ASTM C150

Standard Specification for Portland Cement

Understanding ASTM International Test Procedures for Cement and Concrete - Staying Up to Standard

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Portland Cement Types (ASTM C150)

- Type I – Normal
  - General-purpose portland cement
- Type II – Moderate Sulfate Resistance
  - Used where protection from sulfate is required for structures exposed to soil or ground water

Severity of potential exposure	Water-soluble sulfate (SO_4) in soil, % by mass*	Sulfate (SO_4)* in water, ppm	*w/cm* by mass, max.†‡	Cementitious material requirements
Class 0 exposure	0.00 to 0.10	0 to 150	No special requirements for sulfate resistance	No special requirements for sulfate resistance
Class 1 exposure	> 0.10 and < 0.20	> 150 and < 1500	0.50‡	C150 Type II or equivalent§
Class 2 exposure	0.20 to < 2.0	1500 to < 10,000	0.45‡	C150 Type V or equivalent§
Class 3 exposure	2.0 or greater	10,000 or greater	0.40‡	C150 Type V plus pozzolan or slag§

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Portland Cement Types (ASTM C150)

- Type III – High early strength
  - Chemically similar to Type I, but ground finer
  - Used in precast construction
- Type IV – Low heat of hydration
  - Mass concrete structures
  - Not commonly manufactured in North America
- Type V – High Sulfate resistance

ASTM C150 Requirements

Chemical Requirements

Chemical analysis
Compound composition
Chemical limits

Physical Requirements

Fineness
Soundness
Consistency (Flow and Normal Consistency)
Setting Time
False set and flash set
Compressive strength
Heat of hydration
Loss on ignition
Density
Air content
Sulfate expansion

Composition

Chemical Name	Chemical Formula	Notation	Mass (%)
Tricalcium silicate	$3CaO•SiO_2$	C_3S	50-70
Dicalcium silicate	$2CaO• SiO_2$	C_2S	15-30
Tricalcium aluminate	$3CaO•Al2O_3$	C_3A	5-10
Tetracalcium aluminoferrite	$4CaO•Al_2O_3•Fe_2O_3$	C_4AF	5-15
Calcium sulfate dihydrate	$CaSO_4.2H_2O$	CSH_2	~ 5

Composition

- The relative quantities of each of these phases affects:
  - setting time
  - rate of strength development
  - overall strength
  - durability
  - color
- It is important, then, to know the composition of the cement.

Chemical Analysis: Determine Composition

- X-Ray Fluorescence (XRF) Spectroscopy
  - Provides bulk elemental composition of materials
  - Results are used for Bogue calculations
- X-ray Powder Diffraction (XRD)
  - Rapid analytical technique used for phase identification of a crystalline material
  - Rietveld refinement used to analyze results and provide more precise portland cement phases

Chemical Analysis

Oxide	Element
SiO_2	Silicon dioxide
Al_2O_3	Aluminum oxide
Fe_2O_3	Ferric oxide
CaO	Calcium oxide
MgO	Magnesium oxide
SO_3	Sulfur trioxide
LOI	Loss on ignition
Na_2O	Sodium oxide
K_2O	Potassium oxide
TiO_2	Titanium dioxide
P_2O_5	Phosphorus pentoxide
ZnO	Zinc oxide
Mn_2O_3	Manganic oxide
Sulfide sulfur	

ASTM C 114 - Standard Test Methods for Chemical Analysis of Hydraulic Cement

Major Components

Minor Components

Chemical Analysis

Oxide	%
SiO_2	20.6
Al_2O_3	5.07
Fe_2O_3	2.90
CaO	63.9
MgO	1.53
SO_3	2.53
Na_2O	0.15
K_2O	0.73
LOI	1.58

90-95%

Oxide	Shorthand	Common Name
CaO	C	Lime
SiO_2	S	Silica
Al_2O_3	A	Alumina
Fe_2O_3	F	Ferric Oxide
MgO	M	Magnesia
K_2O	K	Alkalis
Na_2O	Na	
SO_3	S	Sulfate
CO_2	C	Carbonate
H_2O	H	Water

Compound Composition

- Bogue Composition/Calculations

Alite (Tricalcium Silicate)

$C_3S = 4.07C – 7.60S – 6.72A – 1.43F – 2.85S$

Belite (Dicalcium Silicate)

$C_2S = 2.87S – 0.75C_3S$

Aluminate Phase (Tricalcium Aluminate)

$C_3A = 2.65A – 1.69F$

Ferrite Compounds(Tetracalcium Aluminoferrite)

$C_4AF = 3.04F$

Compound Composition: Example Bogue

Oxide	%
SiO_2	20.6
Al_2O_3	5.07
Fe_2O_3	2.90
CaO	63.9
MgO	1.53
SO_3	2.53
Na_2O	0.15
K_2O	0.73
LOI	1.58

Calculated Phase Composition

C_3S = 4.07(63.9) – 7.60(20.6) – 6.72(5.07) – 1.43(2.90) – 2.85(2.53) = **58.1**

C_2S = 2.87(20.6) – 0.75(58.1) = **15.6**

C_3A = 2.65(5.07) – 1.69(2.90) = **8.5**

C_4AF = 3.04(8.8) = **8.8**

Phase	%
C_3S	58
C_2S	16
C_3A	9
C_4AF	9

Bogue Composition Assumptions

- All 4 phases are pure
- All the F present occurs as C_4AF, and the quantities of A = 0.64(% F) and C = 1.40 (% F) are subtracted from the appropriate totals.
- The remaining Al_2O_3 is combined as C_3A and a further quantity of C = 1.65 (% Al_2O_3) is subtracted from the total remaining CaO.
- The SiO_2 combines initially with CaO to form C_2S giving a provisional C_2S figure. The CaO combining with SiO_2 = 2.87%(SiO_2) is subtracted from the total CaO figure, and the remaining CaO is then combined with a part of the C_2S = 4.07(%CaO) to form C_3S.

As a result, Bogue compositions may be "off" by as much as 10% compared to XRD-determined compositions.

Compound Composition: Example Equivalent Alkalis

Oxide	%
SiO_2	20.6
Al_2O_3	5.07
Fe_2O_3	2.90
CaO	63.9
MgO	1.53
SO_3	2.53
Na_2O	0.15
K_2O	0.73
LOI	1.58

Sodium equivalent, Na_2O_e

$$Na_2O_e = Na_2O + (0.658 \times K_2O)$$

$$Na_2O_e = 0.15 + (0.658 \times 0.73)$$

$$Na_2O_e = 0.63\%$$

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Chemical Limits

	Cement Type				
	I	II	III	IV	V
SiO_2, min. %	-	20.0	-	-	-
Al_2O_3, max. %	-	6.0	-	-	-
Fe_2O_3, max. %	-	6.0	-	6.5	-
MgO, max. %	6.0	6.0	6.0	6.0	6.0
SO_3, max. %					
$C_3A \leq 8\%$	3.0	3.0	3.5	2.3	3.0
$C_3A > 8\%$	3.5	n/a	4.5	n/a	n/a
LOI, max. %	3.0	3.0	3.0	2.5	3.0
Insoluble residue, max. %	0.75	0.75	0.75	0.75	0.75

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Bogue Limits

	Cement Type				
	I	II	III	IV	V
C_3A, max. %	-	-	8	-	-
C_3A, max. %	-	-	5	-	-
$C_33 + C_3A$, max. %	-	58	-	-	-
Na_2Oe, max. %	0.60	0.60	0.60	0.60	0.60

Physical Requirements for Portland Cement Types

- Compressive Strength

Minimum Strength Requirements, Mpa (psi)

Age	Cement Type				
	I	II	III	IV	V
1 day	-	-	12.0 (1740)	-	-
3 days	12.0 (1740)	10.0 (1450)	24.0 (3480)	-	8.0 (1160)
7 days	19.0 (2760)	17.0 (2470)	-	7.0 (1020)	15.0 (2180)
28 days	-	-	-	17.0 (2470)	21.0 (3050)

Physical Requirements for Portland Cement Types

Cement Type	I	II	III	IV	V
Air content of mortar, volume %					
max	12	12	12	12	12
Air permeability test (blaine)					
Average value, min.	160	160	…	160	160
Any one sample, min.	150	150	…	150	150
Average value, max.	…	240	…	240	…
Any one sample, max.	…	245	…	245	…
Autoclave expansion, max. %	0.8	0.8	0.8	0.8	0.8
Time of setting; Vicat test:					
Time of Setting, min. (not less than)	45	45	45	45	45
Time of Setting, min. (not more thar	375	375	375	375	375

Additional Cement Specifications

- ASTM C150 – Standard Specification for Portland Cement
- ASTM C595 – Standard Specification for Blended Hydraulic Cements
- ASTM C1157 – Standard Specification for Hydraulic Cement

Questions & Answers

ASTM C989

Standard Specification for Slag Cement for Use in Concrete and Mortars

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Slag Cement

- Glassy granular material formed when molten blast-furnace slag is rapidly chilled, as by immersion in water
- Non-metallic product, consisting of silicates and aluminosilicates of calcium and other bases

Component	Mass (%)
CaO	30-50
SiO_2	28-38
Al_2O_3	8-24
MgO	1-18

Classification

- Slag is Classified as Grade 80, 100, and 120
- Determined from compressive strength
- ASTM C109 and ASTM C1437
- (2 Mixes)
  - Slag mixture 50/50 slag and reference cement
  - Reference mixture – only reference cement

Total Alkalies (Na_2O + 0.658 K_2O)	min %	0.60
	max %	0.90
Compressive Strength, MPa, min, 28 days[A]		35 [5000 psi]

Classification

Slag Activity Index, % = (SP / P) X 100

SP = Average compressive strength of slag−cement mortar cubes, MPa
P = Average compressive strength of cement mortar cubes, MPa

	Average of Last Five Consecutive Samples	Any Individual Sample
Slag Activity Index		
28-Day Index, min.%		
Grade 80	75	70
Grade 100	95	90
Grade 120	115	120

Physical Requirements

	Item
Fineness:	
Amount retained when wet screened on a 45-µm Sieve, max. %	20
Specific surface by air permeability, Test Methods C204 shall be determined and reported although no limits are requried.	…
Air Content of Slag Mortar, max. %	12

Chemical Requirements

- Composition Depends mainly on the composition blast furnace oxides
- Variability between sources exist, but relatively low within the same plant
- ASTM C989 Limits
  - Sulfide sulfur content (S), to 2.55
  - Determined per ASTM C114

Portland Cement and Slag Cement Standards

- Portland Cement Standards
  - Require more testing than slag cement
  - Variability within and between sources
  - Make up large percentage of concrete mixtures
- Slag Cement
  - Used increasing quantities in North America
  - Concern on titanium concentrations

Questions & Answers