



وزارة التعليم العالي والبحث العلمي

الجامعة المستنصرية

الكيمياء الصناعية

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علوم الكيمياء
المرحلة الثالثة

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مع تحيات ...

مكتب البيت الهندسي للطباعة والاستنساخ

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Module: 5

Lecture:

CEMENT MANUFACTURE

MANUFACTURE

It involves the following steps

1. Mixing of raw material
2. Burning
3. Grinding
4. Storage and packaging

1. Mixing of raw material

Mixing can be done by any one of the following two processes

- (a) Dry process
- (b) Wet process

a) Dry Process

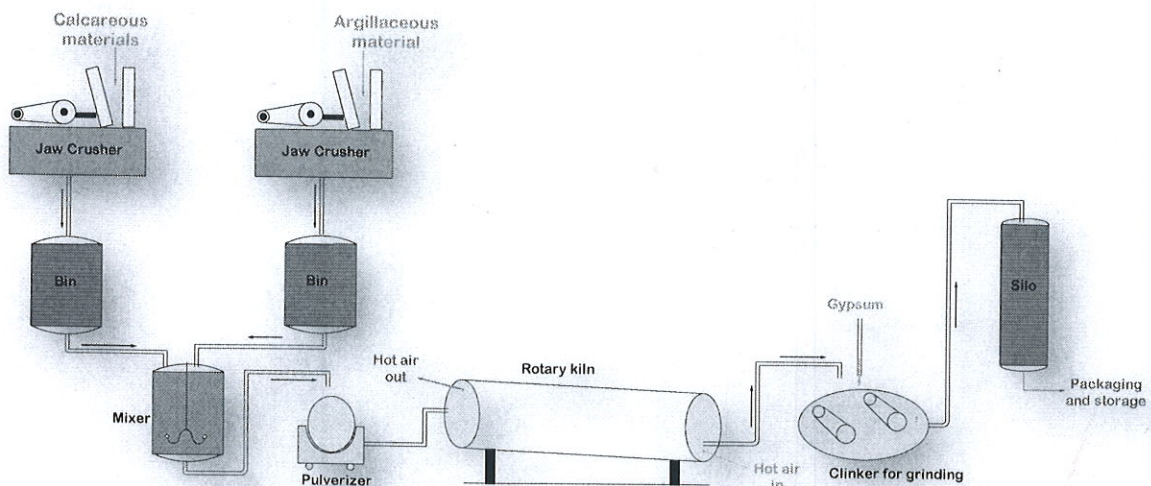


Figure: Manufacturing of Cement by Dry Process

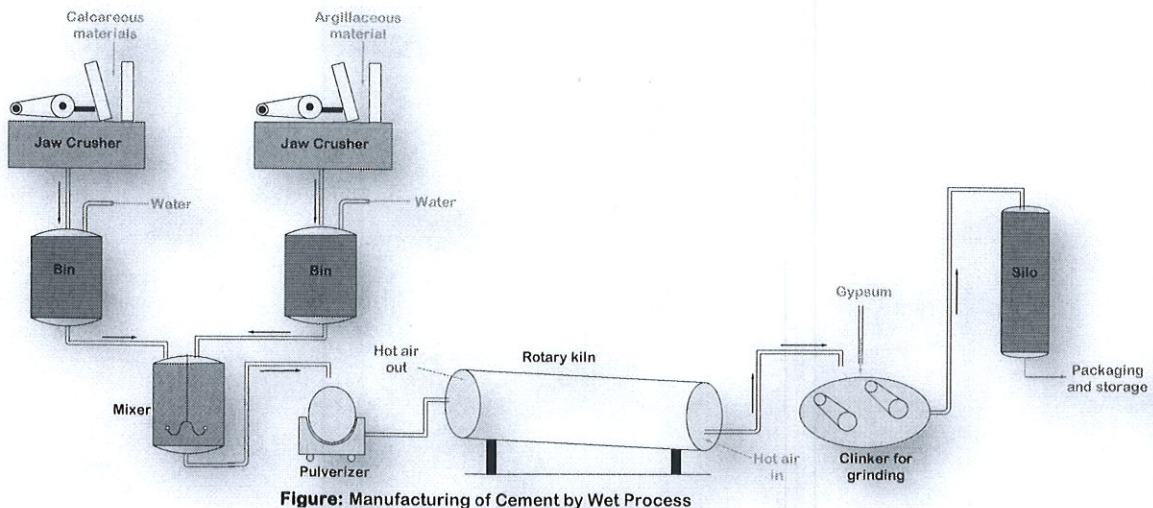
Block diagram of manufacturing process

Diagram with process equipment

Animation

Lime stone or chalk and clay are crushed into gyratory crusher to get 2-5 cm size pieces. Crushed material is ground to get fine particle into ball mill or tube mill. Each material after screening stored in a separate hopper. The powder is mixed in require proportions to get dry raw mix which is stored in silos (storage tank) and kept ready to be fed into the rotary kiln. Raw materials are mixed in required proportions so that average composition of the final product is maintained properly.

b) Wet process



Block diagram of manufacturing process

Diagram with process equipment

Animation

Raw materials are crushed, powdered and stored in silos. The clay is washed with water in wash mills to remove adhering organic matter. The washed clay is stored separately. Powdered lime stone and wet clay are allowed to flow in channel and transfer to grinding mills where they are intimately mixed and paste is formed known as slurry. Grinding may be done either in ball mill or tube mill or both. Then slurry is led to correcting basin where chemical composition may be adjusted. The slurry contains 38-40% water stored in storage tank and kept ready for feeding to a rotary kiln.

Comparison of dry process and wet process

Criteria	Dry process	Wet process
Hardness of raw material	Quite hard	Any type of raw material
Fuel consumption	Low	High
Time of process	Lesser	Higher
Quality	Inferior quality	Superior quality
Cost of production	High	Low
Overall cost	Costly	Cheaper
Physical state	Raw mix (solid)	Slurry (liquid)

The remaining two operations burning and grinding are same for both the process.

2. Burning

Burning is carried out in rotary kiln which rotating at 1-2 rpm at its longitudinal axis. Rotary kiln is steel tubes having diameter in between 2.5-3.0meter and length varies from 90-120meter. The inner side of kiln is lined with refractory bricks. The kiln is rested on roller bearing and supported columns of masonry or concrete in slightly inclined position at gradient of 1 in 25 to 1 in 30. The raw mix or corrected slurry is injected into the kiln from its upper end. Burning fuel like powdered coal or oil or hot gases are forced through the lower end of the kiln so long hot flame is produced.

Due to inclined position and slow rotation of the kiln, the material charged from upper end is moving towards lower end (hottest zone) at a speed of 15meter/hour. As gradually descends the temperature is rises. In the upper part, water or moisture in the material is evaporated at 400°C temperature, so it is known as drying zone.

In the central part (calcination zone), temperature is around 1000°C, where decomposition of lime stone takes place. After escapes of CO₂, the remaining material in the forms small lumps called nodules.



The lower part (clinkering zone) have temperature in between 1500-1700°C where lime and clay are reacts to yielding calcium aluminates and calcium silicates. This aluminates and silicates of calcium fuse to gather to form small and hard stones are known as clinkers. The size of the clinker is varies from 5-10mm.



About one-third of the raw meal mass can be attributed to Loss on Ignition (LOI), which is almost exclusively due to the calcination of the CaCO_3 used as a precursor for forming CaO . This corresponds to the fact that the raw meal contains about 75 wt% of CaCO_3 .

The mass loss in the calcination process corresponds to a raw meal to cement clinker ratio of about 1.5, if the raw meal is dry when fed into the kiln system. The raw meal composition stated in table: 1 is usually obtained by blending limestone and clay (clay being rich in Si, Fe and Al oxides). If needed, correctives like sand and iron ore can be added to the raw meal in order to achieve the correct composition.

In order to ensure the proper quality of the final product, the amount of certain minor components is limited. Column 4 in table: 1 shows some general upper limits for certain elements, but the exact amount that can be allowed depends on a wide range of factors such as what the cement will be used for, the amount of other impurities, production facilities and so on, which is why the acceptable amount must be determined from case to case. The limits stated in table: 1 cannot be exceeded significantly, and in many cases it is actually desirable to be well below these limits.

Components	Content in clinker	Content in raw meal	Impurity limits
	Wt. %	Wt. %	Wt. %
CaO	63.8-70.1	~43	
SiO ₂	19.7-24.3	~14	
Al ₂ O ₃	3.8-6.8	~4	
Fe ₂ O ₃	1.3-1.6	~5	
MgO	0.0-4.5		5
SO ₃	0.2-2.1		4.5
K ₂ O	0.3-1.8		0.8 as $(\text{NaO}_2)_e^*$
Na ₂ O	0.0-0.3		0.8 as $(\text{NaO}_2)_e^*$
Mn ₂ O ₃	0.0-0.7		0.5
TiO ₂	0.2-0.5		
P ₂ O ₅	0.0-0.3		0.2
CO ₂	0.0-0.8		
H ₂ O	0.0-1.1		
Cl ₂			0.1
LOI	0.1-1.6	~34	3

* $(\text{NaO}_2)_e$, the effective amount of alkali, is calculated as $0.658(\%K_2O) + \%Na_2O$.

Table :1 Composition of Portland cement clinker and raw meal and impurities limit

If the raw materials used in this process contain sulfide, can lead to emissions of SO_2 from the preheater tower. SO_2 emissions are most often caused by the oxidation of pyritic sulfide, which occurs between 300 and 600°C. Of the formed SO_2 , around 50% is often said to be emitted from the preheater. However, large variations

in this number have been observed, with the circulation of CaO from the calciner given as the main reason for this phenomenon.

Also, the chlorine level in raw material should be below 0.1% , if it will exceed then free chlorine will accumulate in rotary kiln.

K_2O and Na_2O , known as the alkalis have been found to react with the reactive silica found in some aggregates, the products of the reaction causing increase in volume leading to disintegration of the concrete. The increase in the alkalis percentage has been observed to affect the setting time and the rate of the gain of strength of cement.

SO_3 form low percentage of cement weight. SO_3 comes from the gypsum added (2-6% by weight) during grinding of the clinker, and from the impurities in the raw materials, also from the fuel used through firing process.

MgO , present in the cement by 1-4%, which comes from the magnesia compounds present in the raw materials. MgO by 5%, to control the expansion resulted from the hydration of this compound in the hardened concrete. When the magnesia is in amorphous form, it has no harmful effect on the concrete.

Other minor compounds such as TiO_2 , Mn_2O_3 , P_2O_5 represent < 1%, and they have little importance.

The upper and lower limit of impurities present in lime stone is tabulated in table: 2

Impurity	Typical range		Unit	Impurity	Typical range		Unit
	Low	High			Low	High	
Silica (as SiO_2)	0.1	2	w/w%	Copper	1	30	mg/kg
Alumina (as Al_2O_3)	0.04	1.5	w/w%	Fluoride	5	3000	mg/kg
Iron (as Fe_2O_3)	0.02	0.6	w/w%	Lead	0.5	30	mg/kg
sulphur (as $CaSO_4$)	0.01	0.5	w/w%	Mercury	0.02	0.1	mg/kg
Carbonaceous matter	0.01	0.5	w/w%	Molybdenum	0.1	4	mg/kg
Manganese (as MnO_2)	20	1000	mg/kg	Nickel	0.5	15	mg/kg
Antimony	0.1	3	mg/kg	Selenium	0.02	3	mg/kg
Arsenic	0.1	15	mg/kg	Silver	0.2	4	mg/kg
Boron	1	20	mg/kg	Tin	0.2	15	mg/kg
Cadmium	0.1	1.5	mg/kg	Vanadium	1	20	mg/kg
Chromium	3	15	mg/kg	Zinc	3	500	mg/kg

Table: 2 Impurities often found in limestone

Engineering aspects

Cyclone preheater

The raw materials are preheated or calcined in preheater or series of cyclones before entering to the rotary kiln. A preheater, also called as suspension preheater is a heat exchanger in which the moving crushed powder is dispersed in a stream of hot gas coming from the rotary kiln. Common arrangement of series of cyclones is shown in figure.

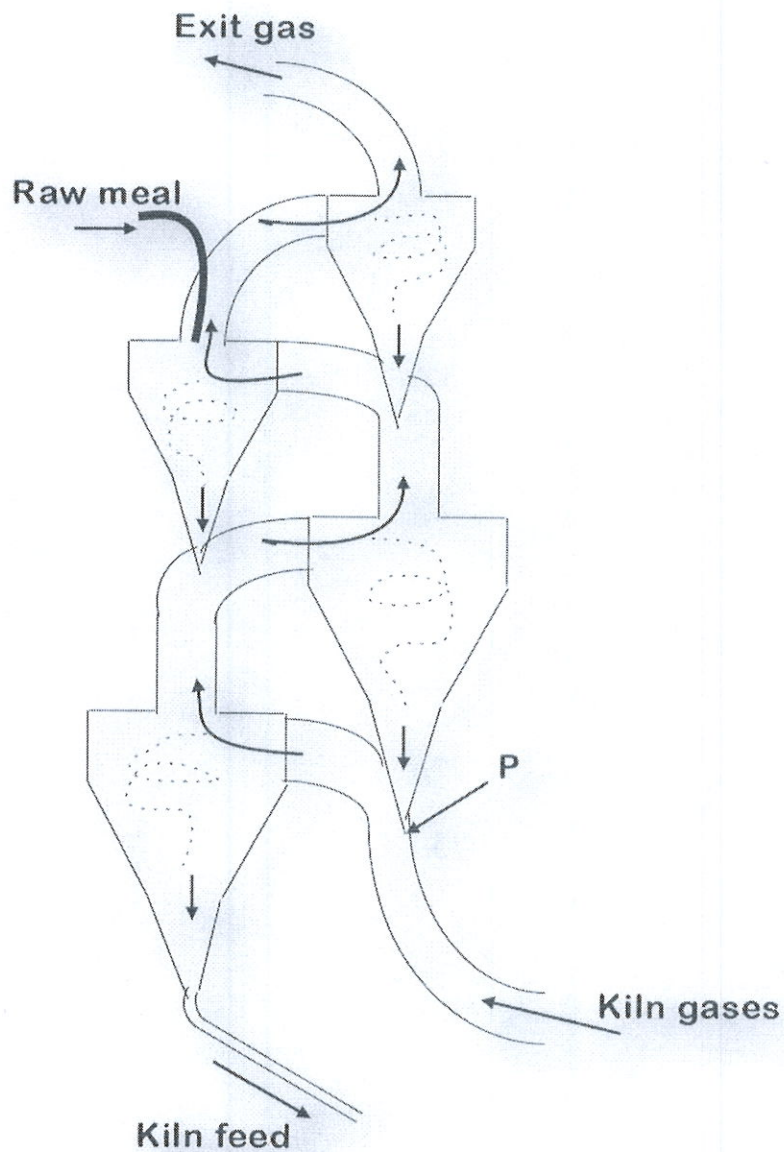


Figure: Cyclone preheaters

The heat transfer of hot kiln gases to raw meal is takes place in co-current. The raw materials are heated upto 800°C within a less than a minutes. About 40% of the calcite is decarbonated during the heat transfer.

The quality and quantity of fuel used in the kiln can be reduced by introducing a proportion of the fuel into preheater. 50 – 65 % of the total amount of fuel is introduced into preheater or precalciner which is often carried out by hot air ducted from cooler.

The fuel in the precaliner is burnt at relatively low temperature, there so heat transfer to the raw meal is very efficient. The material has residence time in the hottest zone of a few seconds and its exit temperature is about 900°C, 90 – 95% of calcite is decomposed. Ash from the fuel burn in the precalciner is effectively incorporated into mix.

Advantages of precalination

- Decrease the size of kiln
- Decrease in capital cost
- Increase in rate of material passes to the kiln.
- Decrease in rate of heat provided which ultimately lengthens the life of refractory lining
- Less NO_x is formed, since much of the fuel is burnt at a low temperature, and with some designs NO_x formed in the kiln may be reduced to nitrogen.

Rotary Kiln

Rotary kiln is a tube, sloping at 3 – 4 % from the horizontal and rotating at 1 – 4 revolution/minute into which material enters at the upper end and then slides, rolls and flows counter to the hot gas produced by a flame at the lower or front end.

The kiln is lined with refractory bricks. The type and size of the bricks may vary depending up on the length of rotary kiln and the maximum temperature employed. Further, arranging the bricks in a ring requires perfect closing of the ring which is difficult, time consuming and expensive. Two types of the joints, the radial and axial joints are used for bricks. The redial joints are between the brick in each ring and axial joints are between the successive rings. The bricks are coated with thin layer of clinker for extending the life as well as insulation.

The rotary kiln used which precalciner is 50 – 100 meter long having length to diameter (L/D) ratio between 10 to 15. The kiln having very small L/D ratio ensures rapid clinker formation and quick reaction run without recrystallization phenomena. Due to this higher hydraulic activity of cement is achieved

Conveyors

The following types of conveyors are used during the cement manufacturing process.

- Belt conveyor
- Bucket conveyor
- Screw conveyor
- Roller conveyor

Animation

➤ **Belt conveyor**

Belt conveyor is used for transportation of raw material from storage to the initial crushing devices mostly jaw crusher. Belt conveyor consists of two or more pulleys, with a continuous loop of material or the conveyor belt which rotates about them. Either one or both of the pulleys are powered, moving the belt and the material on the belt forward. The powered pulley is called the drive pulley while the unpowered pulley is called the idler.

➤ **Bucket conveyor**

Bucket conveyor are used for transportation of crushed material and clay to mixing zone in cement industries. A bucket conveyor, also called a grain leg, is a mechanism for carrying the bulk materials vertically. It consists of buckets to contain the material, a belt to carry the buckets and transmit the pull, means to drive the belt and accessories for loading the buckets or picking up the material, for receiving the discharged material, for maintaining the belt tension and for enclosing and protecting the elevator.

➤ **Screw conveyor**

A screw conveyor or auger conveyor is a mechanism that uses a rotating helical screw blade, called a "flighting", usually within a tube, to move liquid or granular materials. Screw conveyors are often used horizontally or at a slight incline as an efficient way to move semi-solid materials. Screw conveyor are used for transportation of material for storage to homogeneous siloes.

➤ **Roller conveyor**

Roller conveyors are line restricted device and consist of rollers mounted between two side members. Bearings are usually incorporated in the idlers to cut down the mechanical losses. An unpowered gravity roller conveyor is set at an appropriate incline and goods move down it by gravity. In power unit normally an electric motor drive the rollers via chains or belt, providing controlled movement of goods. They are generally used for transportation of packed material.

PROPERTIES

- Cement-modification improves the properties of certain silt clay soils that are unsuitable for use in subgrade construction. The objectives may be to decrease the soil's cohesiveness (plasticity), to decrease the volume change characteristics of expansive clay, to increase the bearing strength of a weak soil, or to transform a wet, soft subgrade into a surface that will support construction equipment.
- **Tricalcium Silicate (C3S):** Hardens rapidly and is largely responsible for initial set and early strength. In general, the early strength of Portland cement concrete is higher with increased percentages of C3S.
- **Dicalcium Silicate (C2S):** Hardens slowly and contributes largely to strength increases at ages beyond 7 days.
- **Tricalcium Aluminate (C3A):** Liberates a large amount of heat during the first few days of hardening and together with C3S and C2S may somewhat increase the early strength of the hardening cement. It affects setting time.
- **Tetracalcium Aluminoferrite (C4AF):** Contributes very slightly to strength gain. However, acts as a flux during manufacturing. Contributes to the colour effects that makes cement gray.