भारतीय मानक **IS 18189 : 2023**

Indian Standard

पोर्टलैंड निस्तापित मृत्तिका चूना पत्थर सीमेंट — विशिष्टि

Portland Calcined Clay Limestone Cement — Specification

ICS 91.100.10

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Cement Concrete Sectional Committee, CED 02

FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft finalised by the Cement and Concrete Sectional Committee had been approved by the Civil Engineering Division Council.

This standard pertains to Portland calcined clay limestone cement and covers the requirements such as its manufacture, chemical and physical requirements, packing and marking. It covers the requirements of raw materials, that is, calcined clay, limestone and clinker and their proportions to be used in the manufacture of Portland calcined clay limestone cement.

Ternary cements with low clinker contents have been demonstrated to be technically and environmentally beneficial in many scenarios. The manufacture of ternary cements through inter-grinding of its components requires that sufficient care is taken to ensure that all constituents are ground to requisite fineness. Individual constituents, especially clinker, remaining coarse after grinding can significantly hamper the performance of the cement. The advantage of Portland calcined clay limestone cement is known to be the dual hydration of its additions, namely, the formation of calcium alumino silicate hydrate from the hydration of calcined clay with lime and the formation of carboaluminate phases from the hydration of limestone with aluminates from the calcined clay and clinker. The production of these solid hydration products improves the mechanical properties and durability of the cement at relatively lower clinker content.

Quantity of cement packed in bags and the tolerance requirements for the quantity of cement packed in bags shall be in accordance with the relevant provisions of *the Standards of Weights and Measures (Packaged Commodities) Rules*, 2011 and **D-1.2**. Any modification in these rules in respect of tolerance on quantity of cement would apply automatically to this standard.

This standard contains Table 2 Sl No. (vii) and **13.2.2** which give option to the purchaser and the supplier; and Table 3, Sl No. (vi) and **10.2**, **10.3**, **10.4** and **10.4.3**, which call for an agreement between the purchaser and the supplier.

This standard contributes to the following Sustainable Development Goal 12 ‘Ensure sustainable consumption and production patterns’ towards achieving sustainable management and efficient use of natural resources.

The composition of the committee responsible for the formulation of this standard is listed in Annex E.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded of in accordance with IS 2 : 2022 ‘Rules for rounding off numerical values (*second revision*)’. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

PORTLAND CALCINED CLAY LIMESTONE CEMENT — SPECIFICATION

1 SCOPE

This standard covers the manufacture, and chemical and physical requirements of Portland calcined clay limestone cement.

2 REFERENCES

The standards listed in Annex A contain provisions which, through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards listed in Annex A.

3 TERMINOLOGY

For the purpose of this standard, the definitions given in IS 4845 and the following shall apply.

3.1 Portland Calcined Clay Limestone Cement — An intimately interground mixture of Portland cement clinker, calcined clay and limestone with addition of gypsum or an intimate and uniform blending of ordinary Portland cement, finely ground limestone and fine calcined clay with addition of ground gypsum, if required.

3.2 Calcined Clay — A clay with at least 40 percent kaolinite content activated through thermal calcination.

4 RAW MATERIAL

4.1 Calcined Clay Pozzolana

The raw clay used in the manufacture of the calcined clay shall contain a minimum of 40 percent kaolinite and meet the requirements listed in Annex B. The process for calcination is also given in Annex B.

4.2 Limestone

The limestone used in the manufacture of Portland calcined clay limestone cement shall contain at least 75 percent of calcium and magnesium carbonates, including limestone and dolomite, when calculated from the CaO and MgO content determined as per IS 1760 (Part 3) and the carbon dioxide content determined as per IS 1760 (Part 4). The total of calcium oxide and magnesium oxide content in the limestone shall not be less than 44 percent when determined as per IS 1760 (Part 3). The mass loss of the limestone when measured according to Annex C shall be not less than 33 percent of the weight of the limestone.

4.3 Portland Cement Clinker

The Portland cement clinker used in the manufacture of the cement shall conform to IS 16353. When the cement is produced by blending of the individual components, the fineness of the clinker shall be between 225 m^2/kg and 250 m^2/kg.

4.4 Portland Cement

Portland cement for blending for manufacture of cement as per this standard shall conform to the requirements of 43 Grade OPC as specified in IS 269.

5 MANUFACTURE

5.1 Portland calcined clay limestone cement shall be manufactured either by:

a) intimately inter-grinding Portland cement clinker, calcined clay and limestone; or

b) intimately and uniformly blending ordinary Portland cement, finely ground calcined clay and finely ground limestone.

At the time of grinding or blending, required addition of gypsum (natural/mineral/flue gas desulphurization gypsum from thermal power plants and chemical gypsum including phosphogypsum from fertilizer plants) is done so as to produce a cement capable of complying with this standard, maintaining the proportion as given in Table 1.

NOTE — The compositional consistency of the mixture may preferably be generated within ± 3 percent of the declared limestone and calcined clay addition in the same consignment. Suitable chemical agents may be utilized for achieving the above.

5.2 When Portland calcined clay limestone cement is obtained by grinding limestone and calcined clay with Portland cement clinker, no material, other than water, gypsum and not more than a total of 1.0 percent of air-entraining agents or other agents including colouring agents, which have proved not to be harmful, shall be added after calcination. The limitation of all such additions shall also apply to manufacture of Portland calcined clay limestone cement by the blending process. Furthermore, when

the grinding of the clinker is carried out along with limestone and calcined clay, care must be taken to ensure that a uniform fineness is achieved for all constituents of the cement, that is, clinker, calcined clay and limestone. Grinding aids may be used to achieve a proper grinding of all components.

NOTE — Additional measurements of retention on 90 µm (generally less than 3 percent) and 45 µm (generally less than 20 percent) sieves may be carried out to ensure that the cement is sufficiently well ground. Particle size analysis may also be carried out to ensure that a uniform grinding of all components.

When Portland calcined clay limestone cement is produced by blending of the individual components, the fineness of the calcined clay, or the blend of calcined clay and fine ground limestone, as may be the case, shall not be less than 600 m^2/kg, when measured according to IS 4031 (Part 2).

6 CHEMICAL REQUIREMENTS

When tested in accordance with the methods given in IS 4032, Portland calcined clay limestone cement, shall comply with the chemical requirements given in Table 2.

Table 1 Material Proportions to be Used in Portland Calcined Clay Limestone Cement
(*Clause* 5.1)

Sl No.	Material	Proportion (Percent by Weight)
(1)	(2)	(3)
i)	Portland cement clinker	50 to 80 (in case clinker is used)
	or	
	Ordinary Portland cement	55 to 85 (in case OPC is used)
ii)	Calcined clay	10 to 35
iii)	Limestone	5 to 20

Table 2 Chemical Requirements for Portland Calcined Clay Limestone Cement
(*Clause* 6)

Sl No.	Characteristic	Requirement
(1)	(2)	(3)
i)	Insoluble residue, percent by mass, *Max*	$x + \frac{4.0 \times (100 - x)}{100}$ where, x is the declared percentage of calcined clay in the given Portland calcined clay limestone cement
ii)	Insoluble residue, percent by mass, *Min*	$0.40 \times x$
iii)	Magnesia, percent by mass, *Max*	6.0
iv)	Total sulphur content calculated as sulphuric anhydrite (SO_3), percent by mass, *Max*	3.5
v)	Loss on ignition (as per IS 4032), percent by mass *Max*:	10.0
vi)	Chloride content, percent by mass, *Max*	0.1
vii)	Alkali content	0.05 (for prestressed concrete structures) (*see* Note)

NOTE — Alkali aggregate reactions have been noticed in aggregates in some parts of the region. On large and important jobs where the concrete is likely to be exposed to humid atmosphere or wetting action, it is advisable that the aggregate be tested for alkali aggregate reaction. In the case of reactive aggregates, the use of cement with alkali content below 0.75 percent expressed as sodium oxide ($Na_2O + 0.658\ K_2O$) is recommended. Where, however, such cements are not available, use of alternative means may be resorted to for which a reference may be made to appropriate provisions on durability in the concrete codes. If so desired by the purchaser, the manufacturer shall carry out test for alkali content.

7 PHYSICAL REQUIREMENTS

Portland calcined clay limestone cement shall comply with the physical requirements given in Table 3.

Table 3 Physical Requirements for Portland Calcined Clay Limestone Cement
(*Clause* 7)

Sl No.	Characteristic	Requirement	Method of Test, Ref to
(1)	(2)	(3)	(4)
i)	Fineness, m^2/kg, *Min*	400	IS 4031 (Part 2)
ii)	Soundness:		
	a) By Le-Chatelier method, mm, *Max*	10	IS 4031 (Part 3)
	b) By autoclave test method, percent, *Max*	0.8 (*see* Note 1)	
iii)	Setting time:		
	a) Initial, min, *Min*	30	IS 4031 (Part 5)
	b) Final, min, *Max*	600 (*see* Note 2)	
iv)	Compressive strength, MPa (*see* Note 3):		
	a) 72 ± 1 h, *Min*	23	IS 4031 (Part 6)
	b) 168 ± 2 h, *Min*	33	
	c) 672 ± 4 h, *Min*	43	
v)	Drying shrinkage, percent, *Max*	0.15	IS 4031 (Part 10)
vi)	Transverse strength (optional)	*See* Notes 3, 4 and 5	IS 4031 (Part 8)

NOTES

1 In the event of cements failing to comply with one or both the requirements of soundness specified in the above table, further tests in respect of failure shall be made as described in IS 4031 (Part 3), from another portion of the same sample after aeration. The aeration shall be done by spreading out the sample to a depth of 75 mm at a relative humidity of 50 percent to 80 percent for a total period of 7 days. The expansion of cements so aerated shall not be more than 5 mm and 0.6 percent when tested by Le-Chatelier method and autoclave test, respectively.

2 If cement exhibits false set, the ratio of final penetration measurement after 5 min of completion of mixing period to the initial penetration measured exactly after 20 s of completion of mixing period, expressed as percent, shall not be less than 50. In the event of cement exhibiting false set, the initial and final setting time of cement when tested by the method described in IS 4031 (Part 5) after breaking the false set, shall confirm to the value given in the above table.

3 For measurement of the compressive and transverse strength of the cement, the specimens shall be cured under conditions specified in IS 4031 (Part 6).

4 By agreement between the purchaser and the manufacturer, transverse strength test of plastic mortar in accordance with the method described in IS 4031 (Part 8) may be specified. The permissible values of the transverse strength shall be mutually agreed to between the purchaser and the supplier at the time of placing the order.

5 Notwithstanding the compressive and transverse strength requirements specified as per the above table, the cement shall show a progressive increase in strength from the strength at 72 h.

8 STORAGE

The cement shall be stored in such a manner as to permit easy access for proper inspection and identification, and in a suitable weather-tight building to protect the cement from dampness and to minimise warehouse deterioration (*see* also IS 4082).

9 MANUFACTURER'S CERTIFICATE

9.1 The manufacturer shall satisfy himself that the cement conforms to the requirements of this standards and, if requested, shall furnish a test certificate to this effect to the purchaser or his representative within ten days of testing of the cement (except for 28 days compressive strength test results, which shall be furnished after completion of the test).

9.2 The manufacturer shall furnish a certificate indicating the alkali content, if required.

10 PACKING

10.1 The cement shall be packed in any of the following bags:

a) Multi-wall paper sacks conforming to IS 11761;
b) HDE/PP woven sacks conforming to IS 11652;
c) PP woven laminated block bottom valve sacks conforming to IS 16709;

d) Jute synthetic union bags conforming to IS 12174; or
e) Any other approved composite bag.

Bags shall be in good condition at the time of inspection.

10.1.1 The net quantity of cement per bag shall be 50 kg subject to provisions and tolerance given in Annex D.

10.2 The net quantity of cement per bag may also be 40 kg, 25 kg, 10 kg, 5 kg, 2 kg or 1 kg and packed in suitable bags as agreed to between the purchaser and the manufacturer but the bag shall be of the material and quality as given in with **10.1**. The quantity of cement in the bags shall also be subject to tolerances as given in Annex D for 50 kg bags.

10.3 Supplies of cement in drums or in bulk may be made by arrangement between the purchaser and the supplier (manufacturer or stockist).

NOTE — A single bag or container containing 1 000 kg and more net quantity of cement, shall be considered as the bulk supply of cement. Supplies of cement may also be made in intermediate bags/containers, for example, drums of 200 kg, by agreement between the purchaser and the manufacturer.

10.4 When cement is intended for export and if the purchaser so requires, packing of cement may be done in packs or in drums with net quantity of cement per bag or drum as agreed to between the purchaser and the manufacturer.

10.4.1 For this purpose, the permission for the certifying authority shall be obtained in advance for each export order.

10.4.2 The words "FOR EXPORT" and the net quantity of cement per bag/drum shall be clearly marked in indelible ink on each bag/drum.

10.4.3 The packing material shall be agreed to between the manufacturer and the purchaser.

10.4.4 The tolerance requirements for the quantity of cement packed in bags/drum shall be as given in **D-1.1** except the net quantity which shall be equal to or more than the quantity in **10.4**.

11 MARKING

11.1 Each bag or drum of cement shall be legibly and indelibly marked with the following:

a) Manufacturer's name and his registered trade-mark, if any;
b) The words 'PORTLAND CALCINED CLAY LIMESTONE CEMENT';
c) Net quantity, in kg;
d) The words 'USE NO HOOKS' on the bags;
e) Batch/control unit number in terms of week, month and year of packing;
f) Best before date (that is, 3 months from date of packing);
g) The need for testing of cement more than 3 months old to check conformity before its use;
h) Address of the manufacturer; and
j) Percentage of calcined clay and limestone addition.

11.2 Similar information shall be provided in the delivery advices accompanying the shipment of packed or bulk cement and on cement drums (*see* **10.3**).

11.3 BIS Certification Marking

11.3.1 The cement may also be marked with the Standard Mark.

11.3.2 The use of the Standard Mark is governed by the provisions of the *Bureau of Indian Standards Act*, 2016 and the Rules and Regulations framed thereunder, and the cement may be marked with the Standard Mark.

12 SAMPLING

12.1 A sample or samples for testing may be taken by the purchaser or his representative, or by any person appointed to superintend the work for the purpose of which the cement is required or by the latter's representative.

12.1.1 The samples shall be taken within three weeks of the delivery and all tests shall be commenced within one week of sampling.

12.1.2 When it is not possible to test the samples within one week, the samples shall be packed and stored in air-tight containers and tested at the earliest but not later than 3 months since the receipt of samples for testing.

12.2 In addition to the requirements of **12.1**, the methods and procedure of sampling shall be in accordance with IS 3535.

12.3 The manufacturer or the supplier shall afford every facility, and shall provide all labour and materials for taking and packing the samples for testing the cement and for subsequent identification of cement sampled.

13 TESTS

13.1 The sample or samples of cement for test shall be taken as described in **12** and shall be tested in the manner described in the relevant clauses.

13.2 Independent Testing

13.2.1 If the purchaser or his representative requires independent tests, the samples shall be taken before or immediately after delivery at the option of the purchaser or his representative, and the tests shall be carried out in accordance with this standard on the written instructions of the purchaser or his representative.

13.2.2 The manufacturer/supplier shall supply, free of charge, the cement required for testing. Unless otherwise specified in the enquirer and order, the cost of the tests shall be borne as follows:

a) By the manufacturer/supplier, if the results show that the cement does not comply with the requirements of this standard, and

b) By the purchaser, if the results show that the cement complies with the requirement of this standard.

13.2.3 After a representative sample has been drawn, tests on the sample shall be carried out as expeditiously as possible (*see* **12.1.1** and **12.1.2**).

14 REJECTION

14.1 Cement may be rejected, if it does not comply with any of the requirements of this specification.

14.2 Cement remaining in bulk storage at the factory prior to shipment, for more than six months, or cement in bags, in local storage such as, in the hands of a vendor for more than 3 months after completion of tests, shall be retested before use and shall be rejected if it fails to conform to any of the requirements of this specification.

ANNEX A
(*Clause* 2)

LIST OF REFERRED INDIAN STANDARDS

IS No.	*Title*
IS 269 : 2015	Ordinary portland cement — Specification (*sixth revision*)
IS 1727 : 1967	Methods of test for pozzolanic materials
IS 1760	Chemical analysis of limestone, dolomite and allied materials:
(Part 3) : 1992	Determination of iron oxide, alumina, calcium oxide and magnesia (*first revision*)
(Part 4) : 1991	Determination of carbon dioxide (*first revision*)
IS 3535 : 1986	Methods of sampling hydraulic cement
IS 4031	Methods of physical tests for hydraulic cement:
(Part 2) : 1999	Determination of fineness by blaine air permeability method (*second revision*)
(Part 3) : 1988	Determination of soundness (*first revision*)
(Part 5) : 1988	Determination of initial and final setting times (*first revision*)
(Part 6) : 1988	Determination of compressive strength of hydraulic cement (other than masonry cement) (*first revision*)
(Part 8) : 1988	Determination of transverse and compressive strength of plastic mortar using prism (*first revision*)
(Part 10) : 1988	Determination of drying shrinkage (*first revision*)
IS 4032 : 1985	Method of chemical analysis of hydraulic cement (*first revision*)
IS 4082 : 1996	Recommendations on staking and storage of construction materials and components at site (*second revision*)
IS 4845 : 1968	Definitions and terminology relating to hydraulic cement
IS 4905 : 2015/ISO 24153 : 2009	Random sampling and randomization procedures (*first revision*)
IS 11652 : 2017	Textiles — High density polyethylene (HDPE)/polypropylene (PP) woven sacks for packaging of 50 kg cement — Specification (*third revision*)
IS 11761 : 1997	Multi-wall paper sacks for cement — Specification (*first revision*)
IS 12174 : 1987	Specification for jute synthetic union bags for packing cement
IS 16353 : 2015	Portland cement clinker — Specification
IS 16709 : 2017	Textiles — Polypropylene (PP) woven, laminated, block bottom valve sacks for packaging of 50 kg cement — Specification

ANNEX B
(*Clause* 4.1)

SPECIFICATION FOR CALCINED CLAY FOR USE IN PORTLAND CALCINED CLAY LIMESTONE CEMENT

B-1 INTRODUCTION

For the purpose of this standard, calcined clay is a material manufactured under controlled conditions by calcination of kaolinitic clay at a suitable temperature.

B-2 RAW MATERIALS

B-2.1 Kaolinitic clay is a type of clay that has the crystalline mineral of kaolinite as a major constituent. Kaolinite has a layered structure with the chemical formula of $3Al_2O_3.2SiO_2.2H_2O$, giving an approximate theoretical composition of 40 percent of Al_2O_3, 46 percent of SiO_2 and 14 percent of H_2O. Quartz, hematite, montmorillonite, illite, calcite, muscovite and anatase are commonly found impurities in these clays.

B-2.2 Kaolinite undergoes dehydroxyllation upon calcination at temperatures between 450 ˚C and 700 ˚C with a mass loss equivalent to approximately 14 percent by weight of the dry kaolinite. The material thus produced is amorphous and is known as metakaolin.

B-2.3 A number of clays, which have been investigated in India and have given satisfactory results, contain a minimum of 40 percent kaolinite. This corresponds to a minimum mass loss of 5.6 percent by weight of the dry clay. This mass loss may either be measured using thermogravimetric analysis between the temperature range of 300 ˚C and 750 ˚C, in a thermogravimetric analyzer or by using the procedure described in **B-4**. Care must be taken to avoid clays containing minerals that decompose at temperatures below 300 ˚C.

B-2.4 Clays in India that have given satisfactory results generally conform to the following chemical requirements on an oven dry basis (at 105 ˚C):

Constituent	*Content*
Al_2O_3	Not less than 16 percent
SiO_2	Not less than 35 percent
CaO	Not more than 10 percent
Fe_2O_3	Not more than 12 percent
MgO	Not more than 3 percent

NOTE — However, clays that meet the requirements of **B-2.3** but not those of **B-2.4** may also be used.

B-3 CALCINATION

B-3.1 Calcined clay shall be obtained by calcining kaolinitic clay at a suitable temperature. Depending upon the process used for calcination, the clay shall be processed by crushing, grinding or preparing lumps.

The clay shall be calcined by maintaining it at high temperatures for a duration long enough to achieve temperatures above 750 ˚C throughout the mass of the clay. To avoid sintering and recrystallisation into mullite during calcination, the temperature of the clay shall, in no case, be higher than 950 ˚C.

NOTE — Clay is currently calcined using rotary kilns, flash calciners or static furnaces. While the process for preparation varies based on the specifications of the equipment, the clay is crushed into nodules of a few centimetres size for rotary kilns, it is ground into grains of a few millimetres size for flash calciners and it is mixed with water and pressed or moulded into lumps or bricks for static furnaces. The duration of calcination varies from a few hours in the case of static furnaces to less than an hour in the case of a rotary kiln, to less than a minute in the case of a flash calciner.

B-3.2 The mass loss of calcined clay measured using thermogravimetric analysis between the temperature range of 300 ˚C and 750 ˚C, in a thermogravimetric analyzer or by using the procedure described in **B-4**, shall be less than 1.5 percent of the mass of dry calcined clay.

B-3.3 The lime reactivity of calcined clay crushed to a fineness of more than 600 m^2/kg, measured in accordance with IS 1727, shall not be less than 8.0 MPa.

B-4 DETERMINATION OF APPROXIMATE KAOLINITE CONTENT IN CLAY

B-4.1 The kaolinite content in clay shall be estimated as given below.

B-4.2 Apparatus

a) Oven, capable of reaching 105 ˚C.
b) Muffle furnace, capable of reaching 800 ˚C.
c) Platinum or ceramic crucibles (at least 3 nos).
d) Weighing balance, with least count of 0.01 g or better.

B-4.3 Procedure

The procedure for determining the approximate kaolinite clay content shall be as given below:

a) Clean the crucibles thoroughly and keep them in an oven at 105 ˚C ± 5 ˚C for at least 1 h for drying.

b) Increase the temperature of the muffle furnace to 100 ˚C ± 5 ˚C and maintain for at least 15 min.

c) Remove the crucibles from the oven and measure the weight of the individual empty crucibles to the nearest 0.01 g (A).

d) Take approximately 5 g of clay on each of the crucibles and measure the weight of the clay along with the crucibles to the nearest 0.01 g (B).

e) Place the crucibles with the clay in the muffle furnace and increase the temperature to 300 ˚C ± 5 ˚C. Maintain at 300 ˚C ± 5 ˚C for at least 60 min.

f) Remove the crucibles from the muffle furnace and measure the weight of the crucibles with the clay to the nearest 0.01 g (C).

g) Place the crucibles back in the muffle furnace. Increase the temperature of the muffle furnace to 750 ˚C ± 5 ˚C and maintain at this temperature for at least 120 min.

h) Remove the crucibles from the muffle furnace and measure the weight of the crucibles with the clay to the nearest 0.01 g (D).

B-4.4 Calculation

The loss of mass on ignition (LOI) of the clay can be measured as:

$$LOI = 1 - \frac{(D - A)}{(C - A)}$$

The approximate kaolinite content (k, in percent) in the clay can be approximately determined as below:

$$k = \frac{LOI}{0.14} \times 100$$

Alternatively, quantitative X-Ray Diffraction (XRD) analysis may also be utilized to measure the kaolinite content in the clay.

The kaolinite content in the clay may be determined using thermogravimetric analysis, by measuring the value of k above as the percent weight loss between 300 ˚C and 750 ˚C.

ANNEX C

(*Clause* 4.2)

DETERMINATION OF MASS LOSS OF LIMESTONE

C-1 The approximate mass loss of limestone and the calcium carbonate content in limestone shall be estimated as per the procedure given hereunder.

NOTE — The calcium carbonate and calcium magnesium carbonate content in limestone shall be determined using the methodology defined in IS 1760 (Part 3). The methods below may be used as alternative methods for the combined mass of calcium carbonate and calcium magnesium carbonate content.

C-2 APPARATUS

The following apparatus shall be used:

a) Oven capable, of reaching 105 ˚C;
b) Muffle furnace, capable of reaching 100 ˚C;
c) Platinum or ceramic crucibles (at least 3 nos); and
d) Weighing balance, with least count of 0.01 g or better.

C-3 PROCEDURE

The procedure for determining the approximate calcium carbonate content in limestone shall be as given below:

a) Clean the crucibles thoroughly and keep them in an oven at 105 ˚C $\pm$ 5 ˚C for at least 1 h for drying.
b) Increase the temperature of the muffle furnace to 100 ˚C $\pm$ 5 ˚C and maintain for at least 15 min.
c) Remove the crucibles from the oven and measure the weight of the individual empty crucibles to the nearest 0.01 g (A_1).
d) Take approximately 5 g of limestone on each of the crucibles and measure the weight of the limestone along with the crucibles to the nearest 0.01 g (B_1).
e) Place the crucibles with the limestone in the muffle furnace and increase the temperature to 500 ˚C $\pm$ 5 ˚C. Maintain at 500 ˚C $\pm$ 5 ˚C for at least 60 min.
f) Remove the crucibles from the muffle furnace and measure the weight of the crucibles with the limestone to the nearest 0.01 g (C_1).
g) Place the crucibles back in the muffle furnace. Increase the temperature of the muffle furnace to 950 ˚C $\pm$ 10 ˚C and maintain at this temperature for at least 120 min.
h) Remove the crucibles from the muffle furnace and measure the weight of the crucibles with the limestone to the nearest 0.01 g (D_1).

The loss of mass on ignition (LOI) of the limestone can be measured as:

$$LOI = 1 - \frac{(D_1 - A_1)}{(C_1 - A_1)}$$

The approximate calcium carbonate plus magnesium carbonate content (l, in percent) in the limestone can be approximately determined as below:

$$l = \frac{LOI}{0.44} \times 100$$

An error of 5 percent to 8 percent may be expected when the above method is used for limestones with a higher dolomite content.

Alternatively, quantitative X-Ray Diffraction (XRD) analysis or infrared spectroscopy may also be utilized to measure the carbonate content in the limestone.

Alternatively, the carbonate content in the limestone maybe determined using thermogravimetric analysis, by measuring the value of l above as the percent weight-loss between 500 ˚C and 950 ˚C.

ANNEX D
(*Clauses* 10.1.1 and 10.2)

TOLERANCE REQUIREMENTS FOR THE QUANTITY OF CEMENT PACKED IN BAGS

D-1 The average of the net quantity of cement packed in bags at the plant in a sample shall be equal to or more than 50 kg. The number of bags in a sample shall be as given below:

Batch Size	*Sample Size*
100 to 150	20
151 to 280	32
281 to 500	50
501 to 1200	80
1 201 to 3 200	125
3 201 and over	200

The bags in a sample shall be selected at random. For methods of random sampling, IS 4905 maybe referred to.

D-1.1 The number of bags in a sample showing a minus error greater than 2 percent of the specified net quantity (50 kg) shall be not more than 5 percent of the bags in the sample. Also the minus error in none of such bags in a sample shall exceed 4 percent of the specified net quantity of cement in the bag.

D-1.2 In case of a wagon/truck load of up to 25 tonne, the overall tolerance on net quantity of cement shall be 0 percent to 0.5 percent.

NOTE — The mass of a 6-ply paper bag to hold 50 kg of cement is approximately 400 g, the mass of a HDPE/PP woven sack to hold 50 kg of cement is approximately 70 g/71 g respectively, and the mass of a jute synthetic union bag to hold 50 kg of cement is approximately 420 g.

ANNEX E
(*Foreword*)

COMMITTEE COMPOSITION

Cement and Concrete Sectional Committee, CED 02

Organization	*Representative(s)*
In Personal Capacity (*Grace Villa, Kadamankulam PO, Thiruvalla 689583, Kerala*)	SHRI JOSE KURIAN **(*Chairperson*)**
ACC Limited, Mumbai	SHRI RAKESH J. MODI DR MANISH V. KARANDIKAR (*Alternate*)
Ambuja Cements Limited, Ahmedabad	SHRI UMESH P. SONI SHRI SUKURU RAMARAO (*Alternate*)
Atomic Energy Regulatory Board, Mumbai	SHRI L. R. BISHNOI SHRI SOURAV ACHARYA (*Alternate*)
Builders' Association of India, Mumbai	SHRI SUSHANTA KUMAR BASU SHRI D. R. SEKOR (*Alternate*)
Cement Manufacturers Association, Noida	DR V. RAMACHANDRA SHRI PRAKHAR SRIVASTAVA (*Alternate*)
Central Public Works Department, New Delhi	SHRI A. K. RAJDEV SHRI SAUROBH KUMAR (*Alternate*)
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Cement, Pozzolana and Cement Additives Subcommittee, CED 2 : 1

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Panel for Revision of Cement Standards, CED 2 : 1/P1

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