Durable Concrete in a Low-Ash World

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Iowa State University
Institute for Transportation

National Concrete Pavement Technology Center
CP Tech Center

What's Coming Up…

A Virtual Better Concrete Conference

Noon webinars

Nov. 4	ACI 301 – Specifications for Concrete Construction Michelle Wilson, PCA
Nov. 18	Wet Weather Strategies for Handling Concrete Placements Ron Kozikowski, North Starr Concrete Consulting
Dec. 2	The Future of Fly Ash: Dystopia or Hysteria Larry Sutter, Michigan Tech University
Dec. 16	Project Bluejay & Krause Gateway Center Dan Goldsworth, Mark Stinocher, Jordan Stokes, Nick Aldrich

https://register.gotowebinar.com/register/6780190539906386191

Special Thank you

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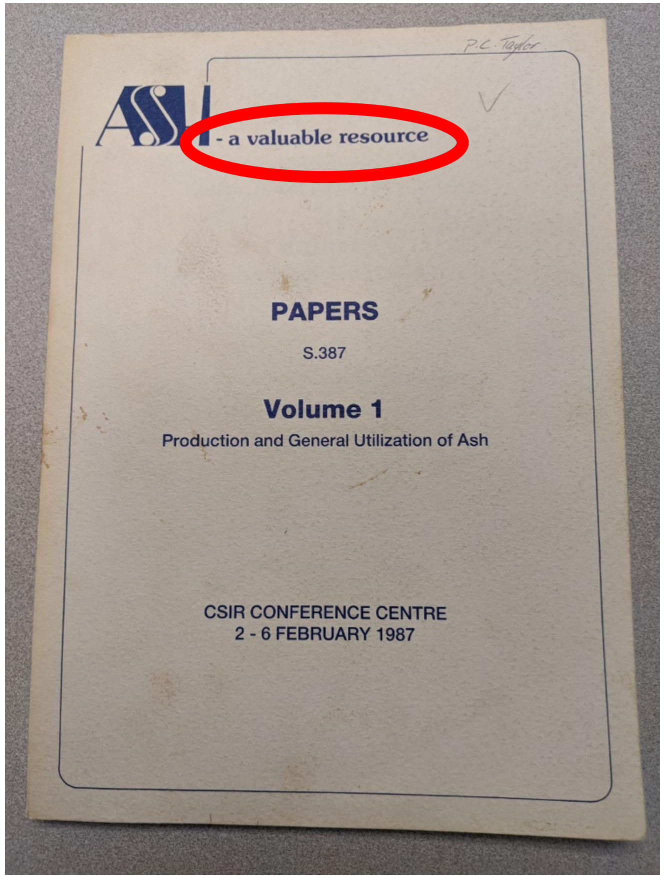
Overview

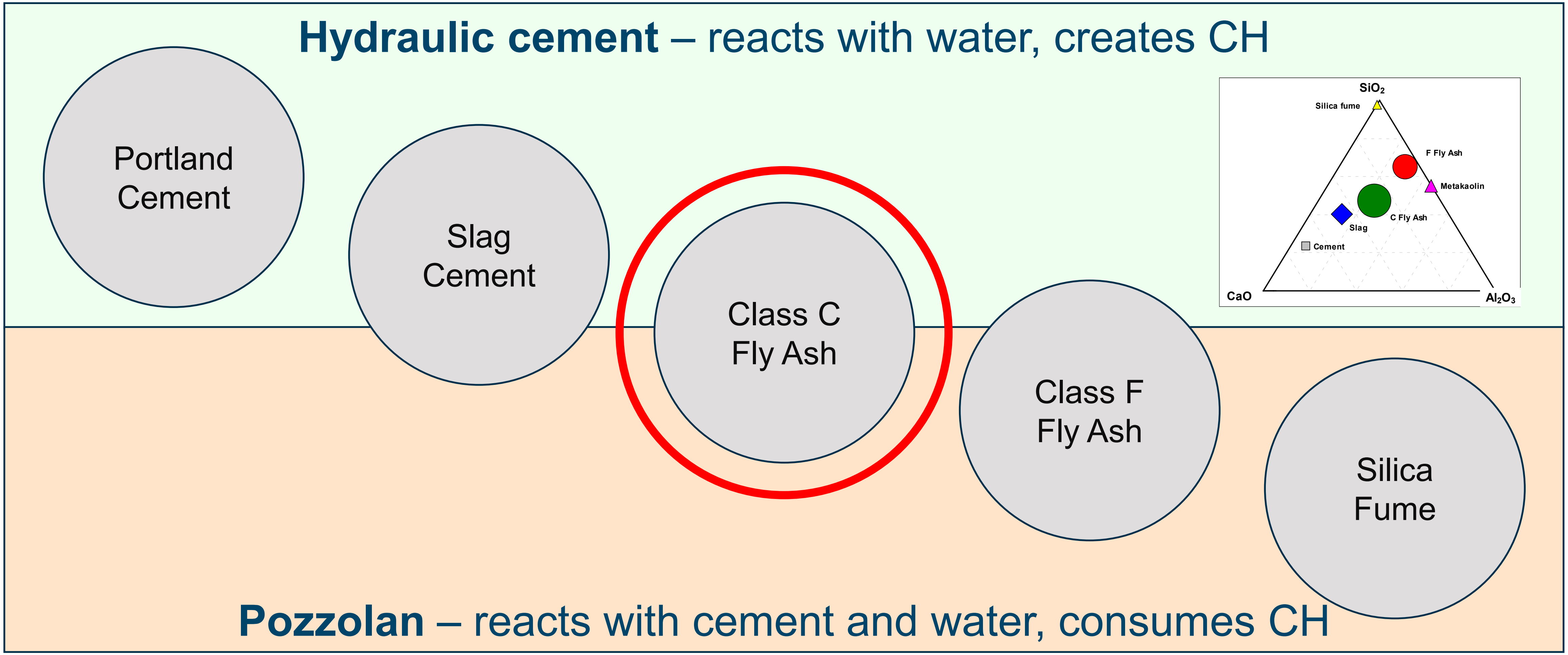
- Introduction
- Controlled mixtures
- Other products
- Impacts in Iowa
- Crystal ball gazing

Introduction

- Fly ash is amazing!
  - Less expensive $
  - More workable
  - <u>Reduces permeability</u>
  - ASR / sulfate / oxychloride resistant
  - Cooler (lower heat of hydration)
- But…
  - There are no fly ash factories
  - Utilities are changing
  - 2020…



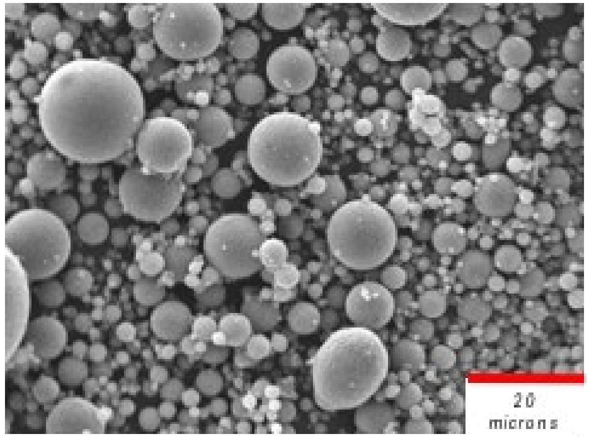
Cementitious Materials

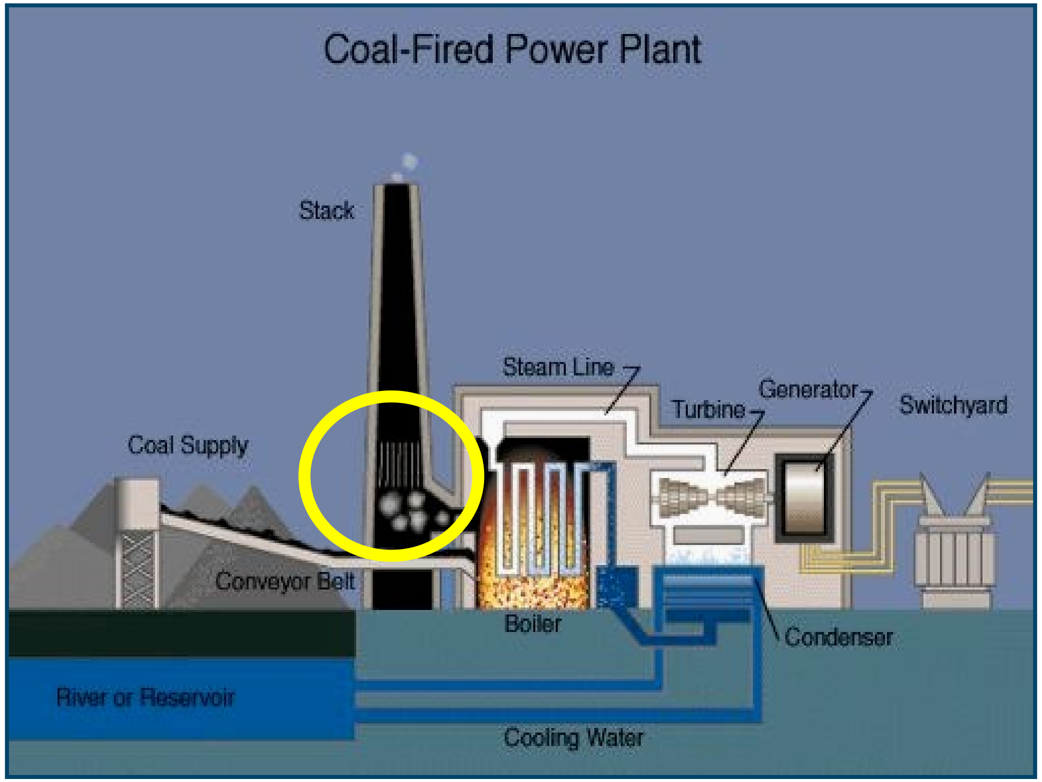


Not to scale

Fly Ash Production

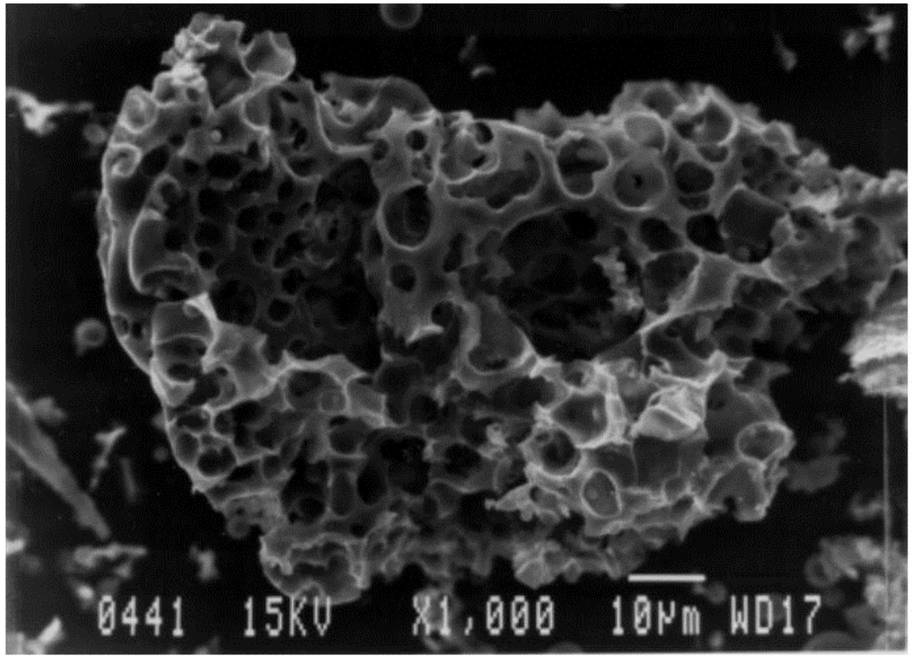
- By-product of combustion of pulverized coal
- During combustion
  - Volatiles & carbon burned off
  - Mineral impurities remain in flue gas
  - Fused materials cool into glass spheres





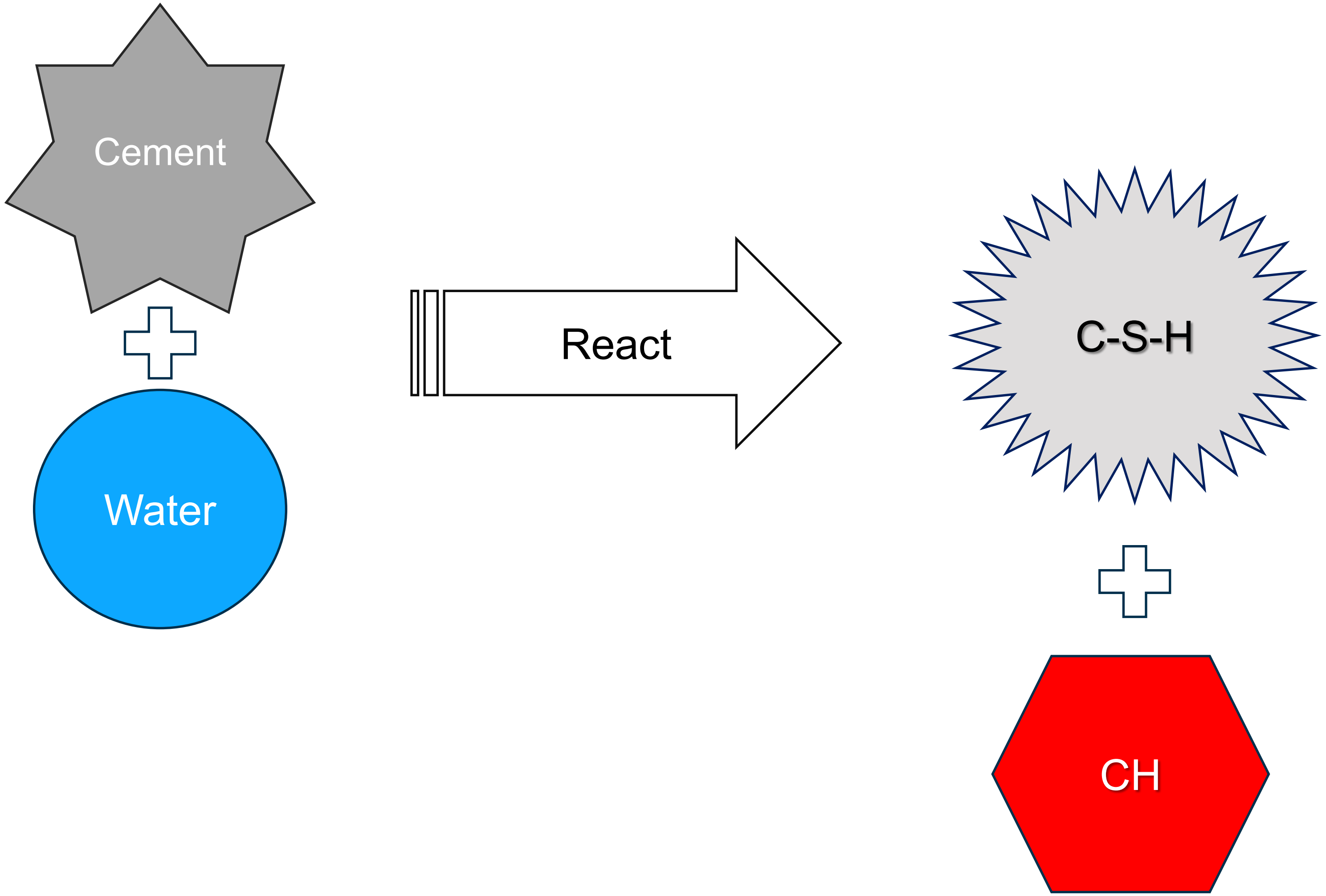
Fly Ash Contaminants

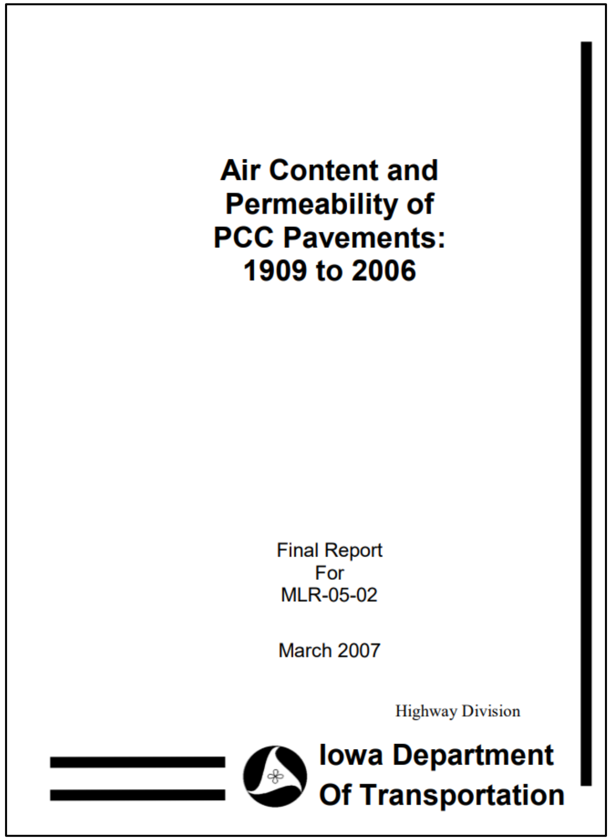
- Carbon (LOI)
  - Sucks up air entrainers
- Sulfates
  - Expansion
- Moisture
  - Handling, workability
- C_3A
  - Can contribute to incompatibility



Hwang, Sun, Li

How SCMs Work




Air Content and Permeability of PCC Pavements: 1909 to 2006

Final Report
For
MLR-05-02

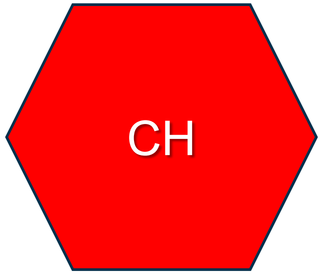
March 2007

Highway Division

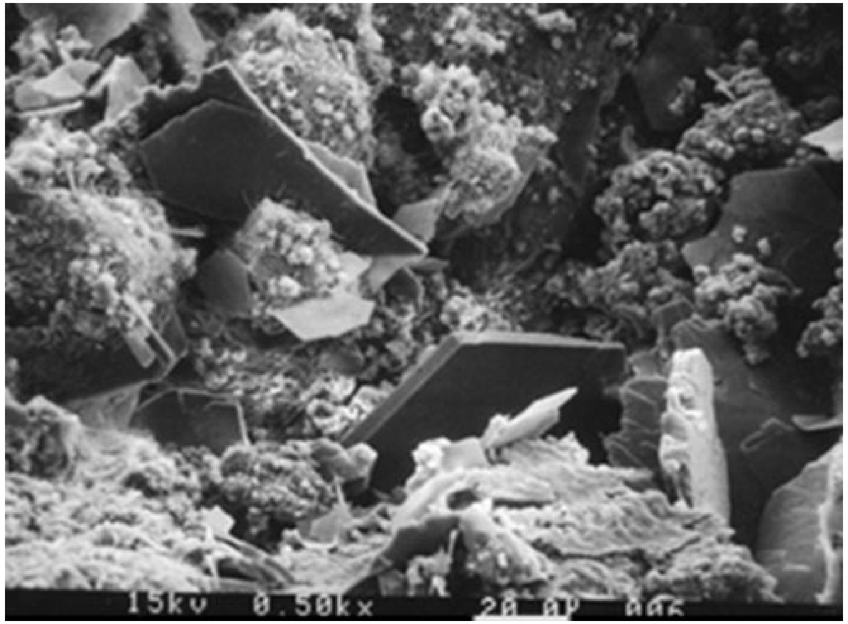
Iowa Department Of Transportation

https://iowadot.gov/research/reports/Year/2007/fullreports/MLR-05-02.pdf

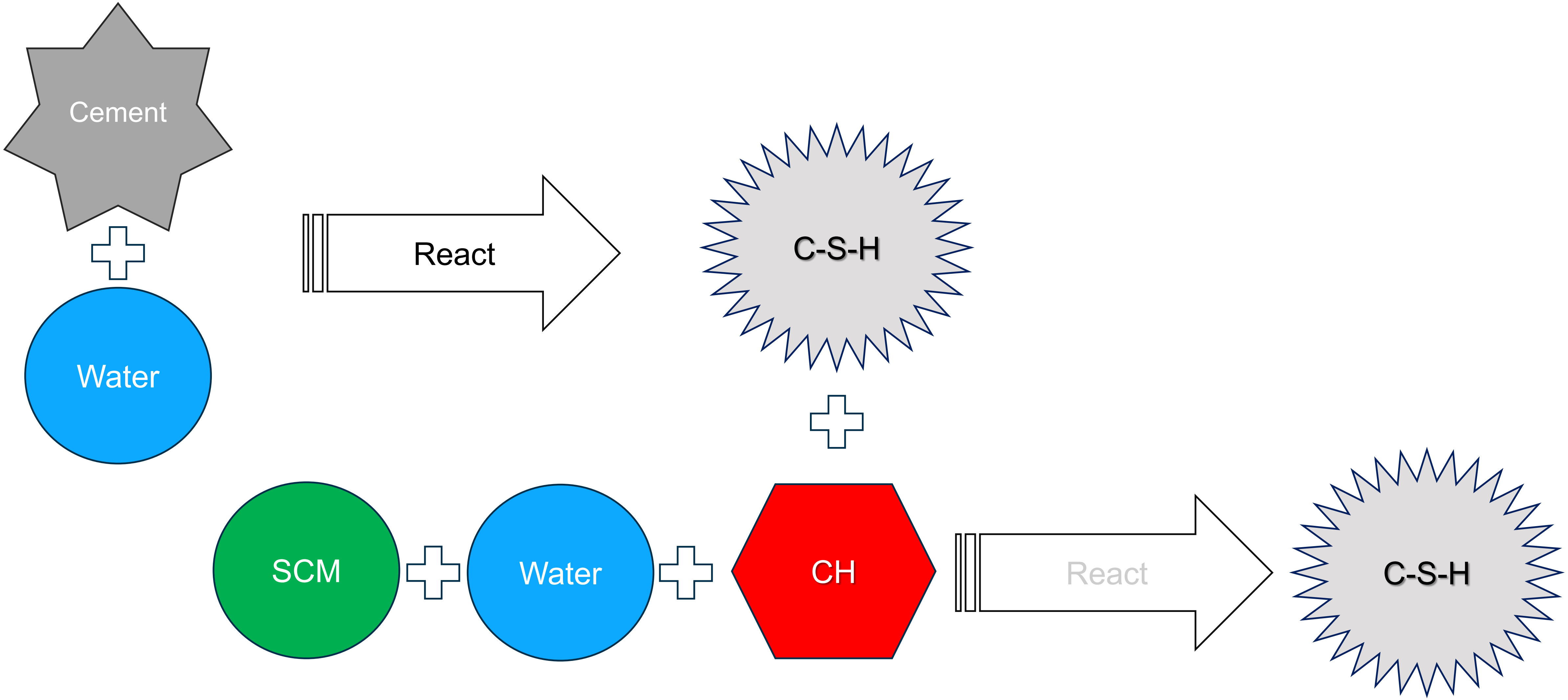
Calcium Hydroxide



- Good for raising pH and protecting steel
- Bad for
  - Oxychloride
  - Solubility
  - Shear strength

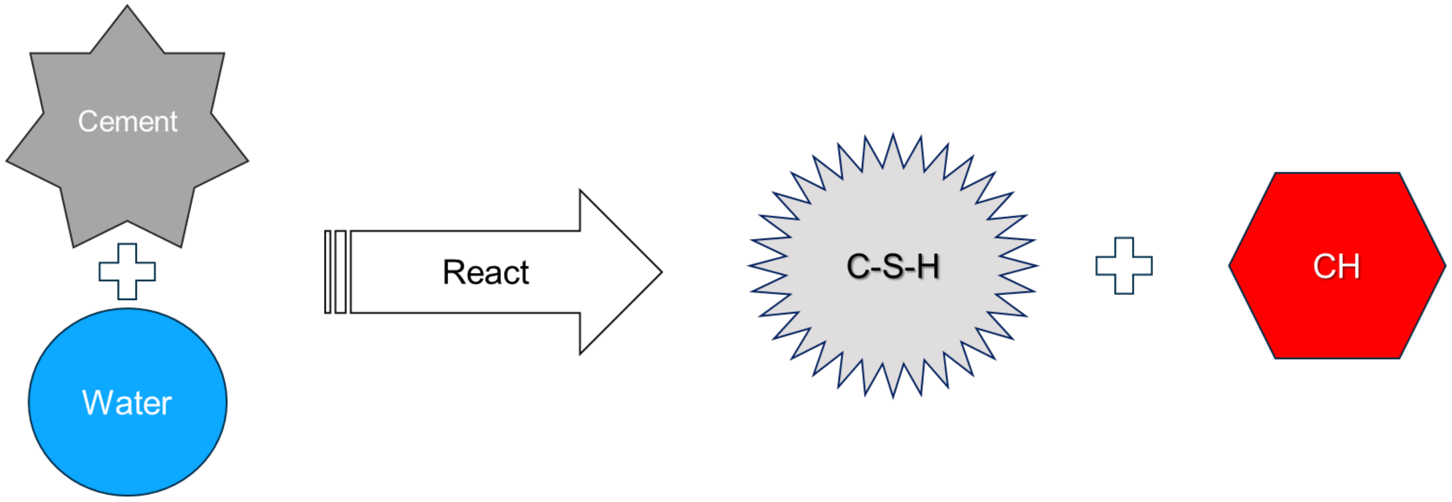


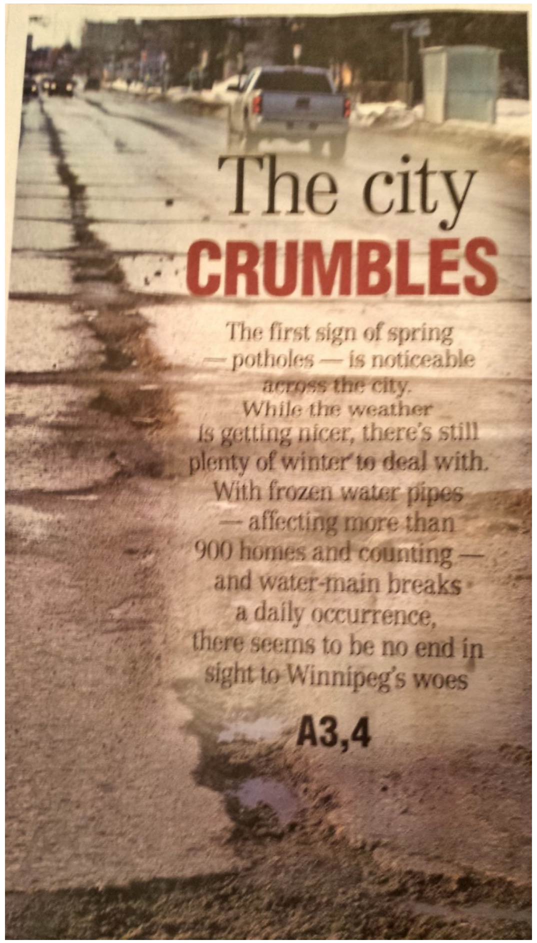
How SCMs Work



Introduction

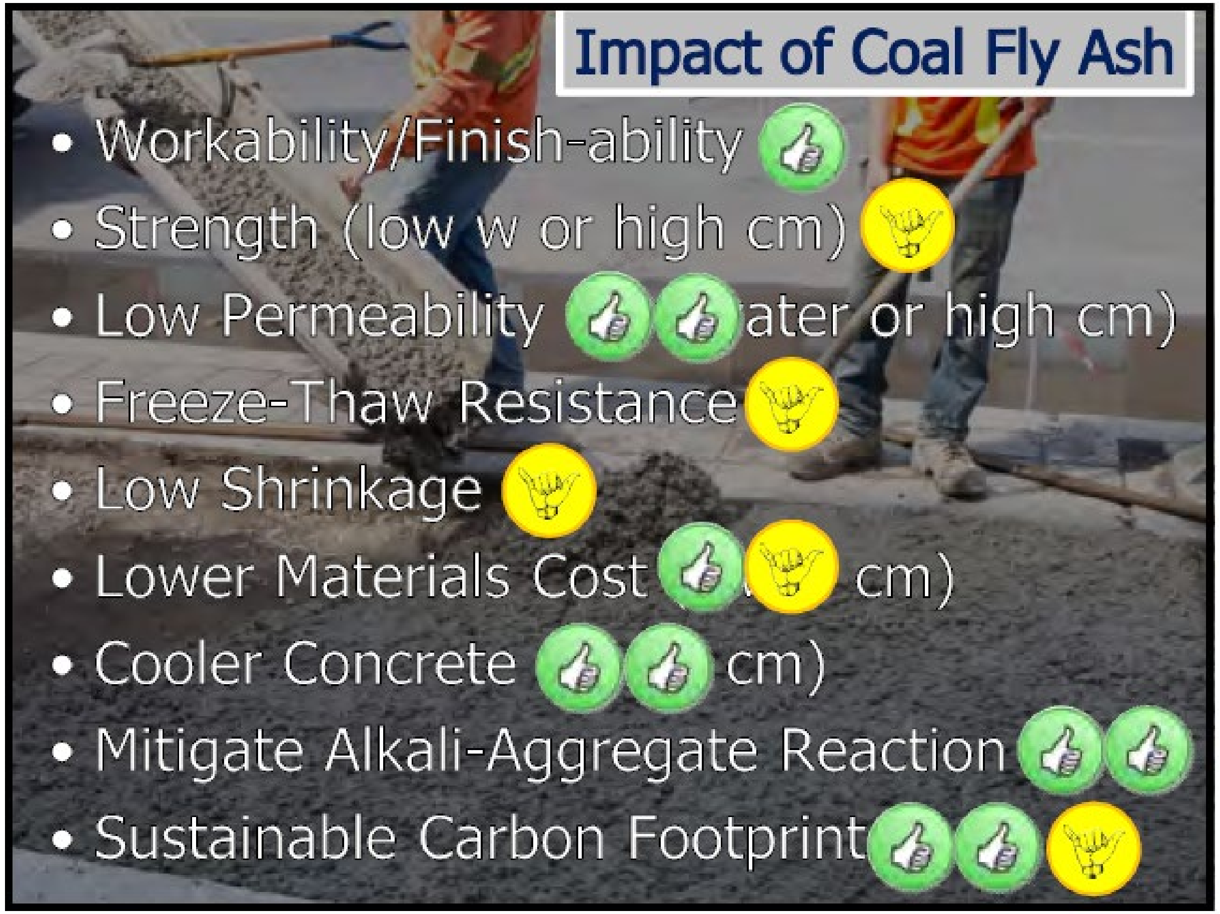
- Can we go back to this?





Introduction

- Review the benefits



Hover 2020

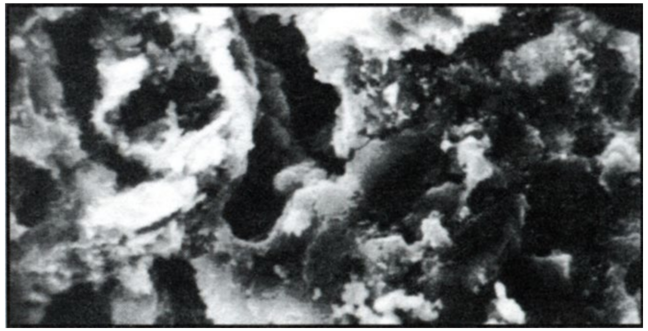
Workability

- Does workability matter to anybody other than the contractor?
  - “Add 10”
    - Hurts long term performance
  - The right vibration
    - How fast, how long
    - Moves air, water and aggregates
  - Aesthetics
    - Matter to the owner
  - Fly ash and admixtures help

Durability

- Durability is largely governed by permeability / transport
  - Most failure mechanisms involve water

- Getting low permeability
  - Low water/cement (MN history)
  - Appropriate SCM dose



Oxychloride

- MgCl2 and CaCl2
  - React with CaOH to form calcium oxychloride
  - Forms when temperature >32 ºF
  - Expands ~300%
  - Unstable at higher temperatures

- Prevented by using SCMs to reduce CH

Review

- What do we (really) need from fly ash
  - ASR
  - Oxychloride

Limited alternatives to fly ash

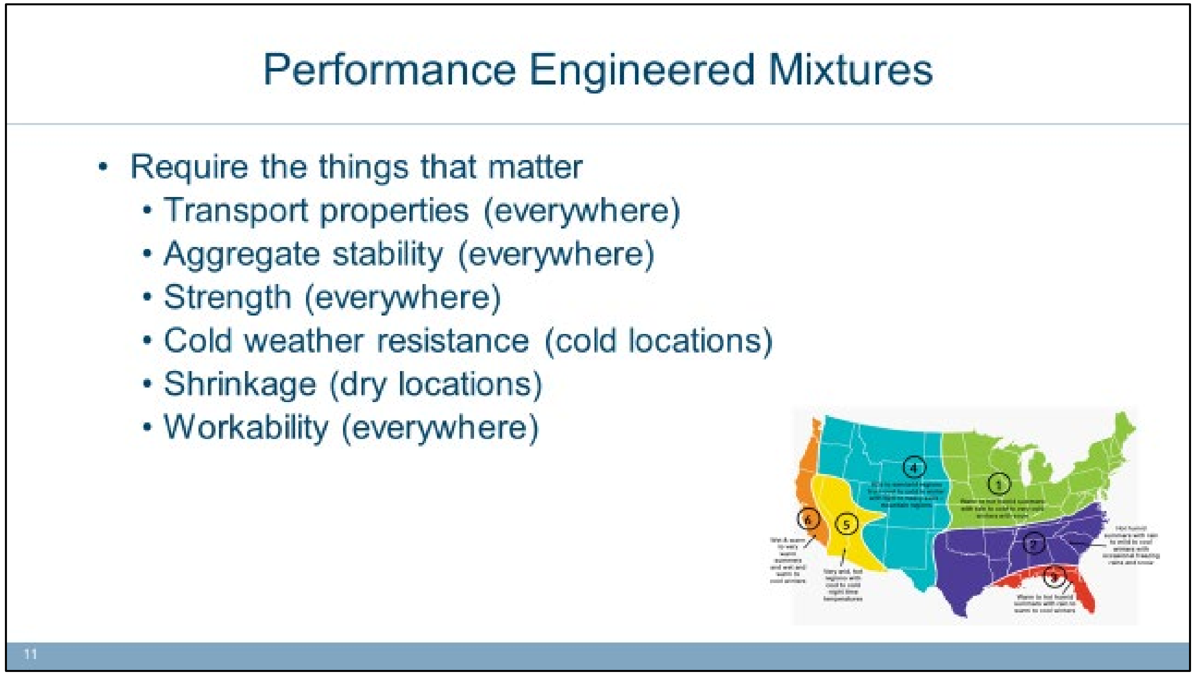
  - Permeability
  - Workability
  - Strength
  - Heat

Alternatives available

  - Sustainability
  - Cost

Controlled mixtures

- Prepare the mixture for the application
  - Use what you need (and no more)
  - From what you have
  - Control the cementitious content



Controlled mixtures

- Use what you need (and no more)
  - Its like balancing the family checkbook

  - ASR – depends on the aggregate
  - Oxychloride – depends on the cement

  - Permeability
  - Workability
  - Strength
  - Heat
  - Sustainability

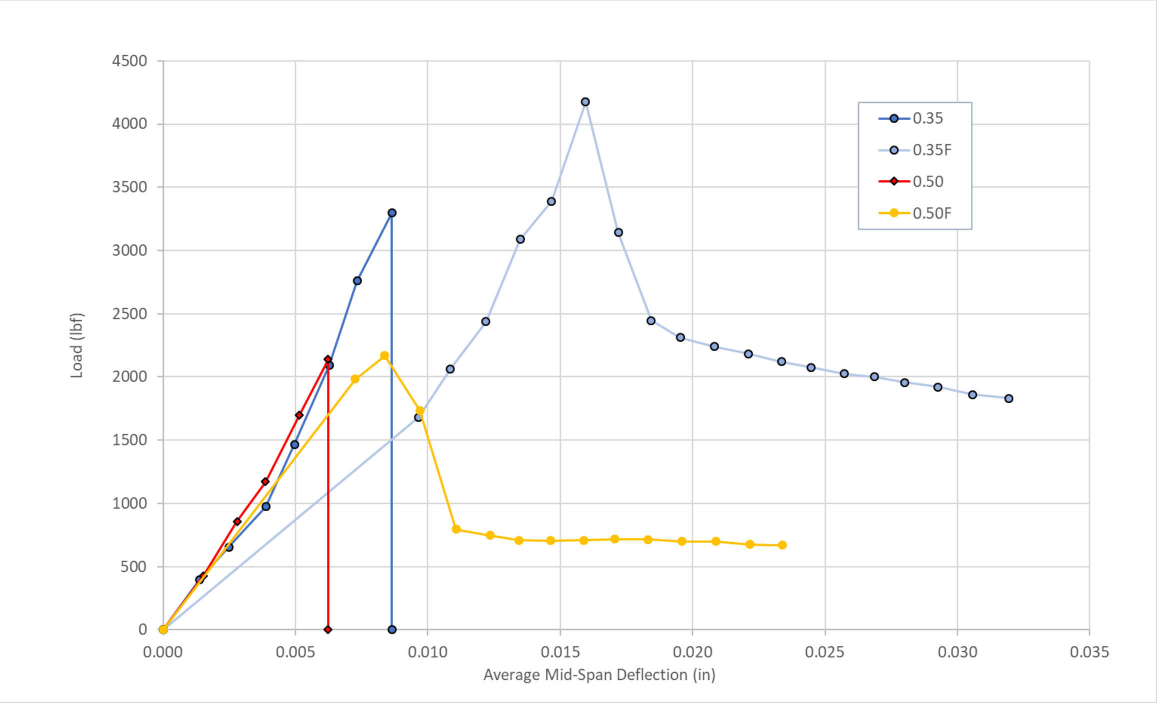
Limited alternatives

Alternatives available

True or False?

- More cement = more strength
- Strength is everything
- Slump indicates quality
- Stronger concrete is more “brittle”

BUSTED!

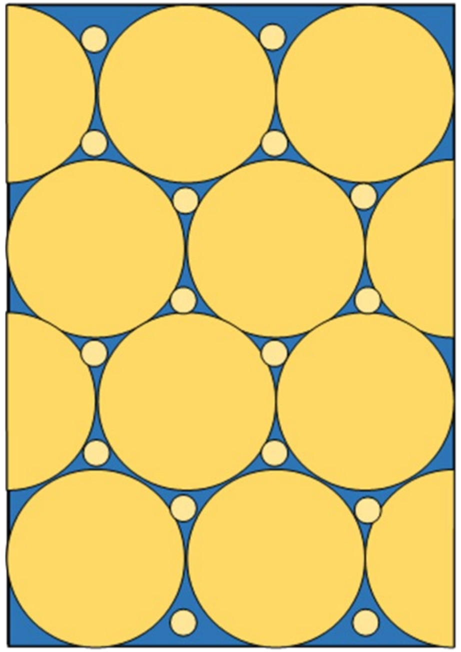


Controlled mixtures

- Control the cementitious content
  - With more cement you need more fly ash

  - Excess has a:
    - Negative effect on permeability, shrinkage, cost
    - Small negative effect on strength

  - “Optimum” depends on:
    - Aggregate type
    - Gradation

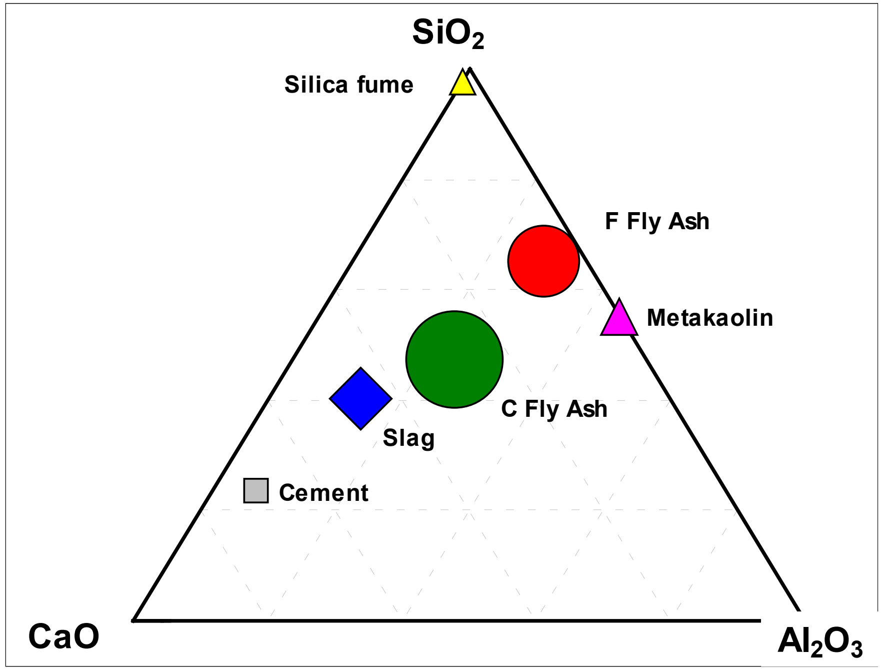


How do we proportion to achieve design goals?

		Workability	Transport	Strength	Cold weather	Shrinkage	Aggregate stability
Aggregate System	Type, gradation	✓✓	-	-	-	-	✓✓
Paste quality	Air, w/cm, SCM type and dose	✓	✓✓	✓✓	✓✓	✓	✓
Paste quantity	Vp/Vv	✓	-	-	-	✓✓	-

Controlled mixtures

- From what you have
  - Class C or F
  - Behave differently



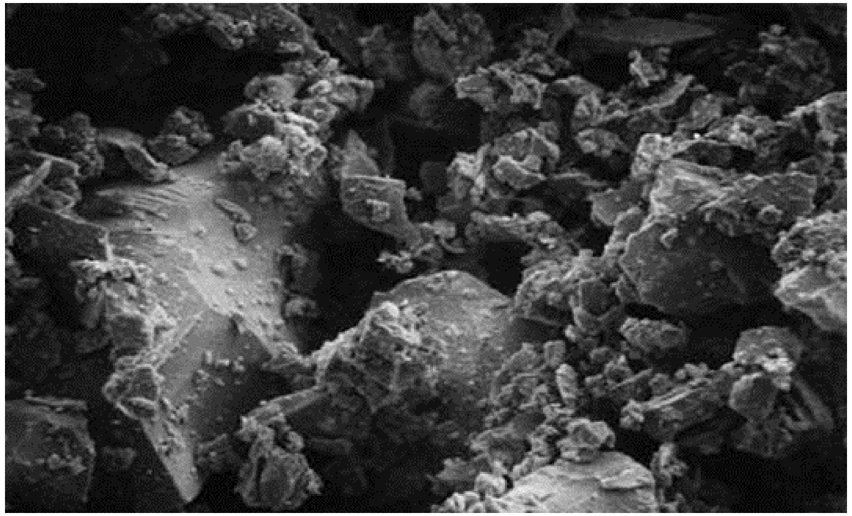
Other Products

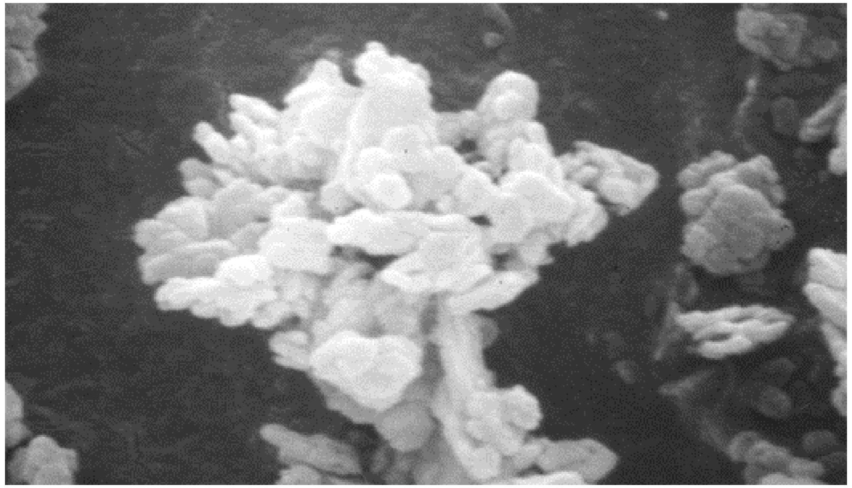
- Slag cement
- Metakaolin
- Other minerals like zeolite?

- Microspheres for f/t protection

- IP cements

- But…

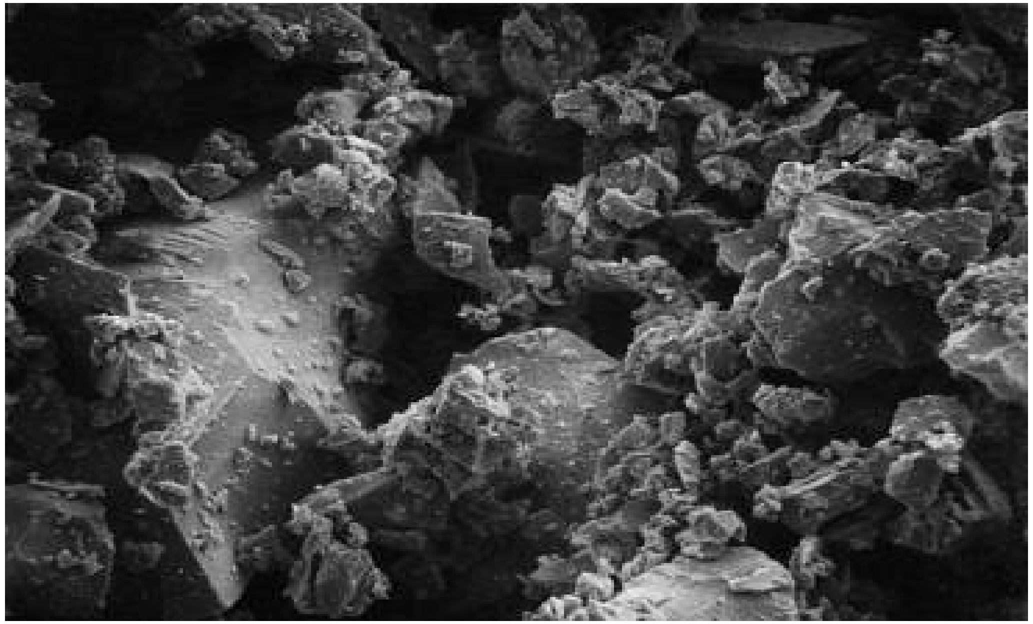




Sutter

But

- Do they do what we need?
- They change mix properties
- Cost
  - Particularly shipping
  - Is it worth it?
- Availability
  - “Free market?”



But

- Education
  - Every product has its own quirks
- Specifications
  - Have to be appropriate
  - AASHTO PP84
  - Iowa
    - DOT: QM-C
    - SUDAS: C-SUD

AASHTO PP84

- Require the things that matter
  - Transport properties (everywhere)
  - Aggregate stability (everywhere)
  - Strength (everywhere)
  - Cold weather resistance (cold locations)
  - Shrinkage (dry locations)

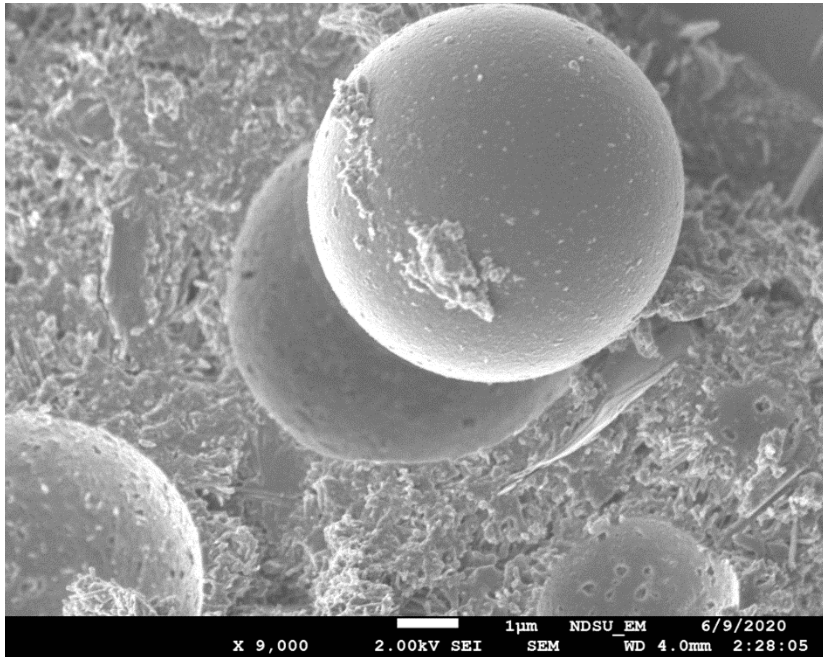
  - Workability (everywhere)

AASHTO PP84

- Measure them at the right time
  - Prequalification
  - Process control
  - Acceptance
- A buffet of approaches
  - Prescriptive: w/cm, paste volume
  - Performance: Formation factor

AASHTO PP84

- Allow contractor to develop the mixture to meet requirements
  - w/cm (within limits)
  - SCM dose (within limits)
  - Aggregate gradation
  - Iowa's QM-C and C-SUD mix specs are informed by these principles



Measuring what we need

- ASR
  - Follow AASHTO R80 / ASTM C1778
- Oxychloride
  - LTDSC
  - Expansion at 40°F

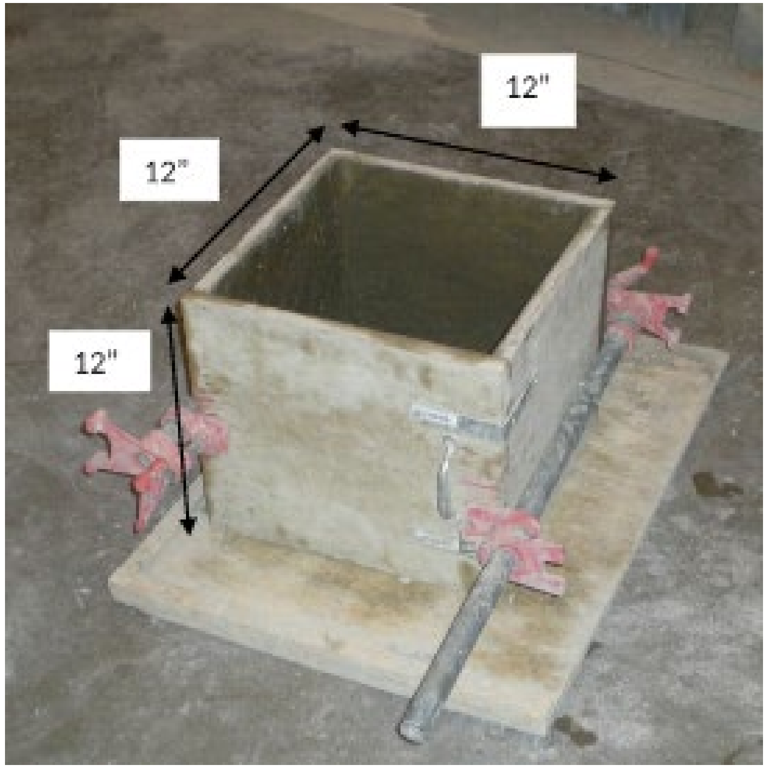
Measuring what we need

- Permeability / Transport
  - Resistivity
- Strength
- Heat
  - Calorimetry
- Air void system
  - SAM

Measuring what we need

- Workability
  - VKelly
  - Box

Measure the response to vibration



Fly Ash in Iowa

- Likely to continue seeing reduced fly ash production

- Events in 2020 causing a short-term supply crunch:
  - Mild winter
  - COVID-19

- Other issues
  - Consistency
  - Substitutes are not immediately available

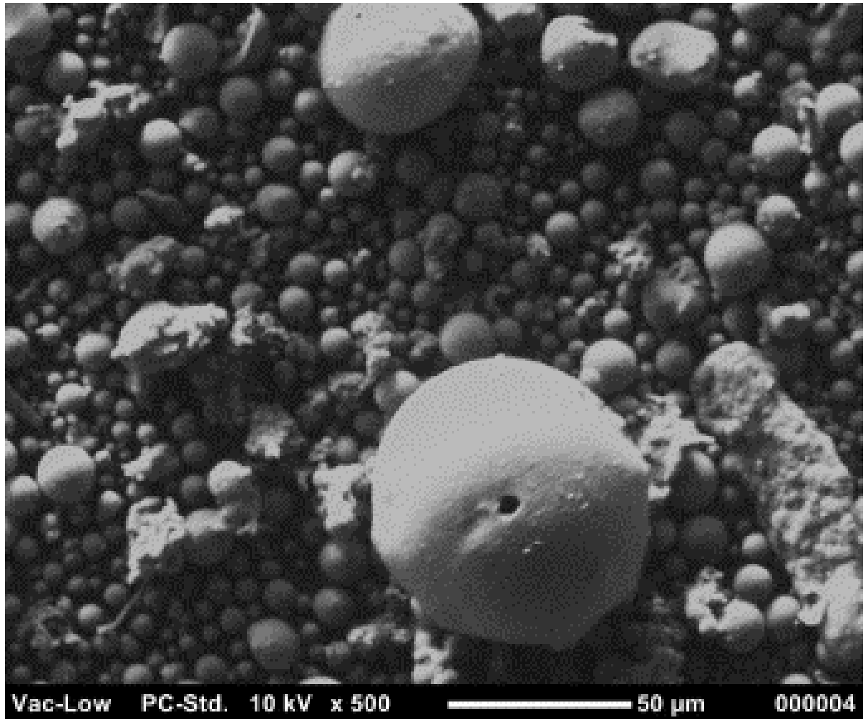
Iowa Specifications

- What can we do right now with our Iowa mixes to maximize durability?
  - Save the fly ash for where you need it
  - The C-SUD mix specification can be used regardless of fly ash content
  - Follow good principles (control the paste):
    - Lower total cementitious content via optimized gradation
    - Appropriate w/cm
    - Good air void system

The Future

- Blended ashes
  - “Good enough for engineering purposes”
  - Coming soon to Iowa?

- Reclaimed ash
  - Quality control
  - Transportation



The Future

- Reclaimed ash
  - CP Tech Center September 2020 Tech Brief:
  - Fly ash harvesting is being done in PA, SC, and WI, and should continue to expand

TECH BRIEF September 2020

Advancing Concrete Pavement Technology Solutions

USE OF RECLAIMED FLY ASH IN HIGHWAY INFRASTRUCTURE

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Summary and Disclaimers

The purpose of this Tech Brief is to describe the characteristics of harvested or reclaimed coal fly ash and identify considerations for its use in highway infrastructure. The document is intended for highway agency and contractor engineers.

The contents of this document do not have the force and effect of law and are not meant to bind the public in any way. While this is non-binding guidance, compliance with applicable statutes and regulations cited is required.

ASTM International and American Association of State Highway and Transportation Officials (AASHTO) standards are private, voluntary standards that are not required under Federal law. These standards, however, are commonly cited in Federal and State construction contracts and may be enforceable when included as part of the contract.

Introduction

Coal fly ash is an integral part of durable concrete for use in highway infrastructure. Historically, fly ash has been obtained directly from coal-fired power plants as it is being produced. Recent changes in fly ash production and availability, however, have resulted in challenges regarding both the supply and quality of fly ash in some markets, which in turn has caused providers to turn to a new source for the material, harvested fly ash.

Harvested fly ash is ash that was not used as it was produced but was instead deposited in landfills or impoundments for disposal. In many cases, the disposed ash is good-quality ash; there simply was not sufficient market demand for it to be used beneficially at the time of production. Harvested fly ash is becoming a principal source of fly ash for the concrete industry in some geographic areas and is soon expected to become a significant portion of the total fly ash supply.

Background

Fly ash is the airborne, non-combustible residue that results from coal-fired electric power production. Its use in concrete was first described in 1937 (Davis et al. 1937), but despite the compelling research presented in that early publication, fly ash was initially used only to replace the most expensive part of a concrete mixture (i.e., the portland cement) as a less expensive filler, not as a supplementary cementitious material (SCM).

Over time, largely in the last 50 years, concrete engineers have come to understand how to improve the properties of concrete by including fly ash in a concrete mixture, and fly ash has now become a common component in concrete.

Benefits of Fly Ash in Concrete

Workability – Replacing, on a weight basis, portland cement with fly ash, which typically has a lower specific gravity than cement, increases the paste volume if the water-to-cementitious material mass ratio (w/cm) is held constant. The volume of the concrete mixture typically is corrected by withholding an equal volume of fine aggregate. Increased paste content improves concrete workability.

The Future

- Local powders
  - Limited availability
  - Testing can be onerous (ASTM C 1709)
  - But all help is good help
  - Economics may be helping

Philosophical Ramblings

- What about those old pavements?
  - Cements have changed
  - Placement methods have changed
  - Curing!!!!!

  - Traffic has changed
  - Salting has changed

Philosophical Ramblings

- Life is changing – we have to adapt
- There are solutions
- We have to think
- Quality matters

- Call us if you need help

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