Silica Fume in Concrete

Silica Fume ...

Very fine noncrystalline silica produced in electric arc furnaces as a byproduct of the production of elemental silicon or alloys containing silicon; also known as condensed silica fume or microsilica.

-- ACI 116R

Silica Fume Summary

- Smoke by-product from furnaces used in the production of ferrosilicon and silicon metals
- Amorphous silica with high SiO_2 content, extremely small particle size, and large surface area
- Highly reactive pozzolan used to improve mortar and concrete

Silica Fume (AKA)

- Condensed silica fume
- Microsilica
- “Micropoz” (trademark)
- Silica dust
- Volatilized silica

Silica Fume is NOT:

- Precipitated silica
- Fumed silica
- Gel silica
- Colloidal silica
- Silica flour

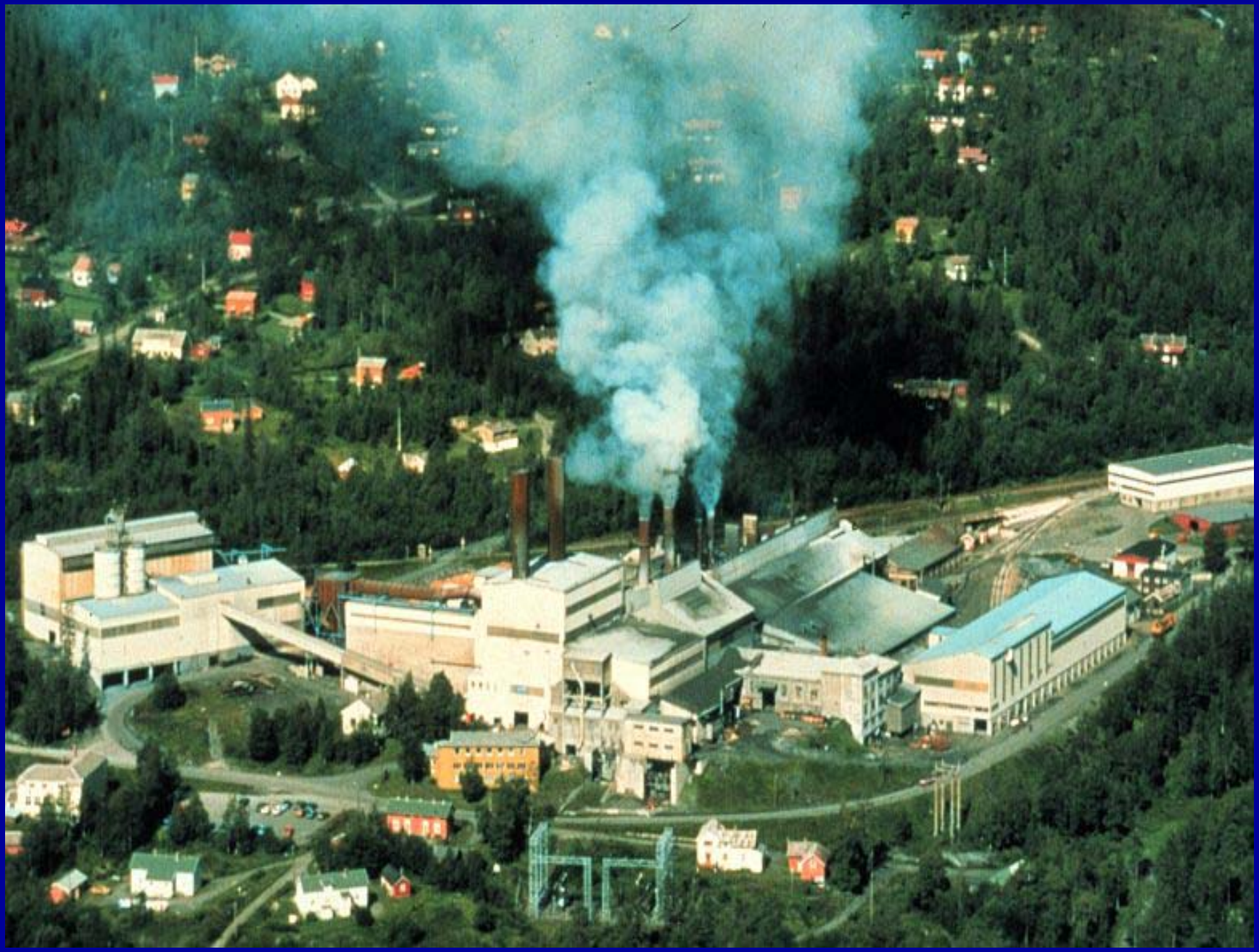
Silica Fume Health Issues

The committee is not aware of any reported health-related problems associated with the use of silica fume in concrete.

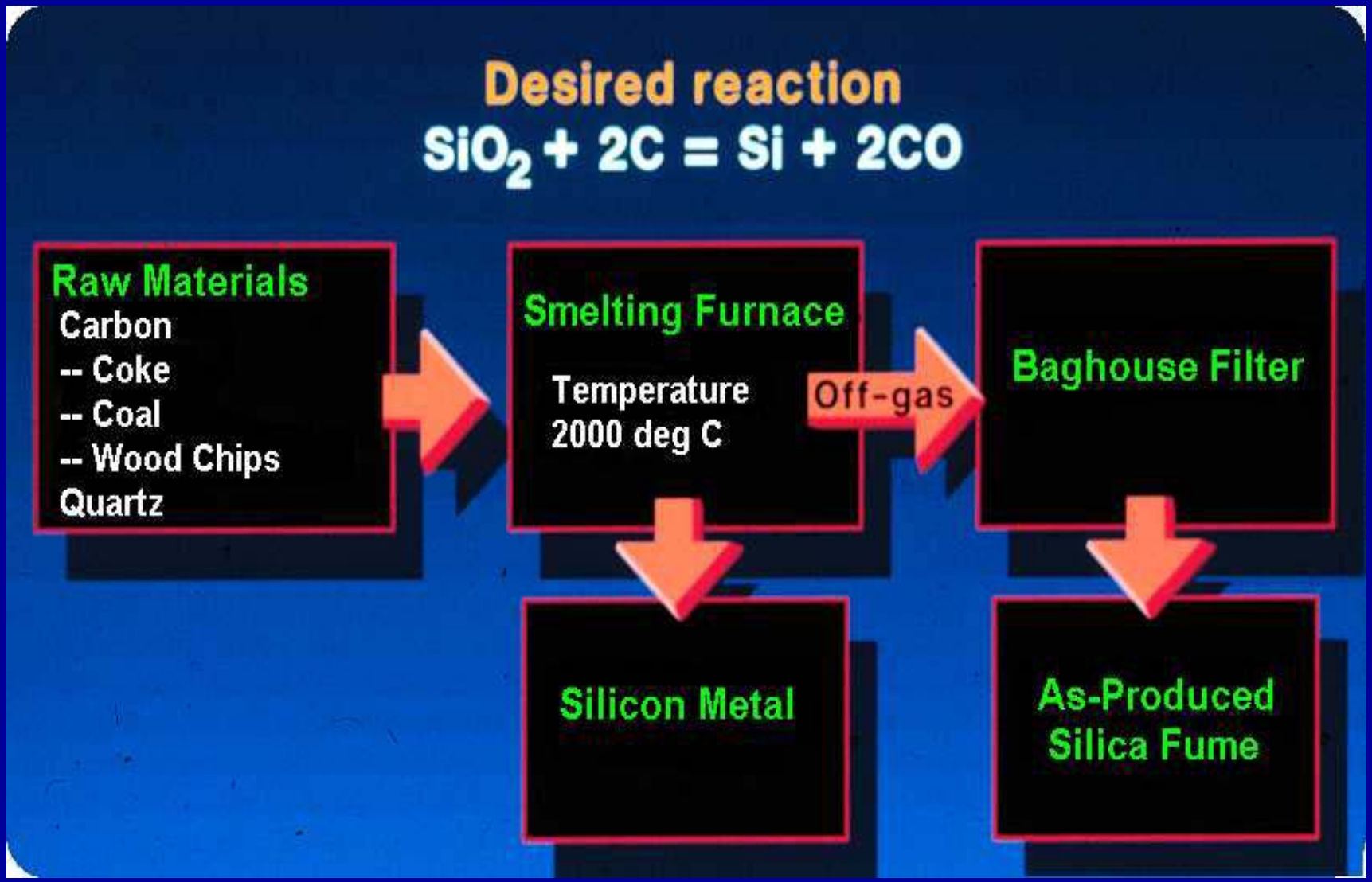
--ACI 234R

Silica Fume Health Issues

- Silica fume may contain trace amounts of crystalline quartz -- requires warnings on bags
- Treat as respirable dust
- Refer to materials safety data sheets (MSDS) for safety measures



Silica Fume Production

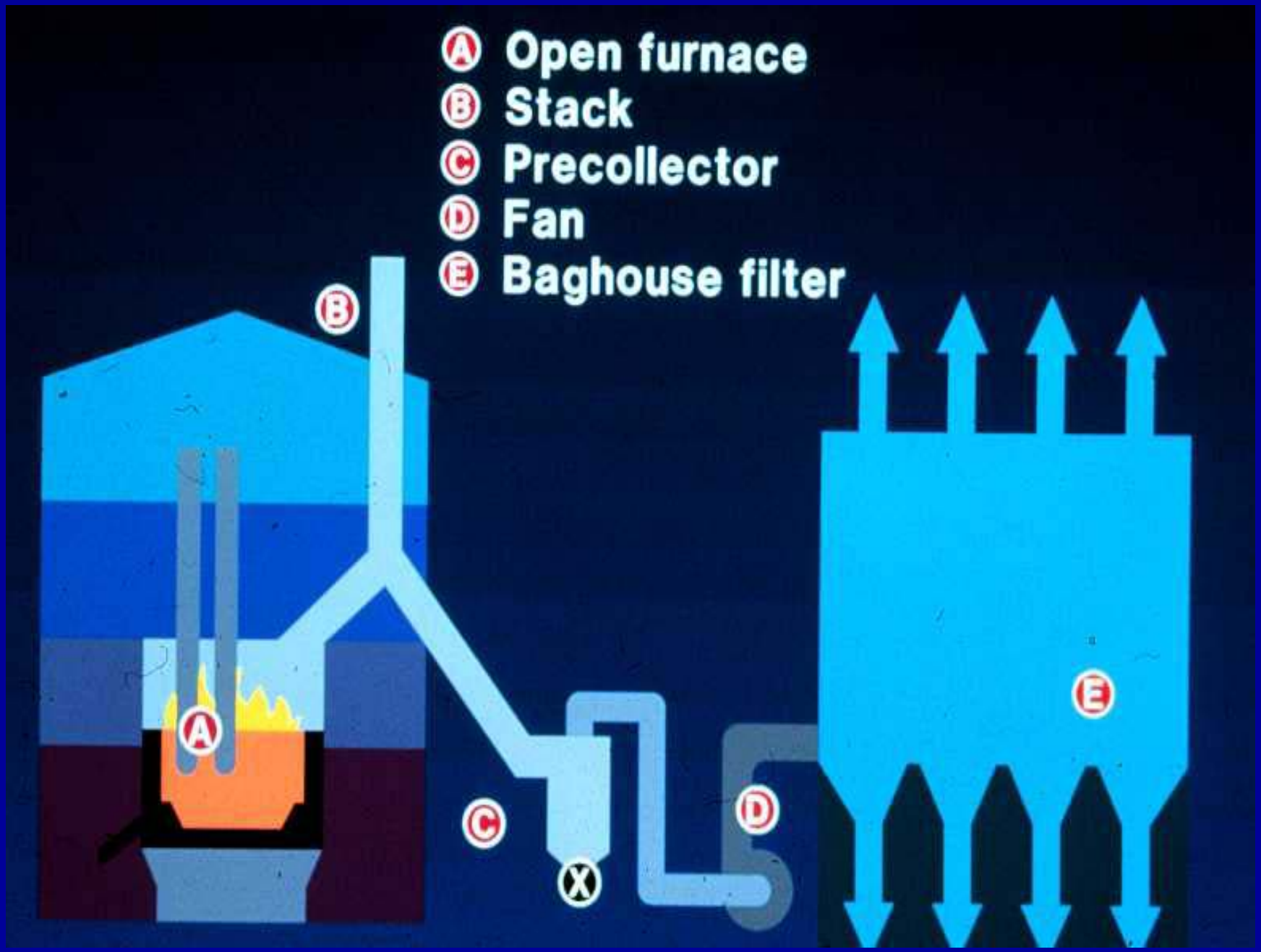


Coal and quartz

Wood chips


Quartz gravel


Translucent silicone sealant provides adhesion of glass to metal frame.
Silicone II
White
Clear
General Household Sealant
35 Year Durability
Paintable Sealant
50 Year Durability
ARRID EXTRA DRY
50¢ OFF
REGULAR
NET WT. 4 OZ
Silicone adhesives adhere the emblem on this gas cap.


A Open furnace
B Stack
C Precollector
D Fan
E Baghouse filter
B
A
C
X
D
E

Metals That Produce Silica Fume

- Silicon metal - typically greater than 97% silicon
- Ferrosilicon alloys -ranging from 40 to 90% silicon alloyed with iron

Silica Fume Product Forms

- As-produced powder
- Water-based slurry
- Densified
- Blended silica-fume cement
- Pelletized


250ml
KIMAX
USA
NO. 14000
APPROX. VOLUMES

Product Characteristics -- As-Produced Silica Fume

- As produced directly from bag house
- Extremely fine and dusty
- Difficult to handle pneumatically -- sticky
- Self agglomerating with a tendency to create small weak lumps
- Low density yields small loads (8 - 10 tons) (7 - 9 Mg) in bulk tankers

Product Characteristics -- Silica-Fume Slurry

- 50 - 52% solids (as-produced silica fume dispersed in water)
- Storage tanks require agitation and protection from freezing
- Transported in bulk tankers 4,000 gallons (12 tons of silica fume) (15 kL, 10 Mg)

Product Characteristics -- Densified Silica-Fume

- Reversible agglomeration process
- Flows well pneumatically
- Bulk transportation is economical, 22 tons (20 Mg) on a bulk tanker
- Product density can be controlled for handling conditions and applications

Product Characteristics -- Blended Silica-Fume Cement

- Primarily used in Northeastern Canada, limited availability in US
- Fixed silica fume content of 7.5% to 8.5%
- Produced from as-produced, densified, or pelletized silica fume
- Portland cement-silica fume blend is primary product. One blend of silica fume, fly ash, and portland cement now being marketed

Product Characteristics -- Pelletized Silica Fume

- Dustless
- Non-reversible agglomeration
- Small pellets, typically 3/8 to 1 inch (10 to 25 mm) diameter
- Utilized in interground silica fume blended cement
- Not suitable for direct use in concrete!

Silica Fume Colors

Premium -- White

Standard -- Grey

Silica Fume -- Chemical Properties

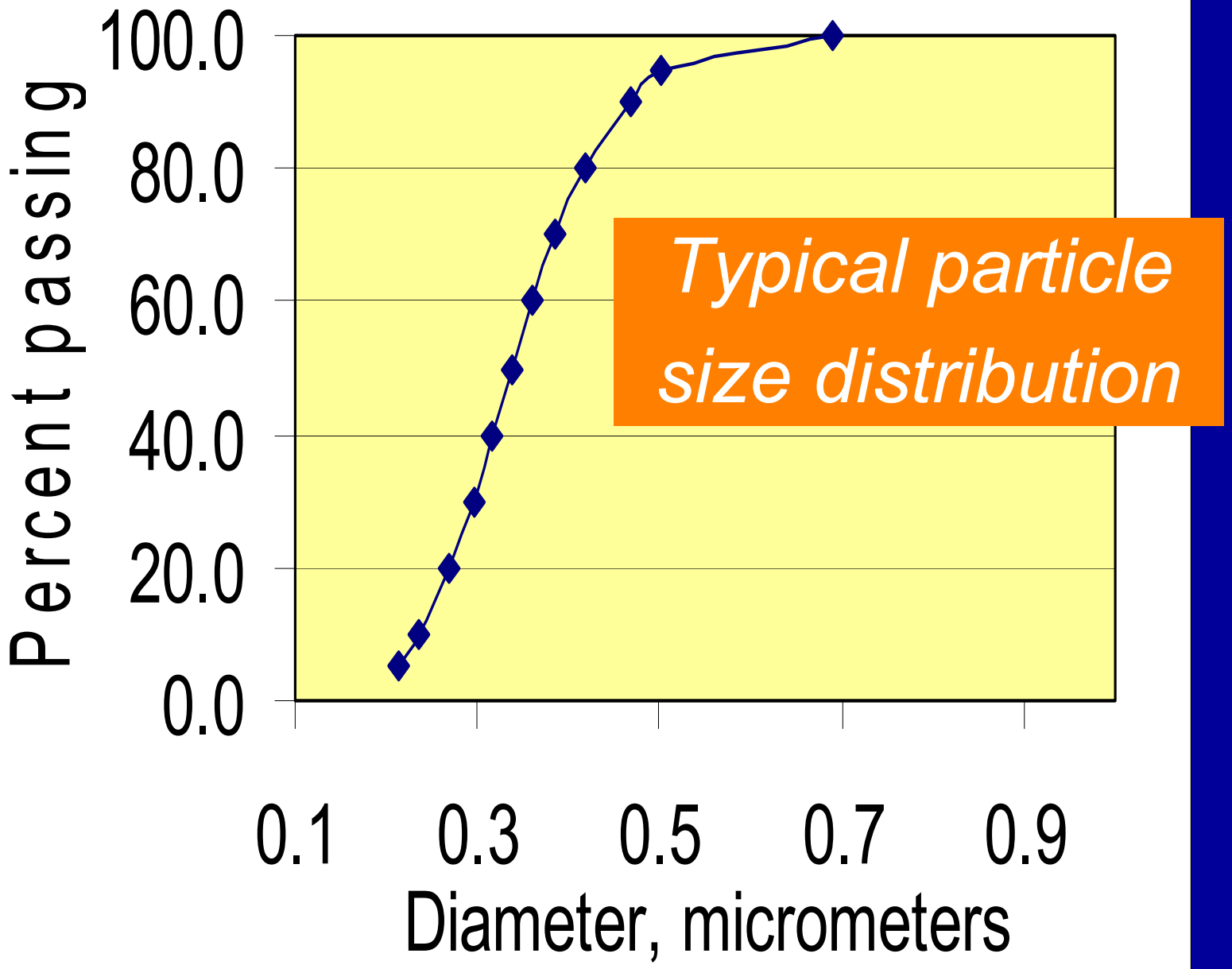
- Amorphous
- Silicon dioxide > 85%
- Trace elements depending upon type of fume

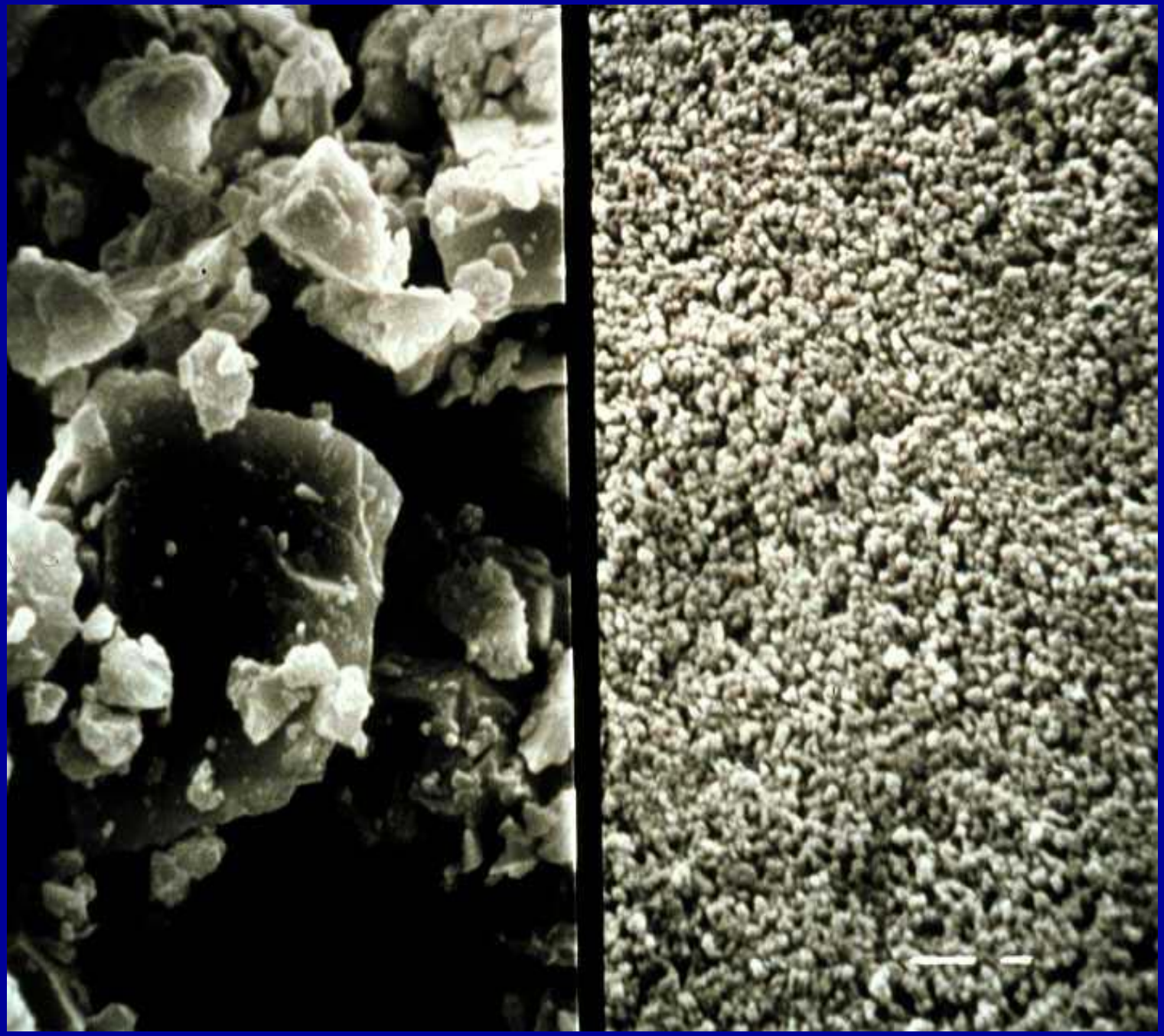
Silica Fume -- Physical Properties

Particle size (typical)	$< 4 \times 10^{-6}$ in.
Bulk density	
(as-produced)	8 to 27 lb/ft^3
(slurry)	11 to 12 lb/gal
(densified)	30 to 45 lb/ft^3
Specific gravity	2.2
Surface area (BET)	60,000 to 150,000 ft^2/lb

Silica Fume -- Physical Properties

Particle size (typical)	< 1 μ m
Bulk density	
(as-produced)	130 to 430 kg/m^3
(slurry)	1320 to 1440 kg/m^3
(densified)	480 to 720 kg/m^3
Specific gravity	2.2
Surface area (BET)	13,000 to 30,000 m^2/kg


Percent passing
100.0
80.0
60.0
40.0
20.0
0.0
0.1
0.3
0.5
0.7
0.9
Diameter, micrometers
Typical particle size distribution



Comparison of Chemical and Physical Characteristics -- Silica Fume, Fly Ash and Cement

	Silica Fume	Fly Ash	Cement
SiO_2 Content	85- 97	35 - 48	20 -25
Surface Area m^2/kg	17,000 - 30,000	400 - 700	300 - 500
Pozzolanic Activity (with cement, %)	120 - 210	85 - 110	n/a
Pozzolanic Activity (with lime, psi) (MPa)	1,200 - 1,660 (8.3 - 11.4)	800 - 1,000 (5.5 - 6.9)	n/a

How Does Silica Fume Work in Concrete?

- Physical effect
- Chemical effect

Silica Fume: Physical Effect

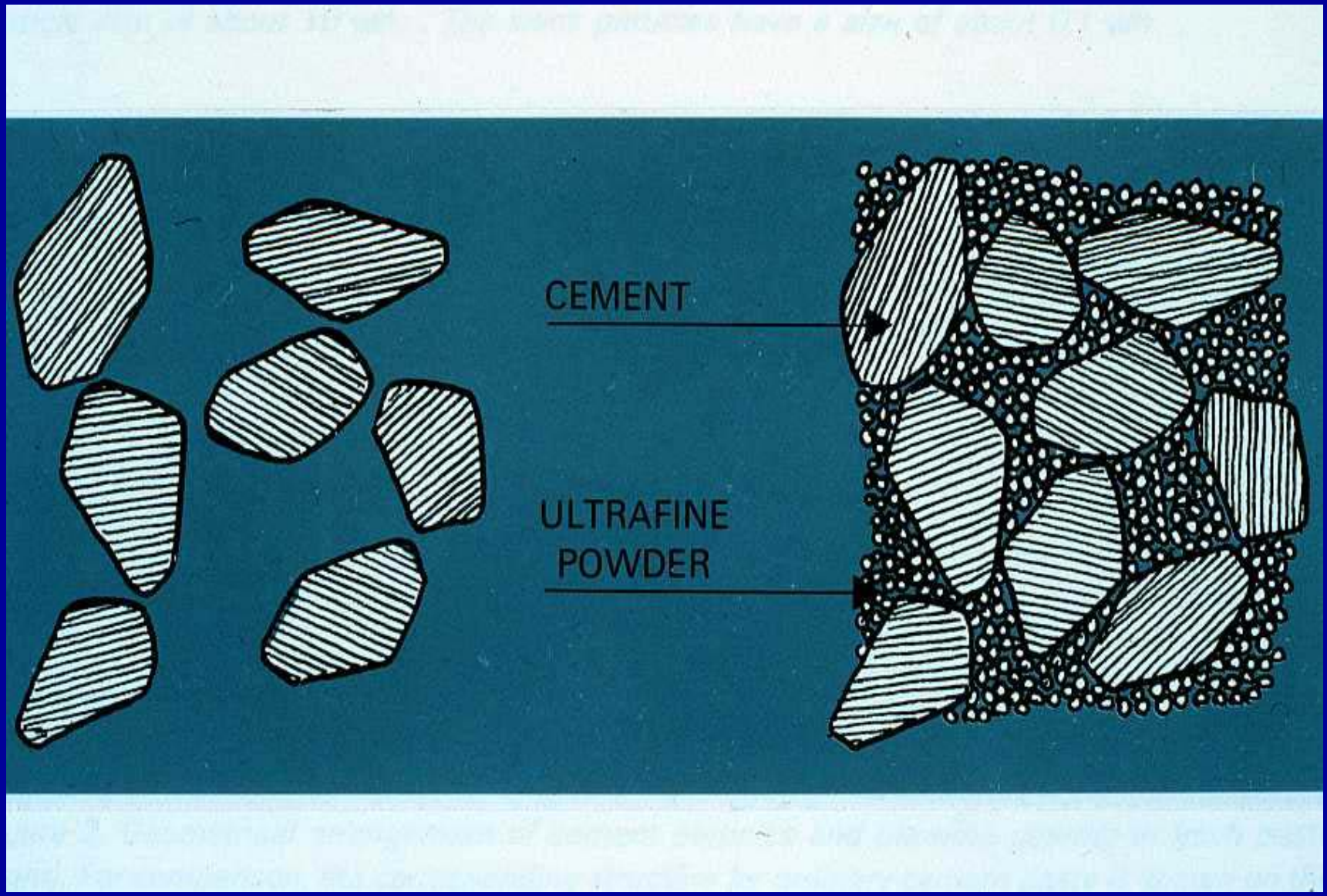
The presence of any type of very small particles will improve concrete properties. This effect is termed either “particle packing” or “micro filling”.

Physical Effect

The carbon black and plain cement mixes showed comparable strengths at both 7 and 28 days, even though the carbon black mixes contained 10 percent less cement (by mass) ... physical mechanisms do play a significant role, particularly at early ages.

-- Detwiler and Mehta

ACI Materials Journal


CEMENT
ULTRAFINE
POWDER

Silica Fume: Chemical Effect

Silica fume is simply a very effective pozzolanic material

What is a Pozzolan?

A siliceous or siliceous and aluminous material, which in itself possess little or no cementitious value but will, in finely divided form and in the presence of moisture , chemically react with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties.

-- ACI 116R

portland cement + water

=

calcium silicate hydrate

+

calcium hydroxide

pozzolan + calcium hydroxide

+

water

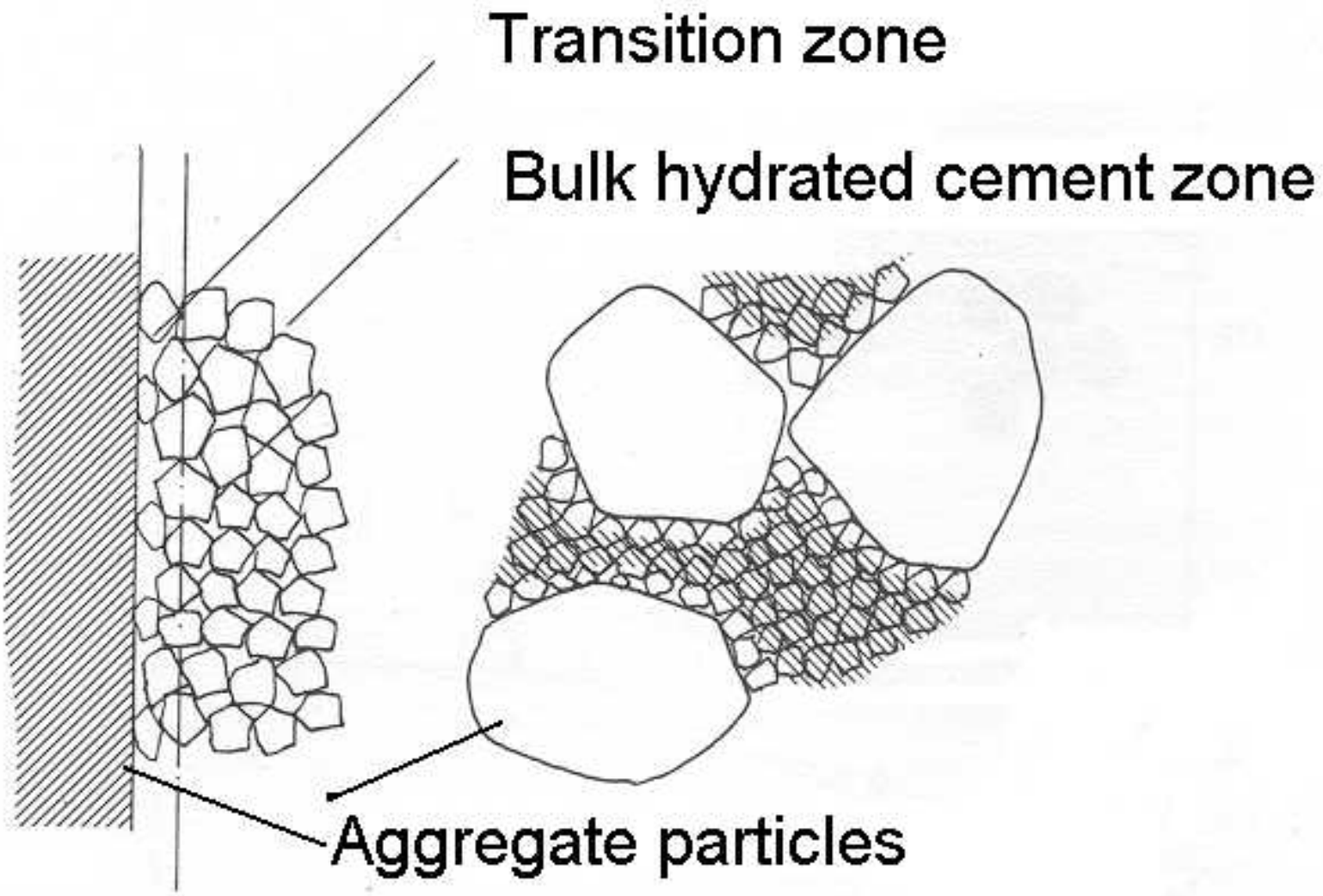
=

calcium silicate hydrate

CALCIUM HYDROXIDE CONTENT

The Transition Zone

The transition zone is a thin layer between the bulk hydrated cement paste and the aggregate particles in concrete. This zone is the weakest component in concrete, and it is also the most permeable area. Silica fume plays a significant role in the transition zone through both its physical and chemical effects.


Transition zone
Bulk hydrated cement zone
Aggregate particles