Types of Cement

The properties of cement during hydration vary according to:

- Chemical composition
- Degree of fineness

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

Types of Portland Cement

- Ordinary Portland cement - Type I
- Modified cement - Type II
- Rapid-hardening Portland cement - Type III
- Low heat Portland cement - Type IV
- Sulfate-resisting Portland cement - Type V

It is possible to add some additive to Portland cement to produce the following types:

- Portland blast furnace cement - Type IS
- Pozzolanic cement - Type IP
- Air-entrained cement - Type IA
- White Portland cement
- Colored Portland cement

1- Ordinary Portland cement

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:

$$L.S.F. = \frac{(\mathrm{CaO}) - 0.7(\mathrm{SO3})}{2.8(SiO2) + 1.2(AL2O3) + 0.65(Fe2O3)}$$

- **Lime Saturation Factor (**L.S.F.) is limited between **0.66-1.02**

Where, each term in brackets denotes the percentage by mass of cement composition.

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 causes the presence of free lime after the occurrence of chemical equilibrium. While too low a L.S.F. would make the burning in the kiln difficult and the proportion of C3S in the clinker would be too low.

Free lime - cause the cement to be unsound.

• **Insoluble residue (I.R)** not more than 1.5%

• **Percentage of SO3** limited by 2.5% when C3A<5%,and not more than 2.8% when C3A>5%

• **Loss of Ignition (L.O.I.)** - 4% (max.)

• **Percentage of MgO** - 5% (max.)

2- Modified Cement (Type II)

This modified cement successfully combines a lower heat of hydration than ordinary cement and higher rate of heat development than that of low heat cement with a rate of gain of strength similar to that of ordinary Portland cement. Modified cement is recommended for use in structures where a moderately low heat generation is desirable or where moderate sulfate attack may occur. This cement is extensively used in the United States.

3- 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 C3S compound, and due to finer grinding of the cement clinker (the minimum value of fineness is 320 m2 /Kg (according to IQS 5)

• Rate of heat evolution is higher than in ordinary Portland cement due to the increase in C3S and C3A, and due to its higher fineness

• Chemical composition and soundness requirements are similar to that of ordinary Portland cement

• Rate of heat evolution is higher than in ordinary Portland cement due to the increase in C3S and C3A, and due to its higher fineness

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 possible, such as concrete blocks manufacturing, sidewalks and the places that cannot be closed for a long time.

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

2.1 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: 700 to 900 m2 /Kg. Because of this, the gypsum content has to be higher (4 percent expressed as SO3). 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 putting in service is of importance.

This type of cement contains no integral admixtures.

2.2 Extra Rapid Hardening Portland Cement

This type prepares by grinding CaCl2 with rapid hardening Portland cement. The percentage of CaCl2 should not be more than 2% by weight of the rapid hardening Portland cement.

By using CaCl2:

• 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 CaCl2 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.

4- Low Heat Portland Cement

Composition

It contains less C3S and C3A percentage, and higher percentage of C2S in comparison with ordinary Portland cement.

Properties

1) The delay Reduce the heat of hydration. British standard (B. S.1370 : 1974) limit the heat of hydration of this cement by:

• 60 cal/g at 7 days age • 70 cal/g at 28 days age

2) It has lower early strength (half the strength at 7 days age and two third the strength at 28 days age) compared with ordinary Portland cement.
3) Its fineness is not less than 3200 cm /g (according to B. S. 1370:1974).

Uses

It is used in mass concrete constructions because it limits the rate of heat evolution in this type of construction.

5- Sulfate- resisting Cement

Composition

It contains:

• Lower percentage of C3A and C4AF - which considers as the most affected compounds by sulfates.

• Higher percentage of silicates - in comparison with ordinary Portland cement.

• For this type of cement - C2S represents a high proportion of the silicates.

• Iraqi specification no. (5) limits - max. C3A content by 3.5%, min. fineness by 2500 cm /g

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, 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%.

• The resultant of reaction C4AF with sulfates is calcium sulfoaluminate and calcium sulfoferrite, leading to expansion. C4AF is more resistant to sulfates effect than C3A.

6- Portland Blast-furnace Cement

Production

This type of cement consists of mixture of Portland cement and ground blast-furnace slag.

Slag - is a waste product in the manufacture of 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. 146: 1974 to be 65%, and by American standard ASTM C595-76 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 (although actually its fineness is higher than that 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.

7- Pozzolanic Cement

Production

This type of cement consists of a 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.

Types of Pozzolana

- Natural Pozzolanic materials, such as - volcanic ash
-Industrial Pozzolanic materials, such as – silica fume, rice husks ash

Properties & Uses

They are similar to those of Portland blast-furnace cement.

8- 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). China clay (white kaolin) is generally used, together with or limestone.

- 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.
- The compounds in this cement are similar for those in ordinary Portland cement, but C4AF percentage is very low.

- The cost of grinding is higher, and this, coupled with the more expensive raw materials, makes white cement rather expensive.

- 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 /g) than ordinary Portland cement.

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.

The 28-day compressive strength is required to be not less than 90% of the strength of a pigment-free control mix, and the water demand is required to be not more than 110% of the control mix.

It is required that pigments are insoluble. They should be chemically inert and don't contain gypsum that is harmful to the concrete.