

SPECIFICATION

Title of the Invention Manufacturing Method of Portland Cement Clinker

Field of the Invention

[0001]

The present invention relates to a manufacturing method of cement clinker. More specifically, the present invention relates to a manufacturing method of cement clinker: baking at a lower temperature than conventional cement clinker; effectively utilizing waste concrete materials as raw material for the cement clinker; and exhibiting excellent initial strength development.

Background Art

[0002]

The cement industry is a mass production and mass consumption industry; due to emission of CO₂ and other environmental issues, resource conservation and energy efficiency are the most critical topic. For example, Portland cement, the most widely produced cement, is produced by baking raw materials adjusted to a specific chemical composition, at a high temperature of 1,450 degree Celsius to 1,550 degree Celsius, to produce the clinker. As a result, the baking process is the most energy-intensive process during the production. In other words, reducing the baking temperature of the clinker leads to energy saving. To reduce the baking temperature of the clinker, a technology which increases the C₄AF (4CaO-Al₂O₃-Fe₂O₃) content, one of the major minerals in the clinker, has been developed (Patent Document 1: JP2012-224504A). When the C₄AF content is increased, the liquid phase is increased during the baking process, and the generation of clinker mineral, for example, the transition from C₂S (2CaO-SiO₂) to C₃S (3CaO-SiO₂), is promoted by the presence of the liquid phase. This reduces the baking temperature of the clinker.

[0003]

Furthermore, for resource circulation, the effective utilization of wastes and by-products is an important issue. With utilizing the characteristics of the cement industry and cement manufacturing facilities, utilizing or processing wastes as raw materials for the clinker or as a heat energy source during cement manufacturing is effective for the

safe and large-scale disposal of wastes and by-products. Many species of wastes and by-products contain a large quantity of Al_2O_3 , and the above clinker which contains a large quantity of C_4AF has a higher content of Al_2O_3 than conventional Portland cement clinkers. Therefore, the low temperature baking clinker consumes a large amount of wastes and by-products. In this regard, the clinker according to Patent Document 1 is superior.

[0004]

The clinker containing a large amounts of C_3A ($3\text{CaO}-\text{Al}_2\text{O}_3$) and C_4AF as clinker minerals consumes a large amount of wastes and is suitable for effective utilization of wastes.

[0005]

On the other hand, utilizing wastes and by-products introduces their constituents into the cement clinker. In addition to CaO , SiO_2 , Al_2O_3 , and Fe_2O_3 , which are the major constituents of cement clinker, other minor constituents affect to the baking property, actual mineral composition of the clinker, and to cement properties. For example, it has been reported that the clinker according to Patent Document 1 becomes to have a low initial strength development property till day 7 when its MgO content increases (Non-Patent Document 1).

Prior Art Documents

Patent Documents

[0006]

Patent Document 1: JP 2012-224504A

Non-Patent Document

[0007]

Non-Patent Document 1: Masami Ota et al., Proceedings of the 74th Cement Technology Conference, Japan, p.p. 114-115 (2020)

Summary of the Invention

Problem to be Solved by the Invention

[0008]

The clinker of Patent Document 1 is baked at the relatively low temperature and

consumes a large amount of wastes containing Al_2O_3 and Fe_2O_3 . However, since Non-Patent Document 1 reveals the increase in its MgO content results in low initial strength development property, the use of raw materials containing MgO may be restricted. Therefore, the object of the present invention is to provide a manufacturing method of clinker that contains MgO but exhibits good initial cement strength development property.

Means for Solving the Problem

[0009]

The present inventors diligently have considered for solving the problem and have found that when waste concrete materials are used as part of the raw materials of the above clinker, and when the MgO content is adjusted between 1.1 - 1.5 mass%, a better initial strength development property in comparison with a clinker having a conventional MgO content is obtained. Thus, the inventors have completed the invention. According to the manufacturing method of cement clinker of the present invention, waste concrete material is used as part of the raw materials, the raw materials are prepared such that the total content of C_3A and C_4AF is 22 mass% or more, the content of C_3S is 60 mass% or more, both according to Bogue's formulae, iron modulus is 1.3 or under, and the MgO content is 1.1 - 1.5 mass%. The raw materials are baked at a temperature not lower than 1300 degree Celsius and not higher than 1400 degree Celsius. In this specification, when a range is indicated using " - " or the like, such as "1.1-1.5 mass%," it includes both the upper and lower limits.

Advantageous Effects of the Invention

[0010]

According to the present invention, a clinker: baked at a lower temperature than conventional cement clinker; effectively utilizing waste concrete materials; and having good initial strength development property (at day 7 day or after) compared to those having conventional MgO contents is provided. Furthermore, according to the present invention, waste concrete material is used as a cement clinker raw material and reduces the consumption of limestone for the CaO source. Therefore, the generation of CO_2 from limestone during baking cement clinker is reduced.

Features for Carrying out the Invention

[0011]

In this specification, waste concrete materials include, for example, ready-mixed concrete sludge, returned concrete, excess concrete, waste concrete, and so on. Waste concrete materials may include waste mortar. Waste concrete materials contain aggregates such as sand and gravel when generated, but it is preferable to remove the aggregates with crushing and sieving. This is because the aggregates contain Na_2O and K_2O of 3 mass% or more and 6 mass% or under in total, for example, and because the constituents in the waste concrete materials derived from old cement clinker replaces limestone as a new cement clinker raw material and reduces the CO_2 generation. Crushed waste concrete materials may be used without sieving.

[0012]

The MgO concentration in ready-mixed concrete sludge is, for example, 2 mass% or more and 4 mass% or under, and that in aggregates is, for example, 1 mass% or more and 3 mass% or under. The MgO concentration of waste concrete materials takes an intermediate value between them. The MgO concentration of usual Portland cement clinker is, for example, 0.9 mass% or the like. The high MgO concentration in waste concrete materials is due to the constituents derived from blast furnace cement containing a large amount of MgO and aggregates which contain MgO. According to the inventors' experiences, when waste concrete is crushed and then sieved, the under-sieve fraction with opening of 1.2 mm had a higher MgO concentration than the under-sieve fraction with opening of 5 mm.

[0013]

Regarding the Portland cement clinker (hereinafter referred to as "cement clinker") produced according to the present invention, the quantities of C_3A , C_4AF , and C_3S are determined by Bogue's formulae.

[0014]

The Bogue's formulae have been used, along with various indexes and moduli, based upon major chemical analysis values, to calculate approximately the major mineral composition and have been well known in the art. For reference, calculation of the mineral contents in cement clinkers by Bogue's formulae is described below.

$$\text{C}_3\text{S content} = (4.07 \times \text{CaO}) - (7.60 \times \text{SiO}_2) - (6.72 \times \text{Al}_2\text{O}_3) - (1.43 \times \text{Fe}_2\text{O}_3)$$

$$\text{C}_2\text{S content} = (2.87 \times \text{SiO}_2) - (0.754 \times \text{C}_3\text{S})$$

$$C_3A \text{ content} = (2.65 \times Al_2O_3) - (1.69 \times Fe_2O_3)$$

$$C_4AF \text{ content} = 3.04 \times Fe_2O_3.$$

[0015]

Iron modulus (I.M.), hydraulic modulus (H.M.), siliceous modulus (S.M.), activity index (A.I.), and lime saturation degree (L.S.D.) have been well known coefficients in the art. They are determined based upon major chemical constituents and have been used for the cement production control along with other coefficients. For the sake of clarity, the calculation methods for iron modulus and other coefficients are described below.

$$\text{Hydraulic modulus (H.M.)} = CaO / (SiO_2 + Al_2O_3 + Fe_2O_3)$$

$$\text{Siliceous modulus (S.M.)} = SiO_2 / (Al_2O_3 + Fe_2O_3)$$

$$\text{Iron modulus (I.M.)} = Al_2O_3 / Fe_2O_3$$

$$\text{Activity index (A.I.)} = SiO_2 / Al_2O_3$$

$$\text{Lime saturation degree (L.S.D.)} = CaO / (2.8 \times SiO_2 + 1.2 \times Al_2O_3 + 0.65 \times Fe_2O_3).$$

[0016]

The above CaO, SiO₂, Al₂O₃, and Fe₂O₃ are measurable according to JIS R 5202 "Chemical Analysis of Portland cement," JIS R 5204 "X-ray fluorescence analysis of cement," and so on.

[0017]

As described above, according the present invention, the total content of C₃A and C₄AF is 22 mass% or more. When the total content is under 22 mass%, the production of cement clinker having good strength development property at the relatively low baking temperature becomes difficult. The total content is preferably 24 mass% or more. As will be described, for the high strength development property, the content of C₃S is at least 60 mass%. Therefore, the total content of C₃A and C₄AF is at most 40 mass%. The total content is preferably 35 mass% or under, more preferably, 32 mass% or under, and most preferably, 28 mass% or under. Since C₄AF contributes the baking at the relatively low temperature and reduces the free CaO content in the cement clinker, C₄AF is preferably present 15 mass% or more.

[0018]

The C₃S content is very important regarding the strength development property

of the cement compositions (hereinafter, referred to as "cement") using the cement clinker according to the invention. If it is under 60 mass%, good strength development property is not obtainable, even if the total content of C_3A and C_4AF and the iron modulus described later are within the prescribed ranges. The C_3S content is preferably 62 mass% or more and more preferably 63 mass% or more. Since the total content of C_3A and C_4AF is at least 22 %, the upper limit of C_3S content is 78 %. For obtaining a suitable period from the start of hardening to the end of hardening, the C_3S content is preferably 70 mass% or under and more preferably 65 mass% or under.

[0019]

According to the present invention, the cement clinker may further contains C_2S . The content is preferably 18 mass% or under and 3mass% or more. For obtaining long term strength, it is particularly preferable that the total content of C_2S and C_3S is 69 mass% or more.

[0020]

According to the present invention, the iron modulus (I.M.) of the cement clinker is 1.3 or less. When the iron modulus exceeds 1.3, sufficient strength development (more specifically, for example, mortar strength development) is not obtainable even when other requirements for the cement clinker are met. Furthermore, when the iron modulus exceeds 1.3, the period from the start of hardening to the end of hardening becomes too long, and therefore, the iron modulus is 1.3 or less. The preferable range of iron modulus is 1.0 to 1.3, and more preferably 1.14 to 1.27.

[0021]

The hydraulic modulus and the siliceous modulus are not particularly limited, however, the hydraulic modulus is preferably 1.8 - 2.2, and more preferably 1.9 - 2.1 for achieving a good balance of various properties. The siliceous modulus is preferably 1.0 - 2.0 and more preferably 1.1 - 1.7 according to the similar reasons.

[0022]

The most important feature according to the present invention is the use of waste concrete materials as part of raw materials and that the MgO content is 1.1 to 1.5 mass%. Examples of waste concrete materials include ready-mixed concrete sludge, returned concrete, excess concrete, waste concrete, and waste mortar. They may be used alone

or in combination. The ready-mixed concrete sludge is obtained with washing concrete mixer trucks, recovering ready-mixed concrete, separating it into aggregates and sludge comprising cement, and separating solid components from the sludge. Returned concrete refers to ready-mixed concrete returned without being used in a construction site. Excess concrete includes returned concrete and refers to those not used due to various reasons such as failing inspections, excessive production, and so on. Waste concrete refers to discarded concrete material resultant from demolition of buildings and so on.

[0023]

Waste concrete materials have higher MgO contents than conventional cement raw materials (CaO source such as limestone, SiO₂ source such as silica stone, Al₂O₃ source such as clay, and Fe₂O₃ source such as iron source). Presumably, this is because waste concrete materials include components derived from blast furnace cement and because the aggregates of concrete have a high content of MgO. The MgO content in cement clinker is measurable according to JIS R 5202 "Chemical Analysis of Portland cement" and JIS R 5204 "X-ray fluorescence analysis of cement."

[0024]

Furthermore, limestone (calcium carbonate), which has been a CaO raw material in cement clinker production, emits carbon dioxide during baking. In contrast, the waste concrete materials used according to the invention contain calcium oxide and they serve as CaO raw materials. Therefore, the waste concrete materials reduce the limestone, which is a carbon dioxide source, and reduces the emission of carbon dioxide during cement clinker production.

[0025]

When cement clinker with the above composition is prepared with conventional raw materials not containing waste concrete materials, the resultant cement clinker contains MgO at most 0.90 mass% or the like. When waste concrete materials are used as part of the raw materials such that the MgO content is 1.1 - 1.5 mass% in the produced clinker, superior initial strength development property is achieved than those usual MgO content, while the mechanism is not clear. Further, when the MgO content is adjusted with other materials in place of the waste concrete materials, for example, with reagent chemicals, the good initial strength development property is not achieved. With the

effective use of waste concrete materials, the MgO content in the clinker increases. The preferable MgO content is 1.2 to 1.5 mass%, and more preferably, 1.35 to 1.50 mass%.

[0026]

The cement clinker according to the present invention, with usage of waste concrete materials as part of the raw materials, has a large MgO content. This cement clinker exhibits good initial strength development property compared to cement clinker with usual MgO contents.

[0027]

Preferably, waste concrete materials are added to the raw materials such that the MgO content derived from the waste concrete material is 0.25 mass% or more and 1.0 mass% or less in the Portland cement clinker after baking.

[0028]

Preferably, the waste concrete material content in the raw materials of the cement clinker is 10 mass% or more and 30 mass% or less.

[0029]

According to the present invention, Portland cement clinker is baked at a lower temperature compared to conventional Portland cement clinkers. Namely, conventional ordinary Portland cement clinkers have been baked at a temperature of around 1,450 degree Celsius, but according to the present invention, the cement clinker is baked at a temperature of 1300 - 1,400 degree Celsius.

[0030]

The manufacturing method of Portland cement clinker according to the present invention is not particularly limited, except for the usage of waste concrete material as part of the raw materials and adjusting the raw materials to the specific mineral composition and the specific coefficients. When known cement (clinker) raw materials and waste concrete material are mixed in predetermined proportion to the specific mineral composition and the specific coefficients, and then baked in an SP kiln or NSP kiln, the Portland cement clinker according to the present invention is obtained.

[0031]

The preparation and mixing of the cement raw materials may be appropriately selected from known methods. For example, the compositions of waste materials, by-

products, and other raw materials (CaO sources such as limestone, quicklime, and slaked lime, SiO₂ sources such as silica stone, Al₂O₃ sources such as clay, Fe₂O₃ sources such as iron sources, and so on) are measured in advance, and the mixing ratio thereof is calculated such that the raw material composition is within the specific range based upon the compositions of the raw materials. The raw materials are mixed according to the mixing ratio.

[0032]

The raw materials used in the manufacture of the cement clinker according to the present invention include those used in the production of conventional cement clinkers without particular restrictions. Wastes and by-products are, of course, usable.

[0033]

In the manufacture of cement clinker according to the present invention, the use of one or more of waste, by-products, and so on is preferable for promoting the effective utilization of wastes, by-products, and so on. Specific examples of usable wastes and by-products include blast furnace slag, steel slag, non-ferrous slag, coal ash, sewage sludge, water treatment sludge, paper mill sludge, construction waste soil, foundry sand, fly ash, incineration fly ash, molten fly ash, chlorine bypass dust, wood chips, waste white clay, bota, waste tires, shells, municipal waste, and their incineration ash. (Some of them serve as cement raw materials and as thermal energy sources.)

[0034]

Coal ash contains MgO of 1 mass% to 2 mass%, for example. However, coal ash includes Al₂O₃ at a high concentration and affects the composition of the cement clinker, if added by a large amount. Further, the addition of coal ash does not reduce the CO₂ emission. Therefore, according to the invention, the MgO content in the cement clinker is adjusted with the waste concrete materials.

[0035]

In particular, the cement clinker according to the invention contains a large quantities of C₃A and C₄AF which include Al₂O₃ as constituent. As a result, compared to conventional cement clinker, the cement clinker according to the invention consumes large amounts of wastes and by-products containing a large quantity of Al₂O₃.

[0036]

To adjust the MgO content in the cement clinker, the above wastes, by-products, natural raw materials, and waste concrete materials are analyzed, and the mixing ratio of the raw materials is determined to achieve the specific MgO content. The Mg components in the raw materials are oxides, composite oxides, and, in some cases, magnesium alloys or metallic magnesium and they are not volatile at the baking temperature of clinker. Therefore, all Mg components in the raw materials are presumed to be transferred to the clinker, and the mixing ratios are calculated accordingly. If some Mg components are volatile during the pulverization and the baking processes and, therefore, is not transferred to the clinker, these amounts are taken into account in the calculations.

[0037]

The cement clinker according to the present invention is pulverized together with gypsum or pulverized separately and then mixed with gypsum to make cement, in the same manner as conventional cement clinkers. Examples of such cement include ordinary Portland cement, early strength Portland cement, and ultra-early strength Portland cement. In addition, it is usable as a component of various mixed cements or as a component of solidifying agents such as soil solidifier.

[0038]

When gypsum is added to make a cement composition, the species of gypsum is not particularly restricted. Gypsums commonly used as a raw material for cement, such as dihydrate gypsum, hemihydrate gypsum, and anhydrous gypsum, and so on are usable. The amount of gypsum is, in the case of Portland cement, preferably 1.8 - 3 mass% in conversion into the amount of SO_3 in the Portland cement. The pulverizing method for cement clinker and gypsum is selected from known pulverization methods.

[0039]

The cement composition may be pulverized with admixtures and a pulverization agent such as blast furnace slag, siliceous admixture, fly ash, calcium carbonate, and limestone, or pulverized separately and mixed with the admixture. Chlorine bypass dust or similar materials may also be mixed.

[0040]

The fineness of the cement composition is not particularly limited, but it is

preferably 2800 to 4500 cm²/g, in conversion to a Blaine specific surface area.

[0041]

Furthermore, as needed, blast furnace slag, fly ash, or the like may be mixed after pulverizing to produce blast furnace cement, fly ash cement, or the like.

Brief Description of the Drawing

[0042]

Figure 1: A characteristic diagram indicating the relationship between MgO concentrations in cement clinkers and mortar compressive strengths, in the embodiments.

Embodiments

[0043]

The following embodiments will illustrate examples and advantageous effects of the present invention, but the invention is not limited to these embodiments.

[0044]

Reference Example, Comparative Example 1, and Embodiments 1 to 3

Industrial raw materials including wastes (limestone, silica sand, coal ash, and karami (mineral slag containing iron) , and ready-mixed concrete sludge, which is one of waste concrete materials, were used to prepare the raw materials. The raw materials were baked at 1,360 degree Celsius for 100 minutes to obtain cement clinker. The ready-mixed concrete sludge was one immediately after being dried to a completely dry state, after separating aggregate from returned concrete at a ready-mix concrete plant and then dewatering it by a filter press. Table 1 shows the chemical composition of the ready-mixed concrete sludge after being heated at 1000 degree Celsius. Table 2 shows the mixing ratios of ready-mixed concrete sludge in the raw materials (in mass% unit) and the chemical composition of the clinker obtained after being baked (in mass% unit) . Table 3 shows the mineral composition (in mass% unit) according to the Bogue's formulae, the moduli, and the indexes. Since mineral compositions are calculated according to Bogue's formulae without consideration to impurities, the total is slightly less than 100 mass%.

[0045]

To 100 mass parts of cement clinker, 2.2 mass parts of dihydrate gypsum and 1.8 mass parts of hemihydrate gypsum were mixed, and they were pulverized to a Blaine specific surface area of $3200 \pm 100 \text{ cm}^2/\text{g}$ to respective cements. The mortar compressive strengths of the cements are shown in Table 4 and Fig. 1. Cement produced from the cement clinker without ready-mixed concrete sludge and without adjusting the MgO content is the reference example. The mortar compressive strength of the reference example was set to 100% and it was used as the standard to indicate the mortar strength of other cements. The measurement method will be described later.

[0046]

As shown in Table 4 and Fig. 1, when the MgO concentration in cement clinker was maintained between 1.1 mass% and 1.5 mass%, the initial mortar compressive strengths at day 3 and day 7 increased. Furthermore, there was a significant difference in initial mortar compressive strengths between MgO concentrations of 1.03 mass% and 1.16 mass%. Furthermore, addition of reagent chemical MgO did not improve the initial strength.

[0047]

- (1) Measurement of MgO and other chemical compositions of raw materials and cement clinker: JIS R 5204 "X-ray fluorescence analysis of cement."
- (2) Measurement of mortar compressive strength: JIS R 5201.

[0048]

[Table 1]

	Chemical Composition (%)							
	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	SO ₃	Na ₂ O	K ₂ O
Sludge	29.31	8.64	4.81	50.24	2.78	1.57	0.74	0.88

[0049]

Comparative Example 2

The adjustment of MgO content was performed, instead of the ready-mixed concrete sludge, one of waste concrete materials, by special grade reagent chemical (MgO), and the similar tests as those in Comparative Example 1 and Embodiments 1 to 3 were conducted. Table 2 shows the chemical compositions of the clinkers after baking, Table 3 shows the mineral compositions according to the Bogue's formulae and the moduli, and Table 4 shows the mortar compressive strengths of the cements in % unit.

[0050]

[Table 2]

	Sludge Composition Rate (%)	Chemical Composition (%)												
		MgO	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	SO ₃	Na ₂ O	K ₂ O	TiO ₂	P ₂ O ₅	MnO	SrO	Cl
Ref.	0	0.90	19.54	7.12	5.56	65.49	0.18	0.16	0.30	0.34	0.12	0.04	0.04	0
Comp.1	6.0	1.03	19.50	7.09	5.57	65.22	0.25	0.21	0.36	0.36	0.13	0.04	0.04	0
Emb.1	12.0	1.16	19.36	7.10	5.64	65.00	0.35	0.24	0.38	0.35	0.14	0.04	0.04	0
Emb.2	18.0	1.29	19.31	7.03	5.59	64.84	0.47	0.28	0.42	0.34	0.15	0.04	0.04	0
Emb.3	25.0	1.43	19.34	6.92	5.40	64.80	0.56	0.32	0.44	0.35	0.15	0.05	0.04	0
Comp.2	0	1.26	19.47	6.97	5.64	65.27	0.18	0.16	0.31	0.34	0.12	0.04	0.04	0

[0051]

[Table 3]

	Mineral Composition by Bogue's Formulae				Moduli		
	C ₃ S	C ₂ S	C ₃ A	C ₄ AF	H.M.	S.M.	I.M
Ref.	62.2	9.2	9.5	16.9	2.03	1.54	1.28
Comp.1	61.6	9.5	9.4	16.9	2.03	1.54	1.27
Emb.1	61.6	9.1	9.3	17.1	2.02	1.52	1.26
Emb.2	61.9	8.7	9.2	17.0	2.03	1.53	1.26
Emb.3	62.5	8.4	9.2	16.4	2.05	1.57	1.28
Comp.2	62.8	8.5	8.9	17.1	2.03	1.54	1.24

[0052]

[Table 4]

	Mortar Compression Strength (%)		
	Day 3	Day 7	Day 28
Ref.	100.0	100.0	100.0
Comp.1	100.4	99.5	98.1
Emb.1	110.8	103.5	99.5
Emb.2	111.2	105.1	98.2
Emb.3	110.4	103.2	99.2
Comp.2	101.0	98.2	102.3

[0053]

In the reference example, no ready-mixed concrete sludge, which is waste concrete material, was used, and the MgO content was not adjusted to obtain the cement clinker. The MgO content was 0.90 mass%, which is at the conventional level. The results of embodiments and comparative examples were evaluated based on the comparison with the reference example.

[0054]

Comparative Example 1 had a MgO content of less than 1.1 mass%, and the mortar compressive strength up to 7 days after setting was equivalent to that of the reference example.

[0055]

Embodiments 1-3 were prepared according to the invention, the MgO content was higher than that of the conventional clinker, and the initial mortar compressive strength up to 7 days after setting exceeded that of the reference example. Additionally, the MgO content did not affect the mortar compressive strength at day 28.

[0056]

Comparative Example 2 was prepared without waste concrete materials and with the addition of special grade reagent chemical MgO to make the MgO content within the range of 1.1 to 1.5 mass%. The mortar compressive strength at day 3 was comparable to the reference example, but the mortar compressive strength at day 7 was lower than that of the reference example. Therefore, it was found that when the MgO content was adjusted with the addition of special grade reagent chemical, within the range according to the invention, the advantageous effect of the present invention is not obtainable.

What is claimed is:

1. A manufacturing method of Portland cement clinker: baking raw materials having a total content of C_3A and C_4AF of 22 mass% or more, a content of C_3S of 60 mass% or more, both according to Bogue's formulae, and iron modulus of 1.3 or under, at a temperature not lower than 1300 degree Celsius and not higher than 1400 degree Celsius, being characterized in that

waste concrete material is added into the raw materials such that the Portland cement clinker after baking has a MgO content not less than 1.1 mass% and not higher than 1.5 mass.

2. The manufacturing method of Portland cement clinker according to claim 1, being characterized in that said waste concrete material is at least one member selected from a group of ready-mixed concrete sludge, returned concrete, excess concrete, waste concrete, and waste mortar.

3. The manufacturing method of Portland cement clinker according to claim 1 or 2, being characterized in that the C_4AF content in the Portland cement clinker is 15 mass% or higher.

4. The manufacturing method of Portland cement clinker according to claim 1, being characterized in that the total content of C_3S and C_2S is 69 mass% or higher.

5. The manufacturing method of Portland cement clinker according to claim 1 being characterized in that gypsum is added into Portland cement clinker after baking.

6. The manufacturing method of Portland cement clinker according to claim 5, being characterized in that admixture selected from a group consisting of at least one of blast furnace slag, siliceous admixture, fly ash, and limestone is added into Portland cement clinker after baking.

7. The manufacturing method of Portland cement clinker according to claim 1 or 2, being characterized in that the waste concrete material is added such that the MgO content derived from the waste concrete material is 0.25 mass% or higher and 1.0 mass% or lower in Portland cement clinker after baking.

8. The manufacturing method of Portland cement clinker according to claim 7, being characterized in that the waste concrete material is added such that the waste concrete material has a concentration not less than 10 mass% and not higher than 30 mass% in the raw material.