Chemistry of Major Compounds of Cement

Cements, in a general sense, are adhesive materials which are capable of bonding together fragments or particles of solid matter into a compact whole.

The term hydraulic cements referred to cements that harden by reaction with water and form a water-resistant product. Thus, Portland cement is a hydraulic cement capable of setting, hardening and remains stable under water.

Raw material for Portland Cement (P.C)

(60%) Calcareous material such as Limestone, chalk, etc. ⟶ Calcium ($CaO+CO_2$)

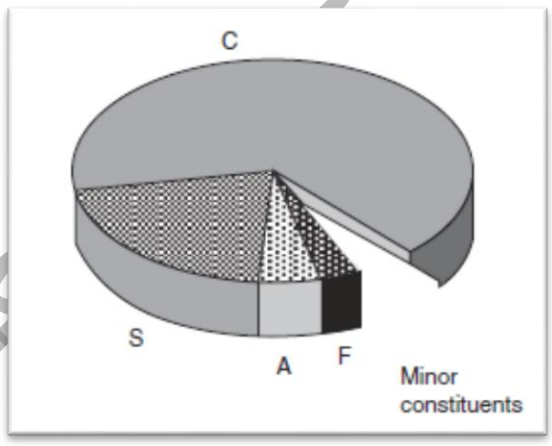
(30%) Argillaceous materials such as Clays and shales ⟶ Silica (SiO_2) and Oxides $Al_2O_3+Fe_2O_3$)

(4%) Gypsum ⟶ SO3

Accordingly, Portland cement consists of mainly of lime (Cao), silica (Sio_2), alumina (Al_2O_3) and iron oxide(Fe_2O_3) which, internationally referred to as C, S, A and F respectively. The combined content of the four oxides is approximately 90% of the cement weight and they are generally referred to as “major oxides”. The remaining 10% consists of magnesia (MgO), alkali oxides (Na_2O and K_2O), titania (TiO_2), phosphorous pentoxide (P_2O_5) and gypsum. These are referred to as “minor constituents”.

Oxide	Common Name	Abbreviation	Approx. Amount (%)
CaO	Lime	C	60-67
SiO_2	Silica	S	17-25
Al_2O_3	Alumina	A	3-8
Fe_2O_3	Iron-oxide	F	0.5-6
MgO	Magnesia	M	0.1-4
Na_2O	Soda	N	0.2-1.3
K_2O	Potassa	K	
SO_3	Sulfuric Anhydride	Ś	1-3

The amount of oxides in a P.C. depends on the proportion of the raw materials and how well the burning is done in the kiln.



Manufacturing process

a) Clinker production

Burning of raw flour (clay + limestone grist), in a rotary kiln:

Drying takes place with face-flowing exhaust gases coming from the opposite direction.

Preheating: around 450-550°C, clay minerals lose their water of crystallization, at temperatures ranging between 600-800°C, the $MgCO_3$ becomes is de-carbonated (→ MgO)

Calcination: >900°C $CaCO_3$ becomes de-carbonated (→ CaO), around 1200°C silicate producing reactions kick in.

Shrinkage: up to 1450°C. Within the frame of exothermic process of clinker minerals are formed.

Cooling, resting: Through this, free CaO reacts with water in the air, and with Carbon-dioxide (subsequent transformation would cause swelling)

b) Cement production

The cooled down clinker is grinded up with the gypsum stone and – in case of heterogeneous cement production –grinded or added to hydraulic complements.

It is of utmost importance that the clinker is cooled adequately, because

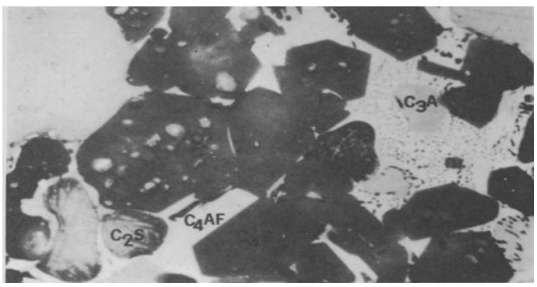
- Hot grinding damages the crushing plants,

-Reactive semi-hydrate can be formed from gypsum-stone, which when used in cement, hardens rather quick with water (pseudo bonding)

COMPOUND COMPOSITION OF P.C.

Oxides interact with each other in the kiln to form more complex products (compounds) in Clinker form. Basically, the major compounds of P.C. can be listed as:

Name	Chemical Formula	Abbreviations
Tri Calcium Silicate	$3CaO.SiO_2$	C_3S
Di Calcium Silicate	$2CaO.SiO_2$	C_2S
Tri Calcium Aluminate	$3CaO.Al_2O_3$	C_3A
Tetra Calcium Alumino Ferrite	$4CaO.Al_2O_3.Fe_2O_3$	C_4AF



Types of clinkers minerals and their characterization

Silicate chemistry abbreviations: C = CaO, S = SiO_2, A = Al_2O_3, F = Fe_2O_3, H = H_2O, furthermore Cs =$CaSO_4$, and CH = Ca $(OH)_2$

The 3CaO SiO_2, alit, tricalcium-silicate (abbr.: C_3S), is the main clinker mineral having large initial strength and high bonding temperature. The amount of it in cement: 37 to 60%

•The $2SiO_2CaO$, Belite, di-Calcium-silicate (abbr.: βC_2S), is having slow initial hardening, small bonding temperature and favorable post hardening properties. Its amount in cement by percentage is: 15-37%

• $3CaOAl_2O_3$, Felite, tricalcium-aluminate (abbr.: C_3A), the fastest bonder, the most heat developer clinker mineral showcasing poor Sulphate resistance (to retard processes gypsum is added). Amount in cement: 7-15%

• $Al_2O_3Fe_2O_34CaO$ Celite, tetracalcium-aluminate-ferrite (abbr.: C_4AF), low strength, favorable Sulphate-resistance