Topic 2 Ingredients of concrete

A cement is a binder, a substance used for construction that sets, hardens, and adheres to other materials to bind them together. Cement is seldom used on its own, but rather to bind sand and gravel (aggregate) together.

Ordinary Portland Cement (OPC) Ordinary Portland cement is the most widely used type of cement, which is suitable for all general concrete construction.

Portland Pozzolana Cement (PPC)

Rapid Hardening Cement

Quick setting cement

Low Heat Cement

Sulfates Resisting Cement

Blast Furnace Slag Cement

High Alumina Cement.

Table 1: Approximate Oxide Composition Limits of Ordinary Portland Cement

S.No.	Oxide	Per cent content
1	CaO	60–67
2	SiO_2	17–25
3	Al_2O_3	3.0–8.0
4	Fe_2O_3	0.5–6.0
5	MgO	0.1–4.0
6	Alkalies (K_2O, Na_2O)	0.4–1.3
7	SO_3	1.3–3.0

Setting, hardening and curing

Cement starts to set when mixed with water, which causes a series of hydration chemical reactions. The constituents slowly hydrate and the mineral hydrates solidify and harden. The interlocking of the hydrates gives cement its strength.

proper curing requires maintaining the appropriate moisture content necessary for the hydration reactions during the setting and the hardening processes.

The concrete at young age must be protected against water evaporation due to direct insolation, elevated temperature, low relative humidity and wind.

Hydraulic cement

By far the most common type of cement is hydraulic cement, which hardens by hydration of the clinker minerals when water is added. Hydraulic cements (such as Portland cement) are made of a mixture of silicates and oxides, the four main mineral phases of the clinker, abbreviated in the cement chemist notation, being:

Table 2: Bogues Compounds

S.No.	Chemical Name	Chemical Formula	Notation	Percentage (%)
1	Tricalcium Silicate	$3CaO, SiO_2$	C_3S	30-50
2	Dicalcium Silicate	$2CaO, SiO_2$	C_2S	20-45
3	Tricalcium Aluminate	$3CaO, Al_2O_3$	C_3A	8-12
4	Tetra-calcium Alumino-ferrite	$4CaO, Al2O_3, Fe_2O_3$	C_4AF	6-10

The silicates are responsible for the cement's mechanical properties

The tricalcium aluminate and Tetra-calcium Alumino-ferrite are essential for the formation of the liquid phase during the sintering (firing) process.

Tricalcium silicate and dicalcium silicate are the most important compounds responsible for strength.

Calcium Silicate Hydrates

During the course of reaction of C3S and C2S with water, calcium silicate hydrate, abbreviated C-S-H and calcium hydroxide, Ca(OH)2 are formed. Calcium silicate hydrates are the most important products. It is the essence that determines the good properties of concrete. It makes up 50-60 per cent of the volume of solids in a completely hydrated cement paste.

Calcium silicate hydrate (also shown as C-S-H) is a result of the reaction between the silicate phases of Portland cement and water.

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

$$2C_3S + 6H \rightarrow C_3S_2H_3 + 3Ca(OH)_2$$

$$2\ (2\ CaO.SiO_2) + 4\ H_2O \rightarrow 3Cao.2\ SiO_2.\ 3H_2O + Ca(OH)_2$$

$$2\ C_2S + 4\ H \rightarrow C_3S_2H_3 + Ca\ (OH)_2$$

C-S-H can be prepared from the reaction of CaO and SiO_2 in water or through the double precipitation method using various salts.

The other products of hydration of C3S and C2S is calcium hydroxide. It constitutes 20 to 25 per cent of the volume of solids in the hydrated paste.

The calcium hydroxide also reacts with sulphates present in soils or water to form calcium sulphate which further reacts with C3A and cause deterioration of concrete. This is known as sulphate attack.

The only advantage is that Ca(OH)2, being alkaline in nature maintain pH value around 13 in the concrete which resists the corrosion of reinforcements.

Gel/Space Ratio

- Since concrete is a brittle material, its porosity primarily governs its strength. The compressive strength is found to be severely decreasing with increase in the porosity.
- The porosity of concrete which governs the strength of concrete is affected by the gel/space ratio in concrete.
- The gel/space ratio is the ratio of the solid products of hydration to the space available for these hydration products.
- A higher gel/space ratio reduces the porosity and therefore increases the strength of concrete.
- The gel/space ratio, which governs the porosity of concrete affecting its strength, is affected by the water/cement ratio of concrete.
- A higher water/cement ratio decreases the gel/space ratio increasing the porosity thereby decreases the strength of concrete.
- Power's experiment showed that the strength of concrete bears a specific relationship with the gel/space ratio.
- He found the relationship to be 240 X^3

where x is the gel/space ratio

240 represents the intrinsic strength of the gel in MPa for the type of cement and specimen used.

Calculation of gel/space ratio for complete hydration

$Gel/space\ ratio = volume\ of\ gel\ /\ Space\ Available = 0.657C\ /\ 0.319\ C + Wo$

Calculation of gel/space ratio for partial hydration

$Gel/Space\ ratio = volume\ of\ gel\ /\ Space\ Availabe = 0.657C\propto\ /\ 0.319\ C\propto + Wo.$