Chapter-5

Cement Processing Technology

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4.1 Cement Definition

❖Portland Cement (P.C.) Portland cement is a hydraulic cement capable of setting, hardening and remains stable under water.

❖It is composed of calcium silicates and some amount of gypsum.

❖Blended cement, as defined, is a mixture of portland cement and blast furnace slag (BFS) or a "mixture of portland cement and a pozzolan (most commonly fly ash)."

❖The use of blended cements in concrete reduces mixing water and bleeding, improves finish ability and workability, enhances sulfate resistance, inhibits the alkali-aggregate reaction, and lessens heat evolution during hydration, thus moderating the chances for thermal cracking on cooling.

Cement Factories in Ethiopia

- Messebo Cement Factory,Mekele
- Dangote Cement Factory, Mugher
- National Cement Share Company, diredawa
- Mugher Cement Factory, Addis ababa
- Mugher Cement Factory, Dire Dawa
- Mugher Cement Factory, Mugher
- Derba Midroc Cement, Derba Midroc
- Ethio Cement, Chanco
- Addis Ababa cement, Addis Ababa

Types of Cement

Cement is classified into several types.

	Code	Chemical Formula	Type
Portland	C_2S	$2CaO.SiO_2$	Silicate
	C_3S	$3CaO.SiO_2$	Silicate
	C_3A	$3CaO.Al_2O_3$	Aluminate
	C_4AF	$4CaO.Al_2O_3.Fe_2O_3$	Aluminate
	-	MgO	
	-	CaO	
High Alumina	C_3A	$3CaO.Al_2O_3$	Aluminate
	C_2S	$2CaO.SiO_2$	Silicate
	C_2AS	$2CaO. Al_2O_3.SiO_2$	Mixed

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	Code	Chemical Formula	Type
Hydraulic hydrated Lime	-	$Ca(OH)_2$	Hydroxide
	C_2S	$2CaO.SiO_2$	Silicate
	C_3A	$3CaO.Al_2O_3$	Aluminate

Types of Portland Cement

❖ Varying the percentage of constituents changes the rate of setting, heat evolution and strength characteristics.

Types	**Constituents**
Type-I	40-60% C_3S, 10-30%C_2S, 7-13% Ca_3A; Hardens to full strength in 28 days.
Type-II	Higher C_2S/C_3S to resist sulfate attack.
Type-III	Attains strength of Type I in only 3 days; High heat rates-useless on massive structures; C_3S/C_3A % with finer grinding to increase hydration rate.
Type-IV	Designed for massive structure work.
Type-V	Good for sea water contact. $C_3A<4\%$

Cement Chemistry

In cement chemistry, the individual oxides and clincker compounds are expressed by their abbreviations

Short Hand Notation

- **C** (CaO, calcium oxide)
- **A** (Al2O3, alumina)
- **S** (SiO2, silica)
- **S** (SO3, sulfate)
- **H** (H20, water)

Reactive Compounds

- **C3S** (tricalcium silicate)
- **C2S** (dicalcium silicate)
- **C3A** (tricalcium aluminate)
- **CSH2** (gypsm)
- **C4AF** (tetra-calcium alumino ferrite)

Approximate oxide Composition of Portland Cement

Oxide	*Per cent content*
CaO	60–67
SiO_2	17–25
Al_2O_3	3.0–8.0
Fe_2O_3	0.5–6.0
MgO	0.1–4.0
Alkalies (K_2O, Na_2O)	0.4–1.3
SO_3	1.3–3.0

- C_3S $3CaO\ .\ SiO_2$
- C_2S $2CaO\ .\ SiO_2$
- C_3A $3CaO\ .\ Al_2O_3$
- C_4AF $4CaO.Al_2O_3.Fe_2O_3$
- $C_4A_3\overline{S}$ $4CaO.3Al_2O_3.SO_3$

$$\begin{cases} C_3S = \text{Tricalcium Silicate} \\ C_2S = \text{Dicalcium Silicate} \\ C_3A = \text{Tricalcium aluminate} \\ C_4AF = \text{Tetracacium aluminate ferrite} \end{cases}$$

- **Hydration Reactions**
  - $2C_3S + 6H \rightarrow C\text{-}S\text{-}H + 3CH$ (120 cal/g)
  - $2C_2S + 4H \rightarrow C\text{-}S\text{-}H + CH$ (62 cal/g)
  - $C_3A + 3C\overline{S}H_2 + 26H \rightarrow C_6A\overline{S}_3H_{32}$ (300 cal/g)
  - $2C_3A + C_6AS_3H_{32} + 4H \rightarrow 3C_4A\overline{S}H_{12}$
  - $C_4AF + 10H + 2CH \rightarrow C_6AFH_{12}$

4.2 Manufacture of Portland Cement

- Cement is made by heating limestone (calcium carbonate) with small quantities of other materials (such as clay) to 1450 °C in a kiln, in a process known as calcination, whereby a molecule of carbon dioxide is liberated from the calcium carbonate to form calcium oxide, or quicklime, which is then blended with the other materials that have been included in the mix.
- The resulting hard substance, called 'clinker', is then ground with a small amount of gypsum into a powder to make 'Ordinary Portland Cement', the most commonly used type of cement (often referred to as OPC).

Methods of Production

Classification of Processes:

There are two types of processes to produce Cement commercially.

i) Cement rock beneficiation

ii) Portland cement production

Cement rock beneficiation Method

- Locally available limestone has too high silica content for direct use in cement manufacture.
- These undesirable constituents are removed by ore dressing (mineral processing) or beneficiation method.

Quantitative Requirements

Basis : 1 ton of low grade limestone

- ❖**Water : 2-3 tons**
- ❖**Reagents : 50-200 grams**
- ❖**Electricity : 2.5 KWH**
- ❖**Plant capapcity : 300-1000 tons/day**

4.2 Process Description (Cement rock beneficiation)

❖The operations are grinding, classification,floatation and thickening.

❖Rock is wet-ground, fed to a hydroseparator where the overflow goes directly to the final thickener.

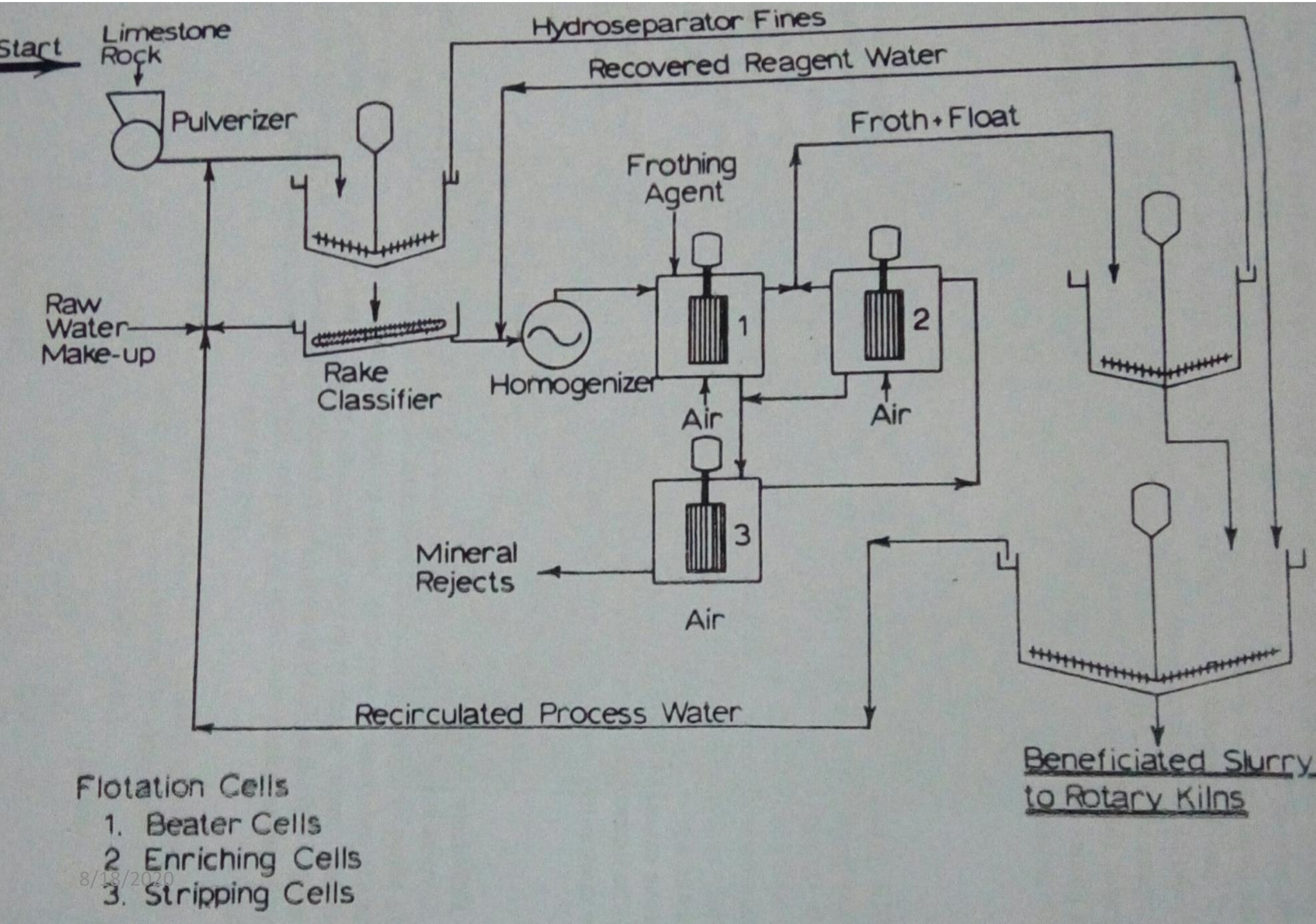
❖Also it is subjected to floatation separation as well as the coarse material which must be floated to remove silica, mica and talc.

❖Floatation is based on the ability of a collecting agent to wet certain minerals.

❖It overflows the floatation cell into the thickener cascade.

❖In thickener cascade, the floatation liquor is recycled and the beneficiated cement rock slurry is fed directly to cement kiln.

Process Flow sheet of rock beneficiation process for cement production



Portland Cement Process

Quantitative requirements:

Basis : 1 ton of Type I cement

- ❖Clay : 0.1-0.3 ton
- ❖Limestone : 1.2-1.3 tons
- ❖Gypsum : 0.03-0.05 ton
- ❖Coal : 0.25-0.40 ton
- ❖Water : 3 tons
- ❖Electricity : 80 KWH
- ❖Plant capacity: 200-1200 tons/day

Chemical Reactions:

In Portland cement process the chemical reactions are as follows.

i) $CaCO_3 \longrightarrow CaO + CO_2$ **; +44 cal.**

ii) $CaO + Al_2O_3 + SiO_2 \longrightarrow$ **Mixture of** C_3S, C_2S, C_3A

Production process of Portland Cement

Quarrying: Limestone and a 'cement rock' such as clay or shale are quarried and brought to the cement works.

- These rocks contain lime ($CaCO_3$), silica (SiO_2), alumina (Al_2O_3) and ferrous oxide (Fe_2O_3) - the raw materials of cement manufacture.

Raw material preparation: To form a consistent product, it is essential that the same mixture of minerals is used every time

- For this reason the exact composition of the limestone and clay is determined at this point, and other ingredients added if necessary.
- The rock is ground into fine particles to increase the efficiency of the reaction.
- Grinding may be a wet process or dry process and dry process is preferable.

The dry process :

- The quarried clay and limestone are crushed separately until nothing bigger than a tennis ball remains. Samples of both rocks are then sent off to the laboratory for mineral analysis.
- If necessary, minerals are then added to either the clay or the limestone to ensure that the correct amounts of aluminium, iron etc. are present. The clay and limestone are then fed together into a mill where the rock is ground until more than 85% of the material is less than 90µm in diameter.

The wet process : The clay is mixed to a paste in a wash mill - a tank in which the clay is pulverised in the presence of water.

- Crushed lime is then added and the whole mixture further ground.
- Any material which is too coarse is extracted and reground. The slurry is then tested to ensure that it contains the correct balance of minerals, and any extra ingredients blended in as necessary.

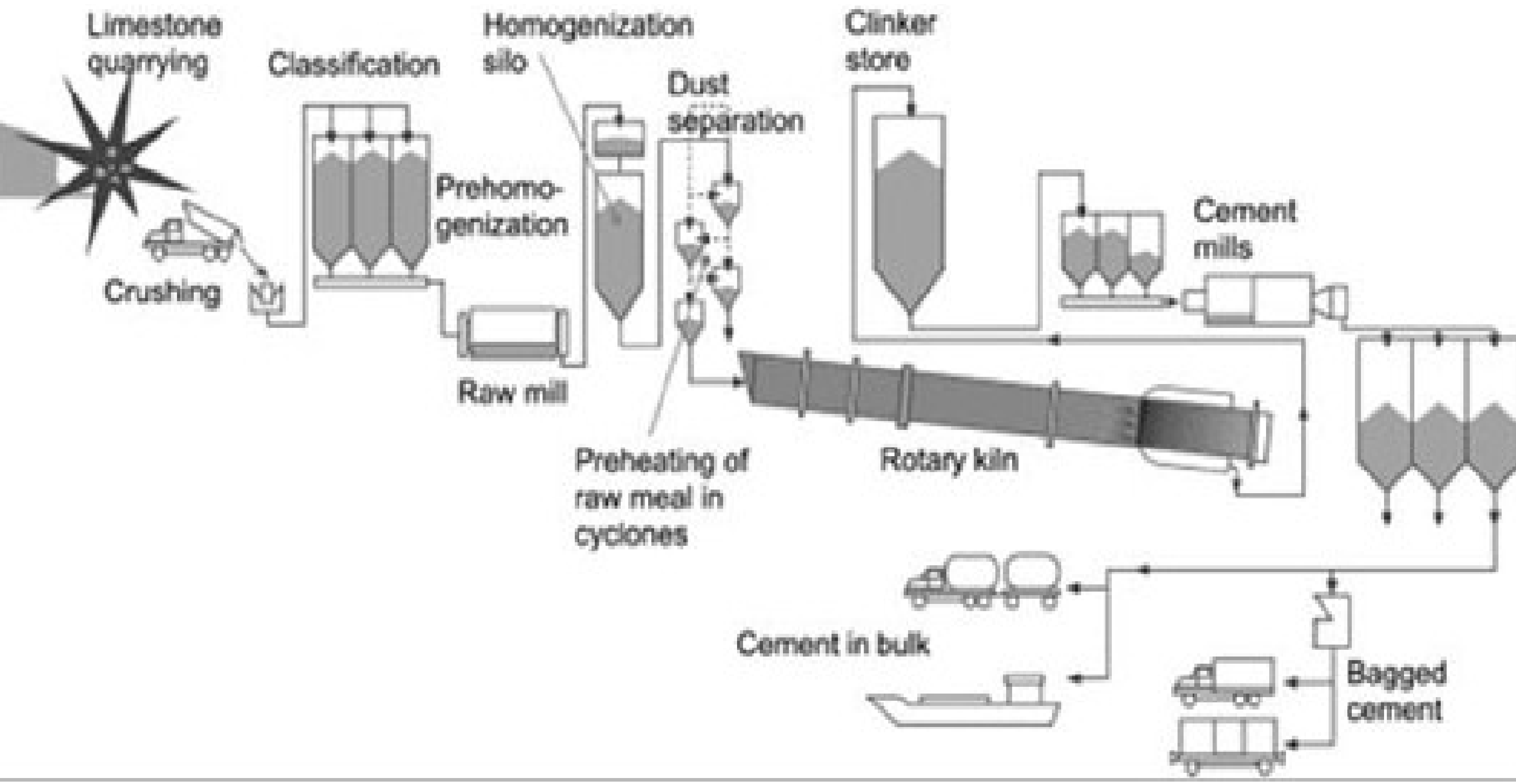
Clinkering : The raw materials are then dried, heated and fed into a rotating kiln.

- ❖ Here the raw materials react at very high temperatures to form $3CaO \cdot SiO_2$ (tricalcium silicate), $2CaO \cdot SiO_2$ (dicalcium silicate), $3CaO \cdot Al_2O_3$ (tricalcium aluminate) and $4CaO \cdot Al_2O_3 \cdot Fe_2O_3$ (tetracalcium alumino-ferrate).

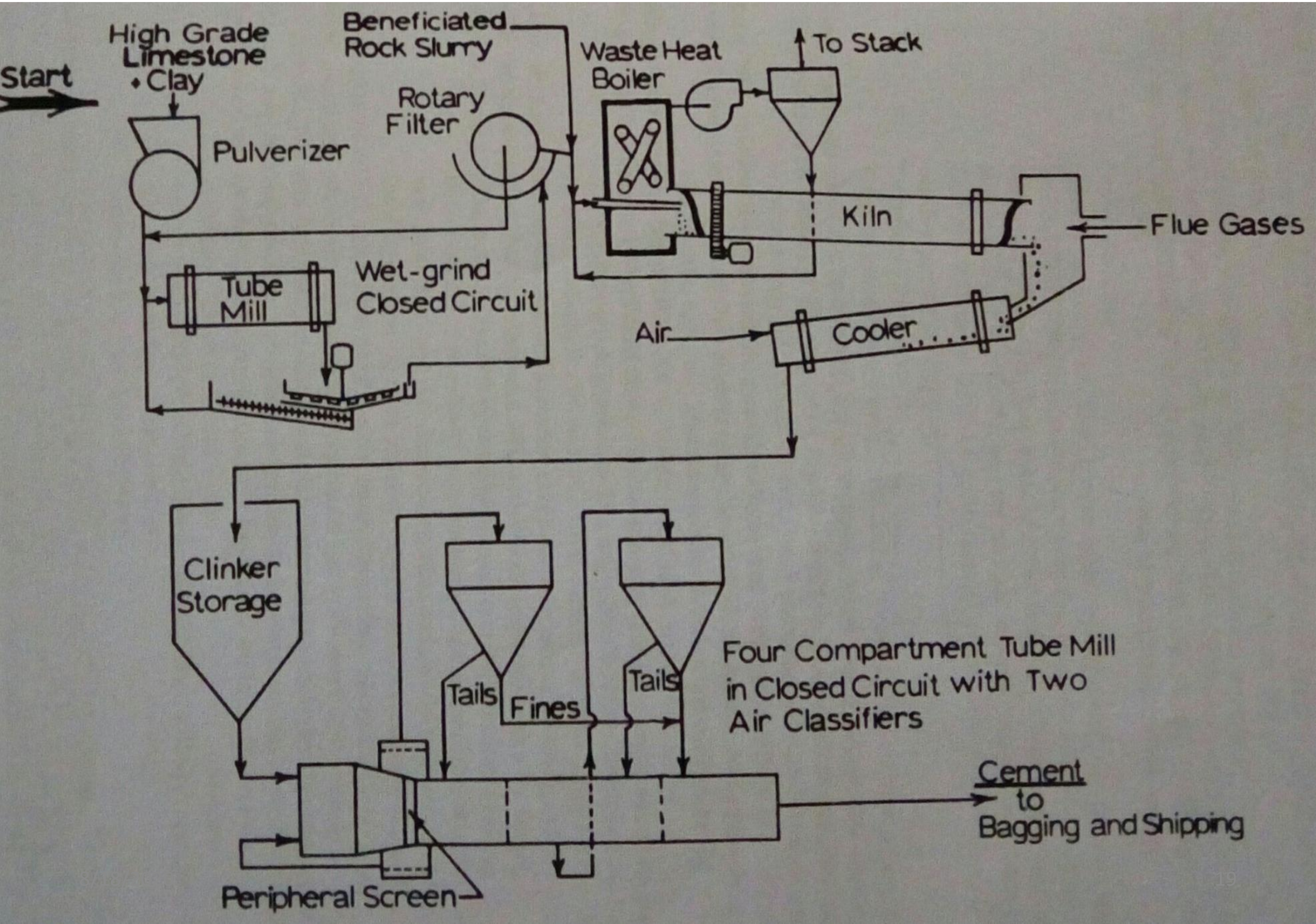
The kiln : The kiln shell is steel, 60m long and inclined at an angle of 1 in 30.

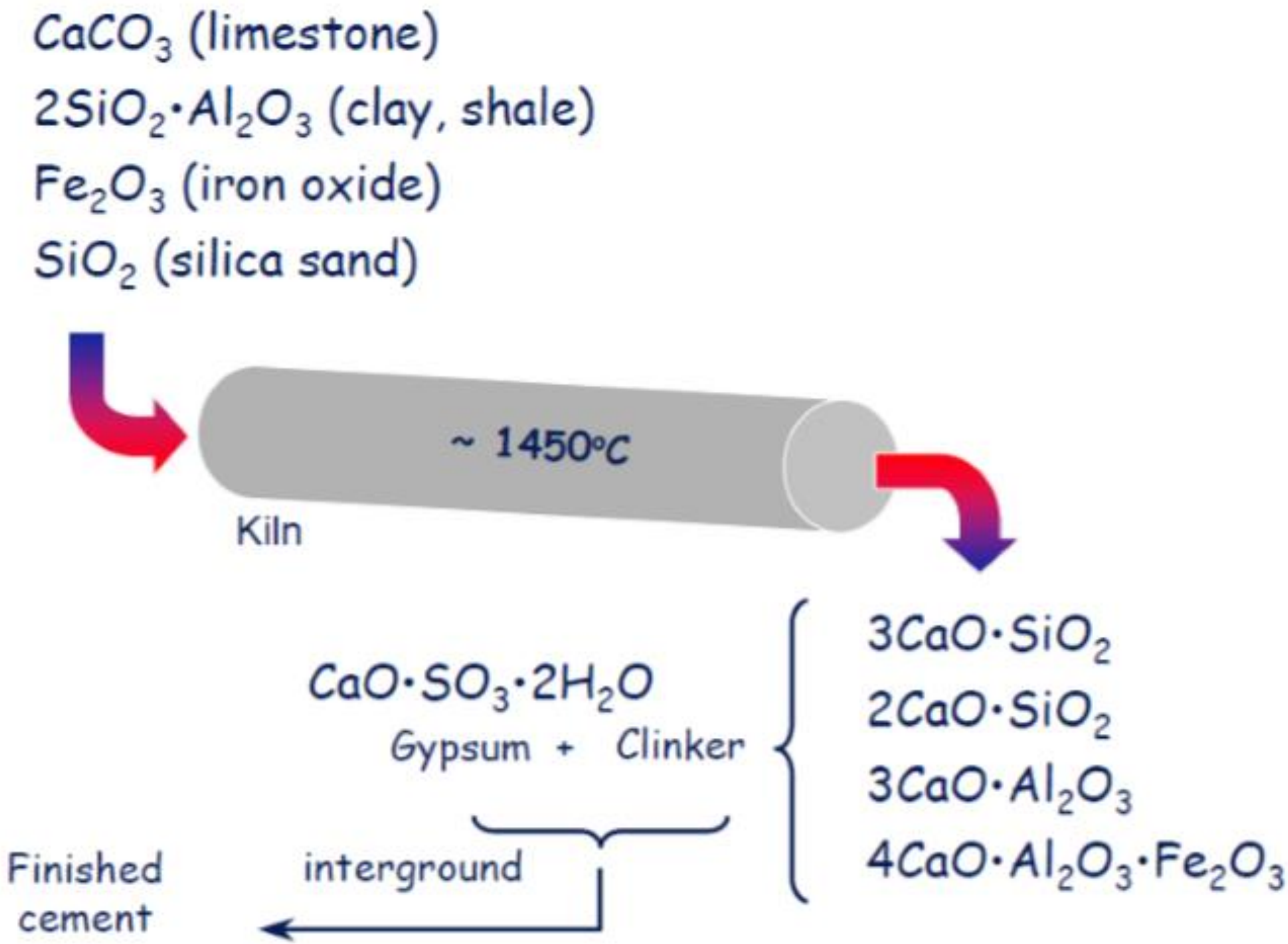
- ❖ The kiln is heated by injecting pulverized coal dust into the discharge end where it spontaneously ignites due to the very high temperatures.
- ❖ Coal is injected with air into the kiln at a rate of 9 - 12 T/hr.

Manufacture of Portland Cement (Dry process)



Process Flow sheet of Portland Cement(wet process)




$CaCO_3$ (limestone)
$2SiO_2 \cdot Al_2O_3$ (clay, shale)
Fe_2O_3 (iron oxide)
SiO_2 (silica sand)
~ 1450°C
Kiln
$CaO \cdot SO_3 \cdot 2H_2O$
Gypsum + Clinker
$3CaO \cdot SiO_2$
$2CaO \cdot SiO_2$
$3CaO \cdot Al_2O_3$
$4CaO \cdot Al_2O_3 \cdot Fe_2O_3$
Finished cement
interground

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Zone 1: 0 - 35 min, 800 - 1100°C

Decarbonation. Formation of $3CaO^{\bullet}Al_2O_3$ above 900°C. Melting of fluxing compounds Al_2O_3 and Fe_2O_3.

$$CaCO_3 \xrightarrow{heat} CaO + CO_2$$

Zone 2: 35 - 40 min, 1100 - 1300°C

Exothermic reactions and the formation of secondary silicate phases as follows:

$$2CaO + SiO_2 \xrightarrow{heat} 2CaO^{\bullet}SiO_2$$

Zone 3: 40 - 50 min, 1300 - 1450 - 1300°C

Sintering and reaction within the melt to form ternary silicates and tetracalcium alumino-ferrates:

$$2CaO^{\bullet}SiO_2 + CaO \xrightarrow{heat + time} 3CaO^{\bullet}SiO_2$$

$$3CaO^{\bullet}Al_2O_3 + CaO + Fe_2O_3 \xrightarrow{heat + time} 4CaO^{\bullet}Al_2O_3{}^{\bullet}Fe_2O_3$$

Zone 4: 50 - 60 min, 1300 - 1000°C

Cooling and crystallisation of the various mineral phases formed in the kiln.

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Cement milling : The 'clinker' that has now been produced will behave just like cement, but it is in particles up to 3 cm in diameter.

- ❖ The product from tube milling the clinker is a powder of which 90% passes through 200 mesh.
- ❖ It is bagged or bulk stored and shipped

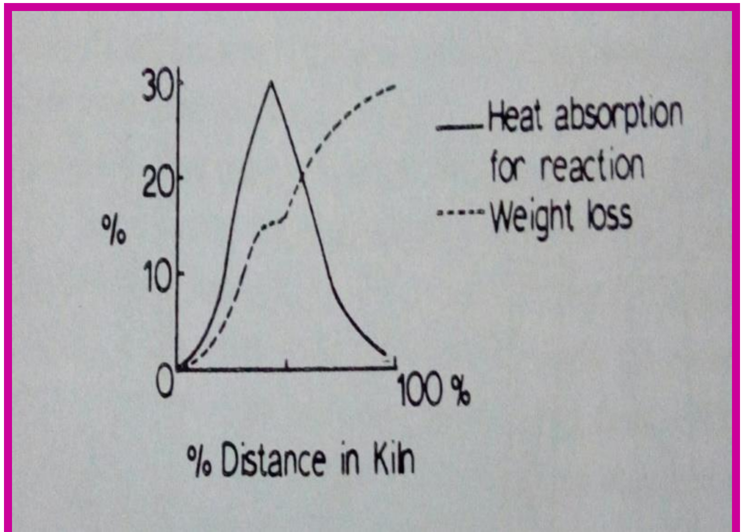
4.3 Energy Utilization

- **Heat Economy:**
- Minimizing fuel consumption is an economic balance between fuel costs and addition of waste –heat boiler and air preheater.
- The theoretical energy or heat requirement is 40 Kcal/kg of portland cement clinker.
- Actual heat requirements vary from 1300-1800 Kcal/kg for wet grinding process.
- Only 700-1000 Kcal/kg is required for dry grinding process.

ii) **Kiln design:**

- Calcining involves decomposition of $CaCO_3$ to CaO and firing at 1400-1500^oC to promote compound formation.
- Heat duty is also required for water evaporation, oxidizing organic material,partial volatilization of sulfates, chlorides and alkalies.
- A typical performance graph is given as follows.

- Wet process feed requires 90-170m length kilns of 2.5-6 m diameter.
- Dry process kilns are 50m length.
- Rotational speed is 2 rpm to ½ rpm.



Overall Factors to be considered in Cement Industry

1) Process Technology

2) Industry problems including

   a) Capital availability

   b) Power

   c) Local Problems

   d) Raw material problems

   e) Transport problems

   f) Export problems

3)The impact of Research and Development

4)Future market influences and trends

4.4 Environmental Assessment

- ❖Environmental Assessment (EA) is the assessment of the environmental consequences (positive & negative) of a plan, policy, program or actual projects prior to the decision to move forward with the proposed action in Cement industries.
- ❖In cement Industries, Environmetal assessment may be governed by rules of administrative procedure regarding public participation,labour welfare and documentation of decision making.
- ❖The overall aim of the Ethiopian Environmental Protection Authority (EPA) is to improve and enhance the health and quality of life of all Ethiopians and to promote sustainable social and economic development through the sound management and use of natural, human-made and cultural resources and the Environment.

Thank you