obtained fly ash paste was measured by a grout flow cone MIC-363-0-03 according to JSCE-F531 "Test Method for Fluidity of PC Grout".

[0044]

(Water-Powder Mass Ratio at Maximum Current Value)

Plural mixtures containing the crushed fly ash and water and having different water-powder mass ratios were prepared. Each of the plural mixtures having different water-powder ratios

was agitated and mixed by JIS R5201 “9.2.3 mixer for mechanical mixing”, and a current value flowing through the mixer for mechanical mixing was measured. Regarding the measurement of the current flowing through the mixer for mechanical mixing, one of two single-phase power cables of the mixer for mechanical mixing was interposed between clamps of a current measuring device (product name: MEMORY HiCORDER MR8870, manufactured by Hioki E.E. Corporation), and the current flowing through the mixer for mechanical mixing during the agitation of each of the mixture was measured. Among the mixtures having different water-powder mass ratios, a water-powder mass ratio at which the current flowing through the mixer for mechanical mixing was maximum, was measured as the water-powder mass ratio at the maximum current value. A maximum current of 500 amperes (A) can be applied to the mixer for mechanical mixing.

As an example of the measurement of the water-powder mass ratio at the maximum current value, water was added to 1000 g of the fly ash (1) type II ash (product (classified product) conforming to Type II of JIS A 6201: 2015 “Fly Ash for use in Concrete”) in amounts shown in Table 1 to prepare mixtures. The respective mixtures were agitated by the mixer for mechanical mixing, and the current values flowing through the mixer for mechanical mixing were measured. The measured values are shown in Table 1. Regarding each of the fly ashes, the same measurement as that of the fly ash (1) type II ash was performed, and the

water-powder mass ratio at the maximum current value flowing through the mixer for mechanical mixing is shown in Table 1.

[0045]

[Table 1]

	Addition Amount of Water (g)	Water-Powder Mass Ratio (%)	Current Value (A)
Reference Example 1	0	0	2.81
Reference Example 2	50	5	2.87
Reference Example 3	100	10	2.86
Reference Example 4	150	15	2.89
Reference Example 5	170	17	2.88
Reference Example 6	190	19	2.92
Reference Example 7	200	20	3.13
Reference Example 8	210	21	3.23
Reference Example 9	220	22	3.81
Reference Example 10	230	23	3.56
Reference Example 11	240	24	3.01
Reference Example 12	250	25	2.92
Reference Example 13	260	26	2.89
Reference Example 14	270	27	2.87

5

[0046]

As shown in Table 1, regarding each of the mixtures (Reference Examples 1 to 14) prepared while changing the ratio of water with respect to 1000 g of the fly ash (1) type II ash (product (classified product) conforming to Type II of JIS A

6201: 2015 "Fly Ash for use in Concrete"), the current value flowing through the JIS R5201 "9.2.3 mixer for mechanical mixing" during the agitation was measured. When the addition amount of water to 1000 g of the crushed fly ash was 220 g and the
5 water-powder mass ratio was 22% of Reference Example 9, the maximum current value flowing through the mixer for mechanical mixing was 3.81 amperes (A). In the fly ash (1) type II ash (product (classified product) conforming to Type II of JIS A 6201: 2015 "Fly Ash for use in Concrete"), the water-powder mass
10 ratio at the maximum current value was 22%. As in Reference Examples 1 to 14 shown in Table 1, mixtures prepared while changing the water-powder ratio with respect to each of the fly ashes were agitated and mixed by the mixer for mechanical mixing, and the current value flowing through the mixer for mechanical
15 mixing was measured. As a result, the water-powder mass ratio at the maximum current value was able to be measured regarding each of the fly ashes.

[0047]

Regarding each of (1) the type II ash, (2) the fly ash raw
20 powder, and (3) to (10) of the crushed fly ashes, the measured values of the bulk specific gravity, the increase rate of the bulk specific gravity, the JA funnel flow time, and the water-powder mass ratio at the maximum current value are shown in Table 2.

[0048]

[Table 2]

	Kind of FA	Bulk Specific Gravity (g/cm ³)	Increase Rate of Bulk Specific Gravity (%)	JA funnel flow time (sec)	Water-Powder Mass Ratio at Maximum Current Value (%)
1	Type II Ash	1.20	–	14.8	22
2	Raw Powder	1.10	–	30.2	29
3	1-Minute Crushed FA	1.10	0.0	29.8	29
4	2-Minute Crushed FA	1.11	0.9	28.1	28
5	3-Minute Crushed FA	1.12	1.8	26.4	27
6	4-Minute Crushed FA	1.13	2.7	22.7	25
7	5-Minute Crushed FA	1.13	2.7	19.2	24
8	10-Minute Crushed FA	1.12	1.8	17.7	23
9	20-Minute Crushed FA	1.11	0.9	15.2	22
10	30-Minute Crushed FA	1.09	–0.9	16.0	21

[0049]

(Manufacturing of Concrete Composition)

(Examples 1 to 6 and Comparative Examples 1 to 9)

5 Using the respective fly ashes, concrete compositions of Examples and Comparative Examples were manufactured according to compositions shown in Table 3.

[0050]

[Table 3]

	FA Used	Unit Amount (kg/m ³)				
		Water	Cement	FA	Fine Aggregate	Coarse Aggregate
Comparative Example 1	None	216	360	0	1045	707
Comparative Example2	Type II Ash	216	360	100	927	707
Comparative Example3	Type II Ash	216	360	150	868	707
Comparative Example4	Raw Powder	216	360	100	927	707
Comparative Example5	Raw Powder	216	360	150	868	707
Example 1	5-Minute Crushed FA	216	360	20	1021	707
Example 2	5-Minute Crushed FA	216	360	100	927	707
Example 3	5-Minute Crushed FA	216	360	150	868	707
Comparative Example6	1-Minute Crushed FA	216	360	100	927	707
Comparative Example7	2-Minute Crushed FA	216	360	100	927	707
Example 4	3-Minute Crushed FA	216	360	100	927	707
Example 5	4-Minute Crushed FA	216	360	100	927	707
Example 6	10-Minute Crushed FA	216	360	100	927	707
Comparative Example8	20-Minute Crushed FA	216	360	100	927	707
Comparative Example9	30-Minute Crushed FA	216	360	100	927	707

[0051]

Regarding each of the concrete compositions manufactured
5 according to the compositions shown in Table 3, the following
tests were performed. The results are shown in Table 4.

[0052]

(Slump)

Regarding each of the concrete compositions manufactured
10 according to the compositions shown in Table 3, a slump (cm)
was measured according to JIS A1101:2014 "Method of Test for

Slump of Concrete".

[0053]

(Number of Times of Spread)

Regarding each of the concrete compositions manufactured
5 according to the compositions shown in Table 3, a test according
to German Industrial Standard DIN 1048 was performed as an
evaluation test for material separation resistance. In this
test, material separation resistance at a high level required
for spray concrete is evaluated. Based on this test value,
10 reduction in rebound of spray concrete can be indirectly
evaluated. In addition, impact deformation resistance required
for reducing rebound can also be evaluated in this test.

The test method will be described in brief. The slump (cm)
was measured according to JIS A1101:2014 "Method of Test for
15 Slump of Concrete", and a single side of a slump plate was pulled
up by 4 cm and then was caused to fall. This falling operation
was repeated. By repeating the falling operation, the number
of times (number of times of spread) was measured until the flow
of concrete reached 60 cm. As the number of times for spread
20 increases, material separation resistance and/or impact
deformation resistance of spray concrete were evaluated to be
superior, and the rebound reducing effect was evaluated to be
higher.

[0054]

[Table 4]

	FA Used	Bulk Specific Gravity of FA (g/cm ³)	Increase Rate of Bulk Specific Gravity of FA (%)	JA Funnel Flow Time (sec)	Water-Powder Mass Ratio at Maximum Current Value (%)	Slump (cm)	Number of Times for Spread
Comparative Example 1	None	-	-	-	-	13.0	23
Comparative Example 2	Type II Ash	1.20	-	14.8	22	16.0	21
Comparative Example 3	Type II Ash	1.20	-	14.8	22	12.0	28
Comparative Example 4	Raw Powder	1.10	-	30.2	29	13.0	24
Comparative Example 5	Raw Powder	1.10	-	30.2	29	7.0	Not Measurable
Example 1	5-Minute Crushed FA	1.13	2.7	19.2	24	16.0	34
Example 2	5-Minute Crushed FA	1.13	2.7	19.2	24	13.0	41
Example 3	5-Minute Crushed FA	1.13	2.7	19.2	24	8.0	57
Comparative Example 6	1-Minute Crushed FA	1.10	0.0	29.8	29	13.5	23
Comparative Example 7	2-Minute Crushed FA	1.11	0.9	28.1	28	13.0	26
Example 4	3-Minute Crushed FA	1.12	1.8	26.4	27	14.0	35
Example 5	4-Minute Crushed FA	1.13	2.7	22.7	25	13.5	42
Example 6	10-Minute Crushed FA	1.12	1.8	17.7	23	12.5	34
Comparative Example 8	20-Minute Crushed FA	1.11	0.9	15.2	22	12.5	24
Comparative Example 9	30-Minute Crushed FA	1.09	-0.9	16.0	21	11.0	26

[0055]

5 As can be seen from the results shown in Table 4, in the concrete compositions of Examples 1 to 6, the JA flow time of the fly ash paste was 17 ~ 27 seconds. Therefore, the fluidity was superior, the viscosity was appropriate, the workability was able to be improved, and the number of times for spread was

10 more than that of the concrete compositions of Comparative Examples 1 to 9.

In addition, as can be seen from the results shown in Table

4, in the concrete compositions of Examples 1 to 6, when the fly ash and water were mixed and agitated by "9.2.3 Mixer for Mechanical Mixing" of JIS R5201, the water-powder mass ratio of the mixture at which the current flowing through the mixer for mechanical mixing was maximum, was 23 ~ 27%. Therefore, the crushed fly ash in the concrete composition appropriately adsorbed water, the concrete composition containing the crushed fly ash has superior fluidity and an appropriate viscosity, and the number of times for spread was more than that of the concrete compositions of Comparative Examples 1 to 9.

As can be seen from Table 4, the increase rate of the bulk specific gravity of the crushed fly ash which was crushed for 4 minutes or 5 minutes was 2.7%, and the increase rate of the bulk specific gravity of the crushed fly ash which was crushed for 3 minutes or 10 minutes was 1.8%. For the concrete compositions of Examples using these crushed fly ashes, the number of times for spread was more than that of the concrete compositions of Comparative Examples 1 to 9.

In the concrete compositions of Examples 1 to 6, the number of times for spread was more than that of the concrete compositions of Comparative Examples 1 to 9. Therefore, it is presumed that the rebound reducing agent as spray concrete was higher, and material separation resistance and/or impact deformation resistance was superior.

[0056]

As shown in Table 4, for the concrete compositions of Comparative Examples 2 to 5 prepared using the fly ash raw powder and the type II ash, the number of times for spread was not significantly different from that of the concrete composition of Comparative Example 1 prepared without using the fly ash, and it is presumed that the rebound reducing agent was low.

As shown in Table 4, in the concrete compositions of Comparative Examples 6 and 7 containing the crushed fly ash in which the JA funnel flow time was longer than 27 seconds, the fluidity was poor. In the crushed fly ashes used in Comparative Examples 6 and 7, the physical properties were not significantly different from those of the fly ash raw powder, and it is presumed that a quality improving effect was not obtained by crushing.

As shown in Table 4, in the concrete compositions of Comparative Examples 8 and 9 containing the crushed fly ash in which the JA funnel flow time was shorter than 17 seconds, the fluidity was poor. On the other hand, in the crushed fly ashes used in Comparative Examples 8 and 9, the JA funnel flow time was shorter than 17 seconds, and it is presumed that the viscosity was insufficient.

[0057]

As shown in Table 4, in the concrete compositions of Comparative Examples 6 and 7 containing the crushed fly ashes in which the water-powder mass ratio at the maximum current value was higher than 27%, the amount of water bound in the crushed

fly ash was large, the fluidity in the fresh state at the start of the agitation of the concrete composition and water was poor, and the viscosity was high. On the other hand, an excessively large amount of water was absorbed. Therefore, the amount of rebound was large, the number of times for spread was less than that of Examples 1 to 6, and impact deformation resistance required to reduce rebound was poor.

As shown in Table 4, for the concrete compositions of Comparative Examples 8 and 9 containing the crushed fly ashes-for which the water-powder mass ratio at the maximum current value was lower than 23%, the amount of water bound in the crushed fly ash was small, the amount of rebound was large, the number of times for spread was less than that of Examples 1 to 6, the rebound reducing agent was low, and material separation resistance and/or impact deformation resistance was poor.

Industrial Applicability

[0058]

According to the present invention, by adding the crushed fly ash obtained by crushing the fly ash raw powder to have specific physical properties, a concrete composition can be provided for which material separation resistance and/or impact deformation resistance can be secured at a high level, and workability is superior.

25

CLAIMS

1. A concrete composition comprising:

cement; and

5 crushed fly ash that is obtained by crushing fly ash raw
powder,

 wherein the crushed fly ash satisfies a condition that a
JA funnel flow time of fly ash paste containing 50 parts by mass
of water with respect to 100 parts by mass of the crushed fly
10 ash is in a range of 17 ~ 27 seconds.

2. A concrete composition comprising:

cement; and

 crushed fly ash that is obtained by crushing fly ash raw
15 powder,

 wherein when a mixture of the crushed fly ash and water
is agitated by "9.2.3 Mixer for Mechanical Mixing" of JIS R5201,
a water-powder mass ratio of the mixture at which a current
flowing through the mixer for mechanical mixing is maximum is
20 23 ~ 27%.

3. A concrete composition comprising:

cement; and

 crushed fly ash that is obtained by crushing fly ash raw
25 powder,

wherein for the crushed fly ash, a bulk specific gravity after crushing increases by 1.5% or higher and 3.0% or lower relative to a bulk specific gravity before crushing.

5 4. The concrete composition according to any one of claims 1 to 3,

wherein an ignition loss of the crushed fly ash is 3 mass% or higher and 10 mass% or lower.

10 5. The concrete composition according to any one of claims 1 to 4,

wherein a mixing amount of the crushed fly ash is 20 kg or more and 150 kg or less per 1 m³ volume of the concrete composition.

15 6. The concrete composition according to any one of claims 1 to 5, further comprising at least one selected from the group consisting of an admixture and a special admixture.

20 7. The concrete composition according to any one of claims 1 to 6,

wherein the cement is at least one selected from the group consisting of normal Portland cement, high early strength Portland cement, moderate heat Portland cement, and low-heat
25 Portland cement.

8. A method of manufacturing a concrete composition containing cement and crushed fly ash that is obtained by crushing fly ash raw powder, the method comprising:

5 a step of obtaining the crushed fly ash by crushing the fly ash raw powder such that a bulk specific gravity after crushing increases by 1.5% or higher and 3.0% or lower relative to a bulk specific gravity before crushing; and

 a step of mixing the cement and the crushed fly ash.

10

9. The method of manufacturing a concrete composition according to claim 8,

 wherein an ignition loss of the fly ash raw powder is 3 mass% or higher and 10 mass% or lower.

15