1.2 CHEMICAL COMPOSITION AND PROPERTIES

Chemical short hand

Because of the complex chemical nature of cement, a shorthand form is used to denote the chemical compounds. The shorthand for the basic compounds is:

Compound	Formula
Calcium oxide (lime)	Ca0
Silicon dioxide (silica)	SiO_2
Aluminum oxide (alumina)	Al_2O_3
Iron oxide	Fe_2O_3
Water	H_2O
Sulfate	SO_3

Chemical composition of clinker

The cement clinker formed has the following typical composition:

Compound	Formula
Tricalcium aluminate	$Ca_3Al_2O_6$
Tetracalcium aluminoferrite	$Ca_4Al_2Fe_2O_{10}$
Belite or dicalcium silicate	Ca_2SiO_5
Alite or tricalcium silicate	Ca_3SiO_4
Sodium oxide	Na_2O
Potassium oxide	K_2O
Gypsum	$CaSO_4.{}_2H_2O$

Bogue's compounds

- Tricalcium silicate $CaO.SiO_2$ C_3S
- Dicalcium silicate $CaO.Sio_2$ C_2S
- Tricalcium aluminate $Cao.Al2O_3$ C_3A
- Tetra calcium aluminoferrite $CaO.Al2O_3.Fe_2O_3$ C_4AF

Properties of cement compounds

These compounds contribute to the properties of cement in different ways

❖ **Tricalcium aluminate, C_3A:-**

It liberates a lot of heat during the early stages of hydration, but has little strength contribution. Gypsum slows down the hydration rate of C_3A. Cement low in C_3A is sulfate resistant.

❖ **Tricalcium silicate, C_3S:-**

This compound hydrates and hardens rapidly. It is largely responsible for Portland cement's initial set and early strength gain.

❖ **Dicalcium silicate, C_2S:**

C_2S hydrates and hardens slowly. It is largely responsible for strength gain after one week.

❖ **Ferrite, C_4AF:**

This is a fluxing agent which reduces the melting temperature of the raw materials in the kiln (from 3,000o F t o 2,600o F). It hydrates rapidly, but does not contribute much to strength of the cement paste.

By mixing these compounds appropriately, manufacturers can produce different types of cement o suit several construction environments.

Ingredients of Cement

- ✓ Lime
- ✓ Silica
- ✓ Alumina
- ✓ Iron oxide
- ✓ Magnesium oxide
- ✓ Sulphur trioxide
- ✓ Alkalies
- ✓ Calcium sulphate

Lime

- ➢ Lime in excess makes the cement unsound and causes the cement to expand and disintegrate.
- ➢ If it is in deficiency, the strength of cement is decreased and cement sets quickly.

Therefore it should be in right proportion to produce the cement sound and strong.

Silica

- Silica imports strength to cement.
- In excess provides greater strength to the cement but at the same time prolongs cement setting time.

Alumina

- It imports quick setting quality to the cement, lowers the clinkering temperature.
- In excess reduces the strength of cement.

Iron oxide

- Provides color, hardness and strength to cement.

Magnesium oxide

- Imparts hardness and color to cement.
- In excess makes the cement unsound.

Sulphur trioxide

- It makes the cement sound.
- In excess it causes the cement unsound.

Alkalies

- In excess will cause efflorescence.

Calcium sulphate

- Control the initial setting time of cement

Oxide	Percent content
Lime CaO	60-67
Silica SiO_2	17-25
Alumina Al_2O_3	3.0-8.0

Iron Oxide Fe_2O_3	0.5-0.6
Magnesia MgO	0.1-4.0
Alkalies(k_2O, Na_2O)	0.4-1.3
Sulphur SO_3	1.3-3.0

Grade of Cement

Grade of cement represents the specific 28 days compressive strength. The following three grades are given along with their compressive strengths

33 Grade OPC –33 MPa

43 Grade OPC – 43 MPa

53 Grade OPC – 53 Mpa

Physical properties	**Grade of cement**		
	33	**43**	**53**
Minimum compressive strength at 28 days (N/mm^2)	33	43	53
Fineness-minimum specific surface area (m^2/kg)	225	225	225
Initial setting time (minimum)	30 min.	30 min.	30 min.
Final setting time (maximum)	600 min.	600 min.	600 min.
Soundness (expansion) in mm	10	10	10
Autoclave test for MgO, percent, maximum	0.8	0.8	0.8
Chemical Properties			
Loss on ignition (%)	5	5	4
Insoluble residue (%), maximum	4	2	2
Magnesia MgO (%), maximum	6	6	6
SO_3 (%) , maximum for $C_3A > 5$ percent	2.5	2.5	2.5
Lime saturation factor (LSF)	0.66-1.02	0.66-1.02	0.8-1.02
Ratio A F minimum	0.66	0.66	0.66

Hydration of Cement

- When water is added to cement, ingredients of the cement react chemically with water and form various complicated chemical compounds, this is called hydration of cement.

- During hydration process, cement produces calcium hydrate silicate (C-H-S) and calcium hydrate aluminate (C-H-A). These products are thick and sticky and it is called C-H-S / C-H-A gel. This gel has adhesion properties and bind the aggregates together, also fill the voids between sand and coarse aggregates.

Heat of hydration:

- The reaction of cement with water is exothermic. The reaction liberates a considerable amount of heat is called heat of hydration.

Abram's water cement law

According to Abram's water cement law, the strength of concrete depends on the water cement ratio used.

In order to delay the setting action of cement, when mixed with water, a little percentage of gypsum is added in the clinker before grinding them to fine powder.