وزارة التعليم العالي والبحث العلمي
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كلية المستقبل الجامعة

Concrete Technology

Second Year

Chapter Two: Types of Cement

قـــــــسم هندسة تقنيات البناء والانشاءات

Building & Construction Technology Engineering Department

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Chapter Two

Types of Cement

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

There are different types of Cement:

1- Portland cement

2- Natural cement

3- Expansive cement

4- High-alumina cement

5-Super sulphated Cement

According to claissfication of american specification (ASTM-C150), there are many types of portland cement, it is the same classification which has been followed by iraqi specification No. 5 (1984).

These types are:

1- Ordinary Portland cement – Type I

2- Modified cement - Type II

3- Rapid-hardening Portland cement – Type III

4- Low heat Portland cement – Type IV

5-Sulfate-resisting Portland cement – Type V

6-Portland blast furnace cement

7- Pozzolanic cement

8- White Portland cement

1- Ordinary Portland Cement (O.P.C) Type I:

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

Lime Saturation Factor =

$$L.S.F = \frac{CaO - 0.7(SO3)}{2.8(SiO2) + 1.2(Al2O3) + 0.65(Fe2O3)}$$

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 cause 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 C_3S in the clinker would be too low.

Free lime – cause the cement to be unsound.

- Percentage of **(Al_2O_3/Fe_2O_3)** is not less than 0.66
- **Insoluble residue** not more than 1.5%
- **Percentage of SO_3** limited by 2.5% when $C_3A <= 7\%$ and not more than 3% when $C_3A > 7\%$
- **Loss of ignition** L.O.I. – 4% (max.)
- **Percentage of MgO** - 5% (max.)
- **Free CaO ≤ 4%**
- Fineness ≥ 2250 cm^3/gm
- C_3S = (40-65)%, C_2S= (8-40)%, C_3A= (8-14)%& C_4AF= (5-15)%
- Initial setting Time ≥45 minutes
- Final setting Time ≤ 10 hours
- Compressive strength

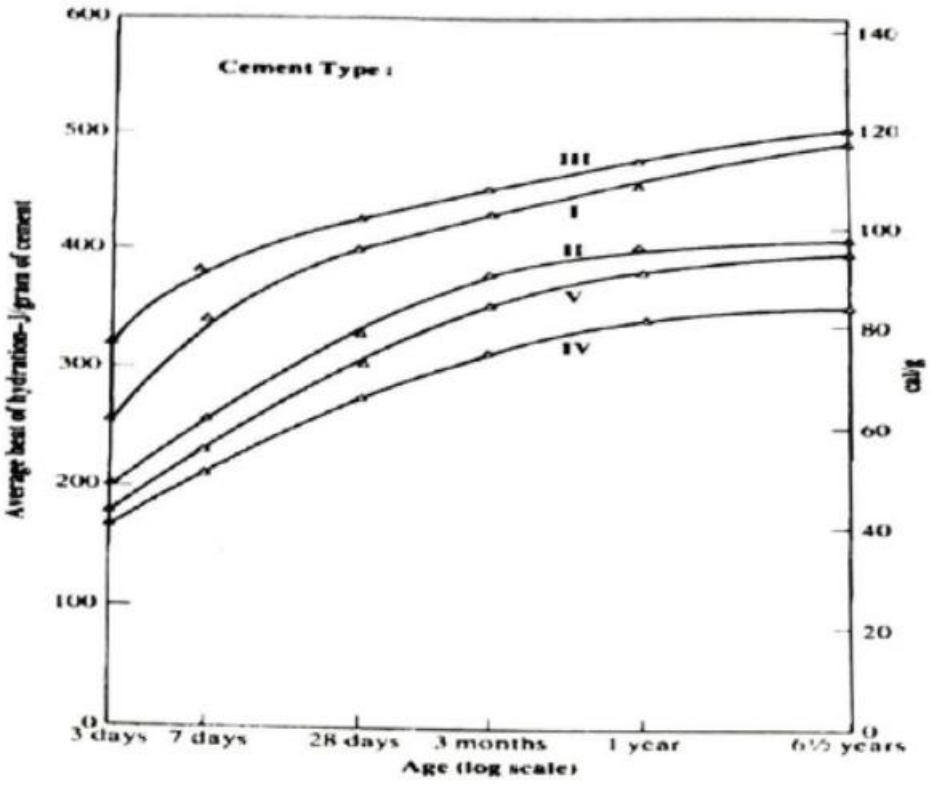
  3 days ≥ 15 Mpa

  7 days ≥ 23 Mpa

2- Rapid Hardening Portland Cement - (Type III)

It charractrized by

1- Contains high percentage of C_3S which may be reaches (70%) and C_3A which may equal to (15%)
2- Has high hygration heat so, it will has very high early strength especially after 3 days of hydration which equal the strenth of type I after 7 days
3- It used in cold weather to prevent the freezing of mixing water
4- It should be not used in mass concrete construction or in large structural section beacuse of its higher rate of heat development as shown below.



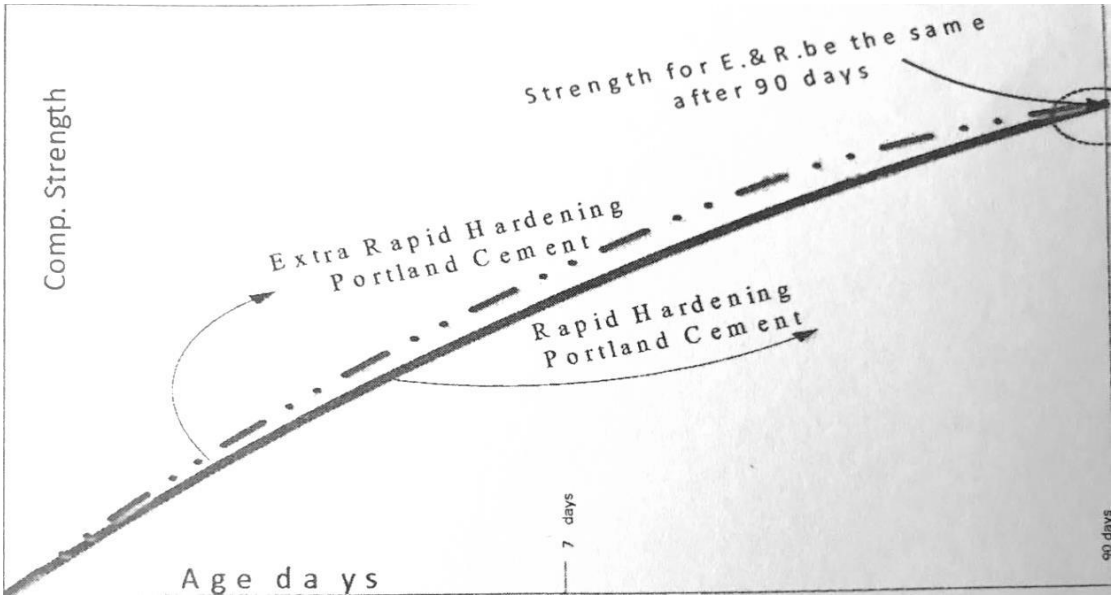
Average of heat development for different types of P.C.

5- The cost of this cement is greater than O.P.C

Special Types of Rapid Hardening Portland cement

2-1 Extra Rapid Hardening Portland cement

1- 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.
2- $CaCl_2$ added to increase the speed of setting and hardening so, it must be casted, compacted and finshing during 20 min.
3- It is store in dry condition because; $CaCl_2$ is a material that takes the moisture from the atmosphere.
4- Do not used with reinforcment concrete because the reinforced bar can be rusting يصدأ according to the acidit حموضه of $CaCl_2$
5- It suitable to use in cold weather
6- The early strength is higher than for rapid hardening Portland cement



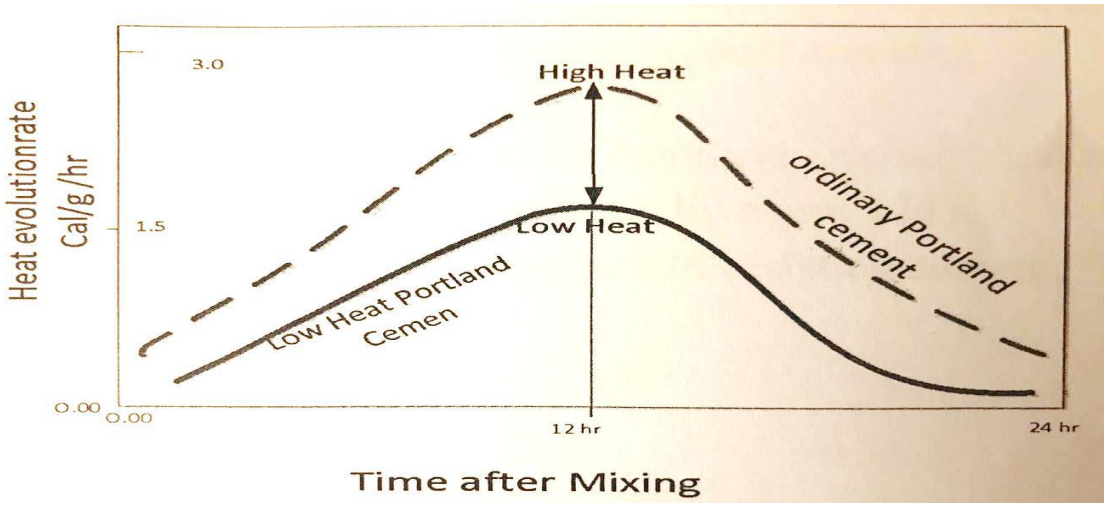
Relation between Age and compressive strength for the types of R.H.P.C.

2-2 Ultra High Early Strength Cement

1- The rapid strength development of this type of cement is achieved by grinding the cement to a very high fineness: 7000 to 9000 cm^3/gm, so it required gypsum > 5%.
2- Because of its high fineness, it has a low bulk density.
3- High fineness leads to rapid hydration, and therefore to a high rate of heat generation at early ages
4- U.RHPC damaged when exposed to weather.
5- Strength (16)hr. for U.RHPC = Strength (3 days) for RHPC
6- Casting in cold weather.
7- Used in rapid ending work such as road maintenance.

3- Low Heat Portland cement (LHPC- Type IV)

1- Low percent of C3S and C_3A and higher percent of C_2S in comparison with ordinary Portland cement.
2- Slower development of strength than OPC but, the final strength is unaffected لم تتأثر
3- L.S.F = (0.66-1.08)
4- Fineness ≥ 3500 cm^3/g to get suitable early strength
5- Low heat of hydration
6- $C_3S \leq 30\%$, $C_2S \geq 70\%$, $C_3A \leq 7\%$



The relation between time after mixing cement paste and heat evolution rate for low heat cement and ordinary Portland cement.

4- Modified portland cement (Type II)

1- Prepeared from 40% OPC + 60% LHPC so, heat of hydration is higer than LHPCand lower than OPC
2- It is used where moderate sulfate attack occurs or where a moderately low heat of hydration is desirable
3- Low percent of C_3S and C_3A ($C_3A \leq 3.3\%$)
4- Fineness = 2500 cm^3/gm

5- Sulfate- resisting Portland Cement (SRPC- Type V)

1- This cement has a low content ($C_3A \leq 3.5\%$), it prepeared either by decreasing alumina content (Al_2O_3) or by increasing the (Fe_2O_3) content this lead to increase C_4AF and decrease C_3A because C_3A inversly proporsion with C_4AF.

2- It is used in the case of sulfate attack.

3- $C_3A \leq 3.5\%$ (IQ Specification) and $C_3A \leq 5\%$ (ASTM & B.S Specification)

4- $SO_3 \leq 2.5\%$

5- $MgO \leq 5\%$

6- $C_3A + C_4AF \leq 20\%$

What is the sulfate attack?

First reaction: is between C_3A & SO_3, (SO_3 may be internal sulfate that found in sand and clay or external sulfate which found in the soil and groundwater), the reaction result is the ettringate which cause disruption اضطراب of concrete due to increase in volume and expansion of 227%.

$$\mathbf{C_3A + 3(\ CaSO_4.}4H_2O) + 26\ H_2O \longrightarrow C_3A.3CaSO_4.30\text{-}32H_2O$$

(ettringate)

Second reaction: between SO_3 from gypsum and hydrated lime الجير المطفأ, the result of reaction is gypsum with vloume increase by 124% so, the concrete will disrupted and cracked.

$$\mathbf{SO_3 + Ca\ (OH)_2 \longrightarrow\ CaSO_4.\ 4H_2O}$$

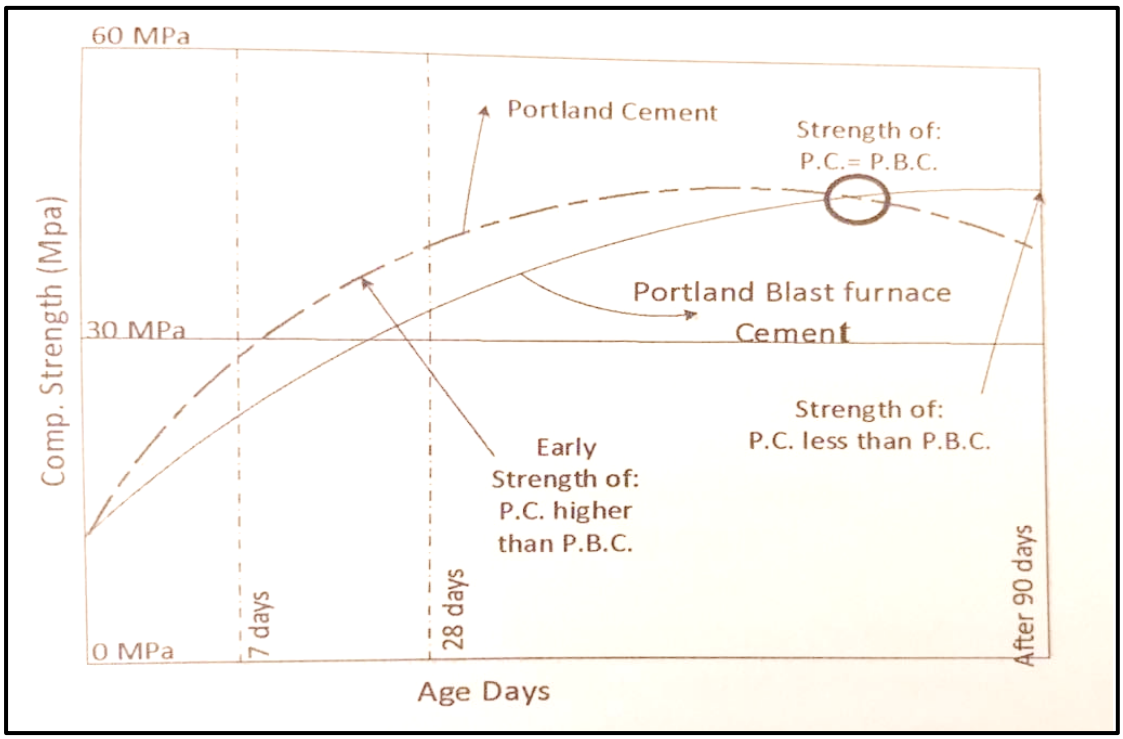
6- Portland Blast furnace Cement

Prepared by blending (OPC clinker + Blast furance slag)

Slag – is a waste product in the manufacture of iron which contains Lime CaO, silica SiO_2 and alumina Al_2O_3, Slag added by (25-70) % from mass of the mixture. That is, the same oxides that make up Portland cement but not in the same proportions.

بمعنى ، نفس الأكاسيد التي يتكون منها أسمنت بورتلاند ولكن ليس بنفس النسب

1- Early strength is lower than that of ordinary cement, but later strength is higher than OPC.
2- Heat of hydration is lower that of ordinary cement.
3- Used in mass concrete.
4- It is possible to be use in constructions subjected to sea water because of a better sulfate resistance (due to low C_3A content).
5- Finessness of this type is lower than of OPC.



Relation between Age of concrete and compressive strength for different types of cement

7- White Portland Cement

1- It made from china clay, which contains little (Fe_2O_3, MgO), together with chalk and lime stone free from specified impurities ($Fe_2O_3 \leq 1\%$).
2- It contains high C_3A.
3- High early strength but low later strength.
4- It very expensive because it prepared from special materials and required special precaution during grinding to avoid contamination.
5- Used for architectural purposes, white concret and surface finishing.

8- Portland - Pozzolana Cement (P.P.C)

1- This type of cement consists of (pozzolana ≤ 20% + OPC).

Pozzolana, according to American standard ASTM C618, can be defined as – a siliceous or siliceous and aluminous material which don't have bonding properties خصائص ربط but when grinding to powder in the presence of water it reacts with $Ca(OH)_2$ at ordinary temperatures to form compounds have cementitious properties مركب ذات خصائص سمنتية .

2- P.P.C gain strength slowly and therefore required curing long period so, long – term strength is high. Its strength is higher than OPC.
3- P.P.C has low cost
4- Used in the case of aggressive attack of external sulfate.
5- The most common types of Pozzolana are fly ash, rice husks ash, fired clay, silica fume .....etc.

Other Type of Cements

1-High Alumina Cement (HAC)

- Prepared by melting of lime stone or chalk with bauxite (sedimentary rock with a relatively high aluminium content) to melting point and then grinding the clinker to fineness of (2250-3200) cm^3/gm.
- $Al_2O_3 \geq 32\%$
- 6hr. $\geq$ Initial setting $\geq$ 2 hr.
- Final setting is two hours after initial setting
- Strength at early age is very high than the other types, but it may decrease at later age especially if the cement exposes to changing in temperture.

2-Super Sulfate Resisting Cement

- Made from

Slag	+	Fired gypsum ($CaSO_4$)	+	Clinker OPC
(80-85) %		(10-15) %		5 %

And then grinding to (3500-5000) cm^3/gm

- Has low rate of hydration so, it used in mass concrete.
- Initial setting (2.5- 4) hr., final setting (4.5 – 7) hr.
- Required high water quantities so, W/C ratio must be not less than 0.4.