

هيئة التقييس لدول مجلس التعاون لدول الخليج العربية
GCC STANDARDIZATION ORGANIZATION (GSO)



GSO 1914/2009 (E)

الأسمنت البورتلاندي
Portland Cement

ICS : 91.100.00

Portland Cement

Date of GSO Technical Council : 14-16/2/1430h (10-12/2/2009)
Issuing Status : Standard

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Foreword

GCC Standardization Organization (GSO) is a regional Organization which consists of the National Standards Bodies of GCC member States. One of GSO main functions is to issue Gulf Standards /Technical regulations through specialized technical committees (TCs).

GSO through the technical program of committee TC No (6) "Technical Committee of Building Materials Standards" has prepared this Standard. The Draft Standard has been prepared by State of Kuwait .

The draft Standard has been prepared based on relevant ADMO, International and National foreign Standards and references.

This standard has been approved as a Gulf Standard by GSO Technical Council in its meeting No.(15), held on 14-16/2/1430h (10-12/2/2009) .

Portland Cement

1 SCOPE

This GSO standard is concerned with the following eight types of Portland cement:

1. Type I cement (ordinary) - for use when the special properties specified for any other type are not required.
2. Type IA – Air-entraining cement for the same uses as type I, where air-entrainment is desired.
3. Type II cement - For general purposes, more especially when moderate sulphate resistance or moderate heat of hydration is desired.
4. Type IIA – Air-entraining cement for the same uses as type II, where air-entrainment is desired.
5. Type III – For use when high early strength is desired.
6. Type IIIA – Air-entraining cement for the same use as type III, where air-entrainment is desired.
7. Type IV – For use when a low heat of hydration is desired.
8. Type V – For use when high sulphate resistance is desired.

Common cements are grouped in the European standard EN 197-1:2000 into (5) major types according to composition. Further they are further divided into (2) major classes according to pressure resistance as stipulated in tables (1) and (2) referred to in Attachment (1).

2 COMPLEMENTARY REFERENCES

- 2.1 GSO Standard 938 "Test Methods for Chemical Properties of Portland Cement "
- 2.2 GSO Standard 1915 " Test Methods for Physical Properties of Portland Cement ".

3 COMPOSITION AND MANUFACTURING

- 3.1 **Portland Cement:** A hydraulic cement produced by pulverizing (grinding) Portland-cement clinker, that mainly contains calcium silica and which often contains calcium sulphate in form of ground additives.
- 3.2 **Air-entraining cement:** Hydraulic cement containing air-entraining addition in such amount as to cause air to be entrained in mortar within specified limits when measured by prescribed method.

Cement can be classified according to European standards EN 197-1:2000 to the five main types of installation and then classified according to the two main Component (N & R) and by resistance to pressure (32.5 and 42.5 and 52.5 MPa), as indicated in Tables 1, 2 mentioned in the annex (1)

3.3 Composition: The cement covered in this standard should contain no additions except as follows:

3.3.1 Portland Cement Clinker

3.3.2 Water or calcium sulphate or both, if added, shall be in amounts such that the limits shown in Table (1) for sulphur trioxide and loss on ignition are not exceeded.

3.3.3 Cement having limestone content up to 5% by weight is allowed, provided it conforms to the physical and chemical requirements of this standard (refer to note 1). The limestone used shall be natural and containing at least 70% by weight of the mineral compounds of calcium carbonate.

3.3.4 Using additions during manufacturing shall comply with the requirements of relevant approved standard as regarding the appropriate quantity *.

3.3.5 Air-entraining Portland cement shall contain ground additives conforming to the requirements of relevant approved standard **.

Note (1): This standard allows the addition of 5% by weight of grinded natural limestone to the final cement product but does not necessarily require the addition of this limestone to the cement. As such, cement not containing grinded limestone can be specified in the purchase order or supply contract.

4 REQUIREMENTS AND RULES OF ACCEPTANCE

4.1 Chemical Composition: Portland cement of each of the eight types shown in Section (1) shall conform to the respective standard chemical requirements prescribed in Table (1). In addition, optional chemical requirements are shown in table (2).

4.2 Physical Properties: Portland cement of each of the eight types shown in Section (1) shall conform to the respective standard physical requirements prescribed in Table (3). In addition, optional physical requirements are shown in Table (4).

5 SAMPLING

When the purchaser desires that the cement be sampled and tested to verify compliance with this specification, he must follow the relevant approved Standard.***

* American Standard ASTM C465

** American Standard ASTM C226

*** ASTM C183 is not designed for manufacturing quality control and is not required for manufacturer's certification.

6 TESTS

6.1 Chemical properties shall be tested according to the requirements of GSO standard 938 on "Test Methods for Chemical Properties of Portland Cement".

6.2 Physical properties shall be tested according to the requirements of GSO standard 1915 on "Test Methods for Physical Properties of Portland Cement".

7 CONDITIONS OF SUPPLY

The supplier shall make sure that the Portland cement, when delivered to the purchaser, conforms to the applicable requirements of this specification. When required, the supplier shall provide the purchaser or his representative with a certificate stating the conformity of the Portland cement. In case the cement sample drawn from the consignment (according to the methods stipulated in this standard) proves to be non-conforming to the afore-mentioned requirements of testing and analysis, the consignment shall be regarded as non-conforming to this standard.

Note (2): When inter-comparing the results of oxides and their compounds analysis made by different bodies at different times, these results should not approved under the same bases. The results obtained according to the requirements of the standard on "moistened chemical analysis", phosphate and titanium may be found in form of aluminates unless the necessary correction is made. However, the results obtained by speedy equipment do not need such correction. This, in turn, leads to a slight difference in the calculated values of compounds. This difference is often within the required precision limits when the two methods are adopted.

Note (3): When cement is delivered in packages, the following words shall be plainly marked on each package:

1. Portland cement
2. Cement type
3. Name of manufacturer and his trade mark
4. Pack weight
5. Date of manufacture

When the cement is the air-entraining type, the words "air-entraining" should be plainly marked on each package. Similar information shall be provided accompanying the shipment of packaged or bulk cement. All packs should be in good condition when tested and inspected.

In case of bulk cement trucks, one sample is drawn from each truck from a depth of 15 cm or deeper and not from the surface. The sample to be tested is prepared by mixing at least (3) drawn samples identical in weight such that it is a true representation of the truck load.

The former items 1, 2, 3, 4 & 5 should be mentioned in the certificate that accompanies each consignment.

Note (4): Comparison test results may be taken from the qualifications tests that the manufacturer had conducted during the formation of the cement from limestone.

Note (5): In case it is desired to change the measuring units to SI units, it is preferable that a whole package of it be set specifically for Portland Cement. In measurement, it is possible to make a package for equating a weight of 42 kgs with 92.5 lbs, as the case is in equating 94 lbs. with 42.6 kgs. in the traditional conversion package.

Note (6): The guideline related to the preparation of the factory report is available in ASTM C150-07, attachment 4.

Table 1 – Chemical Composition Requirements

	Cement Type					Remarks
	I & IA	II & IIA	III & IIIA	IV	V	
Aluminium oxide (Al ₂ O ₃) max. %	-----	6.0	-----	-----	-----	
Ferric oxide (Fe ₂ O ₃) max. %	-----	6.0 ^{B,C}	-----	6.5	-----	
Magnesium oxide (MgO) max. %	5.0	5.0	5.0	5.0	5.0	
Sulphur trioxide (SO ₃) ^D max. %						
when (C ₃ A) ^E ≤ 8%	3.0	3.0	3.5	2.3	2.3	
when (C ₃ A) ^E > 8%	3.5	F	4.5	F	F	
Loss on ignition max. %	3.0	3.0	3.0	2.5	3.0	
Insoluble residue max. %	1.5	1.5	1.5	1.5	1.5	
Tricalcium silicate (C ₃ S) ^E max. %	-----	-----	-----	35 ^B	-----	
Dicalcium silicate (C ₂ S) ^E min. %	-----	-----	-----	40 ^B	-----	
Tricalcium aluminate (C ₃ A) ^E max. %	-----	8	15	7 ^B	5 ^C	
Sum of (C ₃ S + 4.75C ₃ A) max. %		100 ^H				
Tetracalcium Aluminoferrite + twice Tricalcium Aluminate (C ₄ AF + 2C ₃ A) or the solid solution + (C ₄ AF + C ₂ F) as applicable, max. %	-----	-----	-----	-----	25 ^C	
Equivalent alkalines (Na ₂ O + 0.658K ₂ O) max. %	-----	0.60 ^G	0.60 ^G	0.60 ^G	-----	

B: Does not apply when the heat of hydration limit in table (4) is specified

C: Does not apply when the Sulphate resistance limit in table (4) is specified

D: There are cases where optimum of sulphur trioxide SO₃ according to relevant approved standards are close to or exceed the limits of this standard for special types of cement. In such cases, the cement properties can be improved by exceeding the maximum limits of sulphur trioxide shown in this table. Exceeding these limits is permitted provided that the cement containing a high limit of SO₃, would not lead to the increase in water expansion by more than 0.02% on the 14th day according to relevant approved standards. On

supplying cement having such property, the seller should provide the buyer with the information of this type of cement.

E: Refer to calculations in ASTM C150-07, attachment A1.

F: Not applicable.

G: Refer to note (8).

H: The heat of hydration test should be run for at least (7) days once every (6) months. Such test shall not be used for acceptance or rejection of the cement. However, the results should be reported for information purposes.

I: These limits shall be applied if the aggregate used is reactive with the cement. It should be referred to the standard on the aggregate (ASTM C33).

Note (7): The limits allowed for the sum of $(C_3S + 4.75C_3A)$ in table (1) determines the heat of hydration temperature of the cement contained in the test method (ASTM C186) for heat of hydration for (7) days at the rate of 335 kJoul/kg (80 Calorie/gm).

Table 2: Optional Chemical Composition Requirements^A

	Cement Type					Remarks
	I & IA	II & IIA	III & IIIA	IV	V	
Tricalcium aluminate $(C_3A)^B$, max. %	---	---	8	---	---	For moderate sulphate resistance cement
Tricalcium aluminate $(C_3A)^B$, max. %	---	---	5	---	---	For high sulphate resistance cement
Equivalent alkalines $(Na_2O + 0.658K_2O)$ max. %	0.60	---	---	---	0.60	

A: These optional requirements apply only when specifically requested. Verify availability before ordering.

B: Refer to calculation method in (ASTM C150-07, attachment A1)

Calculation Method:

1- When expressing phases, C=CaO, S=SiO₂, A=Al₂O₃, F=Fe₂O₃
For example, Tricalcium silicate is expressed as follows: C₃A=3CaO.Al₂O₃

Titanium dioxide and phosphorus pentoxide (TiO₂ and P₂O₅) shall not be included with the Al₂O₃ content.

2- When the ratio of percentages of aluminium oxide to ferric oxide is 0.64 or more, the percentages shall be calculated from the chemical analysis as follows:

Tricalcium silicate: $(C_3S) = (4.071 \times \%CaO) - (7.600 \times \%SiO_2) - (6.718 \times \%Al_2O_3) - (1.430 \times \%Fe_2O_3) - (2.852 \times \%SO_3)$

Dicalcium aluminate:
 $(C_2S) = (2.867 \times \%SiO_2) - (0.7544 \times \%C_3S)$

Tricalcium aluminate:
 $(C_3A) = (2.650 \times \%Al_2O_3) - (1.692 \times \%Fe_2O_3)$

Tricalcium Aluminoferrite:
 $(C_4AF) = 3.043 \times \%Fe_2O_3$

3- When the alumina-ferric oxide ratio is less than 0.64, a calcium Aluminoferrite solution (expressed as $(C_4AF + C_2F)$) is formed. In this case, no tricalcium aluminate will be present in cements of this composition. Dicalcium silicate shall be calculated as previously shown in note (1). Contents of this solid solution and of tricalcium silicate shall be calculated as follows:

$$(C_4AF + C_2F) = (2.100 \times \%Al_2O_3) + (1.702 \times \%Fe_2O_3)$$

Tricalcium silicate:
 $(C_3S) = (4.071 \times \%CaO) - (7.600 \times \%SiO_2) - (4.479 \times \%Al_2O_3)^C - (2.859 \times \%Fe_2O_3) - (2.852 \times \%SO_3)$

4- In case limestone is added to the cement, the content of carbon dioxide shall be taken into consideration when calculating the tricalcium silicate content (C_3S). (see note 1 and note 3). However, if limestone is not added to the cement, the value of carbon dioxide is considered within the calculation of tricalcium silicate, and the formula for (C_3S) becomes as follows:

i- Case of addition of limestone to cement in note (1):

Tricalcium silicate:

$$(C_3S) = (4.071 \times \%CaO) - (7.600 \times \%SiO_2) - (6.718 \times \%Al_2O_3) - (1.430 \times \%Fe_2O_3) - (2.852 \times \%SO_3)$$

ii- Case of addition of limestone to cement in note (3):

Tricalcium silicate:

$$(C_3S) = (4.071 \times \%CaO) - (7.600 \times \%SiO_2) - (4.479 \times \%Al_2O_3) - (2.859 \times \%Fe_2O_3) - (2.852 \times \%SO_3)$$

Whenever limestone is added to the cement, the supplier must provide the testing body with information on the percent of limestone added, and, accordingly, the testing body would test the carbon dioxide.

Table (3) Standard Physical Requirements

	Cement Type							
	I	IA	II	IIA	III	IIIA	IV	V
Air content in mortar ^B volume, max. % min. %	12 ----	22 16	12 ----	22 16	12 ----	22 16	12 ----	12 ----
Fineness ^C , specific surface, m ² /kg (alternative methods)								
1- Turbidimeter test								
▪ Average value, min. ^D	160	160	160	160	---	---	160	160
▪ For one sample, min. ^E	150	150	150	150	---	---	150	150
▪ Average value, max. ^D	---	---	240 ^F	240 ^F	---	---	240	---
▪ For one sample, max. ^E	---	---	240 ^F	240 ^F	---	---	245	---
2- Air permeability test								
▪ Average value, min. ^D	280	280	280	280	---	---	280	280
▪ For one sample, min. ^E	260	260	260	260	---	---	260	260
▪ Average value, max. ^D	---	---	420 ^F	420 ^F	---	---	420	---
▪ For one sample, max. ^E	---	---	430 ^F	430 ^F	---	---	430	---
Autoclave expansion, max. %	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
Compressive strength, not less than the value shown for the ages indicated as follows: ^G MPa (psi) – 1 day	---	---	---	---	12 (1740)	10 (1450)	---	---
3 days	12 (1740)	10 (1450)	10 (1450) 7.0 ^H 1020 ^H	8 (1160) 6.0 ^H 870 ^H	24 (3480)	19 (2760)	----	8 (1160)
7 days	19 (2760)	16 (2320)	17 (2470) 12 ^H (1740) ^H	14 (2030) 9 ^H (1310) ^H	---	---	7 (1020)	15 (2180)
28 days	28 (4060)	22 (3190)	28 (4060) 22 ^I (3190) ^I	22 (3190) 18 ^I (2610) ^I	---	---	17 (2470)	21 (3050)
Setting time, Vicat test: ^J								
▪ Initial setting time, min.	45	45	45	45	45	45	45	45
▪ Final setting time, max.	375	375	375	375	375	375	375	375

- B:** Compliance with the requirements of this standard does not necessarily ensure that the desired air content will be obtained in concrete.
- C:** The testing laboratory shall select the fineness method to be used. When the sample fails to meet the requirements of air permeability test, the turbidimeter test should be used, and the requirements in this table for the turbidimetric method shall govern.
- D:** The average value is determined from the test results of the last (5) successive samples from a certain source.
- E:** The test result of a sample should be the test result of one or several test for this sample.
- F:** The maximum average value and the maximum value for one sample do not apply when the sum of $(C_3S + 4.75C_3A)$ is less or equal to 90.
- G:** The strength at any specified test age shall not be less than that attained at any previous specific test age.
- H:** When the optional heat of hydration limit listed in Table (4) is specified.
- I:** The allowable limits for the sum $(C_3S + 4.75C_3A)$ listed in Table (1) does not apply when these requirements are specified. These strength requirements apply when the optional heat of hydration requirements are requested.
- J:** The setting time mentioned here is the initial setting time of the testing method specified in GSO Standard 1915 on “Test Methods for Physical Properties of Portland Cement”.

Table (4) - Optional Physical Requirements

Cement Type ^A								
	I	IA	II	IIA	III	IIIA	IV	V
False setting, final penetration, min. %	50	50	50	50	50	50	50	50
Heat of hydration: max. 7 days, max, kJ/kg (cal/ g)	----	----	290 (70) ^B	290 (70) ^B	----	----	250 (60) ^C	----
28 days, max, kJ/kg (cal/ g)	----	----	----	----	----	----	290 (70) ^C	----
Sulphates resistance ^D , 14 days max, expansion %	----	----	---- ^E	---- ^E	----	----	----	0.040
Gilmore test:								
Initial setting time, minute, min	60	60	60	60	60	60	60	60
Final setting time, minute, max	600	600	600	600	600	600	600	600

- A:** These optional requirements apply only when specifically requested. Verify availability before ordering.
- B:** The allowable limit for the sum of (C3S + 4.75C3A) in table (1) does not apply when these optional requirements are specified. These strength requirements apply when the optional heat of hydration requirements are requested.
- C:** When the heat of hydration limit is specified, it shall be instead of the limits of C₃S, C₂S, C₃A, SiO₂ & Fe₂O₃.
- D:** When sulphate resistance is specified, it shall be instead of the limits of C₃A, C₄AF + 2C₃A, SiO₂ & Fe₂O₃.
- E:** Cement meeting the requirements of high sulphate resistance limit for Type V is deemed to meet the moderate sulphate resistance requirement of type II.

Attachment (1)

In accordance with the European Standard EN 197-1, the family of common cements has been grouped into five main types as follows:

- 1) CEM I Portland cement
- 2) CEM II Portland-composite cement
- 3) CEM III Blast furnace cement
- 4) CEM IV Pozzolanic cement
- 5) CEM V Composite cement

The above (5) groups are divided into 27 products, the composition of which is shown in table 1. In case the cement contains other major constituents, they should be indicated in the designation notation.

Moreover, cement has been divided into (2) major classes according to its compressive strength (see Table 2):

- Class N: cement with ordinary early strength, and:
- Class R: cement with high early strength

EXAMPLE 1: Portland cement conforming to EN 197-1 with a high early strength of 42.5 MPa is identified by CEM I 42.5 R

EXAMPLE 2: Portland-composite cement containing more than 80% clinker would be designated according to table 1 as CEM II/A-M, and, if it contains a considerable percentage of blast furnace slag (S), siliceous fly ash (V) and limestone (L), and has an 'early' compressive strength of 32.5 MPa, it would be identified by [CEM II/A-M (S-V-L) 32.5 N].

- The Cement's Early strength is its compressive strength which is evaluated in accordance with the European standard (EN 196-1) at 2 days and at 7 days.

Table 1 – The 27 products in the family of common cements

Main Types	Notation of the 27 products (types of common cement)		Composition [percentage by mass]											
			Main constituents										Minor additional constituents	
			Clinker	Blast-furnace slag	Silica fume	Pozzolana		Fly ash		Burnt shale	Limestone			
						natural	natural Calcined	siliceous	calcareous		L	LL		
K	S	D	P	Q	V	W	T	L	LL					
CEM I	Portland Cement	CEM I	95-100	-	-	-	-	-	-	-	-	-	-	0-5
CEM II	Portland-Slag cement	CEM II/A-S	80-94	6-20	-	-	-	-	-	-	-	-	-	0-5
		CEM II/B-S	65-79	21-35	-	-	-	-	-	-	-	-	-	0-5
	Portland-Silica fume cement	CEM II/A-D	90-94	-	6-10	-	-	-	-	-	-	-	-	0-5
	Portland-Pozzolana cement	CEM II/A-P	80-94	-	-	6-20	-	-	-	-	-	-	-	0-5
		CEM II/B-P	65-79	-	-	21-35	-	-	-	-	-	-	-	0-5
		CEM II/A-Q	80-94	-	-	-	6-20	-	-	-	-	-	-	0-5
		CEM II/B-Q	65-79	-	-	-	21-35	-	-	-	-	-	-	0-5
	Portland-Fly ash cement	CEM II/A-V	80-94	-	-	-	-	6-20	-	-	-	-	-	0-5
		CEM II/B-V	65-79	-	-	-	-	21-35	-	-	-	-	-	0-5
		CEM II/A-W	80-94	-	-	-	-	-	6-20	-	-	-	-	0-5
		CEM II/B-W	65-79	-	-	-	-	-	21-35	-	-	-	-	0-5
	Portland-Burnt shale cement	CEM II/A-T	80-94	-	-	-	-	-	-	-	6-20	-	-	0-5
		CEM II/B-T	65-79	-	-	-	-	-	-	-	21-35	-	-	0-5
	Portland-Limestone cement	CEM II/A-L	80-94	-	-	-	-	-	-	-	-	6-20	-	0-5
		CEM II/B-L	65-79	-	-	-	-	-	-	-	-	21-35	-	0-5
		CEM II/A-LL	80-94	-	-	-	-	-	-	-	-	-	6-20	0-5
		CEM II/B-LL	65-79	-	-	-	-	-	-	-	-	-	21-35	0-5
	Portland-Composite cement	CEM II/A-M	80-94	<-----6-20----->										0-5
CEM II/B-M		65-79	<-----21-35----->										0-5	
CEM III	Blast-furnace cement	CEM III/A	35-64	36-65	-	-	-	-	-	-	-	-	-	0-5
		CEM III/B	20-34	66-80	-	-	-	-	-	-	-	-	-	0-5
		CEM III/C	5-19	81-95	-	-	-	-	-	-	-	-	-	0-5
CEM IV	Pozzolanic Cement	CEM IV/A	65-89	-	<-----11-35----->					-	-	-	0-5	
		CEM IV/B	45-64	-	<-----36-55----->					-	-	-	0-5	
CEM V	Composite Cement	CEM V/A	40-64	18-30	-	<-----18-30----->			-	-	-	-	0-5	
		CEM V/B	20-38	31-50	-	<-----31-50----->			-	-	-	-	0-5	

Table 2 – Mechanical and physical requirements

Strength Class	Compressive strength MPa				Initial Setting Time	Soundness (expansion)
	Early Strength		Standard Strength			
	2 days	7 days	28 days		min	mm
32.5 N	-	≥ 16.0	≥ 32.5	≤ 52.5	≥ 75	≤ 10
32.5 R	≥ 10.0	-				
42.5 N	≥ 10.0	-	≥ 42.5	≤ 62.5	≥ 60	
42.5 R	≥ 20.0	-				
52.5 N	≥ 20.0	-	≥ 52.5	-	≥ 45	
52.5 R	≥ 30.0	-				