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A Fresh Look at Cementitious Materials

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Cementitious Materials

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ACI Education Bulletin E3-13

CEMENTITIOUS MATERIALS FOR CONCRETE

Prepared under the direction and supervision of ACI Committee E-701, Materials for Concrete Construction

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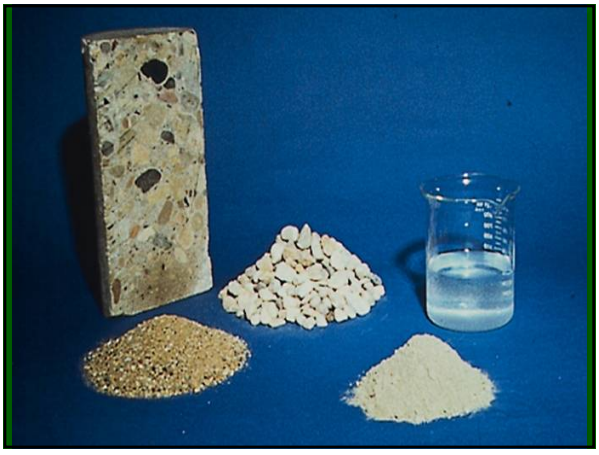
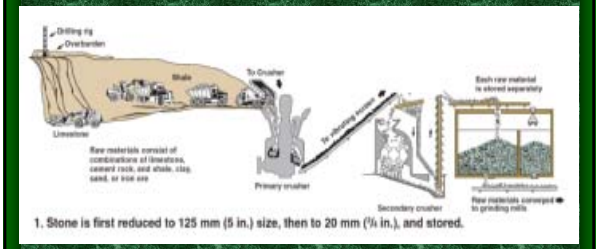


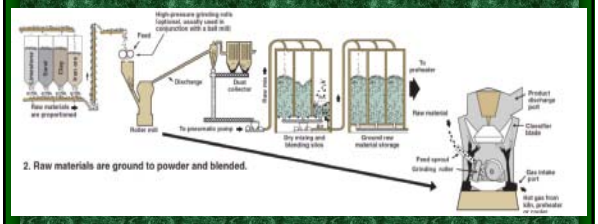
Cementitious Materials

Cements: Portland Cements
Blended Cements
Special Cements
Slag Cement
(GGBFS)

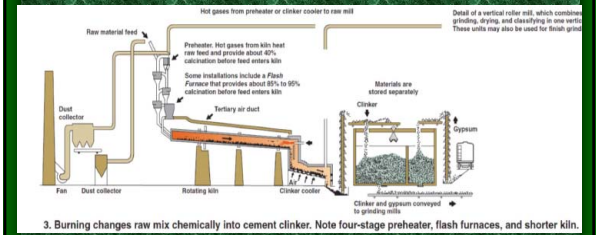
Pozzolans: Fly Ash
Clays & other
Ashes
Silica Fume



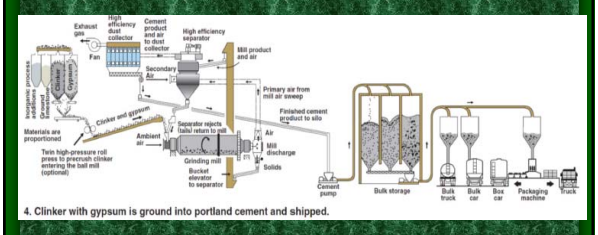
1. Stone is first reduced to 125 mm (5 in.) size, then to 20 mm (¾ in.), and stored.



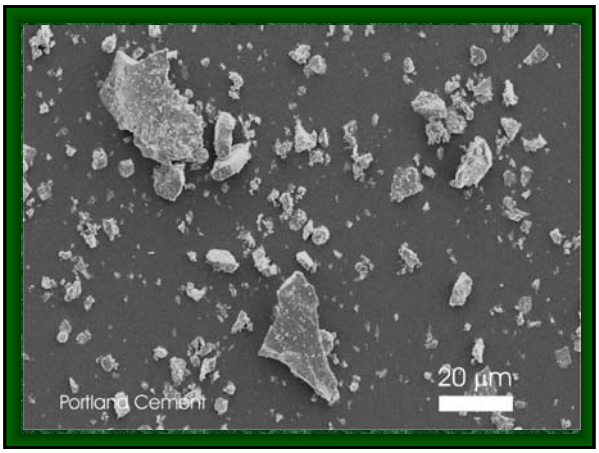
2. Raw materials are ground to powder and blended.



3. Burning changes raw mix chemically into cement clinker. Note four-stage preheater, flash furnaces, and shorter kiln.



4. Clinker with gypsum is ground into portland cement and shipped.



Cement type	ASTM C150/ C150M-12	C_3S, % by mass	C_2S, % by mass	C_3A, % by mass	C_4AF, % by mass	Fine-ness, m^2/kg
I	General-purpose	57	15	9	8	384
II	Moderate sulfate resistance	57	17	7	10	377
III	High early strength	56	16	8	9	556
IV	Low heat of hydration	42	32	4	15	340
V	Sulfate-resistant	58	18	4	12	389

Other Cements

Air-Entrained (C150)
Blended (C595 & C1157)
White

Masonry	**Expansive**
Mortar	**Plastic**
Rapid-Setting	**Water-Repellant**
Calcium Aluminate	**Oil-Well**

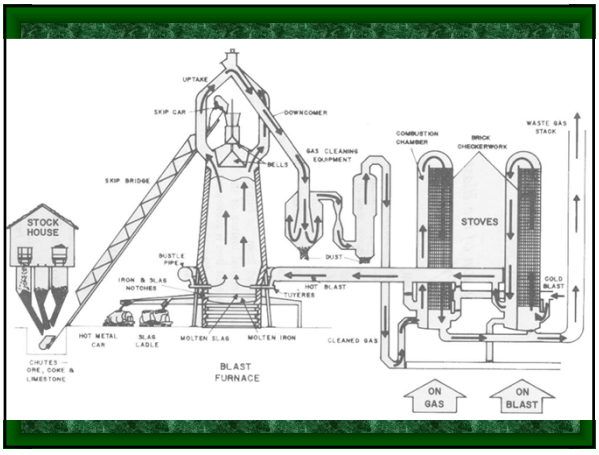
Slag Cement

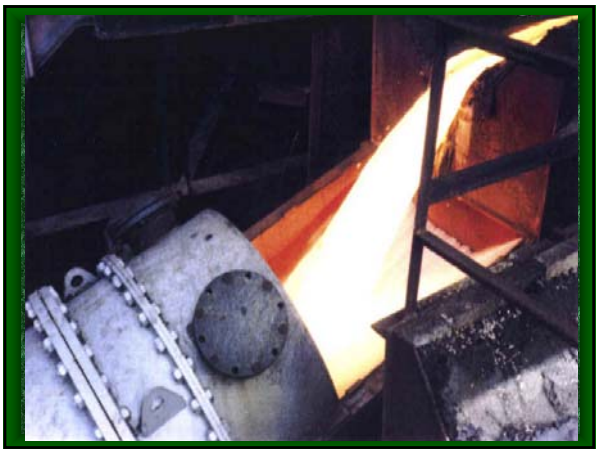
Ground Granulated Blast-Furnace Slag

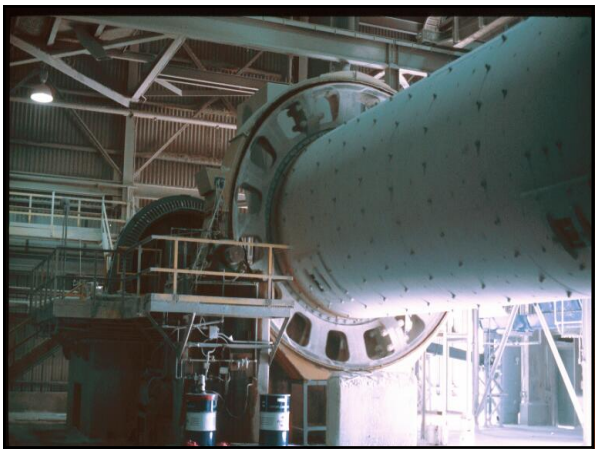
Glassy granular material formed when molten blast-furnace slag is rapidly quenched in water.

Ground and batched into concrete either separately or as a blended cement.

Hydraulic cement and has pozzolanic properties.







Fly Ash

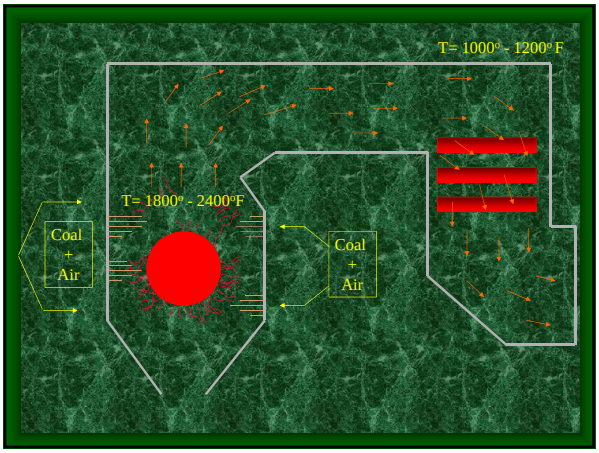
Finely-divided residue that results from the combustion of pulverized coal.

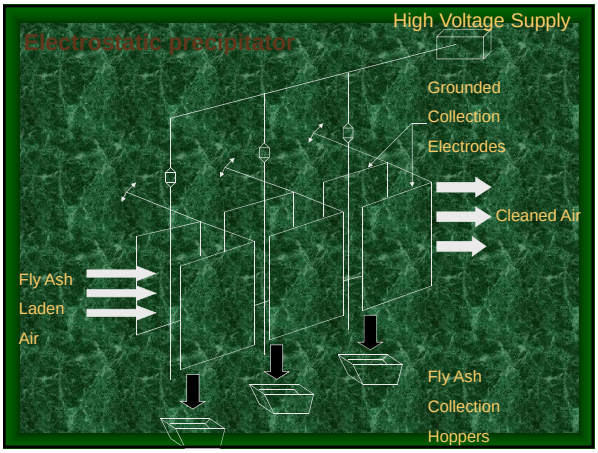
Spherical particles.

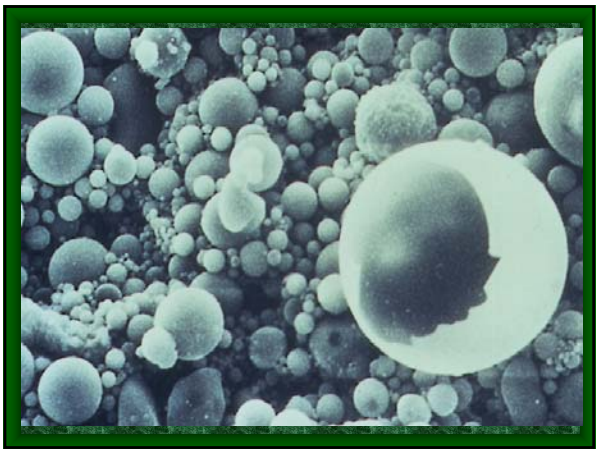
Two types depending on CaO content.

Specification: ASTM C618

Coal Fired Utility Plants







Class C Fly Ash

High lime content; light color due to lower carbon and iron contents.

Originates from burning lignite and sub-bituminous coal.

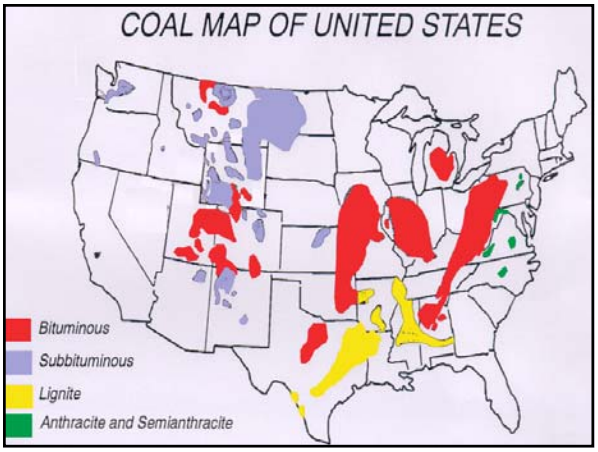
Pozzolanic / Cementitious Reaction.

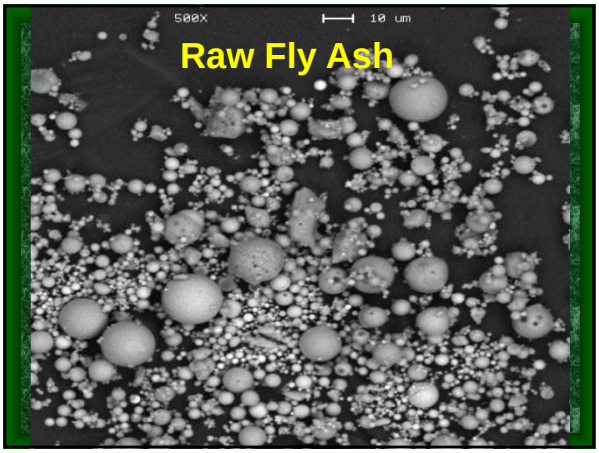
Class F Fly Ash

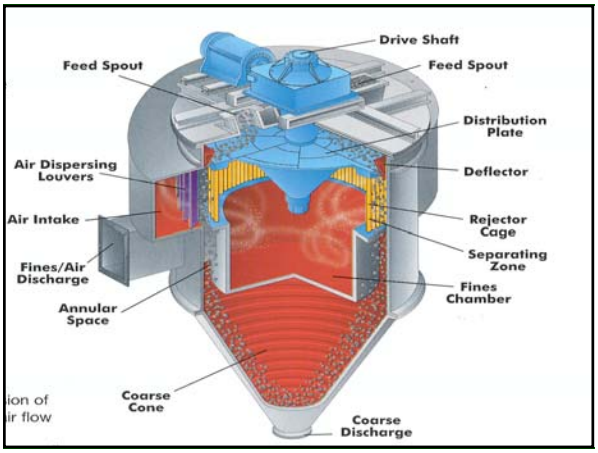
Low lime (CaO) content; dark color due to presence of unburned carbon coal.

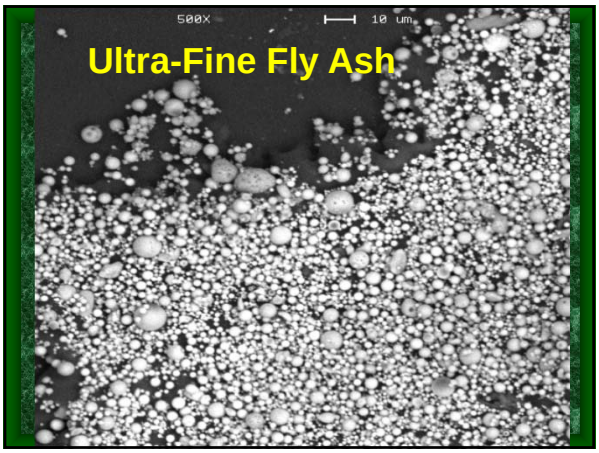
Originates from burning anthracite and bituminous coal.

Pozzolanic Reaction.









Metakaolin

Calcined Kaolin clay

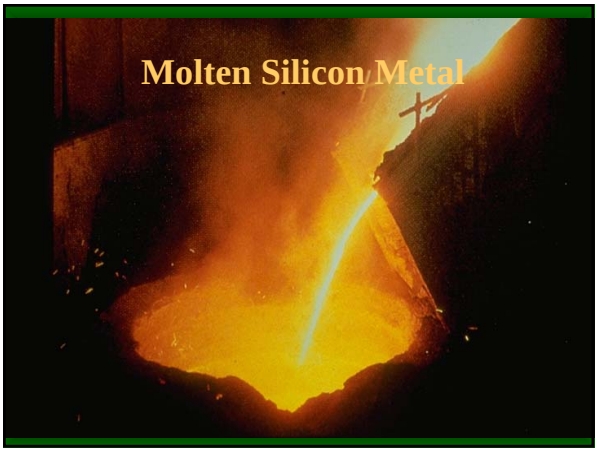
Mined in Georgia
Washed in water
Calcined
Fine white powder
Pozzolanic Reaction.

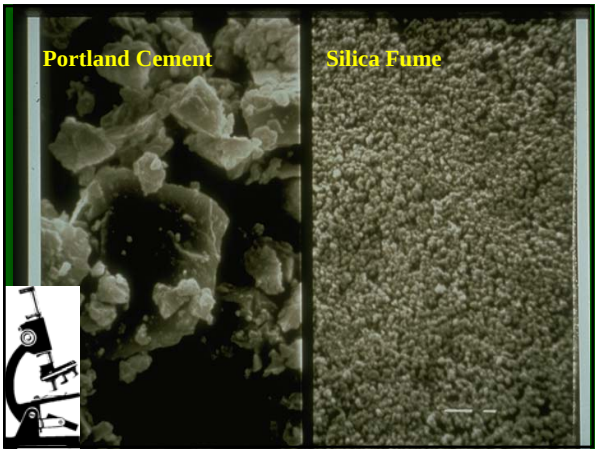
Silica Fume

Finely-divided residue that results from the production of silicon & ferrosilicon metal

Spherical particles.

Specification: ASTM C1240





Dry, Compacted Silica Fume

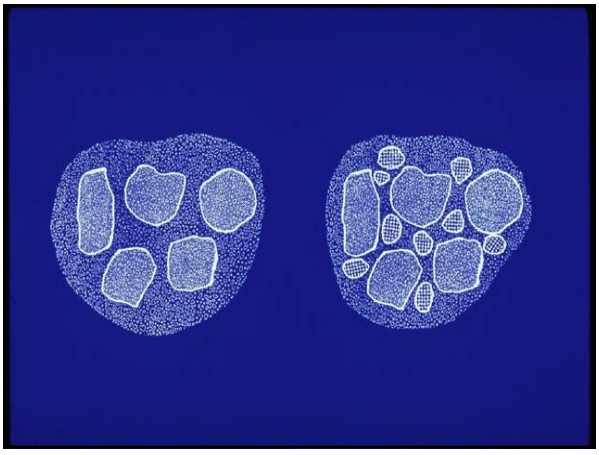
Silica Fume Slurry

Supplementary Cement Materials

- Generally reduce materials cost
- Contribute to improved concrete strength & durability properties
- Reduce heat of hydration
- Utilizes materials otherwise landfilled
- Reduces carbon dioxide production and energy consumption

Fineness

	Blaine
Micron	
Portland 20-30	3500 - 4000
GGBFS 10-15	4000 - 6000
Fly Ash 5-60	3000 - 5000



Chemical Composition

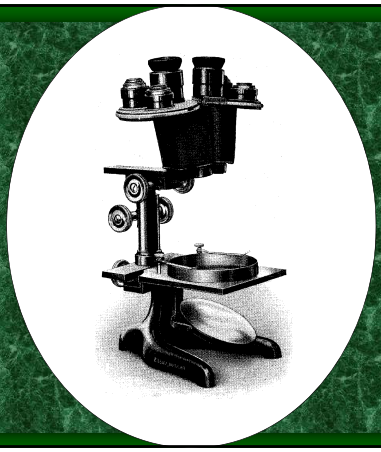
	Portland Cement	Slag Cement	Fly Ash Class C	Fly Ash Class F	Silica Fume
CaO ↑	65	42	24	9	
SiO_2 ↓	22	38	40	55	98
Al_2O_3	4	8	17	26	
Fe_2O_3	3	Trace	6	7	
MgO	2	7	5	2	
SO_3	3	--	4	.6	
Na_2O+K_2O	1	.4			

Hydration of Portland Cement

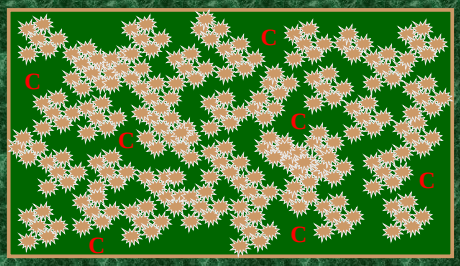
Cement + Water

↓

C-S-H + $Ca(OH)_2$ + *Other*



Hydration of Portland Cement



What is a Pozzolan?

Pozzolans are siliceous or aluminosiliceous materials that in themselves possess little or no cementitious value but will, in finely divided form and in the presence of water, chemically react with the calcium hydroxide released by the hydration of portland cement, to form compounds possessing cementitious properties.

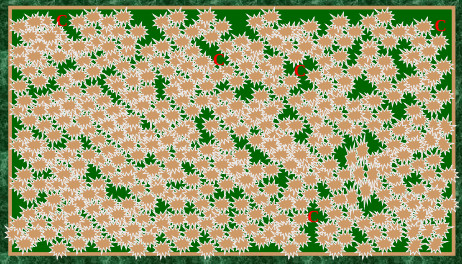
Pozzolanic Reaction in Concrete

$Ca(OH)_2$ + Pozzolan

↓

more….. C-S-H

Effect of Pozzolanic Reaction



Rocket Stages

Portland lift-off	C_3A	Ignition,
Portland	C_3S	First stage
Portland Stage	C_2S	Second
Slag Stage	C_1S	Third
Slag/Ash/SF Stage	Pozz	Fourth

Blended Hydraulic Cements

ASTM C 595….. (Was 5 Types, Now 2)

Pozzolan-Modified Portland Cement

Portland-Pozzolan Cement

Slag-Modified Portland Cement

Portland Blast-Furnace Slag Cement

Blended Hydraulic Cements

ASTM C 595….. (Was 5 Types, Now 2)

Type I(PM)	(P < 15%)
Type IP	(15% < P < 40%)
Type I(SM)	(S < 25%)
Type IS	(25% < S < 70%)

Blended Hydraulic Cements

ASTM C 595….. New Types

Portland-Limestone Cement

Ternary Blended Cement

Blended Hydraulic Cements

ASTM C 595….. New Types

Type IL	(5% < L < 15%)
Type IT	(L < 15%) (P < 40%) (SCM < 70%)