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# Study of Processing and Machinery in Cement Industry

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***Abstract*— This paper analyzes an existing processing management system in a cement factory in India. During the last two decades (80's and 90's), major technological advancements took place in design of cement plant equipment/systems. The analysis shows that there are Strong areas such as opencast lime stone mining, lime Stone crushing & stacking, raw material handling & Grinding, coal grinding, preheater kiln & cooler, Clinker grinding (cement mill), packing plant & Loading plant, quality control. It also provides the brief description about the machinery used in each stage and its working principles. Cement industry has come a long way in technological up gradation, production and quality. India today is the second largest cement producing country in the world with an installed capacity of 119 million metric tons per annum.***

*Index Terms*— **opencast lime stone mining, lime stone crushing & stacking, raw material handling & grinding, coal grinding, preheaterkiln& cooler, clinker grinding (cement mill), packing plant & loading plant, quality control.**

## I. INTRODUCTION

**Cement:** In the most general sense of the word, cement is a binder, a substance that sets and hardens independently, and can bind other materials together. The word "cement" traces to the Romans, who used the term opus caementicium to describe masonry resembling modern concrete that was made from crushed rock with burnt lime as binder. The volcanic ash and pulverized brick additives that were added to the burnt lime to obtain a hydraulic binder were later referred to as cementum, cimentum, cäment, and cement.

**Early uses:** It is uncertain where it was first discovered that a combination of hydrated non-hydraulic lime and a pozzolan produces a hydraulic mixture (see also: Pozzolanic reaction), but concrete made from such mixtures was first used by the Ancient Macedonians and three centuries later on a large scale by Roman engineers. They used both natural pozzolans (trass or pumice) and artificial pozzolans (ground brick or pottery) in these concretes. Many excellent examples of structures made from these concretes are still standing, notably the huge monolithic dome of the Pantheon in Rome and the massive Baths of Caracalla. The vast system of Roman aqueducts also made extensive use of hydraulic cement. Although any preservation of this knowledge in literary sources from the middle Ages is unknown, medieval masons and some military engineers maintained an active tradition of using hydraulic cement in structures such as canals, fortresses, harbors, and shipbuilding facilities. The technical knowledge of making hydraulic cement was later formalized by French and British engineers in the 18th century.

**Modern cement:** Modern hydraulic cements began to be developed from the start of the Industrial Revolution (around 1800), driven by three main needs:

*Hydraulic cement render (stucco) for finishing brick buildings in wet climates.

*Hydraulic mortars for masonry construction of harbor work, etc., in contact with sea water.

*Development of strong concretes.

**Safety issues:** Bags of cement routinely have health and safety warnings printed on them because not only is cement highly alkaline, but the setting process is exothermic. As a result, wet cement is strongly caustic and can easily cause severe skin burns if not promptly washed off with water. Similarly, dry cement powder in contact with mucous membranes can cause severe eye or respiratory irritation. Cement users should wear protective clothing.

## II. STAGES OF CEMENT MANUFACTURING

**Stage-1.Opencast lime stone mining**

Opencast mining refers to a method of extracting rock or minerals from the earth by their removal from an open pit or borrow. These mines are used when deposits of commercially useful minerals or rock are found near the surface. Open-pit mines that produce building materials and dimension stone are commonly referred to as quarries.

**Process of lime stone extraction-**

1. **Area:** To start extracting lime stone from ground we should require an area where the limestone quantities are more with high carbonate and low sio2.
2. **Drilling & blasting:** Open-pit mines are dug on benches, which describe vertical levels of the hole. These benches are usually on four meter to sixty meter intervals, depending on the size of the machinery that is being used.

Most walls of the pit are generally dug on an angle less than vertical, to prevent and minimize damage and danger from rock falls. This depends on how weathered the rocks are, and the type of rock, and also how many structural weaknesses occur within the rocks, such as a fault, shears, joints or foliations. After the drilling is done 2/3 holes are filled with slurry explosives and anfo (ammonium nitrate fuel oil).1/3 part is stemmed with sand and BC soil. After stemming

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detonators are fixed above the hole with detonating fuse. And the blasting is done with the battery charge.


**Vertical drilling machine** **drilled hole**

**Equipment used for blasting ( dc battery)**

During the blasting bulk rocks are crushed in to small pieces which are easier to transport. It is a long process and should take more safety precautions like

a) Wet drilling should be done for preventing environmental pollution.
b) 2. The person who is blasting should be in iron made shelter with blasting kit.
c) 3. Working people should wear helmet and shoe during the work.
d) Stemming (filling of holes with hard material before the detonator is fitted) should be done properly.
e) 5. Siren should be given before and after blasting.
f) 6. During the blasting working people should be 500mts away from blasting area.

**3. Loading & transport:** The muck file (blasted material) is loaded in to dumpers with the help of excavators to transport lime stone to the crusher**.** Precautions to be taken in this stage

a) utilize maximum hours of men and machines in a shift with safe operation methods
b) do not over load, do not over speed, avoid spillages
c) Good haul road maintenance is required to increase dumper tyre life.
d) Dump break should be applied while loading and dumping time.


**Loading the raw material** **transporting the raw materials**

**Stage-2. Lime stone crushing & stacking**

Crusher is a new stone crusher machine that absorbs advanced technologies at home and abroad. Dealing with the material with the side length 500mm, not more than 350Mpa anti-pressure strength, Impact Crusher can be widely used in the primary and secondary crushing process. This impact pressure is also used in lime stone crushing.

**Process of crushing the raw material and transferring the crushed raw material to stock pile**

**1. Dumping of raw material in to hopper:**

This stage continues after transportation of raw materials from mining .The material loaded in dumper at mining is dumped in the crusher hopper**.**


**Dumping in to hopper** **crusher hopper**

**2. Flow of raw material with Push feeder:**

The dumped raw material in the hopper moves in to crusher with the help of push feeder which moves to and fro and sends the material with in a limit.

**Push feeder hydraulic cylinder operation**

**3. Crushing of raw material with impact crusher:**

When the crushed materials get into the impact crusher inner space where the hammers effect, under the impact function of the hammer at a high speed, the materials are thrown to the impact device above the rotor continuously. And then the materials are rebounded from the impact liner to the area where the hammers effects for being recrushed. The materials from large to small all to be crushed at the impact crusher chamber repeatedly. The process won't stop till the materials in the impact crusher are crushed to the required size and then discharged from outlet.

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**Impact Crusher**

**4. Transfer of crushed raw material to stock pile:**

After the raw material is crushed to required size in a crusher. The small size raw material is transferred to stock pile with the help of belt conveyors. Bag filter collects the dust from the raw material at belt conveyor and filter it. This bag filter works with one fan and compressor. This helps to control the dust pollution.

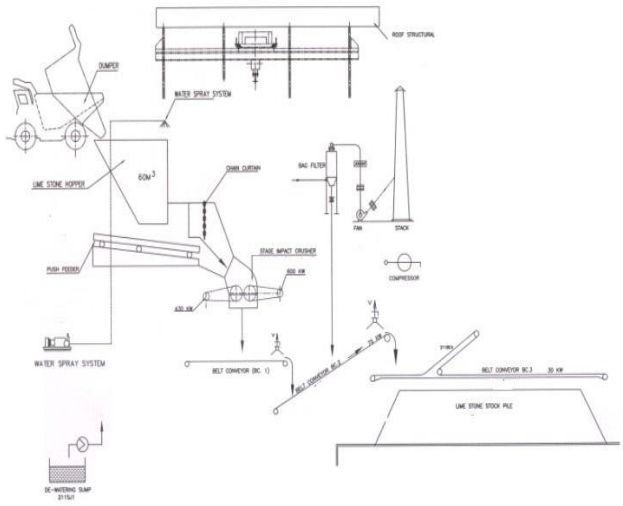
**Belt conveyor transfering crushed raw materials to pile**

**5. Tipper belt:**

At the end of the belt conveyor ther is tipper belt. This helps to drop the raw material in the required area (low grade stock pile, high grade stock pile).

**Tipper belt** **stock pile**

**Flow diagram of lime stone crushing & stacking**




**Stage-3.RAW MATERIAL HANDLING & GRINDING**

A raw mill is the equipment used to grind raw materials into “raw mix" during the manufacture of cement. Dry raw mills are the normal technology installed today, allowing minimization of energy consumption and CO2 emissions.

**Process of raw mill in grinding of raw material and silo storage**

**1. Transporting crushed raw material to raw mill hoppers:**

This stage continues after crusher lime stone stock pile. A belt conveyor collects the raw material from the stock pile with the help of hoppers below the stock pile. So these belts are fixed under the stock pile to collect the raw material.

**Belt conveyor transfering the material to raw mill**

**2. Weigh feeders:**

Weigh feeder is a machine which allows the material to the required quantity from the hopper. These are three types High grade weigh feeder, Low grade weigh feeder, Additives weigh feeder.

**High/lograde feeder** **additives weigh feeder**

**3. Raw mill:**

The conveyors collect the raw material (low or high grade), additives and transfer it to raw mill. This raw mill consists of 3 chambers (dry, 1st, and 2nd chamber).

**Raw mill** **grinding media**

**Dry chamber**

Dry raw mills are the normal technology installed today, allowing minimization of energy consumption and CO2 emissions. Cement raw materials are mainly quarried, and so contain a certain amount of natural moisture. Attempting to grind a wet material is unsuccessful because an intractable "mud" forms. On the other hand, it is much easier to dry a fine material than a coarse one, because large particles hold moisture deep in their structure. It is therefore usual to simultaneously dry and grind the materials in the raw mill. A

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hot-air furnace may be used to supply this heat, but usually hot waste gases from the kiln are used. For this reason, the raw mill is usually placed close to the kiln preheater. Ball mill is used in cement industry. After the dry chamber material enters the 1st grinding chamber.

**1st grinding chamber:**

The chamber allows grinding of the harder limestone that is more common than chalk. A ball mill consists of a horizontal cylinder that rotates on its axis. It holds spherical, cylindrical or rod-like grinding media of size 15–100 mm that may be steel or a variety of ceramic materials, and occupy 20–30% of the mill volume. The shell of the mill is lined with steel or rubber plates. Grinding is effected by impact and attrition between the grinding media and forms as a powder. This process will not continue to 2nd chamber directly. there are several intermediate stages. This mill is a center discharge mill.

**2nd grinding chamber:**

This is similar to the process in 1stchamber but in this chamber coarse material from DAS (dynamic air separator) is grinded.

**4. Grit separator:**

Grit separator allows the grinded raw material (powder).this is placed above the raw mill. It takes the powdered raw material from the center of the raw mill. it separates the unwanted materials and sends useful material to cyclone.

**5. Cyclone:**

This stage continues after grit separator. Cyclone is cone shaped equipment which separates the fine material and unfine material. Unfine material is sent to bag house and fine material is sent to P.G (pnumatic gravity) conveyor. This is above the grit separator.

**6. DAS (dynamic air separator):**

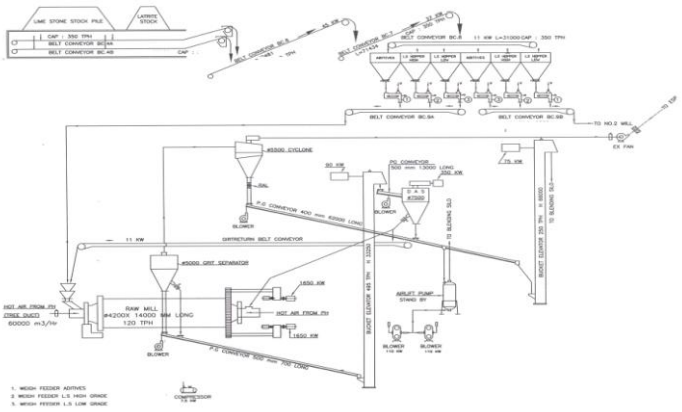
The material which is not taken by grit separator above the raw mill is discharged from the center of the raw mill to the P.G conveyor at the below of raw mill. This P.G conveyor transfer the powdered raw material to the bucket elevator .this bucket elevator drop the material into DAS .this DAS separates the material as fine and coarse material. Fine material is send to P.G.conveyor (cyclone dropped P.G conveyor). Coarse material is send to girtreturn belt conveyor and then to 2nd chamber in raw mill for grinding.

**7. Transfer of fine material to silo:**

Fine material dropped from cyclone and DAS on P.G conveyor is transferred to bucket elevator and then filled to silo**.**

**Raw meal silo**

**Flow diagram of lime stone raw material handling & Grinding**



**Stage-4. COAL GRINDING**

Air Swept Coal Mill is widely used in grinding coal operation of cement processing. It is a kind of special equipment which crushes and grinds coal with the function of drying simultaneously.

**Horizontal Coal nill**

**Process of coal mill in grinding of coal and supply to kiln, calciner**

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**1. Coal yard and raw coal hopper:**

Coal is stored in a big area under the shed. And then coal is dumped in a hopper to supply the coal to the coal crusher. This hopper vibrates to send the coal in a required quantity and drop coal on a belt conveyor

**2. Coal crusher:**

crusher crushes the large coal to the required small size. Hammer Mills operate on the principle that most materials will grind or crush upon impact with the hammers**.**

**3. Raw coal hopper and table feeder:**

The raw coal material from Belt conveyor is dropped in to raw coal hopper. This hopper stores the crushed raw coal material. Below the hopper ther is table feeder which supplies the coal in a limited(required) quantity to the coal mill.

**4. Coal grinding ball mill :**

Raw coal materials are fed into revolution cylinder through hollow shaft neck to be milled in which grinding mediums with lots of diameters are loaded. As cylinder rotating around the horizontal axis at a certain speed and under the help of centrifugal force and friction, the medium and raw material loaded in the cylinder will reaches a certain height. When their own gravity is greater than centrifugal force, they will fall or roll down from breaking away the cylinder inner wall, and then the ore is crushed by impact force.The crushed material is discharged from hollow shaft neck on the other side. In the cylinder, the raw material is pushed to move from feeding side to discharging side due to feeding material continuously. Induced draught fan is connected with discharging side to form negative pressure so that the pulverized coal will be taken out with the pumping air.

**5. Classifier:**

The grinded coal from mill enters the classifier. This classifier separate the coal material as fine and unfine material.unfine material is send back to coal mill with the help of girt return belt conveyor for grinding.fine material is sent to cyclone.

**6. Cyclone and dust collector:**

After the fine material enters the cyclone from classifier Some fine coal is sending to dust collector. This dust collector brings the fine material closer and store in it.

**7. Screw conveyor:**

This screw conveyor collects the fine coal from cyclone, dust collector and drop it in fine coal hopper.

**8. Fine coal hoppers:**

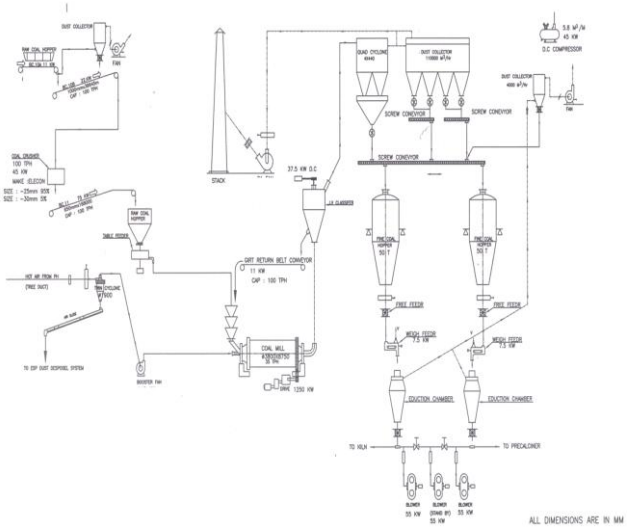
This fine coal from screw conveyor is collected in fine coal hopper and sends to weigh feeders.

**9. Weigh feeders:**

This feeder collects the required amount of coal.and send it to required area. Ther are 2 weigh feeders one is to send coal to killen and another is to send coal to precalciner. 65% coal is send to calciner and 35% coal is send to kiln.

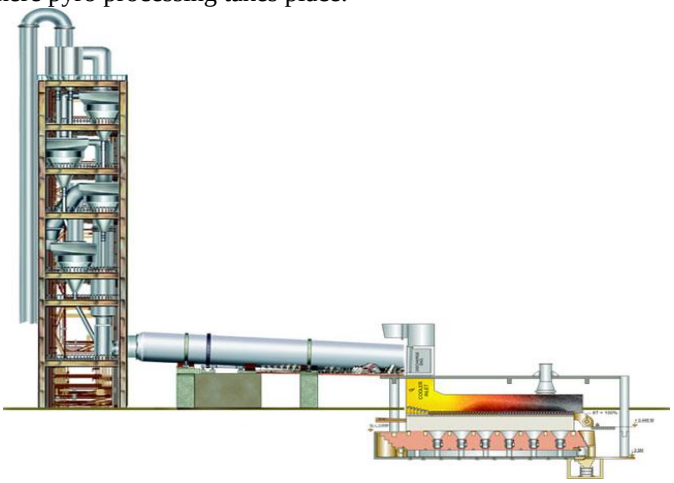
**Weigh feeder for sending the fine coal to preheater and kiln**

**Flow diagram coal grinding:**



**Stage -5. Preheaterkiln& cooler**

Pyro processing is a process in which materials are subjected to high temperatures at 1500C in order to bring about a chemical change. The raw material mix is fed to a kiln where pyro processing takes place.



**Process of kiln feed, preheater, cooler and silo storage**

**1. Transfer of raw material to kiln weigh bin:**

Raw meal stored in a raw mill silo is transfered to bucket

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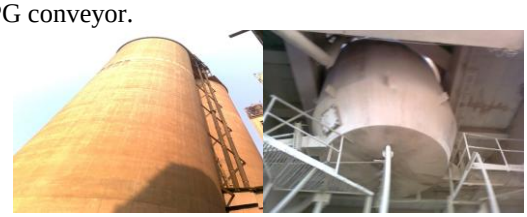
elevators with the PG conveyor at the bottom of the silo. This bucket elevator sends the raw meal to the weigh bin with the help of PG conveyor.



**Raw meal silo** **weigh bin**

**2. Transfer of raw meal from weigh bin to preheaters:**

This weigh bin sends the raw meal material to the PG conveyor. This PG Conveyor transfrers the raw meal to the bucket elevator and to preheater.

**3. Preheaters:**

The preheater tower supports a series of vertical cyclone chambers through which the raw material pass on their way to the kiln.

To save energy,modern cement plants preheat the materials before they enters the kiln rising more than 200feet,hot exit gases from the kiln heat the raw materials as they swirl through the cyclones.

**i. Preheater -4A, 4B:**

The raw meal from bucker elevator enters to preheater-4A, 4B.At that stage raw meal is heated to 3700c or 3800c.and sends to preheater-3**.**

**ii. Preheater -3:**

The molten metal from preheater-4A, 4Benters to preheater-3.At that stage material is heated to 6400c and sends to preheater-2A, 2B.

**iii. Preheater -2A,2B:**

The molten metal from preheater-3 enters to preheater-2A, 2B.At that stage material is heated to 8000c and sends to preheater-1 and calcinar.

**iv. Preheater-1, calcinar:**

The molten metal from preheater-2A, 2Benters to preheater-1 and Calcinar.At that stage material is heated to 880 0c (PH-1), 950 0c (calcinar) and Send to kiln. Coal from coal mill is used in heating of material at calcinar ( 65% of coal from coal mill).

**Pre heaters**

**4. Kiln:**

Kiln is the heart of the cement making process.a horizontal sloped steel cylinder lined with fire brick turning from about one to three revolutions per minute.the kiln is the world's largest piece of moving industrial equipment.

From the preheater, the raw material enters the kiln at the upperend .it slides and tumbles down the kiln through progressively hot zones toward the flame. At the lower end of the kiln, fuels such as powdered coal (35%) from coal mill feed a flame that reaches 3400 0F (1870 0c) one third of the temperature of the sun's surface.here in the hottest part of the kiln, the raw materials reach about 2700 0F(1480 0C) and become molten.

This intense heat triggers chemical and physical changes expressed at its simplest, the series of chemical reactions converts the calcium and silicon oxidesin to calciumsilicates, cemen's primary constituents. At the lower end of the kiln, the raw materials emerge as a new substance: red hot particles called clinker.

**5. Gate cooler:**

The clinker tumbles on to a grate cooled by forced air.there are several moving plates which helps the clinker to move forward. Several fans are also used in cooling process.these send the air from bottom of the plates.

**Cooler fans for cooling the material from kiln**

To save energy, heat recovered from this cooling process is recirculated back to the kiln or preheater tower.

**6. Clinker breaker & silo storage:**

The bulk clinker material is crushed into required size and dumped on DBC. This DBC transfer the clincker to silo.

**Clinker Crusher** **transfering the clincker to silo**

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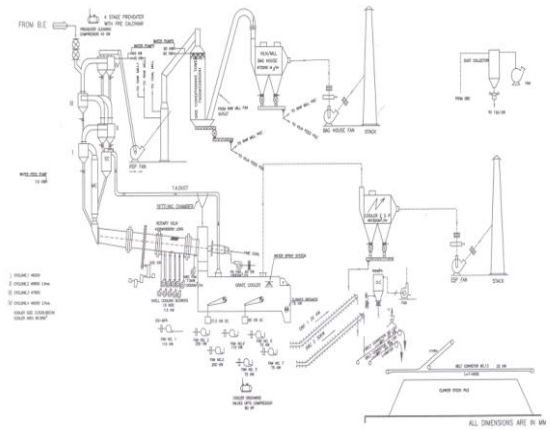
**Flow diagram kiln:**



**Stage -6**

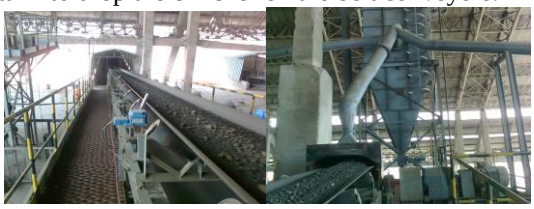
**clinker grinding (cement mill)**

A cement mill is the equipment used to grind the hard, nodular clinker from the kiln area into the fine grey powder that is cement.

**Process of clinker grinding and silo storage**

**1. Transfer of clinker to cement mill hopper from kiln silo:**

After the clincker is stored in the silo . To transport the clinker directly rejects silo is used to fill the lorry. The clinker in the clinker storage tank is passed though a hopper at the bottem of tank to drop the clincker on the belt conveyors.



**From clincker silo to cement mill trough belt conveyors**

**2. Weigh feeders:**

There are 2 weigh feeders (clinker, gypsum) and one fly ash dosing system. These weigh feeders send the required amount of clinker, gypsum in to the cement mill.

**Gypsum feeder** **clinker feeder**

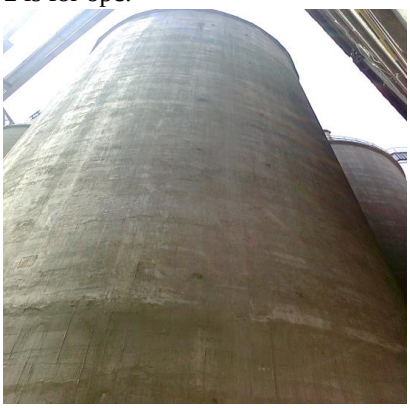
**3. Cement mill:**

Clinker is grinded in a ball mill a horizontal steel tube filled with steel balls. As the tube rotates the steel balls tumble and crush the clinker in to a super fine powder. It can now be considered as Portland cement.the cement is so fine enough to hold water. A small amount of gypsum is added during final grinding to control the setting time.quality depends on mixing of fly ash. More fly ash mixed cement is called ppc.low fly ash mixed cement is called opc.

**4. Transfer of cement to silo:**

The cement from cement mill is passed through bag filter. The heavy material is sent to seperator where the ungrinded material is again send to cement mill for grinding. The fine grinded material is send to cyclone from seperator.

The fine material from bag filter & cyclone is send to PG conveyor.this PG conveyo dumps the cement in the bucket elivator to fill the cement in the silo. There are 4 silos , 2 is for ppc and another 2 is for opc.



**Cement storage silo**

**Stage-7**

**Packing plant & loading plant:**

Finally processed cement enters in packaging unit from here it is packed in equal bags, loaded on trucks and further transported to the customers.

**Process of packing and loading plant:**

**1. Transfer of cement from silo to packers:**

The required cement that is OPC or PPC from silo is transfered to Bucket elevator with the PG conveyor at the bottom of the silo. Those elivators Drop the cement in the rotary screen. This rotary screen rejects the unwanted material from the cement and sends the pure cement material to the rotary packers (electronic packers). Hear the packing of cement bags starts.

**2. Packing of cement bags:**

The cement in the packers is packed in bags with the rotary packers (electronic packers). For these packers there is Handles to hold the cement bag and for filling the bags with cement. The manual work is done for fixing the bags to the handles. It is a sensor operated for correct filling of bags. After filling of bags it automatically stiches the bag and leaves it on a slider.

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**Electronic cement bag packers**

### 3. Loading of cement bags and bulk loading:

After packing the cement bag slider is directly plased in to lorrys. The manual work is done to place the bags in order. But in bulk loading cement is directly filled in tankers from the silo with the help of PG conveyor.

**Cement bags loading**

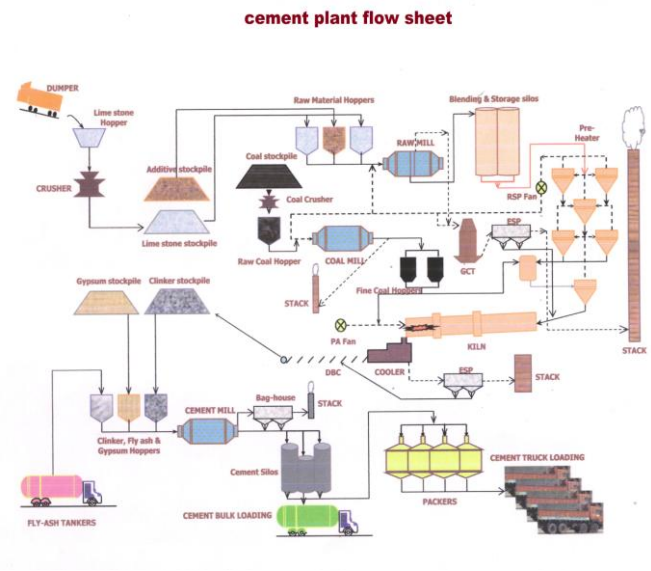
**cement bulk loading**

## III. QUALITY CONTROL

With the onset of globalization and liberalisation of Indian economy, "Quality" has become a buzzword in cement industry. Quality department maintains strict Quality Control at each stage of the manufacturing process to ensure delivery of the best quality cement to the customer all the time. Raw mix samples are analyzed through titrations, X-ray analyzers. Bomb Calorimeter is also used for maintaining quality. A bomb calorimeter is a kind of volume tub used in gauging the heat of combustion of a particular reaction. Bomb calorimeter has to endure the great pressure inside the calorimeter as the response is being calculated. Particle size analysis is also used. There are several Quality tests are done at ending stage of cement manufacturing. Guidance will be given for the various departments for maintaining good quality out put of cement. In modern plants robotic sensors are use to check the quality of cement to decrease the time loss of manual tests. This is the only department linked with all other departments in the industry. The benefits which have accrued to the Company are summarised here under:

*Improvement in quality and productivity
*Reduction in specific fuel and power consumption
*Reduced water consumption
*Production loss recovery
*Reduced maintenance cost
*Reduction in machinery breakdowns
*Development of team work amongst employees
*Safety of man and machinery
*Improvement in problem solving capability of employees

## CEMENT PLANT TOTAL FLOW SHEET

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