Engineering Chemistry

Part 1

Chapter 3 - Cement

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Chapter 3: Chemical industries and their environmental impacts

I- Petrochemical Industries

Plastics (DR Mohamed Magdy)

- ✓ Properties and classifications of plastics
- ✓ Thermoplastics and thermosetting
- ✓ Applications and uses
- ✓ Environmental impacts of plastic industry

II- Building materials

Cement

- ➢ Cement Manufacture Process
- ➢ Functions of Cement Constituents
- ➢ Roles of cement compounds:
- ➢ Chemical reactions
- ➢ Environmental impacts of cement industry

Summary of the chapter

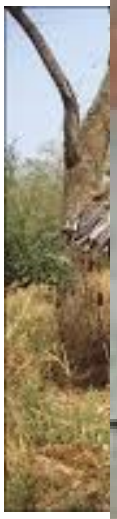
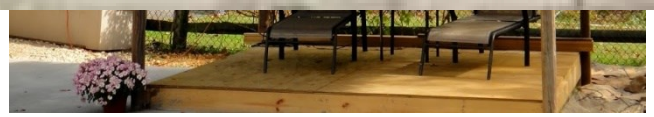
Learning Objectives of Chapter 3

By the end of chapter 3, students will be able to:

1. Understand the importance of chemical industries.
2. Describe the different types of plastics and their uses.
3. Know impacts of plastic production on the environment.
4. Differentiate between the various types of building materials.
5. Describe the manufacturing process of cement.
6. Demonstrate how the constituents and compounds of cement can affect its strength.
7. Understand the pollutions arise from cement industries and the suitable solution for each.

Building materials

- **Building material:** any material which is used in any construction purpose.
- Natural materials: clay, sand, wood, thatch, rocks, twigs and leaves.
- Synthetic: cement, ceramics, plastics, glass, foam, fabric.
- Green materials: produced to protect the environment from greenhouses gases that released from the commercial concrete materials and contributing to climate change.

Building materials - Cement

- **Cement** is a basic material for building and constructions.
- Pozzolanic activity: its binding ability upon mixing with water.
- Pozzolanic activity of **lime** was developed by Romans, and from then, lime mortars and concretes continued to be used.
- In 1824, **Joseph Aspdin** - England, produced a powder made from the calcined mixture of limestone and clay called "**Portland Cement**".
- “Portland” came because the similarity between its hardened and the stones near Portland Island in UK.

Manufacture of Cement

Manufacture of Cement

Raw materials: limestone ($CaCO_3$) – clay (silica) - alumina.

- Sometimes sands and iron were added for improvement.

Manufacture Process includes (three main stages):

(0) Transporting crushed limestone from the quarries to the factory.

(1) Mixing and crushing of raw materials:

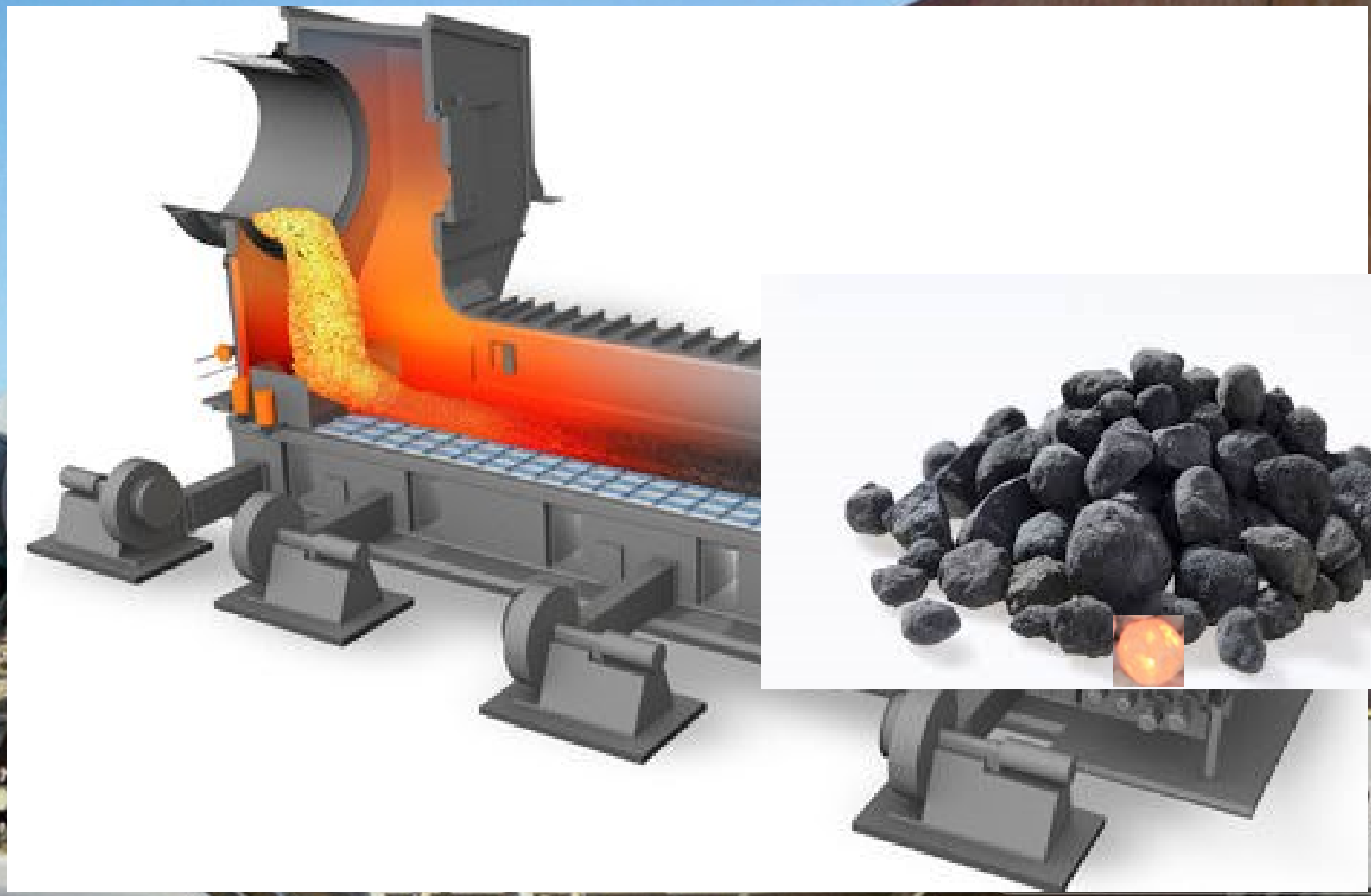
a) Dry process: when raw materials are very strong and hard

b) Wet process: when raw materials are soft

(2) Burning:

(3) Grinding:

(4) Storing and packing the fine ground cement.



Manufacture of Cement

Manufacture Process includes:

(2) Burning: in rotary kilns up to 1500-1650 ^{o}C ⟶ small black lumps called clinkers.

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

(3) Grinding: of clinkers after cooling down to atmospheric temp. It is done in large tube mills.

Then, proper amount of gypsum ($CaSO_4$) in the ratio of 1-4 % is added in order to **control the setting time of cement.**

Manufacture of Cement

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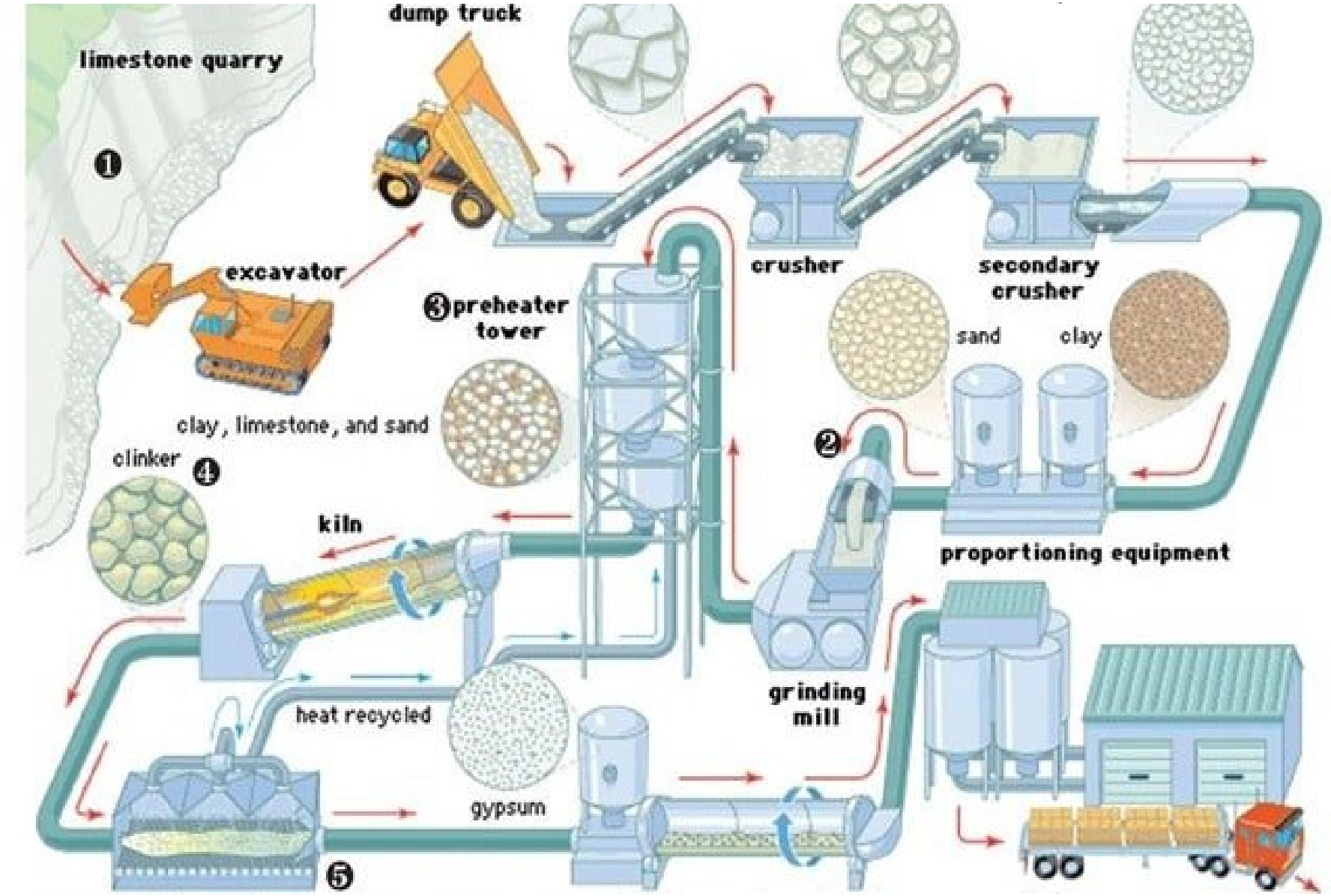


Chemistry of Cement

- **Cement** is a finely ground powder consisting of a mixture of inorganic oxides. Its chemical composition are as follow:

Material	Formula	Abbreviation	% by mass
Lime	CaO	C	60-65
Silica	SiO_2	S	19-25
Alumina	Al_2O_3	A	3-8
Iron oxide	Fe_2O_3	F	1-5
Magnesium oxide	MgO	M	0-5
Gypsum	$CaSO_4$	S	1 - 4

Functions of Cement Constituents

** Cement composed of mixture of oxides, what are their roles??

Lime, CaO: (2/3) of the cement, more than this causes the cement to expand and disintegrate.

Silica (SiO_2): (1/4) of the cement, more than this causes the cement to set slowly.

They form di-calcium silicate (C_2S) and tri-calcium silicate (C_3S) in the manufacturing of cement and they responsible for cement strength.

Alumina (Al_2O_3): 3-8 %, more than this reduces the strength of the cement.

It imparts a quick setting for cement and it also lowers the clinkering temperature.

Fe_2O_3, MgO: they give color to cement, and responsible for hardness, and reduce heat of burning of raw materials .

***Gypsum ($CaSO_4$)*:** It is added at the final stage of manufacturing to slowdown the setting of cement.

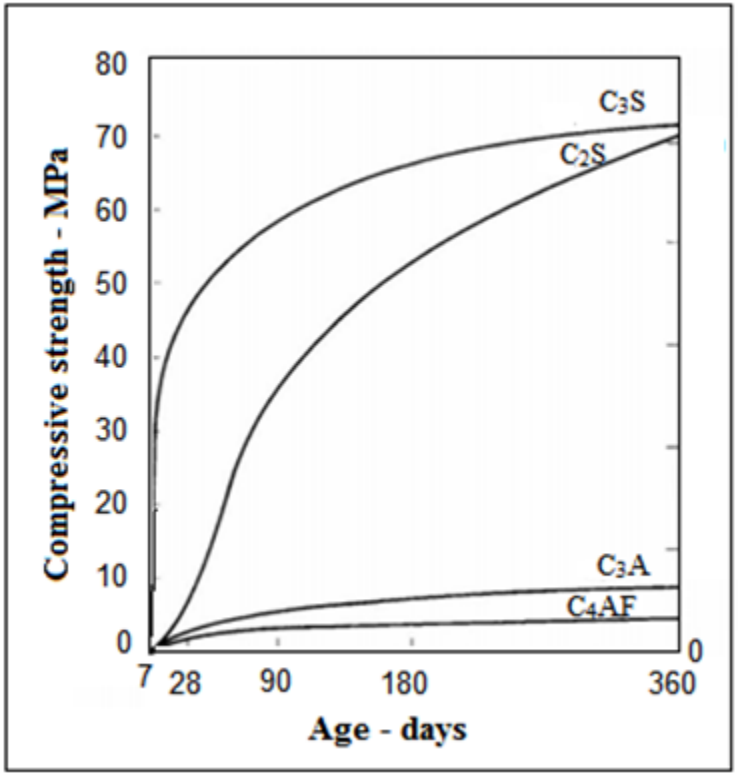
Functions of Cement compounds

Oxides of cement are combined together to form cement compounds: C2S, C3S, C3A, C4AF. Through mixing them with water:

C3S: hydrates and hardens rapidly, responsible for the initial set of cement and its early strength.

C2S: hydrates and hardens slowly, responsible for increasing strength within 7 days

C3A: it hydrates and hardens quickly liberating a large amount of heat and contributes to early strength (1-3days).



C4AF: it hydrates rapidly but contributes very little to strength

Chemical reactions during the cement hydration:

- When cement is mixed with water, it forms a paste that sets and hardens through a chemical reaction called “hydration”.
- This reaction is responsible in producing of a very hard and strong binding medium for the aggregate particles.
- Upon hydration, cement compounds reacts with water liberating heat and producing calcium hydroxide and calcium silicate hydrates as shown in the following chemical equation:

$$2(3CaO.SiO_2) + 6H_2O \rightarrow 3Ca(OH)_2 + 3CaO.2SiO_2.3H_2O + \text{heat}$$

(calcium silicate hydrate)

$$2(2CaO.SiO_2) + 4H_2O \rightarrow Ca(OH)_2 + 3CaO.2SiO_2.3H_2O + \text{heat}$$

These reactions can be abbreviated as:

$$2C_3S + 6H \rightarrow C_3S_2H_3 + 3Ca(OH)_2 + \text{heat}$$

$$2C_2S + 4H \rightarrow C_3S_2H_3 + Ca(OH)_2 + \text{heat}$$

Environmental impacts of cement industry

- ***Emissions to air:***

- ***Emissions to water:***

Cement industry does not produce fluids. Thus, no emissions to water occur because water is recycled back into the process.

- ***Noise emissions:***

Environmental impacts of cement industry

- ***Emissions to air:*** 5–7% of the total CO_2 emission

  Directly (during heating of limestone) and

  Indirectly (during burning of fossil fuels to heat the kiln).

Other emissions such as NO_x - SO_2 - volatile organic compounds Hydrogen fluoride (HF) - Hydrogen chloride (HCl) - CO.

Ways to reduce these emission,

1- By replacing fossil fuels used in kiln by natural gas.

2- By Capturing CO_2 emissions through:

- "carbon capture and storage" (CCS) units.
- accelerated carbonation method (passing CO_2 through $Ca(OH)_2$ solution to form $CaCO_3$).

Environmental impacts of cement industry

- ***Noise emissions:***

➢ throughout the whole cement manufacturing process such as:

Raw materials preparing and transporting process -burning the clinker storage - the dispatch and shipping of the final products.

➢ Using heavy machinery during cement manufacturing process such as: Chutes, hoppers, exhaust fans, or blowers

➢ Operations involving fracture, crushing, milling and screening of raw material, clinker and cement

To reduce Noise emissions:

Natural noise barriers, such as office buildings, walls, or trees.

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cement

- **Definitions:** Building material & Types - Pozzolanic activity – Cement
- **Chemical composition of cement (its oxides and their %)**
- **Raw materials in cement & its manufacture**
- **Functions of Cement Constituents Or Functions of Cement compounds**
- **Chemical reactions during the cement hydration**
- **Environmental impacts of cement industry**:

Emissions to air or (B) Noise emissions & Ways to reduce each .

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