COLORADO READY MIXED CONCRETE ASSOCIATION

Ash an Expert...

A Prelude to Alternative SCMs

Bud Werner – CTL|Thompson, Inc.
Thomas Adams – American Coal Ash Association (ACAA)
Mark Van Kluenen – Skyway Cement Company
Tom McNamee – Master Builders Solutions
Joe Thomas – Magmatics/NPA
Jonathan Dennis – GCC of America, Inc.

April 27, 2021

1

A Brief History of Hydraulic Cement in Construction

COLORADO READY MIXED CONCRETE ASSOCIATION

Bud Werner – CTL|Thompson, Inc.
owerner@ctlthompson.com

2

Hydraulic Cement

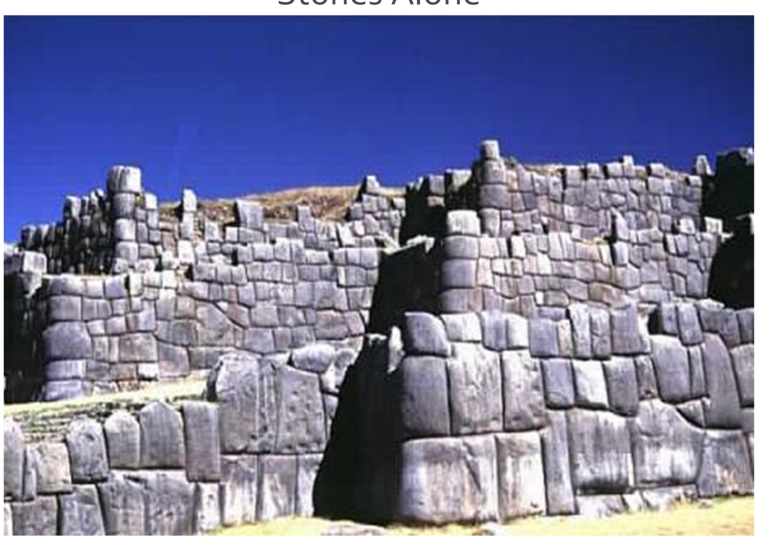
- Definition (ACI) – A binding material that sets and hardens by chemical reaction with water and is capable of doing so underwater.
  - Portland cement.
  - Natural cement.
  - Slag cement.
  - Class C fly ash.
  - Plaster of Paris

Strength in Numbers

3

Ancient Building with Earthen Materials

Stones Alone



Strength in Numbers

4

Stacked Stone Process

- Incredibly labor intensive
- Very slow process
- The “contractor” undoubtedly was looking for a better way.

Strength in Numbers

5

Ancient Building with Earthen Materials

Stones With Mortar

Egypt 2000BC

China 200BC-1600AD

Strength in Numbers

6

Ancient Building with Earthen Materials
Stones With Mortar

Egypt 2000 BC

- Some of the stones were found to be bedded with calcined gypsum (300C).
- Modern day term for this is Plaster of Paris.
- Controversy surrounds all the theories of pyramid construction.

China 200BC – 1600 AD

- Methods varied with age.
- Ming Dynasty construction included use of Plaster of Paris with a "rice pectin" admixture, one of few documented organic admixtures

Strength in Numbers

7

Ancient Building with Earthen Materials
Concrete and Mortar

- Roman Structures (Pantheon / Colosseum and many others)
- Built with calcined Limestone (840C-900C) ground up and mixed with about 85% volcanic ash from Mount Vesuvius, from near Puzzuoli. Ash became known as "pozzolana".
- Combination was later called "Natural Cement"

Strength in Numbers

8

Ancient Building with Earthen Materials

Concrete and Mortar

Crete

Santorini

- Greeks used calcined lime and Santorin Earth , a volcanic tuff from major modern eruptions on Thera.
- They also ground up ceramics to use as pozzolan

Strength in Numbers

9

The Advent of Portland Cement

Eddystone Rock Lighthouse

- In 1756 the third of 4 lighthouses built in this location was completed. Although it later was undermined, it was never totally removed.
- John Smeaton experimented with production of lime by including some clay in the feed – and found it improved its strength properties.
- Trass (Rhine region volcanic material) was combined with the Smeaton cement.
- In spite of Smeaton's experiment, not much improvement was made to his lime for about 100 years.

Strength in Numbers

10

The Advent of Portland Cement

- In 1842, Joseph Aspdin patented Portland Cement.
- He calcined limestone, broke it up and mixed it with clay and water, calcined it yet again and ground it up.
- It is called Portland Cement because of Aspdin's observation that the hardened cement resembled stone bluffs surrounding the Isle of Portland.
- This new product did not take off quickly. Aspdin's son took over its promotion. A man named Charles Johnson noticed that when some of the clinkers were "over burned", they made excellent cement when ground up. Modern day cement is calcined at about 1450C.

Strength in Numbers

11

The Use of Portland Cement in the Past 150 Years

- People started putting stones and sand in mortar.
- Germany formed their own "Portland Cement Assn." in about 1870
- The world started to be more scientific in its development – better tools and more scientific understanding.
  - Petrography was instrumental in understanding the Bogue reactive component composition of cement (C_3S,C_2S,C_3A,C_4AF)
  - Thermal analyses became a useful tools.
- ASCE began formulating test methods to assess it.
- ASTM formed Committee C1 on Cement.

Strength in Numbers

12

Early Standards

- British Standard for Portland Cement – 1904
- First ASTM standard for Portland Cement – 1904
- ASTM Standard for Natural Cement (C10) – 1904
- First ASTM Standard C150 for Portland Cement – 1940
- Carnegie Institute, US Bureau of Standards, and (after 1926) the Portland Cement Institute did a lot of study and research on Portland Cement during the first part of the 20th Century.
- The British "Cement and Concrete Association was formed after WWII

Strength in Numbers

13

Advent of GGBFS (Slag Cement)

- By-product of iron production.
- Mixed with calcined lime in the 1700's to make mortar
- Iron ore is heated to 1500 °C to separate iron from the ore.
- Molten slag is granulated by quenching when dumped from the furnaces.
- Thus, we get "ground, granulated blast-furnace slag"
  - Now called "SLAG CEMENT"

Strength in Numbers

14

Advent of Fly Ash

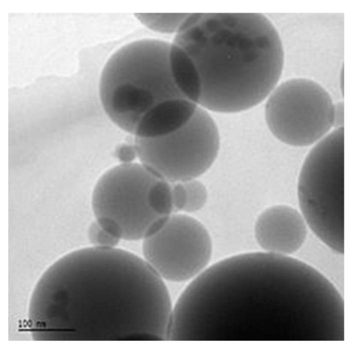
- Not as old as natural pozzolans.
- It gained attention in the 1950's and 1960's as powerplants became more sophisticated and the ash was cleaner and finer.
- USBR, COE, TVA all used it in water resource, hydraulic power and/or flood control structures in the mid 1900's.
- Originally Class F ash was used. The Class C ash was later as the Powder River Basin and similar lignite/sub-bituminous coals were mined for power plants.

Strength in Numbers

15

Advent of Silica Fume

- First tested in 1952
- Mostly not collected until the 1970's.
- By-product of the silicon chip production process.
- Extremely fine in comparison to other pozzolans. (100 times finer than most)
- It became commonly used in the 1980's.
- There is a limited supply.



Strength in Numbers

16

Advent of Metakaolin

- Just a natural pozzolan on steroids.
- Kaolin clay calcined to 700 °C ±50?
- Ground very fine, finer than cement, not as fine as silica fume.
- Used in high performance concrete.
- I remember it first becoming available in the 1970's.
- No separate ASTM specification for it was ever published.

Strength in Numbers

17

Fly Ash State of Affairs

COLORADO READY MIXED CONCRETE ASSOCIATION

Thomas Adams – American Coal Ash Association (ACAA)
thadams@acaa-usa.org

18

ACAA Mission

- The mission of the American Coal Ash Association is to encourage beneficial use of CCP in ways that are
  - *environmentally responsible,*
  - *technically sound,*
  - *commercially competitive,*
  - *supportive of a sustainable global community.*

ACAA
AMERICAN COAL ASH ASSOCIATION

Strength in Numbers

19

What is the state of supply today and why?

- On a national level, some regions are experiencing a significant gap between supply and demand.
- Primary reason for this gap: demand has been increasing while coal-fueled generation has been decreasing
- About 6 years ago, coal fueled about 50% of the generation of electricity
- Today, coal accounts for 20% to 25% of generation
- Base-load generation has declined
- Coal plants are now running mostly in very hot and very cold weather conditions

Strength in Numbers

20

State of Supply - continued

- 2009: U.S. Environmental Protection Agency (EPA) started an attempt to regulate fly ash and other coal combustion products (CCP) as a hazardous waste.
- Many older coal-fueled plants began to hit retirement age or became uneconomical to retrofit to meet increasingly stringent EPA standards
- Combustion stream injections made some fly ash unsuitable for use in concrete
- Fracking caused a rapid increase in supplies of natural gas
- As natural supplies increased, gas prices decreased dramatically
- Fossil fuels became a primary target of environmental activists

Strength in Numbers

21

There is fly ash not in use

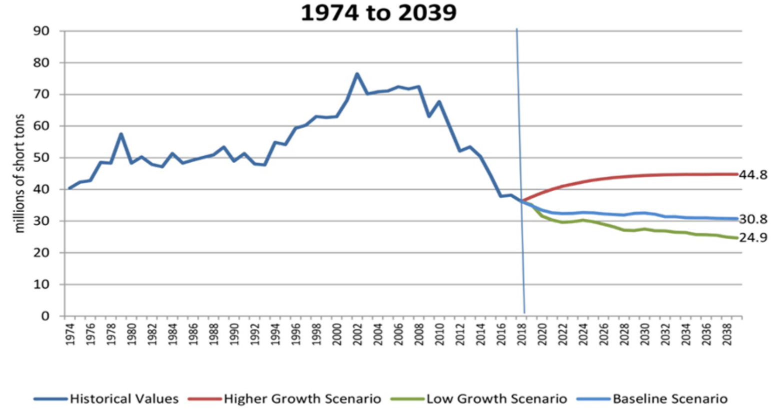
- *Each year millions of tons of fly ash produced goes to disposal rather than into beneficial use.*
- Primary Reason #1 – Dislocation
- Primary Reason #2 – Quality
- 2015 to 2019 185.9 m tons of fly ash produced
- 2015 to 2019 108.7 m tons of fly ash used in all beneficial uses
- 2015 to 2019 69.4 m tons of fly ash used in concrete
- 2015 to 2019 **77.2** m tons of fly ash **not used**

Strength in Numbers

22

Fly Ash Production Forecast

Figure 1. Various Scenarios for Fly Ash Production, 1974 to 2039



Strength in Numbers

23

Fly Ash Production Forecast

2018 to 2039

Table 1. Fly Ash Forecast Scenarios (in millions short tons)

	Volume 2018	Projected Volume 2039	Projected Total Change	Projected Avg. Annual Growth Rate
Fly Ash Production				
Baseline Forecast	36.2	30.8	-14.9%	-0.8%
High Growth Scenario	36.2	44.8	23.8%	1.0%
Low Growth Scenario	36.2	24.9	-31.2%	-1.8%
Fly Ash Utilization	20.1	27.8	38.3%	1.6%

Strength in Numbers

24

What is "harvesting"?

- "Harvesting" is the term selected by consensus to describe to process of removing coal ash from disposal – dry and wet – for beneficial uses.
- Why "harvesting'?
- Disposal of coal ash occurs in landfills and surface impoundments (a.k.a. ponds)
- Coal ash comingled with other materials is likely not to be a candidate for processing for concrete manufacture
- Coal ash in monofills is the target
- Over 2.5 billion tons in disposal in the U.S.

Strength in Numbers

25

Summary

- There are millions of tons of fly ash being produced annually that are not being used.
- Fly ash production is expected to remain fairly constant for the next 15 to 20 years.
- Harvesting will close or eliminate the gap between supply and demand in some regional markets.
- Specification changes can assist with alleviating shortages in some markets.
- Beneficiation technologies are available but can be costly.

Strength in Numbers

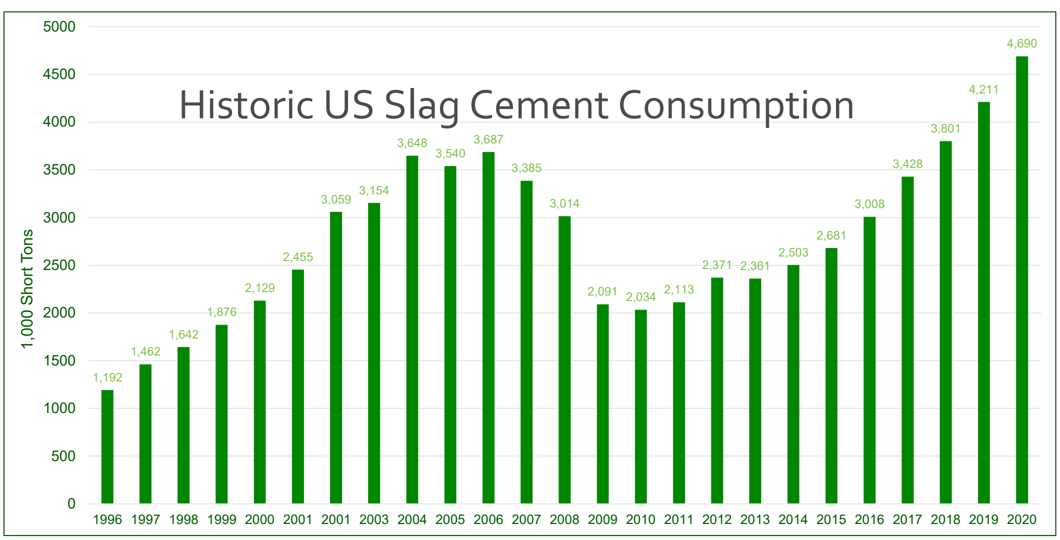
26

Slag Cement in the U.S.

COLORADO READY MIXED CONCRETE ASSOCIATION

Mark Van Kleunen, LEED AP – Skyway Slag Cement
mvankleunen@skywaycement.com

27

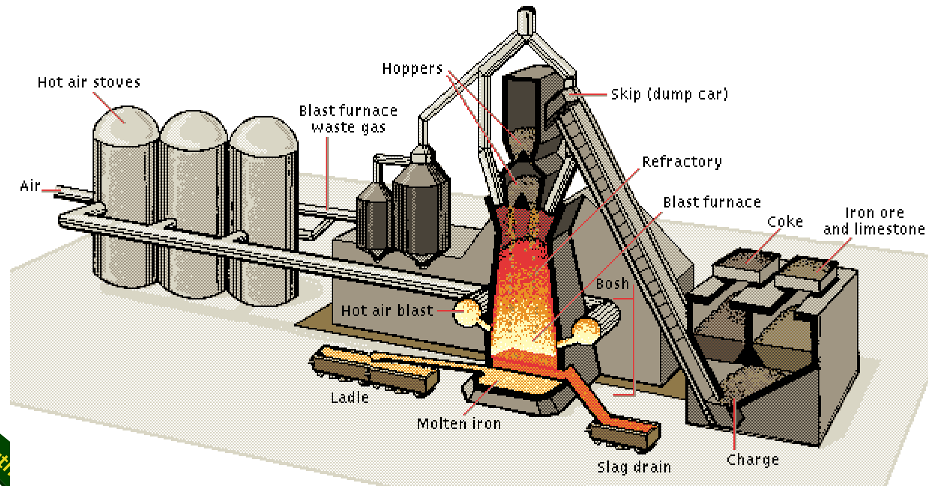


2020 US Cement Consumption – 112,000,000 short tons
2019 US Fly ash Consumption For Concrete – 12,600,000 short tons

Strength in Numbers

28

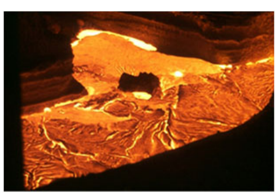
Slag Comes From an Iron Blast Furnace for Manufacturing Steel

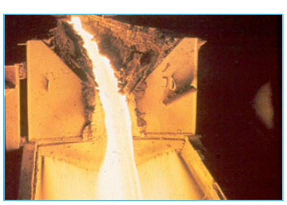


Strength in Numbers

29

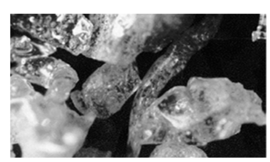
Granulation Process


Slag floating on top


Hot Blast Furnace Slag (BFS)


Slag Diverted to Granulator
High pressure water
6 - 10 tons water/ton slag


Slag is changed to glassy sand like substance known as granulated blast furnace slag - GBFS



Air cooled slag is used for aggregate

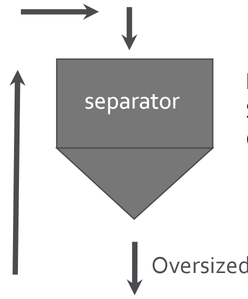
Strength in Numbers

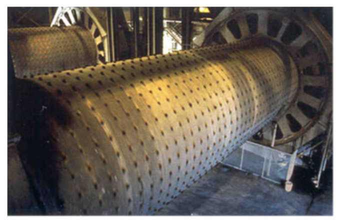
30

Making Slag Cement

Slag cement plant

Granules





Ball Mill

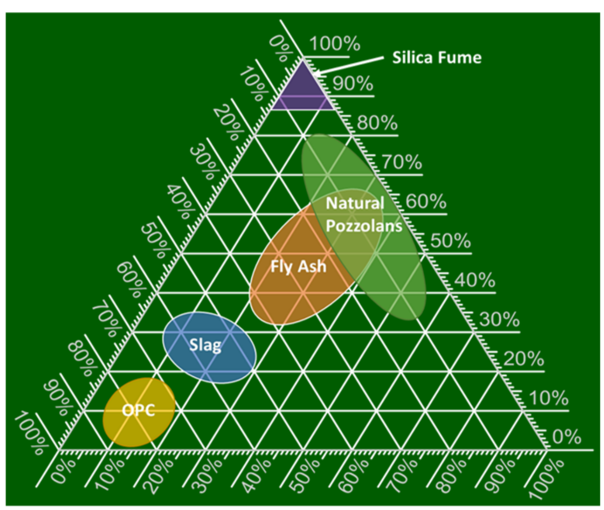
Finished product
Slag Cement /
GGBFS

Product	Blaine (m²/kg)
Slag Cement	500 - 650
Type III	550 - 650
Fly Ash	400 - 450
Type I	350 - 420

Strength in Numbers

31

Ternary CaO-SiO_2-Al_2O_3 Diagram



Strength in Numbers

32

Slag-Activity Index ASTM C989/AASHTO M302

	Min. 28-day
	% of Reference
Grade 100	95
Grade 120	115

A 50% cement / 50% slag cement is compared to 100% Reference cement at the various ages.

The reference cement used has a lot to do with determining the grade of slag cement (Alkalies: 0.60 – 0.90% & 5,000 psi @ 28 days).

Strength in Numbers

33

Slag Cement's Effect on Concrete Properties

General Concrete Properties			
Fresh Concrete		**Hardened Concrete**	
Reduces Water Demand	↓	Lower Early Strength	↓
Improves Workability	↑	Much Higher Later Age Strength	↑↑
Slower Bleeding	↑	Much Lower Permeability	↓↓
Slightly Lower Air Content	↓	Lowers Chloride Ingress	↓
Lower Heat of Hydration Mass Concrete	↓↓	Greatly Reduces ASR Potential	↓↓
Slower Setting Time	↓	Greatly Increases Sulfate Resistance	↑↑
Improves Finishability	↑	No Difference Freeze Thaw Resistance	←→
Improves Pumpability	↑	No Difference Abrasion Resistance	←→
No Difference Plastic Shrinkage	←→	No Difference Drying Shrinkage	←→

Strength in Numbers

34

Slag Cement Replacement %'s

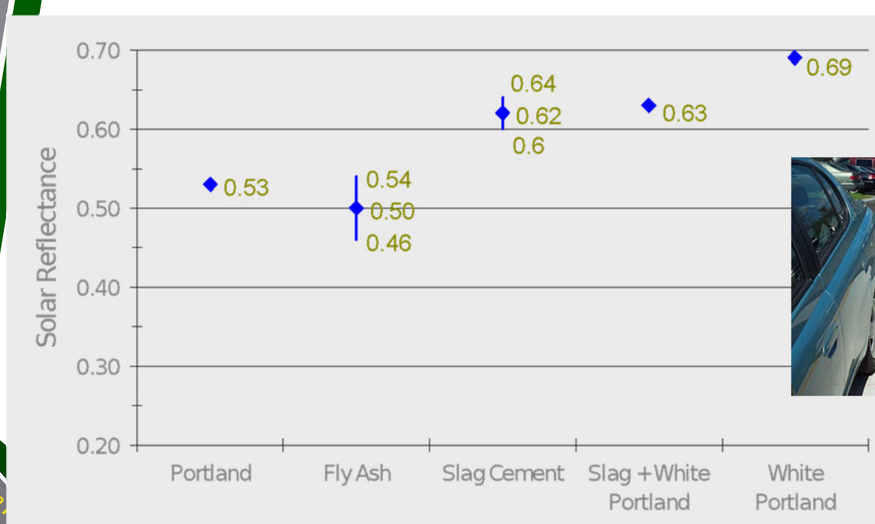
Application	Slag Cement %
Concrete paving	25 – 50 %
Exterior flatwork not exposed to deicer salts	20 – 35 %
Exterior flatwork exposed to deicer salts with (w/cm < 0.45)	10 – 15 %
Interior flatwork	25 – 50 %
Footings	30 – 65 %

Application	Slag Cement %
Masonry/Pavers	20 – 50 %
ICF	25 – 60 %
High strength	25 – 50 %
Tilt-up panels	25 – 50 %
ASR mitigation	25 – 50 %
Lower permeability	25 – 50 %
Mass concrete	25 – 70 %
Sulfate Resistance	
Type II equivalence	25 – 50 %
Type V equivalence	35 – 65 %

Strength in Numbers

35

Improved Reflectivity



36

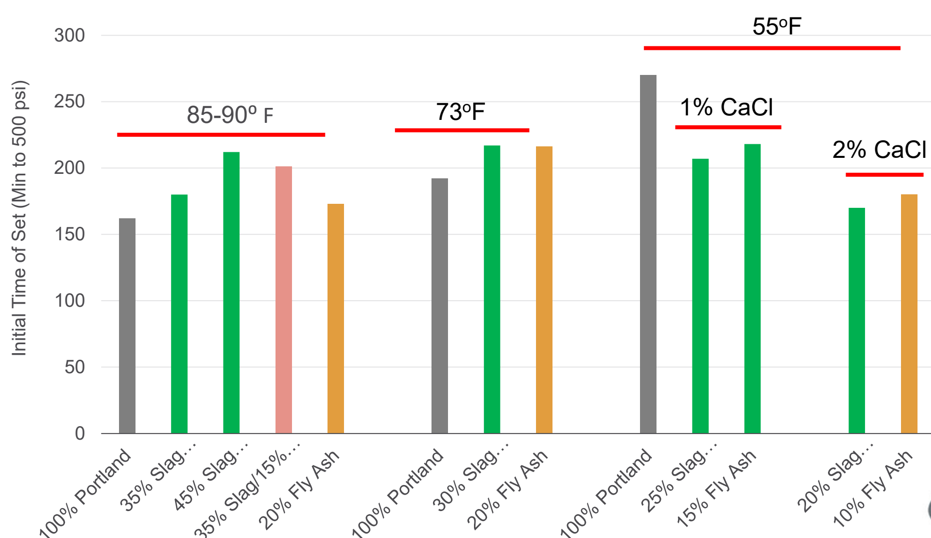
Greening

- "Greening" is a temporary blue-green color showing on the surface of concrete containing slag in the first few days after placement
- Occurs in small percentage of concrete made with slag, disappears within a week of exposure to air and sunlight (oxidizes)

Strength in Numbers

37

Effect on Initial Set Time

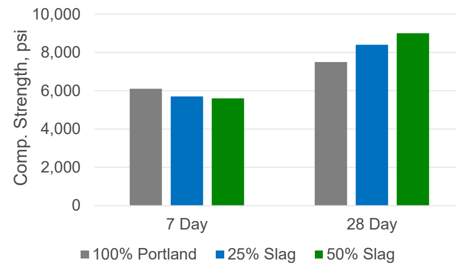


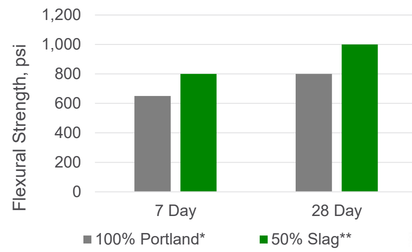
Strength in Numbers

38

Effect on Strength

- Higher 28-day compressive strengths
  - 1,000-2,000 psi higher
- Lower early strengths
- Typically matches portland strengths ~7 days
- Optimum strength replacement 35%-40%

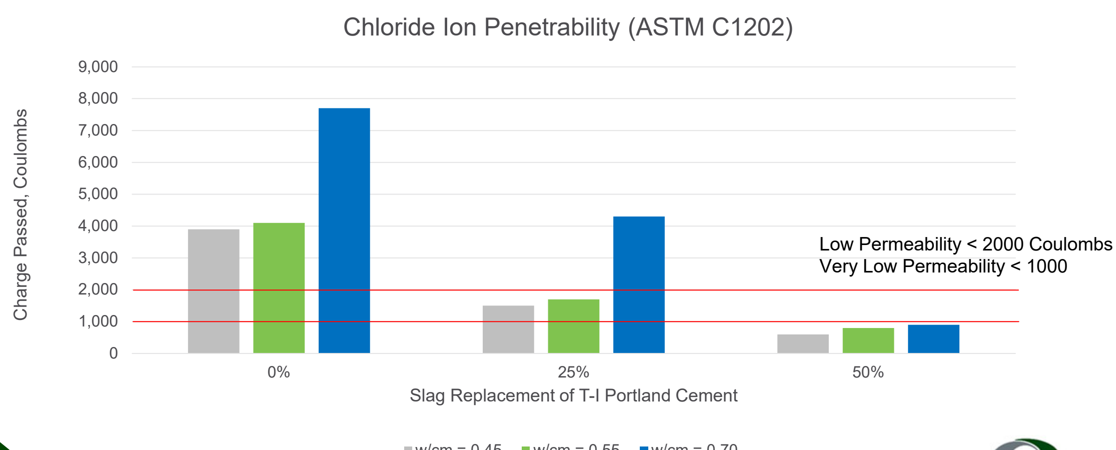




** 635 lbs/cu yd of cementitious*
*** 583 lbs/cu yd of cementitious*

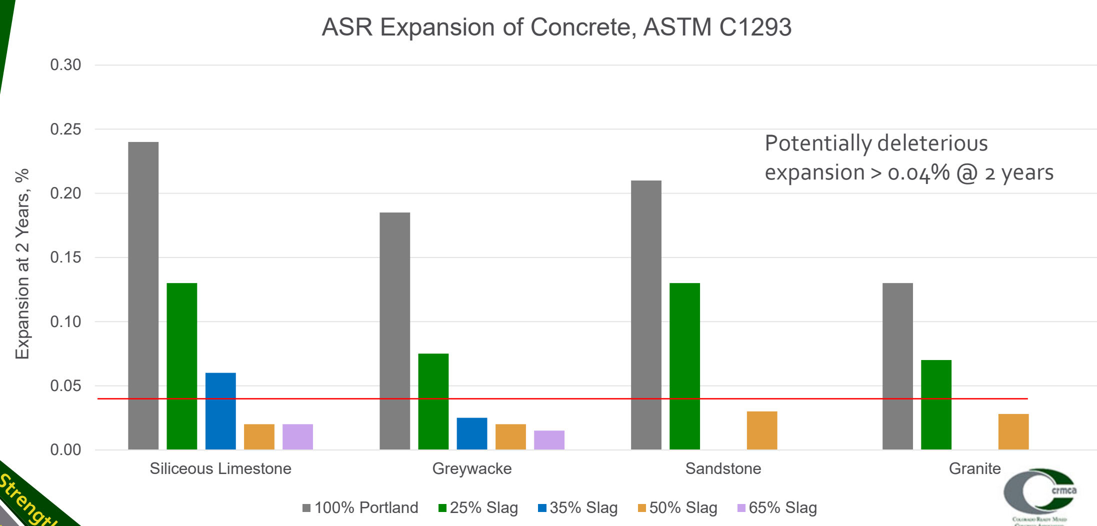
39

Effect of Slag Cement on Concrete Permeability



40

Effect of Slag Cement on ASR



Strength in Numbers

41

Silica Fume

Tom McNamee – Master Builders Solutions
Tom.mcnamee@mbcc-group.com

COLORADO READY MIXED CONCRETE ASSOCIATION

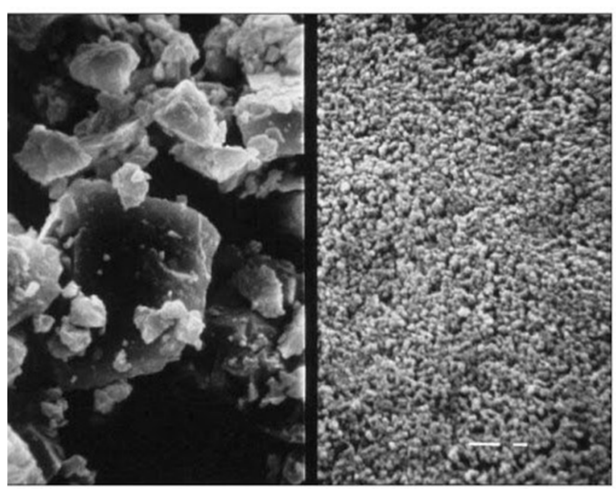
42

43

Silica Fume Products

BENEFITS:

- Increase the Durability of Concrete
- Produce High-Strength Concrete
- Reduces permeability
- Improved Sulfate and Corrosion resistance
- ASR Mitigation

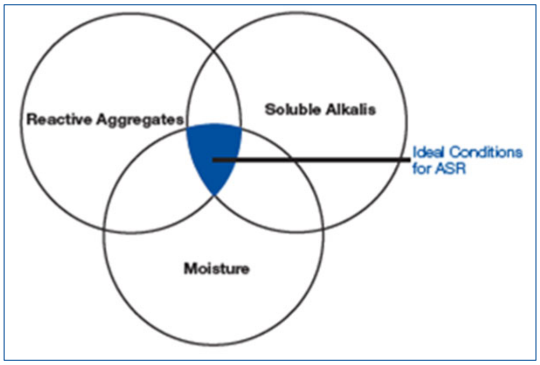


Strength in Numbers

44

Silica Fume
Mitigating ASR

- Limit alkali content in cement/concrete
- Restrict use of reactive aggregates (shipping in from different source)
- Use supplementary cementitious material
- Slag cement
- Fly ash
- Natural pozzolans
- Silica fume
- Metakaolin
- Use lithium admixture

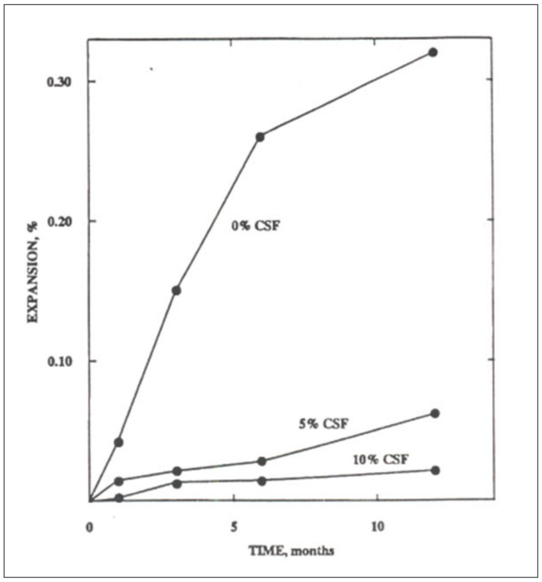


Strength in Numbers

45

Silica Fume
Mitigating ASR

- Silica fume is a highly efficient pozzolan
- Combines rapidly with alkalies in pore water
- Incorporates alkalies as substitutes for calcium in the hydrated cement gel
- Reduces diffusion rate of alkalies through the pores of concrete



Strength in Numbers

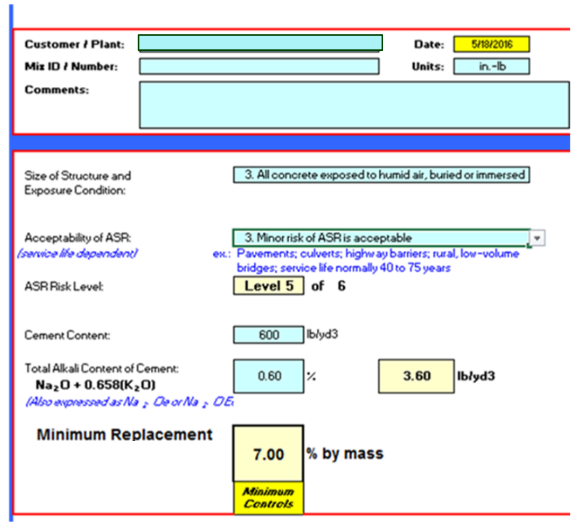
46

Silica Fume

Dosage Calculator

- Based on the recommendations provided in FHWA-HIF-09-001
  - Report on Determining the Reactivity of Concrete Aggregate and Selecting Appropriate Measures for Preventing Deleterious Expansion in New Concrete Construction
- 4 inputs = dosage calculated
  - External Technical Support Group should be contacted as needed

Note: If aggregate supplier or producer has ASTM C 1293 test data, the silica fume dosage can be adjusted / optimized



47

Silica Fume Concrete Production

- Measuring – Add silica fume
- Batching – Add with 70-90% of batch water, followed by aggregates, cementitious materials and then the remaining amount of water . Batch low slump concrete 1-3 inches
- Adding HRWR – Add at end, mix for 70 revolutions
- Mixing – Minimum of 100 revolutions

48

Natural Pozzolans

COLORADO READY MIXED CONCRETE ASSOCIATION

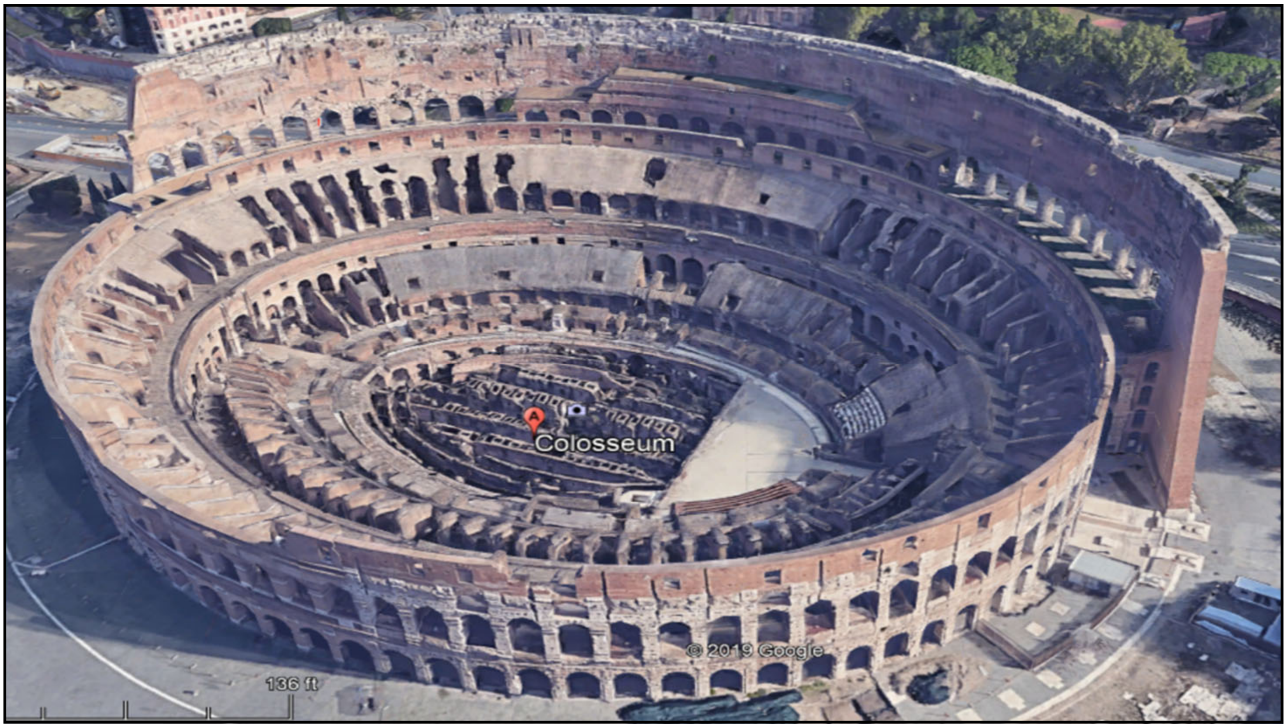
Joe Thomas – Magmatics/NPA
joe@magmatics.com

NPA NATURAL POZZOLAN ASSOCIATION
Established - March 2017
Website: http://www.pozzolan.org/

49

Strength in Numbers

50

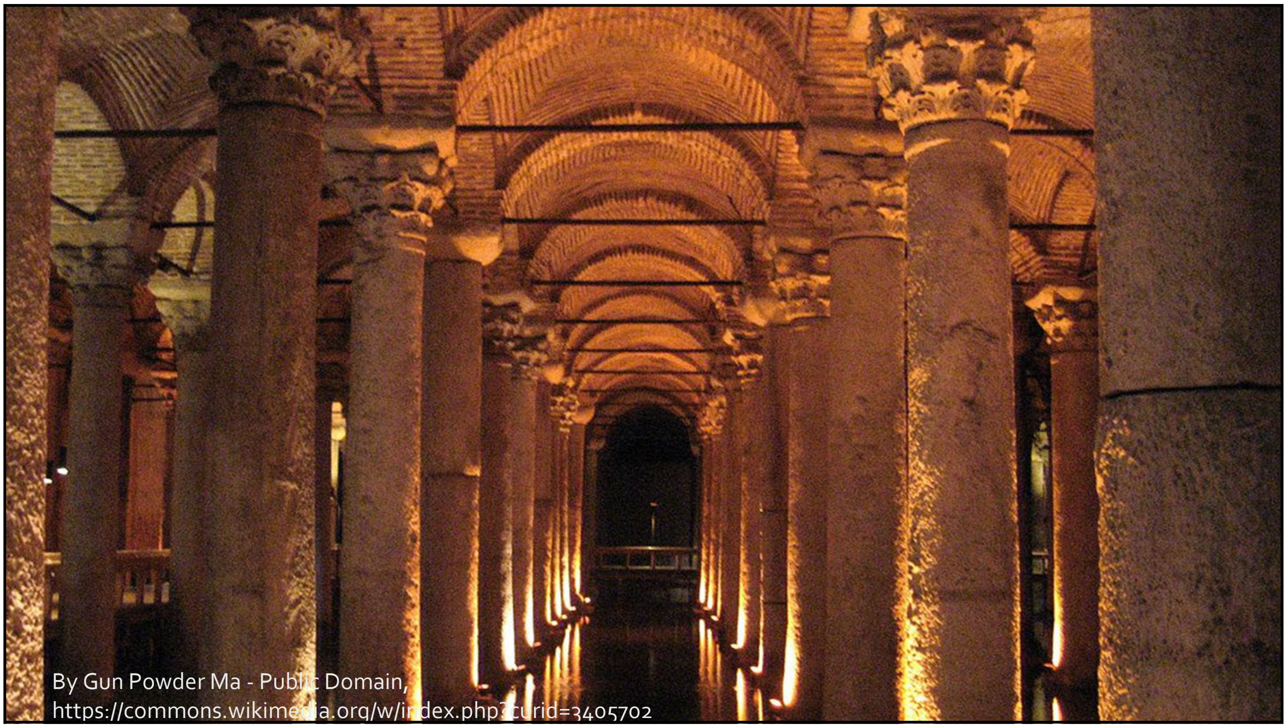


51

52

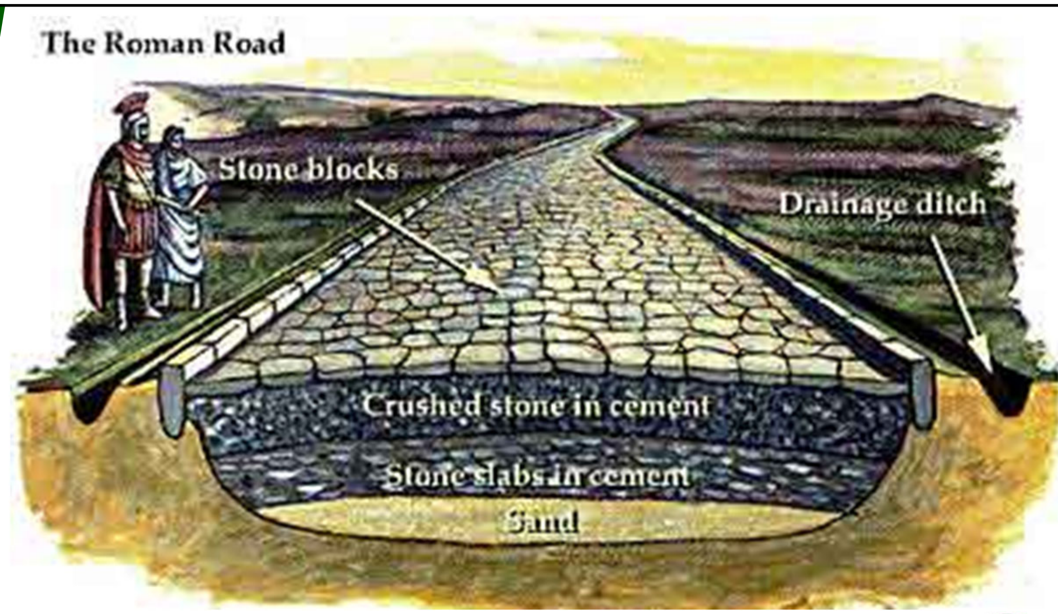
53

54


By Gun Powder Ma - Public Domain,
https://commons.wikimedia.org/w/index.php?curid=3405702

55

56



Strength in Numbers

57

Natural Pozzolans

- The word most associated with Roman Concrete is:
  Durability
- Concrete that lasts, often in pristine condition, for thousands of years, as opposed to 40 or 60 if we're lucky….so, what is this stuff made of?

Strength in Numbers

58

Natural Pozzolans

There are 2 types of Natural Pozzolans (NP):

- **Raw NP** (Volcanic ejecta-based materials – pumice, pumicite, volcanic ash, etc. Pre-calcined by Mother Nature)
- **Calcined NP** (such as MetaKaolin)

Strength in Numbers

59

Strength in Numbers

60

Strength
in Numbers

Roman Lime Kiln near Aachen GR

61

62

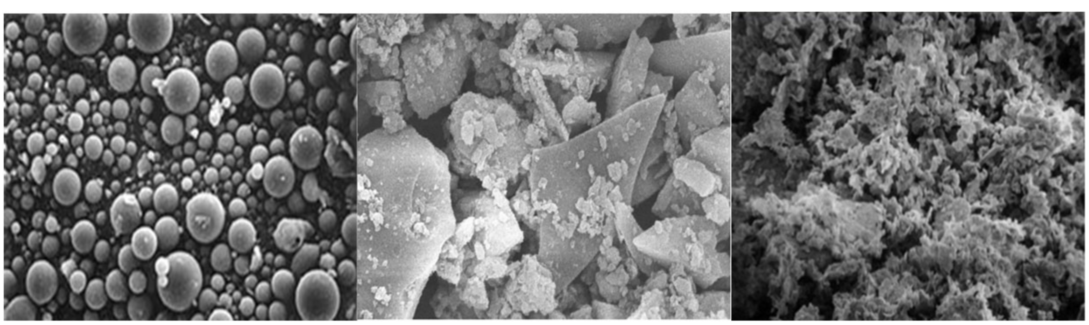
Natural Pozzolans

- **Roman Concrete:** "It's the most durable building material in human history, and I say that as an engineer not prone to hyperbole," Roman monument expert Phillip Brune told the Washington Post. *July 4, 2017, Washington Post*

Strength in Numbers

63

Physical and Chemical Properties of Natural Pozzolan



Fly Ash — Raw Natural Pozzolan — Metakaolin

Strength in Numbers

64

Chemical Analysis			ASTM / AASHTO Limits Class F	ASTM / AASHTO Limits Class C	ASTM Test Method
Silicon Dioxide (SiO2)	59.73	%			
Aluminum Oxide (Al2O3)	23.01	%			
Iron Oxide (Fe2O3)	4.47	%			
Sum of Constituents	87.21	%	70.0% min	50.0% min	D4326
Sulfur Trioxide (SO3)	0.37	%	5.0% max	5.0% max	D4326
Calcium Oxide (CaO)	4.84	%			D4326
Moisture	0.05	%	3.0% max	3.0% max	C311
Loss on Ignition	0.85	%	6.0% max 5.0% max	6.0% max 5.0% max	C311 AASHTO M295
Available Alkalies, as Na2Oe **When required by purchaser**	1.36	%	not required 1.5% max	 1.5% max	C311 AASHTO M295
Physical Analysis					
Fineness, % retained on #325	17.13	%	34% max	34% max	C311, C430
Strength Activity Index - 7 or 28 day requirement					C311, C109
7 day, % of control	84	%	75% min	75% min	
28 day, % of control	84	%	75% min	75% min	
Water Requirement, % control	95	%	105% max	105% max	
Autoclave Soundness	0.00	%	0.8% max	0.8% max	C311, C151
Density	2.25				C604

65

Chemical Composition (%)
(by Wyoming Analytical Laboratories, Inc.)

			ASTM C618-15 Class N
Total Silica, Aluminum, Iron:	*86.6*		70.0 Min
Silicon Dioxide:		*72.5*	
Aluminum Oxide:		*13.2*	
Iron Oxide:		*0.9*	
Sulfur Trioxide:	*0.1*		4.0 Max
Calcium Oxide:	*1.3*		
Moisture Content:	*1.5*		3.0 Max
Loss on Ignition:	*4.1*		10.0 Max
			AASHTO M295-11 Specifications
Available Alkalies (as Na_2O):	*1.5*		1.5 Max
Sodium Oxide:		*0.76*	
Potassium Oxide:		*1.12*	

Physical Test Results

		ASTM C618-15 Class N
Fineness, Retained on #325 Sieve (%):	*5.7*	34 Max
Strength Activity Index (%)		
Ratio to Control @ 7 Days:	*89.6*	
Ratio to Control @ 28 Days:	*95.4*	75 Min
Water Requirement, % of Control:	*99.2*	115 Max
Soundness, Autoclave Expansion (%):	*-0.03*	0.8 Max
Drying Shrinkage, Increase @ 28 Days (%):	*0.02*	0.03 Max
Density Mg/m^3:	*2.40*	

:omments: *Meets ASTM C618-15/ AASHTO M295-11 Type N. Retested SAI.*

66

Chemical Composition (%) (by Wyoming Analytical Laboratories, Inc.)			ASTM C618-15 Class N
Total Silica, Aluminum, Iron:	96.0		70.0 Min
Silicon Dioxide:		53.4	
Aluminum Oxide:		42.0	
Iron Oxide:		0.6	
Sulfur Trioxide:	0.1		4.0 Max
Calcium Oxide:	0.1		
Moisture Content:	0.2		3.0 Max
Loss on Ignition:	0.5		10.0 Max
			AASHTO M295-11 Specifications
Available Alkalies (as Na_2O):	0.0		1.5 Max
Sodium Oxide:		0.03	
Potassium Oxide:		0.00	

Physical Test Results		ASTM C618-15 Class N
Fineness, Retained on #325 Sieve (%):	2.5	34 Max
Strength Activity Index (%)		
Ratio to Control @ 7 Days:	109.8	
Ratio to Control @ 28 Days:	122.0	75 Min
Water Requirement, % of Control:	111.6	115 Max
Soundness, Autoclave Expansion (%):	-0.07	0.8 Max
Drying Shrinkage, Increase @ 28 Days (%):	0.00	0.03 Max
Density Mg/m^3:	2.52	

Comments: *Meets ASTM C618-17 Class N and AASHTO M295-11 Spec.*

Strength in Numbers

67

How does Natural Pozzolan enhance and protect concrete?

- Roman Concrete utilized a balanced cement paste – virtually all of the Calcium Hydroxide was consumed based on the recipe shared by Vitruvius.

Note: Calcium Hydroxide (free lime) in concrete, which is not converted to C-S-H, becomes a volatile, bad actor in concrete…upwards of 25% of free lime is released into the concrete matrix, by weight of cement, as a byproduct of the hydraulic reaction.

Strength in Numbers

68

How does Natural Pozzolan enhance and protect concrete?

- If 20~30% of cement is replaced with NP, the Portland cement system, like the ageless Roman cement, is now better balanced.
- In other words, much of that 20~25% free-ranging lime by-product in the concrete is consumed, over time - in a reaction with the NP to form additional C-S-H, the binder in concrete – thus densifying the concrete.

Strength in Numbers

69

How does Natural Pozzolan enhance and protect concrete?

- By converting the free-lime into additional C-S-H, a concrete using NP at a 20~25% replacement of cement will have greater compressive strength than a 100% cement mix design - up to 140% SAI of the straight cement mixes at 1 year.

Strength in Numbers

70

How does Natural Pozzolan enhance and protect concrete?

- All or most of the free-lime will be converted to C-S-H, providing enhanced strength, reduced permeability, and fortifying the concrete against chemical attack, such as ASR and Sulfate attack.
- The NP converts a bad actor into a good actor, and your concrete will be inoculated from common concrete diseases, giving your customer's concrete a very long service life....

Strength in Numbers

71

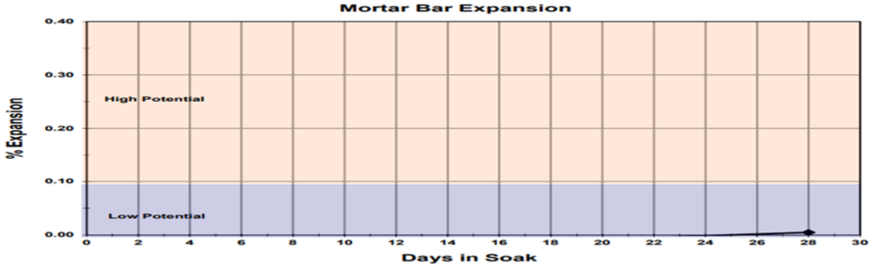
Benefits of Natural Pozzolans

1. Product consistency: No need to continually adjust your mix design based on product variability.
2. Reduce Carbon Footprint: Almost a pound for pound reduction of embodied carbon for every pound of cement replaced for raw NP and more than ½ pound for calcined NPs.
3. Reduced Heat of Hydration (HOH): Up to 25% or more reduction in HOH based on mix design.
4. Mitigate Chemical Attack: NPs are very effective at mitigating ASR and Sulfate attack, as well as Efflorescence.
5. Reduce Permeability: NPs densify and strengthen concrete. This increases durability & strength and reduces chloride ingress – protecting reinforcement.
6. Air Entrainment Consistency: NPs do not cause variability in air entrainment. LOI in NP is measured bound water, not carbon content.

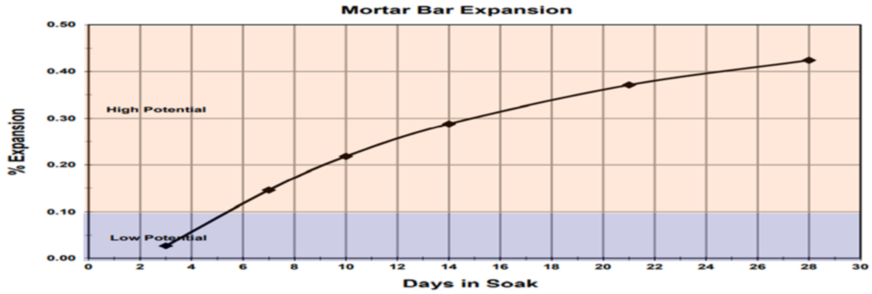
Strength in Numbers

72

C1567 28d FAA Std – NP @ 25% replacement mix results in .01% expansion



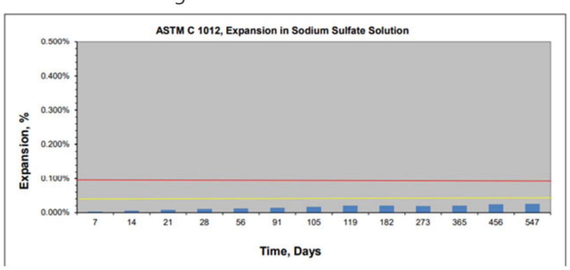
C1567 28d FAA Std – Control 100% cement results in .42% expansion



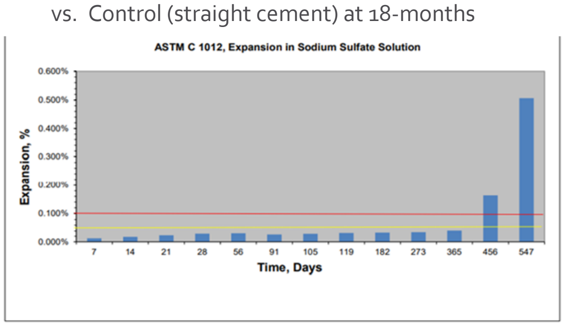
Strength in Numbers

73

NP mix design in 18-month ASTM C1012



vs. Control (straight cement) at 18-months



Project No. CT16208.000 Control - Figure 2 3/2/2021

Strength in Numbers

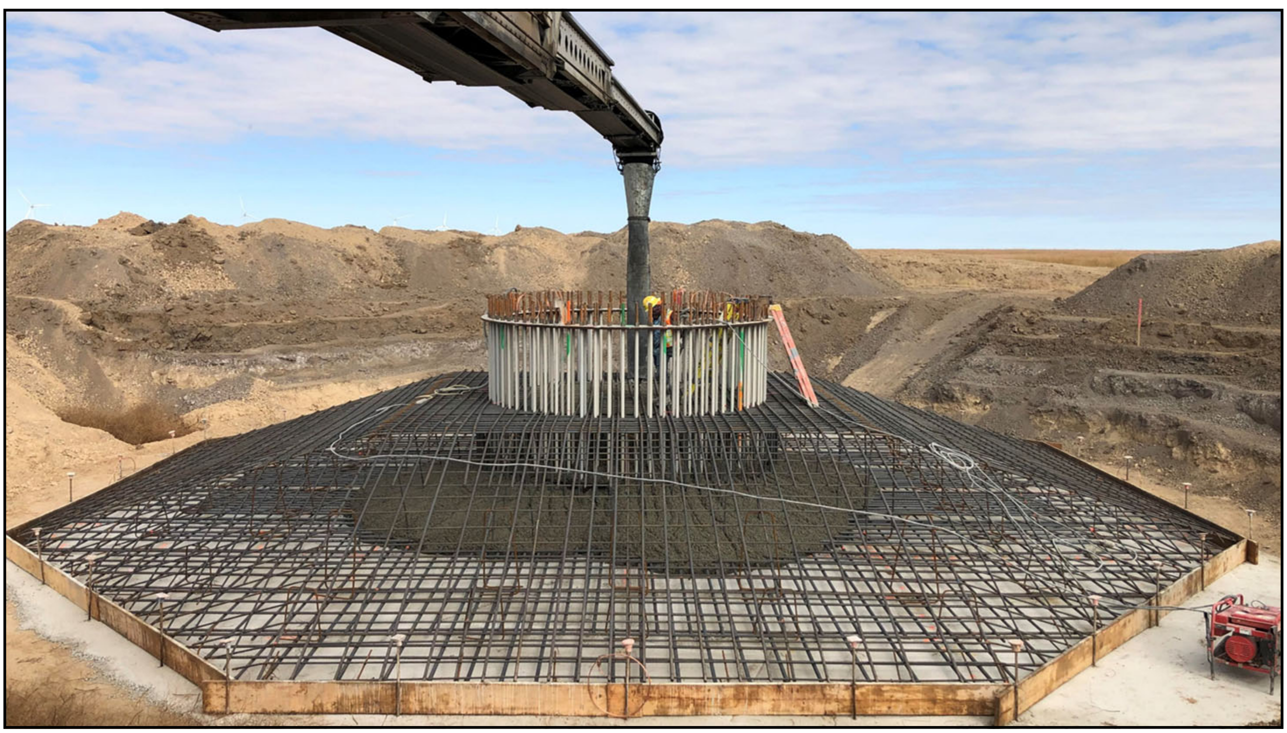
74

NP production locations USA.

- In production or under construction
- Permitted/Proposed Facility
- Permitted site

Strength in Numbers

75



76

77

78

Strength
in Numbers

79

Strength
in Numbers

80

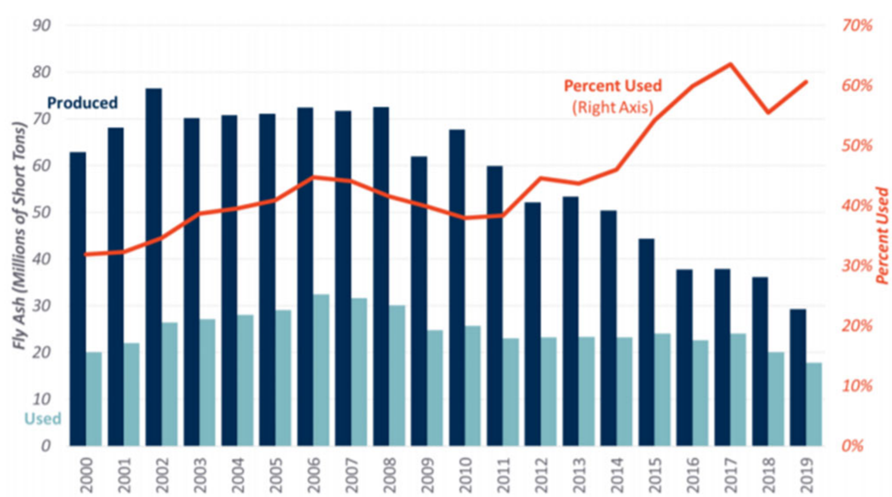
Hydraulic Cement

COLORADO READY MIXED CONCRETE ASSOCIATION

Jonathan Dennis – GCC of America, Inc.
jdennis@gcc.com

81

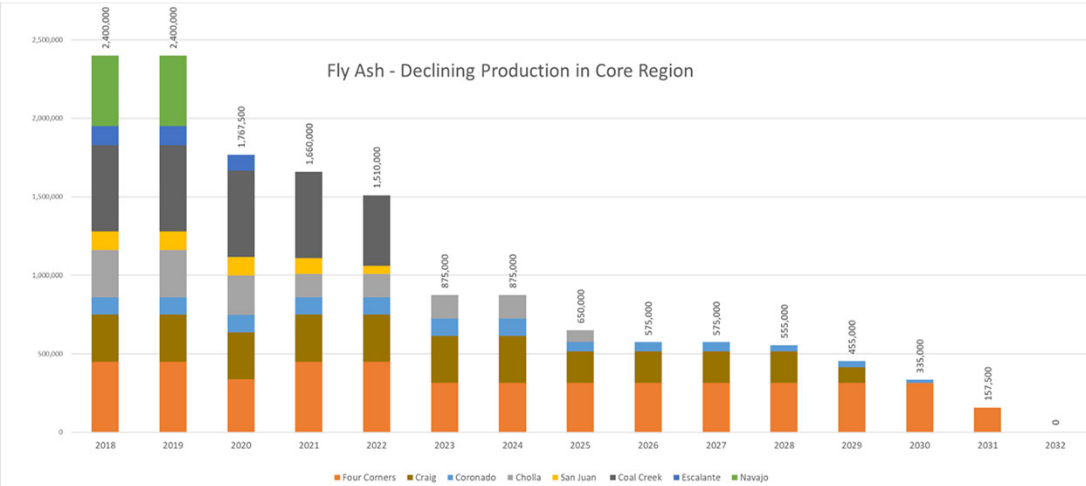
Fly Ash



Strength in Numbers

82

Fly Ash – Declining production

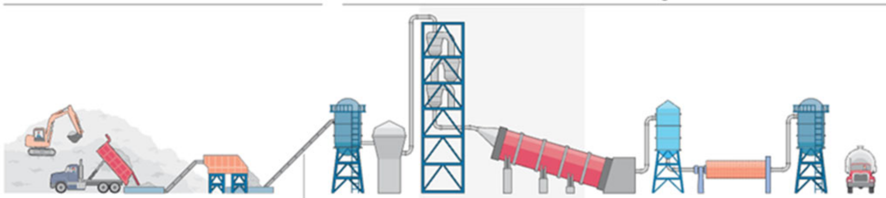


83

CO2 in Cement Production

Raw materials, energy, and resources

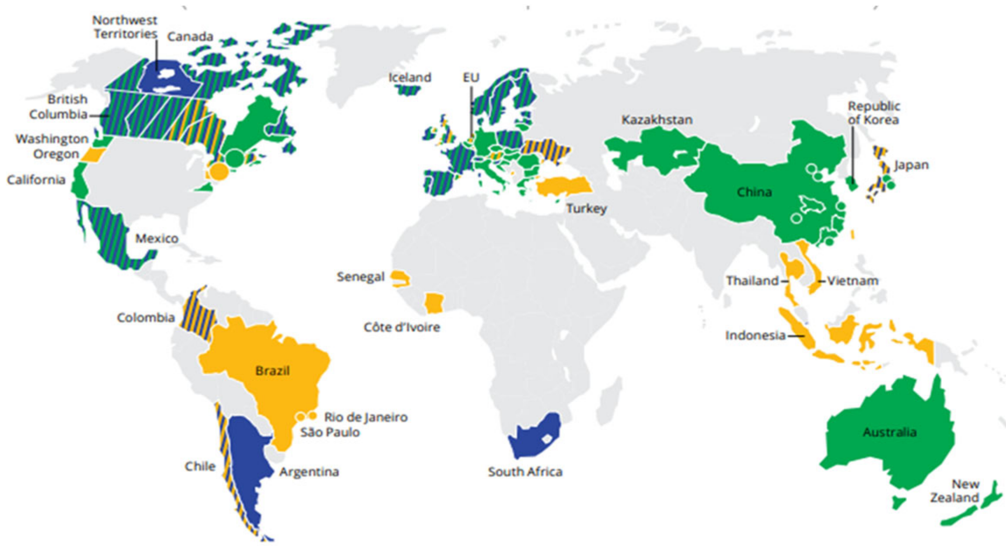
Clinker and cement manufacturing



	Quarry	Crusher	Transport[1]	Raw mill	Kiln and preheater/ precalcinator[2]		Cooler[3]	Cement mill	Logis-tics[4]	**Total**
Energy, mega-joule/ton	40	5	40	100	3,150		160	285	115	3,895
CO_2, kilogram/ton	3	1	7	17	479 Calcination process	319 Fossil fuels	28	49	22	925

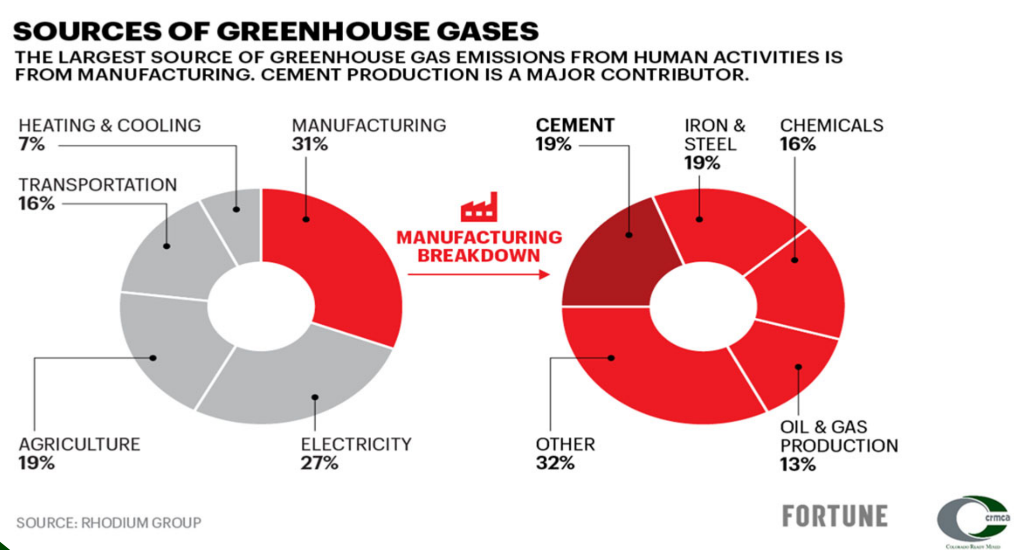
84

CO2 Around the World



85

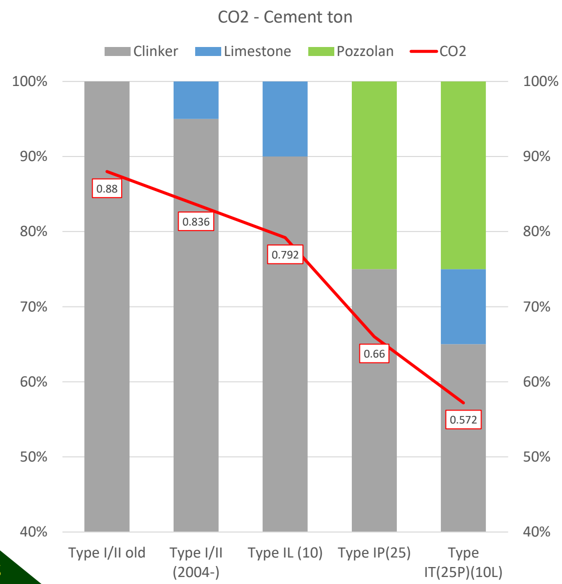
Next target?



Strength in Numbers

86

How to lower CO2 in Cement



Blended Cement

- Portland Limestone Cement (PLC)
- Natural Pozzolans
- Metakaolin
- Fly Ash
- Slag Cement

Strength in Numbers

87

Blended Cement & Specifications

Prescriptive ⟷ Performance

ASTM C150	ASTM C595	ASTM C1157
Type I	Type IL	Type GU
Type II	Type IP	Type HE
Type III	Type IS	Type MS
Type V	Type IT	Type HS
	Options A,MS,HS,MH,LH	Type MH
		Type LH
		Options R & A

Least ⟷ Most

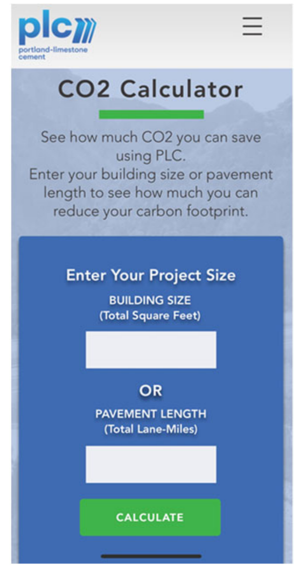
Flexibility to lower CO_2

Strength in Numbers

88

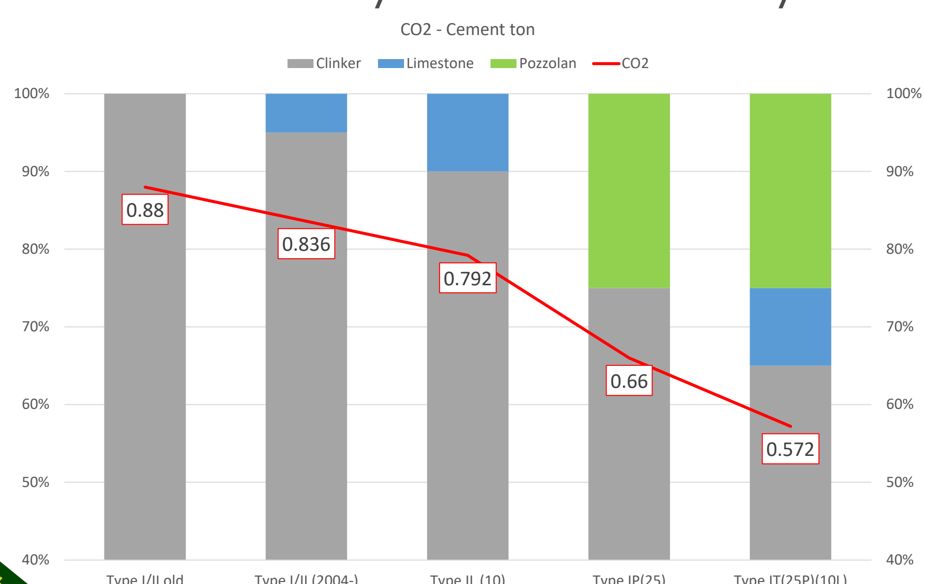
www.greenercement.com

- CO_2 Calculator
- Specification language
- Instructional & Promotional videos
- Case studies



89

Durability and Sustainability



90

Breakdown

COLORADO READY MIXED CONCRETE ASSOCIATION

Bud Werner – CTL|Thompson, Inc.

91

Economics - Supply Transition

- Fly ash has previously been effective, available, and inexpensive. Other SCMs have struggled to compete economically with it for general construction.
  - Shipping (not as many sites for supply)
  - Grinding
  - Drying/Calcining
- Fly ash will continue to be available, but not in excess and for a higher price? Other SCMs are becoming price competitive with fly ash, especially in the West as ASR is a general concern.
- I predict all SCMs will approach and in some cases exceed the cost of Portland cement, so we will see more of them used.

Strength in Numbers

92

Economics of blended cements

- Advantages
  - Handle one cementitious material at batch plant (especially good for portable plants.)
  - Cement manufacturers can chemically and physically optimize the blends.
  - A blend can be prequalified
  - Multiple SCM's in a blend more friendly to concrete suppliers.
- Disadvantages
  - Can't customize for multiple types of mixes at one plant
  - Some blends may be more expensive to produce. (Duplicate shipping expense)

93

Blended Cement & Specifications

Prescriptive ⟷ Performance

ASTM C150	ASTM C595	ASTM C1157
Type I	Type IL	Type GU
Type II	Type IP	Type HE
Type III	Type IS	Type MS
Type V	Type IT	Type HS
	Options A,MS,HS,MH,LH	Type MH
		Type LH
		Options R & A

Least ⟷ Most

Flexibility to lower CO_2

94

What about specs?

- Prescriptive vs. performance
  - It has taken decades for specifiers to understand the nuances of different types of Portland cement.
  - Typical specifiers will not know the difference between a IT(L>P) or IS cement, nor will they know how to specify them. ASTM C-595 will not be particularly useful.
  - ASTM C-1157 offers understandable properties. (Speed of strength gain, sulfate resistance, and heat of hydration potential, and an option for mitigating ASR.) GU, HE, MS, HS, MH, LH, and Option R.
  - However, C-1157 is uncomfortably open ended as to what can be in the cement

Strength in Numbers

95

What about specs?

- Specifiers will be required to make dramatic changes to their specification documents.
- These are complicated changes, and many of them will not be comfortable with the change unless given lots of guidance.
- CDOT, larger government agencies, might be the first to make these positive changes. Commercial specifications will take many years, even with lots of help.

Strength in Numbers

96

Thank You!

Now to your Questions

COLORADO READY MIXED CONCRETE ASSOCIATION

Bud Werner – CTL|Thompson, Inc.
owerner@ctlthompson.com

Thomas Adams – American Coal Ash Association (ACAA)
thadams@acaa-usa.org

Mark Van Kluenen – Skyway Cement Company
mvankleunen@skywaycement.com

Tom McNamee – Master Builders Solutions
Tom.mcnamee@mbcc-group.com

Joe Thomas – Magmatics/NPA
joe@magmatics.com

Jonathan Dennis – GCC of America, Inc.
jdennis@gcc.com

Don't forget to complete the Poll shared while questions are being answered!

97

COLORADO READY MIXED CONCRETE ASSOCIATION

Thank you to our Sponsors!!

MAPEI

CR Minerals

Ash an Expert…

A Prelude to Alternative SCMs

April 27, 2021

98

Addendum – Fly Ash

Strength
in Numbers

99

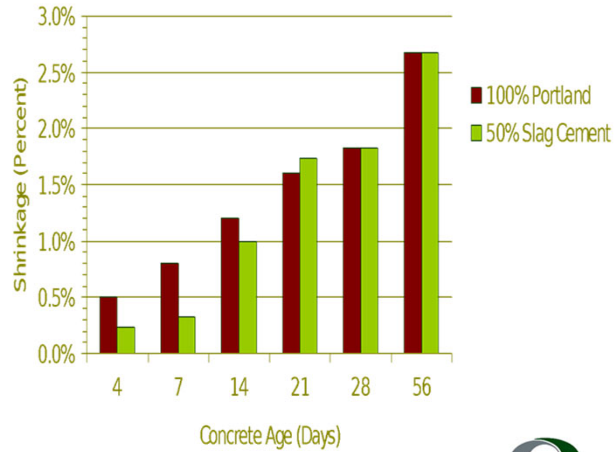
Addendum – Slag

Strength
in Numbers

100

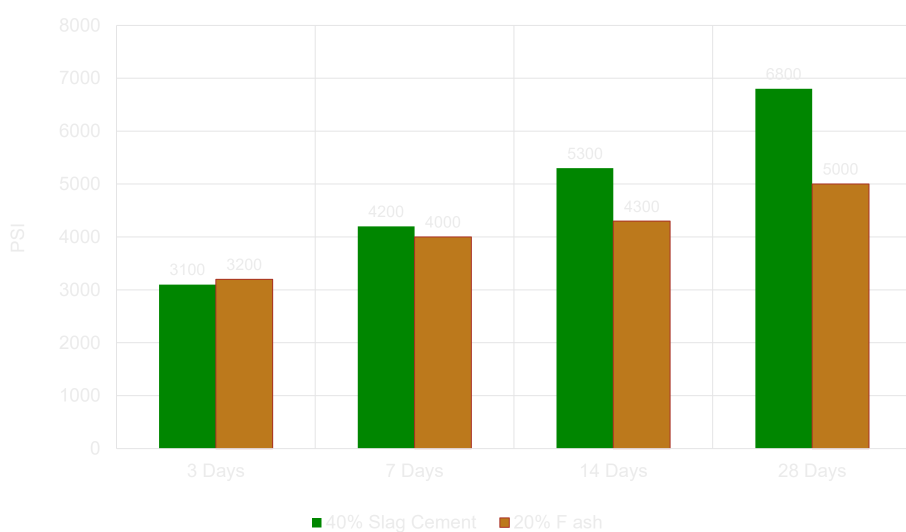
Slag – Drying Shrinkage

Slag cement has little or no effect on drying shrinkage

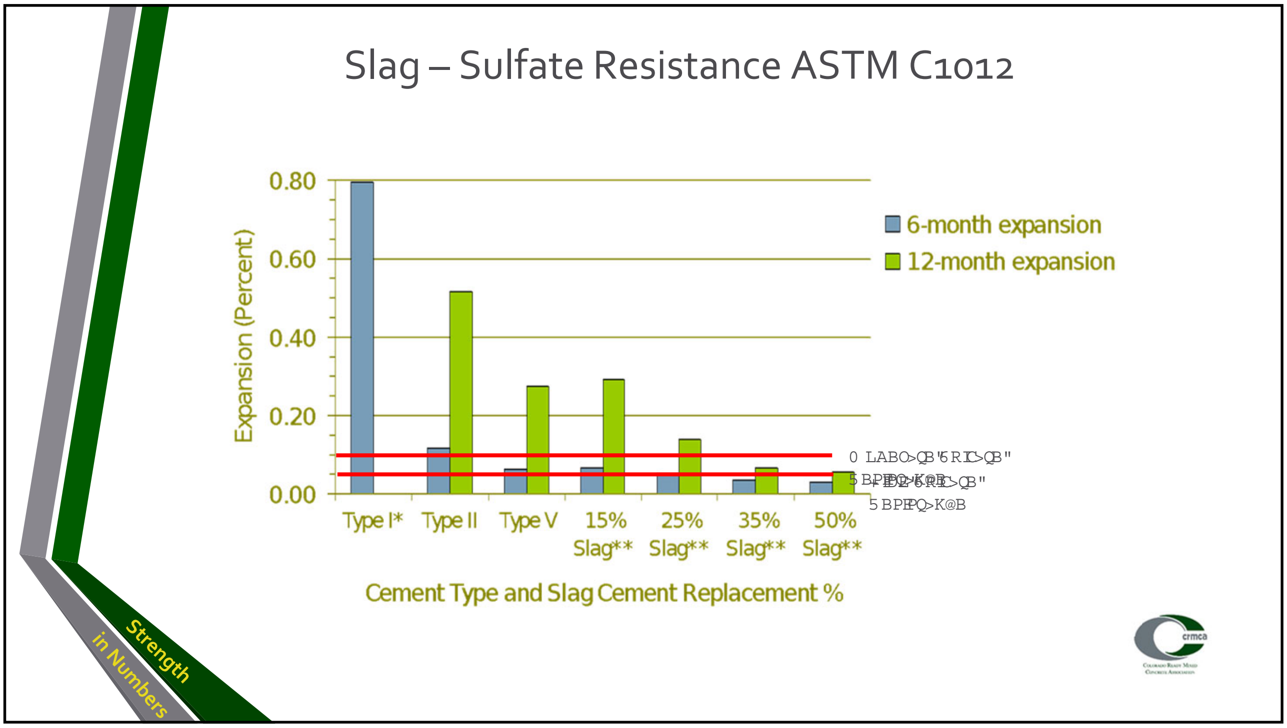


101

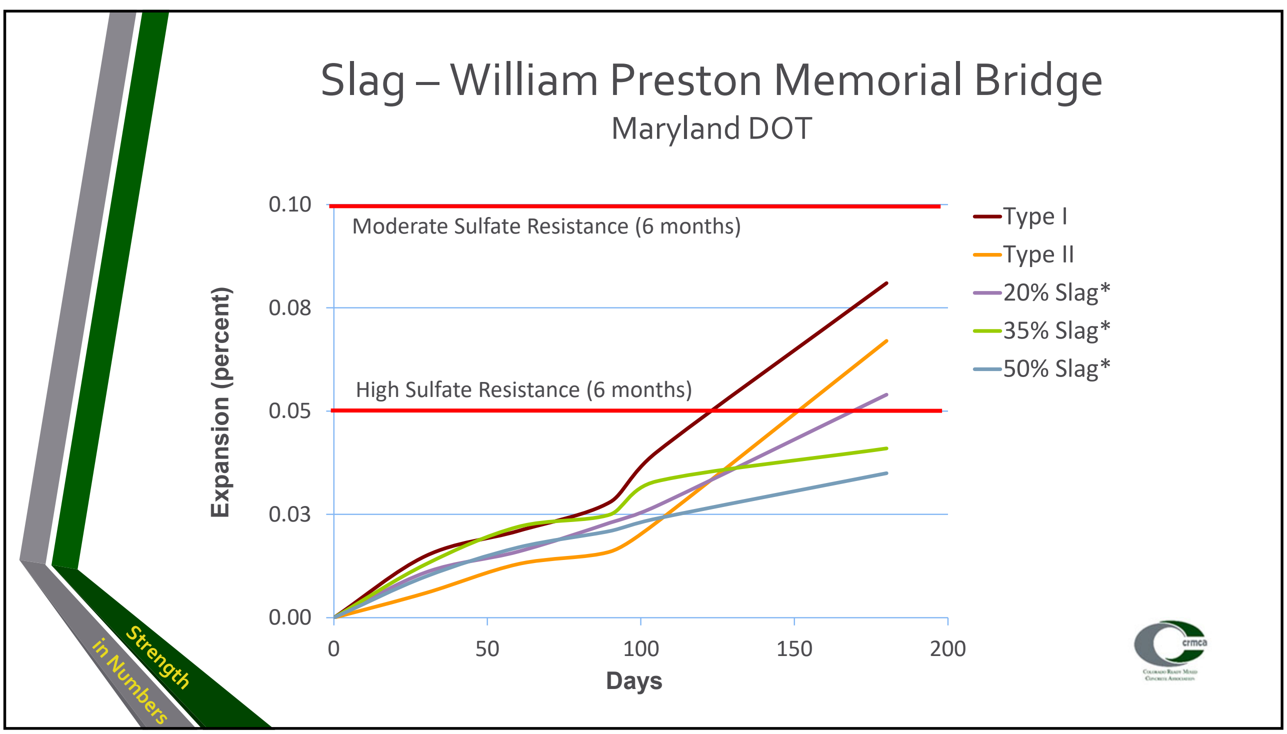
Slag – Strength Comparison of Slag Cement and Class F Fly Ash



102

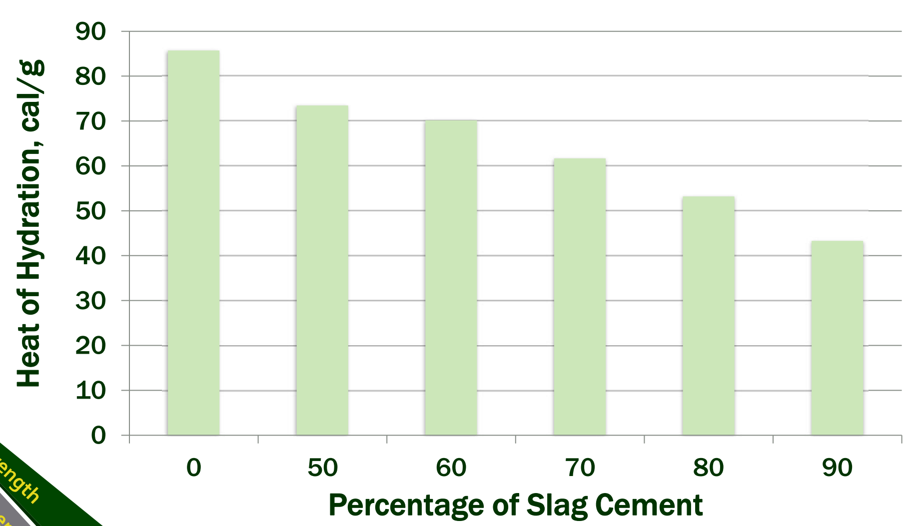

Slag – Sulfate Resistance ASTM C1012
Expansion (Percent)
0.80
0.60
0.40
0.20
0.00
6-month expansion
12-month expansion
Type I*
Type II
Type V
15% Slag**
25% Slag**
35% Slag**
50% Slag**
Cement Type and Slag Cement Replacement %
Strength in Numbers
crmca

103


Slag – William Preston Memorial Bridge
Maryland DOT
Expansion (percent)
0.10
0.08
0.05
0.03
0.00
Moderate Sulfate Resistance (6 months)
High Sulfate Resistance (6 months)
Type I
Type II
20% Slag*
35% Slag*
50% Slag*
0
50
100
150
200
Days
Strength in Numbers
crmca

104

Slag – Effect of Slag Cement on Heat of Hydration for Mass Concrete



Can easily achieve internal concrete temperatures < 135°F in summer at 50% - 70% cement replacement

Strength in Numbers

105

Slag Cement Association website: www.slagcement.org

Strength in Numbers

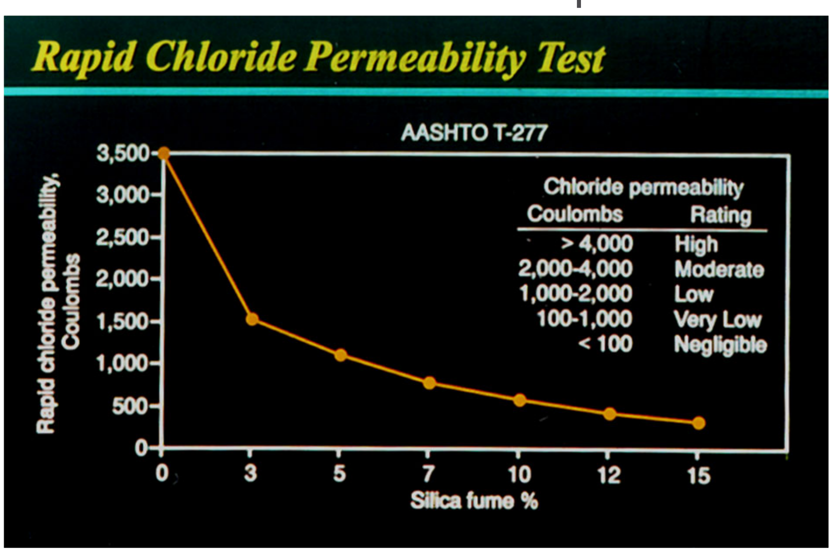
106

Addendum – Silica Fume

Strength
in Numbers

107

Silica Fume –
Hardened Concrete Properties



108

108

Addendum – Natural Pozzolans

Strength in Numbers

109

NPA | NATURAL POZZOLAN ASSOCIATION

Learn More!

Website: Pozzolan.org
Email: Info@pozzolan.org
Tel: 2082522808

Strength in Numbers

110

Addendum – Cement

Strength in Numbers

111