Unit 19 · Cement

STUDY NOTES

WHAT NEB'S GRADE 12 EXAM ASKS

- **CDC's grid (2078):** Applied Chemistry (Units 18–21 together): 8 of 75 marks; 3 MCQs and 1 short question, no long one
- **The paper:** 11 MCQs × 1 · 8 short × 5 · 3 long × 8; 3 hours; 1 mark per expected point
- **CDC's model paper:** MCQ: gypsum ($CaSO_4 \cdot 2H_2O$) **retards setting**; short (a part): OPC and PPC compared
- **MCQ (1 mark)**
  - main raw material limestone; gypsum controls setting; fly ash or volcanic ash in PPC; OPC 43 for general work
  - PPC for dams (less heat); C_3S gives early strength; dry process uses less energy; lime at least 60% of OPC
- **Short (5 marks, in parts)**
  - define cement, its uses; raw materials; clinker; stages; a flow sheet; how cement sets; CaO from 1 t of $CaCO_3$ (0.56 t)
  - OPC vs PPC; dry vs wet; why gypsum, why no wet process now, why not OPC for dams, PPC by the sea
  - merits and demerits of OPC, PPC; challenges in Nepal; curing a slab with water

Key terms

Cement: fine gray powder made by heating limestone and clay and grinding the product; with water it **sets and hardens** and binds: the binder of mortar and concrete.

Mortar: cement + sand + water; **concrete**: + gravel; **RCC**: concrete with steel bars.

Raw meal: the ground, blended raw materials; **slurry**: the same ground with water (30–40%).

Calcination: $CaCO_3 \xrightarrow{800\text{-}900\ ^\circ C} CaO + CO_2$.

Clinker: small hard dark gray lumps from the kiln (about 1450 °C): the four calcium compounds; ground with gypsum to make cement.

Flash setting: C_3A reacting with water at once, stiffening in minutes; gypsum stops it.

Pozzolana: reactive silica (fly ash, volcanic ash): no set alone, reacts with $Ca(OH)_2$ to C–S–H.

Raw materials

Group	Materials	Brings
calcareous	**limestone**, chalk, marl	CaO (60–67% of cement; about 3/4 of the raw mix)
argillaceous	**clay**, shale, slate	SiO_2, Al_2O_3, Fe_2O_3 (20–30%)
corrective	iron ore, bauxite (0–2%)	adjust the oxides
alternative	fly ash, blast-furnace slag (5–10%; PPC 15–35%)	recycle waste, durability
setting regulator	**gypsum**, $CaSO_4 \cdot 2H_2O$ (3–5%)	added at the end, with the clinker

- MgO (0.1–4%) kept low: swells later, cracks concrete; Na_2O, K_2O (0.3–1.5%) lower the melting point but cause **efflorescence**

Making cement

1. **crushing and grinding** → raw meal
2. **blending**: CaO, SiO_2, Al_2O_3, Fe_2O_3 tested and corrected
3. **burning** in the **rotary kiln** (sloping, turning steel tube, fire-brick lining; 1400–1500 °C; countercurrent: meal down, hot gas up)
4. **cooling and final grinding** with 3–5% gypsum → bags

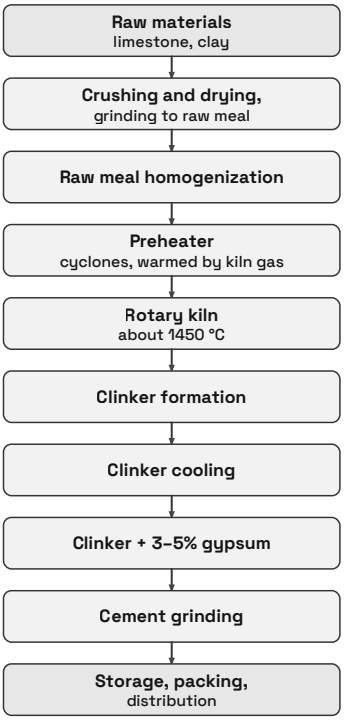
In the kiln (C = CaO, S = SiO_2, A = Al_2O_3, F = Fe_2O_3)

- $CaCO_3 \longrightarrow CaO + CO_2$ (1 t $CaCO_3$ → 0.56 t CaO)
- $2\,CaO + SiO_2 \longrightarrow Ca_2SiO_4$ (C_2S, belite)
- $3\,CaO + SiO_2 \longrightarrow Ca_3SiO_5$ (C_3S, alite)
- $3\,CaO + Al_2O_3 \longrightarrow Ca_3Al_2O_6$ (C_3A)
- $4\,CaO + Al_2O_3 + Fe_2O_3 \longrightarrow Ca_4Al_2Fe_2O_{10}$ (C_4AF)

Compound	Share (%)	Does
C_3S, $3CaO{\cdot}SiO_2$	45–60	**early** strength (hours, days)
C_2S, $2CaO{\cdot}SiO_2$	15–30	**later** strength (weeks, months)
C_3A, $3CaO{\cdot}Al_2O_3$	6–12	first stiffening, early heat (gypsum controls it)
C_4AF	6–10	gray color; lowers the melting point
gypsum	3–5	regulates setting

Setting and hardening: the compounds **hydrate** (a reaction, not drying; gives heat); needles and sheets of **C–S–H** bind the sand and gravel; keep it wet (curing), tested at 28 days

- $2\,Ca_3SiO_5 + 6\,H_2O \longrightarrow 3\,CaO \cdot 2\,SiO_2 \cdot 3\,H_2O + 3\,Ca(OH)_2$
- $2\,Ca_2SiO_4 + 4\,H_2O \longrightarrow 3\,CaO \cdot 2\,SiO_2 \cdot 3\,H_2O + Ca(OH)_2$



The dry process, from quarry to bags.

Dry process	Wet process
ground dry: raw meal	ground with water: slurry, 30–40% water
preheater cyclones (precalciner) use the kiln gas	slurry straight into the kiln
shorter kiln; about **half the fuel**	longer kiln: first part only boils off water
harder to blend (air blending, close control)	easy to blend evenly
almost every plant today	old, rare: too much fuel

- Portland cement: Joseph Aspdin, 1824, after Portland stone

OPC and PPC

	OPC	PPC
made of	clinker + gypsum	clinker + gypsum + **pozzolana** (fly ash 15–35%, volcanic ash)
early strength	**high** (grades 33, **43**, 53)	lower; equal or higher later; no grades
setting	faster	slower
heat of hydration	more (cracks mass concrete)	**less** (dams, foundations)
durability	less resistant to chemical attack	more: sulphate, chloride, sea; less permeable
workability	needs more water	better (fine round fly ash)
cost, energy	dearer, more clinker, more energy	cheaper, less clinker
environment	more CO_2	less CO_2; uses waste
use	high-rise, bridges, roads, precast	dams, foundations, marine, plaster, masonry

- pozzolana + $Ca(OH)_2$ + H_2O → C–S–H: the weak, soluble $Ca(OH)_2$ becomes binder

Nepal

- about 22 million t a year capacity (2024), 50+ companies, 65 plants (2023); about 8 million t used a year
- public: **Himal Cement**, Chobhar (first, closed 2002, dust); **Hetauda Cement** (1986, 750 t/day); **Udayapur Cement**, Jaljale (1992–93, 800 t/day, stopped 2026)
- private: Arghakhanchi, Sagarmatha, Maruti, Agni, Jagdamba, Hongshi-Shivam and many more
- **challenges**: power cuts, old machines, costly imported coal and clinker, licensing, export barriers (India's BIS), bad roads, **oversupply** and price wars, few skilled workers, dust, quarrying and CO_2, loans

COMMON MISTAKES

✗ gypsum speeds up setting
✓ **retards** it (stops flash setting).

✗ C_2S (Ca_2SiO_4) gives early strength
✓ **C_3S** early, C_2S later.

✗ cement hardens by drying
✓ by **hydration**: keep it wet.

✗ AlO_3, FeO_3
✓ **Al_2O_3**, **Fe_2O_3**.

✗ klin
✓ **kiln**.