CEMENT

WHAT IS CEMENT????

- ✓ Material with adhesive and cohesive properties
- ✓ Any material that binds or unites - essentially like glue

FUNCTION OF CEMENT

- ✓ to bind the sand and coarse aggregate together
- ✓ to fill voids in between sand and coarse aggregate particle
- ✓ to form a compact mass

Types of Cement

- ✓ 2 types of cement normally used in building industry are as follows:

a) Hydraulic Cement

b) Nonhydraulic Cement

Hydraulic Cement

- ✓ Hydraulic Cement sets and hardens by action of water. Such as Portland Cement
- ✓ In other words it means that hydraulic cement are:

" Any cements that turns into a solid product in the presence of water (as well as air) resulting in a material that does not disintegrate in water."

Most common Hydraulic Cement is Portland Cement

Nonhydraulic Cement

- ✓ Any cement that does not require water to transform it into a solid product.
- ✓ 2 common Nonhydraulic Cement are

a) Lime

- derived from limestone / chalk

b) Gypsum

PORTLAND CEMENT

- ✓ Chemical composition of Portland Cement:

  a) Tricalcium Silicate (50%)

  b) Dicalcium Silicate (25%)

  c) Tricalcium Aluminate (10%)

  d) Tetracalcium Aluminoferrite (10%)

  e) Gypsum (5%)

FUNCTION :TRICALCIUM SILICATE

- ✓ Hardens rapidly and largely responsible for initial set & early strength
- ✓ The increase in percentage of this compound will cause the early strength of Portland Cement to be higher.
- ✓ A bigger percentage of this compound will produces higher heat of hydration and accounts for faster gain in strength.

FUNCTION :DICALCIUM SILICATE

- ✓ Hardens slowly
- ✓ Its effect on strength development at ages beyond one week .
- ✓ Responsible for long term strength.

FUNCTION :TRICALCIUM ALUMINATE

- ✓ Contributes to strength development in the first few days because it is the first compound to hydrate .
- ✓ It turns out higher heat of hydration and contributes to faster gain in strength.
- ✓ But it results in poor sulfate resitance and increases the volumetric shrinkage upon drying.

- ✓ Cements with low Tricalcium Aluminate contents usually generate less heat, develop higher strengths and show greater resistance to sulfate attacks.
- ✓ It is reactive with soils and water containing moderate to high sulfate concentrations so it's least desirable.

FUNCTION : TETRACALCIUM ALUMINOFERRITE

- ✓ Assists in the manufacture of Portland Cement by allowing lower clinkering temperature.
- ✓ Also act as a filler
- ✓ Contributes very little strength of concrete even though it hydrates very rapidly.
- ✓ Also responsible for grey colour of Ordinary Portland Cement

MANUFACTURING OF PORTLAND CEMENT

- ✓ The 3 primary constituents of the raw materials used in the manufacture of Portland Cement are:

  a) Lime
  b) Silica
  c) Alumina

- ✓ Lime is derived from limestone or chalk
- ✓ Silica & Alumina from clay, shale or bauxite

- ✓ There are 2 chief aspects of the manufacturing process:

  First

  To produce a finely divided mixture of raw materials – chalk / limestone and clay / shale

  Second

  To heat this mixture to produce chemical composition

- ✓ There are 2 main process that can be used in manufacturing of Portland Cement that is

  i) wet process ii) dry process

WET PROCESS

- ✓ Raw materials are homogenized by crushing, grinding and blending so that approximately 80% of the raw material pass a No.200 sieve.
- ✓ The mix will be turned into form of slurry by adding 30 - 40% of water.
- ✓ It is then heated to about 2750ºF (1510ºC) in horizontal revolving kilns (76-153m length and 3.6-4.8m in diameter).

- ✓ Natural gas, petroluem or coal are used for burning.
- ✓ High fuel requirement may make it uneconomical compared to dry process.

DRY PROCESS

- ✓ Raw materials are homogenized by crushing, grinding and blending so that approximately 80% of the raw material pass a No.200 sieve.
- ✓ Mixture is fed into kiln & burned in a dry state
- ✓ This process provides considerable savings in fuel consumption and water usage but the process is dustier compared to wet process that is more efficient than grinding.

DRY PROCES & WET PROCESS

- ✓ In the kiln, water from the raw material is driven off and limestone is decomposed into lime and Carbon Dioxide.

  limestone $\longrightarrow$ lime + Carbon Dioxide

- ✓ In the burning zone, portion of the kiln, silica and alumina from the clay undergo a solid state chemical reaction with lime to produce calcium aluminate.

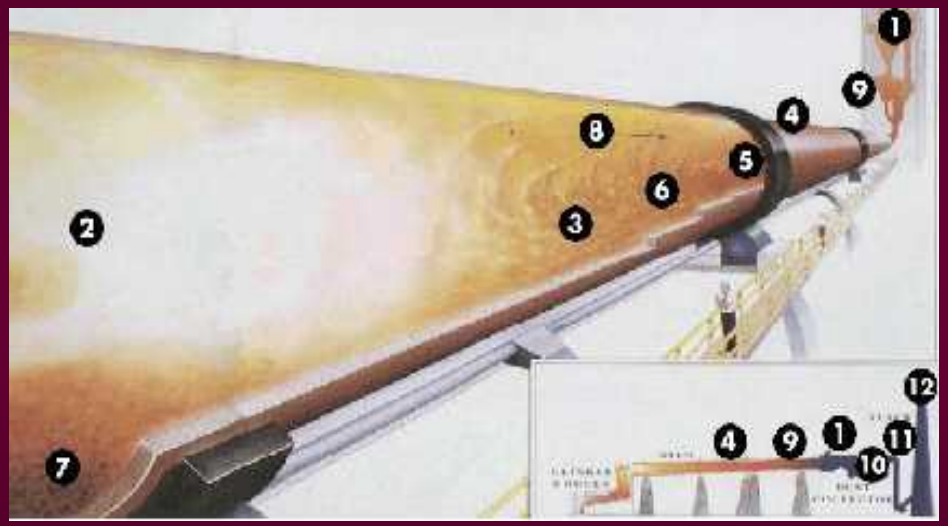
  silica & alumina + lime $\longrightarrow$ calcium aluminate

- ✓ The rotation and shape of kiln allow the blend to flow down the kiln, submitting it to gradually increasing temperature.
- ✓ As the material moves through hotter regions in the kiln, calcium silicates are formed
- ✓ These products, that are black or greenish black in color are in the form of small pellets, called cement clinkers.
- ✓ Cement clinkers are hard, irregular and ball shaped particles about 18mm in diameter.

CEMENT CLINKERS

- ✓ The cement clinkers are cooled to about 150ºF (51ºC) and stored in clinker silos.
- ✓ When needed, clinker are mixed with 2-5% gypsum to retard the setting time of cement when it is mixed with water.
- ✓ Then, it is grounded to a fine powder and then the cement is stored in storage bins or cement silos or bagged.
- ✓ Cement bags should be stored on pallets in a dry place.

KILN



CEMENT SILO

What happens in the kiln?

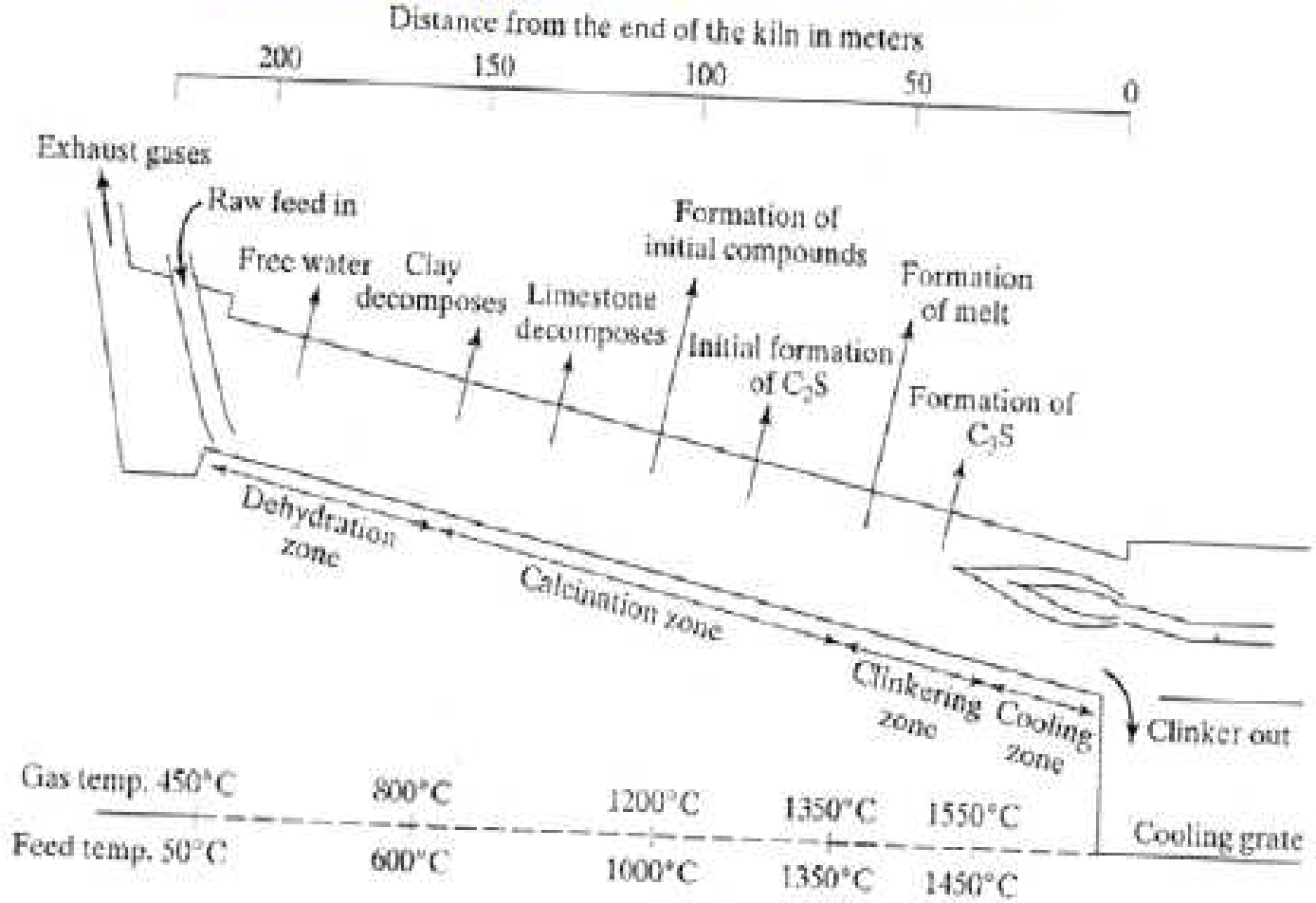


FIGURE 3.2

Schematic outline of conditions and reactions in a typical dry-process rotary kiln. When suspension preheaters are used, dehydration and initial calcination takes place outside the kiln in the preheater tower.

Calcine- to heat (as inorganic materials) to a high temperature but without fusing in order to drive off volatile matter or to effect changes (as oxidation or pulverization)

What are the products?

Two-dimensional processed SEM/X-ray image for cement 133 issued by the CCRL (NIST) in June of 1999. Color assignments are: red- C_3S

aqua- C_2S

green- C_3A

yellow- C_4AF

pale green- gypsum

white- free lime (CaO)

dark blue (purple)- K_2SO_4

light magenta- periclase (magnesium containing phase).

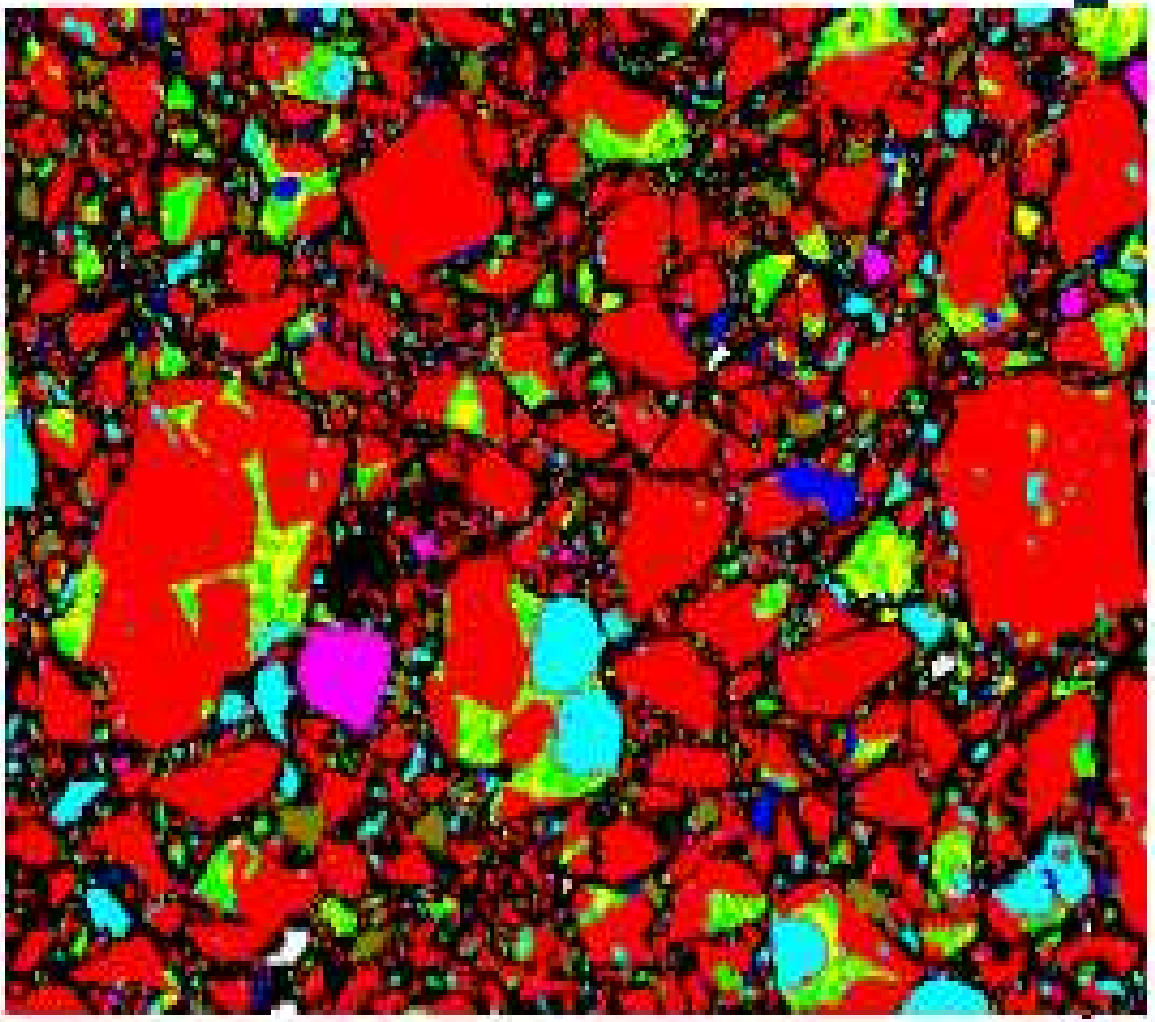
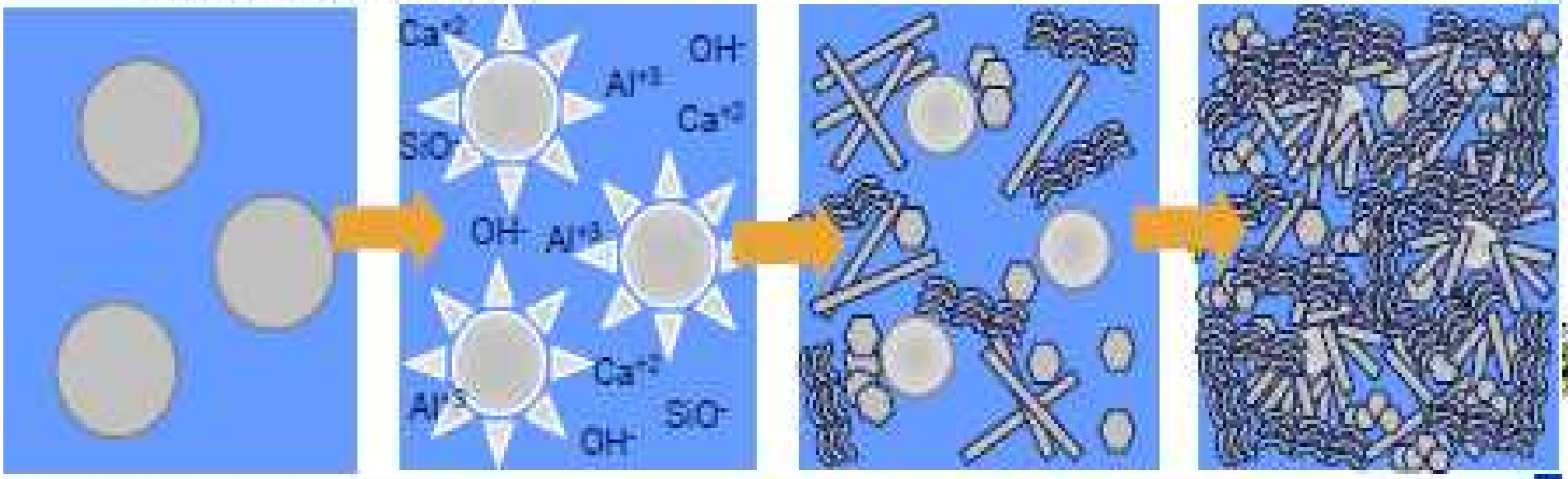


Image is 256 μm x 200 μm.

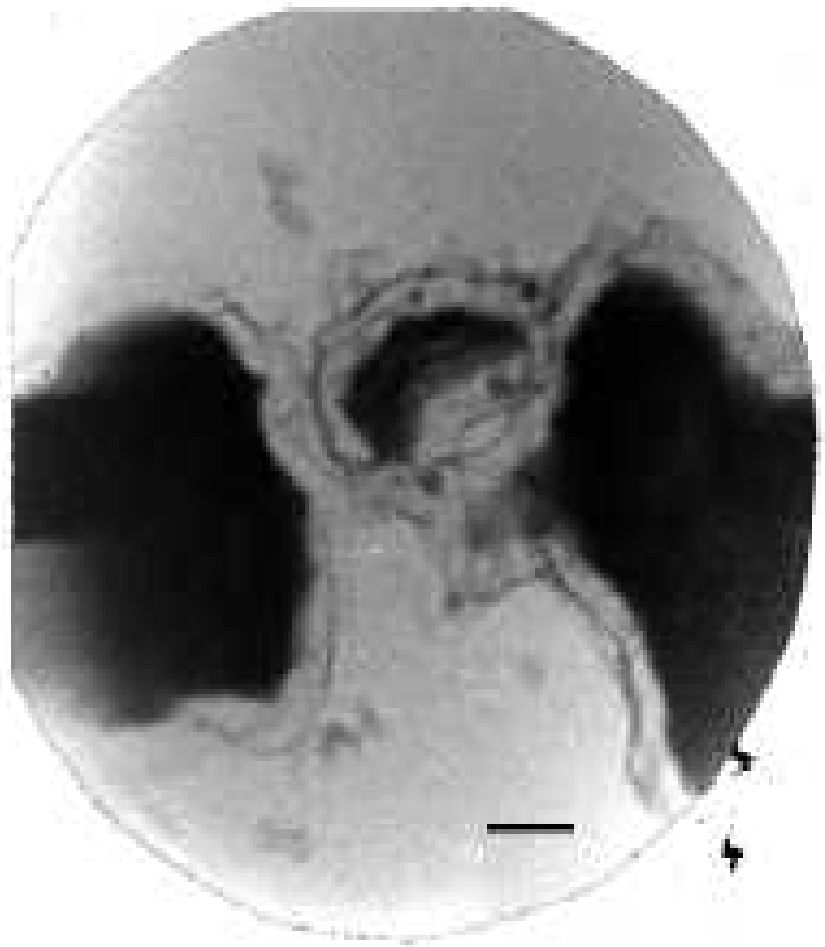
Cement Hydration

When water is added to cement, what happens?

- Dissolution of cement grains
- Growing ionic concentration in "water" (now a solution)
- Formation of compounds in solution
- After reaching a saturation concentration, compounds precipitate out as solids ("hydration products")
- In later stages, products form on or very near the surface of the anhydrous cement



Cement Hydration



Cement Hydration

- Is the chemical combination of cement and water to form hydration products
- Takes time
- May not proceed to 100% completion

Formation of hydration products over time leads to:

- Stiffening (loss of workability)
- Setting (solidification)
- Hardening (strength gain)

Hydration of the Calcium Silicates

$2C_3S + 7H \rightarrow C_3S_2H_8 + 3CH$ ΔH=-500J/g

$2C_2S + 7H \rightarrow C_3S_2H_8 + CH$ ΔH=-250J/g

- Both produce C-S-H and CH as reaction products
- C_2S produces less CH (important for durability in sulfate rich environments)
- More heat is evolved during C_3S hydration
- C_3S hydration is more rapid, contributing to early age strength (2-3h to 14 days)
- C_2S hydration occurs more slowly to contributing to strength after ~14 days.

C-S-H

- Calcium silicate hydrate
- C/S varies between 1.5-2
- H is even more variable
- Structure ranges from poorly crystalline to amorphous - highly variable and poorly understood
- Occupies 50-60% of the solid volume of the hydrated cement paste (hcp)
- Huge surface area (100-700 m^2/g)
- Strength due to covalent/ionic bonding (~65%) and Van der Waals bonding (~35%) within the complex structure
- Primary strength-giving phase in portland cement concrete

Cement Hydration

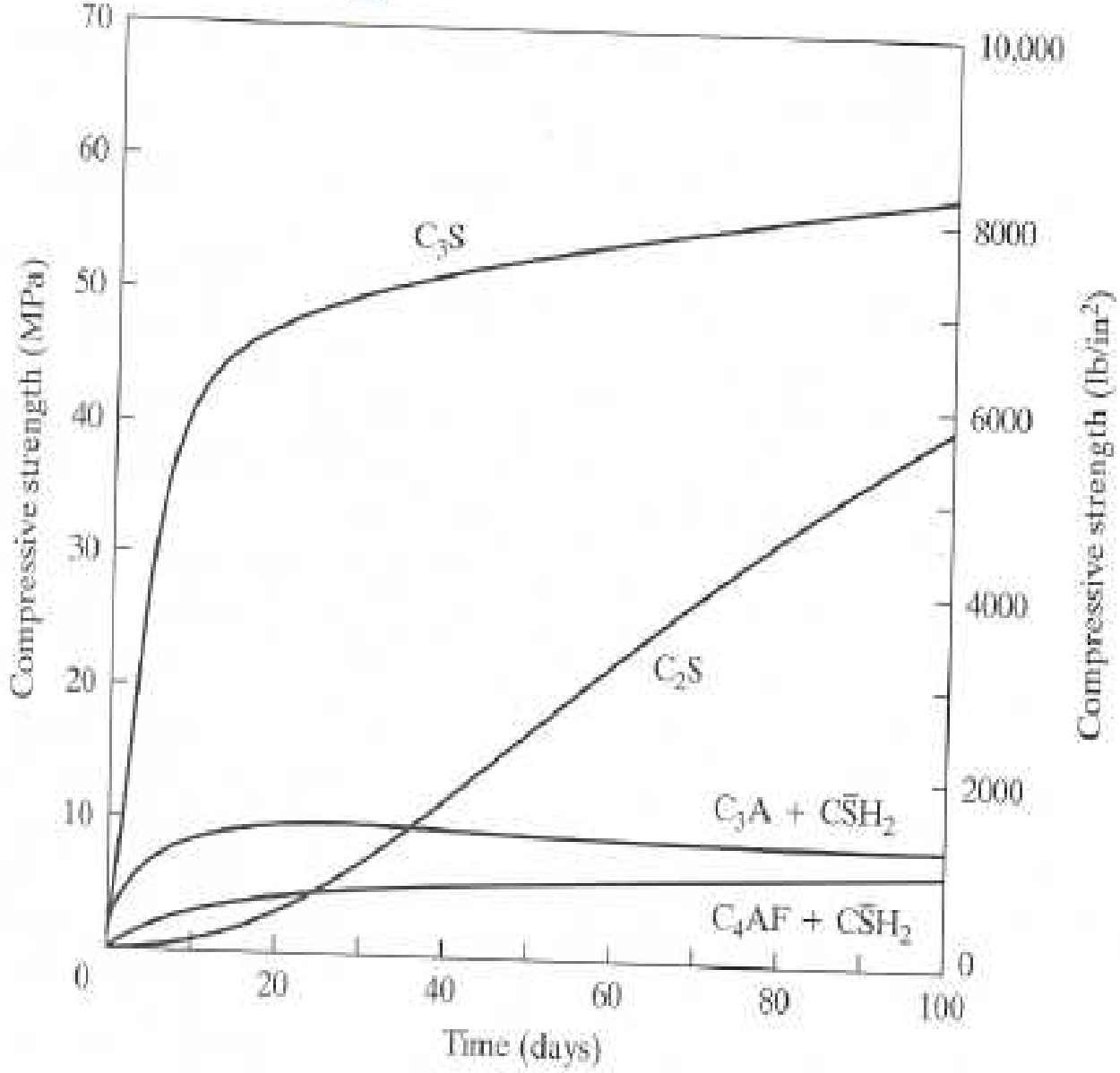
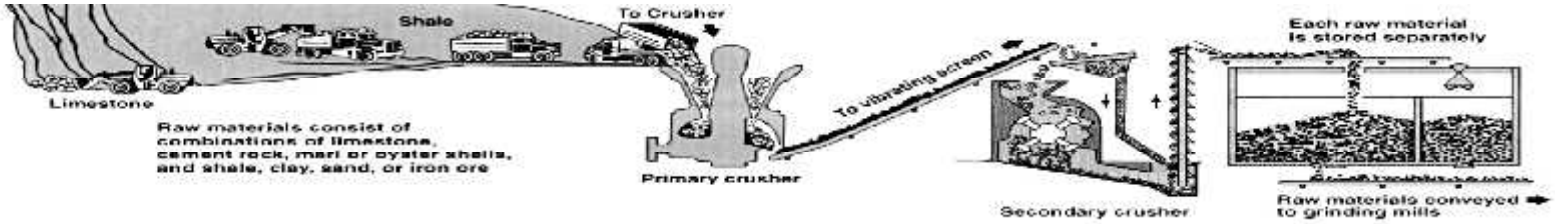


Figure 11.3
Strength development over time of the four main chemical components in portland cement (after S. Mindess and J. F. Young, *Concrete*, Prentice Hall, 1981, Fig. 3.4, p. 29).

Manufacturing Process

- Naturally occurring calcium carbonate materials such as limestone, chalk, marl, and sea-shells are the common industrial sources of calcium.

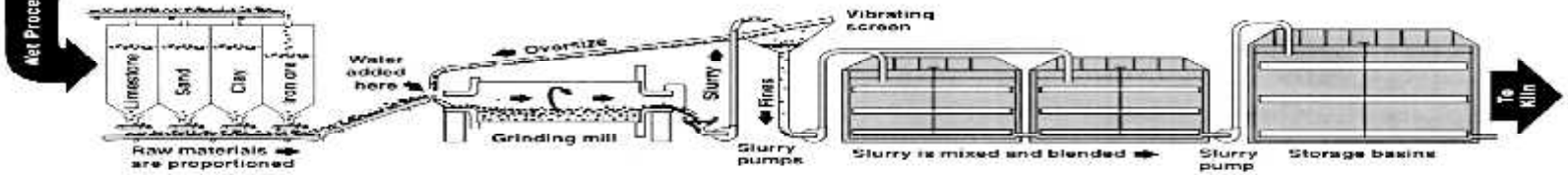
- Clays and shales are the preferred sources of additional silica in the raw-mix for making calcium silicates.



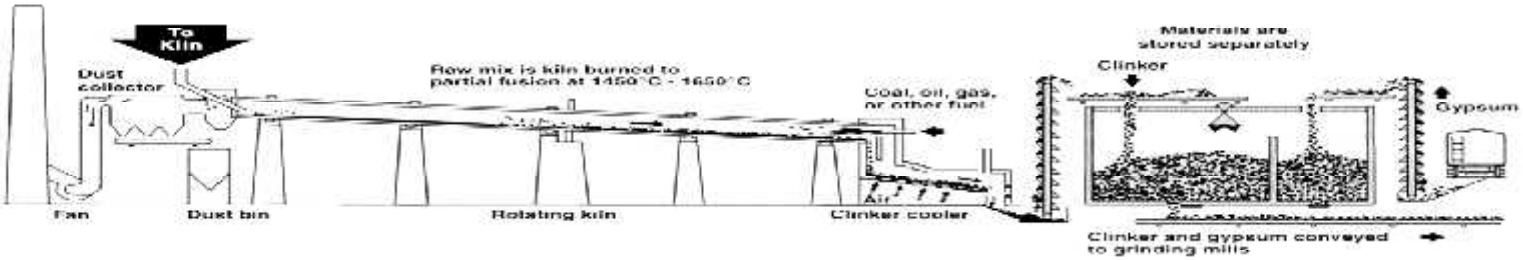
1. Stone is first reduced to 125 mm size, then to 20 mm, and stored.

OR

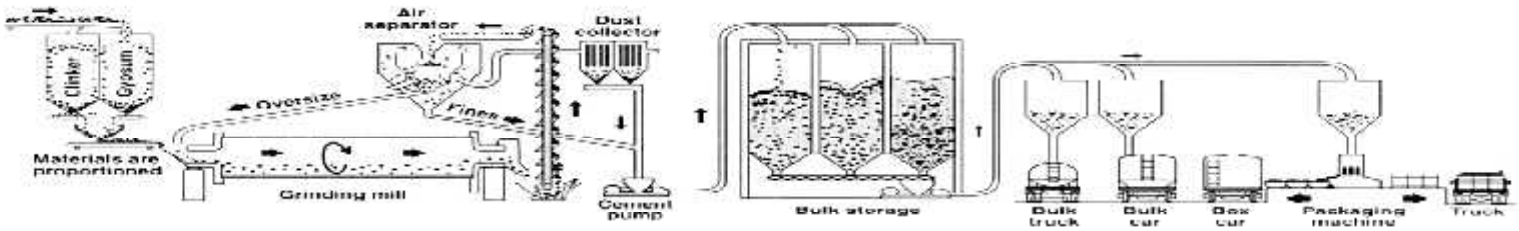
2. Raw materials are ground to powder and blended.



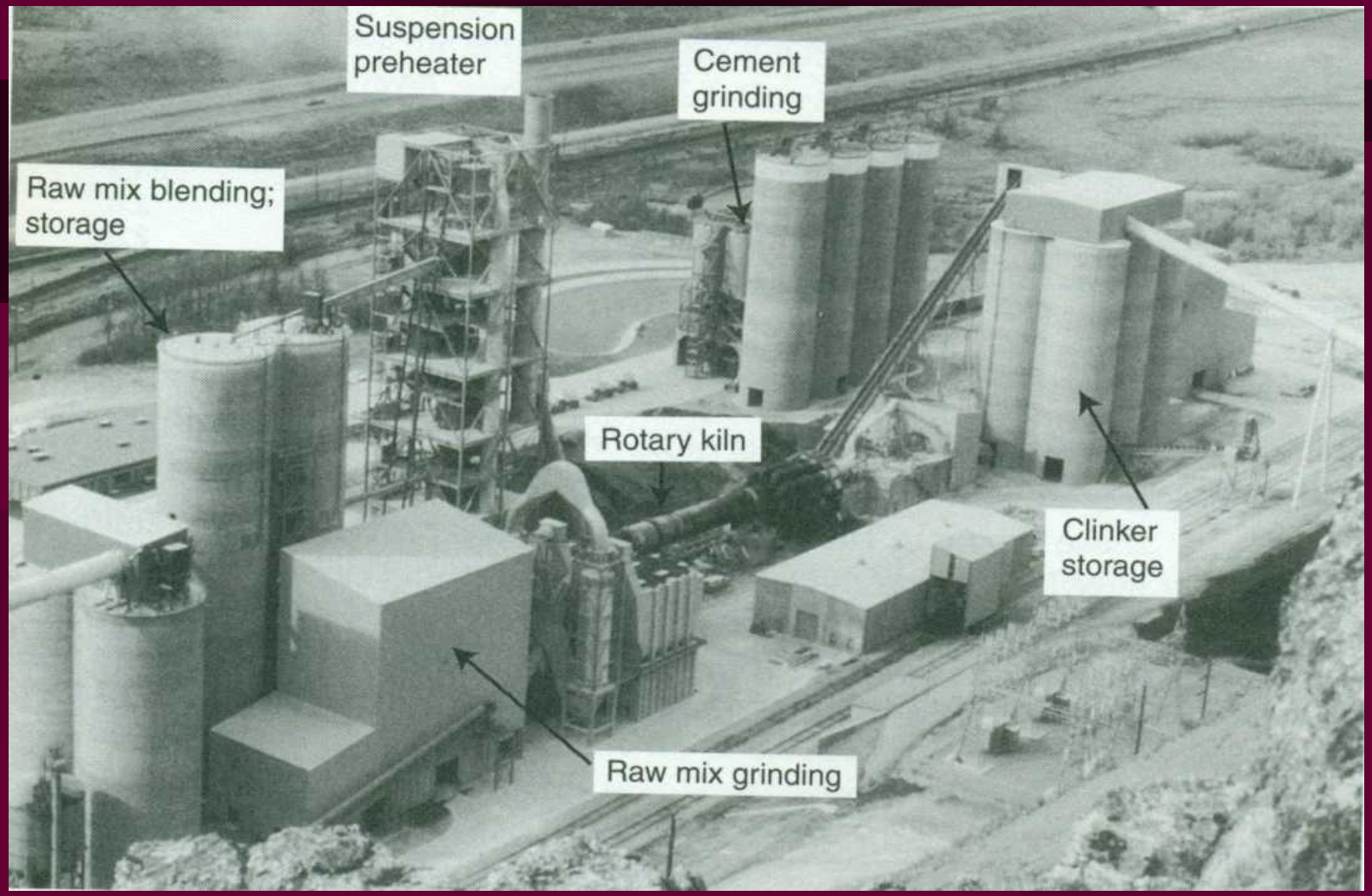
2. Raw materials are ground, mixed with water to form slurry, and blended.



3. Burning changes raw mix chemically into cement clinker.



4. Clinker with gypsum is ground into portland cement and shipped.


Suspension preheater
Cement grinding
Raw mix blending; storage
Rotary kiln
Clinker storage
Raw mix grinding

wet process

The grinding and homogenization of the raw mix is carried our in the form of a slurry containing 30 to 40 percent water.

Modern cement plants favour the **dry process**, which is more energy efficient than the wet process because the water in the slurry must be evaporated before clinkering. For the clinkering operation, the dry-process kilns equipped with multi-stage suspension preheaters, which permit efficient heat exchange between hot gages and the raw-mix.

dry process

Modern cement plants favour this process which is more energy efficient than the wet process because the water in the slurry must be evaporated before clinkering.

For the clinkering operation, it requires a fossil-fuel energy input on the order of 800 kcal/kg of clinker compared to about 1400 kcal/kg for the wet-process kilns.

The chemical reaction taking place in the cement kiln may be expressed as follows:

Limestone $\longrightarrow$ $CaO + CO_2$

Clay $\longrightarrow$ $SiO_2 + Al_2O_3 + Fe_2O_3$

Clay + Limestone $\longrightarrow$

$3CaO.SiO2$

$2CaO.SiO2$

$3CaO.Al_2O_3$

$3CaO.Al_2O_3.Fe_2O_3$

Physical properties of Portland cement

(i) fineness

(ii) specific gravity

(iii) soundness

(iv) standard consistence, (v) setting time,

(vi) compressive strength,

(vii) heat of hydration and (viii) loss of ignition.

Fineness of cement

- Affects the rate of hydration.
- Greater fineness increases the surface available for hydration, causing greater early strength and more rapid generation of heat.
- The Wagner Turbidimeter and the Blaine air permeability test for measuring cement fineness are both required by ASTM and AASHTO.
- Ranges from 3,000 to 5,000 cm^2/g (300 to 500 m^2/kg).

Specific gravity

Specific gravity is not an indication of the quality of the cement, but is required for concrete mix design calculations. The specific gravity of Portland cement is approximately 3.15

Soundness

- Soundness refers to the ability of the cement paste to retain its volume after setting, and is related to the presence of excessive amounts of free lime or magnesia in the cement.
- Expansion in OPC is limited to 10 mm or 0.5%.
- This change in volume is known as unsoundness and may cause cracks, distortion and disintegration of concrete

Standard consistence

- Consistence indicates the degree of density or stiffness of cement. Therefore, it is necessary to determine the amount of water content for a given cement to get a mixture of required consistency.

- Consistency of cement is measured by vicat apparatus. The paste is said to be of standard consistency, when the penetration of plunger, attached to Vicat apparatus, is 33-35 mm.

- The water content of the standard paste is expressed as a percentage by weight of the dry cement. The usual range is between 26-33%.

Setting Time

- A change from a fluid to a rigid state
- Initial setting of cement is that stage in the process of hardening, after which any cracks that may appear do not reunite.
- Final setting is that when it has occurred, sufficient strength and hardness is attained.
-
- The setting process is accompanied by temperature changes in the cement paste
- Setting time decreases with rise in temperature. Setting time of cement can be increased by adding some admixture, as sodium carbonate. The setting time of cement is measured using vicat apparatus with different penetrating attachments.

Compressive Strength

The compressive strength of cement is one of the most important mechanical properties.

Variation in cement properties

- Composition of clinker minerals
- Microstructure of clinker minerals
- Amount and form of calcium sulphate
- Amount and form of alkalies
- Material temperature
- Particle size gradation (fineness)
- Particle shape