Types of Portland cement

The properties of cement during hydration vary according to:

1) Chemical composition 2) Degree of fineness

It is possible to manufacture different types of cement by changing the percentages of their raw materials.

1- Ordinary Portland cement (type I)

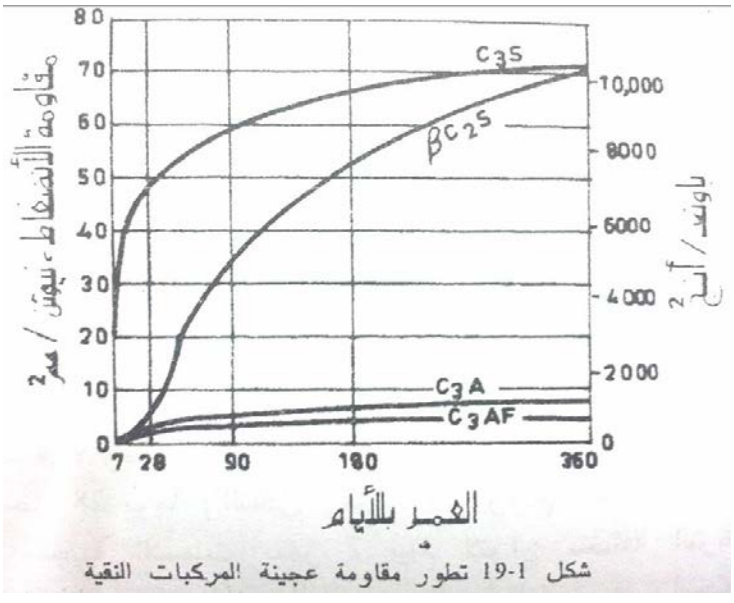
This type of cement use in constructions when there is no exposure to sulfates in the soil or groundwater.

The chemical composition requirements are listed in Iraqi specification NO. 5., as shown below:

- Lime Saturation Factor = $\frac{CaO - 0.7(SO_3)}{1.1(C_3S) + 1.4(C_2S) + 0.7(C_3A + C_4AF)}$

  L.S.F. is limited between 0.66-1.02

  This factor is limited – to assure that the lime in the raw materials, used in the cement manufacturing is not so high, so as it cause the presence of free lime after the occurrence of chemical equilibrium which cause unsoundness of cement. While too low a L.S.F. would make the burning in the kiln difficult and the proportion of C_3S in the clinker would be too low.
- Percentage of SO_3 limited by 2.5% when ≤7%, and not more than 3% when C_3A>7%
- Loss of ignition L.O.I 4% (max.)
- Percentage of MaO 5% (max.)
- Fineness not less than 2250 cm^2/g
- C_3S limits (42 – 67)%
- C_2S limits (8 – 31)%
- C_3A limits (5 – 14)%
- C_4AF limits (6 – 12)%



2- ***Rapid Hardening Portland Cement (type III)***

This type develops strength more rapidly than ordinary Portland cement. The initial strength is higher, but they equalize at 2-3 months .Setting time for this type is similar for that of ordinary Portland cement .The rate of strength gain occur due to increase of C_3S compound, and due to finer grinding of the cement clinker (the min. fineness is 3250 cm^2/g (according to IQS 5). Rate of heat evolution is higher than in ordinary Portland cement due to the increase in C_3S and C_3A, and due to its higher fineness. Chemical composition and soundness requirements are similar to that of ordinary Portland cement.

Uses

a) The uses of this cement is indicated where a rapid strength development is desired (to develop high early strength, i.e.(its 3 days strength equal that of 7 days ordinary Portland cement), for example:

i) When formwork is to be removed for re-use

ii) Where sufficient strength for further construction is wanted as quickly as practicable, such as concrete blocks manufacturing, sidewalks and the places that cannot be closed for a long time, and repair works needed to construct quickly.

b) For construction at low temperatures, to prevent the frost damage of the capillary water.

c) This type of cement does not use at mass concrete constructions.

Special Types of Rapid Hardening Portland Cement

A-Ultra High Early Strength Cement

The rapid strength development of this type of cement is achieved by grinding the cement to a very high fineness: 7000 to 9000 cm^2/g. Because of this, the gypsum content has to be higher (4 percent expressed as SO_3). Because of its high fineness, it has a low bulk density. High fineness leads to rapid hydration, and therefore to a high rate of heat generation at early ages and to a rapid strength development (7 days strength of rapid hardening Portland cement can be reached at 24 hours when using this type of cement). There is little gain in strength beyond 28 days.

It is used in structures where early prestressing or putting in service is of importance.

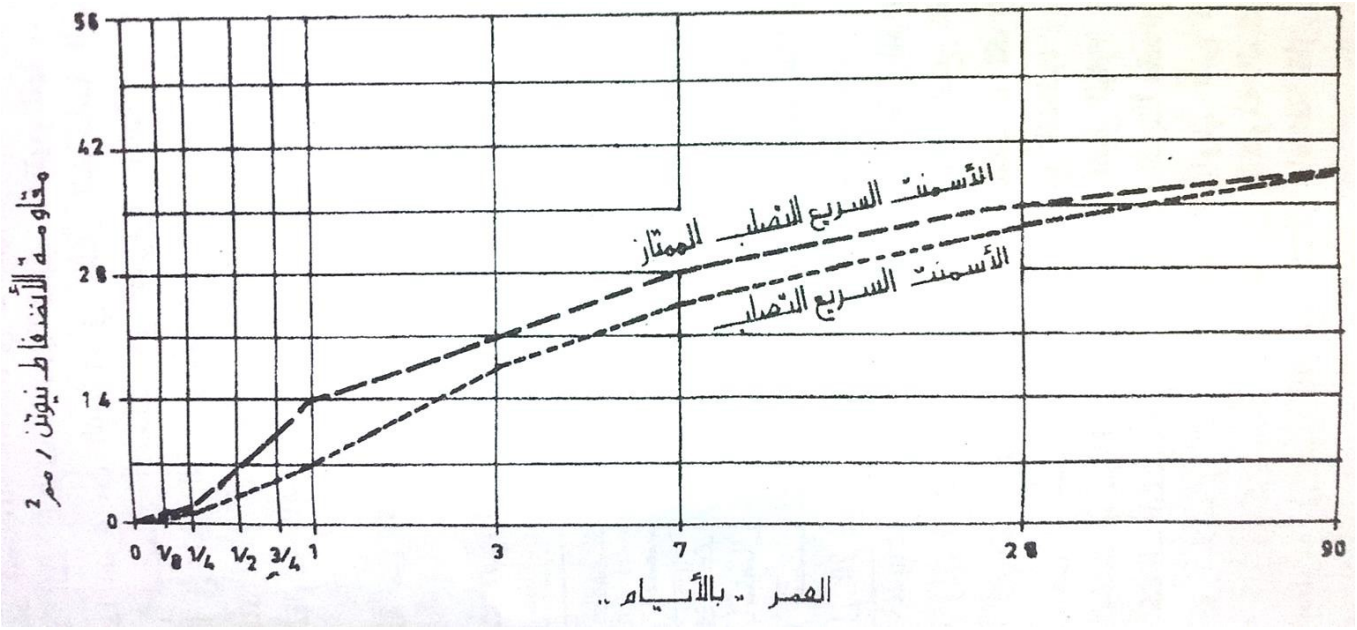
This type of cement contains no integral admixtures.

B- Extra Rapid Hardening Portland Cement

This type prepare by grinding $CaCl_2$ with rapid hardening Portland cement. The percentage of $CaCl_2$ should not be more than 2% by weight of the rapid hardening Portland cement.

By using $CaCl_2$:

- The rate of setting and hardening increase (the mixture is preferred to be casted within 20 minutes).
- The rate of heat evolution increase in comparison with rapid hardening Portland cement, so it is more convenient to be use at cold weather.
- The early strength is higher than for rapid hardening Portland cement, but their strength is equal at 90 days.
- Because $CaCl_2$ is a material that takes the moisture from the atmosphere, care should be taken to store this cement at dry place and for a storage period not more than one month so as it does not deteriorate.



3- ***Low Heat Portland Cement (Type IV)***

Its composition contains less C_3S and C_3A percentage, and higher percentage of C_2S in comparison with ordinary Portland cement.

Properties

1) Reduce and delay the heat of hydration.
2) It has lower early strength compared with ordinary Portland cement.
3) Its fineness is not less than 3200 cm^2/g

Uses

It is used in mass concrete constructions: the rise of temperature in mass concrete due to progression in heat of hydration cause serious cracks. So it is important to limit the rate of heat evolution in this type of construction, by using the low heat cement.

4- ***Sulfate- resisting Cement (Type V)***

This type is similar to ordinary Portland cement but it contains Lower percentage of C_3A and C_4AF which considers as the most affected compounds by sulfates and higher percentage of silicates in comparison with ordinary Portland cement. For this type of cement C_2S represents a high proportion of the silicates.

C_4AF is more resistance to sulfate than C_3A because a layer will form which surround the free C_3A leading to reduce its affect by sulfates, and since it is not easy to reduce Al_2O_3 in raw material so Fe_2O_3 (iron powder) may be add to mix to increase C_4AF and decrease C_3A.

$$Fe_2O_3 + C_3A \rightarrow C_4AF$$

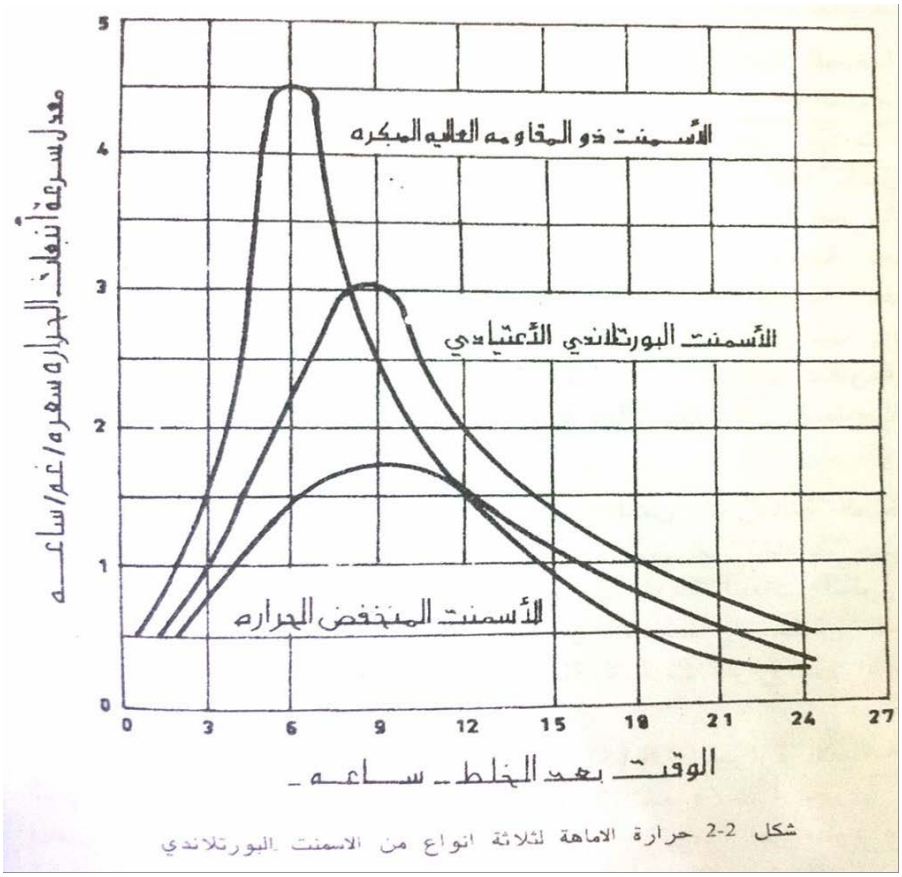
- Iraqi specification no. (6) limits - max. C_3A content by 3.5%
  - min. fineness by 2500 cm^2/g
- American standard (ASTM) - Max C_3A content by 5%
  - $2C_3A + C_4AF \leq 20\%$

Properties

- Low early strength.
- Its resulted heat of hydration is little higher than that resulted from low heat cement.
- Its cost is higher than ordinary Portland cement – because of the special requirements of material composition, including addition of iron powder to the raw materials.

For the hardened cement, the effects of sulfates are on two types:

1. Hydrated calcium aluminates in their semi-stable hexagonal form (before its transformation to the stable state – C_3AH_6 as cubical crystal form – which have high sulfate resistance) react with sulfates (present in fine aggregate, or soil and ground water), producing hydrated calcium sulfoaluminate, leading to increase in the volume of the reacted materials by about 227% causing gradual cracking.
2. Exchange between $Ca(OH)_2$ and sulfates resulting gypsum, and leading to increase in the volume of the reacted materials by about 124%.



شكل 2-2 حرارة الاماهة لثلاثة انواع من الاسمنت البورتلاندي

5- ***Portland Blast furnace Cement (Type IS)***

This type of cement consists of an intimate mixture of Portland cement and ground granulated blast furnace slag.

Slag – is a waste product in the manufacture of pig iron.

Chemically, slag is a mixture of 42% lime, 30% silica, 19% alumina, 5% magnesia, and 1% alkalis, that is, the same oxides that make up Portland cement but not in the same proportions.

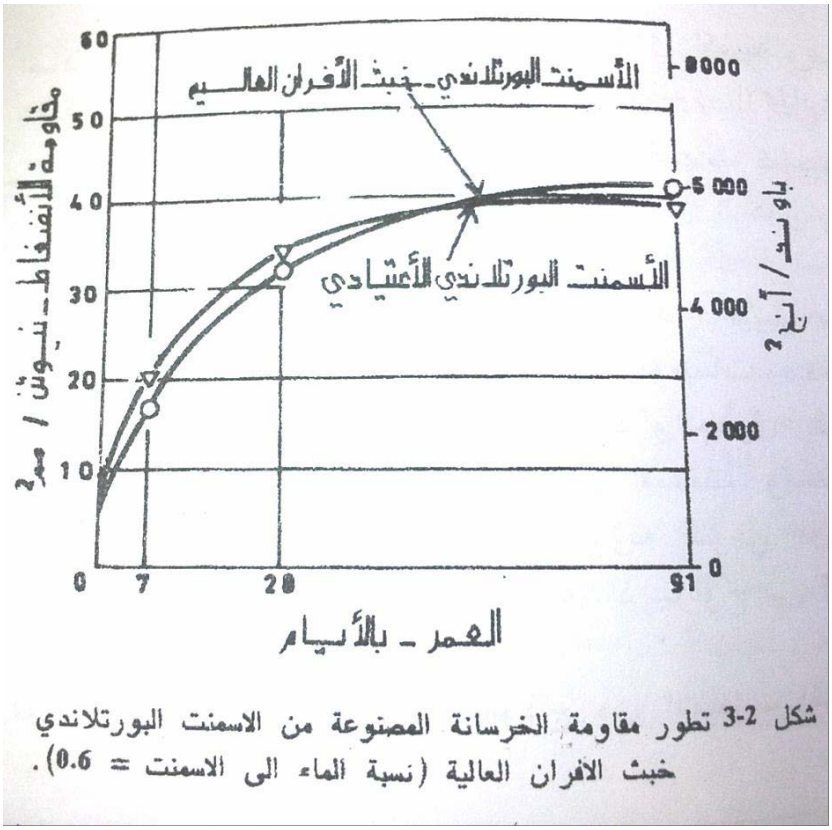
The maximum percentage of slag use in this type of cement is limited by British standard B.S. to be 65%, and by American standard ASTM C595 to be between 25-65%.

Properties

- Its early strength is lower than that of ordinary cement, but their strength is equal at late ages (about 2 months).
- The requirements for fineness and setting time and soundness are similar for those of ordinary Cement.
- The workability is higher than that of ordinary cement.
- Heat of hydration is lower that of ordinary cement.
- Its sulfate resistance is high.

Uses

- Mass concrete
- It is possible to be use in constructions subjected to sea water (marine constructions).
- May not be use in cold weather concreting.



شكل 3-2 تطور مقاومة الخرسانة المصنوعة من الاسمنت البورتلاندي خبث الافران العالية (نسبة الماء الى الاسمنت = 0.6).

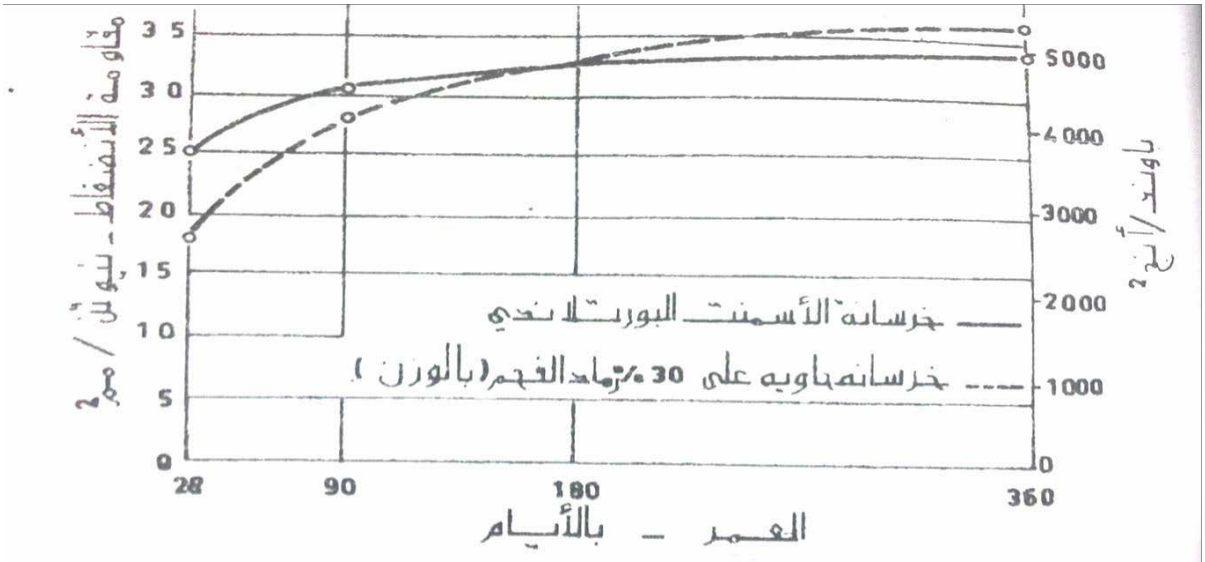
6- ***Pozzolanic Cement***

This type of cement consists of an intimate mixture of Portland cement and pozzolana. American standard limit the pozzolana content by 15-40% of Pozzolanic cement. Pozzolana, according to American standard ASTM C618, can be defined as – a siliceous or siliceous and aluminous material which in itself possesses little or no cementitious value but will, in finely divided form and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties.

It is essential that pozzolana be in finely divided state as it is only then that silica can combine with calcium hydroxide (produced by the hydrating Portland cement) in the presence of water to form stable calcium silicates which have cementitious properties. Types of Pozzolana are Natural Pozzolanic materials, such as – volcanic ash and Industrial Pozzolanic materials, such as – fired clay, rice husks ash

Properties & Uses

They are similar to those of Portland blastfurnace cement.



شكل 2-4 تأثير تعويض البوزولانا عن جزء من وزن الاسمنت البورتلاندي على مقاومة الخرسانة المصنوعة من 167 كغم من الاسمنت للمتر المكعب من الخرسانة

*7- **White Cement***

White Portland cement is made from raw materials containing very little iron oxide (less than 0.3% by mass of clinker) and magnesium oxide (which give the grey color in ordinary Portland cement). white clay is generally used, together with chalk or limestone, free from specified impurities.

Its manufacture needs higher firing temperature because of the absence of iron element that works as a catalyst in the formation process of the clinker. In some cases kreolite (sodium-aluminum fluoride) might be added as a catalyst .

The compounds in this cement are similar for those in ordinary Portland cement, but C_4AF percentage is very low.

Contamination of the cement with iron during grinding of clinker has also to be avoided. For this reason, instead of the usual ball mill, the expensive nickel and molybdenum alloy balls are used in a stone or ceramic-lined mill. The cost of grinding is thus higher, and this, coupled with the more expensive raw materials, makes white cement rather expensive.

Properties

- It has a slightly lower specific gravity (3.05-3.1), than ordinary Portland cement.
-The strength is usually somewhat lower than that of ordinary Portland cement.
-Its fineness is higher (4000-4500 cm^2/g) than ordinary Portland cement
-It used in architectural purposes.

8- Modified Portland cement (Type II)

In some application, a very low early strength may be a disadvantage, and for this reason a modified cement was developed (60% low heat Portland cement and 40% ordinary Portland cement) this cement has a higher rate of heat development than that of low heat Portland cement, and a rate of gain of strength similar to that of ordinary Portland cement. This cement is recommended for structures where a moderately low heat generation is desirable or where moderate sulfate attack may occur.

9- Colored Portland Cement

It is prepared by adding special types of pigments to the Portland cement. The pigments added to the white cement (2-10% by weight of the cement) when needed to obtain light colors, while it added to ordinary Portland cement when needed to obtain dark colors.

Pigment properties

- It is required that pigments are insoluble and not affected by ambience.
- They should be chemically inert
- Don't contain gypsum that is harmful to the concrete.
- Don't affect on strength development of concrete.

10- Other types of Portland Cements

a) Anti-bacterial Portland Cement

It is a Portland cement grounded with an anti-bacterial agent which prevents microbiological fermentation. This bacterial action is encountered in concrete floors of food processing plants where the leaching out of cement by acids is followed by fermentation caused by bacteria in the presence of moisture.

b) Hydrophobic Cement

It is prepared by mixing certain materials (stearic acid, oleic acid, … etc by 0.1-0.4%) with ordinary Portland cement clinker before grinding, to form water repellent layer

around the cement particles, so as the cement can be store safely for a long period. This layer removes during mixing process with water.

c) Water proof Portland cement

It is prepared by mixing waterproofing substance (calcium stearate, Aluminum stearate, gypsum treated with tannic acid, and non saponifable oils) with ordinary Portland cement clinker while grinding. These materials make cement impermeable to liquids.