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GB/T 12960-2007

Replacing GB/T 12960-1996

Quantitative determination of constituents of cement

水泥组分的定量测定

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Foreword

This standard replaces GB/T 12960-1996 “Quantitative determination of constituents of cement”.

This standard, through modification, adopts the ENV 196-4:1989 “Test methods for cement - Quantitative determination of constituents” European Standard Draft (English version) and the carbon dioxide determination method (English version) in EN 196-2:2005 “Test methods for cement - Cement chemical analysis” European standard.

As compared with GB/T 12960-1996, the main changes of this standard are as follows:

- MODIFY the relevant determination conditions for the selective dissolution methods:
 - a) As for the selective dissolution conditions for hydrochloric acid solution, MODIFY the water addition from 50 mL to 80 mL (Clause 8.2.1.2 of this version; Clause 6.2.5 of 1996 version);
 - b) When preparing the EDTA solution, INCLUDE the sodium hydroxide in EDTA solution (Clause 5.12 of this version; Clause 6.1.3.4 and 6.1.3.5 of 1996 version);
 - c) As for the EDTA solution selective dissolution conditions, CANCEL the addition of sodium hydrogen phosphate solution and sodium hydroxide solution, and MODIFY the water addition from 25 mL to 80 mL (Clause 8.2.2.3 of this version; Clause 6.1.5 of 1996 version).
- In accordance with the type of cement (Portland cement and common Portland cement, slag Portland cement, pozzolanic Portland cement or fly ash Portland cement, compound Portland cement), respectively PROVIDE the determination method and calculation formula of constituents.
- ADD the reference method (Clause 8.3.4, 9.2.3, 10.2.2 and 11.2.4 of this version).
- In the alternative method, in accordance with the different modes of production of cement, respectively PROVIDE the calculation formula of constituents (Clause 8.3.5, 9.2.4, 10.2.3 and 11.2.5 of this version; Clause 6.1.6.2; 6.2.6.2; 7.5.4.3 and 7.5.4.4 of 1996 version).

Quantitative determination of constituents of cement

1 Scope

This standard specifies the quantitative determination of constituents of cement.

This standard applies to the determination of the common Portland cement (Portland cement, common Portland cement, slag Portland cement, pozzolanic Portland cement, fly ash Portland cement, and compound Portland cement).

2 Normative references

The provisions in following documents become the provisions of this Standard through reference in this Standard. For the dated references, the subsequent amendments (excluding corrections) or revisions do not apply to this Standard; however, parties who reach an agreement based on this Standard are encouraged to study if the latest versions of these documents are applicable. For undated references, the latest edition of the referenced document applies.

GB/T 176 Method for chemical analysis of cement (GB/T 176-1996, eqv ISO 680:1990)

GB/T 2007.1 General rules for the sampling and sample preparation of minerals in bulk - Manual method of sampling

GB/T 5484 Methods for chemical analysis of gypsum

GB/T 6682 Water for analytical laboratory use - Specification and test methods

GB 12573 Sampling method for cement

3 Terms and definitions

The following terms and definitions apply to this standard.

3.1

Reference method

4.5.1 The content of the insoluble slag, carbon dioxide, and sulfur trioxide after selective dissolution is expressed in mass fraction, AND the value is expressed in percentage (%) to two decimal places.

4.5.2 The determination result of the content of each constituent is in mass fraction, AND the value is expressed in percentage (%) to one decimal place.

4.5.3 If the content of a certain determined constituent is less than or equal to 1.0%, then the content of this constituent is deemed as zero; in the calculation of the other constituent content, if the content of this constituent is used, then it is used for calculation as zero; AND as for the constituent content more than 1.0%, it shall not deduct the 1.0% to represent the results.

5 Reagent

Reagents used shall be no lower than analytical pure, unless otherwise stated. The reagent used for calibration shall be the reference reagent. The water used shall comply with the level III water requirements as specified in GB/T 6682.

The density of commercially available concentrated liquid reagents as listed in this standard refers to the density (ρ) at 20 ° C, in grams per cubic centimeter (g/cm^3). In chemical analysis, the acid used refers to the commercially available concentrated acid unless otherwise the concentration is indicated. The volume ratio is used to represent the reagent dilution degree. For example: Hydrochloric acid (1 + 2) means that 1 part by volume of concentrated hydrochloric acid is mixed with 2 parts by volume of water.

5.1 Hydrochloric acid (HCl)

Density of $1.18 \text{ g}/\text{cm}^3 \sim 1.19 \text{ g}/\text{cm}^3$ AND mass fraction of 36% ~ 38%.

5.2 Sulfuric acid (H_2SO_4)

Density of $1.84 \text{ g}/\text{cm}^3$ AND mass fraction of 95% ~ 98%.

5.3 Phosphoric acid (H_3PO_4)

Density of $1.68 \text{ g}/\text{cm}^3$ AND mass fraction $\geq 85\%$.

5.4 Triethanolamine [$\text{N}(\text{CH}_2\text{CH}_2\text{OH})_3$]

Density of $1.12 \text{ g}/\text{cm}^3$ AND mass fraction of 99%.

5.5 Ethanol ($\text{C}_2\text{H}_5\text{OH}$)

15 mL of thymolphthalein indicator solution (5.20); SHAKE it uniformly; STORE it in a plastic bottle.

5.19.2 Calibration of carbon dioxide titer by potassium hydroxide-ethanol standard titration solution

Before calibration, CONNECT an empty reaction bottle to the instrumentation unit (6.9) as shown in Figure 3. START up the suction pump; CONTROL the gas flow rate at about 50 mL/min ~ 150 mL/min to make aeration for more than 20 min, so as to remove the carbon dioxide from the system; and USE the potassium hydroxide-ethanol standard titration solution (5.19.1) for titration until the color of the solution in the titration cell is same as that of the reference solution.

WEIGH about 0.1 g of calcium carbonate (CaCO_3) (m_1) which has been dried at $105\text{ }^\circ\text{C} \pm 5^\circ\text{C}$ for 2 h, accurate to 0.0001 g; PLACE it into a 100 mL dry reaction bottle; CONNECT a reaction bottle to the instrumentation unit (6.9) as shown in Figure 3. START up the suction pump; CONTROL the gas flow rate at about 50 mL/min ~ 150 mL/min; ADD 20 mL of phosphoric acid (5.3) into the separatory funnel 4; carefully UNSCREW the separatory funnel piston to let the phosphoric acid drop into the reaction bottle 5; RETAIN a small amount of phosphoric acid in the funnel to act as a liquid seal; HEAT it to slight boiling state for 5 min; TURN off the electrical furnace; CONTINUE aeration for 10 min. In the process of heating and aeration, the blue color of solution in the titration cell starts fading; immediately USE the potassium hydroxide-ethanol standard titration solution (5.19.1) for tracking titration until the color of the solution in the titration cell is basically same as that of the reference solution. AND at the end point, the color of the solution in the titration cell is same as the color of the reference solution (V_2).

At the same time, PERFORM a blank test. Except that no calcium carbonate is added, the same amount of reagents is used for the test (V_1) using exactly the completely same analytical procedure.

The titer of potassium hydroxide-ethanol standard titration solution for carbon dioxide is calculated in accordance with the formula (1):

$$T_{\text{CO}_2} = \frac{m_1 \times 1\,000}{V_2 - V_1} \times \frac{44.01}{100.09} \quad \dots\dots\dots (1)$$

Where:

T_{CO_2} - Titer of potassium hydroxide-ethanol standard titration solution for carbon dioxide, in milligrams per milliliter (mg/mL);

6.3 Acidity meter: Measuring pH range 0 ~ 14, accurate to 0.02.

6.4 Glass sand core funnel: diameter 60 mm or diameter 40 mm, model G4 (average pore size 4 μm ~ 7 μm).

6.5 Filtration bottles: 1000 mL.

6.6 Suction pump: pumping speed 0.25 L/s.

6.7 Cement constituent measuring apparatus: constant temperature 10 °C $\pm$ 2 °C, 20 °C $\pm$ 2 °C, with the schematic diagram as shown in Figure 1.

6.8 Carbon dioxide determination device (alkali asbestos absorption gravimetric method)

Instrument installation diagram is as shown in Figure 2. INSTALL a suitable suction pump and a glass rotor flow meter to ensure uniform flow of gas through the device.

Gas entering the device is first passed through an absorption tower 1 containing sodium lime (5.24) or carbon dioxide absorbent (5.22) AND a U-shaped tube 2 containing a carbon dioxide absorbent (5.22) to remove carbon dioxide from the gas. The upper part of the reaction bottle 4 is connected with the spherical condenser tube 7.

After the gas passes through the spherical condenser tube 7, it enters the scrubbing bottle 8 containing sulfuric acid (5.2), and then passes through the U-shaped tube 9 containing the hydrogen sulfide absorbent (5.21) and the U Tube 10 containing the moisture absorbent (5.23), to remove the hydrogen sulfide and moisture from the gas. Then it passes through the U-shaped tube 11 and 12, which can be weighed AND respectively contain 3/4 carbon dioxide absorbent (5.22) and 1/4 moisture absorbent (5.23). For gas flow direction, the carbon dioxide absorbent (5.22) shall be placed before the moisture absorbent (5.23). U-shaped tubes 11 and 12 are connected downstream by an additional U-shaped tube 13 containing sodium lime (5.24) or carbon dioxide absorbent (5.22), to prevent carbon dioxide and moisture in the air from entering the U-shaped tube 12.

8.2.1.1 In the reference method, the hydrochloric acid solution selective dissolution method is used to determine the content of insoluble slag in cement and mixed pozzolanic materials or fly ash and Portland cement (P • I) respectively; AND in the alternative method, the hydrochloric acid solution selective dissolution method is used to determine the content of insoluble slag in cement.

8.2.1.2 WEIGH about 0.5 g of sample (m_4) (wherein pozzolanic mixed material or fly ash sample weighed about 0.25 g), accurate to 0.0001 g; PLACE it into a 200 mL dry beaker; ADD 80 mL of water; PLACE a stirring rod in. PLACE the beaker on the cement constituent determination device (6.7) as shown in Figure 1; CONTROL the temperature at $10\text{ }^{\circ}\text{C} \pm 2\text{ }^{\circ}\text{C}$; STIR it for 5 min, to let the sample completely disperse.

Then, ADD 40 mL of hydrochloric acid (1 + 2) which has been heated in water at constant temperature of $10\text{ }^{\circ}\text{C} \pm 2\text{ }^{\circ}\text{C}$ for 8 min ~ 10 min; CONTINUE stirring for 25 min; TAKE it off. Immediately USE the glass sand core funnel which had been dried at $105\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$ to a constant mass for suction filtration.

Note: A constant mass of glass sand funnel is pre-treated, that is, it is first washed with a brush and water AND then washed with hot hydrochloric acid (1 + 5) and water through suction filtration, respectively. Then it is dried in a drying oven at $105\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$ to reach constant mass, cooled to room temperature in a desiccator AND weighed (m_2).

USE the tweezers to take out the stirring rod and USE the water at $25\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$ to wash it clean; TRANSFER all the insoluble slag onto the glass sand core funnel; USE water to rinse the insoluble slag for six times; then USE ethanol (5.5) to rinse it for two times (the total rinsing solution volume is 80 mL ~ 100 mL).

During filtering, LET the rinsing solution flow empty before performing the next rinsing. The filtering must be fast; AND if the filtering duration is more than 20 min (including rinsing time), it shall make this test again.

PLACE the glass sand funnel into a $105\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$ oven to dry it for more than 40 min. TAKE it out; PLACE it in a desiccator to cool it to room temperature; WEIGH it. REPEAT drying until reaching to constant mass (m_3).

8.2.2 Determination of insoluble slag after selective dissolution by EDTA solution

8.2.2.1 In the reference method, the EDTA solution selective dissolution method is used to determine the content of insoluble slag in cement and mixed slag and Portland cement (P • I) respectively; AND in the alternative method,

10, 11, 12, 13. START the suction pump; CONTROL the air flow rate at about 50 mL/min ~ 100 mL/min (3 to 5 bubbles per second); PERFORM aeration for more than 30 min, to remove carbon dioxide and moisture from the system.

Note: Every time at the beginning of the test, instead of connecting the U-shaped tubes 11 and 12 to the instrumentation (6.8) as shown in Figure 2, the U-shaped tube 10 is connected directly to the U-shaped tube 13, to control the gas flow rate at about 50 mL/min ~ 100 mL/min (3 ~ 5 bubbles per second), AND the aeration is performed for about 20 min; then the U-shaped tube 11 and 12 are connected to the instrumentation (6.8) as shown in Figure 2; the aeration is continued for 10 min, so as to extend the valid period of U-shaped tubes 11 and 12.

TURN off the suction pump; CLOSE the grind plug of the U-shaped tubes 10, 11, 12, 13. TAKE off the U-shaped tubes 11 and 12; PLACE them on a flat pan. MAKE it subject to constant temperature in the balance chamber for 10 min; then WEIGH it respectively. REPEAT this operation; MAKE aeration for another 10 min; TAKE it off; MAKE it subject to constant temperature; WEIGH it, until the difference between the two consecutive weighing results for each tube is not more than 0.0010 g; AND the last weighing result shall prevail.

Note: When taking and using a U-shaped tube, care shall be taken to avoid affecting the quality, breaking or damaging it. It is recommended to wear protective gloves during operation.

If the mass changes of the U-shaped tubes 11 and 12 continuously exceed 0.0010 g, REPLACE the U-shaped tubes 9 and 10.

WEIGH about 1 g of sample (m_{10}), accurate to 0.0001 g; PLACE it in a 100 mL dry reaction bottle; CONNECT the reaction bottle to the instrumentation (6.8) as shown in Figure 2; and CONNECT the weighed U-shaped tubes 11 and 12 to the instrumentation (6.8) as shown in Figure 2. START the suction pump; CONTROL the gas flow rate at about 50 mL/min ~ 100 mL/min (3 to 5 bubbles per second). ADD 20 mL of phosphoric acid (5.3) into the separatory funnel 5, carefully UNSCREW the funnel piston, to let the phosphoric acid drip into the reaction bottle 4; RETAIN a small amount of phosphoric acid in the funnel which functions as the liquid seal; CLOSE the piston. TURN on the small electric furnace under the reaction bottle; ADJUST the voltage so that the electric furnace wire is dark red; slowly HEAT the liquid in the reaction bottle at low temperature to make it boil; HEAT it to slight boiling for 5 min; TURN off the electric furnace; CONTINUE aeration for 25 min.

Note: Do not heat violently to prevent backflow of liquid from the reaction bottle.

TURN off the suction pump and CLOSE the grind plug of the U-shaped tube 10, 11, 12, 13. TAKE off the U-shaped tubes 11 and 12 and PLACE them on a flat pan; MAKE it subject constant temperature at balance chamber for 10 min; then WEIGH it respectively. USE the increased mass (m_8 and m_9) of each U-shaped tube to calculate the content of carbon dioxide in the cement.

If the mass of the second U-shaped tube 12 changes less than 0.0005 g, this is ignored in the calculation. In fact, carbon dioxide shall all be absorbed by the first U-shaped tube. If the mass of the second U-shaped tube 12 changes continuously by more than 0.0010 g, the first U-shaped tube 11 shall be replaced AND the test restarted.

At the same time PERFORM a blank test. Except that no sample is added, the same amount of reagent is used for test using exactly the same analytical procedure. The blank test value (m_0) is deducted from the determination result during calculation.

8.2.3.2 Potassium hydroxide-ethanol titration volumetric method

Before each determination, CONNECT an empty reaction bottle to the instrumentation (6.9) as shown in Figure 3. START the suction pump; CONTROL the gas flow rate at about 50 mL/min ~ 150 mL/min; MAKE aeration for more than 20 min, to remove the carbon dioxide from the system. And USE the potassium hydroxide-ethanol standard titration solution (5.19.1) for titration, until the color of the solution in the titration cell is same as the color of the reference solution.

WEIGH about 1 g of sample (m_{11}), accurate to 0.0001 g; PLACE it in a 100 mL dry reaction bottle; CONNECT the reaction bottle to the instrumentation (6.9) as shown in Figure 3. START the suction pump; CONTROL the gas flow rate at about 50 mL/min ~ 100 mL/min. ADD 20 mL of phosphoric acid (5.3) into the separatory funnel 4, carefully UNSCREW the funnel piston, to let the phosphoric acid drip into the reaction bottle 5; RETAIN a small amount of phosphoric acid in the funnel which functions as the liquid seal; CLOSE the piston. TURN on the small electric furnace under the reaction bottle; ADJUST the voltage so that the electric furnace wire is dark red; slowly HEAT the liquid in the reaction bottle at low temperature to make it boil; HEAT it to slight boiling for 5 min; TURN off the electric furnace; CONTINUE aeration for 10 min. During heating and aeration, the blue solution in the titration cell starts fading; immediately USE the potassium hydroxide-ethanol standard titration solution (5.19.1) for tracking titration, until the color of the solution in the titration cell is basically same as the color of the reference solution; AND at the end of titration, the color of the solution in the titration cell is same as the color of the reference solution (V_4).

R₄ - Mass fraction of insoluble slag in cement after selective dissolution by EDTA solution, %;

R₅ - Mass fraction of insoluble slag in mineral slag after selective dissolution by EDTA solution, %;

R₆ - Mass fraction of insoluble slag in Portland cement (P • I) after selective dissolution by EDTA solution, %;

P - Mass fraction of pozzolanic materials or fly ash constituent in cement, %.

8.3.4.3 Cement limestone constituent content (D) is calculated in accordance with the formula (8):

$$D = 2.274 \times D_1 - 1.00 \quad \dots\dots\dots (8)$$

Where:

D - Mass fraction of limestone constituent in cement, %;

D₁ - Mass fraction of carbon dioxide in cement, %;

2.274 - Conversion factor of carbon dioxide for calcium carbonate;

1.00 - Correction factor.

8.3.4.4 The cement gypsum constituent content (G) is calculated in accordance with the formula (9):

$$G = \frac{w_1 - w_2}{w_3} \times 100 \quad \dots\dots\dots (9)$$

Where:

G - Mass fraction of gypsum constituent in cement, %;

w₁ - Mass fraction of sulfur trioxide in cement, %;

w₂ - Mass fraction of sulfur trioxide in clinker, %;

w₃ - Mass fraction of sulfur trioxide in gypsum, %.

8.3.4.5 The cement clinker constituent content (C) is calculated in accordance with the formula (10):

$$C = 100 - P - S - D - G \quad \dots\dots\dots (10)$$

R_3 - Mass fraction of insoluble slag in Portland cement ($P \cdot I$) after the selective dissolution by hydrochloric acid solution, %;

R_5 - Mass fraction of insoluble slag in mineral slag after selective dissolution by EDTA solution, %;

R_6 - Mass fraction of insoluble slag in Portland cement ($P \cdot I$) after selective dissolution by EDTA solution, %;

R_7 - Mass fraction of insoluble slag in slag silicate cement after selective dissolution by hydrochloric acid solution, %;

R_8 - Mass fraction of insoluble slag in mineral slag after selective dissolution by hydrochloric acid solution, %;

R_9 - Mass fraction of insoluble slag in slag silicate cement after selective dissolution by EDTA solution, %;

R_{10} - Mass fraction of insoluble slag in pozzolanic materials or fly ash after selective dissolution by EDTA solution, %.

9.2.3.2 The content of mineral slag constituent in the slag silicate cement is calculated in accordance with formula (17):

$$S = \frac{R_9 - R_6}{R_5 - R_6} \times 100 - P \quad \dots\dots\dots (17)$$

Where:

S - Mass fraction of slag constituent in slag silicate cement, %;

R_5 - Mass fraction of insoluble slag in mineral slag after selective dissolution by EDTA solution, %;

R_6 - Mass fraction of insoluble slag in Portland cement ($P \cdot I$) after selective dissolution by EDTA solution, %;

R_9 - Mass fraction of insoluble slag in slag silicate cement after selective dissolution by EDTA solution, %;

P - Mass fraction of pozzolanic materials or fly ash constituents in slag silicate cement, %.

9.2.4 Calculation of constituent content in slag silicate cement (alternative method)

9.3 Determination of limestone constituent content and gypsum constituent content in slag silicate cement

The determination of limestone content and gypsum content in slag silicate cement is carried out in accordance with Clause 8.

10 Determination of constituents in volcanic silicate cement or fly ash silicate cement

10.1 Analytical procedures

In accordance with the procedures in 8.2.1. As for the reference method, the hydrochloric acid solution selective dissolution method is used to respectively determine the content of the insoluble slag in cement, the pozzolanic materials or fly ash mixed in cement, and Portland cement (P • I); AND as for the alternative method, the hydrochloric acid solution selective dissolution method is used to respectively determine the insoluble slag content in cement and in pozzolanic materials or fly ash mixed in cement.

10.2 Result calculation

10.2.1 Calculation of insoluble slag content after selective dissolution by hydrochloric acid solution

After the selective dissolution by hydrochloric acid solution, the insoluble slag content (R_{11}) of pozzolanic silicate cement or fly ash silicate cement, the insoluble slag content (R_2) in pozzolanic material or fly ash mixed in cement, AND the insoluble slag content (R_3) in Portland cement (P • I) are calculated in accordance with formula (2).

10.2.2 Calculation of the constituent content in pozzolanic silicate cement or fly ash silicate cement (reference method)

The content of pozzolanic material or fly ash constituent (P) in the pozzolanic silicate cement or fly ash silicate cement is calculated in accordance with formula (22):

$$P = \frac{R_{11} - R_3}{R_2 - R_3} \times 100 \quad \dots\dots\dots (22)$$

Where:

P - Mass fraction of pozzolanic materials or fly ash constituents in pozzolanic silicate cement or fly ash silicate cement, %;

11 Determination of constituent content in complex silicate cement

11.1 Analytical procedures

11.1.1 Determination of insoluble slag content after selective dissolution by hydrochloric acid solution

In accordance with the procedures in 8.2.1. As for the reference method, the hydrochloric acid solution selective dissolution method is used to respectively determine the content of the insoluble slag in cement, the pozzolanic materials or fly ash mixed in cement, limestone, and Portland cement (P • I); AND as for the alternative method, the hydrochloric acid solution selective dissolution method is used to respectively determine the insoluble slag content in cement and in pozzolanic materials or fly ash mixed in cement.

11.1.2 Determination of insoluble slag content after selective dissolution by EDTA solution

In accordance with the procedures in 8.2.2. As for the reference method, the EDTA solution selective dissolution method is used to respectively determine the content of the insoluble slag in cement, the pozzolanic materials or fly ash mixed in cement, mineral slag, limestone, and Portland cement (P • I); AND as for the alternative method, the EDTA solution selective dissolution method is used to respectively determine the insoluble slag content in cement, pozzolanic materials or fly ash mixed in cement, and mineral slag.

11.1.3 Determination of carbon dioxide content

The content of carbon dioxide in complex silicate cement and limestone mixed in cement is determined in accordance with the procedures of 8.2.3. When determining the content of carbon dioxide in limestone, the weighed amount of sample is changed to about 0.1 g.

11.2 Result calculation

11.2.1 Calculation of insoluble slag after selective dissolution by hydrochloric acid solution

After the selective dissolution by hydrochloric acid solution, the content of insoluble slag (R_{12}) in complex silicate cement, the content of insoluble slag (R_2) in pozzolanic material or fly ash mixed in cement, the content of insoluble slag (R_{13}) in limestone, AND the content of insoluble slag (R_3) in Portland cement (P • I) are calculated in accordance with formula (2).

11.2.2 Calculation of insoluble slag after selective dissolution by EDTA solution

After the selective dissolution by EDTA solution, the content of insoluble slag (R_{14}) in complex silicate cement, the content of insoluble slag (R_{10}) in pozzolanic material or fly ash mixed in cement, the content of insoluble slag (R_5) in mineral slag, the content of insoluble slag (R_{15}) in limestone, and the content of insoluble slag (R_6) in Portland cement ($P \cdot I$) are calculated in accordance with formula (3).

11.2.3 Calculation of carbon dioxide content

Carbon dioxide content in complex silicate cement (D_1) and carbon dioxide content in limestone mixed in cement (D_2) are calculated in accordance with 8.3.3.

11.2.4 Calculation of constituent content in complex silicate cement (reference method)

11.2.4.1 The content of pozzolanic material or fly ash constituent (P) in the complex silicate cement is calculated in accordance with formula (25):

$$P = \frac{R_{12} - (R_{13} - R_5) \times D \times 10^{-2} - R_6}{R_2 - R_5} \times 100 \quad \text{..... (25)}$$

Where:

P - Mass fraction of pozzolanic materials or fly ash constituents in complex silicate cement, %;

R_2 - Mass fraction of insoluble slag in pozzolanic materials or fly ash after selective dissolution by hydrochloric acid solution, %;

R_3 - Mass fraction of insoluble slag in Portland cement ($P \cdot I$) after the selective dissolution by hydrochloric acid solution, %;

R_{12} - Mass fraction of insoluble slag in complex silicate cement after selective dissolution by hydrochloric acid solution, %;

R_{13} - Mass fraction of insoluble slag in limestone after selective dissolution by hydrochloric acid solution, %;

D - Mass fraction of limestone constituent in complex silicate cement, %.

11.2.4.2 The mineral slag content (S) in the complex silicate cement is calculated in accordance with the formula (26):

P - Mass fraction of pozzolanic materials or fly ash constituents in complex silicate cement, %;

2.20, 3.80 - correction factor.

11.2.5.3 The limestone constituent content (D) in complex silicate cement is calculated in accordance with formula (32):

$$D = 2.274 \times D_1 - 1.00 \quad \text{..... (32)}$$

Where:

D - Mass fraction of limestone constituents in cement, %;

D₁ - Mass fraction of carbon dioxide in cement, %;

2.274 - Conversion factor of carbon dioxide for calcium carbonate;

1.00 - Correction factor.

11.3 Determination of gypsum content in complex silicate cement

The content of gypsum in complex silicate cement is determined in accordance with Clause 8.

12 Allowable difference

The allowable difference listed in this standard are absolute deviations, expressed in terms of mass fraction.

The allowable difference of the same laboratory refers that the difference between the two analysis results obtained in the same analytical laboratory by the same analyst (or two analysts), using the method of this standard to analyze the same sample shall comply with the provisions on allowable difference. If it exceeds the allowable range, it shall make the third determination in a short time (or perform the third party determination); AND if the difference between the determination result and either of the previous two analysis results complies with the provisions on the allowable difference, the average is taken; otherwise, it shall find the causes AND make analysis again in accordance with the requirements above.

The allowable difference of different laboratories refers that the difference of the average values of the analysis results obtained in two laboratories using the method of this standard to analyze the same sample, respectively, shall comply with the provisions of the allowable difference. In case of dispute, the

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