DESCRIPTION

Title of Invention

CEMENT COMPOSITION AND METHOD FOR PRODUCING CEMENT COMPOSITION

Technical Field

[0001]

The present invention relates to a cement composition and a method for manufacturing a cement composition. Particularly, the present invention relates to a cement composition using Portland cement.

Background Art

[0002]

For quality assurance of buildings constructed using structures prepared using mortar or concrete, a cement composition used in the mortar or concrete needs to exhibit high strength. Therefore, conventionally, various cement compositions that exhibit high strength have been developed.

[0003]

As one of such cement compositions, a cement composition is known which is made exhibit higher strength by the adjustment of particle size distribution or specific surface area of the cement composition. For example, in the cement-containing

powder composition described in Patent Literature No. 1, the Blaine specific surface area of a cemental material is set to 1,500 to 3,300 cm^2/g, and the amount of components that remain on a 100 μm sieve is set to 0.5% to 40% by mass, so that the cement-containing powder composition exhibits higher strength.

Citation List

Patent Literature

[0004]

[Patent Literature No. 1] Japanese Laid-open Patent Publication No. 2014-166927

Summary of Invention

Technical Problem

[0005]

In Patent Literature No. 1, the strength that a cement composition exhibits is evaluated using a test piece prepared from mortar. According to this Literature, in a case where a cement composition is confirmed to exhibit high strength by the evaluation with mortar, the cement composition is regarded as exhibiting high strength as well in concrete. However, unfortunately, the cement composition regarded as exhibiting high strength by the evaluation with mortar does not always exhibit high strength when used in concrete.

[0006]

The present invention has been made in consideration of the above problem, and an object of the present invention is to provide a cement composition which can ensure strength of concrete by evaluation with mortar when used in the concrete and makes it possible to control the quality of concrete by evaluation with mortar.

Solution to Problem

[0007]

As a result of intensive studies, the inventors of the present invention have found that there is a strong correlation between a calcite lattice volume of limestone used in a cement composition and a concrete/mortar strength ratio (a ratio between the strength of a concrete test piece prepared from the cement composition and the strength of a mortar test piece prepared from the same cement composition). Furthermore, the inventors have found that in a case where limestone having a specific calcite lattice volume is used, the concrete/mortar strength ratio tends to be high even though the mortar strength is substantially the same, and the variation in the concrete strength is reduced. Based on this finding, the inventors have accomplished the present invention.

[0008]

In order to achieve the above object, the present invention provides the following [1] to [5].

[1] A cement composition containing clinker, gypsum, and limestone, in which a calcite lattice volume of the limestone is 366.76 Å^3~~Å3~~ or more and 368.00 Å^3~~Å3~~ or less.

[2] The cement composition described in [1], in which in the clinker, a proportion of $3CaO \cdot SiO_2$ is 50% to 75% by mass, a proportion of $2CaO \cdot SiO_2$ is 8% to 30% by mass, and a proportion of $3CaO \cdot Al_2O_3$ and $4CaO \cdot Al_2O_3 \cdot Fe_2O_3$ is 15% to 25% by mass in total, and each of the proportions is calculated by the Bogue's equation.

[3] The cement composition described in [1] or [2], in which a proportion of particles having a particle size distribution of 11 μm or more and less than 22 μm is 18.0% or higher and 26.0% or lower, a proportion of particles having a particle size distribution of 22 μm or more and less than 44 μm is 31.8% or higher and 38.0% or lower, and each of the particle size distributions is analyzed by a Microtrac method.

[4] The cement composition described in any one of [1] to [3], which has a Blaine specific surface area of 3,200 cm^2/g or more and 3,800 cm^2/g or less.

[5] A method for manufacturing a cement composition, including a step of crushing and mixing together clinker, gypsum, and limestone which has a calcite lattice volume of 366.76 Å^3~~Å3~~ or more and 368.00 Å^3~~Å3~~ or less.

Advantageous Effects of Invention

[0009]

According to the present invention, it is possible to ensure the strength of concrete by evaluation with mortar when the present invention is used in the concrete. Furthermore, because the strength of concrete can be estimated with high accuracy by evaluation with mortar, the quality of the concrete can be appropriately controlled.

Brief Description of Drawings

[0010]

FIG. 1 is a graph showing the relationship between mortar strength and concrete strength.

Description of Embodiments

[0011]

Hereinafter, a cement composition of the present invention will be specifically described. In the present specification, the notation of a numerical range, such as “AA to BB”, means “AA or more and BB or less”.

[0012]

[Cement composition]

The cement composition of the present invention contains clinker, gypsum, and limestone, and a calcite lattice volume of the limestone is 366.76 Å^3~~Å3~~ or more and 368.00 Å^3~~Å3~~ or less.

Specifically, the cement composition of the present invention is ordinary Portland cement, rapid hardening Portland cement, or extra rapid hardening Portland cement.

Hereinafter, each component of the cement composition will be described.

[0013]

[Clinker]

The clinker used in the cement composition of the present invention contains $3CaO \cdot SiO_2$ (abbreviation: C_3S), $2CaO \cdot SiO_2$ (abbreviation: C_2S), $3CaO \cdot ~~Al~~Al_2O_3$ (abbreviation: C_3A), and $4CaO \cdot ~~Al~~Al_2O_3 \cdot FeO_3$ (abbreviation: C_4AF). Cement clinker is constituted with main minerals, alite (C_3S) and belite (C_2S), an interstitial phase of an aluminate phase (C_3A) and a ferrite phase (C_4AF) between the crystals of the main minerals, and the like.

[0014]

The clinker used in the cement composition of the present invention is not particularly limited as long as the clinker satisfies the quality specified in JIS R 5210: 2009 "Portland cement". However, the clinker is preferably a material in which a proportion of $3CaO \cdot SiO_2$ calculated by the Bogue's equation is 50% to 75% by mass, a proportion of $2CaO \cdot SiO_2$ calculated by the Bogue's equation is 8% to 30% by mass, and a proportion of $3CaO \cdot Al_2O_3$ and $4CaO \cdot Al_2O_3 \cdot Fe_2O_3$ calculated by the Bogue's equation is 15% to 25% by mass in total.

[0015]

<Clinker manufacturing process>

The clinker of the present invention can be manufactured as follows, for example. As raw materials of the clinker, any of materials can be used regardless of their forms, such as a simple element, an oxide, and an oxycarbide, as long as they contain Ca, Si, ~~AI~~ Al, Fe, and the like. Furthermore, a mixture of these can be used. Examples of natural raw materials include limestone, clay, silica stone, and iron oxide raw materials. Examples of industrial raw materials include recycled raw materials, blast furnace slag, fly ash, and the like containing the above elements. The mixing ratio of the clinker raw materials is not particularly limited as long as clinker satisfying the values calculated by the Bogue's equation can be manufactured. The formulation of the raw materials can be determined so that the clinker is composed of components at the desired proportions corresponding to the values calculated by the Bogue's equation.

[0016]

Then, the raw materials of clinker mixed together at the proportions to obtain the desired clinker is calcined under the following calcination conditions and cooled. Generally, calcination is performed using an electric furnace, a rotary kiln, or the like. Examples of the calcination method include a method including a first calcination step of calcining the

raw materials of clinker by heating them at a predetermined first calcination temperature for a first calcination time, a temperature raising step of raising the temperature up to a predetermined second calcination temperature from the first calcination temperature for a predetermined temperature raising time after the first calcination step, and a second calcination step of calcining the raw materials of clinker by heating them at the second calcination temperature for a predetermined second calcination time after the temperature raising step. For example, in a case where an electric furnace is used, clinker can be manufactured by calcining raw materials of clinker by heating them at a calcination temperature (first calcination temperature) of 1,000°C for 30 minutes (first calcination time) (first calcination step), then raising the temperature up to 1,450°C (second calcination temperature) for 30 minutes (temperature raising time) (temperature raising step), further calcining the raw materials of clinker by heating them at 1,450°C for 15 minutes (second calcination time) (second calcination step), and then quenching the calcined material.

[0017]

[Gypsum]

The cement composition of the present invention contains gypsum. Furthermore, the gypsum in the present invention includes hemihydrate gypsum. The gypsum in the present invention may further include anhydrous gypsum and/or dihydrate

gypsum.

The ratio of the mass of the gypsum expressed in terms of SO_3 to the mass of the cement composition is preferably 0.8% by mass or higher, and more preferably 1.0% by mass or higher. In a case where the ratio of the gypsum is within the above range, it is possible to appropriately control drying shrinkage of the cement composition and to improve the long-term strength (for example, the strength of concrete at the age of 28 days) that the cement composition exhibits.

The proportion of SO_3 in the gypsum can be measured according to JIS R 5202: 2010 "Methods for chemical analysis of Portland cements". The ratio of the mass of the gypsum expressed in terms of SO_3 to the mass of the cement composition can be determined from the amount of the gypsum mixed in and the proportion of SO_3 contained in the gypsum.

[0018]

[Limestone]

The limestone of the present invention is required to have a calcite lattice volume of 366.76 Å^3~~Å3~~ or more and 368.00 Å^3~~Å3~~ or less. In the present invention, the calcite lattice volume is a value calculated from the lattice constant which is obtained by performing X-ray diffraction analysis on limestone and analyzing the diffraction pattern by Rietveld refinement.

[0019]

The limestone is added to the cement composition mainly

for the purpose of improving fluidity, durability, and strength of mortar or concrete. Generally, the limestone contains trace components. The trace components are dissolved in the lattice of calcium carbonate which is a main component of the limestone, hence the calcite lattice volume changes. MgO is the main trace component. Because the ion radius of magnesium is smaller than the ion radius of calcium, the calcite lattice volume tends to decrease depending on the content rate of MgO. The content of trace components of limestone varies with the limestone mining area. Therefore, the calcite lattice volume also varies with the limestone mining area.

The calcite lattice volume of the limestone is preferably 366.82 Å^3~~Å3~~ or more. Particularly, the calcite lattice volume of the limestone is preferably 366.90 Å^3~~Å3~~ or more.

The effect obtained using the limestone having a calcite lattice volume in the above range will be described later.

[0020]

The proportion of the limestone in the cement composition is not particularly limited as long as the composition satisfies the quality specified in JIS R 5210: 2009 “Portland cement”. However, the proportion of the limestone is preferably 1.0% by mass or higher, and more preferably 1.5% by mass or higher. In a case where the proportion of the limestone is within the above range, the long-term strength (for example, the strength of concrete at the age of 28 days) that the cement composition

exhibits can be improved, and the fluidity of the cement composition is enhanced. As a result, the workability of concrete prepared using the cement composition can be improved. Furthermore, in a case where the proportion of the limestone is within the above range, by crushing and mixing together the limestone, the gypsum, and the clinker in manufacturing the cement composition, it is possible to appropriately adjust the particle size distribution in the cement composition. The proportion of the limestone in the cement composition can be calculated from the amount of the limestone mixed in.

[0021]

[Other components]

For controlling fluidity, hydration rate, or strength to be exhibited, fly ash, blast furnace slag, fumed silica, and the like can be added to the cement composition of the present invention. Furthermore, by adding an AE water-reducing agent, a high performance water-reducing agent, or a high performance AE water-reducing agent, particularly, by adding a polycarboxylic acid-based high performance AE water-reducing agent to the cement composition of the present invention, it is possible to further improve the fluidity and strength of concrete.

[0022]

[Method for manufacturing cement composition]

The method for manufacturing a cement composition includes

a step of crushing and mixing together clinker, gypsum, and limestone which has a calcite lattice volume of 366.78 Å^3~~Å3~~ or more and 368.00 Å^3~~Å3~~ or less. In this step, it is preferable to mix together clinker, gypsum, and limestone together at a predetermined ratio and crush the mixture. The mixture is crushed by a known method so that the desired Blaine specific surface area is obtained. Examples of the crushing method include a method using a ball mill which is a commonly used crusher.

[0023]

Alternatively, in the present invention, the cement composition can be manufactured by mixing together preliminarily crushed clinker, gypsum, and limestone (having a calcite volume of 366.76 Å^3~~Å3~~ or more and 368.00 Å^3~~Å3~~ or less) at a predetermined ratio so that the desired Blaine specific surface area is obtained after mixing.

[0024]

[Particle size distribution of cement composition]

In the cement composition of the present invention, a proportion of particles having a particle size distribution of 11 μm or more and less than 22 μm is preferably 18.0% or higher and 26.0% or lower, and a proportion of particles having a particle size distribution of 22 μm or more and less than 44 μm is preferably 31.8% or higher and 38.0% or lower. Each of the particle size distributions is analyzed by a Microtrac method.

In the present invention, the use of limestone having a calcite lattice volume of 366.76 Å^3~~Å3~~ or more and 368.00 Å^3~~Å3~~ or less makes it possible to easily adjust the particle size distribution of the cement composition to be within the above range.

The proportion of particles having a particle size distribution of 11 μm or more and less than 22 μm is more preferably 21.0% or higher and 24.0% or lower, and the proportion of particles having a particle size distribution of 22 μm or more and less than 44 μm is more preferably 32.0% or higher and 35.0% or lower.

The particle size distribution analysis by a Microtrac method can be performed based on JIS R 1629 "Determination of particle size distributions for fine ceramic raw materials by laser diffraction·scattering method".

[0025]

[Blaine specific surface area of cement composition]

The Blaine specific surface area of the cement composition of the present invention is preferably 3,200 cm^2/g or more and 3,800 cm^2/g or less. In a case where the Blaine specific surface area of the cement composition is within the above range, the long-term strength (for example, the strength of concrete at the age of 28 days) that the cement composition exhibits can be further improved. In addition, the fluidity of the cement composition can be improved. The Blaine specific surface area is a specific surface area measured by the Blaine method

according to JIS R 5201: 2015 “Physical testing methods for cement”.

[0026]

[Mortar and concrete]

Cement milk can be prepared by mixing the cement composition of the present invention with water. Mortar can be prepared by mixing the cement composition of the present invention with water and sand. Concrete can be manufactured by mixing the cement composition of the present invention with sand and gravel. Furthermore, blast furnace slag, fly ash, and the like can also be added in preparing mortar or concrete by using the cement composition.

[0027]

[Concrete/mortar strength ratio]

The closer the ratio between the strength of a concrete test piece prepared from the cement composition and the strength of a mortar test piece prepared from the same cement composition (concrete/mortar strength ratio) to 1, the more preferable. Because the limestone having a calcite lattice volume of 366.76 Å^3~~Å3~~ or more and 368.00 Å^3~~Å3~~ or less is used in the cement composition of the present invention, the concrete/mortar strength ratio is 0.74 or higher. This ratio is higher than the ratio obtained in a case where limestone having a calcite lattice volume outside the above range is used. That is, the cement composition of the present invention can ensure the concrete strength by the

evaluation with mortar.

In addition, the cement composition of the present invention can reduce the variation in the concrete/mortar strength ratio. In other words, the difference between the concrete strength estimated from the mortar strength (estimated strength) and the measured concrete strength is reduced. Therefore, by the evaluation with mortar, the concrete strength can be estimated with high accuracy. Accordingly, the cement composition of the present invention makes it possible to appropriately control the quality of concrete by the evaluation with mortar.

In the present invention, "mortar strength" is the compressive strength of mortar at 28 days measured according to JIS R 5201: 2015 "Physical testing methods for cement". In the present invention, "concrete strength" is the compressive strength of concrete at 28 days measured according to JIS A 1108 "Method of test for compressive strength of concrete".

[0028]

Hitherto, embodiments of the present invention have been described. However, the present invention is not limited to the embodiments. The present invention includes various aspects included the gist and claims of the present invention, and can be modified in various ways within the scope of the present invention.

Example

[0029]

Hereinafter, the present invention will be more specifically described with reference to examples. However, the present invention is not limited to the following examples.

1. Evaluation method

1-1. Calcite lattice volume

For the limestones of examples and comparative examples, X-ray diffraction analysis was performed using a powder X-ray diffractometer (X'Part Powder, manufactured by Malvern Panalytical Ltd) under the conditions of analysis range: 2θ = 10° to 70°, step size: 0.017°, scan speed: 0.1012°/s, voltage: 45 kV, and current: 40 mA, thereby obtaining X-ray diffraction profiles.

By using crystal structure analysis software (manufactured by Malvern Panalytical Ltd, X'Part High Score Plus version 2.1b) included in the aforementioned powder X-ray diffractometer, analysis was performed by the Rietveld method. From the obtained lattice constant, a lattice volume was calculated. During the Rietveld refinement, ICDD number 50586 was used as the initial value of data on the basic crystal structure.

[0030]

1-2. Clinker composition

The mass ratio of CaO, SiO_2, ~~Al_2O_3~~Al_2O_3, and Fe_2O_3 in the clinker in the cement composition of each of examples and comparative

examples was calculated according to JIS R 5204: 2019 “Chemical analysis method of cement by X-ray fluorescence”. By using the calculation results, the proportion of each component in the clinker was calculated by the following Bogue’s equation.

$C_3S = (4.07 \times CaO) - (7.60 \times SiO_2) - (6.72 \times Al_2O_3) - (1.43 \times Fe_2O_3)$

$C_2S = (2.87 \times SiO_2) - (0.754 \times C_3S)$

$C_3A = (2.65 \times Al_2O_3) - (1.69 \times Fe_2O_3)$

$C_4AF = 3.04 \times Fe_2O_3$

[0031]

1-3. Ratio of mass of gypsum expressed in terms of SO_3 to mass of cement composition

The ratio of the mass of gypsum expressed in terms of SO_3 to the mass of the cement composition of each of examples and comparative examples was calculated from the amount of the gypsum mixed in and the proportion of SO_3 in the gypsum. The proportion of SO_3 in the gypsum was measured according to JIS R 5202: 2010 “Methods for chemical analysis of Portland cement”.

[0032]

1-4. Blaine specific surface area

The Blaine specific surface area of the cement composition of each of examples and comparative examples was measured according to JIS R5201: 2015 “Physical testing methods for cement”.

[0033]

1-5. Particle size distribution

The particle size distribution of the cement compositions of each of examples and comparative examples was analyzed by a Microtrac method according to JIS R 1629 “Determination of particle size distributions for fine ceramic raw materials by laser diffraction·scattering method”. As an analyzer, MT3300EXII manufactured by MicrotracBEL Corp. was used. Before being analyzed, the cement composition was dispersed for 30 seconds in ethanol used as a dispersion medium by using an ultrasonic device.

[0034]

1-6. Mortar strength

The compressive strength of mortar was measured according to JIS R 5201: 2015 “Physical testing methods for cement: 10.5”.

[0035]

1-7. Concrete strength

The compressive strength of concrete after 28 days was measured according to JIS A 1108 “Method of test for compressive strength of concrete”.

[0036]

2. Preparation of cement composition

2-1. Clinker

As raw materials of clinker, silicon dioxide (manufactured by KANTO CHEMICAL CO., INC., reagent grade 1, SiO_2), iron (III) oxide (manufactured by KANTO CHEMICAL CO., INC., special reagent

grade, Fe_2O_3), calcium carbonate (manufactured by Kishida Chemical Co., Ltd., reagent grade 1, $CaCO_3$), aluminum oxide (manufactured by KANTO CHEMICAL CO., INC., reagent grade 1, ~~Al_2O_3~~Al_2O_3), basic magnesium carbonate (manufactured by Kishida Chemical Co., Ltd., special reagent grade, approximate formula: $4MgCO_3 \cdot Mg(OH)_2 \cdot 5H_2O$), sodium carbonate (manufactured by Kishida Chemical Co., Ltd., anhydrous·special grade, Na_2CO_3), and tricalcium phosphate (manufactured by Kishida Chemical Co., Ltd., reagent grade 1, $Ca_3(PO_4)_2$) were used.

[0037]

The raw materials of clinker were mixed together in different amounts appropriately determined, put into an electric furnace, and calcined at 1,000°C for 30 minutes. Then, the temperature of the mixture was raised to 1,450°C from 1,000°C for 30 minutes, and the mixture was further calcined at 1,450°C for 15 minutes. Thereafter, the calcined material was taken out to the atmosphere and quenched, thereby preparing clinker used in each of examples and comparative examples.

[0038]

2-2. Preparation of cement composition

Cement clinker prepared as above, gypsum (hemihydrate gypsum (hemihydrate gypsum manufactured by KANTO CHEMICAL CO., INC., product number: 07108-01 (calcined gypsum CICA grade 1)), dihydrate gypsum (manufactured by NORITAKE CO., LIMITED, product number: Raw Plaster A)), and limestone were mixed

together. Then, the mixture was crushed with a ball mill so that the Blaine specific surface area fell into a range of about 3,000 to 3,800 cm^2/g, thereby preparing a cement composition of each of examples and comparative examples.

The ratio of the mass of the gypsum expressed in terms of SO_3 to the mass of the cement composition of each of examples and comparative examples was varied among the cement compositions by changing the amount of the gypsum mixed in.

As the limestones of examples and comparative examples, a plurality of types of limestones mined from different areas and having different lot numbers was prepared.

[0039]

2-3. Preparation of mortar test piece

Mortar prepared from the cement composition of each of examples and comparative examples was poured into 3 metal molds having a size of 40 mm x 40 mm x 160 mm. After 24 hours, the mortar was released from the molds, thereby preparing 3 mortar test pieces. Thereafter, the test pieces were aged in water at 20°C for 28 days, thereby obtaining mortar test pieces of each of examples and comparative examples.

[0040]

2-4. Preparation of concrete test piece

The cement composition of each of examples and comparative examples, sand (river sand from Ibigawa, particle size: 25 to 5 mm), gravel (crushed stone from Nishijima, particle size: 5

mm or less), an AE water-reducing agent (manufactured by BASF Pozoris, trade name: MasterPolyheed 15S), and water were homogeneously mixed together at the mixing ratio shown in Table 1 by using a pan-type forcible mixer (manufactured by OKASAN Co., Ltd., product number: STR-N2 8H), thereby preparing concrete. The obtained concrete was poured into 3 metal molds having a diameter Φ of 100 mm and a height of 200 mm. After 24 hours, the concrete was released from the molds, thereby obtaining 3 concrete test pieces. Thereafter, the test pieces were aged in water at 200°C for 28 days, thereby obtaining concrete test pieces of each of examples and comparative examples.

[0041]

[Table 1]

Cement composition (C) (kg/m^3)	Sand (kg/m^3)	Gravel (kg/m^3)	Water (W) (kg/m^3)	W/C (% by mass)	Admixture (C x %)	Amount of air (%)
305	781	1,022	168	55	0.8	4.5

[0042]

Table 2 shows the results obtained using limestones having different calcite lattice volumes, under the conditions where the proportions of clinker components calculated by the Bogue's equation, the amount of gypsum, the amount of limestone, and the fineness are the same for all the examples and comparative examples. In Table 2, "11 to 22 μm" means that the particle size is 11 μm or more and less than 22 μm, and "22 to 44 μm" means that the particle size is 22 μm or more and less than 44 μm.

[0043]

[Table 2]

	Clinker composition (Bogue's equation)			Gypsum (expressed in terms of SO_3) (% by mass)	Limestone (% by mass)	Calcite lattice volume ($Å^3$)	Fineness (cm^2/g)	Proportion of particles (%)		Mortar strength σm (N/mm^2)	Concrete strength σc (N/mm^2)	σc/σm
	C_3S	C_2S	$C_3A + C_4AF$					11 to 22 μm	22 to 44 μm			
Example 1	61.0	16.0	19.0	1.5	3.0	367.64	3,350	23.5	34.5	58.0	43.6	0.75
Example 2						367.49		23.1	33.7	58.7	44.0	0.75
Example 3						367.24		23.2	32.8	57.0	42.5	0.75
Comparative Example 1						366.72		24.4	31.2	62.0	43.6	0.70
Comparative Example 2						366.68		24.3	31.5	57.4	41.3	0.72
Comparative Example 3						366.66		23.9	31.7	64.1	43.2	0.67

[0044]

As is evident from the results in Table 2, the larger the calcite lattice volume, the higher the concrete/mortar strength ratio (ac/am) and the smaller the variation. This result tells that the calcite lattice volume affects the concrete/mortar strength ratio.

Furthermore, it has been found that as the calcite lattice volume increases, the proportion of particles having a size of 22 μm or more and less than 44 μm tends to relatively increase while the proportion of particles having a size of 11 μm or more and less than 22 μm tends to relatively decrease. From this result, it was considered that there may be a correlation between the calcite lattice volume and the particle size distribution of the cement composition.

[0045]

Table 3 shows the results of Examples 4 to 19 and Comparative Examples 4 to 12. FIG. 1 shows the relationship

between the mortar strength and the concrete strength in Examples 1 to 19 and Comparative Examples 1 to 12.

[0046]

[Table 3]

	Clinker composition (Bogue's equation)			Gypsum (expressed in terms of SO_3) (% by mass)	Limestone (% by mass)	Calcite lattice volume (Å^3)	Fineness (cm^2/g)	Proportion of particles (%)		Mortar strength σm (N/mm^2)	Concrete strength σc (N/mm^2)	σc/σm
	C_3S	C_2S	$C_3A + C_4AF$					11 to 22 μm	22 to 44 μm			
Example 4	62.7	15.5	19.1	1.1	2.0	367.71	3,200	23.5	32.4	61.9	47.1	0.76
Example 5	56.6	20.3	18.9	1.0	2.1	367.00	3,300	22.5	34.6	58.7	45.2	0.77
Example 6	59.3	17.2	18.7	1.7	3.7	367.88	3,290	22.3	34.2	60.6	46.3	0.76
Example 7	61.1	17.0	19.2	1.5	4.1	367.53	3,400	22.6	32.5	59.0	44.3	0.75
Example 8	61.4	17.8	18.4	2.1	3.3	367.23	3,240	22.0	33.0	65.5	50.2	0.77
Example 9	60.0	19.1	18.0	1.7	2.3	367.05	3,430	22.9	33.3	60.4	45.1	0.75
Example 10	58.6	19.2	18.3	1.6	2.8	367.62	3,210	22.7	32.7	59.6	44.6	0.75
Example 11	60.5	17.6	17.3	1.5	2.7	367.23	3,420	21.9	32.9	59.5	44.2	0.74
Example 12	64.5	12.5	18.6	2.3	2.0	366.93	3,360	22.7	32.6	63.1	47.4	0.75
Example 13	52.0	25.5	19.2	1.1	2.0	366.90	3,390	22.4	32.5	58.0	42.8	0.74
Example 14	62.0	17.0	18.2	1.2	3.1	367.65	3,230	22.9	32.6	60.4	46.9	0.78
Example 15	60.3	16.4	19.1	2.5	4.4	367.24	3,270	22.7	32.6	64.2	49.2	0.77
Example 16	61.6	17.6	16.5	1.6	4.2	367.63	3,410	22.9	32.0	61.3	47.4	0.77
Example 17	54.1	23.2	19.3	1.0	4.4	367.23	3,380	23.3	32.5	60.0	45.3	0.76
Example 18	63.2	14.5	17.9	1.3	2.0	366.90	3,290	22.1	33.1	63.0	46.9	0.74
Example 19	56.2	23.0	18.0	1.5	1.5	366.82	3,350	23.9	31.6	58.8	43.5	0.74
Comparative Example 4	64.7	14.8	17.7	2.5	2.4	366.74	3,340	24.8	30.7	64.3	45.6	0.71
Comparative Example 5	59.2	17.8	18.3	1.1	2.0	366.67	3,250	25.7	31.2	65.9	45.1	0.68
Comparative Example 6	60.3	17.5	17.8	1.7	2.5	366.54	3,320	25.8	31.3	60.3	36.4	0.60
Comparative Example 7	58.7	18.7	17.5	1.9	2.5	366.56	3,330	24.3	31.5	60.5	38.0	0.63
Comparative Example 8	63.9	12.5	18.7	1.3	2.4	366.50	3,360	24.6	31.7	62.3	38.2	0.61
Comparative Example 9	62.7	15.2	18.0	2.2	3.2	366.75	3,240	24.0	30.9	58.2	36.3	0.62
Comparative Example 10	61.5	19.9	16.5	1.1	2.0	366.63	3,430	24.1	31.5	61.0	44.1	0.72
Comparative Example 11	53.5	24.5	19.2	1.4	2.2	366.68	3,210	26.4	34.8	60.0	41.2	0.69
Comparative Example 12	63.7	12.6	19.0	1.4	4.4	366.68	3,500	20.5	29.6	61.2	37.6	0.61

[0047]

As is evident from the results shown in Tables 2 and 3, the concrete/mortar strength ratio was 0.74 or higher in all examples, which was higher than the concrete/mortar strength ratio in comparative examples. As shown in FIG. 1, the variation in the concrete/mortar strength ratio was smaller in examples than in comparative examples. These results tell that even in a case where the clinker composition, the amount of gypsum, the amount of limestone, and the fineness are changed, there is a correlation between the calcite lattice volume and ac/am. That is, in a case where limestone having a calcite lattice volume of 366.76 Å^3~~Å3~~ or more and 368.00 Å^3~~Å3~~ or less is used, high concrete strength can be obtained even at the same mortar strength. In addition, the accuracy of the concrete strength estimated from the evaluation with mortar can be improved.

[0048]

In all of Examples 1 to 18, the proportion of particles having a size of 11 μm or more and less than 22 μm was 18.0% to 26.0%, and the proportion of particles having a size of 22 μm or more and less than 44 μm was 31.8% to 38.0%. From this result, it was considered that the appropriate distribution of particles in the cement composition may be one of the factors improving the concrete/mortar strength ratio in Examples 1 to 18.

CLAIMS

1. A cement composition comprising:

clinker;

gypsum; and

limestone,

wherein a calcite lattice volume of the limestone is 366.76 Å^{3}Å^3 or more and 368.00 Å^{3}Å^3 or less.

2. The cement composition according to claim 1,

wherein in the clinker, a proportion of $3CaO \cdot SiO_2$ is 50% to 75% by mass, a proportion of $2CaO \cdot SiO_2$ is 8% to 30% by mass, and a proportion of $3CaO \cdot Al_2O_3$ and $4CaO \cdot Al_2O_3 \cdot Fe_2O_3$ is 15% to 25% by mass in total, and

each of the proportions is calculated by the Bogue's equation.

3. The cement composition according to claim 1 or 2,

wherein a proportion of particles having a particle size distribution of 11 μm or more and less than 22 μm is 18.0% or higher and 26.0% or lower,

a proportion of particles having a particle size distribution of 22 μm or more and less than 44 μm is 31.8% or higher and 38.0% or lower, and

each of the particle size distributions is analyzed by a

Microtrac method.

4. The cement composition according to any one of claims 1 to 3, which has a Blaine specific surface area of 3,200 cm^2/g or more and 3,800 cm^2/g or less.

5. A method for manufacturing a cement composition, comprising:

a step of crushing and mixing together clinker, gypsum, and limestone which has a calcite lattice volume of 366.76 $Å^3$~~$Å^3$~~ or more and 368.00 $Å^3$~~$Å^3$~~ or less.