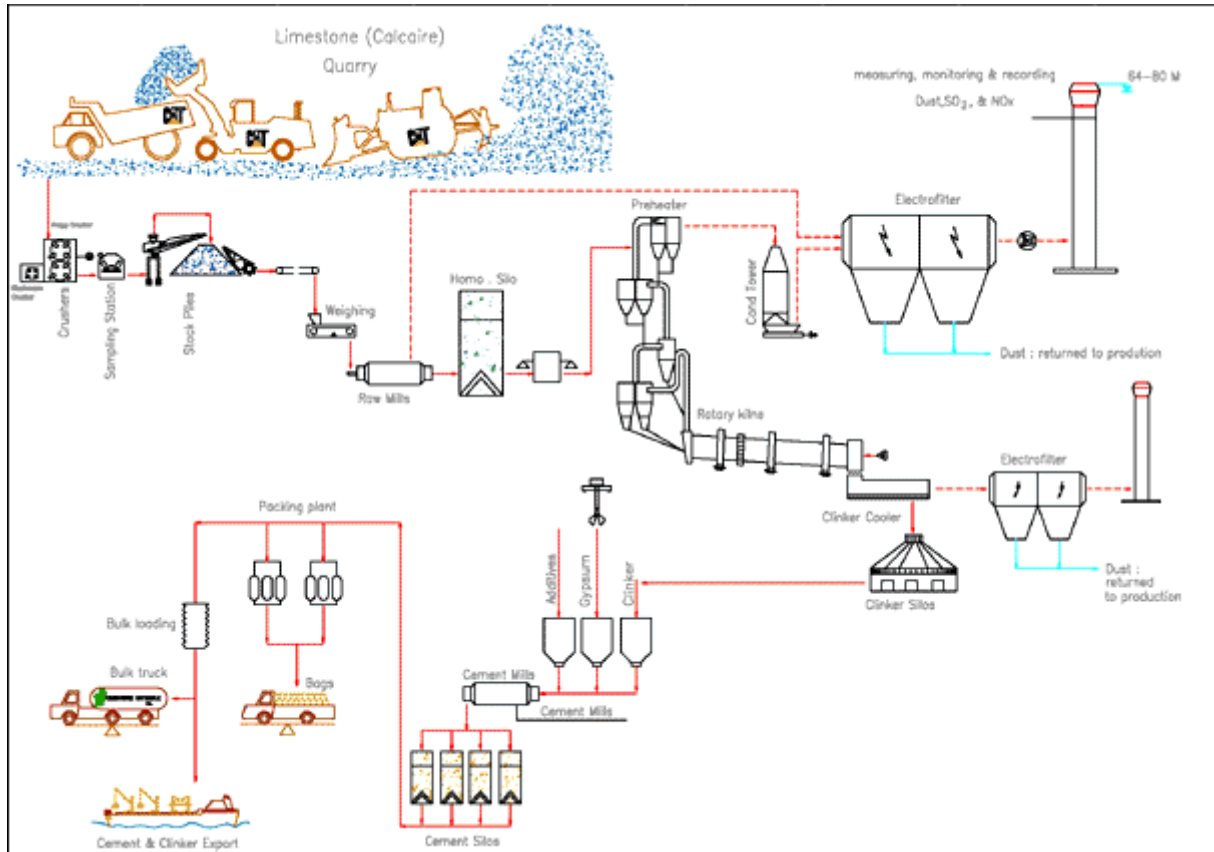


Manufacture of Ordinary Portland Cement

Cement is a hydraulic binder and is defined as a finely ground inorganic material which, when mixed with water, forms a paste which sets and hardens by means of hydration reactions and processes which, after hardening retains its strength and stability even under water. Ordinary Portland Cement (OPC) is one of several types of cement being manufactured throughout the world.



OPC consists mainly of lime (CaO), silica (SiO_2), alumina (Al_2O_3), iron (Fe_2O_3) and sulphur trioxide (SO_3). Magnesium (MgO) and other Oxide elements are present in small quantities as an impurity associated with raw materials. When cement raw materials containing the proper proportions of the essential oxides are ground to a suitable fineness and then burnt to incipient fusion in a kiln, chemical combination takes place, largely in the solid state resulting in a product named clinker. This clinker, when ground to a suitable fineness, together with a small quantity of gypsum (SO_3) is Portland Cement. SO_3 is added at the grinding stage to retard the setting time of the finished cement.

PORTLAND CEMENT				
Types	ASTM	MS	Properties	Uses
Ordinary portland cement	type I	522	ordinary	General
Super High early strength portland cement	type III	522	rich in C3S, finer ground, high early strength	Winter, Urgent
Super high early strength portland cement			good particle size distribution, rich in SO_3 higher in early strength than type III	Winter, Urgent
Moderate heat portland cement	type II		low in C3S, low in C3A, low heat of hydration & high long term strength	Dam, Mass concrete
Low heat portland cement	type IV		low heat of hydration, low early strength	Dam, Mass concrete
Sulphate resisting cement	type V	1037	low in C3A, high chemical resistance	Underground water
White portland cement		888	minute in iron, pure-white, fine ground, high early strength	Buildings, Arts

Raw Material Preparation

The raw materials used in the manufacture of cement are limestone, shale, sand and iron ore, typical chemical compositions of which are given in the table below. Limestone makes up approximately 80% of the raw material requirements, composes of mainly calcium carbonate with small intrusions of magnesium carbonate. Quarrying operations are geared to minimizing the intrusions. The limestone is crushed to less than 25mm in size. MgO in the cement, if present in sufficient quantities will cause expansion upon hydration thus resulting in unsoundness in the concrete.

Component	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	SO ₃	K ₂ O	Na ₂	LOI
Limestone	2.53	1.42	0.78	51.92	0.64	-	0.05	0.02	41.5
Iron ore	28.45	7.49	56.23	-	0.53	0.11	0.12	-	8.7
Shale	60.62	13.55	7.34	1.43	1.55	-	3.73	-	6.1
Sand	89.25	3.68	1.12	0.39	0.13	-	1.17	-	1
Fuel Ash	44.05	18.34	5.69	8.5	1.3	-	0.75	-	-
Gypsum	1.16	0.18	0.2	32.12	0.13	44.2	-	-	21.1

Due to the variable nature of these components, they are pre-blended prior to their use. It is crushed and stored in a pre-blending hall, utilizing the chevron pile stacking method. In this method, stacking takes place at one end of the pile. At the other end of the pile the material is reclaimed and then stored in a feeding hopper which is ready for use.

Raw Material Proportioning & Grinding

The raw materials are extracted from the hoppers via weigh-feeders. The materials are conveyed to the grinding mill and are ground to a suitable fineness, called raw meal at this stage. This is then stored in a blending silo and blended to ensure homogeneity. The proportions of the 4 components are controlled by the continuous sampling and testing of this raw meal. The raw meal chemical composition is determined by the use of an x-ray fluorescence analyzer. This is linked to the computer which will automatically adjust the weigh-feeders, so that the resultant raw meal stored in the blending silo meets the preset parameters. After blending this material is then discharged into the storage silos ready for the next phase of production. The parameters used in the control of the raw meal are lime saturation factor, silica modulus and iron modulus. These are actually proportions of the various chemical components which are desired in the resultant clinker.

$$\begin{aligned} \text{LSF} &= \frac{\text{CaO}}{2.8 \text{ SiO}_2 + 1.18 \text{ Al}_2\text{O}_3 + 0.65 \text{ Fe}_2\text{O}_3} = 0.90 - 0.97 \\ \text{SM} &= \frac{\text{SiO}_2}{\text{Al}_2\text{O}_3 + \text{Fe}_2\text{O}_3} = 2.0 - 2.8 \\ \text{IM} &= \frac{\text{Al}_2\text{O}_3}{\text{Fe}_2\text{O}_3} = 1.3 - 1.8 \end{aligned}$$

As coal is used as a fuel the coal ash, a combustion product of the coal, has to be treated as an individual raw material component and the appropriate corrections made at the weigh-feeder stage.

Clinker Burning

For the production of cement clinker, the raw meal which is known as kiln feed at this stage has to be heated to a temperature of about 1450 degree celcius in the long cylindrical rotating kiln. The kiln feed enters the system at the top of the pre-heater and fall until the lower end of the kiln. The heat exchange occurs during this process when the hot gases from the kiln end rise up to the top of the pre-heater. The clinker formation process is divided into four parts: drying, calcining, sintering and cooling. As the kiln feed moves towards the lower end of the kiln it undergoes successive reactions as shown in the table:

Temperature	Process	Chemical Transformation
< 200	Escape of free water (drying)	
100 - 400	Escape of adsorbed water	
400 - 750	Decomposition of shale, e.g., with formation of metakaolinite	$\text{Al}_4(\text{OH})_8\text{Si}_4\text{O}_{10} \rightarrow 2(\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2) + 4\text{H}_2\text{O}$
600 - 900	Decomposition of metakaolinite of limestone and other compounds, with formation of a reactive oxide mixture	$\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2 \rightarrow \text{Al}_2\text{O}_3 + 2\text{SiO}_2$
600 - 1000	Decomposition of limestone, with formation of CS and CA	$\text{CaCO}_3 \rightarrow \text{CaO} + \text{CO}_2$ $3\text{CaO} + 2\text{SiO}_2 + \text{Al}_2\text{O}_3 \rightarrow 2(\text{CaO} \cdot \text{SiO}_2) + \text{CaO} \cdot \text{Al}_2\text{O}_3$
800 - 1300	Uptake of lime by CS and CA, formation of C4AF	$\text{CS} + \text{C} \rightarrow \text{C}_2\text{S}$ $2\text{C} + \text{S} \rightarrow \text{C}_2\text{S}$ $\text{CA} + 2\text{C} \rightarrow \text{C}_3\text{A}$ $\text{CA} + 3\text{C} + \text{F} \rightarrow \text{C}_4\text{AF}$

The principal chemical compounds in the clinker are tricalcium silicate, C3S (40-60%), dicalcium silicate, C2S (16-30%), tricalcium aluminate, C3A (7-15%) and tetracalcium aluminoferrite, C4AF (7-12%). The cooling zone in the kiln is actually quite short but it is in this zone that notarization of the melt occurs.

The red hot clinker is then discharged into the cooler, where it is quenched cooled to around 100 degrees centigrade. The heat dissipated by the clinker is used as secondary air for the combustion in the calciner. This hot gas is also used in the dryers at the raw materials preparation stage. Rapid cooling of the clinker is essential as this hampers the formation of crystals, causing part of the liquid phase to solidify as glass. The faster the clinker cooling the smaller the crystals will be when emerging from the liquid phase.

Cement Grinding

Cement is produced by grinding clinker with gypsum (calcium sulfate) in the finish-grinding mill to a required fineness. A small quantity of gypsum, about 3 to 5 %, is needed to control the setting time of cement produced. The amount of gypsum being used is determined by the Sulphuric Anhydride (SO3) contents in cement.

ITEM	CaO.SiO ₂	2CaO.SiO ₂	3CaO.Al ₂ O ₃	4CaO.Al ₂ O ₃ .Fe ₂ O ₃
Abbreviated notation	C3S	C2S	C3A	C4AF
Common Name	Alite	Belite	Aluminate phase	Ferrite phase
Foreign ions commonly incorporated	Mg, Al, Fe	Alkalies, Al, Fe, fluoride	Alkalies, Fe, Mg	Si, Mg
Common crystalline form	Monoclinic	Monoclinic	Cubic, Orthorhombic	Orthorhombic
Range present (%)	40-60	16-30	7-15	7-12
Colour of the pure phase	White	White	White	Dark grey-green
Reaction with water	Medium	Slow	Fast	Medium
Technical properties	<ul style="list-style-type: none"> • High initial and good final strength • Moderate heat of hydration • Main strength constituent in cement 	<ul style="list-style-type: none"> • Good final strength • Low heat of hydration 	<ul style="list-style-type: none"> • High heat of hydration which promotes early strength • Reacts with sulphates and cause expansion 	<ul style="list-style-type: none"> • Hardly any strength development • Moderate heat of hydration • Gives normal cement its colour

Cement Storage & Distribution

After the grinding process, cement is pumped into the storage silos. This silo is preventing the moisture to react with cement. When needed cement from the silos is packed into bags or loaded into road tankers and rail wagons for dispatch.

References:

<http://www.cima.com.my>
<http://www.cimnat.com.lb>