

PCA Since 1916
America's Cement Manufacturers™

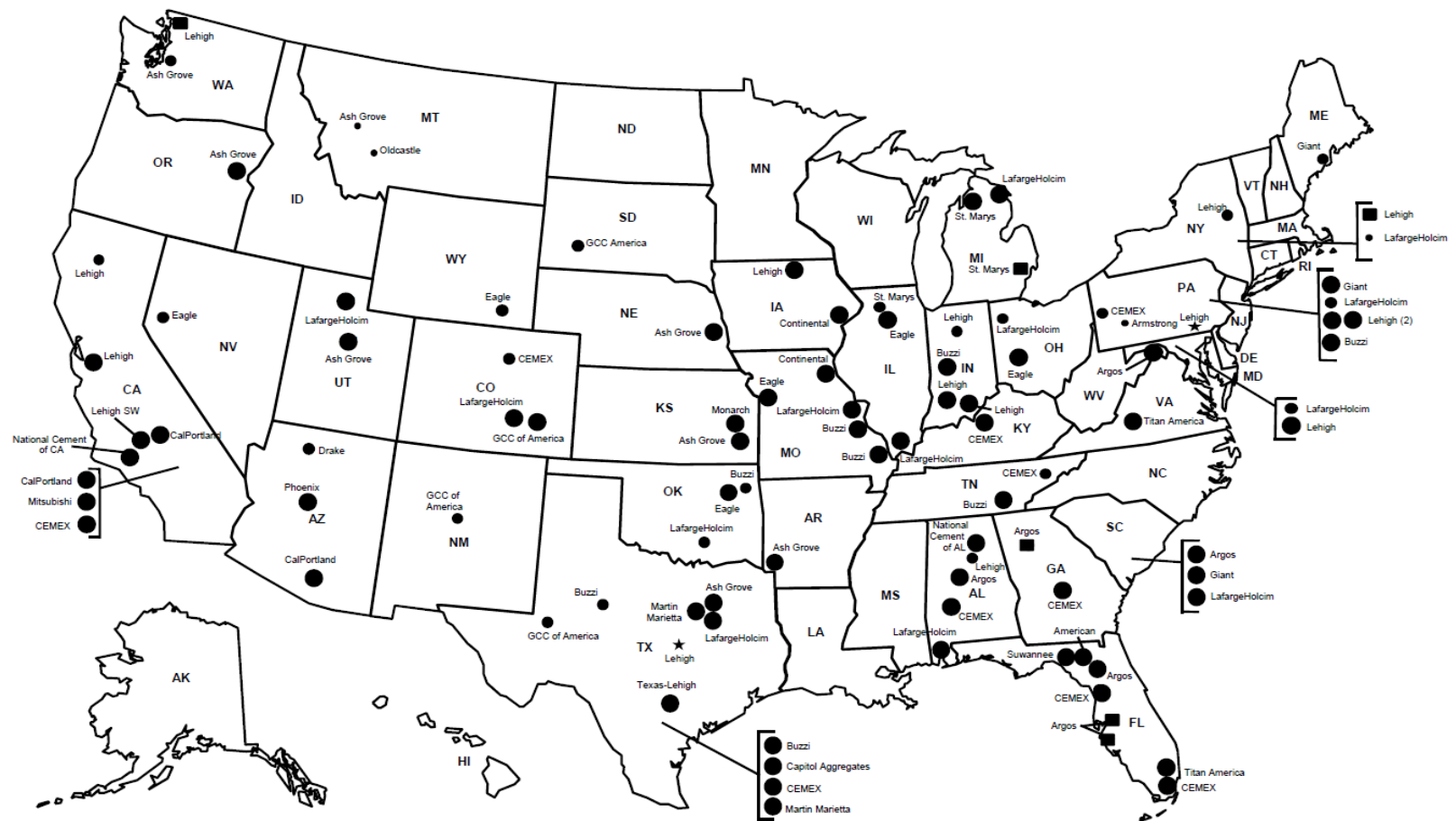
Portland Cement Association
Ordinary Portland Cement (OPC): Overview
Anything But Ordinary

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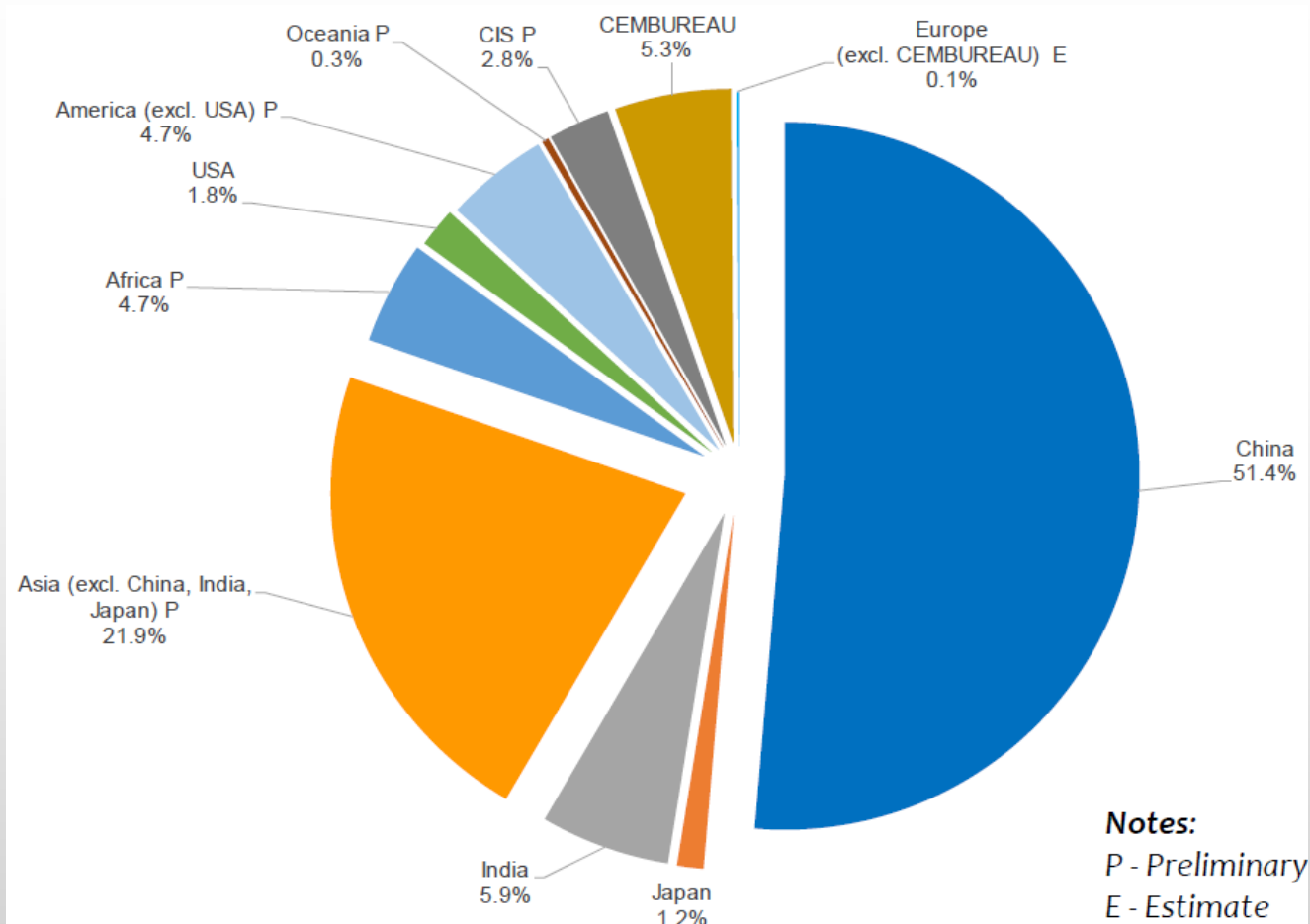
April 10, 2018 | Dallas

US Cement Industry

US Cement Plants



World Cement Production 2015



Concrete Proportions by Volume



Up to 8% Air

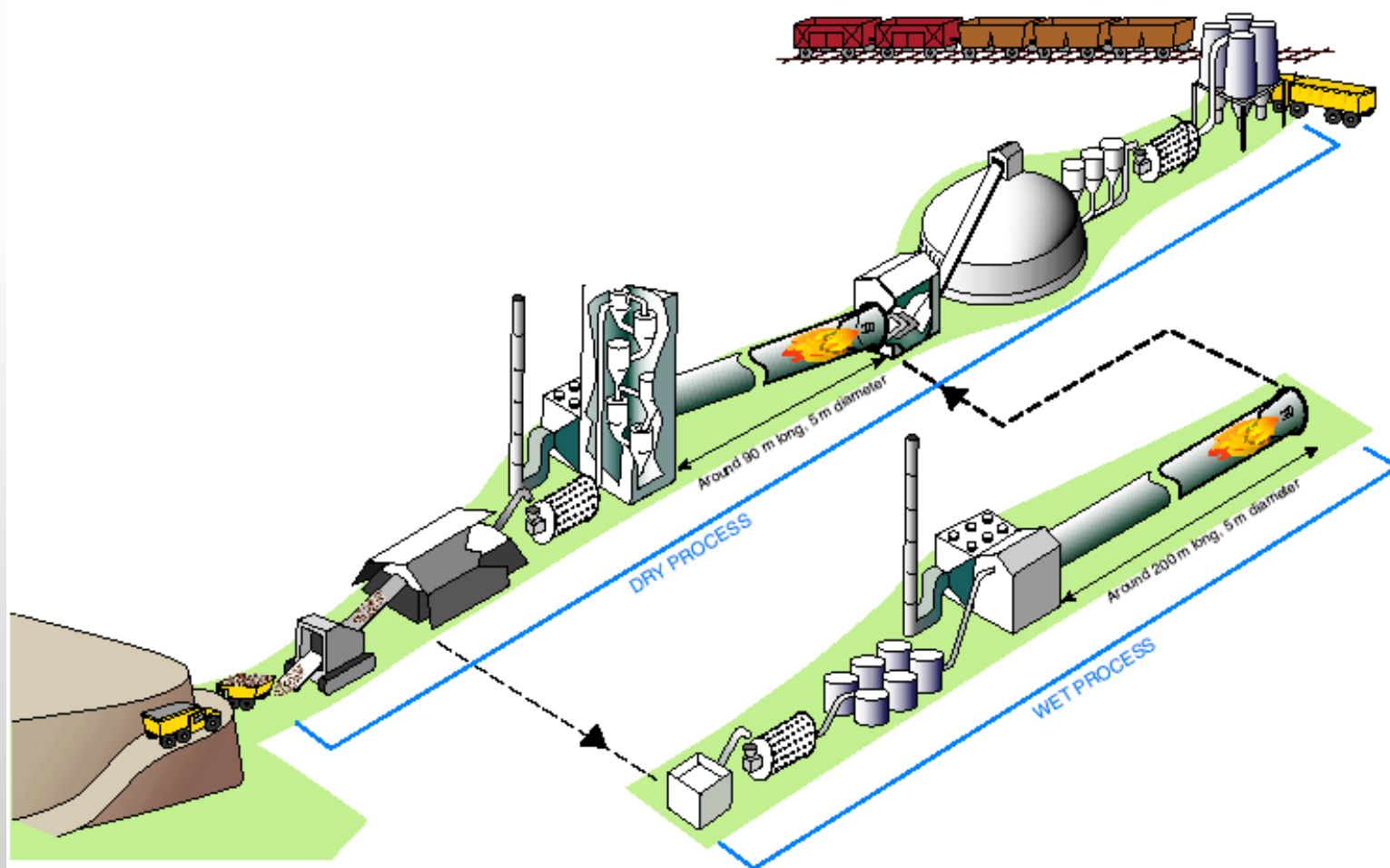
7-15% Cement

**60-75% Aggregates
(Coarse and Fine)**

14-21% Water

Hydraulic Cement Manufacture

Overview



Phase Composition

Chemical Name	Shorthand	Mass (%)
Tricalcium silicate (Alite)	C_3S	48 – 68
Dicalcium silicate (Belite)	C_2S	6 – 27
Tricalcium aluminate (Aluminate)	C_3A	0 – 12
Tetracalcium aluminoferrite (Ferrite)	C_4AF	4 – 13
Calcium sulfate dihydrate (gypsum)	$C\bar{S}H_2$	~ 5

Cement Types

Hydraulic Cements

- Portland
- Blended (or composite)
- Other

Portland Cements

- ASTM C150 (AASHTO M 85)
 - Type I
 - Type II
 - Type II(MH)
 - Type III
 - Type IV
 - Type V

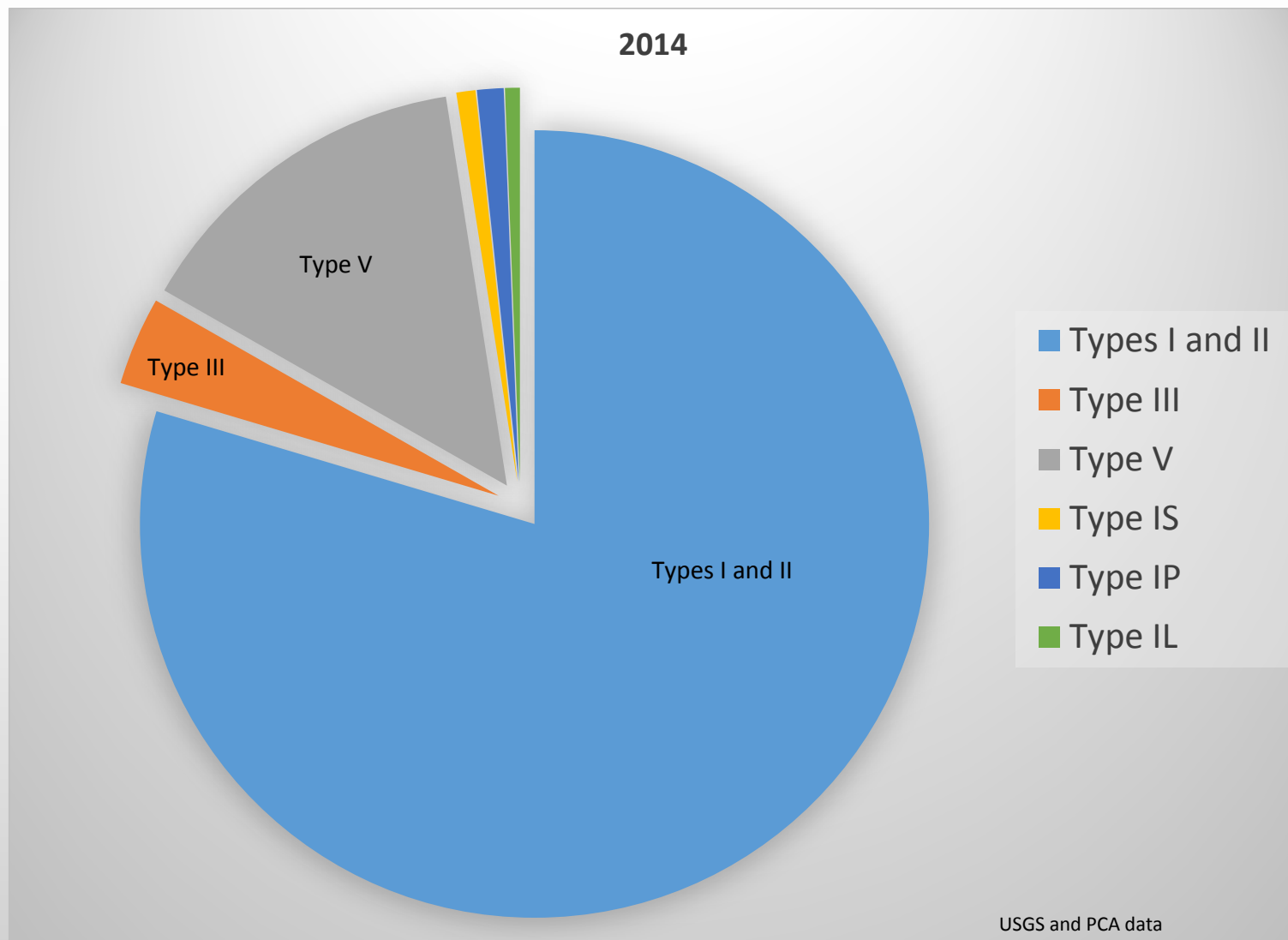


Blended Cement Types

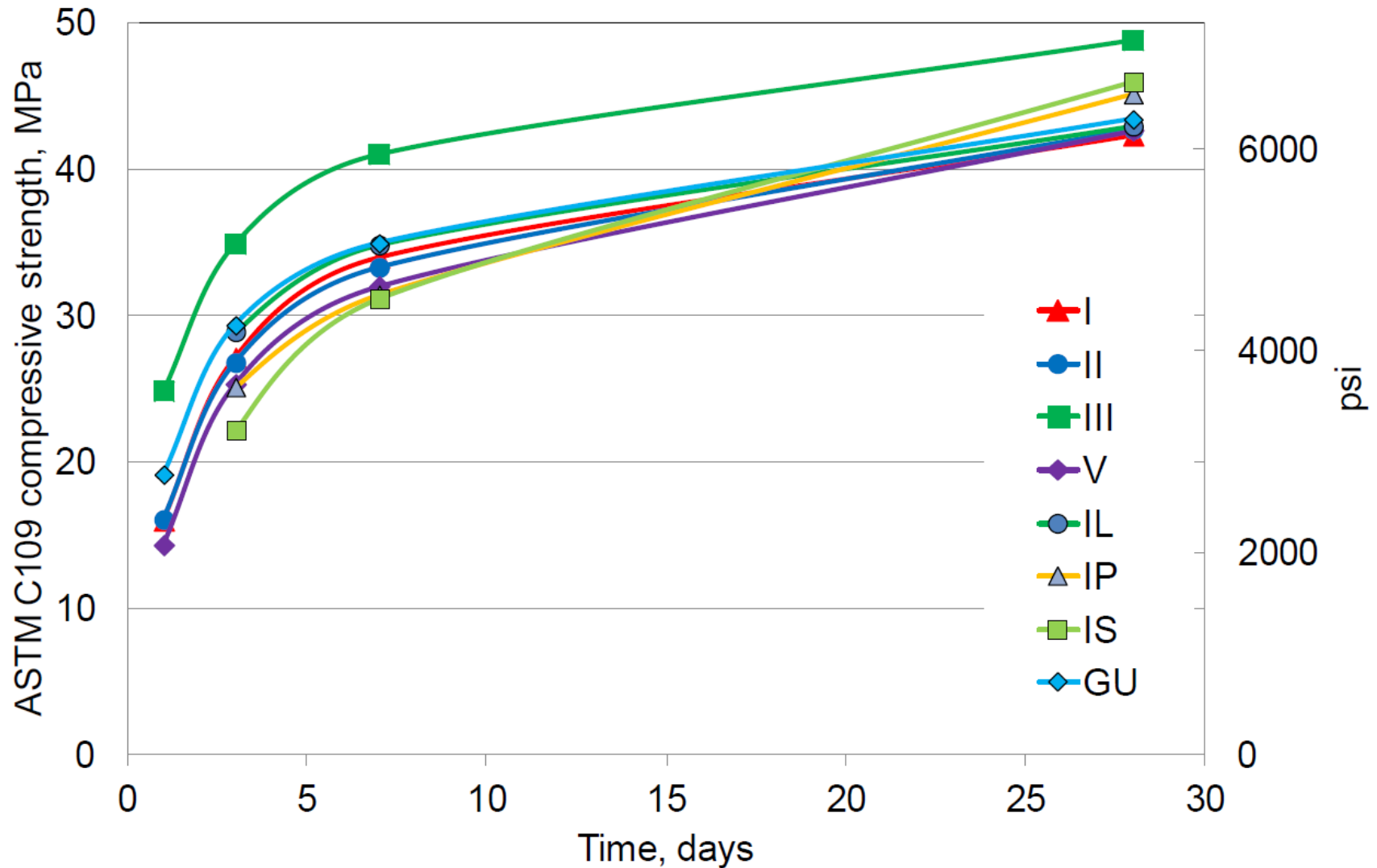
- ASTM C595 (AASHTO M 240)
 - Type IS(X) Portland blast-furnace slag cement
 - Type IP(X) Portland-pozzolan cement
 - Type IL(X) Portland-limestone cements
 - Type IT(AX)(BY) Ternary blended cement
- MS, HS, MH, LH designations can apply as well



2014 US Cement Shipments

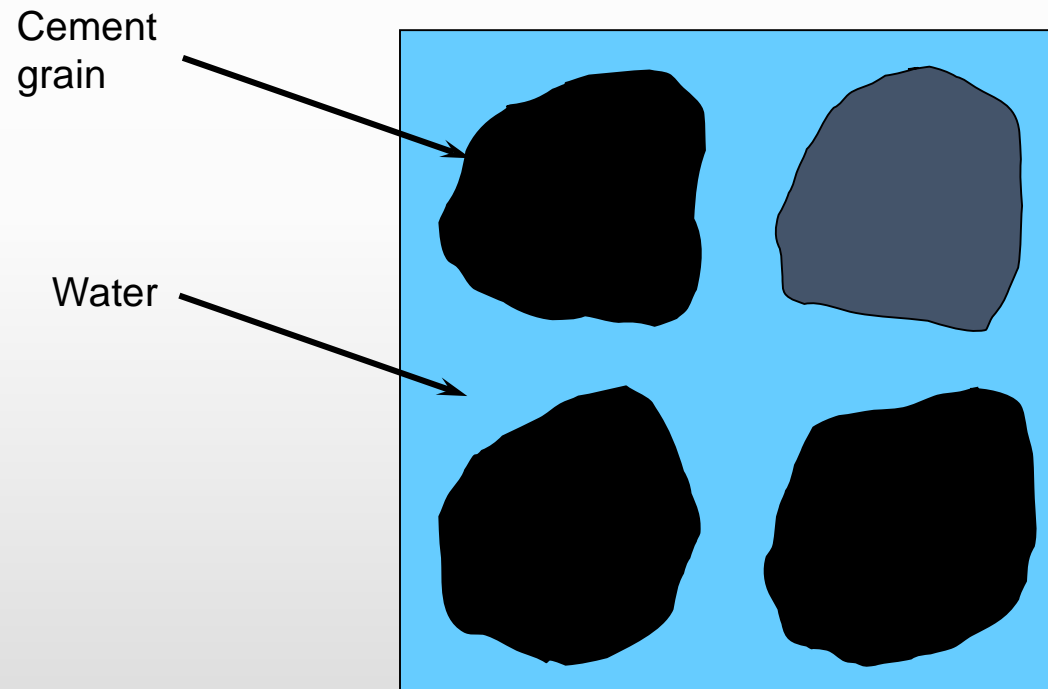


Compressive Strength

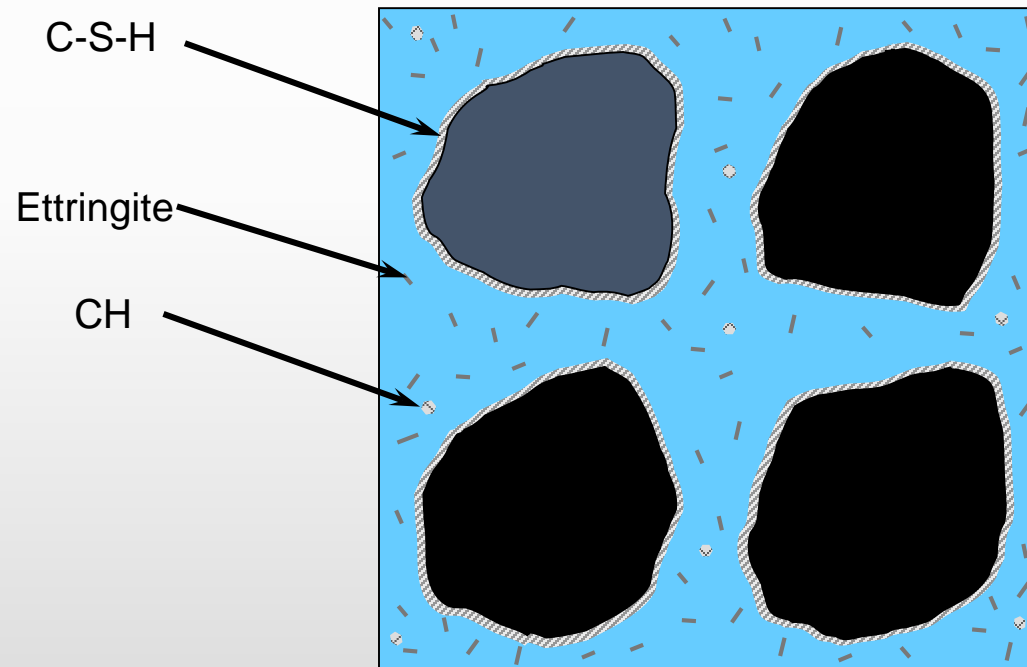


Cement Hydration

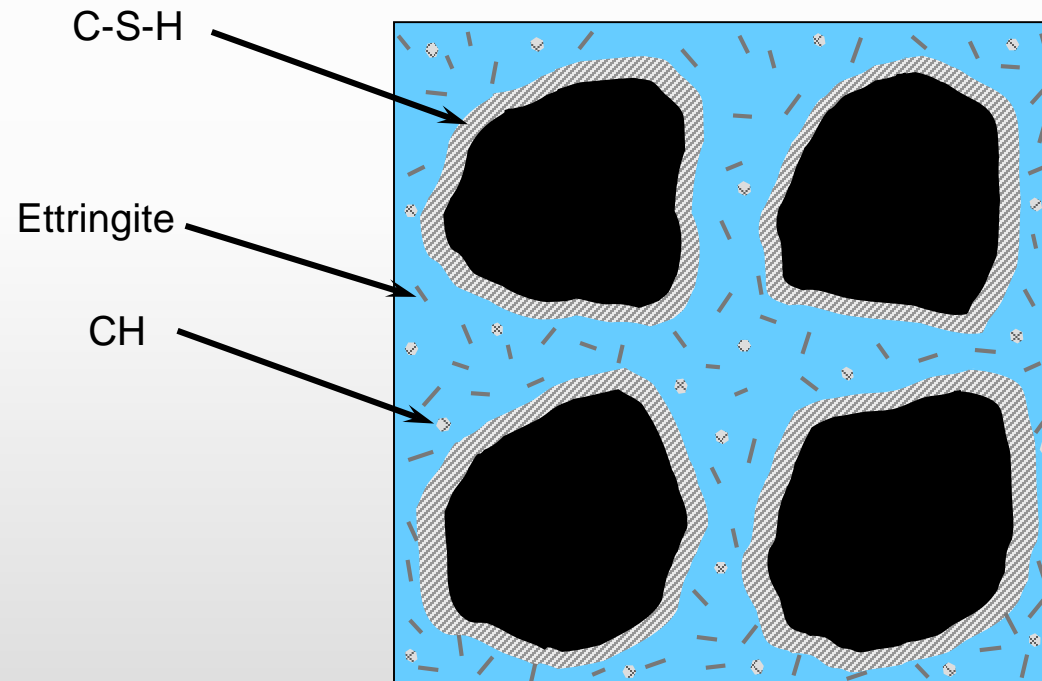
How Cements React with Water



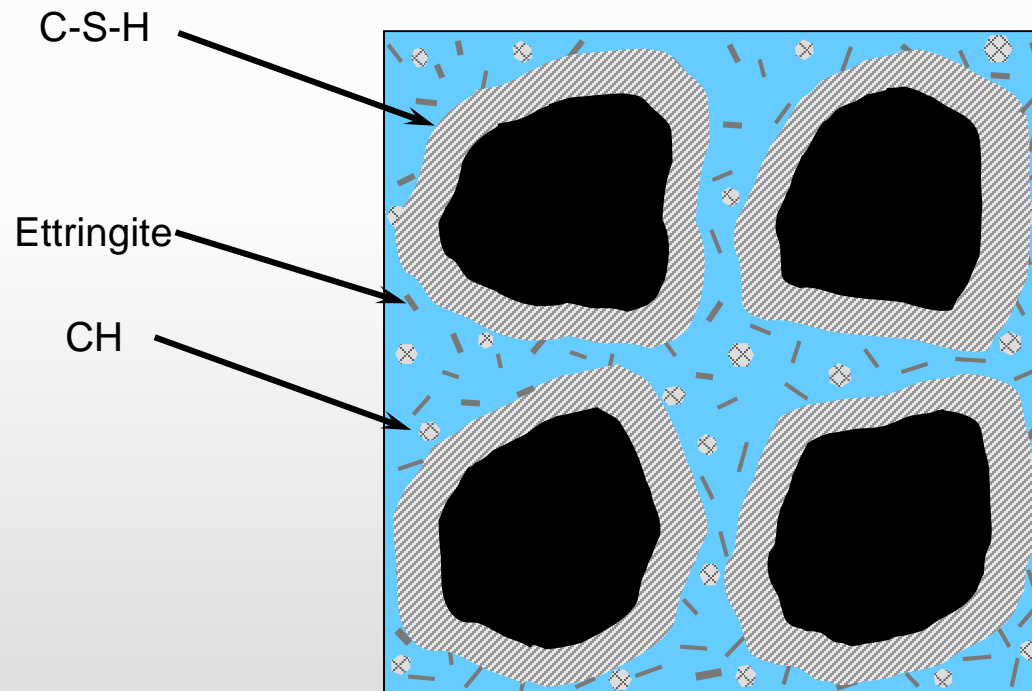
How Cements React with Water



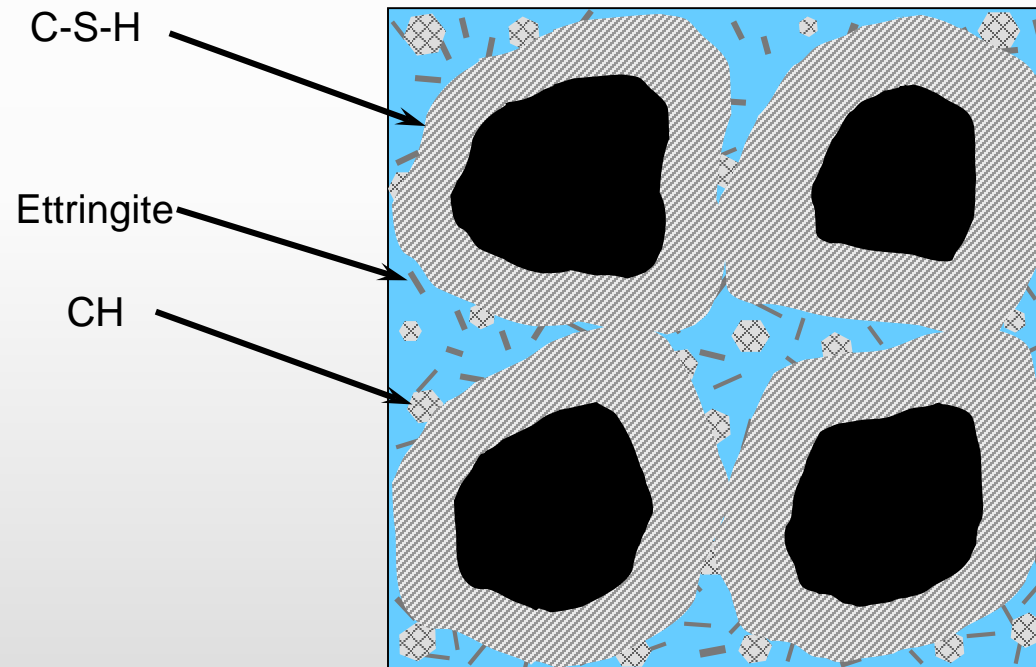
How Cements React with Water



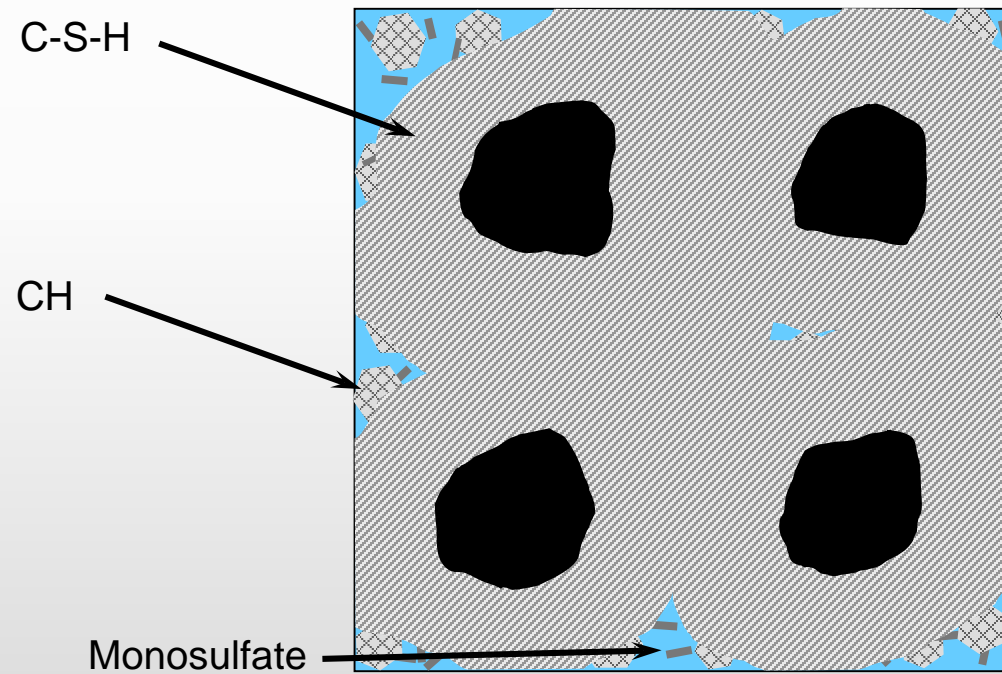
How Cements React with Water



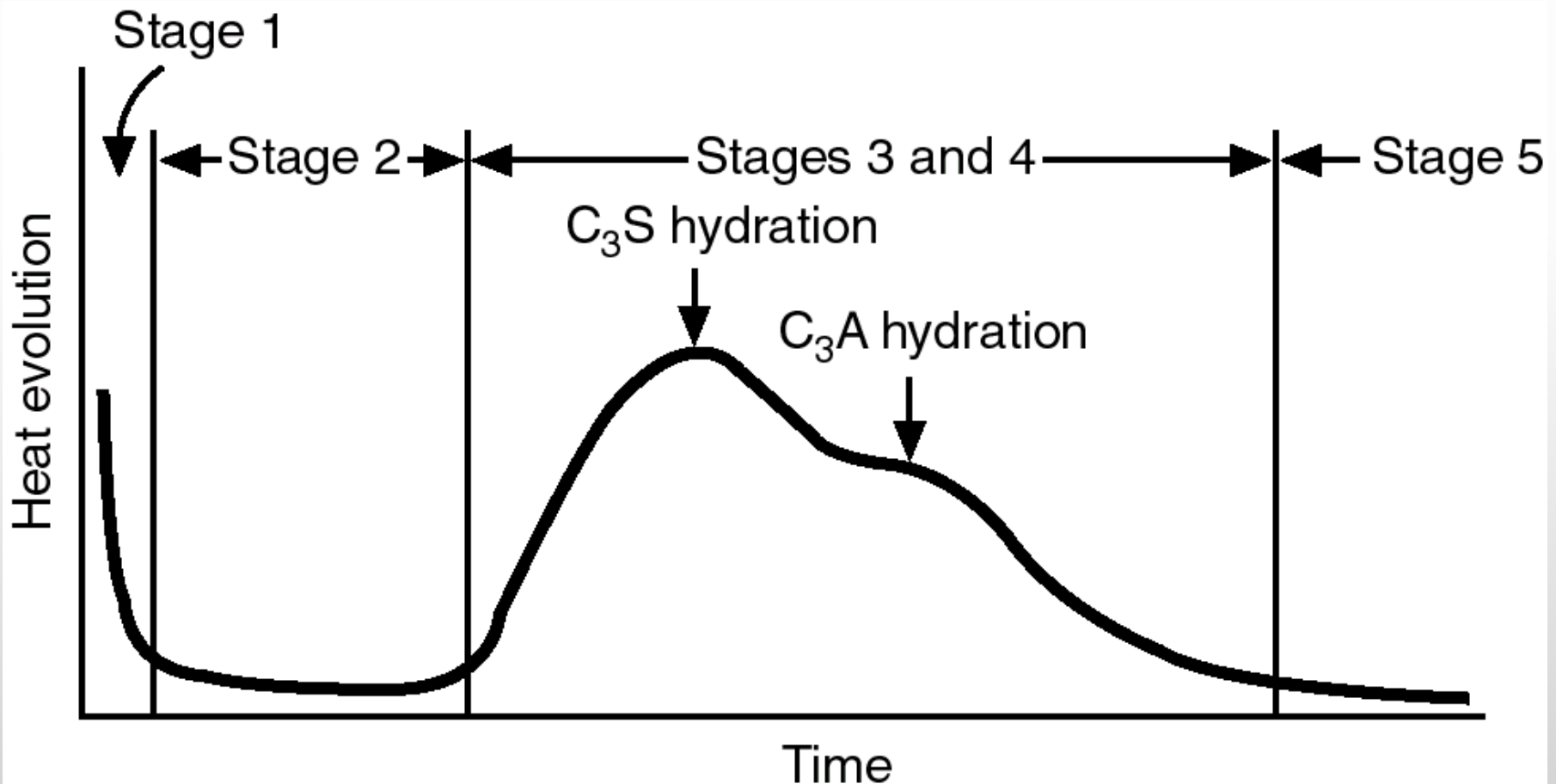
How Cements React with Water



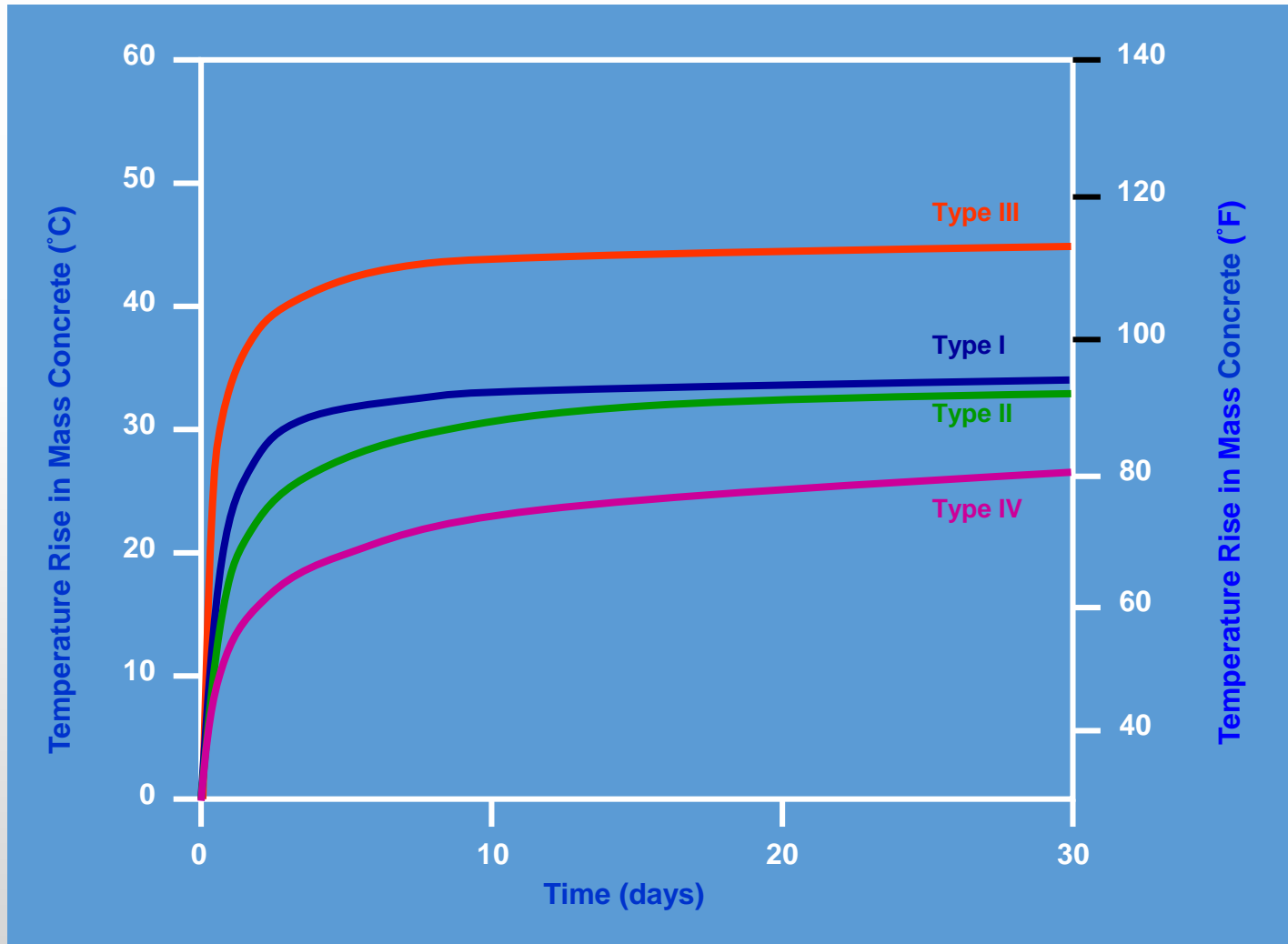
How Cements React with Water



Heat of Hydration



Heat of Hydration



Concrete Durability

Corrosion

- C_3A content
- Alkali content
- w:c
- (admixtures)

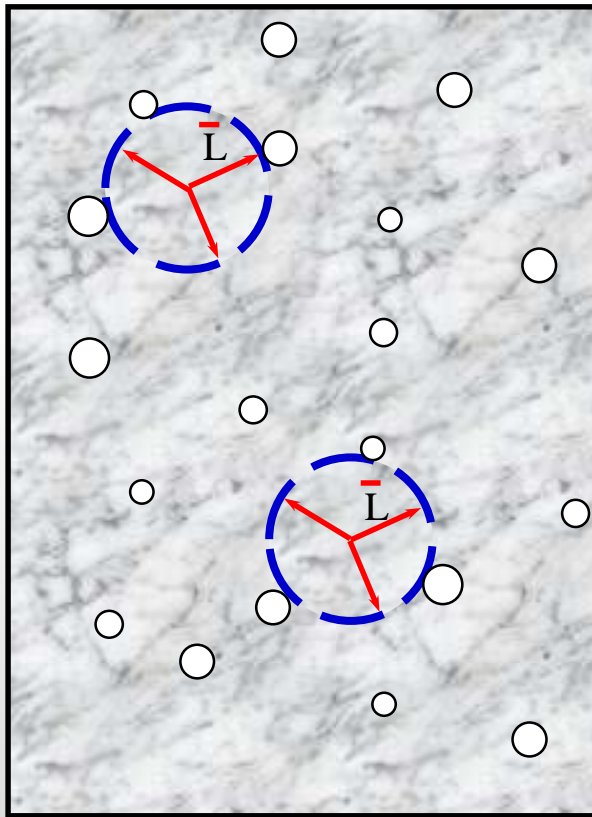


Freeze-Thaw

- Air content and spacing
- Strength
- D-cracking



F-T: Air Void Spacing & Volume

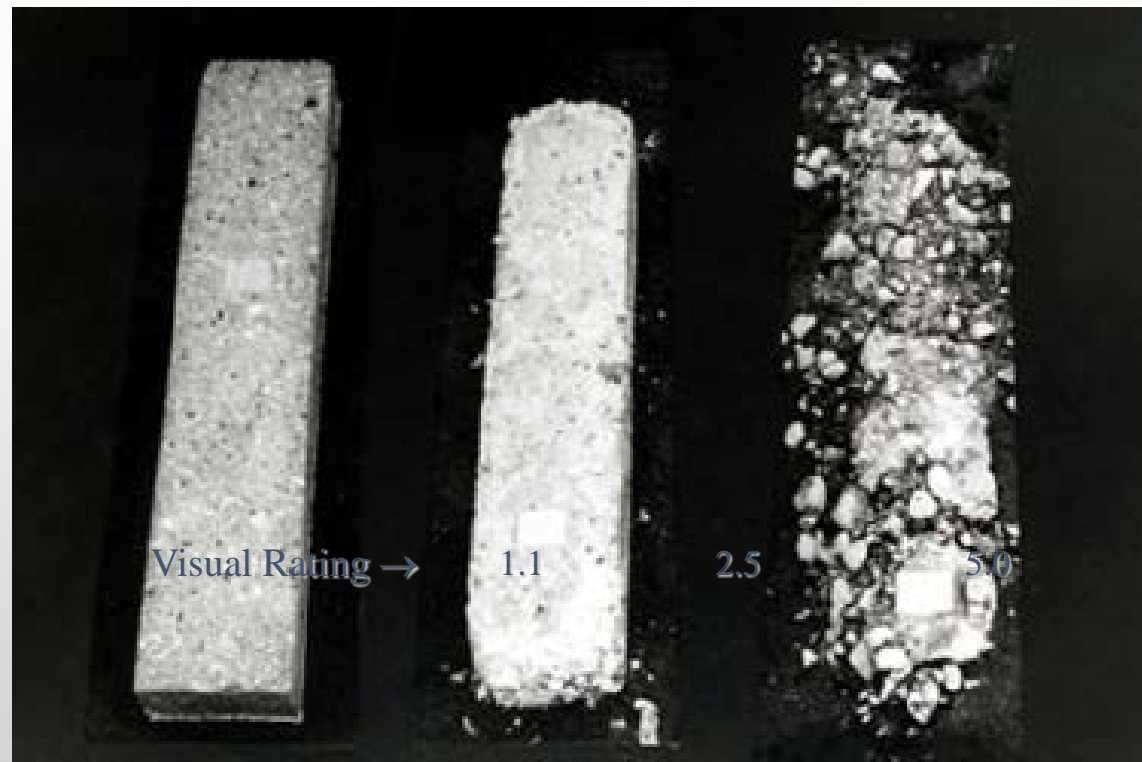


The **spacing factor** \bar{L} is defined as the maximum distance of any point in the cement paste from the periphery of an air void.

The **spacing surface** is defined as the surface area of a quantity of air voids that have a volume of 1 mm³.

Sulfate Attack

- A form of chemical attack
- Internal or external



Alkali-Silica Reactivity

- Discovered 1930s
- Present in most of North America
- Fine and coarse aggregate
- Controllable
 - Aggregate
 - SCMs/blended cements
 - Control alkali loading
 - ASR inhibitors (lithium)



Barriers to Novel Cements

Practical Barriers

- Inertia
- Low profit margins
 - Low-skilled labor
- Codes and standards
 - Life safety
 - Commercial agreements
 - Appropriate test methods
- Raw materials availability
- Durability concerns
 - CAC example





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The background of the slide is a black and white photograph of a large concrete dam with multiple arches, set against a cloudy sky. The foreground shows a rocky, gravelly ground. A blue semi-transparent banner is overlaid on the bottom half of the image.

Thank you!

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