CEMENT

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History Of Cement

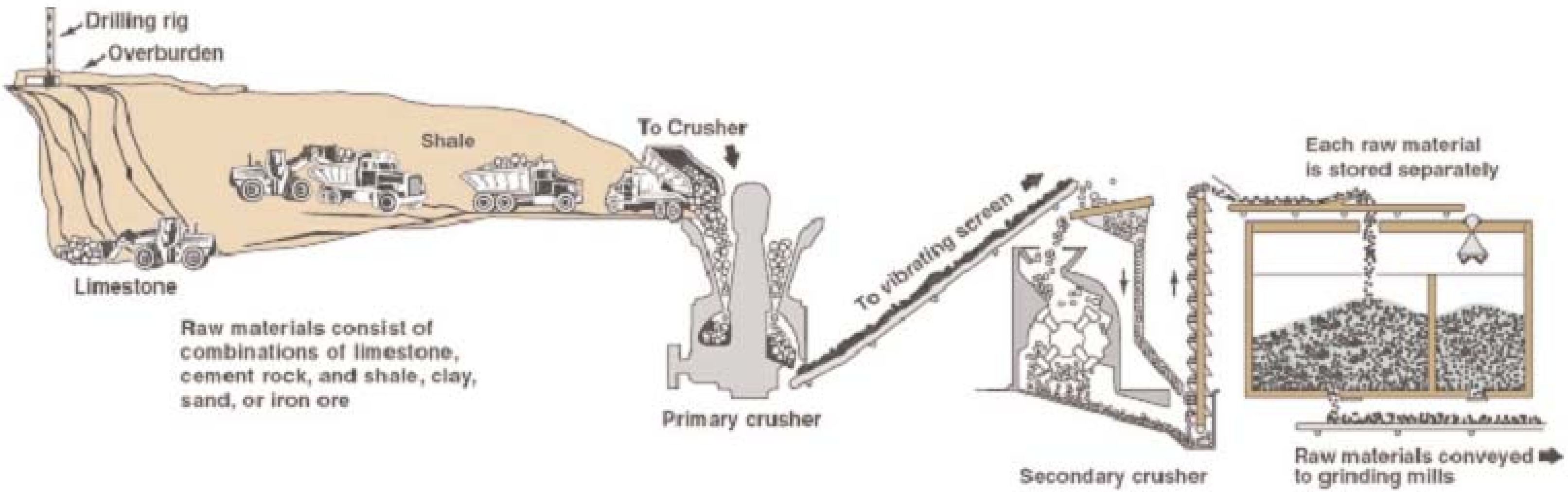
- ✓ The invention of Portland Cement is generally credited to Joseph Aspedin, an English Bricklayer in 1824. The Portland name was given because its color resembled the stone quarried on the **Isle of Portland** off the British coast.

- ✓ In Germany and Belgium cement manufacturing started around 1855

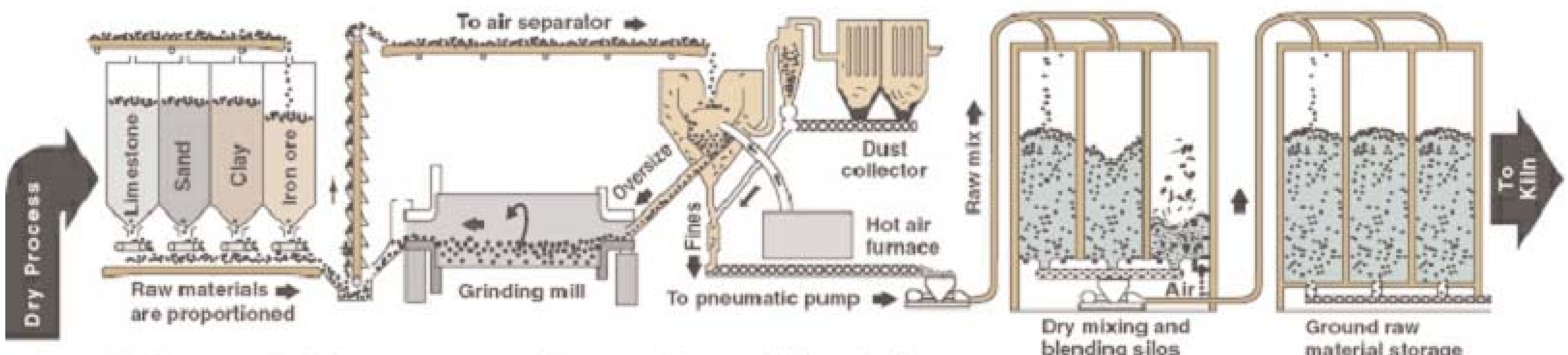
- ✓ In US manufacturing of cement started around 1870's

- ✓ Manufacturing of cement in India started in 1904 in Tamil Nadu but was fully established only by 1912. Till then for many years we were importing cement from England.

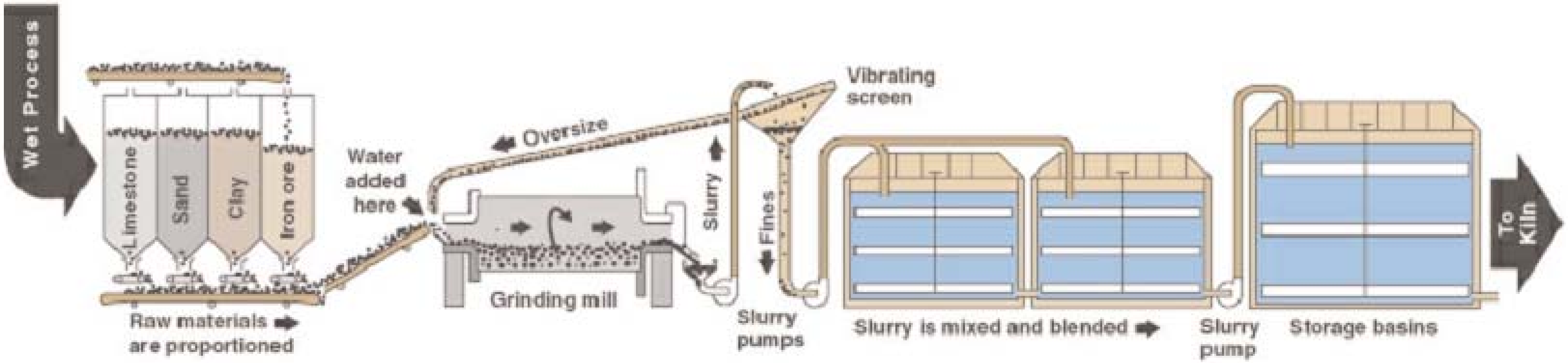
Cement – process of manufacture



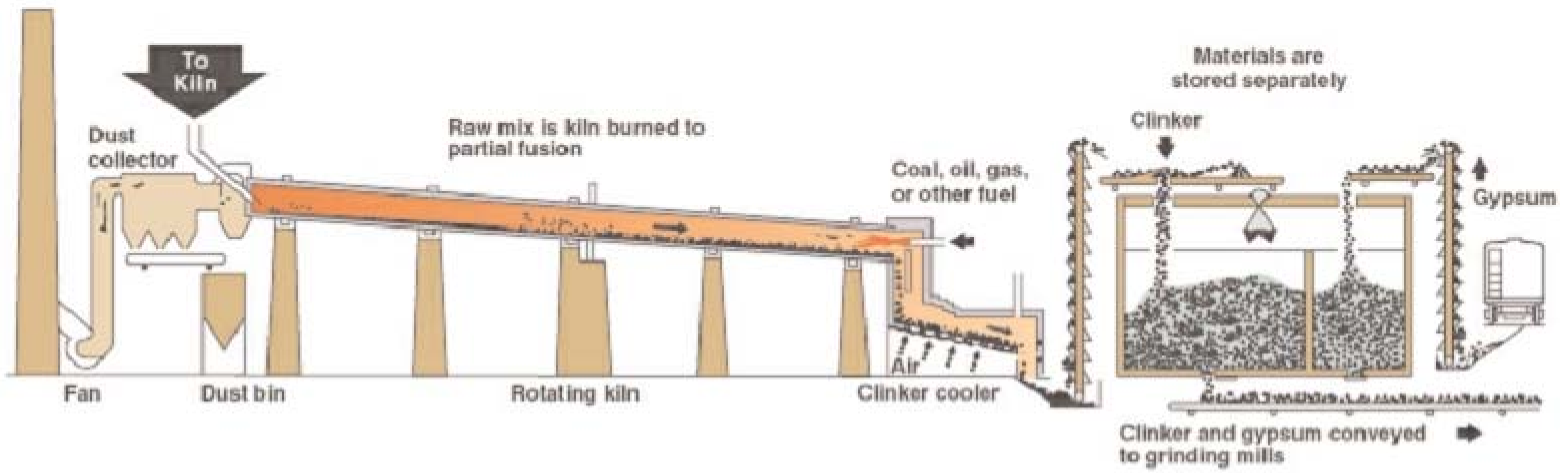
1. Stone is first reduced to 125 mm (5 in.) size, then to 20 mm (¾ in.), and stored.



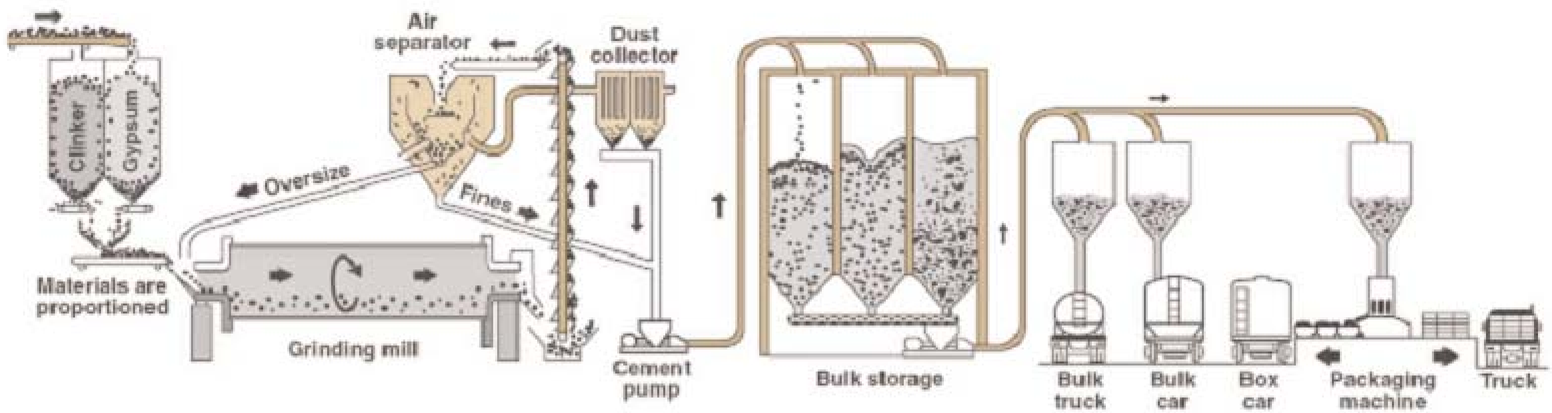
OR 2. Raw materials are ground to powder and blended.



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

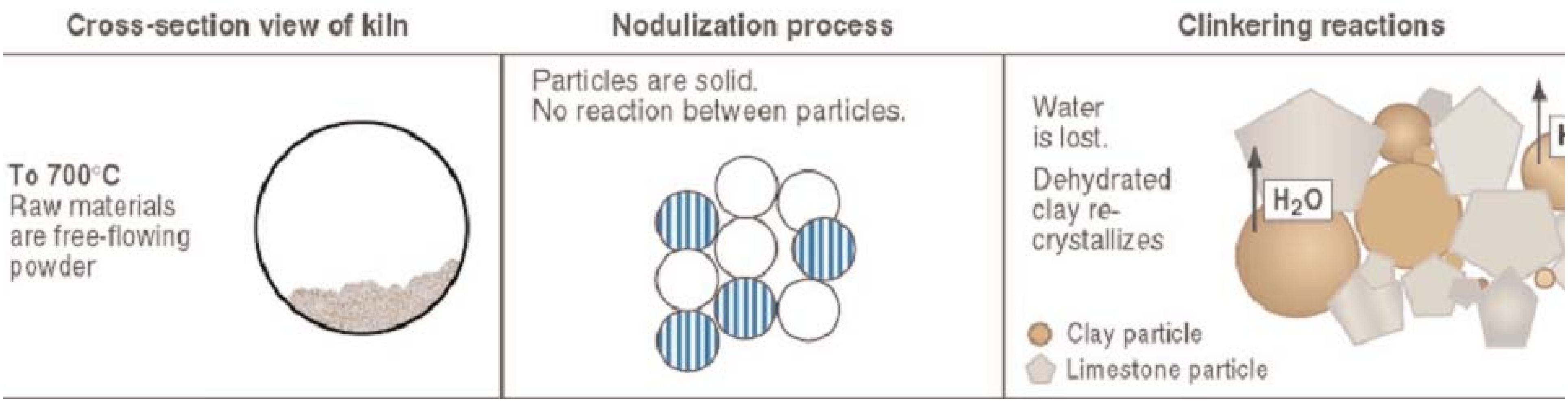


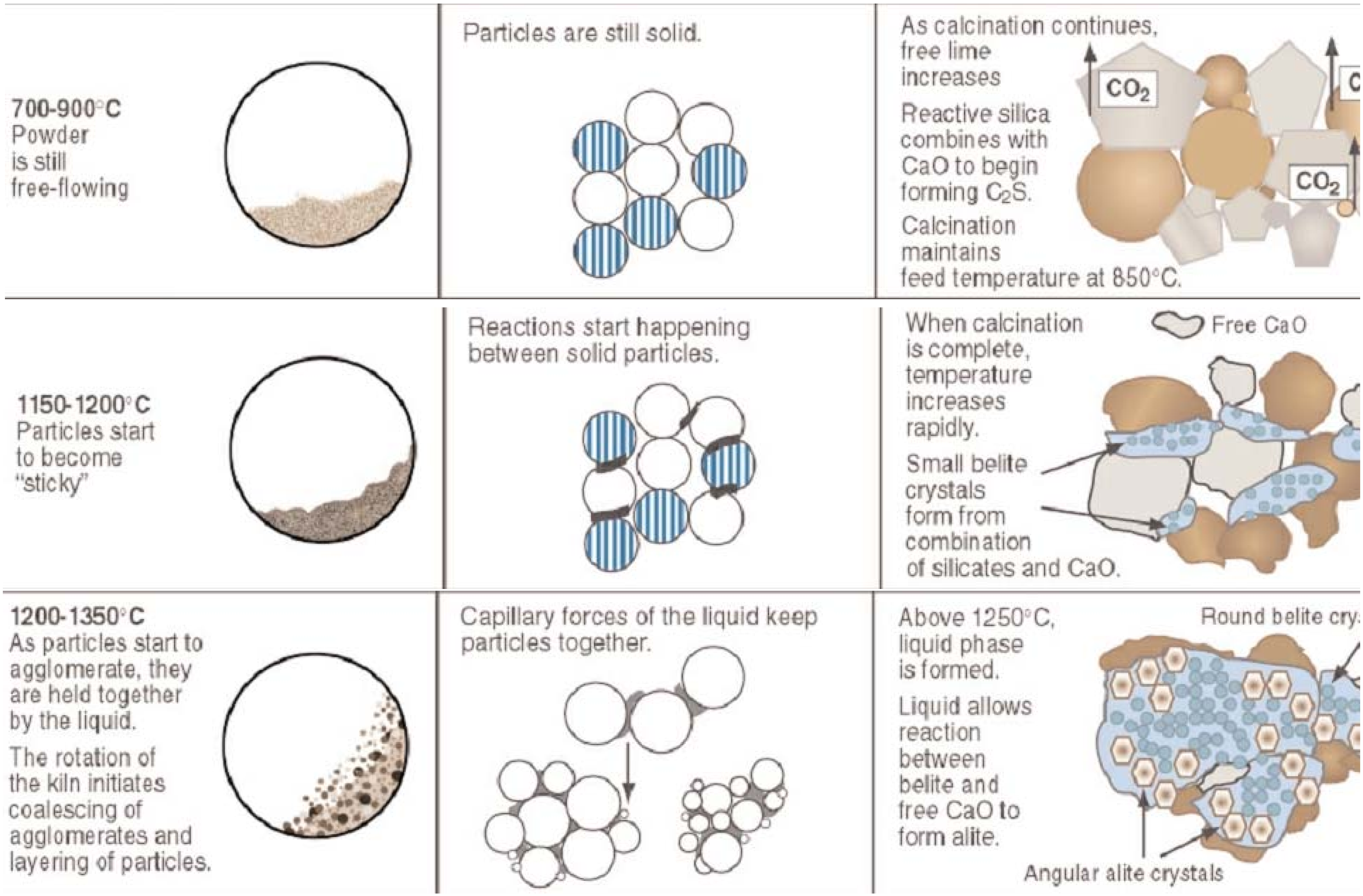
3. Burning changes raw mix chemically into cement clinker.

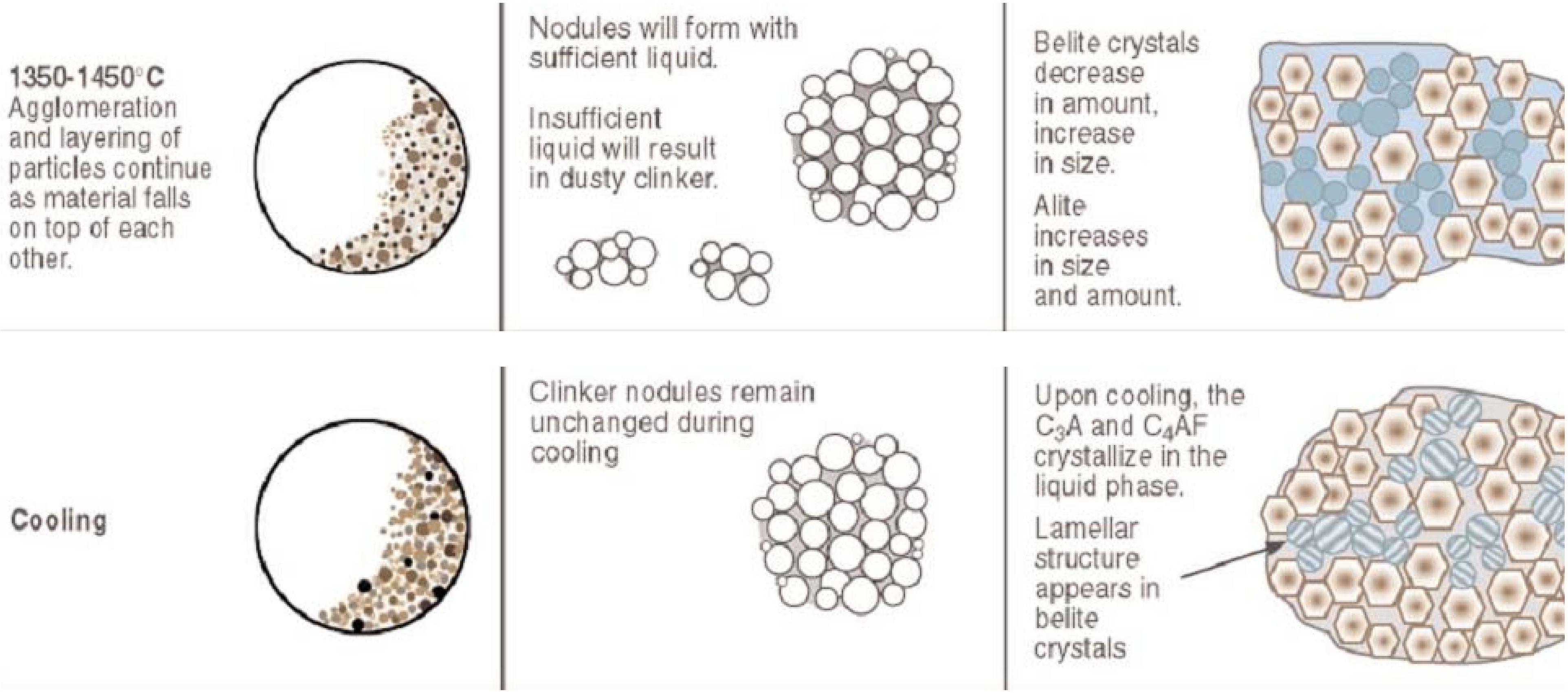


4. Clinker with gypsum is ground into portland cement and shipped.

Fig. 2-9. Portland cement clinker is formed by burning calcium and siliceous raw materials in a kiln. This particular clinker is about 20 mm (¾ in.) in diameter. (60504)




700-900°C
Powder
is still
free-flowing
Particles are still solid.
As calcination continues,
free lime
increases
CO_2
CO_2
Reactive silica
combines with
CaO to begin
forming C_2S.
Calcination
maintains
feed temperature at 850°C.
1150-1200°C
Particles start
to become
"sticky"
Reactions start happening
between solid particles.
When calcination
is complete,
temperature
increases
rapidly.
Free CaO
Small belite
crystals
form from
combination
of silicates and CaO.
1200-1350°C
As particles start to
agglomerate, they
are held together
by the liquid.
The rotation of
the kiln initiates
coalescing of
agglomerates and
layering of particles.
Capillary forces of the liquid keep
particles together.
Above 1250°C,
liquid phase
is formed.
Liquid allows
reaction
between
belite and
free CaO to
form alite.
Round belite cry
Angular alite crystals



1350-1450°C
Agglomeration and layering of particles continue as material falls on top of each other.
Nodules will form with sufficient liquid.
Insufficient liquid will result in dusty clinker.
Belite crystals decrease in amount, increase in size.
Alite increases in size and amount.
Cooling
Clinker nodules remain unchanged during cooling
Upon cooling, the C_3A and C_4AF crystallize in the liquid phase.
Lamellar structure appears in belite crystals

TriCalcium Silicate $3CaO.SiO_2$ ~ C_3S
DiCalcium Silicate $2CaO.SiO_2$ ~ C_2S
TriCalcium Aluminate $3CaO.Al_2O_3$ ~ C_3A
TetraCalcium Aluminoferrite $4CaO.Al_2O_3.Fe_2O_3$ ~ C_4AF

C_3S + C_2S constitute 65-75% by weight of cement and hydrate to form $Ca(OH)_2$ (~25%) and Calcium Silicate hydrate (~50%) (also called tobermorite gel).

C_3S ---- responsible for initial set and early strength
C_2S ---- increase in strength at ages beyond a week
C_3A ---- responsible for heat of hydration and also contributes slightly to early strength
Reducing C_3A increases sulfate resistance
C_4AF --- reduces clinkering temp. Hydrates rapidly but contributes very less to strength
responsible for coloring effects.

Type I ---- normal
Type II --- moderate sulfate resistant
Type III – high early strength
Type IV – low heat of hydration
Type V --- high sulfate resistant
Type I,II,III A --- air-entraining variety

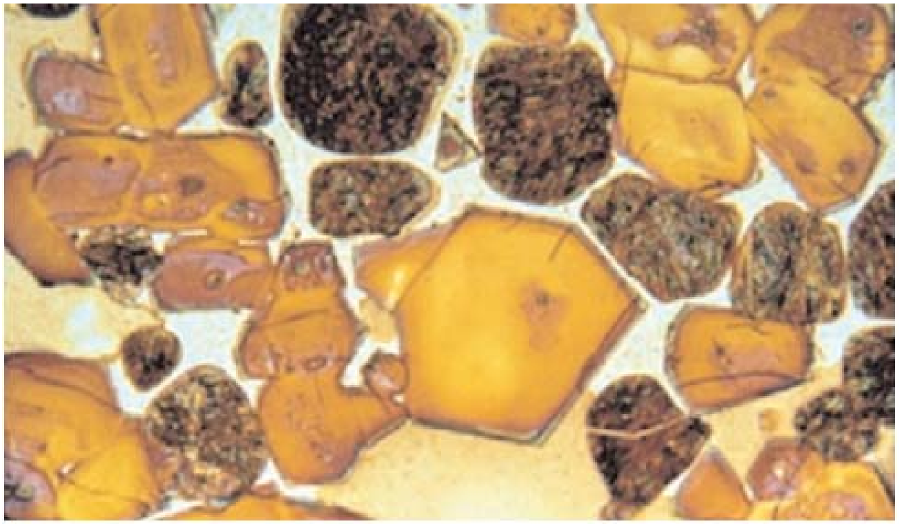
Type I ---- general use; where special properties are not required
Type II --- general use; moderate sulfate resistance and heat of hydration
Type III – when high strength required. Has similarity chemically with Type I but particles are ground finer. typical use cold or underwater structures
Type IV – when low heat of hydration is required, typical use massive structures
Type V --- when high sulfate resistance is required.

White cement --- original color, grey comes in due to iron and manganese oxide, used for architectural purpose, curtain walls, tile grout and so on.

Air-entraining materials --- improved resistance to freeze-thaw; scaling caused by chemicals applied for snow/ice removal

Types of Ordinary portland cement used in India (adopted from German Standards): grade 33, 43, 53

Fineness – greater cement fineness increases rate at which cement hydrates and accelerates strength development typically during the first week.
Soundness – ability of the hardened paste to retain volume after set. (free lime and magnesia responsible for lack of soundness). More sound less shrinkage.
Consistency – ability to flow. Depends on water-cement ratio.
Setting time – affected by gypsum content, cement fineness, w/c ratio, admixtures
Compressive strength – measured by 2 inch mortar cube. Compound composition and fineness of cement affects it.
Heat of hydration – heat generated when cement and water react. Increase in w/c ratio, fineness of cement, curing temp increases heat of hydration.
Specific gravity --- 3.15



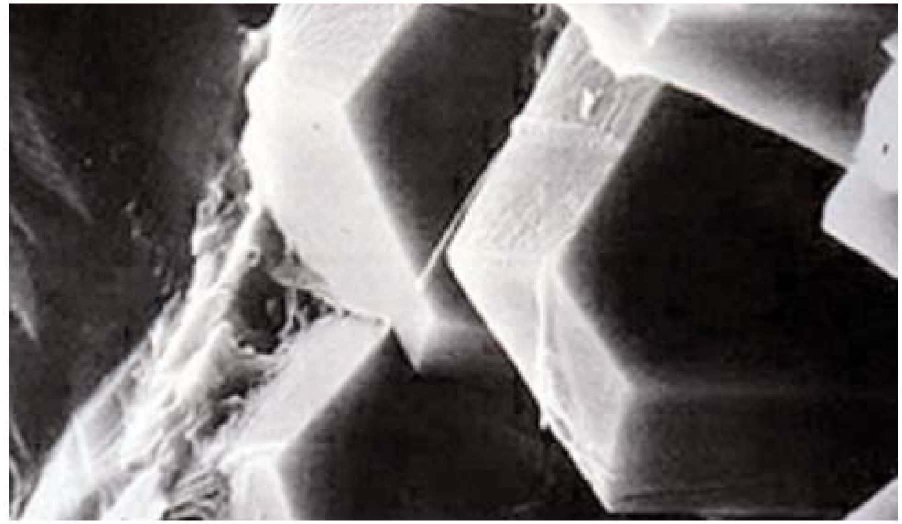


Fig. 2-25. (left) Polished thin-section examination of portland clinker shows alite (C_3S) as light, angular crystals. The darker, rounded crystals are belite (C_2S). Magnification 400X. (right) Scanning electron microscope (SEM) micrograph of alite (C_3S) crystals in portland clinker. Magnification 3000X. (54049, 54068)

Blaine's air permeability test

Wagner's turbidimeter

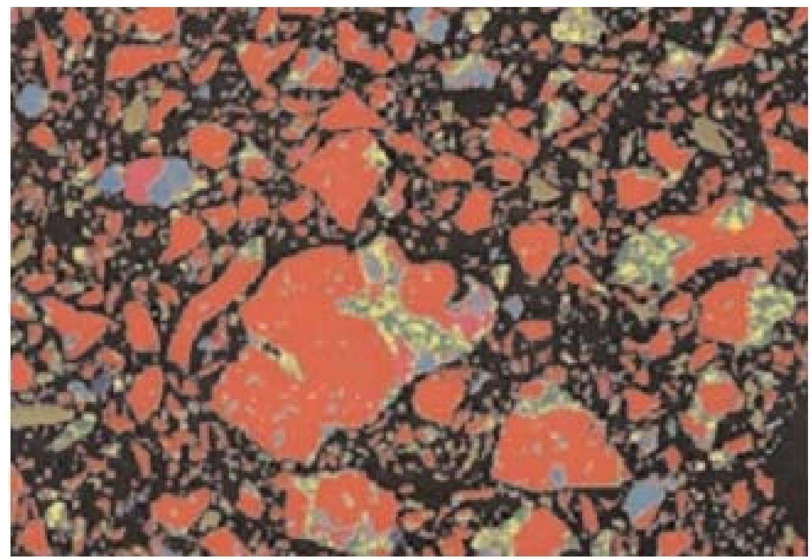


Fig. 2-51. Two-dimensional image of portland cement. Colors are: red–tricalcium silicate, aqua–dicalcium silicate, green–tricalcium aluminate, yellow–tetracalcium aluminoferrite, pale green–gypsum, white–free lime, dark blue–potassium sulfate, and magenta–periclase. The image was obtained by combining a set of SEM backscattered electron and X-ray images (NIST 2001).

Fineness measurement of cement
(sq. cm per kg. of cement)

Fig. 2-35. In the soundness test, 25-mm square bars are exposed to high temperature and pressure in the autoclave to determine the volume stability of the cement paste. (23894)

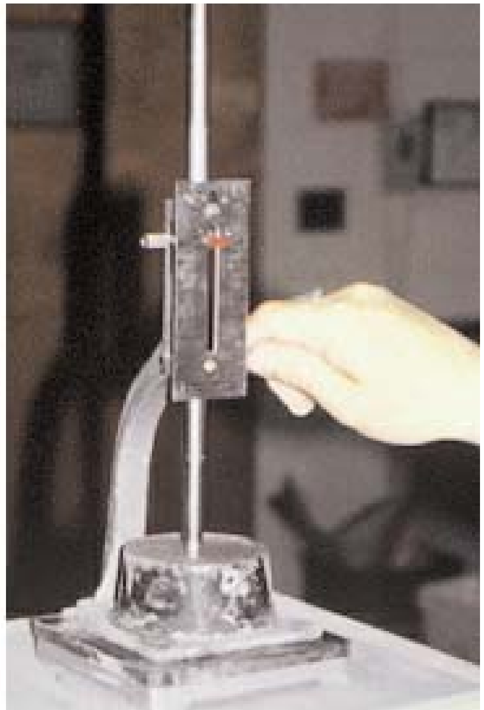


Fig. 2-36. Normal consistency test for paste using the Vicat plunger. (68820)

Fig. 2-37. Consistency test for mortar using the flow table. The mortar is placed in a small brass mold centered on the table (inset). For skin safety the technician wears protective gloves while handling the mortar. After the mold is removed and the table undergoes a succession of drops, the diameter of the pat is measured to determine consistency. (68821, 68822)

Conduction calorimeter – Heat of hydration

Materials to supplement cement

Fig. 3-1. Supplementary cementitious materials. From left to right, fly ash (Class C), metakaolin (calcined clay), silica fume, fly ash (Class F), slag, and calcined shale. (69794)

Pozzolan :- Sliciceous or aluminosiliceous material that in finely divided form and presence of moisture, chemically reacts with calcium hydroxide released by hydration of portland cement to form calcium silicate hydrate and other cementitious material

Contributes to the properties of hardened concrete through hydraulic or pozzolanic activity or both

Fly Ash

Byproduct of combustion of pulverized coal in electric power generating plants

During combustion, coal's mineral impurities (clay, feldspar, quartz, shale) fuse in suspension and are carried away from combustion chamber by exhaust gas. The fused Materials cool and solidifies into spherical glassy particles.

1.9-2.8

Silica, alumina, iron, calcium

Granulated blast-furnace slag

Non-metallic hydraulic cement consisting essentially of silicates and aluminosilicates of calcium developed in a molten condition simultaneously with iron in blast-furnace. Molten slag rapidly chilled by quenching in water → glassy sandlike granulated material

Silica Fume

Byproduct obtained as a result of reduction of high purity quartz with coal in an electric-arc furnace in the manufacture of silicon or ferro-silicon alloy

Types Of Cement (commercially available)

- Hydraulic
  - Portland Cement
  - Portland Cement Blends
  - Non-Portland hydraulic cements
- Non -Hydraulic

→ Classification by BIS (Bureau Of Indian Standards)

Portland Cement

- Grey
- White

Portland Cement Blends

- Portland blast furnace cement
- Portland fly ash cement
- Portland pozzolan cement
- Portland Silica Fume cement
- Masonry Cement

Non-Portland hydraulic cements

- Slag-lime cements
- Super sulfated cements
- Calcium sulfoaluminate cements

According to BIS :

1. IS 269 33 Grade Ordinary Portland cement
2. IS 455 Portland Slag cement
3. IS 1489 Portland pozzolana cement - Part 1 Fly Ash based and Part 2 Calcined Clay based .
4. IS 3466 Masonry cement.
5. IS 6452 High alumina cement for structural use.
6. IS 6909 Super sulphated cement.
7. IS 8041 Rapid hardening Portland cement .
8. IS 8042 White Portland Cement.
9. IS 8043 Hydrophobic Portland Cement.
10. IS 8112 43 Grade Ordinary Portland cement.
11. IS 8229 Oil well cement
12. IS 12269 53 Grade Ordinary Portland cement
13. IS 12330 Sulphate resisting Portland cement
14. IS 12600 Low heat Portland Cement

HYDRAULIC CEMENT :

- These cements are most commonly used nowadays.

- Hydraulic cements are materials which set and harden after combining with water, as a result of chemical reactions with the mixing water and, after hardening, retain strength and stability even under water.

NON HYDRAULIC CEMENT:

- Includes lime and gypsum plaster that must be kept dry in order to gain strength.

- Gain strength very slowly by absorption of carbon dioxide from the atmosphere to re-form calcium carbonate.

Portland Cement

- Portland cement is the most common type of cement as it is a basic ingredient of concrete, mortar and most non-specialty grout.
- It is a fine, grey or white powder that is made by grinding Portland cement clinker, a limited amount of calcium sulfate which controls the set time, with other minor constituents
- A hydraulic cement composed primarily of hydraulic calcium silicates
- The most common use for Portland cement is in the production of concrete.

White Cement

- White Portland cement or white ordinary Portland cement (WOPC) is similar to ordinary, gray Portland cement in all respects except for its high degree of whiteness.

- The color of white cement depends on raw materials and the manufacturing process. It is the metal oxides (primarily iron and manganese) that influence the whiteness and undertone of the material.

- White cements produce clean, bright colors, especially for light pastels. Many different colors can be created by adding pigments to concrete made with white cement.

Portland Cement Blends

PORTLAND BLAST FURNACE CEMENT

Contains up to 70% ground granulated blast furnace slag, with the rest Portland clinker and a little gypsum.

All compositions produce high ultimate strength. It is used as an economic alternative Portland sulfate-resisting and low-heat cements.

PORTLAND FLYASH CEMENT

Contains up to 30% fly ash so that ultimate strength is maintained. Concrete water content, early strength this can be an economic alternative to ordinary Portland cement.

PORTLAND POZZOLAN CEMENT

Includes fly ash cement also includes cements made from other natural or artificial pozzolans, since fly ash is a pozzolan, but also includes cements made from other natural or artificial pozzolans.

In countries where volcanic ashes are available (e.g. Italy, Chile, Mexico, the Philippines) these cements are often the most common form in use.

PORTLAND SILICA FUME CEMENT

Addition of silica fume can yield exceptionally high strengths, and cements containing 5-20% silica fume are occasionally produced. contradictory shows no increases in the strength of cement paste, but substantial increases in concrete strength, when silica fume is used.

MASONRY CEMENTS

Are used for preparing bricklaying mortars, and must not be used in concrete. They are usually complex proprietary formulations containing Portland clinker and a number of other ingredients that may include limestone, hydrated lime, air entertainers, retarders, water proofers and coloring agents.

NON PORTLAND HYDRAULIC CEMENTS

SLAG-LIME CEMENTS : Ground granulated blast furnace slag is not hydraulic on its own, but is “activated” by addition of alkalis, most economically using lime. They are similar to pozzolan lime cements in their properties.

CALCIUM ALUMINATE CEMENTS

are hydraulic cements made primarily from limestone and bauxite. The active ingredients are monocalcium aluminate $CaAl_2O_4$ and Mayenite $Ca_{12}Al_{14}O_{33}$. Strength forms by hydration to calcium aluminate hydrates. They are well-adapted for use in refractory (high-temperature resistant concretes, e.g. for furnace linings.

SUPERSULFATED CEMENT

These contain about 80% ground granulated blast furnace slag, 15% gypsum or anhydrite and a little Portland clinker or lime as an activator. They produce strength by formation of ettringite (Hydrated Calcium Aluminum Sulfate Hydroxide.)