COMPENDIUM OF INDIAN STANDARDS ON

CEMENT

PREPARED BY :

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PREFACE

Cement is one of the most widely used building material in the world. It is used in various applications such as infrastructure projects, building construction, cement matrix products, pavement construction, and many more. It is one of the most important constituents of concrete, the second most consumed material in the world. The quality of cement used in concrete is critical in ensuring the durability and strength of concrete structures. Bureau of Indian Standards (BIS) had formulated various standards on cement in order to establish uniform quality, composition, safety, and performance for different types of cement. These Indian Standards provide specifications related to raw materials used, manufacturing, physical and chemical requirements, storage, packaging and marking.

This compendium aims at providing an overview of Indian Standards on cement, offering insights into their specifications, physical and chemical requirements, and their applications. It is intended for use by cement manufacturers, construction professionals, engineers, quality control personnel, academic professionals, and regulatory authorities to enhance understanding and compliance with industry standards.

By compiling relevant standards on cement in a single document, this compendium serves as a ready reference for professionals involved in cement production, quality assessment, and application, contributing to improved construction quality and safety.

INTRODUCTION

Cement is a fundamental construction material that acts as a binding agent. It is a fine, grey powder composed primarily of calcium, silica, alumina, and iron oxide. When mixed with water, cement undergoes a chemical process known as hydration, forming a hard and durable mass. This property makes it invaluable in the construction industry. Its ability to bind materials together, harden under water, and provide long-lasting durability makes it indispensable for everything from small-scale residential buildings to massive infrastructure projects. With ongoing research, eco-friendly alternatives and advanced formulations are being developed to meet modern construction and environmental needs.

Raw Materials

The raw materials required for manufacture of Portland cement are calcareous materials such as limestone or chalk, and argillaceous materials such as shale or clay.

Manufacturing Process

The process of manufacture of cement consists of grinding the raw materials, mixing them intimately in certain proportions depending upon their purity and composition and burning them in a kiln at a temperature of about 1300 to 1500 degree Celsius, at which temperature, the material sinters and partially fuses to form nodular shaped clinker. The clinker is cooled and ground to fine powder with addition of about 3 to 5 percent of gypsum. The manufacturing of different types of cement had been described in the respective standards on cement.

There are two processes known as ‘wet’ and ‘dry’ processes depending upon whether the mixing and grinding of raw materials is done in wet or dry conditions. At present, dry process is most commonly used by cement plants because of higher energy consumption in the wet process.

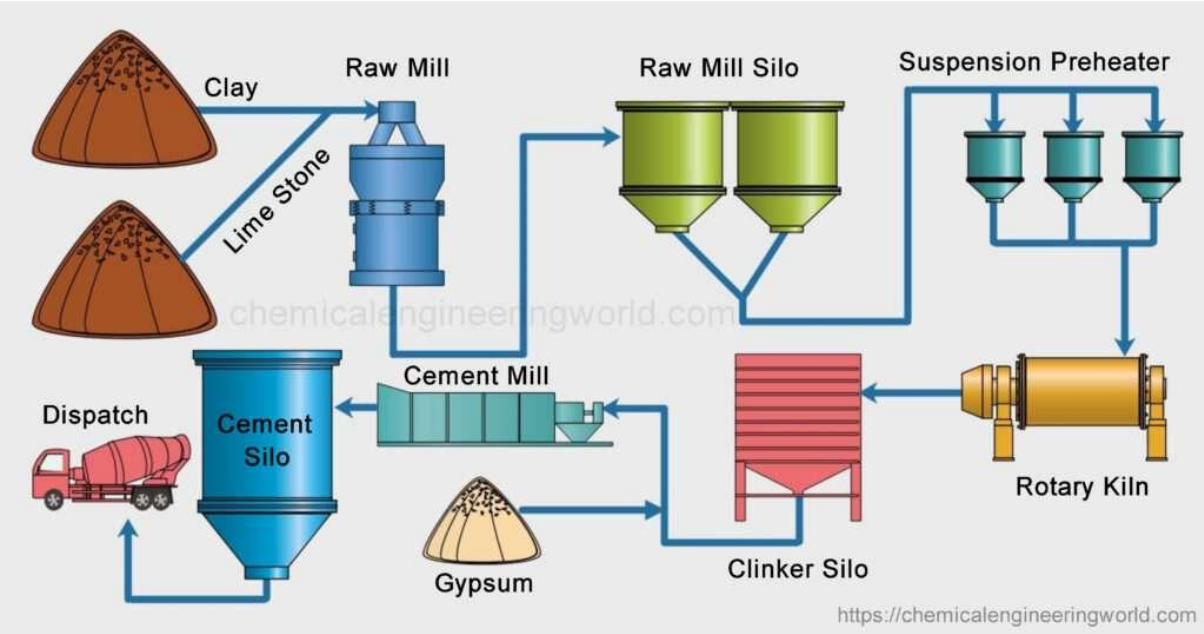

Figure showing manufacturing of cement

Properties of Cement

1) *Fineness* – Blaines Air Permeability Test is done for determining the fineness of cement. The method is based on the permeability to flow of air through a bed of cement. The fineness is expressed as specific surface area per gram of cement.

2) *Setting time (Initial and Final)* – These are measured by vicat apparatus, with different penetrating attachments. The term 'setting' is used to described the stiffening of cement paste, and the 'initial set' and 'final set' are used to describe arbitrary chosen stages of setting.

3) *Soundness* – The soundness of cement is determined in an accelerated manner by Le-Chatelier apparatus. The test detects unsoundness due to free time only. Unsoundness due to magnesia present in the raw materials from which cement is manufactured, is determined by autoclave test. This test is sensitive to both free lime and free magnesia. In this test high pressure steam accelerates the hydration of both magnesia and lime. The results of the autoclave test are affected by, in addition to the compounds causing expansion, the C_3A content.

4) *Compressive strength* – The compressive strength of cement is determined on 1:3 cement-sand mortar cube specimens with standard graded sand, cast and cured under controlled conditions of temperature and humidity. The water content in the mix is determined as ($P/4 + 3$) percent by mass of cement and sand, where P is percentage of water required for standard consistency. In most cases, it corresponds to a water-cement ratio of 0.37 to 0.42. The comprehensive strength is evaluated at 3, 7 and 28 days curing of cubes.

5) Transverse strength

Testing of Cement

The physical properties of cement are determined by the test methods given in IS 4031 (Part 1 to Part 15) whereas chemical properties of tested based on IS 4032.

The following Indian Standards lay down the test methods for checking the quality of various types of cements:

Sl No.	IS No.	Title
1.	IS 4031 (Part 1):1996	Methods of physical tests for hydraulic cement: Part 1 Determination of fineness by dry sieving (*second revision)*
2.	IS 4031 (Part 2):1999	Methods of physical tests for hydraulic cement: Part 2 Determination of fineness by Blaine air permeability method (*second revision)*
3.	IS 4031 (Part 3):1988	Methods of physical tests for hydraulic cement: Part 3 Determination of soundness (*first revision*)
4.	IS 4031 (Part 4):1988	Methods of physical tests for hydraulic cement: Part 4 Determination of consistency of standard cement paste (*first revision*)

5.	IS 4031 (Part 5):1988	Methods of physical tests for hydraulic cement: Part 5 Determination of initial and final setting times (*first revision*)
6.	IS 4031 (Part 6):1988	Methods of physical tests for hydraulic cement: Part 6 Determination of compressive strength of hydraulic cement other than masonry cement (*first revision*)
7.	IS 4031 (Part 7):1988	Methods of physical tests for hydraulic cement: Part 7 Determination of compressive strength of masonry cement (*first revision*)
8.	IS 4031 (Part 8):1988	Methods of physical tests for hydraulic cement: Part 8 Determination of transverse and compressive strength of plastic mortar using prism (*first revision*)
9.	IS 4031 (Part 9):1988	Methods of physical tests for hydraulic cement: Part 9 Determination of heat of hydration (*first revision*)
10.	IS 4031 (Part 10):1988	Methods of physical tests for hydraulic cement: Part 10 Determination of drying shrinkage (*first revision*)
11.	IS 4031 (Part 11):1988	Methods of physical tests for hydraulic cement: Part 11 Determination of density (*first revision*)
12.	IS 4031 (Part 12):1988	Methods of physical tests for hydraulic cement: Part 12 Determination of air content of hydraulic cement mortar (*first revision*)
13.	IS 4031 (Part 13):1988	Methods of physical tests for hydraulic cement: Part 13 Measurement of water retentivity of masonry cement (*first revision*)
14.	IS 4031 (Part 14):1989	Hydraulic cement — Methods of physical tests: Part 14 Determination of false set
15.	IS 4031 (Part 15):1991	Methods of physical tests for hydraulic cement: Part 15 Determination of fineness by wet sieving
16.	IS 4032:1985	Method of chemical analysis of hydraulic cement (*first revision*)

Apart from the above, following are the Indian Standards laying down instrumental methods for speedier testing of cements:

Sl No.	IS No.	Title
1)	IS 12423:1988	Method for colorimetric analysis of hydraulic cement
2)	IS 12803:1989	Methods of analysis of hydraulic cement by X-ray fluorescence spectrometer
3)	IS 12813:1989	Method of analysis of hydraulic cement by atomic absorption spectrophotometer

Hydration of cement

Hydration is the chemical reaction between cement and water that causes cement to harden and gain strength. When water is added to cement, a series of exothermic reactions occur between water and the chemical compounds in the cement, resulting in the formation of hydration products. This process is essential for the setting and hardening of cement and the eventual development of strength in concrete.

Indian Standards on Cement Specifications

Till date, BIS had formulated Indian Standards on 16 types of cement as listed below:

Sl No.	IS No.	Title
1)	IS 269 : 2015	Ordinary Portland cement — Specification (*sixth revision*)
2)	IS 455 : 2015	Portland slag cement — Specification (*fifth revision*)
3)	IS 1489 (Part 1) : 2015	Portland Pozzolana cement — Specification: Part 1 Flyash based (*fourth revision*)
4)	IS 1489 (Part 2) : 2015	Portland Pozzolana cement — Specification: Part 2 Calcined clay based (*fourth revision*)
5)	IS 3466 : 1988	Specification for masonry cement (*second revision)*
6)	IS 6452 : 1989	Specification for high alumina cement for structural use (*first revision*)
7)	IS 6909 : 1990	Specification for supersulphated cement (*first revision*)
8)	IS 8041 : 1990	Specification for rapid hardening Portland cement (*second revision)*
9)	IS 8042 : 2015	White Portland cement — Specification (*third revision*)
10)	IS 8043 : 1991	Specification for hydrophobic Portland cement
11)	IS 8229 : 1986	Specification for Oil-well Cement
12)	IS 12330 : 1988	Specification for sulphate resisting Portland cement
13)	IS 12600 : 1989	Specification for low heat Portland cement
14)	IS 16415 : 2015	Composite cement — Specification
15)	IS 16993 : 2018	Microfine ordinary Portland cement — Specification
16)	IS 18189 : 2023	Portland calcined clay limestone cement – Specification

ORDINARY PORTLAND CEMENT (OPC) [IS 269]

Ordinary Portland Cement (OPC) is the most commonly used cement in building construction. It is available in five grades namely OPC 33, OPC 43, OPC 53, OPC 43S and OPC 53S as per IS 269. It is a fine powder made primarily from limestone and clay, which is heated in a kiln to form clinker and then ground with gypsum to produce cement.

Manufacturing: It is produced by intimately mixing together calcareous and argillaceous and/or other silica, alumina or iron oxide bearing materials, burning them at a clinkering temperature and grinding the resultant clinker so as to produce a cement capable of complying with the standard. Also, no material shall be added after burning, other than gypsum (natural, mineral or chemical), water, 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.

Performance Improvers (PIs): IS 269 permits different types of performance improvers which may be added at grinding stage to enhance the properties of cement. The limits of addition of performance improvers shall be as per table given below and shall be inclusive of 1.0 percent additives used while manufacturing. If a combination of performance improvers is added, the maximum limit of total addition shall be 5 percent.

Sl No.	Performance Improver	Percentage Addition by Mass,	Requirement
i)	Fly ash	5	Conforming to IS 3812 (Part 1)
ii)	Granulated slag	5	Conforming to IS 12089
iii)	Silica fume	5	Conforming to IS 15388
iv)	Limestone	5	$CaCO_3$ content calculated from CaO content shall not be less than 75 percent when tested in accordance with IS 1760 (Part 3)
v)	Rice husk ash	5	a) Reactive silica shall not be less than 80 percent when tested as per IS 3812 (Part 1) b) Pozzolanic activity index shall not be less than 90 percent when tested as per **10** of IS 1727 c) c) Loss on ignition shall not be more than 5.0 percent when tested as per IS 1727
vi)	Metakaolin	5	Conforming to IS 16354
vii)	Copper slag	5	a) Proportion of lumps exceeding 50 mm size shall not be more than 5 percent of the mass of slag b) When tested as per IS 4032 the composition of slag shall comply the following chemical requirements: 1. SiO_2 – 20 percent to 40 percent 2. Fe_2O_3 – 40 percent to 70 percent 3. SO_3,*Max* – 1 percent c) Glass content as determined by the method of optical microscope shall not be less than 25 percent
viii)	Steel slag	5	a) Proportion of lumps exceeding 10 mm size shall not be more than 5 percent of the mass of slag

			b) When tested as per IS 4032 the composition of slag shall comply the following chemical requirements; 1. CaO – 40 percent to 55 percent 2. SiO_2 – 10 percent to 20 percent 3. MgO – 1 percent to 5 percent 4. MnO_2 – 0 percent to 1 percent 5. Al_2O_3 – 0.5 percent to 4 percent 6. Fe (total) – 15 percent to 30 percent 7. P – 0.5 percent to 2 percent c) Glass content as determined by the method of optical microscope shall not be less than 25 percent
ix)	Lead-Zinc slag	5	a) Proportion of lumps exceeding 10 mm size shall not be more than 5 percent of the mass of slag b) When tested as per IS 4032 the composition of slag shall comply the following chemical requirements: 1. ZnO – 5 percent to 15 percent 2. PbO – 0.5 percent to 2 percent 3. Fe_2O_3 – 30 percent to 40 percent 4. SiO_2 – 15 percent to 25 percent 5. CaO – 10 percent to 20 percent 6. Al_2O_3 – 10 percent to 15 percent 7. MgO – 1 percent to 3 percent c) Glass content as determined by the method of optical microscope shall not be less than 25 percent
x)	Spent fluidized catalytic cracking equilibrium catalyst	5	Conforming to IS 1344
xi)	Ground granulated blast furnace slag	5	Conforming to IS 16714

Physical Requirements: The cement shall meet the physical requirements as listed below.

Sl No.	**Characteristic**	**Requirement**					**Method of Test, Ref to**
		OPC 33	**OPC 43**	**OPC 43S**	**OPC 53**	**OPC 53S**	
(1)	(2)	(3)	(3)	(3)	(3)	(3)	(4)
i)	Fineness, m^2/kg, *Min*	225	225	370	225	370	IS 4031 (Part 2)
ii)	Soundness: a) By Le-Chatelier method, mm, *Max* b) By autoclave test method, percent, *Max*	10 (*see* Note 1) 0.8	10 (*see* Note 1) 0.8	5 (*see* Note 1) 0.8	10 (*see* Note 1) 0.8	5 (*see* Note 1) 0.8	IS 4031 (Part 3)
iii)	Setting time: a) Initial, min, *Min* b) Final, min, *Max*	30 (*see* Note 2) 600	30 (*see* Note 2) 600	120 (*see* Note 2) 600	30 (*see* Note 2) 600	120 (*see* Note 2) 600	IS 4031 (Part 5)
iv)	Compressive strength, MPa (*see* Note 4): a) 72 ± 1 h, *Min*	16	23	23	27	27	IS 4031 (Part 6)
	b) 168 ± 2 h, *Min*	22	33	37.5	37	37.5	
	c) 672 ± 4 h, *Min*	33	43	43	53	53	

	Max	48	58	–	–	–	
v)	Transverse strength (optional)	*See* Notes 3 and 4	*See* Notes 3 and 4	*See* Notes 3 and 4	*See* Notes 3 and 4	*See* Notes 3 and 4	IS 4031 (Part 8)

NOTE

1 In the event of cements failing to comply with any one or both the requirements of soundness specified in the above table, further tests in respect of each 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 to 80 percent for a total period of 7 days. The expansion of cements so aerated shall be not more than 5 mm and 0.6 percent when tested by Le-Chatelier method and autoclave test respectively. For OPC 43S and OPC 53S, the requirement of soundness of unaerated cement shall be maximum expansion of 5 mm when tested by the Le-Chatelier method.

2 If cement exhibits false set, the ratio of final penetration measured 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 be not 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 conform to the value given in the above table.

3 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.

4 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.

Chemical Requirements: When tested as per IS 4032, the cement shall meet the chemical requirements as listed below.

Sl No.	**Characteristic**	**Requirement**				
		OPC 33	OPC 43	OPC 43S	OPC 53	OPC 53S
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	Ratio of percentage of lime to percentages of silica, alumina and iron oxide, when calculated by the formula: $\frac{CaO - 0.7\ SO_3}{2.8\ SiO_2 + 1.2\ Al_2O_3 + 0.65\ Fe_2O_3}$	0.66 – 1.02	0.66 – 1.02	0.80 – 1.02	0.80 – 1.02	0.80 – 1.02
ii)	Ratio of percentage of alumina to that of iron oxide, *Min*	0.66	0.66	0.66	0.66	0.66
iii)	Insoluble residue, percent by mass, *Max*	5.0	5.0	2.0	5.0	2.0
iv)	Magnesia, percent by mass, *Max*	6.0	6.0	5.0	6.0	5.0
v)	Total sulphur content calculated as sulphuric anhydride (SO_3), percent by mass, *Max*	3.5	3.5	3.3	3.5	3.3
vi)	Loss on ignition, percent by mass, *Max*	5.0	5.0	4.0	4.0	4.0
vii)	Chloride content, percent by mass, *Max*	0.1 0.05 (for prestressed structures)	0.1 0.05 (for prestressed structures)	0.1 0.05 (for prestressed structures)	0.1 0.05 (for prestressed structures)	0.1 0.05 (for prestressed structures)
viii)	Alkali content	*see* Note 1				

NOTE

1 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 0.6 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.

2 Cement used for railway sleepers shall additionally satisfy the following chemical/mineralogical requirements:

a) Tricalcium aluminate content, percent by mass, *Max*	:	10.0 9.0 (for OPC 43S and OPC 53S)
b) Tricalcium silicate, percent by mass, *Min*	:	45.0

The tricalcium aluminate content (C_3A) and tricalcium silicate content (C_3S) are calculated by the formula:

$C_3A = 2.65 (Al_2O_3) – 1.69 (Fe_2O_3)$

$C_3S = 4.07 (CaO) – 7.60 (SiO_2) – 6.72 (Al_2O_3) – 1.43 (Fe_2O_3) – 2.85 (SO_3)$

where each symbol in brackets refers to the percent (by mass of total cement) of the oxide.

Applications and Uses:

It is used in all types of general construction work such as building construction, concrete pavements and flooring, plastering, etc.

PORTLAND POZZOLANA CEMENT (PPC) FLY ASH BASED [IS 1489 (PART 1)]

An intimately interground mixture of Portland cement clinker/ordinary Portland cement and pozzolana with the possible addition of gypsum (natural or chemical) or an intimate and uniform blending ordinary Portland cement and fine pozzolana with addition of ground gypsum, if required.

Raw Materials and Composition

The raw materials used in the manufacturing of PPC based on fly ash are fly ash (pozzolana) conforming to IS 3812 (Part 1), Portland cement clinker conforming to IS 16353, or ordinary Portland cement conforming to IS 269.

Manufacturing

Portland Pozzolana cement shall be manufactured either by intimately inter-grinding Portland cement clinker/ordinary Portland cement and fly ash or by intimately and uniformly blending ordinary Portland cement and fine fly ash with required addition of gypsum so as to produce a cement capable of complying with this standard. The fly ash constituent shall not be less than 15 percent and not more than 35 percent by mass of Portland pozzolana cement. The homogeneity of the mixture shall be guaranteed within ± 3 percent of the declared fly ash addition, in the same consignment.

When Portland pozzolana cement is obtained by grinding fly ash with Portland cement clinker, no material shall be added after burning, other than gypsum (natural mineral or chemical, *see* Note), water, 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. The limitation of all such additions shall also apply to manufacture of Portland pozzolana cement by blending process.

NOTE – Chemical gypsum shall be added provided that the performance requirements of the final product as specified in this standard are met with.

Physical Requirements – The cement shall meet the physical requirements as listed below.

Sl No.	Characteristic	Requirement	Method of Test, Ref to
(1)	(2)	(3)	(4)
i)	Fineness, m^2/kg, *Min*	300	IS 4031 (Part 2)
ii)	Soundness: a) By Le-Chatelier method, mm, *Max* b) By autoclave test method, percent, *Max*	 10 *see* Note 1 0.8	IS 4031 (Part 3)
iii)	Setting time: a) Initial, min, *Min* b) Final, min, *Max*	 30 *see* Note 2 600	IS 4031 (Part 5)
iv)	Compressive strength, MPa (*see* Note 4): a) 72 ± 1 h, *Min*	 16	IS 4031 (Part 6)
	b) 168 ± 2 h, *Min*	22	
	c) 672 ± 4 h, *Min*	33	

v)	Transverse strength (optional)	*See* Notes 3 and 4	IS 4031 (Part 8)
vi)	Drying shrinkage, percent, *Max*	0.15	IS 4031 (Part 10)

NOTES

1 In the event of cements failing to comply with any one or both the requirements of soundness specified in the above table, further tests in respect of each 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 to 80 percent for a total period of 7 days. The expansion of cements so aerated shall be not 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 measured 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 be not 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 conform to the value given in the above table.

3 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.

4 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.

Chemical Requirements – When tested as per IS 4032, the cement shall meet the chemical requirements as listed below.

Sl No.	Characteristic	Requirement
(1)	(2)	(3)
i)	Insoluble residue, percent by mass a) *Max* b) *Min*	 $x + \frac{4.0(100-x)}{100}$ $0.6\,x$ Where x is the declared percentage of fly ash in the given Portland pozzolana cement.
ii)	Magnesia, percent by mass, *Max*	6.0
iii)	Total sulphur content calculated as sulphuric anhydride (SO_3) percent by mass, *Max*	3.5
iv)	Loss on ignition, percent by mass, *Max*	5.0
v)	Chloride content, percent by mass, *Max*	0.1 0.05 (for prestressed structures)
vi)	Alkali content (*see* Note)	*See* Note 1

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 0.6 percent expressed as sodium oxide ($Na_2O + 0.658\ K_2O$) , is recommended. However, in the case of cement having a minimum fly ash content of 30 percent, a maximum alkali content of 0.9 percent, expressed as sodium oxide (Na2O+ 0.658 K2O) 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.

Applications and uses:

It is most widely used type of cement in the building construction. It is also used in hydraulic structures, mass concrete structures such as dams, bridge piers, foundations, etc, marine structures, and all other situations where OPC is used except where high early strength is of special requirement.

PORTLAND POZZOLANA CEMENT CALCINED CLAY BASED [IS 1489 (Part 2)]

An intimately interground mixture of Portland cement clinker/ordinary Portland cement and pozzolana with the possible addition of gypsum (natural or chemical) or an intimate and uniform blending ordinary Portland cement and fine pozzolana with addition of ground gypsum, if required.

Raw Materials and Composition

The raw materials used in the manufacturing of PPC based on calcined clay are pozzolana which shall be either calcined clay pozzolana conforming to IS 1344 or a mixture of calcined clay pozzolana conforming to IS 1344 and fly ash conforming to IS 3812 (Part 1), Portland cement clinker conforming to IS 16353, or ordinary Portland cement conforming to IS 269.

Manufacturing

Portland Pozzolana cement shall be manufactured either by,

a) intimately inter-grinding Portland cement clinker and calcined clay pozzolana or a mixture of calcined clay pozzolana and fly ash; or
b) intimately and uniformly blending ordinary Portland cement and finely ground calcined clay pozzolana or a mixture of finely ground calcined clay pozzolana and fine fly ash;

with required addition of gypsum so as to produce a cement capable of complying with this standard. The total pozzolana constituent shall not be less than 10 percent and not more than 25 percent by mass of Portland pozzolana cement. The homogeneity of the mixture shall be guaranteed within ± 3 percent of the declared pozzolana addition, in the same consignment.

When Portland pozzolana cement is obtained by grinding calcined clay or a mixture of calcined clay and fly ash with Portland cement clinker, no material shall be added after burning, other than gypsum [natural mineral or chemical, (*see* Note)], water, 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. The limitation of all such additions shall also apply to manufacture of Portland pozzolana cement by blending process.

NOTE – Chemical gypsum shall be added provided that the performance requirements of the final product as specified in this standard are met with.

Physical Requirements: The cement shall meet the physical requirements as listed below.

Sl No.	Characteristic	Requirement	Method of Test, Ref to
(1)	(2)	(3)	(4)
i)	Fineness, m^2/kg, *Min*	300	IS 4031 (Part 2)
ii)	Soundness: a) By Le-Chatelier method, mm, *Max* b) By autoclave test method, percent, *Max*	 10 } *see* Note 1 0.8 }	IS 4031 (Part 3)
iii)	Setting time: a) Initial, min, *Min* b) Final, min, *Max*	 30 } *see* Note 2 600}	IS 4031 (Part 5)

iv)	Compressive strength, MPa (*see* Note 3): a) 72 ± 1 h, *Min*	16	IS 4031 (Part 6)
	b) 168 ± 2 h, *Min*	22	
	c) 672 ± 4 h, *Min*	33	
v)	Transverse strength (optional)	*See* Notes 3 and 4	IS 4031(Part 8)
vi)	Drying shrinkage, percent, *Max*	0.15	IS 4031(Part 10)

NOTES

1 In the event of cements failing to comply with any one or both the requirements of soundness specified in the above table, further tests in respect of each 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 to 80 percent for a total period of 7 days. The expansion of cements so aerated shall be not 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 measured 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 be not 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 conform to the value given in the above table.

3 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.

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.

Chemical Requirements – When tested as per IS 4032, the cement shall meet the chemical requirements as listed below.

Sl No.	Characteristic	Requirement
(1)	(2)	(3)
i)	Insoluble residue, percent by mass a) *Max* b) *Min*	 $x + \frac{4.0(100 - x)}{100}$ $0.6\,x$ Where x is the declared percentage of pozzolana in the given Portland pozzolana cement.
ii)	Magnesia, percent by mass, *Max*	6.0
iii)	Total sulphur content calculated as sulphuric anhydride (SO_3) percent by mass, *Max*	3.5
iv)	Loss on ignition, percent by mass, *Max*	5.0
v)	Chloride content, percent by mass, *Max*	0.1 0.05 (for prestressed structures)
vi)	Alkali content (*see* Note)	*See* Note 1

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 0.6 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.

Applications and Uses:

It is suitable for use in the building construction, marine and coastal structures, mass concrete structures such as dams, bridge piers, foundations, etc, highway and other infrastructure projects.

PORTLAND SLAG CEMENT (IS 455)

An intimately interground mixture of Portland cement clinker and granulated slag with addition of gypsum and permitted additives or an intimate and uniform blend of ordinary Portland cement and finely ground granulated slag with addition of ground gypsum, if required. Slag in granulated form is used for the manufacture of hydraulic cement. Slag is a non-metallic product consisting essentially of glass containing silicates and alumino-silicates of lime and other bases, as in the case of blastfurnace slag, which is developed simultaneously with iron in blastfurnace or electric pig iron furnace. Granulated slag is obtained by further processing the molten slag by rapidly chilling or quenching it with water or steam and air.

Raw Materials and Composition

The raw materials used in the manufacturing of PSC are granulated slag conforming to IS 12089 (Part 1), ground granulated blast furnace slag for blending with Portland cement conforming to IS 16714. Portland cement clinker conforming to IS 16353, or ordinary Portland cement conforming to IS 269.

Manufacturing

Portland slag cement shall be manufactured either by intimately inter-grinding Portland cement clinker and granulated slag or by intimately and uniformly blending ordinary Portland cement and finely ground granulated slag with required addition of gypsum/ground gypsum so as to produce a cement capable of complying with this standard. The granulated slag constituent shall not be less than 25 percent and not more than 70 percent by mass of Portland slag cement. The homogeneity of the mixture shall be guaranteed within ±3 percent of the declared slag addition, in the same consignment.

When Portland slag cement is obtained by grinding granulated slag with Portland cement clinker, no material shall be added after burning, other than gypsum (natural mineral or chemical, *see* Note), water, 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. The limitation of all such additions shall also apply to manufacture of Portland slag cement by blending process.

NOTE – Chemical gypsum shall be added provided that the performance requirements of the final product as specified in this standard are met with.

Physical Requirements: The cement shall meet the physical requirements as listed below.

Sl No.	Characteristic	Requirement	Method of Test, Ref to
(1)	(2)	(3)	(4)
i)	Fineness, m^2/kg, *Min*	225	IS 4031 (Part 2)
ii)	Soundness: a) By Le-Chatelier method, mm, *Max* b) By autoclave test method, percent, *Max*	 10 } *see* Note 1 0.8 }	IS 4031 (Part 3)
iii)	Setting time: c) Initial, min, *Min*	 30 } *see* Note 2	IS 4031 (Part 5)

	b) Final, min, *Max*	600}	
iv)	Compressive strength, MPa (*see* Note 3): a) 72 ± 1 h, *Min*	16	IS 4031 (Part 6)
	b) 168 ± 2 h, *Min*	22	
	c) 672 ± 4 h, *Min*	33	
v)	Transverse strength (optional)	*See* Notes 3 and 4	IS 4031(Part 8)

NOTES

1 In the event of cements failing to comply with any one or both the requirements of soundness specified in the above table, further tests in respect of each 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 to 80 percent for a total period of 7 days. The expansion of cements so aerated shall be not 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 measured 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 be not 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 conform to the value given in the above table.

3 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.

4 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.

Chemical Requirements – When tested as per IS 4032, the cement shall meet the chemical requirements as listed below.

Sl No.	Characteristic	Requirement
(1)	(2)	(3)
i)	Insoluble residue, percent by mass, *Max*	4.0
ii)	Magnesia, percent by mass, *Max*	10.0
iii)	Total sulphur content calculated as sulphuric anhydride (SO_3), percent by mass, *Max*	3.5
iv)	Sulphide sulphur (S), *Max*	1.5
v)	Loss on ignition, percent by mass, *Max*	5.0
vi)	Chloride content, percent by mass, *Max*	0.1 0.05 (for prestressed structures)
vii)	Alkali content (*see* Note)	*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 0.6 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. However, in the case of cement having a minimum slag content of 50 percent, a maximum alkali content of 0.9 percent, expressed as sodium oxide (Na2O+ 0.658 K2O) is recommended.

Applications and Uses:

Portland slag cement offers high resistance to chloride and sulphate attacks and hence highly suitable for marine structures, ports and harbours, sewage treatment plants, canal lining, tunnels, piling works, basement of buildings, etc.

WHITE PORTLAND CEMENT (IS 8042)

White Portland cement shall be manufactured by intimately grinding the Portland cement clinker with appropriate proportion of natural or chemical gypsum so as to produce a cement capable of complying with this standard. No material shall be added after burning, other than gypsum (natural mineral or chemical, *see* Note), water, and not more than a total of 1.0 percent of air-entraining agents or other agents, which have proved not to be harmful and don't have any negative influence on the degree of whiteness of cement. The performance improver(s) may be added at grinding stage; and their limits of addition shall be as given below:

Limestone, dolomite and marble may be added as performance improver either individually or in combination, and the total limit of their addition shall not be more than 10 percent. The performance improver(s) shall be inclusive of 1.0 percent additives as mentioned above and shall meet the following requirements:

a) CaO + MgO shall not be less than 50 percent by mass of performance improver, when tested as per IS 1760 (Part 3), and
b) Whiteness shall not be less than 70 percent when tested as per Annex B of IS 8042.

All the above additions may also be done by interblending process by intimately and uniformly blending the individually ground materials so as to produce a cement capable of complying with this standard.

NOTE – Chemical gypsum shall be added provided that the performance requirements of the final product as specified in this standard are met with.

Physical Requirements: The cement shall meet the physical requirements as listed below.

Sl No.	Characteristic	Requirement	Method of Test, Ref to
(1)	(2)	(3)	(4)
i)	Fineness, m^2/kg, *Min*	225 (see Note 1)	IS 4031 (Part 2)
ii)	Soundness: a) By Le-Chatelier method, mm, *Max* b) By autoclave test method, percent, *Max*	 10 } *see* Note 2 0.8 }	IS 4031 (Part 3)
iii)	Setting time: a) Initial, min, *Min* b) Final, min, *Max*	 30 } *see* Note 3 600}	IS 4031 (Part 5)
iv)	Compressive strength, MPa (*see* Note 3): a) 72 ± 1 h, *Min*	 16	IS 4031 (Part 6)
	b) 168 ± 2 h, *Min*	22	
	c) 672 ± 4 h, *Min*	33	
v)	Transverse strength (optional)	*See* Notes 4 and 5	IS 4031(Part 8)
vi)	Degree of whiteness in terms of reflectance of neat cement ring, percent, *Min*	70	Annex B of IS 8042

NOTES

1 Those industries which require fineness of white Portland cement in terms of residue by dry sieving, tested by the method described in IS 4031(Part 1), may specify the same additionally while placing order to a manufacturer by mutual agreement.

2 In the event of cements failing to comply with any one or both the requirements of soundness specified in the above table, further tests in respect of each 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 to 80 percent for a total period of 7 days. The expansion of cements so aerated shall be not more than 5 mm and 0.6 percent when tested by Le-Chatelier method and autoclave test respectively. For OPC 43-S and OPC 53-S, the requirement of soundness of unaerated cement shall be maximum expansion of 5 mm when tested by the Le-Chatelier method.

3 If cement exhibits false set, the ratio of final penetration measured 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 be not 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 conform to the value given in the above table.

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.

Chemical Requirements – When tested as per IS 4032, the cement shall meet the chemical requirements as listed below.

Sl No.	Characteristic	Requirement
(1)	(2)	(3)
i)	Ratio of percentage of lime to percentages of silica, alumina and iron oxide, when calculated by the formula: $\frac{CaO - 0.7\ SO_3}{2.8\ SiO_2 + 1.2\ Al_2O_3 + 0.65\ Fe_2O_3}$	0.66 – 1.02
ii)	Iron oxide, percent by mass, *Max*	1.0
iii)	Insoluble residue, percent by mass, *Max*	4.0
iv)	Magnesia, percent by mass, *Max*	6.0
v)	Total sulphur content calculated as sulphuric anhydride (SO_3), percent by mass, *Max*	3.5
vi)	Loss on ignition, percent by mass, *Max*	7.0
vii)	Chloride content, percent by mass, *Max*	0.1

Applications and Uses:

1. Aesthetic applications such as interior and exterior wall finishes, architectural panels, etc.
2. Used as a base in tile filler gaps (grouts) and tile adhesives (in kitchens and bathrooms).
3. Suitable for construction and restoration of historical monuments, statues and heritage structures.
4. Used as a binder in terrazzo flooring and mosaic tiles.

COMPOSITE CEMENT (IS 16415)

An intimately interground mixture of Portland cement clinker, granulated slag and fly ash with addition of gypsum (natural or chemical) or an intimate and uniform blending of ordinary Portland cement, finely ground granulated slag and fine fly ash with addition of ground gypsum, if required.

Raw Materials and Composition

The raw materials used in the manufacturing of composite cement are fly ash conforming to IS 3812 (Part 1) (The use of coarser fly ash as per the note under Table 2 of IS 3812 (Part 1) shall also be permitted in case of manufacture of composite cement by intergrinding process), granulated slag conforming to IS 12089, Portland cement clinker conforming to IS 16353, or ordinary Portland cement conforming to IS 269.

Manufacturing

Composite cement shall be manufactured either by,

a) intimately inter-grinding Portland cement clinker, granulated sag and fly ash; or
b) intimately and uniformly blending ordinary Portland cement, finely ground granulated slag and fine fly ash;

with required addition of gypsum so as to produce a cement capable of complying with this standard, maintaining the proportions as given below:

Sl No.	Material	Proportion (Percent by Weight)	Proportion (Percent by Weight as per Amendment No. 1)
(1)	(2)	(3)	(4)
i)	Portland cement clinker/ ordinary Portland cement	35 - 65	45, Min for Portland cement clinker and 50, Min for OPC
ii)	Fly ash	15 - 35	10 - 25
iii)	Granulated slag	20 - 50	25 - 40

The homogeneity of the mixture shall be guaranteed within ± 3 percent of the declared slag and fly ash addition, in the same consignment.

When composite cement is obtained by grinding granulated slag and fly ash with Portland cement clinker, no material shall be added after burning, other than gypsum (natural mineral or chemical, *see* Note), water, 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. The limitation of all such additions shall also apply to manufacture of composite cement by blending process.

NOTE – Chemical gypsum shall be added provided that the performance requirements of the final product as specified in this standard are met with.

Physical Requirements – The cement shall meet the physical requirements as listed below.

Sl No.	Characteristic	Requirement	Method of Test, Ref to
(1)	(2)	(3)	(4)
i)	Fineness, m^2/kg, *Min*	300	IS 4031 (Part 2)
ii)	Soundness: a) By Le-Chatelier method, mm, *Max* b) By autoclave test method, percent, *Max*	 10 } *see* Note 1 0.8 }	IS 4031 (Part 3)
iii)	Setting time: a) Initial, min, *Min* b) Final, min, *Max*	 30 } *see* Note 2 600}	IS 4031 (Part 5)
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)	Transverse strength (optional)	*See* Notes 3 and 4	IS 4031(Part 8)
vi)	Drying shrinkage, percent, *Max*	0.15	IS 4031 (Part 10)

NOTES

1 In the event of cements failing to comply with any one or both the requirements of soundness specified in the above table, further tests in respect of each 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 to 80 percent for a total period of 7 days. The expansion of cements so aerated shall be not 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 measured 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 be not 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 conform to the value given in the above table.

3 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.

4 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.

Chemical Requirements – When tested as per IS 4032, the cement shall meet the chemical requirements as listed below.

Sl No.	Characteristic	Requirement
(1)	(2)	(3)
i)	Insoluble residue, percent by mass: a) *Max* b) *Min*	 $x + \frac{4.0(100-x)}{100}$ $0.6\,x$ Where x is the declared percentage of pozzolana in the given composite cement

ii)	Magnesia, percent by mass, *Max*	8.0
iii)	Total sulphur content calculated as sulphuric anhydride (SO_3) percent by mass, *Max*	3.5
iv)	Sulphide sulphur (S), *Max*	0.75
v)	Loss on ignition, percent by mass, *Max*	5.0
vi)	Chloride content, percent by mass, *Max*	0.1 0.05 (For prestressed structures)
vii)	Alkali content (*see* Note)	*See* Note 1

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 0.6 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.

Applications and Uses:

1. As it uses industrial by-products (fly ash and slag), results in less CO_2 emissions.
2. Due to lower heat of hydration, it reduces thermal cracking in mass concrete works.
3. Due to high resistance to chloride and sulphate attack, it can be used in marine and coastal structures
4. Ideal for use in general construction works.

MASONRY CEMENT (IS 3466)

Product obtained either by intimately intergrinding a mixture of Portland cement clinker with pozzolanic materials, such as flyash and calcined clay pozzolana; and/or non-pozzolanic (inert) materials, such as limestone, conglomerates, dolomitic limestone, dolomite, granulated slag; and waste materials like carbonated sludge, mine tailings; and gypsum (chemical or natural) and an air-entraining plasticizer, if required, in suitable proportions; or by intimately and uniformly blending ordinary Portland cement and finely ground materials mentioned above, so that the resulting product conforms to the requirements laid down in the standard.

Physical Requirements: Masonry cement, when tested in accordance with the methods of test specified in IS 4031, shall conform to the physical requirements given below:

Sl No.	Characteristics	Requirement
(1)	(2)	(3)
i)	Fineness: Residue on 45 micron IS Sieve, *Max,* percent (by wet sieving)	15
ii)	Setting Time:	
	a) Initial, min, *Min*	90
	b) Final, min, *Max*	1440
iii)	Soundness:	
	a) By Le-Chatelier method, mm, *Max*	10
	b) By Autoclave test method, percent, *Max*	1
iv)	Compressive Strength: Average compressive strength of not less than 3 mortar cubes of 50 mm size, composed of 1 part masonry cement and 3 parts standard sand* by volume, MPa, *Min*	
	7 days	2.5
	28 days	5
v)	Air content: Air content of mortar composed of 1 part masonry cement and 3 parts standard sand by volume, percent, *Min*	6
vi)	Water Retention : Flow after suction of mortar composed of 1 part masonry cement and 3 parts standard sand by volume, percent of original flow, *Min*	60

*Standard sand shall conform to IS 650 'Specification for standard sand for testing of cement (*first revision*)'.

Also,

1) If cement exhibits false set, the ratio of final penetration measured after 5 minutes of completion of mixing period to the initial penetration measured exactly after 20 seconds of completion of mixing period, expressed as percent, shall 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 after breaking the false set, shall conform to the requirements given in the standard.

2) In the event of cements failing to comply with any one or both the requirements of soundness specified in Table 1 of IS 3466, further tests in respect of each failure shall be made as described in IS 4031 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.

Staining Requirement

This requirement shall apply only when a purchaser specifically states that cement shall be non-staining to limestone. Non-staining cement shall contain not more than 0.03 percent of water soluble alkali when determined in accordance with the method given in IS 4032. The amount and nature of the staining material in limestones seems to vary with the stone. The alkali in any cement may, therefore, induce markedly different staining on different stones, even though it may have come apparently from the same source. The amount of water soluble alkali permitted by the specification should not cause stain unless stone high in staining material is used, or unless insufficient means have been used to prevent infiltration of water into the masonry.

Applications and uses:

Masonry cement is chiefly intended for use in masonry mortars for brick, stone and concrete block masonry, and for rendering and plastering work. Because of its property of producing a smooth, plastic, cohesive and strong, yet workable, mortar when mixed with fine aggregates, masonry cement is considered superior to lime mortar, lime-cement mortar or cement mortar.

Caution

Masonry cement is not intended for use in structural concrete for flooring and foundation work or for reinforced and prestressed concrete works.

HIGH ALUMINA CEMENT FOR STRUCTURAL USE (IS 6452)

High alumina cement shall be manufactured from aluminous and calcareous materials either by fusion or by sintering, and grinding the resulting clinker so as to produce a cement complying with this specification. No materials, other than water, shall be added during grinding of the cement. The total alumina content (Al_2O_3) determined in accordance with the method specified in IS 4032 shall not be less than 32 percent by mass.

Physical requirements

1) **Fineness –** Fineness of cement expressed in terms of specific surface determined by Blaine's air permeability method described in IS 4031 (Part 2) shall be not less than 225 m^2/kg.

2) Soundness – When tested by the 'Le-Chatelier' method described in IS 4031 (Part 3), (except that the quantity of mixing water shall be 22 percent of cement by mass) the cement shall not have an expansion of more than 5 mm.

3) Setting Time – The setting time of cement, when tested by the Vicat apparatus method described in IS 4031 (Part 5) (except that the quantity of mixing water shall be 22 percent of cement by mass) shall conform to the following requirements:

a) Initial setting time not less than 30 min, and
b) Final setting time not more than 10 h.

4) Compressive Strength – The average compressive strength of at least three mortar cubes (area of face 50 cm^2) composed of one part of cement, three parts of standard sand (conforming to IS 650) by mass and 10.5 to 11 percent (of combined mass of cement plus sand) water, and prepared, stored and tested at temperature 18°C ± 2°C in the manner described in IS 4031 (Part 6) shall be as follows:

a) At 24 h ± 30 min not less than 30 MPa, and
b) At 72 h ± 1 h shall show an increase on the compressive strength at 24 h and shall be not less than 35 MPa.

Applications and Uses:

High alumina cement is mainly a refractory cement but in some cold regions this cement may find use as a structural material taking advantage of high heat of hydration and high early strength development. The use of this cement is restricted to areas of continuously low temperature where highest summer temperatures do not exceed 18°C.

Caution

1) In view of the restrogression in strength and reduced durability, high alumina cement shall not be used in locations where the ambient temperatures are likely to exceed 18°C even for short periods. It shall not be used in mass concrete in view of the high heat of hydration inducing conversion of the hydrated compounds;
2) Accelerators like calcium chloride shall not be used with this cement;
3) Steam curing or elevated temperature of curing shall be avoided; and
4) It shall not be mixed with any other type of cement.

SUPERSULPHATED CEMENT (IS 6909)

A hydraulic cement produced by intergrinding or intimately blending a mixture of granulated blast furnace slag, calcium sulphate and a small amount of Portland cement, Portland cement clinker or any other source of lime. Calcium sulphate shall be obtained by calcining high purity gypsum to convert it to anhydrite; calcination temperature may range from 500°C to 700°C. Naturally occurring anhydrite ($CaSO_4$) or industrial by-product anhydrite may also be used.

Manufacturing

Supersulphated cement shall be manufactured by intergrinding or intimately blending a mixture of granulated blast furnace slag, calcium sulphate and a small amount of 33 grade ordinary Portland cement, Portland clinker or any other source of lime. The dry granulated blast furnace slag component of the mixture shall not be less than 70 percent by mass. The cement shall be ground finer than 33 grade ordinary Portland cement and the technology of production shall ensure most intimate blending of its constituents. When produced by intimate blending, the various ingredients sought to be blended shall also have prior grinding to the fineness required. An approved or established grinding aid may be used provided it is used in very small amounts in a manner similar to the grinding of clinker.

Physical Requirements

Sl No.	Characteristics	Requirement	Method of Test, Ref to
(1)	(2)	(3)	(4)
i)	Fineness, m^2/kg, *Min* (by Blaine's air permeability method)	400	IS 4031 (Part 2)
ii)	Setting Time: (*see* also Note 1)		IS 4031 (Part 5)
	a) Initial, min, *Min*	30	
	b) Final, min, *Max*	600	
iii)	Soundness (By Le-Chatelier method), mm, *Max* (*see* Note 2)	5	IS 4031 (Part 3)
iv)	Compressive Strength: Average compressive strength of not less than 3 mortar cubes (area of face 50 cm^2), composed of 1 part supersulphate cement and 3 parts standard sand (as per IS 650) by mass *$p/4$ + 3.0 percent (of combined mass of cement plus sand) water, MPa, *Min (see* Notes 4 and 5)		IS 4031 (Part 6)
	3 days	15	
	7 days	22	
	28 days	30	

NOTES

1 If cement exhibits false set, the ratio of final penetration measured after 5 minutes of completion of mixing period to the initial penetration measured exactly after 20 seconds of completion of mixing period, expressed as percent, shall be less than 50 when tested according to the method described in IS 4031 (Part 14). 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 conform to the specified requirement.

2 The Le-Chatlier's method as described in IS 4031 (Part 3) is modified to omit the boiling test so that the initial reading is taken immediately after moulding and the final reading after immersion in

water at 27°C ± 2°C for 24 hours shall comply to the requirement given above. The Le-Chatelier boiling test procedure and autoclave expansion are omitted since excessive unhydrated calcium oxide and periclase content are note envisaged.

3 '*p'* is the percentage of water required to produce a paste of standard consistency *(see* 11.3).

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 in addition to the compressive strength test. The permissible values of the transverse strength for supersulphated cement shall be mutually agreed to between the purchaser and supplier at the time of placing order.

5 Notwithstanding the compressive and transverse strength requirements, supersulphated cement shall show at 168 hours and 672 hours a progressive increase in strength from the strength at 72 hours.

Chemical Requirements – When tested as per IS 4032, the cement shall meet the chemical requirements as listed below.

Sl No.	Characteristics	Requirement
(1)	(2)	(3)
i)	Insoluble residue, percent, *Max*	4
ii)	Magnesium oxide, percent, *Max*	10
iii)	Sulphuric anthydride, percent, *Min*	6
iv)	Sulphide sulphur, percent, *Max*	1.5

NOTES

1 The limit of total chloride content in cement for use in plain and other reinforced concrete structures is being reviewed. Till that time, the limit may be mutually agreed to between the purchaser and the manufacturer. (Method of test for determination of chloride content in cement, is given in IS 12423).

2 Granulated slag conforming to IS 12089 has been found suitable for the manufacture of supersulphated cement.

Applications and Uses:

Supersulphated cement has been successfully used in a variety of aggressive conditions, for example, for marine works, mass concrete jobs to resist the attack by aggressive water, reinforced concrete pipes in ground water, concrete construction in sulphate bearing soils, and in chemical works under conditions involving exposure to high concentrations of sulphates of weak solutions of mineral acids. It has been used for the underside of bridges over railways and for concrete sewers carrying industrial effluents. Its use under tropical conditions has also been recommended, provided the prevailing temperature is below 40°C. Although its use as a general purpose cement can be made with adequate precautions, it is not recommended for producing steam-cured products.

RAPID HARDENING PORTLAND CEMENT (IS 8041)

Rapid hardening Portland cement shall be manufactured by intimately mixing together calcareous and argillaceous and/ or other silica, alumina or iron oxide bearing materials, burning them at a clinkering temperature and grinding the resultant clinker so as to produce a cement capable of complying with this specification. No material shall be added after burning other than gypsum (natural or chemical) or water or both, and not more than one percent of air-entraining agents or other agents which have proved not to be harmful.

Physical Requirements

1) Fineness – When tested for fineness in terms of specific surface by Blaine's air permeability method as described in IS 4031 (Part 2), the specific surface of rapid hardening Portland cement shall be not less than 325 m^2/ kg.

2) Soundness – When tested by 'Le-Chatelier' method and autoclave test described in IS 4031 (Part 3), unaerated cement shall not have an expansion of more than 10 mm and 0.8 percent respectively. Also, in the event of cements failing to comply with any one or both the requirements as specified, further tests in respect of each 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 relative humidity of 50 to 80 percent for a total period of 7 days. The expansion of cement so aerated shall be not more than 5 mm and 0.6 percent when tested by 'Le-Chatelier' method and autoclave test respectively.

3) Setting Time – The setting time of the cement, when tested by the Vicat apparatus method described in IS 4031 (Part 5) shall conform to the following requirements:

a) Initial setting time in minutes, not less than 30, and
b) Final setting time in minutes, not more than 600.

If cement exhibits false set, the ratio of final penetration measured after 5 min of completion of mixing period to the initial penetration measured exactly after 20 sec of completion of mixing period, expressed as percent, shall be less than 50 when tested by the method described in IS 4031 (Part 14). 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 conform to the above.

4) Compressive Strength – The average compressive strength of at least three mortar cubes (area of face as 50 cm^2) composed of one part of cement and three parts of standard sand (conforming to IS 650) by mass and P/ 4 + 3.0 percent (of combined mass of cement and sand) water where 'P' is the percentage of water required to produce a paste of standard consistency, and prepared, stored and tested in the manner described in IS 4031 (Part 6), shall be as follows:

a) 24 hours ± 30 minutes	Not less than 16 MPa
b) 72 ± 1 hours	Not less than 27 MPa

Chemical Requirements – When tested as per IS 4032, the cement shall meet the chemical requirements as listed below.

Sl No.	Characteristic	Requirement
(1)	(2)	(3)
i)	Ratio of percentage of lime to percentages of silica, alumina and iron oxide, when calculated by the formula: $\frac{CaO-0.7\,SO_3}{2.8SiO_2+1.2Al_2O_3+0.65Fe_2O_3}$	Not greater than 1.02 and not less than 0.66
ii)	Ratio of percentage of alumina to that of iron oxide	Not less than 0.66
iii)	Insoluble residue, percent by mass	Not more than 4 percent
iv)	Magnesia, percent by mass	Not more than 6 percent
v)	Total sulphur content calculated as sulphuric anhydride (SO_3), percent by mass	Not more than 2.5 and 3.0 when tricalcium aluminate (see Note 1) percent by mass is 5 or less and greater less and greater than 5 respectively
vi)	Total loss on ignition	Not more than 5 percent

NOTE

1 The tri-calcium aluminate content ($\boldsymbol{C_3A}$) is calculated by the formula:

$$\boldsymbol{C_3A = 2.65\,(Al_2O_3) - 1.69(Fe_2O_3)}$$

where each symbol in brackets refers to the percentage (by mass of total cement) of the oxide, excluding any contained in the insoluble residue referred at Sl No. (iii).

2 Alkali aggregate reactions have been noticed in aggregates in some parts of the country. 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 0'6 percent expressed as sodium (Na_2O), is recommended. Where however, such cements are not available, use of Portland pozzolana cement or cement pozzolanic admixture is recommended.

3 Total chloride content in cement shall not exceed 0.05 percent by mass for cement used in prestressed concrete structures and long span reinforced concrete structures. (Method of test for determination of chloride content in cement is given in IS 12423).

4 The limit of total chloride content in cement for use in plain and other reinforced concrete structures shall be as per IS 456. Till such time, the limit may be mutually agreed to between the purchaser and the manufacturer.

Applications and Uses:

1. Prefabricated concrete construction
2. Where formwork is required to be removed early for re-use
3. Road repair works

HYDROPHOBIC CEMENT (IS 8043)

Hydrophobic cement obtained by grinding 33 grade ordinary Portland cement clinker with an additive which will impart to ground cement, a water repelling property which shall be destroyed only by wet attrition, such as in concrete mixer. The hydrophobic quality of cement would facilitate its storage for longer periods in extremely wet climatic conditions.

Manufacturing

Hydrohobic cement shall be manufactured by intimately mixing together calcareous and argillaceous and/or other silica, alumina or iron oxide bearing materials burning them at clinkering temperature and grinding the resultant clinker with natural or chemical gypsum and small quantities (0.1 percent to 0.5 percent by mass of clinker) of a hydrophobic agent. Some of the hydrophobic agents used in the manufacture of hydrophobic cement are oleic acid, naphthenic acid, stearic acid, pentachlorophenol, etc.

Physical Requirements

1) Fineness – When tested for fineness in terms of specific surface by Blaine's air permeability method as described in IS 4031 (Part 2), the specific surface of the hydrophobic cement shall be not less than 350 m^2/kg.

2) The physical requirements, such as soundness and setting time shall be as laid down in IS 269.

3) Compressive Strength – The average compressive strength of at least three mortar cubes (area of face 50 cm^2) composed of one part of cement, three parts of standard sand (conforming to IS 650) by mass and P/4 + 3.0 percent (of combined mass of cement and sand) water, and prepared, stored and tested in the manner described in IS 4031 (Part 6) shall be as follows:

a) 72 ± 1 hours	Not less than 15.69 MPa
b) 168 ± 2 hours	Not less than 21.57 MPa
c) 672 ± 4 hours	Not less than 30.40 MPa

4) Hydrophobicity of the cement shall be tested and accepted in accordance with the method described in Annex B of the standard.

Chemical requirements – The chemical requirements of hydrophobic cement shall be as laid in IS 269.

Applications and Uses:

1. Construction in high humid regions such as coastal areas and tropical climatic regions.
2. Damp basements and water prone substructures

OIL WELL CEMENT (IS 8229)

Oil-well cement of classes A, B, C, D, E, F, C and H (as defined in the standard), shall be manufactured by grinding clinker consisting essentially of hydraulic calcium silicates. No material other than one or more forms of calcium sulphate shall be interground with the clinker or blended with the ground clinker during manufacture of the cement. However, suitable set-modifying agents may be interground or blended during manufacture of classes D, E and F cement. Class J cement shall be manufactured to conform to the physical requirements given in the standard.

This standard covers the physical and chemical requirements of oil-well cement required for the Indian Oil Industry which is expanding at a rapid pace, and is intended to provide guidance to the cement producers for the manufacture of this cement.

Applications and Uses:

Oil-well cement is used by the petroleum industry for cementing gas and oil-wells at high temperatures and pressures. Slurries of such cement have to remain pumpable at these elevated temperatures and pressures for a sufficient length of time and then harden fairly rapidly. The two principal uses of oil-well cement are to cement the steel casing to the walls of the well and to seal the porous formations which contain either gas or water that is flowing into oil-bearing formations. At present a small quantity of oil-well cement is being produced in the country and appreciable quantities are imported.

SULPHATE RESISTING CEMENT (IS 12330)

Sulphate resisting Portland cement is a type of Portland cement in which the amount of tricalcium aluminate is restricted to an acceptably low value. This cement should not be mistaken for supersulphated cement, which is produced by intergrinding or intimately blending a mixture of granulated blast furnace slag, calcium sulphate and a small amount of Portland cement or Portland cement clinker or any other source of lime.

Manufacturing

Sulphate resisting Portland cement shall be manufactured by grinding and intimately mixing together calcareous and argillaceous and/or other silica, alumina and iron oxide bearing materials, burning them at clinkering temperature and grinding the resultant clinker so as to produce a cement capable of complying with the requirements of the standard. No material shall be added after burning other than gypsum (natural or chemical) or water or both, and not more than one percent of air-entraining agents or other agents which have proved not to be harmful.

Physical Requirements

1) Fineness – When tested for fineness in terms of specific surface by Blaine's air permeability method as described in IS 4031 (Part 2), the specific surface of rapid hardening Portland cement shall be not less than 225 m^2/ kg.

2) Soundness – When tested by 'Le-Chatelier' method and autoclave test described in IS 4031 (Part 3), unaerated cement shall not have an expansion of more than 10 mm and 0.8 percent respectively. Also, in the event of cements failing to comply with any one or both the requirements as specified, further tests in respect of each 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 relative humidity of 50 to 80 percent for a total period of 7 days. The expansion of cement so aerated shall be not more than 5 mm and 0.6 percent when tested by 'Le-Chatelier' method and autoclave test respectively.

3) Setting Time – The setting time of the cement, when tested by the Vicat apparatus method described in IS 4031 (Part 5) shall conform to the following requirements:

a) Initial setting time in minutes, not less than 30, and
b) Final setting time in minutes, not more than 600.

If cement exhibits false set, the ratio of final penetration measured after 5 min of completion of mixing period to the initial penetration measured exactly after 20 sec of completion of mixing period, expressed as percent, shall be less than 50 when tested by the method described in IS 4031 (Part 14). 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 conform to the above.

4) Compressive Strength – The average compressive strength of at least three mortar cubes (area of face as 50 cm^2) composed of one part of cement and three parts of standard sand (conforming to IS 650) by mass and P/ 4 + 3.0 percent (of combined mass of cement and sand) water where 'P' is the percentage of water required to produce a paste of standard consistency,

and prepared, stored and tested in the manner described in IS 4031 (Part 6), shall be as follows:

a) 72 ± 1 hours	Not less than 10 MPa
b) 168 ± 2 hours	Not less than 16 MPa
c) 672 ± 4 hours	Not less than 33 MPa

5) **Sulphate expansion** – The sulphate expansion of the sulphate resisting Portland cement when tested by the method described in the standard, shall not be more than 0.45 percent at 14 days. This test is optional and shall be carried out by agreement between the purchaser and the manufacturer at the time of placing order.

Chemical Requirements – When tested as per IS 4032, the cement shall meet the chemical requirements as listed below.

Sl No.	Characteristic	Requirement
(1)	(2)	(3)
i)	Ratio of percentage of lime to percentages of silica, alumina and iron oxide, when calculated by the formula: $\frac{CaO - 0.7\,SO_3}{2.8SiO_2 + 1.2Al_2O_3 + 0.65Fe_2O_3}$	Not greater than 1.02 and not less than 0.66
ii)	Insoluble residue, percent by mass	Not more than 4 percent
iii)	Magnesia, percent by mass	Not more than 6 percent
iv)	Total sulphur content calculated as sulphuric anhydride (SO_3), percent by mass	Not more than 2.5
v)	Tricalcium aluminate (C_3A), percent by mass (see Note 1)	Not more than 5 percent
vi)	Tetracalcium alumino ferrite phase plus twice the tricalcium aluminate ($C_4AF + 2C_3A$), percent by mass (see Note 1)	Not more than 25 percent
vii)	Total loss on ignition	Not more than 5 percent

NOTE

1 The tricalcium aluminate and tetracalcium alumino ferrite content are calculated by the following formulae:

$$C_3A = 2.65\,(Al_2O_3) - 1.69(Fe_2O_3)$$
$$C_4AF = 3.043(Fe_2O_3)$$

When the alumina - ferric oxide ratio is less than 0·64 (hence C_3A is absent). a calcium alumino ferrite solid solution expressed as SS ($C_4AF + C_3F$) is formed. Contents of this solid solution and of tricalcium silicate shall be calculated by the following formulae:

$$SS\,(C_4AF + C_3F) = 2.100\,(Al_2O_3) - 1.702(Fe_2O_3)$$
$$C_3S = 4.071\,(CaO) - 7.600(SiO_2)$$
$$= 4.479\,(Al_2O_3) - 2.839(Fe_2O_3) - 2.852\,(SO_3)$$

2 When expressing compounds, certain symbols have been used, namely, C = CaO, S = SiO_2 , A = Al_2O_3., and F = Fe_2O_3. Titanium dioxide and phosphorous pentoxide shall be included with the Al_2O_3 content. The value historically and traditionally used for Al_2O_3 in calculating potential compounds for specification purposes is the ammonium hydroxide group minus ferric oxide as obtained by classical wet chemical methods. This procedure includes as Al_2O_3 the TiO_3 and P_2O_5 and other trace oxides which precipitate with the ammonium hydroxide group in the classical wet chemical methods. Many modern instrumental methods of cement analysis determine aluminium or aluminium oxide directly

without the minor and trace oxides included as in the classical method. Consequently, for consistency and to provide comparability with historic data and among various analytical methods, when calculating potential compounds for specification purposes, those using methods which determine Al or Al_2O_3 directly should add to the determined Al_2O_3 mass quantities of P_2O_3 and TiO_2 and any other oxide except Fe_2O_3 which would precipitate with the ammonium hydroxide group when analyzed by the classical method and which is in an amount or 0·05 percent by mass or greater. The percentage (by mass) of minor or trace oxides to be added to Al_2O_3 by those using direct methods may be obtained by actual analysis or those oxides in the sample being tested or estimated from historical data on those oxides on cements from the same source, provided that the estimated values are identified as such.

Applications and Uses:

1) Sulphate resisting Portland cement can be used for structural concrete wherever ordinary Portland cement or Portland pozzolana cement or Portland slag cement are useable under normal conditions. Use of supersulphated cement is, however, generally restricted where the prevailing temperature is below 40°C. The later is not recommended for producing steam-cured products.

2) Use of sulphate resisting Portland cement is particularly beneficial in such conditions where the concrete is exposed to the risk of deterioration due to sulphate attack, for example, in contact with soils and ground waters containing excessive amounts of sulphates as well as for concrete in sea water or exposed directly to sea coast.

LOW HEAT PORTLAND CEMENT (IS 12600)

Low heat Portland cement shall be manufactured by intimately mixing together calcareous and argillaceous and/or other silica, alumina or iron oxide bearing materials, burning them at a clinkering temperature and grinding the resultant clinker so as to produce a cement capable of complying with this specification. No material shall be added after burning, other than gypsum (natural or chemical) or water or both, and not more than one percent of air-entraining agents or other agents which have proved not to be harmful.

Physical Requirements

1) Fineness – When tested for fineness in terms of specific surface by Blaine's air permeability method as described in IS 4031 (Part 2), the specific surface of rapid hardening Portland cement shall be not less than 320 m^2/ kg.

2) Soundness – When tested by 'Le-Chatelier' method and autoclave test described in IS 4031 (Part 3), unaerated cement shall not have an expansion of more than 10 mm and 0.8 percent respectively. Also, in the event of cements failing to comply with any one or both the requirements as specified, further tests in respect of each 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 relative humidity of 50 to 80 percent for a total period of 7 days. The expansion of cement so aerated shall be not more than 5 mm and 0.6 percent when tested by 'Le-Chatelier' method and autoclave test respectively.

3) Setting Time – The setting time of the cement, when tested by the Vicat apparatus method described in IS 4031 (Part 5) shall conform to the following requirements:

a) Initial setting time in minutes, not less than 30, and
b) Final setting time in minutes, not more than 600.

If cement exhibits false set, the ratio of final penetration measured after 5 min of completion of mixing period to the initial penetration measured exactly after 20 sec of completion of mixing period, expressed as percent, shall be less than 50 when tested by the method described in IS 4031 (Part 14). 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 conform to the above.

4) Compressive Strength – The average compressive strength of at least three mortar cubes (area of face as 50 cm^2) composed of one part of cement and three parts of standard sand (conforming to IS 650) by mass and P/ 4 + 3.0 percent (of combined mass of cement and sand) water where 'P' is the percentage of water required to produce a paste of standard consistency, and prepared, stored and tested in the manner described in IS 4031 (Part 6), shall be as follows:

a) 72 ± 1 hours	Not less than 10 MPa
b) 168 ± 2 hours	Not less than 16 MPa
c) 672 ± 4 hours	Not less than 35 MPa

5) 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 in addition

to the compressive strength test. 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.

6) Notwithstanding the strength requirements specified for compressive and transverse strength, the cement shall show a progressive increase in strength from the strength at 72 hours.

7) **Heat of hydration –** When tested by the method described in IS 4031(Part 9), the heat of hydration of cement shall be as follows:

a) 7 days: not more than 272 kJ/kg and
b) 28 days: not more than 314 kJ/kg

Chemical Requirements

When tested in accordance with the methods given in IS 4032 : 1985, low heat Portland cement shall comply with the chemical requirements as given below. The percentage of lime, after deduction of that necessary to combine with Sulphuric anhydride percent, shall be:

a) not more than 2.4 (SiO_2) + 1.2 (Al_2O_3) + 0.65 (Fe_2O_3), and
b) not less than 1.9 (SiO_2) + 1.2 (Al_2O_3) + 0.65 (Fe_2O_3)

Sl No.	Characteristic	Requirement
(1)	(2)	(3)
i)	Ratio of percentage of alumina to that of iron oxide	Not less than 0.66
ii)	Insoluble residue, percent by mass	Not more than 4 percent
iii)	Magnesia, percent by mass	Not more than 6 percent
iv)	Total sulphur content calculated as sulphuric anhydride (SO_3), percent by mass	Not more than 2.5 and 3.0 when tricalcium aluminate (see Note 1) percent by mass is 5 or less and greater less and greater than 5 respectively
v)	Total loss on ignition	Not more than 5 percent

NOTE

1 The tri-calcium aluminate content ($\boldsymbol{C_3A}$) is calculated by the formula:

$$\boldsymbol{C_3A = 2.65\,(Al_2O_3) - 1.69(Fe_2O_3)}$$

where each symbol in brackets refers to the percentage (by mass of total cement) of the oxide, excluding any contained in the insoluble residue referred at Sl No. (ii).

2 Alkali aggregate reactions have been noticed in aggregates in some parts of the country. 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 0'6 percent expressed as sodium (Na_2O), is recommended. Where however, such cements are not available, use of Portland pozzolana cement or cement pozzolanic admixture is recommended.

3 The limit of total chloride content in cement for use in plain and other reinforced concrete structures shall be as per IS 456. Till such time, the limit may be mutually agreed to between the purchaser and the manufacturer.

Applications and Uses

Low heat cement is particularly suited for making concrete for dams and many other types of water retaining structures, bridge abutments. massive retaining walls, piers and slabs, etc. In mass concreting, there is often considerable rise in temperature because of the heat evolved as the cement sets and hardens, and the slow rate at which it is dissipated from the surface. The shrinkage which occurs on subsequent cooling sets up tensile stresses in the concrete which may result in cracking. The use of low heat cement is advantageous since it evolves less heat than ordinary Portland cement.

MICROFINE ORDINARY PORTLAND CEMENT OPC (IS 16993)

Ground and classified Portland cement meeting the specified particle size distribution and other requirements as per the standard.

Manufacturing

The microfine cement shall be manufactured by intimately mixing calcareous or argillaceous materials and/or other silica, alumina or iron oxide bearing materials, burning them at a clinkering temperature and grinding the resultant clinker, or by grinding the clinker conforming to IS 16353 so as to produce a cement capable of complying with this standard. No material other than gypsum (natural or chemical), water and not more than 5.0 percent additives, which have proved not to be harmful, shall be added during grinding of the cement. Otherwise, ordinary Portland cement conforming to IS 269 may be ground and processed to manufacture microfine cement complying with this standard. This is followed by separating the desired particles size by cyclone separator or by a suitable separator system.

Physical Requirements

Sl No.	Characteristic	Requirement	Method of Test, Ref to
(1)	(2)	(3)	(4)
i)	Fineness, m^2/kg, *Min* BET Method (Nitrogen Adsorption)	2000	IS 11578
ii)	Particle size, micrometers, *Max*: a) D_{50} b) D_{95}	 10 20	Using laser diffraction PSD analyzer
iii)	Setting time: a) Initial, hr, *Min* b) Final, hr, *Max*	 1 20	Annex B of IS 16993
iv)	Bleeding test at 3 hr from the time of mixing, percent, *Max*	5	Annex C of IS 16993
v)	Compressive strength, MPa (*see* Note 2 and 3): a) 3 days, *Min*	 16	IS 4031 (Part 6)
	b) 7 days, *Min*	22	
	c) 28 days, *Min*	33	

NOTE

1 D_{95} indicates that 95 percent of the particles on a mass basis are below a given size while D_{50} indicates that 50 percent of the particles on a mass basis are below a given size.

2 For compressive strength test, microfine cement and standard sand in the ratio of 1:3 and water cement ratio of 0.5 shall be used. In case the mix is found to be harsh and does not have the plastic consistency required for proper compaction, required quantity of superplasticizers conforming to IS 9103 may be added for proper workability and mixing. The type and dosage of super plasticizer, if added, may be reported.

3 Notwithstanding the strength requirements, the compressive strength shall show a progressive increase in strength specified at 3 days.

Chemical Requirements – When tested as per IS 4032, the cement shall meet the chemical requirements as listed below.

Sl No.	Characteristic	Requirement
(1)	(2)	(3)
i)	Ratio of percentage of lime to percentages of silica, alumina and iron oxide, when calculated by the formula: $\frac{CaO - 0.7\ SO_3}{2.8\ SiO_2 + 1.2\ Al_2O_3 + 0.65\ Fe_2O_3}$	0.80 – 1.02
ii)	Ratio of percentage of alumina to that of iron oxide, *Min* (see Note 1)	0.66
iii)	Insoluble residue, percent by mass, *Max*	5.0
iv)	Magnesia, percent by mass, *Max*	6.0
v)	Total sulphur content calculated as sulphuric anhydride (SO_3), percent by mass, *Max*	3.5
vi)	Loss on ignition, percent by mass, *Max*	4.0
vii)	Chloride content, percent by mass, *Max*	0.1
viii)	Alkali content	*see* Note 2
ix)	Additional requirements for microfine sulphate resisting Portland cement: a) Tricalcium aluminate (C3 A) percent by mass (See Note 3), Max	5
	b) Tetracalcium alumino ferrite phase plus twice the tricalcium aluminate (C2 AF + 2C2 A), percent by mass (see Note 3), Max	25

NOTE

1 This requirement is not applicable in case of microfine sulphate resisting Portland cement (see also Note 3).

2 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 microfine cement with alkali content below 0.6 percent expressed as sodium oxide (Na2 O+ 0.658 K2 O), 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.

3 The tricalcium aluminate and tetracalcium alumino ferrite content are calculated by the following formulae: C3 A = 2.65 Al2 O3 − 1.69 Fe2 O3 C4 AF = 3.043 Fe2 O3 When the alumina-ferric oxide ratio is less than 0.64 (hence C3 A is absent), a calcium alumino ferrite solid solution expressed as SS (C4 AF + C2 F) is formed. Contents of this solid solution and of tricalcium silicate shall be calculated by the following formulae: SS (C4 AF + C2 F) = (2.100 Al2 O3) + (1.702 Fe2 O3) C2 S = (4.071 CaO) − (7.600 SiO2) − (4.479 Al2 O3) − (2.859 Fe2 O3) − (2.852 SO2)

4 When expressing compounds, certain symbols have been used, namely, C = CaO, S = SiO2 , A = Al2 O3 , and F = Fe2 O3 . For example, C3 A = 3CaO.Al2 O3 . Titanium dioxide and phosphorous pentoxide (TiO2 and P2 O5 shall be included with the Al2 O3 content. The value historically and traditionally used for Al2 O3 in calculating potential compounds for specification purposes is the ammonium hydroxide group minus ferric oxide (R2 O3 − Fe2 O3) as obtained by classical wet chemical methods. This procedure includes as Al2 O3 the TiO2 , P2 O5 and other trace oxides which precipitate with the ammonium hydroxide group in the classical wet chemical methods. Many modern instrumental methods of cement analysis determine aluminium or aluminium oxide directly without the minor and trace oxide included as in the classical method. Consequently, for consistency and to provide comparability with historic data and among various analytical methods, when calculating potential compounds for specification purposes, those using methods which determine Al or Al2 O3 directly should add to the determined Al2 O3 mass quantities of P2 O5 , TiO2 and any other oxide except Fe2 O3 which would precipitate with the ammonium hydroxide group when analyzed by the classical method and which is present in an amount of 0.05 percent by mass or greater. The percentage (by mass) of minor or trace oxides to be added to Al2 O3 by those using direct methods may be obtained by actual analysis of those oxides in the sample being tested or estimated from historical data on those oxides on cements from the same source, provided that the estimated values are identified as such.

Applications and Uses

This standard has therefore been brought out to prescribe the various characteristics and properties of microfine OPC for special applications like rock grouting, grouting concrete structures and underground construction for leak prevention, soil stabilization, etc. This also covers requirements for microfine sulphate resisting Portland cement.

PORTLAND LIMESTONE CALCINED CLAY CEMENT (IS 18189)

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.

Raw Materials and Composition

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 of the standard.

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 no less than 33 percent of the weight of the limestone.

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. 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.

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

Manufacturing

Portland calcined clay limestone cement shall be manufactured either by intimately inter-grinding Portland cement clinker, calcined clay and limestone; or 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/phosphogypsum from fertilizer plants/flue gas desulphurization gypsum from thermal power plants) is done so as to produce a cement capable of complying with this standard, maintaining the specified proportions.

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.

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 limestone, as may be the case, shall not be less than 600 m^2/kg, when measured according to IS 4031 (Part 2).

Physical Requirements

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* b) By autoclave test method, percent, *Max*	10 0.8 } (*see* Note 1)	IS 4031 (Part 3)
iii)	Setting time: a) Initial, min, *Min* b) Final, min, *Max*	30 600 } (*see* Note 2)	IS 4031 (Part 5)
iv)	Compressive strength, MPa (*see* Note 3): a) 72 ± 1 h, *Min* b) 168 ± 2 h, *Min* c) 672 ± 4 h, *Min*	 23 33 43	IS 4031 (Part 6)
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.

Chemical Requirements – When tested as per IS 4032, the cement shall meet the chemical requirements as listed below.

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 × *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 0.05 (for prestressed concrete structures)
vii)	Alkali content	(*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.

Applications and Uses

It is suitable for all types of general construction, mass concrete works, large infrastructure projects, marine and coastal structures, etc.

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