ALTERNATIVE SUPPLEMENTARY CEMENTITIOUS MATERIALS FOR CONCRETE

CHARACTERIZATION CHALLENGES

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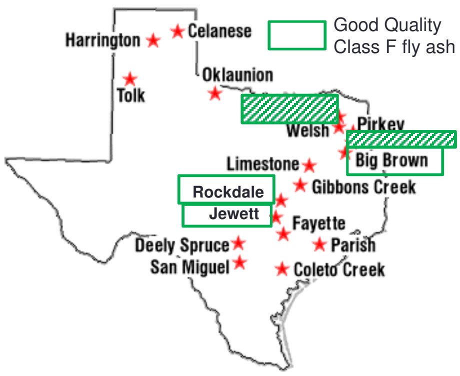
The Future of Fly Ash

Aerial Image Of Kingston Ash Slide 12/23/08

The Future of Fly Ash

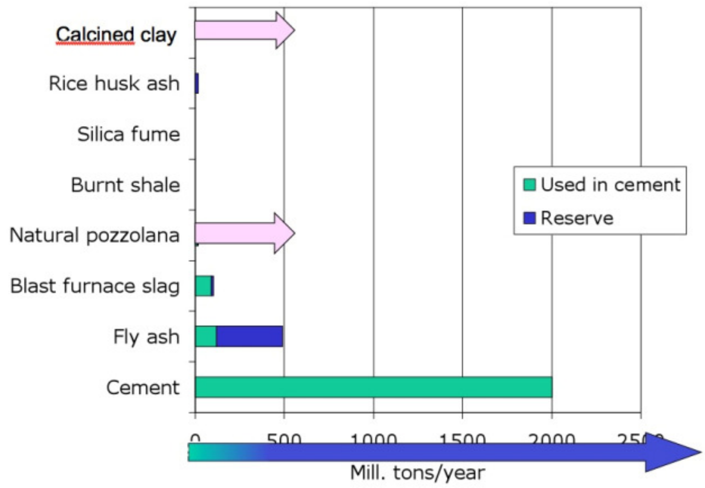
- EPA Cross-State Air Pollution Rule (CSAPR) threatens the supply of Class F fly ash in Texas
- Power plants may move to "cleaner" burning Powder River Basin coal

Coal burning power plants in Texas



feww.wordpress.com

SCM Availability



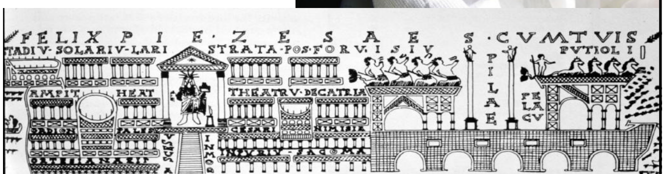
From K. Scrivener

Fly Ash Alternatives

We have come full circle…back to the Roman pozzolana

"Natural" Supplementary Cementitious Materials

- Volcanic ash
- Tuffs
- Zeolites
- Pumice
- Perlite
- Diatomaceous earth
- Metakaolin
- Rice husk ash



web.uvic.ca FIG. 12. Italy. No. 5. Drawing: The National Museum, Prague.

SCM Characterization

- Most SCMs are not directly manufactured to meet a specification
- Characterization is critical for selection

- There are several standards that define physical and chemical characteristics of SCMs to be used in concrete:
  - ASTM C618, EN 450, AS 3582.1

Designation: C 618 – 08a

Standard Specification for
Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete[1]

SCM Chemical requirements

- Chemical requirements focus on oxide analysis (typically measured through x-ray fluorescence)

C 618 – 08a

TABLE 1 Chemical Requirements

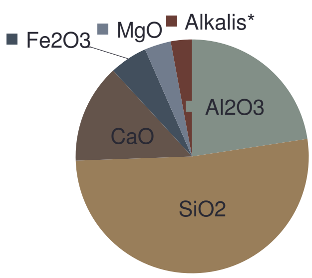
	Class		
	N	F	C
Silicon dioxide (SiO_2) plus aluminum oxide (Al_2O_3) plus iron oxide (Fe_2O_3), min, %	70.0	70.0	50.0
Sulfur trioxide (SO_3), max, %	4.0	5.0	5.0
Moisture content, max, %	3.0	3.0	3.0
Loss on ignition, max, %	10.0	6.0[A]	6.0

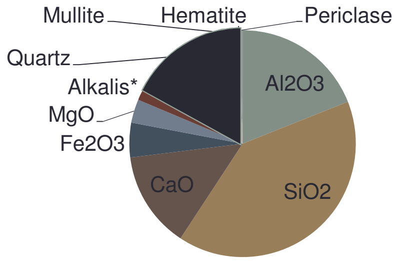
[A]The use of Class F pozzolan containing up to 12.0 % loss on ignition may be approved by the user if either acceptable performance records or laboratory test results are made available.

- Many materials meet the Class N criteria of SiO_2+Al_2O_3+Fe_2O_3>70% but are not good pozzolans

SCM Chemical characterization

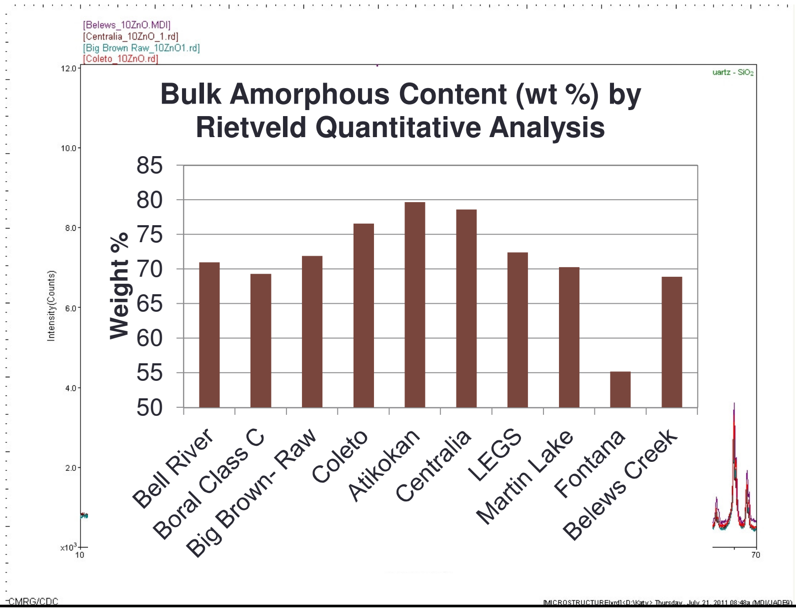
- Not all oxides in SCMs are soluble





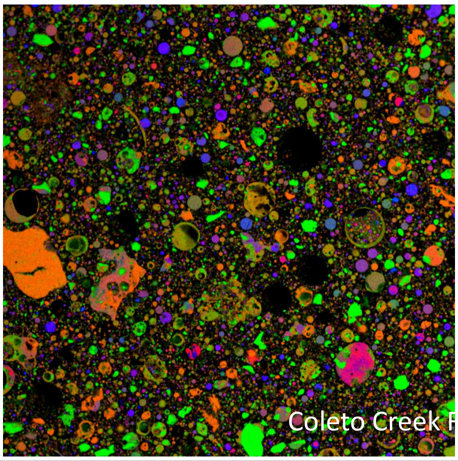
* Alkalis are Na_2O + K_2O

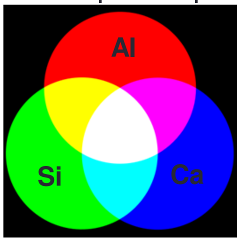
SCM Chemical characterization

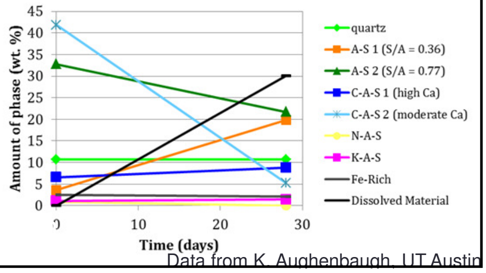


SCM Chemical characterization

- Multispectral Image Analysis (MSIA) for amorphous phase characterization



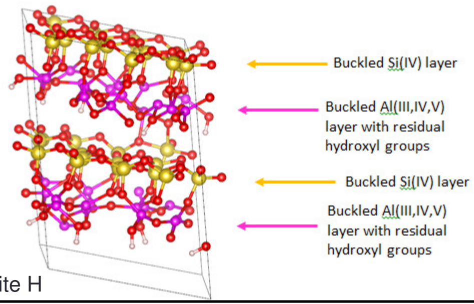




Data from K. Aughenbaugh, UT Austin

SCM Chemical Characterization

- Structure of calcined clays is related to reactivity, particularly the coordination environments of Al and Si
  - Metakaolin appears amorphous in x-ray diffraction
  - New work has modeled the structure using density functional computations and neutron pair distribution function analysis (White et al., Physical Chemistry Chemical Physics, 2010).



Yellow atoms are Si, purple Al, red O, and white H

SCM Physical Characterization

Designation: C 618 – 08a

TABLE 2 Physical Requirements

	Class		
	N	F	C
Fineness:			
Amount retained when wet-sieved on 45 µm (No. 325) sieve, max, %	34	34	34
Strength activity index: [A]			
With portland cement, at 7 days, min, percent of control	75[B]	75[B]	75[B]
With portland cement, at 28 days, min, percent of control	75[B]	75[B]	75[B]
Water requirement, max, percent of control	115	105	105
Soundness: [C]			
Autoclave expansion or contraction, max, %	0.8	0.8	0.8
Uniformity requirements:			
The density and fineness of individual samples shall not vary from the average established by the ten preceding tests, or by all preceding tests if the number is less than ten, by more than:			
Density, max variation from average, %	5	5	5
Percent retained on 45-µm (No. 325), max variation, percentage points from average	5	5	5

ASTM C 204
Blaine Air-Permeability

- Rate of flow through a porous bed of material is related to its surface area

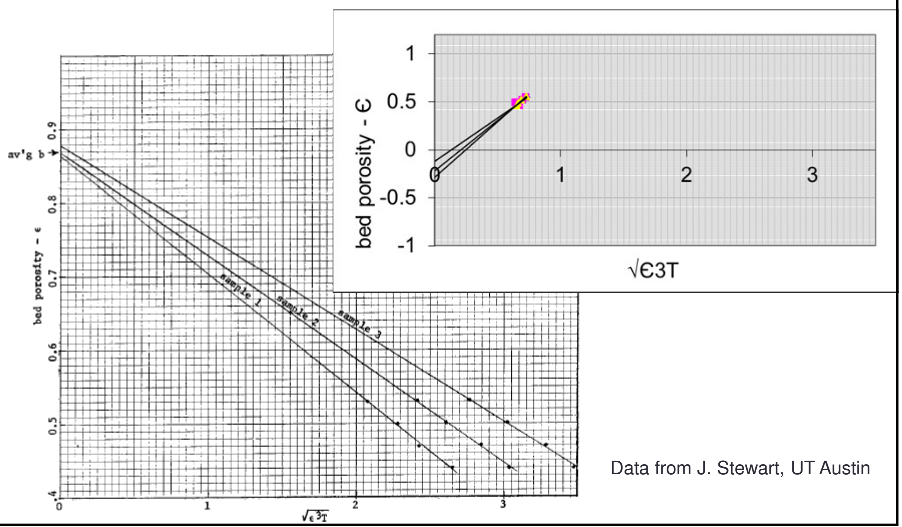
$$S = \frac{S_s \rho_s (b_s - \varepsilon_s)\sqrt{\varepsilon^3}\sqrt{T}}{\rho (b - \varepsilon)\sqrt{\varepsilon_s^3}\sqrt{T_s}}$$

S is the specific surface area; S_s is that of a standard material
T is the measured time interval and T_s is that of a standard material
ρ is the density of the material and ρ_s is the density of the standard material
ε is the porosity of the prepared bed and ε_s is that for the standard
b is a constant appropriate for the test sample

D is the powder density; ε is the porosity of the bed; A is the cross-sectional area of the bed; i is the hydraulic gradient; ν is the kinematic velocity; Q is the rate of flow

SCM Physical Characterization: Blaine

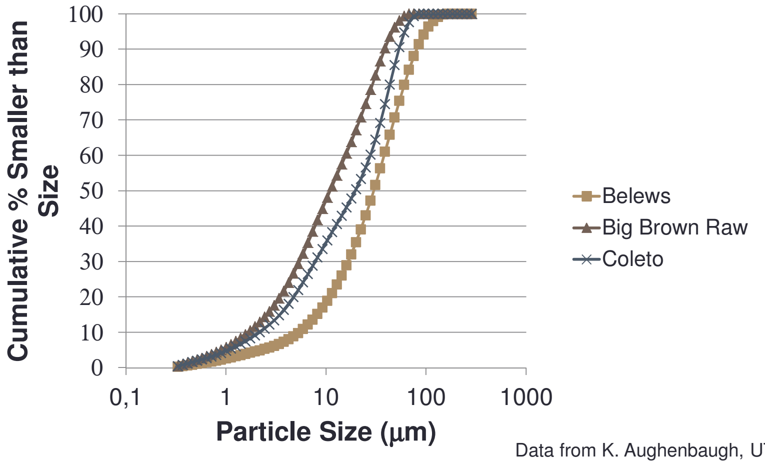
X1. ILLUSTRATIVE METHOD FOR THE DETERMINATION OF THE VALUE FOR THE CONSTANT *b*



Data from J. Stewart, UT Austin

SCM Physical characterization: Particle Size

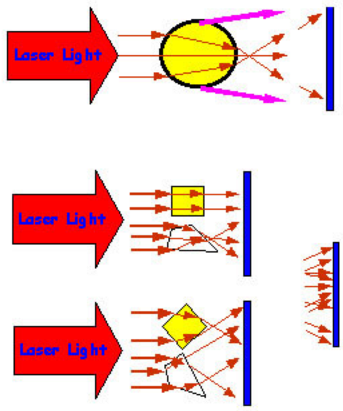
- Particle size distribution by laser diffraction



Data from K. Aughenbaugh, UT Austin

Laser Techniques (LAS)

- Absorption is dependent on the size and the composition
- Diffraction in LAS is dependent only on the geometry of the particle, not the composition
- Scattering is dependent on the refractive indices and, therefore, the composition, but also the size and shape



Summary and Conclusions

- SCMs, both traditional and alternative, are valuable components of modern concrete mixtures and their use will only increase
- We need to characterize SCMs thoroughly before use in order to:
  - Determine if they are appropriate for use
  - Determine optimal replacement levels
- Characterization tests in the standards are inadequate and new thought must be given to the best means of characterizing this diverse group of materials