

DESCRIPTION

Title of Invention

WET CEMENT MORTAR FOR THREE-DIMENSIONAL MOLDING FOR CONSTRUCTION, AND THREE-DIMENSIONAL MOLDING METHOD FOR CONSTRUCTION

Technical Field

[0001]

The present invention relates to wet cement mortar for three-dimensional molding for construction that is used mainly in the civil engineering and construction field and the industrial product field, and a three-dimensional molding method for construction using the same.

Background Art

[0002]

In recent years, the three-dimensional molding technique is being actively used for the production of models and components in the manufacturing industry and the like. The known classification of the technique includes the optical molding (which is a method of curing and laminating an ultraviolet ray-curable resin layer by layer), the ink-jet method (which is a method of ejecting and laminating an ultraviolet ray-curable resin from a printer head under irradiation of an ultraviolet ray), the powder gypsum molding (which is a method of ejecting a resin or an adhesive from a printer head for solidifying powder gypsum), the powder sintering molding (which is a method of sintering and laminating a resin or metal powder with laser), and the hot melt lamination molding (which is a method of discharging and laminating a thermoplastic resin melted by heating from a thin nozzle). The molded article is formed mainly of a resin, gypsum, or a metal, and the investigative research for the technique of producing a large molded article, such as a construction component, using a cementitious material is more advanced outside Japan than in Japan. In Western countries and China, large molded articles having a size equivalent to a stand-alone house have been produced with an automatic construction machine.

[0003]

For example, as a three-dimensional molding technique using a cementitious material, PTL 1 describes a technique for molding in which three-dimensional data produced with a computer is sliced into a prescribed thickness to form two-dimensional sliced data, mortar having a quick setting agent mixed therein is sprayed onto a bed (pedestal) while moving and controlling a spraying nozzle in the lengthwise and crosswise directions based on the two-

dimensional sliced data, the sprayed mortar is hardened to self-stand, so as to form a solidified layer having a shape based on the two-dimensional sliced data, and the operation of forming the solidified layer is repeated to laminate sequentially in the vertical direction. PTL 2 describes a material for producing a cast mold for producing a cast material with a 3D printer, and describes a material formed of cement, sand, and a water soluble silicate salt as an accelerator. PTLs 3 and 4 describe a method of producing a prefabricated component by using a 3D printer, and a method of producing a concrete earthquake-resistant wall by using a 3D printer. PTL 5 describes a technique relating to a nozzle for discharging a material for 3D printing. PTL 6 describes a method of producing a cementitious hardened material in which a cementitious hardened material is molded by using a resin formwork produced by using a three-dimensional molding system.

[0004]

As a cementitious material, a material using a combination of a lignin sulfonic acid-based dispersant and a melamine sulfonic acid-based dispersant has been known as a grout composition and a high strength concrete composition (PTLs 7 and 8). As a material using a combination of a dispersant and a thickening agent, a PC grout material has been known (PTL 9). As a material containing calcium aluminate containing SiO_2 , a cement admixture containing 300 parts by weight or less of a gypsum material and 0.1 to 20 parts by weight of a setting modifier as essential components per 100 parts by weight of calcium aluminosilicate glass, and a cement composition having the admixture mixed therein (PTL 10), a cement composition containing calcium aluminosilicate having a $\text{CaO}/\text{Al}_2\text{O}_3$ molar ratio of 2.0 to 3.5 and a SiO_2 content of 10 to 25%, and one kind or two or more kinds of a latent hydraulic substance and a pozzolanic substance (PTL 11), and the like have been known.

[0005]

As a cementitious material for three-dimensional molding for construction, a cementitious material containing cement, an aggregate, a dispersant having a mass ratio of a lignin sulfonic acid-based dispersant and a melamine sulfonic acid-based dispersant $\text{R}/\text{M} = 100/80$ to 400, a thickening agent, a setting retarder, amorphous calcium aluminosilicate containing SiO_2 in an amount of 10 to 25% in terms of oxide, gypsum, and short fibers has been known (PTL 12).

[0006]

A continuous kneading and spraying system and a spraying method capable of continuously performing a kneading and spraying operation of dry cement mortar containing a highly viscous polymer with a stable quality have been known (PTL 13).

Citation List

Patent Literatures

[0007]

PTL 1: JPH10-235623A
PTL 2: US8,211,226B
PTL 3: CN104308988A
PTL 4: CN104153493A
PTL 5: US2014/0308381A
PTL 6: JP2016-101737A
PTL 7: JP2008-247677A
PTL 8: JPS62-10949B
PTL 9: JP2006-290694A
PTL 10: JPH04-97932A
PTL 11: JP2006-232603A
PTL 12: JP2018-140906A
PTL 13: JP2007-245596A

Summary of Invention

Technical Problem

[0008]

PTL 1 relates to a technique in which dry mixed mortar obtained by pre-mixing cement and a fine aggregate, and water containing a quick setting agent are sprayed while mixing and agitating with a spraying nozzle, for hardening and self-standing, and therefore has a problem that the molded article has poor finish, and dust generation occurs. PTL 2 uses a water soluble silicate salt as an accelerator, and therefore has a problem of a low hardening rate and a possibility of deteriorated strength development capability. PTLs 3 and 4 relate to a production technique using a 3D printer, and have no description of the use of a particular material. PTL 5 relates to a nozzle shape of a 3D printer, and has no description of the use of a particular material. PTL 6 relates to a technique in which a resin formwork is produced with a 3D printer, and a cementitious material is charged in the formwork to produce a cementitious hardened material, and has a problem that a cementitious hardened material as a molded article cannot be produced efficiently due to the production of the formwork as an essential factor.

Various kinds of cementitious materials have been known as in PTLs 7 to 11, but a cementitious material that can solve the aforementioned problems has not yet been known. Furthermore, PTL 12 relates to a cementitious material for three-dimensional molding for

construction, but does not describe about the kneading method, and does not describe about the achievement of a sufficient construction speed. PTL 13 relates to a spraying construction system, which is different from the use in three-dimensional molding for construction.

[0009]

A problem to be solved by the present invention is to provide wet cement mortar for three-dimensional molding for construction that is excellent in self-standing capability and short term and long term strength development capabilities, and a three-dimensional molding method for construction using the same.

Solution to Problem

[0010]

As a result of various investigations performed for solving the problem, the present inventors have found that the problem can be solved by wet cement mortar obtained by kneading a dry cementitious material using a combination of an aggregate, a dispersant containing a lignin sulfonic acid-based dispersant and a melamine sulfonic acid-based dispersant at a particular ratio, diutan gum having an average molecular weight in a range of 2,000,000 to 8,000,000 and a viscosity of a 0.25% aqueous solution thereof in a range of 2,000 to 10,000 mPa·s, a setting retarder, amorphous calcium aluminosilicate containing SiO₂ at a particular ratio, gypsum, and short fibers, with a continuous kneading system, and thus the present invention has been completed.

The present invention includes the following points.

(1) Wet cement mortar for three-dimensional molding for construction, obtained by continuously kneading a dry cementitious material for three-dimensional molding for construction containing cement (A), an aggregate (B), a dispersant (C) containing a lignin sulfonic acid-based dispersant (R) and a melamine sulfonic acid-based dispersant (M) at a mass ratio $R/M = 100/80$ to 400, diutan gum (D) having an average molecular weight in a range of 2,000,000 to 8,000,000 and a viscosity of a 0.25% by mass aqueous solution thereof in a range of 2,000 to 10,000 mPa·s, a setting retarder (E), amorphous calcium aluminosilicate (F) containing SiO₂ in an amount of 10 to 25% by mass in terms of oxide, gypsum (G), and short fibers (H), with a continuous kneading system including a device (a) continuously supplying the dry cementitious material, a device (b) continuously supplying water, and a cylindrical agitation device (c) having a horizontal screw shaft therein capable of continuously mixing the dry cementitious material and water to produce wet mortar.

(2) The wet cement mortar for three-dimensional molding for construction according to the item (1), wherein the wet cement mortar contains 13 to 20 parts by mass of

water per 100 parts by mass of the dry cementitious material for three-dimensional molding for construction.

(3) The wet cement mortar for three-dimensional molding for construction according to the item (1) or (2), wherein the wet cement mortar contains 0.2 to 3 parts by mass of the dispersant (C) per 100 parts by mass of the cement (A).

(4) The wet cement mortar for three-dimensional molding for construction according to any one of the items (1) to (3), wherein the wet cement mortar contains 0.03 to 1.0 part by mass of the diutan gum (D) per 100 parts by mass of the cement (A).

(5) The wet cement mortar for three-dimensional molding for construction according to any one of the items (1) to (4), wherein the wet cement mortar contains 50 to 250 parts by mass of the gypsum (G) per 100 parts by mass of the amorphous calcium aluminosilicate (F).

(6) The wet cement mortar for three-dimensional molding for construction according to any one of the items (1) to (5), wherein the wet cement mortar contains 5 to 30 parts by mass in total of the amorphous calcium aluminosilicate (F) and the gypsum (G) per 100 parts by mass of the cement (A).

(7) The wet cement mortar for three-dimensional molding for construction according to any one of the items (1) to (6), wherein the aggregate (B) contains a balloon aggregate.

(8) The wet cement mortar for three-dimensional molding for construction according to any one of the items (1) to (7), wherein the setting retarder (E) contains an oxycarboxylic acid compound.

(9) The wet cement mortar for three-dimensional molding for construction according to any one of the items (1) to (8), wherein the short fibers (H) have an average fiber length of 5 to 15 mm.

(10) The wet cement mortar for three-dimensional molding for construction according to the item (9), wherein the short fibers (H) have an average fiber diameter of 20 to 250 μm and a number of fibers per 1 g of 5,000 or more.

(11) A three-dimensional molding method for construction including pumping the wet cement mortar for three-dimensional molding for construction according to any one of the items (1) to (10) with a pump, and laminating the wet mortar for three-dimensional molding for construction discharged from a nozzle, while moving the nozzle, so as to build a molded article.

(12) The three-dimensional molding method for construction according to the item (11), wherein the pump is a rotary volumetric eccentric single screw pump.

Advantageous Effects of Invention

[0011]

The use of the wet cement mortar for three-dimensional molding for construction and the three-dimensional molding method for construction of the present invention enables the supply of the material at a constant rate and secures a constant lamination rate. Furthermore, the excellent self-standing capability and strength development capability obtained thereby enable the build of a large molded article in a short period of time.

Brief Description of Drawing

[0012]

Fig. 1 is a schematic illustration showing one example of a continuous kneading system used in the production of wet cement mortar for three-dimensional molding for construction of the present invention.

Fig. 2 is a schematic illustration showing one example of a three-dimensional molding system used in a three-dimensional molding method for construction of the present invention.

Fig. 3(a) is a schematic illustration showing a spraying nozzle viewed from the side, and Fig. 3(b) is a schematic illustration showing the spraying nozzle viewed from a discharge port.

Fig. 4 is a schematic illustration showing a three-dimensional molded article produced in Example 8 described later.

Description of Embodiments

[0013]

In the present invention, the "three-dimensional molding" means a technique of producing a molded article having an optional shape through direct lamination molding of cross sectional shapes based on three-dimensional data, without the use of a dedicated tool, such as a formwork. The "three-dimensional molding" may also be referred to as "lamination molding" or "rapid prototyping".

[0014]

(Wet Cement Mortar for Three-dimensional Molding for Construction)

The wet cement mortar for three-dimensional molding for construction of the present invention is obtained by continuously kneading a dry cementitious material for three-dimensional molding for construction containing cement (A), an aggregate (B), a dispersant (C) containing a lignin sulfonic acid-based dispersant (R) and a melamine sulfonic acid-based dispersant (M) at a mass ratio $R/M = 100/80$ to 400, diutan gum (D) having an average

molecular weight in a range of 2,000,000 to 8,000,000 and a viscosity of a 0.25% by mass aqueous solution thereof in a range of 2,000 to 10,000 mPa·s, a setting retarder (E), amorphous calcium aluminosilicate (F) containing SiO₂ in an amount of 10 to 25% by mass in terms of oxide, gypsum (G), and short fibers (H), with a continuous kneading system including a device (a) continuously supplying the dry cementitious material, a device (b) continuously supplying water, and a cylindrical agitation device (c) having a horizontal screw shaft therein capable of continuously mixing the dry cementitious material and water to produce wet mortar. According to the configuration, the wet cement mortar for three-dimensional molding for construction of the present invention becomes excellent in self-standing capability, short term strength development capability, and long term strength development capability.

[0015]

[Dry Cementitious Material for Three-dimensional Molding]

The dry cementitious material for three-dimensional molding used in the wet cement mortar for three-dimensional molding for construction of the present invention (which may also be referred to as a "dry cementitious material") contains cement (A), an aggregate (B), a dispersant (C) containing a lignin sulfonic acid-based dispersant (R) and a melamine sulfonic acid-based dispersant (M) at a mass ratio R/M = 100/80 to 400, diutan gum (D) having an average molecular weight in a range of 2,000,000 to 8,000,000 and a viscosity of a 0.25% by mass aqueous solution thereof in a range of 2,000 to 10,000 mPa·s, a setting retarder (E), amorphous calcium aluminosilicate (F) containing SiO₂ in an amount of 10 to 25% by mass in terms of oxide, gypsum (G), and short fibers (H).

[0016]

<Cement (A)>

Examples of the cement (A) used in the present invention include various types of Portland cement, such as ordinary, high early strength, ultrahigh early strength, low heat, and moderate heat, various types of mixed cement obtained by mixing the Portland cement with blast furnace slag, fly ash, or silica, filler cement obtained by mixing limestone powder or blast furnace slowly cooled slag fine powder having a Blaine specific surface area of 2,000 cm²/g or more, environment friendly cement (eco-cement) produced from municipal waste incineration ash and sewage sludge incineration ash as a raw material, and alumina cement used for refractory. One kind or two or more kinds among these may be used. The Blaine specific surface area of the cement (A) is preferably 2,000 cm²/g or more, and more preferably 3,000 cm²/g or more. The upper limit value of the Blaine specific surface area of the cement (A) is not particularly limited, and is generally 5,000 cm²/g.

[0017]

<Aggregate (B)>

The aggregate (B) used in the present invention is not particularly limited, and an aggregate derived from natural limestone, an aggregate derived from a silicate material, a heavy aggregate having a specific gravity exceeding 3.0, and the like, which are commercially available, may be used. A part of the aggregate used may be a balloon aggregate for the purpose of enhancing the self-standing capability. The balloon aggregate is generally referred to as a lightweight aggregate, and examples thereof include fly ash balloons, shirasu balloons, and balloons obtained by firing and foaming obsidian with a kiln. The specific gravity of the aggregate (B) is preferably 3 or less, more preferably 2.0 or less, further preferably 1.8 or less, and most preferably 1.0 or less. The lower limit value of the specific gravity of the aggregate (B) is not particularly limited, and is generally 0.3.

The maximum particle diameter of the aggregate (B) (including the balloon aggregate) is preferably 10 mm or less, and more preferably 5 mm or less, in consideration of the pumpability. The lower limit value of the maximum particle diameter of the aggregate (B) is not particularly limited, and is generally 0.03 mm.

The amount of the aggregate (B) used is preferably 50 to 300 parts by mass, and more preferably 100 to 200 parts by mass, per 100 parts by mass of the cement (A). In the case where the amount of the aggregate (B) used is 50 parts by mass or more per 100 parts by mass of the cement (A), the self-standing capability can be easily secured. In the case where the amount of the aggregate (B) used is 300 parts by mass or less per 100 parts by mass of the cement (A), suitable softness can be easily secured, resulting in a good pumpability.

In the case where the balloon aggregate is used, the amount thereof used is preferably 25 parts by mass or less, more preferably 1 to 25 parts by mass, and further preferably 3 to 15 parts by mass, per 100 parts by mass of the aggregate (B). In the case where the amount of the balloon aggregate used is 25 parts by mass or less per 100 parts by mass of the aggregate (B), the strength development capability is enhanced, and suitable softness can be secured, resulting in a good pumpability. In the case where the amount of the balloon aggregate used is 1 part by mass or more per 100 parts by mass of the aggregate (B), a better effect of enhancing the self-standing capability can be obtained.

[0018]

<Dispersant (C)>

The dispersant (C) used in the present invention is a dispersant that is formed of a lignin sulfonic acid-based dispersant (R) and a melamine sulfonic acid-based dispersant (M), and is a dispersant that uses a combination of the lignin sulfonic acid-based dispersant (R) and the melamine sulfonic acid-based dispersant (M) at a mass ratio $R/M = 100/80$ to 400. The

use of the dispersant (C) can secure the flowability of the cementitious material kneaded with water added thereto, and can enhance the thixotropy thereof. The ratio is more preferably $R/M = 100/100$ to 250. In the case where the mixing ratio of the melamine sulfonic acid-based dispersant (M) is smaller than the lower limit value, there is a concern that the amount of the dispersant required for achieving the prescribed flowability is increased, and the temporal change of the flowability becomes too large to impair the pumpability. In the case where the mixing ratio of the melamine sulfonic acid-based dispersant (M) exceeds the upper limit value, there is a concern that the setting is retarded to decrease the temporal change of the flowability, and thereby the self-standing capability after the pumping is difficult to secure.

The amount of the dispersant (C) used is preferably 0.2 to 3 parts by mass, and more preferably 0.5 to 2 parts by mass, per 100 parts by mass of the cement (A). In the case where the amount of the dispersant (C) used is 0.2 part by mass or more per 100 parts by mass of the cement (A), the sufficient flowability can be easily obtained. In the case where the amount of the dispersant (C) used is 3 parts by mass or less per 100 parts by mass of the cement (A), the decrease of the temporal change of the flowability due to the retardation of setting can be further prevented, and as a result, the self-standing capability can be further enhanced.

[0019]

<Diutan Gum (D)>

In the present invention, diutan gum (D) having an average molecular weight in a range of 2,000,000 to 8,000,000 and a viscosity of a 0.25% by mass aqueous solution thereof in a range of 2,000 to 10,000 mPa·s can be used. The viscosity of an aqueous solution thereof having a concentration of 0.25% by mass is a value that is measured at 25°C with a B-type viscometer under a condition of 3 rpm. Diutan gum is a natural polymer polysaccharide containing, for example, two glucose molecules, one glucuronic acid molecule, and three rhamnose molecules, as structural units. The use of the diutan gum (D) can impart thixotropy to the wet cement mortar for three-dimensional molding for construction of the present invention. From this standpoint, the average molecular weight of the diutan gum (D) is preferably 2,500,000 to 6,000,000, and the viscosity of a 0.25% by mass aqueous solution thereof is preferably 2,500 to 8,000 mPa·s.

The amount of the diutan gum (D) used is preferably 0.03 to 1.0 part by mass, and more preferably 0.05 to 0.5 part by mass, per 100 parts by mass of the cement (A). In the case where the amount of the diutan gum (D) used is 0.03 part by mass or more per 100 parts by mass of the cement (A), further sufficient thixotropy can be imparted. In the case where the amount of the diutan gum (D) used is 1.0 part by mass or less per 100 parts by mass of the cement (A), the pumpability and the strength development capability can be further improved.

[0020]

<Setting Retarder (E)>

The setting retarder (E) used in the present invention may be a commercially available product for a cementitious material. Examples of the setting retarder (E) include an inorganic retarder, such as a phosphate salt, a silicofluoride, copper hydroxide, boric acid or a salt thereof, zinc oxide, zinc chloride, and zinc carbonate, and one kind thereof or a mixture of two or more kinds thereof may be used. Examples of the setting retarder (E) also include an organic retarder, such as an oxycarboxylic acid (such as citric acid, gluconic acid, malic acid, tartaric acid, glucoheptonic acid, oxymalonic acid, and lactic acid) or a salt thereof (an oxycarboxylic acid and a salt of an oxycarboxylic acid may be generically referred to as an oxycarboxylic acid compound), and a sugar represented by sucrose, and one kind thereof or a mixture of two or more kinds thereof may be used. The setting retarder (E) used may also be a mixture of a combination of an inorganic compound, such as a carbonate salt, a bicarbonate salt, a nitrate salt, a hydroxide, and a silicate salt, with the aforementioned oxycarboxylic acid compound or a salt thereof. Among these, from the standpoint of improving the pumpability and facilitating the securement of the self-standing capability after pumping, a compound containing the oxycarboxylic acid is preferred, and the oxycarboxylic acid compound alone or a mixture of the oxycarboxylic acid compound and the inorganic compound is more preferred.

The amount of the setting retarder (E) used is preferably 0.05 to 0.7 part by mass, and more preferably 0.07 to 0.5 part by mass, per 100 parts by mass of the cement. In the case where the amount of the setting retarder (E) used is 0.05 part by mass or more per 100 parts by mass of the cement, the usable time in consideration of the kneading time and the pumping can be easily secured. In the case where the amount of the setting retarder (E) used is 0.7 part by mass or less per 100 parts by mass of the cement, the failure in securing the self-standing capability due to the excessive prolongation of the hardening time can be prevented.

[0021]

<Amorphous Calcium Aluminosilicate (F)>

The amorphous calcium aluminosilicate (F) used in the present invention (which may be hereinafter referred simply to as "calcium aluminosilicate") can be obtained by subjecting a mixture obtained by mixing a CaO material, an Al₂O₃ material, and an SiO₂ material, to a heat treatment, such as firing with a kiln, and melting with an electric furnace or the like, and is amorphous calcium aluminosilicate containing SiO₂ in an amount of 10 to 25% by mass in terms of oxide. The calcium aluminosilicate is an amorphous material, and thus has high reactivity. In the case where the content of SiO₂ is less than 10% by mass, there is a possibility that the hydration activity thereof is increased, and the amount of the setting retarder required

for regulating the hardening time is increased, which affect the thixotropy and the self-standing capability, and in the case where the content thereof exceeds 25% by mass, there is a possibility that the hydration activity thereof is decreased, and a suitable hardening rate cannot be obtained. From this standpoint, the content of SiO_2 in terms of oxide of the amorphous calcium aluminosilicate (F) is preferably 12 to 20% by mass.

The calcium aluminosilicate (F) preferably has a $\text{CaO}/\text{Al}_2\text{O}_3$ molar ratio of CaO and Al_2O_3 in terms of oxide of 1.5 to 3.5, and more preferably 1.7 to 2.0. The calcium aluminosilicate (F) may further contain as a part of solid solution an alkali metal, such as sodium, potassium, and lithium.

The granularity of the calcium aluminosilicate (F) is preferably $3,000 \text{ cm}^2/\text{g}$ or more in terms of Blaine value. In the case where the granularity of the calcium aluminosilicate (F) is $3,000 \text{ cm}^2/\text{g}$ or more in terms of Blaine value, the strength development capability can be further improved. From this standpoint, the granularity of the calcium aluminosilicate (F) is more preferably $4,000 \text{ cm}^2/\text{g}$ or more in terms of Blaine value. The upper limit value of the granularity of the calcium aluminosilicate (F) is not particularly limited, and is generally $7,000 \text{ cm}^2/\text{g}$ in terms of Blaine value.

[0022]

<Gypsum (G)>

The gypsum (G) used in the present invention is a component that further enhances the strength through combination use with the calcium aluminosilicate. Examples of the kind of the gypsum (G) include anhydrous gypsum, hemihydrate gypsum, and dihydrate gypsum, and gypsum by-produced in factories and naturally occurring gypsum can be used. Among these, anhydrous gypsum is preferably used from the point of the strength development capability.

The granularity of the gypsum (G) is preferably $3,000 \text{ cm}^2/\text{g}$ or more in terms of Blaine value. In the case where the granularity of the gypsum (G) is $3,000 \text{ cm}^2/\text{g}$ or more in terms of Blaine value, the strength development capability can be further improved. From this standpoint, the granularity of the gypsum (G) is more preferably $4,000 \text{ cm}^2/\text{g}$ or more in terms of Blaine value. The upper limit value of the granularity of the gypsum (G) is not particularly limited, and is generally $7,000 \text{ cm}^2/\text{g}$.

The amount of the gypsum (G) used is preferably 50 to 250 parts by mass, and more preferably 100 to 200 parts by mass, per 100 parts by mass of the calcium aluminosilicate (F). In the case where the amount of the gypsum (G) used is 50 parts by mass or more per 100 parts by mass of the calcium aluminosilicate (F), the strength can be further enhanced. In the case where the amount of the gypsum (G) used is 250 parts by mass or less per 100 parts by mass of

the calcium aluminosilicate (F), the strength development capability can be enhanced corresponding to the amount of the gypsum (G) used.

[0023]

The total amount of the calcium aluminosilicate (F) and the gypsum (G) used is preferably 5 to 30 parts by mass, and more preferably 10 to 20 parts by mass, per 100 parts by mass of the cement (A). In the case where the total amount of the calcium aluminosilicate (F) and the gypsum (G) used is 5 parts by mass or more per 100 parts by mass of the cement (A), the strength development effect by the calcium aluminosilicate (F) and the gypsum (G) can be further enhanced. In the case where the total amount of the calcium aluminosilicate (F) and the gypsum (G) used is 30 parts by mass or less per 100 parts by mass of the cement (A), the usable time can be further easily secured, and the strength development capability can be further enhanced.

[0024]

<Short Fibers (H)>

The short fibers (H) used in the present invention may be an ordinary product that are commercially available as an admixture for cement. Examples of the short fibers (H) include vinylon fibers, acrylic fibers, nylon fibers, steel fibers, glass fibers, polypropylene fibers, polyethylene fibers, polyester fibers, and basalt fibers, and one kind of the fibers or a combination of two or more kinds thereof may be used. Among these, vinylon fibers having wide variations in fiber diameter and fiber length, and nylon fibers excellent in dispersibility are preferably used.

The average fiber length of the short fibers (H) is preferably in a range of 3 to 15 mm, and more preferably in a range of 5 to 10 mm, in consideration of premixing in advance. The average fiber diameter of the short fibers (H) is preferably 20 to 250 μm , and more preferably 100 to 250 μm . In the case where the average fiber diameter of the short fibers (H) is 20 μm or more, the fibers are easily available. In the case where the average fiber diameter of the short fibers (H) is 250 μm or less, the pumpability of the wet material can be further improved. In the case where the average fiber diameter of the short fibers (H) is 20 μm or more, and particularly 100 μm or more, the frictional heat generating in pumping the wet material containing the cementitious material having water added thereto is increased, and thereby the temperature of the wet material discharged from the nozzle tip is increased to shorten the hardening time appropriately, achieving continuous higher lamination.

The short fibers (H) are preferably fibers in the form of bundled fibers including monofilaments bundled with a binder, rather than fibers in the form of monofilaments, since a larger number of fibers can be mixed.

The number of fibers per 1 g of the short fibers (H) is preferably 5,000 or more, and more preferably 6,000 or more. In the case where the number of fibers per 1 g of the short fibers (H) is 5,000 or more, the reinforcing effect and the effect of preventing initial cracking by the short fibers (H) can be sufficiently exerted. The upper limit value of the number of fibers per 1 g of the short fibers (H) is not particularly limited, and is generally 400,000, and preferably 50,000. The number of fibers per 1 g of the short fibers (H) is obtained from (the fineness (dtex)) / (the mass (g) of the monofilament per 10,000 m) according to the following expression.

$$\text{Number of fibers (g)} = (1/(\text{fineness}/10,000 \text{ (m)})) / \text{average fiber length (m)}$$

The amount of the short fibers (H) used is preferably 0.1 to 1.0 part by mass, and more preferably 0.2 to 0.5 part by mass, per 100 parts by mass in total of the cement (A) and the aggregate (G). In the case where the amount of the short fibers (H) used is 0.1 part by mass or more per 100 parts by mass in total of the cement (A) and the aggregate (G), the reinforcing effect can be further exerted. In the case where the amount of the short fibers (H) used is 1.0 part by mass or less per 100 parts by mass in total of the cement (A) and the aggregate (G), the short fibers (H) can be further prevented from impairing the pumpability.

[0025]

<Additional Components>

The wet cement mortar for three-dimensional molding for construction of the present invention may contain various additives, for example, an anti-foaming agent, a rust inhibitor, an antifreezing agent, a shrinkage reducing agent, an inorganic mineral, such as bentonite and sepiolite, and an anion exchange material, such as hydrotalcite, a polymer emulsion, and the like. In addition to the inorganic powder mixed in the cement in advance, inorganic powder having hydration activity, such as blast furnace slag, silica fume, and fly ash, may also be used.

[0026]

<Amount of Water used>

The dry cementitious material used in the wet cement mortar for three-dimensional molding for construction of the present invention and water added thereto are continuously kneaded with a continuous kneading system to prepare wet cement mortar for three-dimensional molding (which may be hereinafter referred simply to as "wet cement mortar"), which is used for three-dimensional molding. The amount of water used is preferably 13 to 20 parts by mass, and more preferably 15 to 18 parts by mass, per 100 parts by mass of the cementitious material. In the case where the amount of water used is 13 parts by mass or more

per 100 parts by mass of the cementitious material, the kneading can be easily performed. In the case where the amount of water used is 20 parts by mass or less per 100 parts by mass of the cementitious material, the flowability of the wet cement mortar can be prevented from increasing, and the self-standing capability can be further enhanced.

[0027]

<Continuous Kneading System>

The continuous kneading system used for the wet cement mortar for three-dimensional molding for construction of the present invention will be described below with reference to the continuous kneading system shown in Fig. 1 as an example. The continuous kneading system shown in Fig. 1 does not limit the continuous kneading system used for the wet cement mortar for three-dimensional molding for construction of the present invention.

The continuous kneading system used for the wet cement mortar for three-dimensional molding for construction of the present invention includes a device (a) continuously supplying the dry cementitious material, a device (b) continuously supplying water, and a cylindrical agitation device (c) having a horizontal screw shaft therein capable of continuously mixing the dry cementitious material and water to produce wet mortar.

[0028]

The device (a) continuously supplying the dry cementitious material of a continuous kneading system 1 includes a storage hopper 10 and a horizontal screw shaft 70 housed therein, and is for introducing the dry cementitious material inputted therein to an ejection port 40 through rotation of the screw shaft 70, and for delivering the material to an agitation unit 50 for continuously kneading. The shape and the capacity of the storage hopper 10 are not particularly limited, and the capacity thereof is preferably approximately 30 to 200 L for enabling to handle any type of repair and any reinforcing position. Since the screw shaft 70 is provided at the bottom of the storage hopper, the shape thereof preferably has a slope for delivering the dry cementitious material spontaneously to the screw shaft 70 without applying vibration or impact thereto. In the case where the storage hopper 10 is a closed system, a cover, which is not shown in the figure, having a piping port and a filter capable of exhausting only compressed air is provided over the material input port, for enabling to store the dry cement mortar pneumatically delivered. The cover may be fixed via a rubber packing at the contact part of the cover and the storage hopper, for enabling to detach the cover easily and to prevent powder dusts from being leaked.

[0029]

The device (b) continuously supplying water of the continuous kneading system 1 is for supplying water stably via a flow meter 20 or the like. The supplying position of water is

preferably 0.2 to 1.5 m, and more preferably 0.3 to 1.2 m, distant from the ejection port 40 of the wet cement mortar. In the case where the supplying position of water is 0.2 to 1.5 m or more distant from the ejection port of the wet cement mortar, the agitation efficiency can be further improved. The amount of water supplied may be appropriately set to an amount that is determined by measuring the supplied amount only of the dry cementitious material in advance. The amount of water supplied can be measured by connecting a tube 30 having flow meter 20 to the supplying port, and the fine control thereof can be performed, for example, by regulating the opening of a needle valve provided on the tube 30. Water is supplied under a certain water pressure thereto, and the water pressure is preferably 0.2 MPa or more. In the case where the water pressure is 0.2 MPa or more, water can be supplied more stably.

[0030]

The cylindrical agitation unit 50 having the screw shaft 70 therein of the continuous kneading system 1 is capable of continuously supplying water to the continuously supplied dry cementitious material, so as to produce wet cement mortar continuously, and is a device that adds water to the dry cementitious material delivered from the storage hopper 10, so as to produce wet cement mortar. The cylindrical agitation unit 50 has an agitation blade 60 therein, which is connected to the screw shaft 70 of the storage hopper 10 for transferring the rotational motion thereto. The rotation number of the agitation blade 60 is preferably 100 to 400 rpm, and more preferably 200 to 300 rpm. In the case where the rotation number of the agitation blade 60 is 100 rpm or more, the kneading efficiency can be improved, and in the case where the rotation number of the agitation blade 60 is 400 rpm or less, the mortar can be prevented from being heated, and thus prevented from suffering flow down and shortening of the hardening time.

[0031]

<Three-dimensional Molding Method for Construction>

The three-dimensional molding method for construction of the present invention includes pumping the wet cement mortar for three-dimensional molding for construction of the present invention with a pump, and laminating the wet mortar for three-dimensional molding discharged from a nozzle, while moving the nozzle, so as to build a molded article. The pump is preferably a rotary volumetric eccentric single screw pump.

The three-dimensional molding method for construction of the present invention (which may be hereinafter referred simply to as a "three-dimensional molding method") will be described below with reference to a three-dimensional molding system 2 shown in Fig. 2 as an example. The three-dimensional molding system 2 shown in Fig. 2 does not limit the three-dimensional molding method of the present invention. The three-dimensional molding

method of the present invention can be divided, for example, into a continuous kneading step of a dry cementitious material, a pumping step of wet cement mortar obtained by kneading, and a three-dimensional molding step through controlled nozzle movement.

[0032]

The dry cementitious material of the present invention can be kneaded with a continuous kneading mixer 80.

[0033]

A pump 90 used in the present invention for pumping the kneaded wet cement mortar is not particularly limited, as far as being capable of pumping the wet cement mortar without deteriorating the quality thereof, and is preferably a rotary volumetric eccentric single screw pump 90. The rotary volumetric eccentric single screw pump 90, which is also referred to as Mohno Pump or Snake Pump, can perform volumetric pumping without pulsation in pumping as compared to a squeeze pump, and can be regulated for the discharge amount by controlling the rotation number of the motor. It is considered that the rotary volumetric eccentric single screw pump 90 allows the temperature of the pumped wet cement mortar to rise due to the structure thereof, and thus is preferred from the point that the hardening reaction of the wet cement mortar proceeds in a short time, and the self-standing stability is enhanced to increase the continuous lamination height. Specifically, the rotary volumetric eccentric single screw pump 90 has a structure including a rotor as an external thread and a stator as an internal thread, which form a closed space referred to as a cavity as a gap between the stator and the rotor inserted thereto (i.e., the space between the rotor and the stator), and the rotor is rotated inside the stator, so that the cavity is moved to the discharge side while generating a strong suction force, thereby continuously transferring the material. In transferring, for example, the rotor performs eccentric rotational motion, i.e., rotates while revolving around the center axis of the stator. At the time when the material from the initial cavity is moved to the front (discharge side) cavity through the suction force, it is considered that the material is heated through the frictional resistance to the stator surface. This heating phenomenon can be utilized to achieve three-dimensional molding excellent in self-standing stability while securing the usable time. For the rotary volumetric eccentric single screw pump 90, for example, reference may be made to WO2014/142239A, paragraphs 0063 to 0064.

A pumping pipe 100 used may be a flexible hose having a withstanding pressure of 2 to 4 MPa, which may be partially combined with a metal pipe, and the pipe diameter thereof is preferably 20 to 50 mm while varying depending on the set discharge amount. The distance of the pumping pipe 100 is not particularly limited, and is preferably 20 m or less in consideration of the pumpability.

[0034]

A nozzle 110 is provided at the discharge part (i.e., the tip of the pumping pipe) discharging the wet cement mortar of the present invention. The diameter of a discharge port 111 (see Fig. 3) is not particularly limited, and may be appropriately determined depending on the diameter of the aggregate used and the lamination width. For example, in the case where the diameter of the aggregate is 5 mm or less, and the lamination width is 50 mm or less, the diameter of the discharge port 111 is preferably 8 to 20 mm. The shape of the discharge port 111 is not particularly limited, examples of which include a circular shape, an elliptical shape, a rectangular shape, a cruciform shape, and a star shape, and a flange may be provided around the discharge port for the purpose of smoothing the surface of the discharged wet cement mortar. The discharge port 111 may be provided vertically with respect to a bed 120, and the discharge port 111 may also be provided horizontally in some cases.

[0035]

The nozzle movement in the horizontal direction and the vertical direction of the three-dimensional molding system 2 is preferably controlled, for example, with a computer, while fixing the spray nozzle 110 to a robot arm 130 or a portal plotter. For example, a usable method therefor includes slicing three-dimensional data produced with a computer into a prescribed thickness to form two-dimensional sliced data, discharging the wet cement mortar from the spray nozzle 110 to the bed 120 while controlling the movement of the nozzle 110 in the horizontal directions, such as the longitudinal, transverse, and diagonal directions, based on the two-dimensional sliced data, and repeating the movement of the nozzle in the vertical direction to laminate the wet material to mold a three-dimensional molded article 140 (see Fig. 4). In fixing the spray nozzle 110 to the robot arm 130 or a portal plotter, a pulley 150 is preferably used for preventing the pumping pipe 100 from being clogged through flexure.

The moving speed of the nozzle 110 is not particularly limited, and may be changed depending on the lamination width of the wet material. In the case where the discharge amount of the wet material is constant, the decrease of the speed increases the lamination width of the wet material, and the increase of the speed decreases the lamination width of the wet material.

Examples

[0036]

The present invention will be described in more detail below with reference to examples, but the present invention is not limited to the examples.

[0037]

<Example 1>

100 parts by mass of cement was blended with 150 parts by mass of an aggregate, 1.0 part by mass of a dispersant containing a lignin sulfonic acid-based dispersant (R) and a melamine sulfonic acid-based dispersant (M) at a mass ratio $R/M = 100/200$, diutan gum of the kind and the amount shown in Table 1, 0.25 part by mass of a setting retarder A, and 20 parts by mass of a mixture containing 100 parts by mass of the calcium aluminosilicate shown in Table 1 blended with 150 parts by mass of gypsum, and also blended with 0.2 part by mass of short fibers a per 100 parts by mass in total of the cement and the aggregate, so as to prepare a dry cementitious material. The supply amounts of the dry cementitious material supplying part and the water supplying part of the continuous kneading device ("continuous" in Table 1) were regulated to make 100 parts by mass of the material thus prepared and 17 parts by mass of water, which were then kneaded. The resulting wet cement mortar was measured for the mortar flow (MF, in standing and 15-stroke), the hardening time, and the compressive strength, and also calculated for the thixotropy. For comparison, wet cement mortar kneaded with a commercially available batch mixer ("batch" in Table 1) was similarly measured. The results are shown in Table 1.

[0038]

(Materials)

<Cement (A)>

Cement: ordinary portland cement (available from Denka Co., Ltd., Blaine specific surface area: $3,400 \text{ cm}^2/\text{g}$)

<Aggregate (B)>

Aggregate: limestone aggregate (available from Denka Co., Ltd., maximum particle diameter: 1.2 mm, specific gravity: 2.71)

<Dispersant (C)>

Lignin sulfonic acid-based dispersant (R): "San X P252", trade name, available from Nippon Paper Industries Co., Ltd.

Melamine sulfonic acid-based dispersant (M): "Sikament FF86/100", trade name, available from Sika Japan Ltd.

<Diutan Gum (D)>

Diutan gum A: synthesized from glucose as raw material through aerobic fermentation with *Alcaligenes* bacteria, molecular weight: 4,100,000, viscosity of 0.25% by mass aqueous solution: $5,600 \text{ mPa}\cdot\text{s}$

Diutan gum B: synthesized in the same manner as in diutan gum A except for changing fermentation time, molecular weight: 2,200,000, viscosity of 0.25% by mass aqueous solution:

2,300 mPa·s

Diutan gum C: synthesized in the same manner as in diutan gum A except for changing fermentation time, molecular weight: 5,300,000, viscosity of 0.25% by mass aqueous solution: 7,500 mPa·s

Diutan gum D: synthesized in the same manner as in diutan gum A except for changing fermentation time, molecular weight: 7,800,000, viscosity of 0.25% by mass aqueous solution: 9,600 mPa·s

Diutan gum E: synthesized in the same manner as in diutan gum A except for changing fermentation time, molecular weight: 1,800,000, viscosity of 0.25% by mass aqueous solution: 1,800 mPa·s

<Thickening Agent other than Diutan Gum>

Thickening agent A: cellulose ether-based ("hi90SH-30000", trade name, available from Shin-Etsu Chemical Co., Ltd. (viscosity of 2% by mass aqueous solution at 20°C: 30,000 mP·s

<Setting Retarder (E)>

Setting retarder A: citric acid (first grade reagent)

<Amorphous Calcium Aluminosilicate (F)>

Calcium aluminosilicate A: prepared by mixing SiO₂, CaCO₃, and Al₂O₃, commercially available special grade reagents, to make prescribed ratio, melting by heating to approximately 2,000°C in high-frequency furnace, quenching in water, and pulverizing (amorphous, SiO₂ content: 10.1%, CaO/Al₂O₃ molar ratio: 1.85, Blaine specific surface area: 5,900 cm²/g)

Calcium aluminosilicate B: prepared in the same manner as in calcium silicate A except for changing mixing ratio of reagents (amorphous, SiO₂ content: 14.9%, CaO/Al₂O₃ molar ratio: 1.85, Blaine specific surface area: 5,800 cm²/g)

Calcium aluminosilicate C: prepared in the same manner as in calcium silicate A except for changing mixing ratio of reagents (amorphous, SiO₂ content: 24.6%, CaO/Al₂O₃ molar ratio: 1.85, Blaine specific surface area: 5,800 cm²/g)

<Gypsum (G)>

Gypsum: pulverized product of natural anhydrous gypsum (Blaine specific surface area: 5,200 cm²/g)

<Short Fibers (H)>

Short fibers a: vinylon fibers (average fiber length: 12 mm, average fiber diameter: 50 μm, number of fibers per 1 g: 55,500)

[0039]

(Continuous Kneading System)

In Fig. 1, the rotation number of the agitation blade (60) was 280 rpm, the distance between the water supplying port from the water supplying tube (30) and the ejection port (40) of the wet cement mortar was 1 m, and after measuring the discharge amount of the dry cementitious material per one minute in advance, the water supplying amount was regulated with the valve to make the amount of water of 17 parts by mass with respect thereto by checking the flow meter.

(Commercially Available Batch Mixer)

An ordinary pan type mixer having a blade rotating at a rotation number of 45 rpm was used for kneading. The amount of the dry cementitious material kneaded was 50 kg, to which 17 parts by mass of water was added and kneaded for 4 minutes.

[0040]

(Test Methods)

The tests were performed under an environment at 20°C.

(1) Blaine Specific Surface Area

The Blaine specific surface area was measured according to JIS R5201-1997.

(2) Maximum Particle Diameter

The aggregate was sieved according to JIS A1102, and the dimension of the largest sieve mesh that did not completely pass the aggregate was designated as the maximum particle diameter.

(3) Standing and 15-Stroke Mortar Flow (MF)

The mortar flow was measured according to JIS R5201. The mortar flow immediately after withdrawing the flow cone was measured and designated as the standing flow, and after applying a falling motion to the flow table 15 times, the mortar flow was measured and designated as the 15-stroke flow.

(4) Thixotropy

The thixotropy was calculated from the difference between the 15-stroke flow and the standing flow according to the following expression.

$$\text{Thixotropy (\%)} = ((15\text{-stroke flow}) - (\text{standing flow})) / ((\text{standing flow}) \times 100)$$

The thixotropy is a property that influences the pumpability and the self-standing capability of the laminated mortar, in which a smaller standing flow means a better self-standing capability, and a larger 15-stroke flow means a better pumpability.

(5) Hardening Time

After completing the kneading, 2 kg of the wet material was packed in a resin bag, and the time when the wet material did not dent by pressing with a finger was designated as the hardening time. The timing of pressing with a finger was set at 2 minute intervals.

(6) Compressive Strength

The kneaded material was charged in a triple formwork of $4 \times 4 \times 16$ cm according to JIS R5201, and the compressive strength thereof was measured at material ages of 3 hours, 12 hours, 1 day, and 7 days.

(7) Air Amount in Hardened Mortar

The bubble structure was observed according to the linear traverse method of ASTM C457-98 "Microscopical Determination of Parameters of the Air-Void System in Hardened Concrete". The air amount after hardening was a value obtained by dividing the total of the traverse lengths of air bubbles by the entire traverse length, and the air amounts in the bubble diameter ranges each were a value obtained by dividing the total of the traverse lengths calculated for each of the air bubble diameter ranges by the entire traverse length. The total amount of for an air bubble diameter of 0.3 mm or less and the total amount of for an air bubble diameter of 0.3 mm or more were calculated.

[0041]

Table 1

Experiment No.	Mixer	Calcium aluminosilicate	Diutan gum	Amount of diutan gum (% by mass)	MF (mm)		Thixotropy (%)	Hardening time (min)	Air amount (% by volume)		Compressive strength (N/mm ²)				Note
					Standing	15-Stroke			≤0.3 mm	≥0.3 mm	3 hours	12 hours	1 day	7 days	
1-1	continuous	A	A	0.03	109	188	72.5	50	6.4	2.5	8.1	12.3	26.5	67.9	Example
1-2				0.05	107	187	74.8	51	6.4	2.5	8.2	12.3	26.7	68.8	Example
1-3				0.1	104	183	76.0	53	6.6	2.4	8.3	12.4	26.9	69.0	Example
1-4				0.3	104	181	74.0	54	6.6	2.5	8.3	12.3	26.6	68.7	Example
1-5				0.5	104	180	73.1	56	6.6	2.6	8.2	12.3	26.5	68.4	Example
1-6				1	103	174	68.9	59	6.6	2.6	8.4	12.1	26.4	67.6	Example
1-7		B	A	0.03	105	193	83.8	53	6.6	2.4	8.4	12.5	26.2	67.5	Example
1-8				0.05	104	194	86.5	57	6.7	2.3	8.5	12.7	26.9	68.0	Example
1-9				0.1	102	195	91.2	59	6.9	2.0	8.9	13.0	28.3	70.2	Example
1-10				0.3	102	192	88.2	60	6.9	2.1	8.5	12.9	28.0	69.8	Example
1-11				0.5	102	191	87.3	60	6.9	2.2	8.4	12.8	28.0	69.7	Example
1-12				1	102	191	87.3	61	6.9	2.2	8.3	12.6	27.6	61.9	Example
1-13		C	A	0.03	107	191	78.5	69	6.6	2.3	8.4	9.8	26.2	67.9	Example
1-14				0.05	106	192	81.1	70	6.6	2.2	8.4	9.9	26.5	68.0	Example
1-15				0.1	104	193	85.6	73	6.7	2.2	8.5	12.2	27.0	68.8	Example
1-16				0.3	104	192	84.6	79	6.7	2.3	8.2	10.1	26.6	68.2	Example
1-17				0.5	104	191	83.7	86	6.7	2.3	8.1	10.1	26.6	68.1	Example
1-18				1	103	191	85.4	90	6.8	2.3	8.4	9.7	26.4	60.8	Example
1-19		B	B	0.03	107	191	78.5	54	6.6	2.3	8.4	10.4	26.1	67.9	Example
1-20				0.05	106	192	81.1	58	6.6	2.3	8.5	10.6	26.2	68.1	Example
1-21				0.1	104	193	85.6	60	6.7	2.1	8.5	12.2	26.6	68.6	Example
1-22				0.3	104	192	84.6	61	6.7	2.2	8.3	10.5	26.4	68.3	Example
1-23				0.5	104	191	83.7	63	6.7	2.3	8.2	10.3	25.9	68.1	Example
1-24				1	103	191	85.4	65	6.7	2.3	8.2	10.3	25.7	67.7	Example
1-25		B	C	0.03	107	192	79.4	54	6.4	2.6	8.2	10.5	25.9	67.9	Example
1-26				0.05	106	192	81.1	58	6.4	2.4	8.2	10.6	26.3	68.1	Example
1-27				0.1	105	191	81.9	62	6.5	2.4	8.4	12.3	26.4	68.3	Example
1-28				0.3	105	189	80.0	64	6.5	2.5	8.3	10.7	26.2	68.2	Example
1-29				0.5	105	189	80.0	65	6.5	2.5	8.2	10.5	26.0	68.2	Example
1-30				1	104	189	81.7	69	6.6	2.5	8.2	10.3	25.9	67.8	Example
1-31		B	D	0.03	108	190	75.9	55	6.4	2.3	8.1	9.5	26.2	67.7	Example
1-32				0.05	106	190	79.2	59	6.5	2.3	8.2	9.7	26.2	68.1	Example
1-33				0.1	104	192	84.6	63	6.6	2.3	8.4	12.3	26.5	68.5	Example
1-34				0.3	104	192	84.6	64	6.6	2.4	8.3	9.9	26.4	68.4	Example
1-35				0.5	103	190	84.5	66	6.6	2.5	8.2	9.8	26.3	68.3	Example
1-36				1	103	189	83.5	67	6.7	2.5	8.1	9.4	21.3	67.9	Example

(continued)

Table 1 (continued)

Experiment No.	Mixer	Calcium aluminosilicate	Diutan gum	Amount of diutan gum (% by mass)	MF (mm)		Thixotropy (%)	Hardening time (min)	Air amount (% by volume)		Compressive strength (N/mm ²)				Note
					Standing	15-Stroke			≤ 0.3 mm	≥ 0.3 mm	3 hours	12 hours	1 day	7 days	
1-37	continuous	B	E	0.03	124	181	46.0	68	3.5	5.2	2.0	6.5	15.4	57.0	Comparative Example
1-38				0.05	122	182	49.2	67	3.6	5.2	1.8	6.7	15.5	57.2	Comparative Example
1-39				0.1	120	183	52.5	65	3.7	5.2	1.5	6.8	16.2	57.1	Comparative Example
1-40				0.3	118	183	55.1	62	3.7	5.5	0.9	6.0	15.4	55.6	Comparative Example
1-41				0.5	117	183	56.4	64	3.7	5.5	-	4.4	13.2	52.0	Comparative Example
1-42				1	113	182	61.1	71	3.3	5.5	-	3.9	12.9	51.5	Comparative Example
1-43	batch	B	thickening agent A	0.1	131	199	51.9	66	2.1	6.7	-	3.3	11.8	52.2	Comparative Example
1-44		A		0.03	126	175	38.9	24	1.1	7.7	6.1	10.9	24.8	60.4	Comparative Example
1-45				0.05	124	177	42.7	25	1.2	7.7	6.2	11.0	24.9	61.3	Comparative Example
1-46				0.1	122	179	46.7	27	1.2	7.7	6.5	11.3	25.1	62.5	Comparative Example
1-47				0.3	121	178	47.1	28	1.3	7.6	6.4	11.1	24.3	61.9	Comparative Example
1-48				0.5	120	178	48.3	28	1.3	7.4	6.2	11.1	24.0	61.8	Comparative Example
1-49				1	119	177	48.7	27	1.3	7.5	6.0	10.9	24.0	61.0	Comparative Example
1-50		B	A	0.1	120	175	45.8	29	1.2	7.3	6.7	11.3	25.6	63.3	Comparative Example
1-51		C	A	0.1	121	174	43.8	28	1.2	7.5	5.9	10.2	23.7	61.5	Comparative Example
1-52		B	B	0.1	123	175	42.3	26	1.1	7.8	5.8	10.5	23.4	60.5	Comparative Example
1-53		B	C	0.1	122	173	41.8	26	1.0	7.7	5.8	10.6	23.1	60.1	Comparative Example
1-54		B	D	0.1	122	174	42.6	27	1.0	7.2	5.7	10.2	22.4	59.7	Comparative Example

-: unmeasurable or unable to collect test piece

[0042]

As shown in Table 1, the wet cement mortar obtained by using the dry cementitious material having a composition within the range of the present invention with the continuous kneading system in the present invention has an enhanced kneading efficiency, and has a decreased amount of air with a large bubble diameter and an increased amount of air with a small bubble diameter resulting in excellent thixotropy, and thereby the pumpability thereof is not impaired, and the self-standing capability after pumping can be secured. Furthermore, excellent values are obtained for both the initial strength and the long term strength, and thereby an excellent lamination speed and an excellent construction speed can be obtained. On the other hand, in the case where diutan gum deviating from the range of the present invention or the other thickening agent is used, the wet cement mortar obtained by kneading with the batch mixer is deteriorated in thixotropy and the initial strength development capability, and cannot provide a sufficient lamination speed and a sufficient construction speed.

[0043]

<Example 2>

100 parts by mass of the cement was blended with 150 parts by mass of the aggregate, the dispersant of the kind and the amount shown in Table 1, 0.1 part by mass of the diutan gum A, 0.25 part by mass of the setting retarder A, and 20 parts by mass of a mixture containing 100 parts by mass of the calcium aluminosilicate B blended with 150 parts by mass of the gypsum, and also blended with 0.2 part by mass of the short fibers a per 100 parts by mass in total of the cement and the aggregate, so as to prepare a dry cementitious material. The supply amounts of the dry cementitious material supplying part and the water supplying part of the continuous kneading device were regulated to make 100 parts by mass of the material thus prepared and 17 parts by mass of water, which were then kneaded. The resulting wet cement mortar was measured for the mortar flow (MF, in standing and 15-stroke), the hardening time, and the compressive strength, and also calculated for the thixotropy. The results are shown in Table 2.

[0044]

Table 2

Experiment No.	R/M (mass ratio)	R+M total (part by mass)	MF (mm)		Thixotropy (%)	Hardening time (min)	Compressive strength (N/mm ²)				Note
			Standing	15-Stroke			3 hours	12 hours	1 day	7 days	
2-1	-	0	-	-	-	-	-	-	-	-	Comparative Example
2-2	100/80	0.2	100	185	85.0	40	8.4	12.6	26.3	68.4	Example
2-3		0.5	101	187	85.1	44	8.5	12.7	26.9	68.5	Example
2-4		1.0	102	189	85.3	53	8.9	13.0	28.0	69.0	Example
2-5		2	104	190	82.7	58	8.5	12.8	27.9	68.9	Example
2-6		3	105	189	80.0	67	8.4	12.8	27.6	68.9	Example
2-7	100/100	0.2	100	190	90.0	44	8.4	12.6	27.6	67.5	Example
2-8		0.5	101	191	89.1	50	8.5	12.7	26.8	68.0	Example
2-9		1.0	103	192	86.4	56	8.9	13.0	27.9	69.8	Example
2-10		2	104	195	87.5	60	8.5	12.8	27.4	69.6	Example
2-11		3	106	199	87.7	69	8.4	12.8	27.3	69.5	Example
2-12	100/200	0.2	101	192	90.1	45	8.4	12.5	26.2	69.8	Example
2-13		0.5	101	193	91.1	52	8.5	12.7	26.9	69.9	Example
1-9		1.0	102	195	91.2	59	8.9	13.0	28.3	70.2	Example
2-14		2	103	195	89.3	63	8.5	12.9	28.0	69.8	Example
2-15		3	103	195	89.3	70	8.4	12.8	28.0	69.7	Example
2-16	100/400	0.2	104	194	86.5	48	8.3	12.6	27.6	69.4	Example
2-17		0.5	104	194	86.5	55	8.5	12.7	26.6	69.5	Example
2-18		1.0	104	195	87.5	60	8.9	13.0	28.0	69.9	Example
2-19		2	105	195	85.7	68	8.5	12.8	27.7	69.0	Example
2-20		3	107	193	80.4	75	8.4	12.8	27.4	68.7	Example
2-21	0/100	1.0	119	192	61.3	32	6.3	10.0	23.6	59.4	Comparative Example
2-22	100/0	1.0	100	135	35.0	86	3.2	8.5	23.9	60.0	Comparative Example

-: unmeasurable or unable to collect test piece

R: lignin sulfonic acid-based dispersant

M: melamine sulfonic acid-based dispersant

R+M total: part by mass per 100 parts by mass of cement

[0045]

As shown in Table 2, the wet cement mortar obtained by using the combination of the lignin sulfonic acid-based dispersant (R) and the melamine sulfonic acid-based dispersant (M) within the range of the present invention shows excellent thixotropy, the pumpability thereof is not impaired, and the self-standing capability after pumping can be secured.

[0046]

<Example 3>

100 parts by mass of the cement was blended with 150 parts by mass of the aggregate, 1.0 part by mass of the dispersant containing the lignin sulfonic acid-based dispersant (R) and the melamine sulfonic acid-based dispersant (M) at a mass ratio $R/M = 100/200$, 0.1 part by mass of the diutan gum A, 0.25 part by mass of the setting retarder A, and 20 parts by mass of a mixture containing the calcium aluminosilicate B and the gypsum at the ratio shown in Table 3, and also blended with 0.2 part by mass of the short fibers a per 100 parts by mass in total of the cement and the aggregate, so as to prepare a dry cementitious material. The supply amounts of the dry cementitious material supplying part and the water supplying part of the continuous kneading device were regulated to make 100 parts by mass of the material thus prepared and 17 parts by mass of water, which were then kneaded. The resulting wet cement mortar was measured for the mortar flow (MF, in standing and 15-stroke), the hardening time, and the compressive strength, and also calculated for the thixotropy. The results are shown in Table 3.

[10047]

Table 3

Experiment No.	CAS/CS (mass ratio)	MF (mm)		Thixotropy (%)	Hardening time (min)	Compressive strength (N/mm ²)				Note
		Standing	15-Stroke			3 hours	12 hours	1 day	7 days	
3-1	100/50	102	194	90.2	44	7.5	11.1	26.6	66.8	Example
3-2	100/100	102	194	90.2	50	8.0	12.0	27.4	67.9	Example
1-9	100/150	102	195	91.2	59	8.9	13.0	28.3	70.2	Example
3-3	100/200	103	196	90.3	60	8.8	12.6	27.6	68.8	Example
3-4	100/250	103	196	90.3	62	8.7	12.6	27.5	68.4	Example

CAS: calcium aluminosilicate B

CS: gypsum

[0048]

It is understood that the wet cement mortar obtained by using 50 to 250 parts by mass of gypsum per 100 parts by mass of calcium aluminosilicate provides a thixotropy and a hardening time that are suitable for securing the self-standing capability, and a high compressive strength.

[0049]

<Example 4>

100 parts by mass of the cement was blended with 150 parts by mass of the aggregate, 1.0 part by mass of the dispersant containing the lignin sulfonic acid-based dispersant (R) and the melamine sulfonic acid-based dispersant (M) at a mass ratio $R/M = 100/200$, 0.1 part by mass of the diutan gum A, 0.25 part by mass of the setting retarder A, and a mixture containing 100 parts by mass of the calcium aluminosilicate B and 150 parts by mass of the gypsum of the amount shown in Table 4, and also blended with 0.2 part by mass of the short fibers a per 100 parts by mass in total of the cement and the aggregate, so as to prepare a cementitious material for three-dimensional molding. The supply amounts of the dry cementitious material supplying part and the water supplying part of the continuous kneading device were regulated to make 100 parts by mass of the material thus prepared and 17 parts by mass of water, which were then kneaded. The resulting wet cement mortar was measured for the mortar flow (MF, in standing and 15-stroke), the hardening time, and the compressive strength, and also calculated for the thixotropy. The results are shown in Table 4.

[0050]

Table 4

Experiment No.	CAS+CS total (part by mass)	MF (mm)		Thixotropy (%)	Hardening time (min)	Compressive strength (N/mm ²)				Note
		Standing	15-Stroke			3 hours	12 hours	1 day	7 days	
4-1	5	104	196	88.5	88	4.9	10.2	27.0	68.8	Example
4-2	10	104	196	88.5	75	6.0	10.9	27.1	69.2	Example
4-3	15	103	195	89.3	62	7.2	11.8	27.9	69.5	Example
1-9	20	102	195	91.2	59	8.9	13.0	28.3	70.2	Example
4-4	25	102	193	89.2	47	9.1	13.4	29.1	69.9	Example
4-5	30	101	191	89.1	31	9.9	14.1	29.4	69.8	Example

CAS: calcium aluminosilicate B

CS: gypsum

CAS+CS total: part by mass per 100 parts by mass of cement

[0051]

It is understood that the wet cement mortar obtained by using 5 to 30 parts by mass in total of calcium aluminosilicate and gypsum per 100 parts by mass of cement provides a thixotropy and a hardening time that are suitable for securing the self-standing capability.

[0052]

<Example 5>

100 parts by mass of the cement was blended with an aggregate and a balloon aggregate of the amounts shown in Table 5, 1.0 part by mass of the dispersant containing the lignin sulfonic acid-based dispersant (R) and the melamine sulfonic acid-based dispersant (M) at a mass ratio $R/M = 100/200$, 0.1 part by mass of the diutan gum A, 0.25 part by mass of the setting retarder A, and 20 parts by mass of a mixture containing 100 parts by mass of the calcium aluminosilicate B and 150 parts by mass of the gypsum, and also blended with 0.2 part by mass of the short fibers a per 100 parts by mass in total of the cement and the aggregate, so as to prepare a cementitious material for three-dimensional molding. The supply amounts of the dry cementitious material supplying part and the water supplying part of the continuous kneading device were regulated to make 100 parts by mass of the material thus prepared and 17 parts by mass of water, which were then kneaded. The resulting wet cement mortar was measured for the mortar flow (MF, in standing and 15-stroke), the hardening time, and the compressive strength, and also calculated for the thixotropy. The results are shown in Table 5.

[0053]

(Materials)

<Aggregate (B)>

Aggregate: limestone aggregate (available from Denka Co., Ltd., maximum particle diameter: 1.2 mm, specific gravity: 2.71)

Balloon aggregate: "Cenolite SA", trade name, available from Tomoe Engineering Co., Ltd. (particle size regulated product of fly ash balloons formed in thermal power plants, made in China, specific gravity: 0.88, maximum particle diameter: 120 μm or less)

[10054]

Table 5

Experiment No.	Aggregate (part by mass)	Balloon aggregate (part by mass)	MF (mm)		Thixotropy (%)	Hardening time (min)	Compressive strength (N/mm ²)				Note
			Standing	15-Stroke			3 hours	12 hours	1 day	7 days	
5-1	50	0	105	198	88.6	26	8.6	12.9	28.1	70.1	Example
5-2	100	0	104	197	89.4	27	8.8	13.0	28.2	70.2	Example
1-9	150	0	102	195	91.2	59	8.9	13.0	28.3	70.2	Example
5-3	200	0	102	195	91.2	58	8.3	12.4	28.0	69.5	Example
5-4	300	0	102	194	90.2	59	8.0	12.1	27.3	67.9	Example
5-5	149	1	101	194	92.1	59	8.8	12.9	28.1	70.1	Example
5-6	147	3	101	194	92.1	59	8.8	12.9	28.0	69.9	Example
5-7	140	10	100	194	94.0	58	8.6	12.2	27.4	68.8	Example
5-8	135	15	100	194	94.0	60	8.3	11.9	26.9	67.9	Example

Aggregate and Balloon aggregate: part by mass per 100 parts by mass of cement

[0055]

It is understood that the wet cement mortar obtained by using 50 to 300 parts by mass of an aggregate per 100 parts by mass of cement provides a thixotropy and a hardening time that are suitable for securing the self-standing capability. The wet cement mortar obtained by using a balloon aggregate has an increased thixotropy and is enhanced in self-standing capability.

[0056]

<Example 6>

100 parts by mass of the cement was blended with 150 parts by mass of the aggregate, 1.0 part by mass of the dispersant containing the lignin sulfonic acid-based dispersant (R) and the melamine sulfonic acid-based dispersant (M) at a mass ratio $R/M = 100/200$, 0.1 part by mass of the diutan gum A, the setting retarder of the kind and the amount shown in Table 6, and 20 parts by mass of a mixture containing 100 parts by mass of the calcium aluminosilicate B and 150 parts by mass of the gypsum, and also blended with 0.2 part by mass of the short fibers a per 100 parts by mass in total of the cement and the aggregate, so as to prepare a cementitious material for three-dimensional molding. The supply amounts of the dry cementitious material supplying part and the water supplying part of the continuous kneading device were regulated to make 100 parts by mass of the material thus prepared and 17 parts by mass of water, which were then kneaded. The resulting wet cement mortar was measured for the mortar flow (MF, in standing and 15-stroke), the hardening time, and the compressive strength, and also calculated for the thixotropy. The results are shown in Table 6.

[0057]

(Materials)

<Setting Retarder (E)>

Setting retarder A: citric acid (first grade reagent)

Setting retarder B: gluconic acid (first grade reagent)

Setting retarder C: trisodium citrate (first grade reagent)

[10058]

Table 6

Experiment No.	Setting retarder (part by mass)		MF (mm)		Thixotropy (%)	Hardening time (min)	Compressive strength (N/mm ²)				Note
			Standing	15-Stroke			3 hours	12 hours	1 day	7 days	
6-1	A	0.05	101	194	92.1	43	9.1	13.8	28.9	70.1	Example
1-9		0.25	102	195	91.2	59	8.9	13.0	28.3	70.2	Example
6-2		0.50	103	196	90.3	68	7.9	10.8	27.9	69.9	Example
6-3		0.70	103	196	90.3	80	7.1	10.7	27.8	69.9	Example
6-4	B	0.05	103	194	88.3	39	9.1	13.6	28.8	70.1	Example
6-5		0.07	103	194	88.3	43	8.8	12.9	28.1	70.2	Example
6-6		0.10	103	194	88.3	55	8.6	12.7	27.9	70.1	Example
6-7		0.25	104	195	87.5	61	8.6	10.9	27.7	70.0	Example
6-8	C	0.50	104	195	87.5	77	7.8	10.7	27.6	69.9	Example
6-9		0.70	104	195	87.5	88	6.9	10.5	27.5	69.9	Example
6-10		0.05	102	194	90.2	40	8.9	13.7	28.6	70.1	Example
6-11		0.07	103	195	89.3	47	8.6	12.9	27.9	70.2	Example
6-12		0.10	103	195	89.3	51	8.3	12.7	27.8	70.1	Example
6-13		0.25	104	195	87.5	57	8.0	11.0	27.6	70.0	Example
6-14		0.50	104	196	88.5	64	7.7	10.7	27.5	69.9	Example
6-15		0.70	104	196	88.5	77	7.0	10.6	27.4	69.9	Example

Setting retarder: part by mass per 100 parts by mass of cement

[0059]

It is understood that the wet cement mortar obtained by using 0.05 to 0.7 part by mass of a setting retarder containing an oxycarboxylic acid compound per 100 parts by mass of the cement provides a thixotropy and a hardening time for securing the self-standing capability, without impairing the short term compressive strength.

[0060]

<Example 7>

100 parts by mass of the cement was blended with 150 parts by mass of the aggregate, 1.0 part by mass of the dispersant containing the lignin sulfonic acid-based dispersant (R) and the melamine sulfonic acid-based dispersant (M) at a mass ratio $R/M = 100/200$, 0.1 part by mass of the diutan gum A, 0.25 part by mass of the setting retarder A, and 20 parts by mass of a mixture containing 100 parts by mass of the calcium aluminosilicate B and 150 parts by mass of the gypsum, and also blended with the short fibers of the kind and the amount shown in Table 7 per 100 parts by mass in total of the cement and the aggregate, so as to prepare a cementitious material for three-dimensional molding. The supply amounts of the dry cementitious material supplying part and the water supplying part of the continuous kneading device were regulated to make 100 parts by mass of the material thus prepared and 17 parts by mass of water, which were then kneaded. The resulting wet cement mortar was measured for the mortar flow (MF, in standing and 15-stroke), the hardening time, and the compressive strength, and also calculated for the thixotropy. The results are shown in Table 7.

[0061]

(Materials)

<Short Fibers (H)>

Short fibers a: vinylon fibers (average fiber length: 12 mm, average fiber diameter: 50 μm , number of fibers per 1 g: 55,500)

Short fibers b: nylon fibers ("Tough Binder", trade name, available from Toray Amtecs, Inc. (average fiber length: 10 mm, average fiber diameter: 28 μm , number of fibers per 1 g: 185,200)

Short fibers c: nylon fibers ("Tough Binder", trade name, available from Toray Amtecs, Inc. (average fiber length: 5 mm, average fiber diameter: 28 μm , number of fibers per 1 g: 370,500)

Short fibers d: vinylon fibers ("RECS100L", trade name, available from Kuraray Co., Ltd. (average fiber length: 12 mm, average fiber diameter: 130 μm , number of fibers per 1 g: 8,300)

[0062]

(Test Method)

Initial Crack Width:

A formwork was provided on a concrete flat plate (30 cm in length $\times$ 30 cm in width $\times$ 6 cm in thickness), and the wet material of the present invention was cast to a thickness of 2 cm, the surface of which was finished with a trowel, so as to provide a test material. The test material was aged under an environment of a humidity of 60% and a temperature of 5°C, and the crack width after 72 hours was measured. The crack width herein means the width at the position around the center of one crack that was arbitrarily selected from cracks occurring in the test material. The case where no crack occurred even after 72 hours was denoted as 0.0 mm.

[0063]

Table 7

Experiment No.	Short fibers (part by mass)	MF (mm)		Thixotropy (%)	Initial crack width (mm)	Compressive strength (N/mm ²)				Note
		Standing	15-Stroke			3 hours	12 hours	1 day	7 days	
7-1	0	108	197	82.4	0.25	8.7	12.8	28.2	69.9	Comparative Example
7-2	a	103	195	89.3	0.1	8.8	12.9	28.2	70.0	Example
1-9		102	195	91.2	0	8.9	13.0	28.3	70.2	Example
7-3		101	194	92.1	0	8.8	12.8	28.1	70.0	Example
7-4		100	194	94.0	0	8.8	12.8	27.9	69.9	Example
7-5	b	100	194	94.0	0	8.7	12.7	27.9	69.7	Example
7-6		104	195	87.5	0.1	8.6	12.9	28.0	69.9	Example
7-7		103	195	89.3	0	8.7	12.9	27.8	69.9	Example
7-8		101	194	92.1	0	8.8	12.8	27.7	70.0	Example
7-9	c	100	193	93.0	0	8.7	12.7	27.6	69.8	Example
7-10		100	193	93.0	0	8.7	12.6	27.5	69.5	Example
7-11		103	195	89.3	0.1	8.6	12.9	28.2	69.5	Example
7-12		103	195	89.3	0	8.5	12.8	28.2	69.6	Example
7-13	d	102	194	90.2	0	8.7	12.7	28.1	69.8	Example
7-14		101	193	91.1	0	8.7	12.7	27.8	69.6	Example
7-15		100	192	92.0	0	8.7	12.7	27.6	69.5	Example
7-16		103	194	88.3	0.1	8.5	12.8	28.1	69.8	Example
7-17		102	194	90.2	0	8.6	12.7	28.1	69.8	Example
7-18		102	193	89.2	0	8.7	12.6	28.1	70.0	Example
7-19		100	190	90.0	0	8.7	12.6	27.7	69.6	Example
7-20		100	190	90.0	0	8.5	12.6	27.5	69.5	Example

Short fibers: part by mass per 100 parts by mass in total of cement and aggregate

[0064]

It is understood that the wet cement mortar obtained by using 0.1 to 1.0 part by mass of short fibers having an average fiber length of 5 to 15 mm per 100 parts by mass in total of the cement and the aggregate provides a thixotropy and a hardening time for securing the self-standing capability, and prevents initial cracks from occurring.

[0065]

<Example 8>

A three-dimensional molding test was performed by using the three-dimensional molding system shown in Fig. 2, using the formulation of Experiments Nos. 1-9, 1-50, 7-17, and 7-18. The environment temperature was 24°C. At this time, the temperature of the wet cement mortar immediately after kneading with the mixer, the temperature of the wet cement mortar pumped with the rotary volumetric eccentric single screw pump 90 and discharged from the discharge port 111 at the nozzle tip, the hardening time, and the continuous lamination height were measured. The results are shown in Table 8.

[0066]

(Three-dimensional Molding System)

Mixer 80: continuous kneading mixer of the present invention

Pumping pump 90: rotary volumetric eccentric single screw pump ("PFT Bolero", trade name, available from Knauf PFT GmbH & Co. KG)

Pumping pipe 100: flexible hose having withstanding pressure of 4 MPa (available from Knauf PFT GmbH & Co. KG, inner diameter: 1 inch, length of pumping pipe: 10 m)

Nozzle 110: internal product (see Fig. 3 (Fig. 3(a) is a schematic illustration showing the spraying nozzle viewed from the side, and Fig. 3(b) is a schematic illustration showing the spraying nozzle viewed from the discharge port.)), diameter of discharge port of nozzle: 18 mm (circular shape) (see numeral 111 in Fig. 3(b) (The shadow area shows the end surface of the discharge port of the spray nozzle.))

Robot arm 130: robot arm available from Yasukawa Electric Corporation ("MOTOMAN-MA2010, trade name), modified by fixing the nozzle to the tip of the arm

[0067]

(Molding Condition)

Height of cementitious material per one layer: 10 mm

Shape of three-dimensional molded article: truss shape (length: 500 mm, width: 1,000 mm, lamination width (thickness): ca. 30 mm) (see Fig. 4)

Discharge amount of wet material: 0.25 m³/hr

Moving speed of nozzle: 180 mm/sec

[0068]

(Test Method)

The temperature of the material was measured with a digital thermometer.

The hardening time was measured in the same manner as in Example 1 for the sampled material discharged from the discharge port at the nozzle tip.

For the continuous lamination height, the height of the molded article that was laminated until collapsing was measured.

[0069]

Table 8

Experiment No.	Formulation	Temperature (°C)		Hardening time (min)	Continuous lamination height (mm)	Note
		Immediately after discharging	Nozzle tip			
8-1	No. 1-9	25.5	31.0	28	2240	Example
8-2	No. 1-50	25.4	30.3	31	1080	Comparative Example
8-3	No. 7-17	25.9	35.2	26	2600	Example
8-4	No. 7-18	26.2	40.4	12	3000 ≤	Example

[0070]

The wet cement mortar obtained by using the dry cementitious material having a composition within the range of the present invention with the continuous kneading system of the present invention is excellent in thixotropy, and thus is enhanced in continuous lamination height. On the other hand, the wet cement mortar obtained by using batch kneading, which is outside the range of the present invention, has a low thixotropy, and cannot be continuously laminated due to the failure to withstand to the own weight thereof.

Industrial Applicability

[0071]

The use of the wet cement mortar for three-dimensional molding for construction and the three-dimensional molding method for construction of the present invention enables the supply of the material at a constant rate and secures a constant lamination rate. Furthermore, the excellent self-standing capability and the excellent strength development capability (particularly, the initial strength development capability) obtained thereby enable the build of a large molded article in a short period of time. Moreover, the present invention is hard to generate dusts during molding. Therefore, the present invention can be favorably applied to the production of civil engineering and construction components, and the like.

Reference Sign List

[0072]

- 1 Continuous kneading system
- 2 Three-dimensional molding system
- 10 Storage hopper
- 20 Flow meter
- 30 Tube
- 40 Ejection port
- 50 Agitation unit
- 60 Agitation blade
- 70 Screw shaft
- 80 Continuous kneading mixer
- 90 Rotary volumetric eccentric single screw pump
- 100 Pumping pipe (flexible hose)
- 110 Nozzle
- 111 Discharge port
- 120 Bed
- 130 Robot arm
- 140 Three-dimensional molded article
- 150 Pulley

CLAIMS

[Claim 1]

Wet cement mortar for three-dimensional molding for construction, obtained by continuously kneading a dry cementitious material for three-dimensional molding for construction containing cement (A), an aggregate (B), a dispersant (C) containing a lignin sulfonic acid-based dispersant (R) and a melamine sulfonic acid-based dispersant (M) at a mass ratio $R/M = 100/80$ to 400, diutan gum (D) having an average molecular weight in a range of 2,000,000 to 8,000,000 and a viscosity of a 0.25% by mass aqueous solution thereof in a range of 2,000 to 10,000 mPa·s, a setting retarder (E), amorphous calcium aluminosilicate (F) containing SiO_2 in an amount of 10 to 25% by mass in terms of oxide, gypsum (G), and short fibers (H), with a continuous kneading system including a device (a) continuously supplying the dry cementitious material, a device (b) continuously supplying water, and a cylindrical agitation device (c) having a horizontal screw shaft therein capable of continuously mixing the dry cementitious material and water to produce wet mortar.

[Claim 2]

The wet cement mortar for three-dimensional molding for construction according to claim 1, wherein the wet cement mortar contains 13 to 20 parts by mass of water per 100 parts by mass of the dry cementitious material for three-dimensional molding for construction.

[Claim 3]

The wet cement mortar for three-dimensional molding for construction according to claim 1 or 2, wherein the wet cement mortar contains 0.2 to 3 parts by mass of the dispersant (C) per 100 parts by mass of the cement (A).

[Claim 4]

The wet cement mortar for three-dimensional molding for construction according to any one of claims 1 to 3, wherein the wet cement mortar contains 0.03 to 1.0 part by mass of the diutan gum (D) per 100 parts by mass of the cement (A).

[Claim 5]

The wet cement mortar for three-dimensional molding for construction according to any one of claims 1 to 4, wherein the wet cement mortar contains 50 to 250 parts by mass of the gypsum (G) per 100 parts by mass of the amorphous calcium aluminosilicate (F).

[Claim 6]

The wet cement mortar for three-dimensional molding for construction according to any one of claims 1 to 5, wherein the wet cement mortar contains 5 to 30 parts by mass in total of the amorphous calcium aluminosilicate (F) and the gypsum (G) per 100 parts by mass of the

cement (A).

[Claim 7]

The wet cement mortar for three-dimensional molding for construction according to any one of claims 1 to 6, wherein the aggregate (B) contains a balloon aggregate.

[Claim 8]

The wet cement mortar for three-dimensional molding for construction according to any one of claims 1 to 7, wherein the setting retarder (E) contains an oxycarboxylic acid compound.

[Claim 9]

The wet cement mortar for three-dimensional molding for construction according to any one of claims 1 to 8, wherein the short fibers (H) have an average fiber length of 5 to 15 mm.

[Claim 10]

The wet cement mortar for three-dimensional molding for construction according to claim 9, wherein the short fibers (H) have an average fiber diameter of 20 to 250 μm and a number of fibers per 1 g of 5,000 or more.

[Claim 11]

A three-dimensional molding method for construction comprising pumping the wet cement mortar for three-dimensional molding for construction according to any one of claims 1 to 10 with a pump, and laminating the wet mortar for three-dimensional molding for construction discharged from a nozzle, while moving the nozzle, so as to build a molded article.

[Claim 12]

The three-dimensional molding method for construction according to claim 11, wherein the pump is a rotary volumetric eccentric single screw pump.