RPSC 2024

Rajasthan Public Service Commission

Assistant Engineer

CIVIL ENGINEERING

Building Materials

CONTENTS

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CEMENT

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INTRODUCTION

- Cement is an extremely ground material having adhesive and cohesive properties which provide a binding medium for the discrete ingredients.
- It is obtained by burning together, in a definite proportion, a mixture of naturally occurring argillaceous (containing alumina) and calcareous (calcium carbonate or lime) materials to a partial fusion at high temperature (about 1450°C). The product obtained on burning called clinker, is cooled and ground to the required fineness to produce a material known as cement.
- Joseph Aspdin, a Leeds builder and brick layer first manufactured cement and called it Portland cement because when it hardened it produced a material resembling stone from the quarries near Portland in England.
- During grinding of clinker, gypsum or plaster of Paris is added to prevent flash setting of the cement. The amount of gypsum is about 3 to 5 per cent by weight of clinker. It also improves the soundness of cement.
- The common calcareous materials are lime stone, chalk, oyster shells and marl.
- The argillaceous materials are clay, shale, slate and selected blast furnace slag.
- Certain clays formed during volcanic eruption, known as volcanic ash or pozzolana found near Italy have properties similar to that of Portland cement.
- The processes used for the manufacture of cement can be classified as dry and wet.
- In the wet process, the limestone brought from the quarries is first crushed to smaller fragments. Then, it is taken to a ball or tube mill where it is mixed with clay or shale as the case may be and ground to a fine consistency of slurry with addition of water. The slurry is stored in tanks under constant agitation and fed into huge firebrick lined rotary kilns.
- In the dry process the raw materials are ground, mixed and fed to the rotary kiln in the dry state.
- The rotary kiln is fired from the lower end and the raw material or slurry is fed at the higher end.
- By the time the material rolls down to the lower end of the rotary kiln, the dry material undergoes a series of chemical reactions until finally, in the hottest part of the kiln where the temperature is of the order of 1500°C, about 20 to 30 per cent of the materials get fused.
- The fused mass turns into nodular form of size 3 mm to 20 mm known as clinker which has its own physical and chemical properties.
- This clinker is coated, crushed, mixed with 3 to 5 per cent of crushed gypsum and fed into a tube mill for final grinding. The finished product known as Portland cement is finally bagged.

Cement and Lime

Following points of differences may be noted between ordinary cement and lime:

1. The cement can be used under conditions and circumstances which are not favourable for lime.
2. The cement, when converted into a paste form, sets quickly.
3. The colours of cement and lime are different.
4. When water is added to the cement, no heat is produced and there is no slaking action.

CHEMICAL COMPOSITION

- The raw materials used for the manufacture of cement consist mainly of lime, silica, alumina and iron oxide.
- The relative proportions of these oxide compositions are responsible for influencing the various properties of cement.
- These oxides present in the raw materials when subjected to high clinkering temperature combine with each other to form complex compounds.
- The identification of the major complex compounds is largely based on R.H. Bogue's work and hence these are called Bogue's compounds.
- In addition to the four major compounds (Bogue's compounds), there are many minor compounds formed in the kiln.
- The influence of these minor compounds on the properties of cement or hydrated compounds is not significant. Two of the minor oxides namely K_2O and Na_2O referred to as alkalis in cement are of some importance.

Constituents	Percentage	Average
Lime (CaO)	62 to 67%	62
Silica (SiO_2)	17 to 25%	22
Alumina (Al_2O_3)	3 to 8%	5
Calcium sulphate ($CaSO_4$)	3 to 4%	4
Iron oxide (Fe_2O_3)	3 to 4%	3
Magnesia (MgO)	0.1 to 3%	2
Sulphur	1 to 3%	1
Soda and Potash ($Na_2O + K_2O$)	0.5 to 1.3%	1

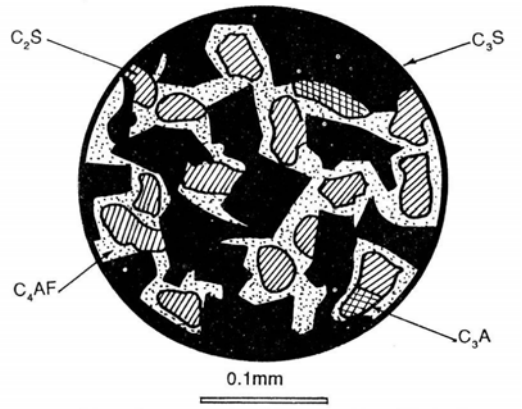
Chemistry of Cement

Formation of Cement Compounds

- Portland cement consists of the following principal compounds.

Chemical formula	
Tricalcium silicate, designated as C_3S	$3\,CaOSiO_2$
Dicalcium silicate, designated as C_2S	$2\,CaOSiO_2$
Tricalcium aluminate, designated as C_3A	$3\,CaOAl_2O_3$
Tetracalcium Alumino ferrite, designated as C_4AF	$4CaO.Al_2O_3.Fe_2O_3$

There are also other impurities present such as free calcium oxide (CaO) and magnesium oxide (MgO), effects of which will be considered later.



Schematic representation of the composition of Portland cement

Bogue's Compounds

Name	Chemical formula	Percentage
Tricalcium Silicate (C_3S)	$3CaO.SiO_2$	30-50
Dicalcium Silicate (C_2S)	$2\,CaO.SiO_2$	20-45
Tricalcium Aluminate (C_3A)	$3CaO.Al_2O_3$	8-12
Tetracalcium Alumino Ferrite (C_4AF)	$4\,CaO.Al_2O_3.Fe_2O_3$	6-10

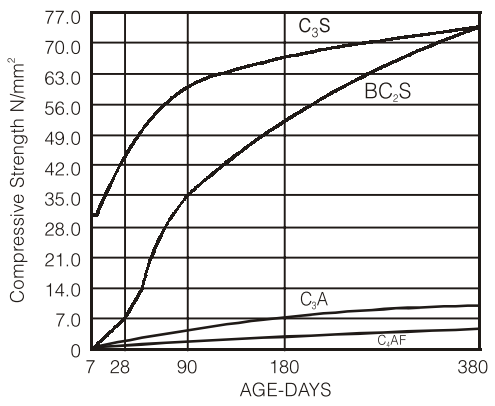
Functions of Cement Ingredients

1. **Lime (CaO):** This is the important ingredient of cement and its proportion is to be carefully maintained. The lime in excess makes the cement unsound and causes the cement to expand and disintegrate. On the other hand, if lime is in deficiency, the strength of cement is decreased and it causes cement to set quickly.
2. **Silica (SiO_2):** This is also an important ingredient of cement and it gives or imparts strength to the cement due to the formation of dicalcium and tricalcium silicates. If silica is present in excess quantity, the strength of cement increases but at the same time, its setting time is prolonged.
3. **Alumina (Al_2O_3):** This ingredient imparts quick setting property to the cement. It acts as a flux and it lowers the clinkering temperature. However the high temperature is essential for the formation of a suitable type of cement and hence the alumina should not be present in excess amount as its weakens the cement.

4. **Calcium Sulphate ($CaSO_4$):** This ingredient is in the form of gypsum and its function is to increase the initial setting time of cement.
5. **Iron Oxide (Fe_2O_3):** This ingredient imparts colour, hardness and strength to the cement.
6. **Magnesia (MgO):** This ingredient, if present in small amount, imparts hardness and colour to the cement. A high content of magnesia makes the cement unsound.
7. **Sulphur (S):** A very small amount of sulphur is useful in making sound cement. If it is in excess, it causes unsoundness in cement.
8. **Alkalies:** The most of the alkalies present in raw materials are carried away by the flue gases during heating and the cement contains only a small amount of alkalies. If they are in excess in cement, they cause a number of troubles such as alkali aggregate reaction, efflorescence and staining when used in concrete, brickwork or masonry mortar.

BASIC PROPERTIES OF CEMENT COMPOUNDS

- C_3S and C_2S which together constitute about 70 to 80 per cent of the cement control most of the strength giving properties.
- C_3S giving a faster rate of reaction accompanied by greater heat evolution develops early strength. On the other hand, dicalcium silicate (C_2S) hydrates and hardens slowly and provides much of the ultimate strength.



Compressive strength of cement compound with age

- A higher percentage of C_3S results in rapid hardening with an early gain in strength at a higher heat of hydration. On the other hand, a higher percentage of C_2S results in slow hardening, less heat of hydration and greater resistance to chemical attack.
- C_3A is characteristically fast reacting with water and may lead to an immediate stiffening of paste, and this process is termed as flash set. The role of gypsum added in the manufacture of cement is to prevent such a fast reaction.
- C_3A provides weak resistance against sulphate attack and its contribution to the development of strength of cement is perhaps less significant than that of C_3S and C_2S.
- Like C_3A, C_4AF also hydrates rapidly but its individual contribution to the overall strength of cement is insignificant. However, it is more stable than C_3A.

Do You know?

- *Le Chatelier and Tornbohm observed four different kinds of crystals in thin sections of cement clinkers. Tornbohm called these crystals as Alite, Belite, Celite and Felite. His description of the minerals in the cement was found to be similar to Bogue's descriptions of the compounds. Therefore Bogue's Compounds C_3S, C_2S, C_3A and C_4AF are sometimes called Alite, Belite, Celite and Felite.*
- *A high lime and silica content generally increases setting time and results in higher strengths. On the other hand a decrease in lime and silica content reduces the strength of concrete.*
- *The presence of excess unburnt lime is harmful since it results in delayed hydration causing expansion (unsoundness) and deterioration of concrete.*
- *Iron oxide is not a very active constituent of cement and generally acts as a catalyst and helps the burning process. Owing to its presence, cement derives the characteristic grey colour.*
- *Magnesia, if present in large quantities, causes unsoundness in cement.*

Practice Questions : Level-1

Q.1 The main ingredients of Portland cement are
(a) line and silica
(b) line and alumina
(c) silica and alumina
(d) line and iron

Q.2 The constituent of cement which is responsible for all the undesirable properties of cement is
(a) dicalcium silicate
(b) tricalcium silicate
(c) tricalcium aluminate
(d) tetra calcium alumino ferrite

Q.3 Le Chatelier's device is used for determining the
(a) setting time of cement
(b) soundness of cement
(c) tensile strength of cement
(d) compressive strength of cement

Q.4 Addition of pozzolana to ordinary Portland cement increase
(a) bleeding
(b) shrinkage
(c) permeability
(d) heat of hydration

Q.5 Proper amount of entrained air in concrete results in
1. better workability
2. better resistance of freezing and thawing
3. lesser workability
4. less resistance to freezing and thawing

The correct answer is
(a) 1 and 2 (b) 1 and 4
(c) 2 and 3 (d) 3 and 4

Practice Questions : Level-2

Q.6 The most commonly used retarder in cement is
(a) gypsum
(b) calcium chloride
(c) calcium carbonate
(d) none of the above

Q.7 The most common admixture which is used to accelerate the initial set of concrete is
(a) gypsum
(b) calcium chloride
(c) calcium carbonate
(d) none of these

Q.8 According to IS specifications, the compressive strength of ordinary portland cement after three days should not be less than
(a) 7 MPa (b) 11.5 MPa
(c) 26 MPa (d) 21 MPa

Q.9 Increase in fineness of cement
(a) reduces the rate of strength development and leads to higher shrinkage
(b) increases the rate of strength development and reduces the rate of deterioration
(c) decreases the rate of strength development and increases the bleeding of cement
(d) increases the rate of strength development and leads to higher shrinkage

Q.10 The initial setting time for ordinary Portland cement as per IS specifications should not be less than
(a) 10 minutes (b) 30 minutes
(c) 60 minutes (d) 600 minutes

ANSWERS

1.	(a)	**2.**	(c)	**3.**	(b)	**4.**	**(b)**	**5.**	(a)
6.	(a)	**7.**	**(b)**	**8.**	(c)	**9.**	(d)	**10.**	(b)

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