Headwaters Resources

Influences of Class F and C Fly Ash Blending

Ben Franklin
Technical Director

Doug Rhodes
Laboratory Manager

POZZOLAN BLENDING OBJECTIVES

- Individual materials are tested for chemical oxides, particle density and LOI.
- Objectives keep the sum of constituents between 72% and 75%.
- Material is blended to conform with ASTM C1697 uniformity ±5.0%.
- LOI is kept below 2.0%.
- Available Alkalis are held at 1.3%.
- Lower the CaO found in Class C ash that can exacerbate sulfate attack and ASR

ASTM C1697
BLENDED SUPPLEMENTARY CEMENTITIOUS MATERIALS
APPENDIX X1 VERIFYING BLEND PROPORTIONS

- X1.1 This Appendix provides information for purchasers of blended supplementary cementitious materials about typical methods that manufacturers use to control the blend production process and verify product conformance.
- X1.2 Mechanical methods, such as weighing individual constituents as each goes to the blending system are adequate to provide production control but chemical analysis as described below is required by this specification for verifying actual blend proportions:
- X1.2.1 Ensure weigh feeders are maintained and calibrated before production. Weigh feeders are to provide for general control and adjustment during production.
- X1.2.2 Ensure that the analysis method, X-ray fluorescence (XRF) or other qualified method is calibrated within the ranges of materials being tested.

X1.2.3 Sample and chemically analyze individual constituents before production begins and at established frequencies during production.

X1.2.4 Sample and chemically analyze finished blended supplementary cementitious materials at established frequencies during production runs for quality control purposes and verification of blend proportions

X1.2.5 Proportion analysis, as used here, is a calculation using the chemical analysis of the individual constituents and the resultant blend.

X1.2.5.1 The individual constituents are analyzed and predominant elements are chosen as chemical identifiers.

X1.2.5.2 Those chosen identifiers are then used to calculate the mass % of constituents in the blended supplementary cementitious material.

An example of this calculation follows. This is a basic example for illustrative purposes using one element. A more detailed analysis using multiple elements can be performed using a spreadsheet program such as EXCEL Solver

BLENDED FLY ASH

Blended fly ashes is a homogeneous blend of sub-bituminous and bituminous coal ash. Combining sub-bituminous and bituminous coal ashes provides consumers the positive attributes of both materials and reduces variations that are sometimes experienced from power plants operating under today's more stringent environmental climate. The blended fly ash offers end users more benefits versus the sum of their parts. Blended fly ashes can be used in any application where a Class F fly ash is specified.

ASTM C-1697

BLENDED SUPPLEMENTARY CEMENTITIOUS MATERIALS

- **Appendix X1. Verifying Blend Proportions (summary).**

- X1.2 Mechanical methods … weighing individual constituents as each goes to the blending system . . .but chemical analysis as described below is required . . . for verifying actual blend proportions.
- X1.2.3 Sample and chemically analyze individual constituents before production begins.
- X1.2.4 Sample and chemically analyze finished blended supplementary cementitious materials at established frequencies . . . For quality control purposes and verification of blend proportions.
- X1.2.5.2 Those chosen identifiers are then used to calculate the mass % of constituents in the blended supplementary cementitious material.

ASTM-1697

HEADWATERS RESOURCES

ASTM C1697-10 Appendix X1.2.5.2 (Worksheet)

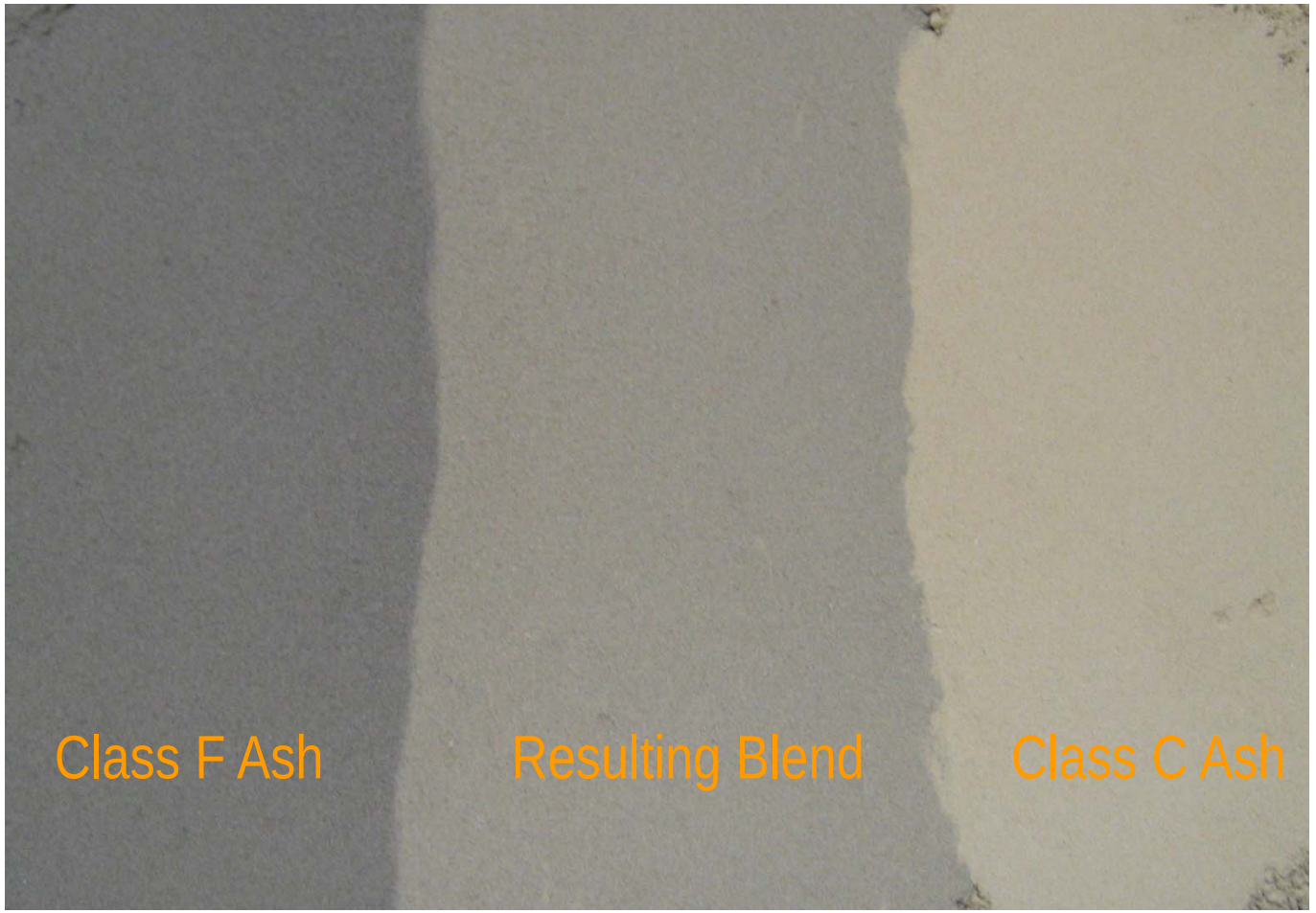
Date	Sample IDs	Sample Type	Miller Total Sum	Gaston Total Sum	Blend % C | F Class C	Blend % C | F Class F	Theoretical Total Sum	P2 Actual Total Sum	± 5% Max Variance Actual vs Theoretical
7/1/13	*1480MR; 1612GT; 1652P2A*	*Monthly*	65.73	88.91	51%	49%	77.09	77.96	1.1%
8/1/13	*1723MR; 1921GT; 1937P2A*	*Monthly*	62.89	88.67	51%	49%	75.52	76.2	0.9%
9/1/13	*2071MR; 2056GT; 2143P2A*	*Monthly*	62.85	87.69	51%	49%	75.02	75.78	1.0%
10/1/13	*2335MR; 2296GT; 2352P2A*	*Monthly*	65.39	87.82	51%	49%	76.38	76.51	0.2%
11/1/13	*2422MR; 2614GT; 2571P2A*	*Monthly*	63.61	88.83	51%	49%	75.97	76.72	1.0%
12/1/13	*2680MR; 218GT; 44P2A*	*Monthly*	65.54	88.54	51%	49%	76.81	76.88	0.1%

Calculations: ASTM C1697-10X1.2.5.2 limits +/- 5%

VERIFICATION OF COMPLIANCE

- Industry Specifications
  - ASTM – American Society for Testing Materials
  - AASHTO – American Association of State Highway the Transportation Officials
- DOT Specifications
- Headwaters Resources' Standard Operating Procedures (SOP)

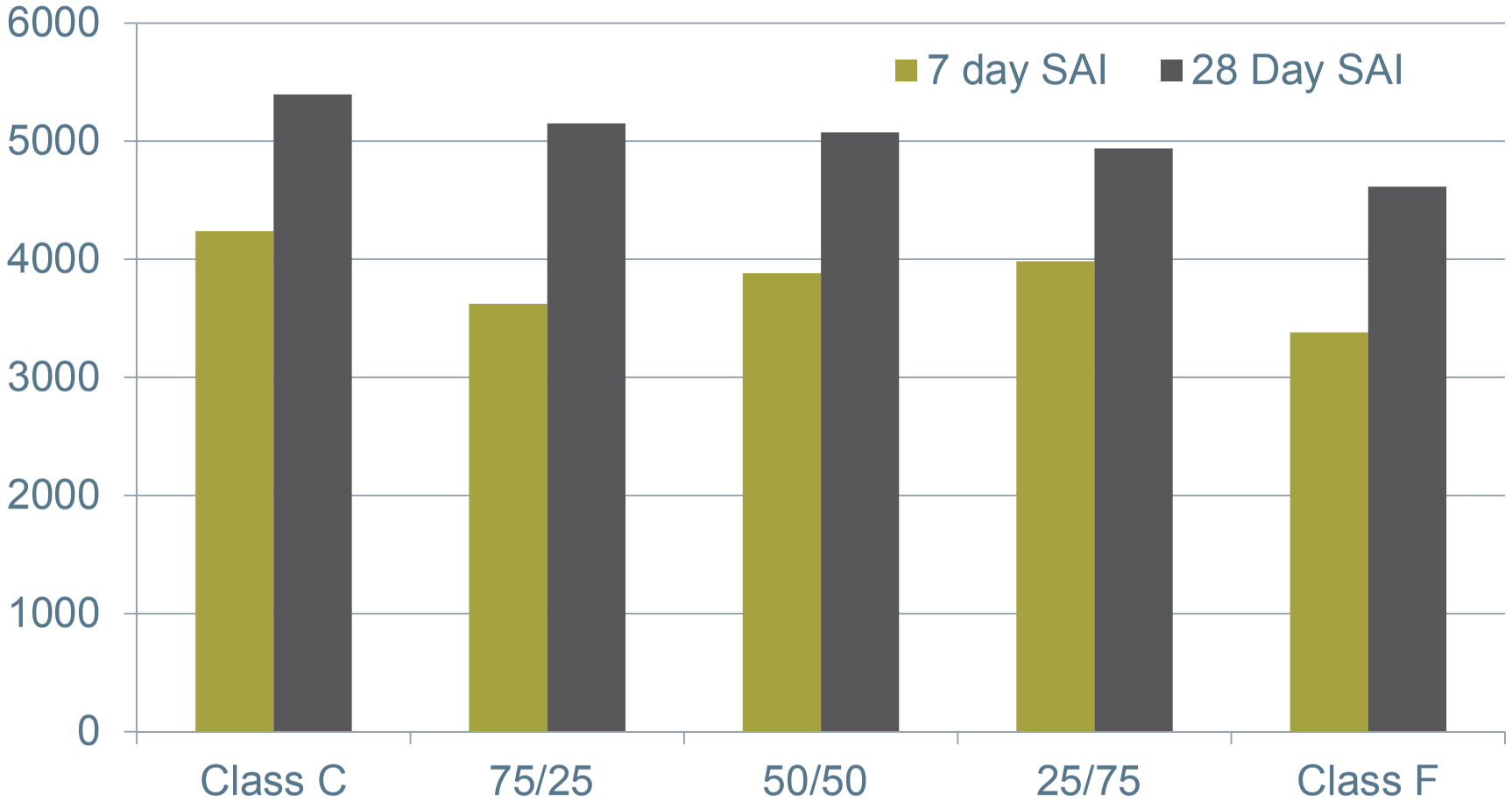
BLENDING IMPACT TO COLOR



Summary of Chemical and Physical Properties

Chemical	Class F	75% F / 25% C	50% F / 50% C	25% F/ 75% C	Class C
Silicon Dioxide, SiO_2	47.73%	45.26%	42.74%	40.85%	39.32%
Aluminum Oxide, Al_2O_3	28.19%	25.65%	23.21%	21.17%	19.24%
Iron Oxide, Fe_2O_3	11.92%	10.51%	9.28%	8.23%	6.22%
Sulfur Trioxide, SO_3	0.32%	0.78%	1.03%	1.27%	1.52%
Calcium Oxide, CaO	4.02%	8.75%	13.56%	18.51%	23.25%
Sum Of Oxides (Class)	**87.84%**	**81.42%**	**75.23%**	**70.25%**	**64.78%**
Available Alk.	.75	1.26	1.1	.91	1.33
Carbon % (Leco)	1.94	1.47	1.06	0.58	0.157
Specific Gravity gm/cm^3	2.38	2.42	2.42	2.46	2.49
LOI %	2.13	1.57	1.09	0.7	0.31
Fineness %	24.02	24.02	23.76	22.64	25.1
Moisture %	0.13	0.11	0.1	0.1	0.106

COMPRESSIVE STRENGTH
ASTM C-109

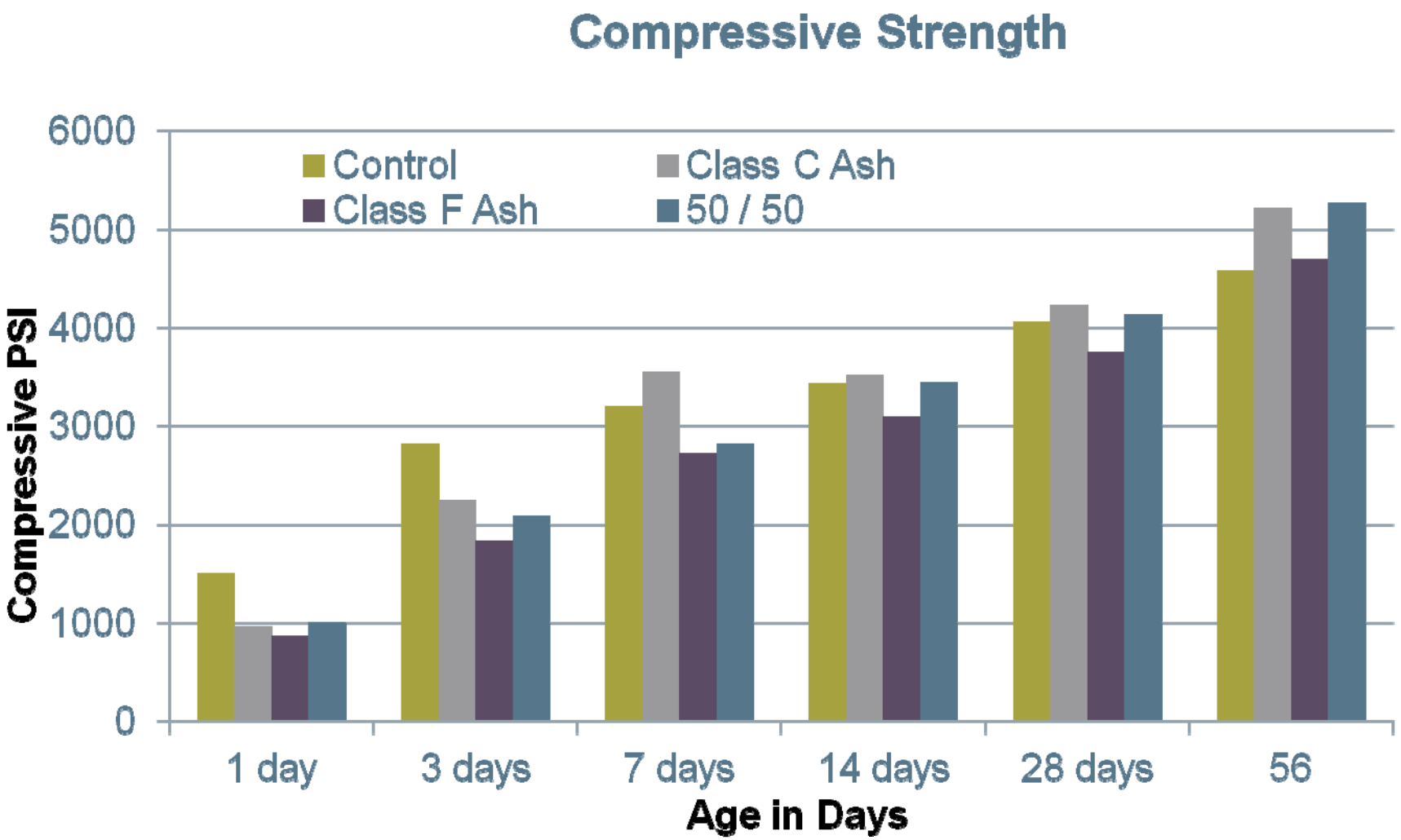


ASTM C-192 CONCRETE DATA

	Control	Class C	Class F	50/50
Slump .25 inch	6	6	6	6.5
Unit Wt lb/ft	145.6	146.3	146.3	147.1
Air % Pressure	6	5.5	5.2	5
WC Ratio	0.62	0.58	0.63	0.59
Temp. F	65	65	65	65
1 Day Compressive **	1501	962	862	1007
3 Day Compressive **	2819	2245	1837	2088
7 Day Compressive	3197	3552	2726	2813
14 Day Compressive	3432	3513	3097	3440
28 Day Compressive	4058	4228	3755	4132
56 Day Compressive	4580	5212	4693	5268

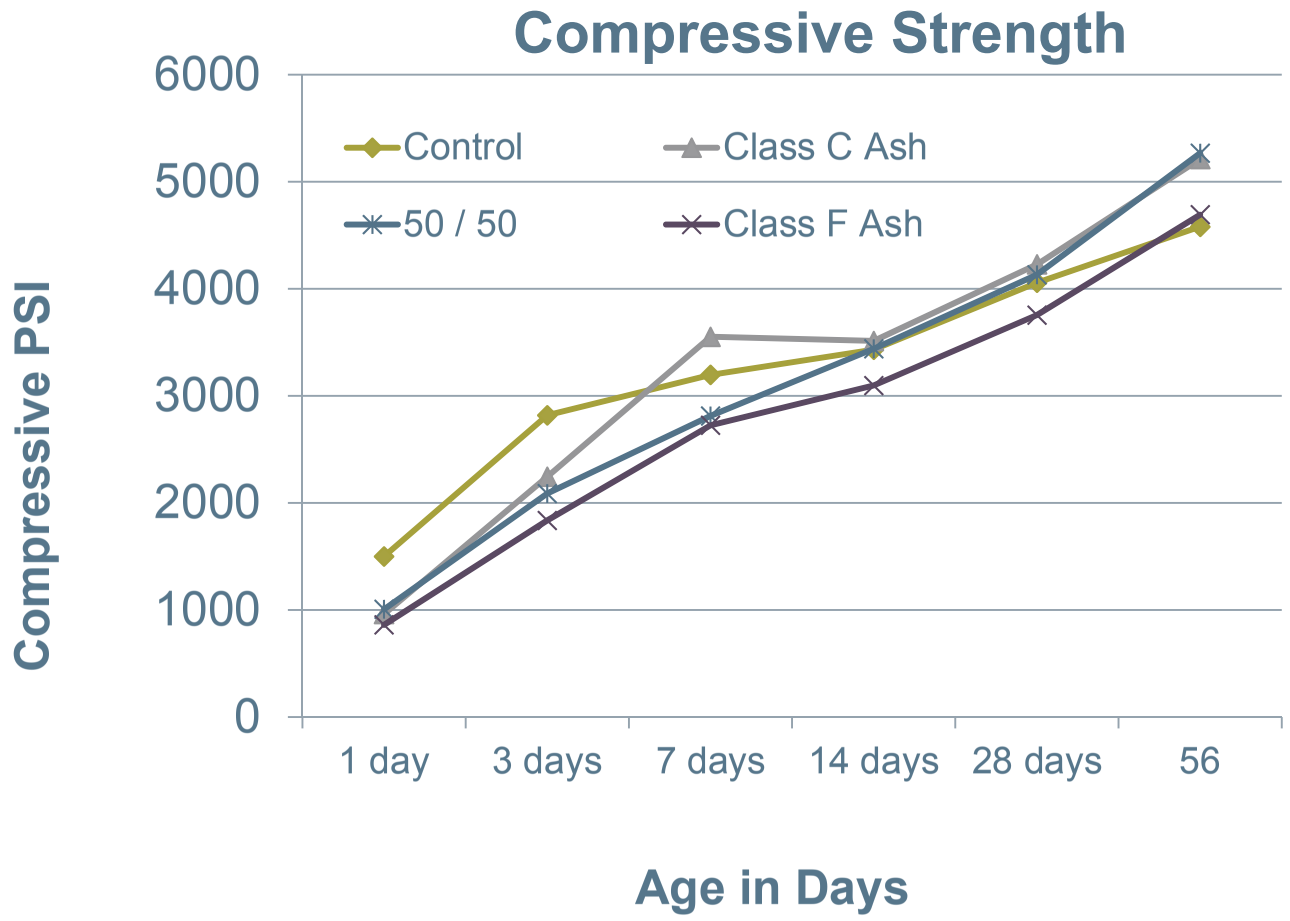
*** 3X6 Cylinders all other ages 4X8*

CONCRETE STRENGTH
ASTM C-39

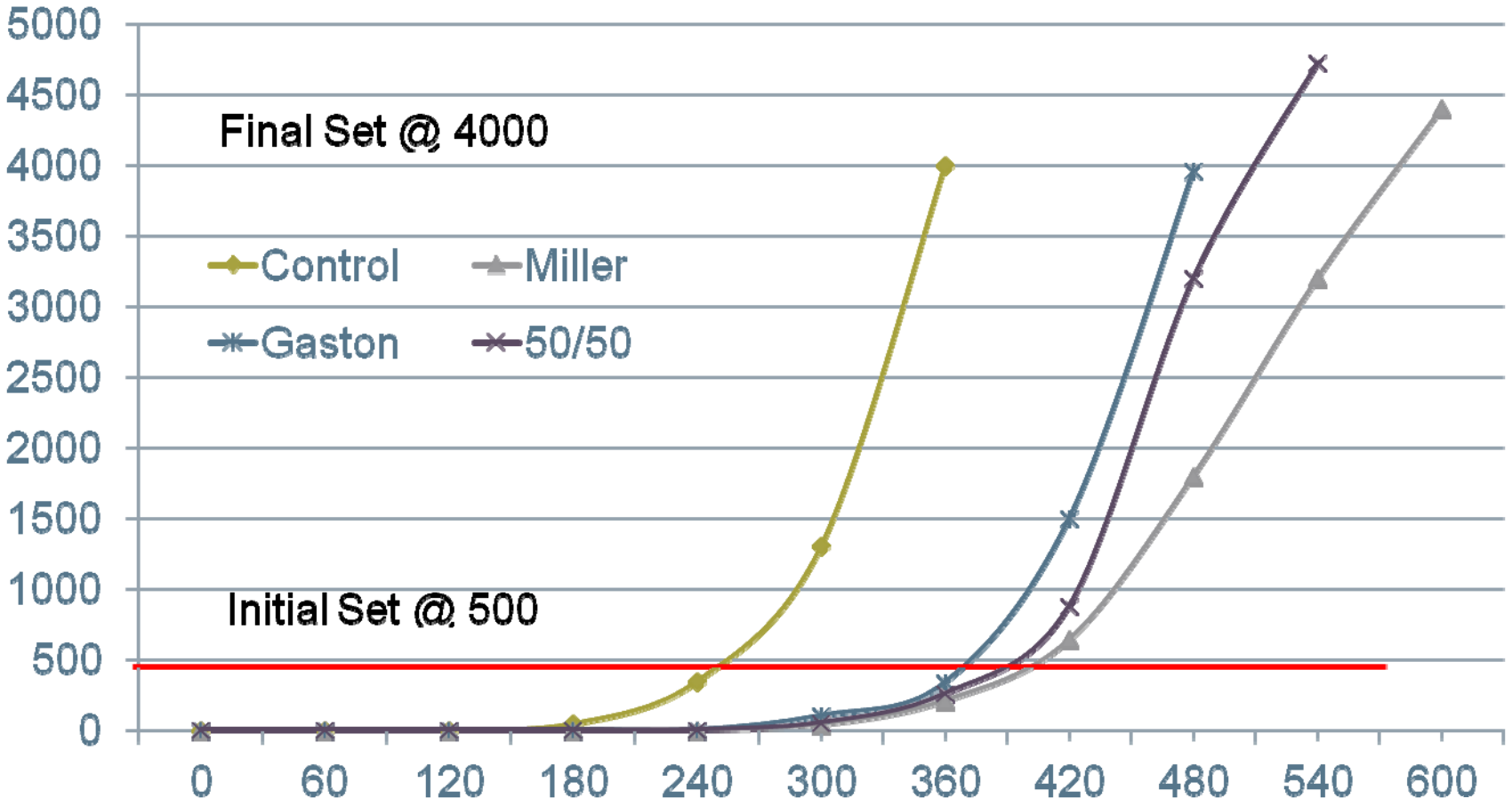


CONCRETE STRENGTH

The blending process reduces variability of Class F fly ash from the power plant. The blend in concrete at a 25 percent substitution rate performs better than the control mix and the Class F mix at 28 and 56 days.



SETTING TIME OF CONCRETE ASTM C-403

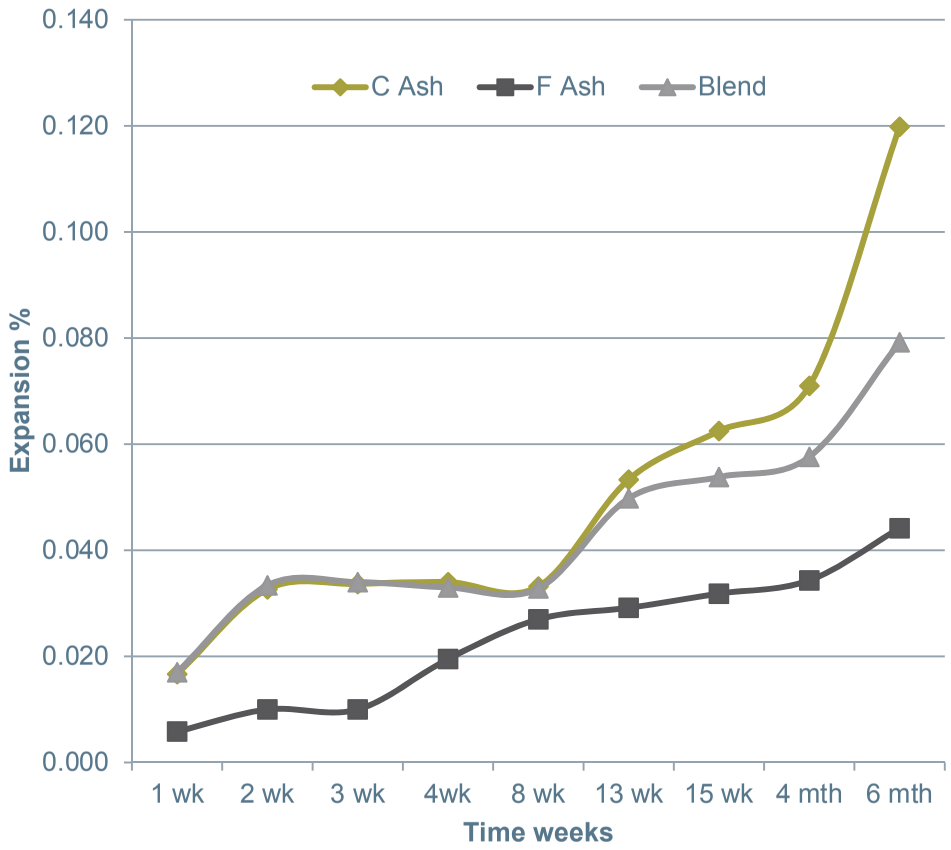


ASTM C-1012

ASTM C-1012 sulfate expansion graph results, Class C fly ash is exceeding maximum expansion limits at six months. Blend does not perform as well as a straight Class F ash; however, performs better than straight Class C fly ash.

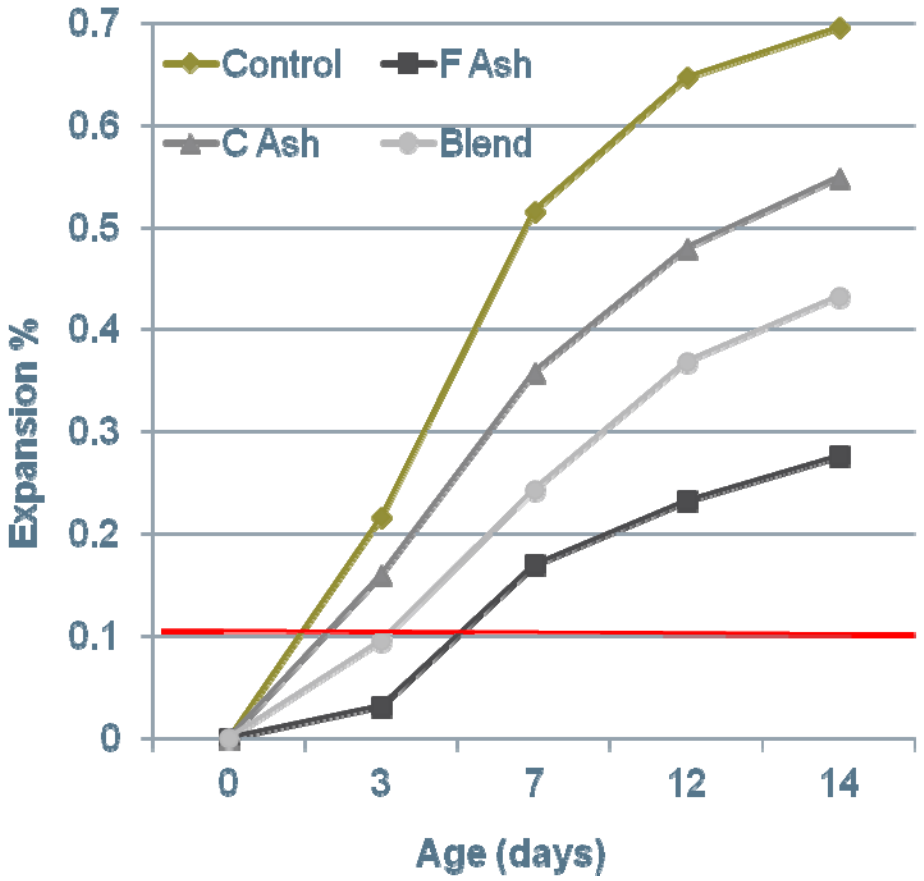
"Tilkasky and Carrasquillo (1993); and Dunstan (1976); showed that concrete containing some high-calcium fly ashes are susceptible to sulfate attack, and generally, higher volumes of high-calcium fly ash mixtures have a greater susceptibility to sulfate deterioration" (American Concrete Institute [ACI], 2008, p. 17).

Blending C with F fly ash mitigates problems caused by high CaO C ashes.



ASTM C-1567 DATA

- ASTM C 1567 comparison graph shows the blend outperforms straight Class C's ability to inhibit alkali silica reactivity expansion.
- Combining Class C and Class F fly ash clearly lowers the percentage of alkali available in Class C fly ash, complimenting the advantages of both products resulting improved concrete durability.
- Added benefit of allowing concrete producers to use higher percentages of fly ash in their concrete products as compared to typical Class F fly ashes.
- Higher percentages of fly ash replacement, improves concrete durability

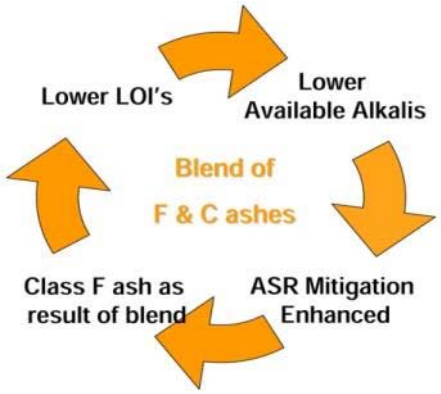


Combining Class C and Class F fly ash has the following benefits:

Lower CaO

Lower LOI

Lower available Na2O



HEADWATERS RESOURCES

Adding Value to Energy ™

ASTM C618-05 / AASHTO M 295-0 Testing of Performance Pozzolan Alabama Fly Ash

Sample Type:	**3200-ton**		**Report Date:**	**6/15/2009**	
Sample Date:	**4/1-4/15/09**		**MTRF ID**	**601P2A**	
			Sample ID:		
			ASTM / AASHTO Limits		**ASTM Test**
Chemical Analysis			**Class F**	**Class C**	**Method**
Silicon Dioxide (SiO2)	44.11	%			
Aluminum Oxide (Al2O3)	23.22	%			
Iron Oxide (Fe2O3)	8.11	%			
Sum of Constituents	75.44	%	70.0% min	50.0% min	D4326
Sulfur Trioxide (SO3)	1.14	%	5.0% max	5.0% max	D4326
Calcium Oxide (CaO)	12.81	%			D4326
Moisture	0.08	%	3.0% max	3.0% max	C311
Loss on Ignition	1.50	%	6.0% max	6.0% max	C311
(AASHTO M 295-00 req.)			5.0% max	5.0% max	
Available Alkalies, as Na2O	1.15	%			C311
(AASHTO M 295-00 req.)			1.5% max	1.5% max	
Physical Analysis					
Fineness, % retained on #325	17.76	%	34% max	34% max	C311, C430
Strength Activity Index - 7 or 28 day requirement					C311, C109
7 day, % of control	100	%	75% min	75% min	
28 day, % of control	99	%	75% min	75% min	
Water Requirement, % control	94	%	105% max	105% max	
Autoclave Soundness	0.05	%	0.8% max	0.8% max	C311, C151
True Particle Density	2.48				

Headwaters Resources certifies that, to the best of its knowledge, the test data listed herein was generated by applicable ASTM methods and meets the requirements of ASTM C618-05 for Class F fly ash.

Bobby Bergman
MTRF Manager

AAR AASHTO R18

Materials Testing & Research Facility
2650 Highway 113 S.W.
Taylorsville, Georgia 30178
P: 770.684.0102
F: 770.684.5114
www.headwaters.com

BENEFITS C/F BLENDS

- Use of ASTM C-1697
- Performance driven sales with ash that can be tailored to a particular region.
- Ability to maintain constant supplies of material.
- Possibility to use other SCM such as Slag, Silica Fume and natural Pozzolans in blend.
- Ability to beneficiate one source, with another of better properties.
- Provide binary performance product to the market for single silo use.

C-ASH & F-ASH DOT PRE BLEND APPROVALS

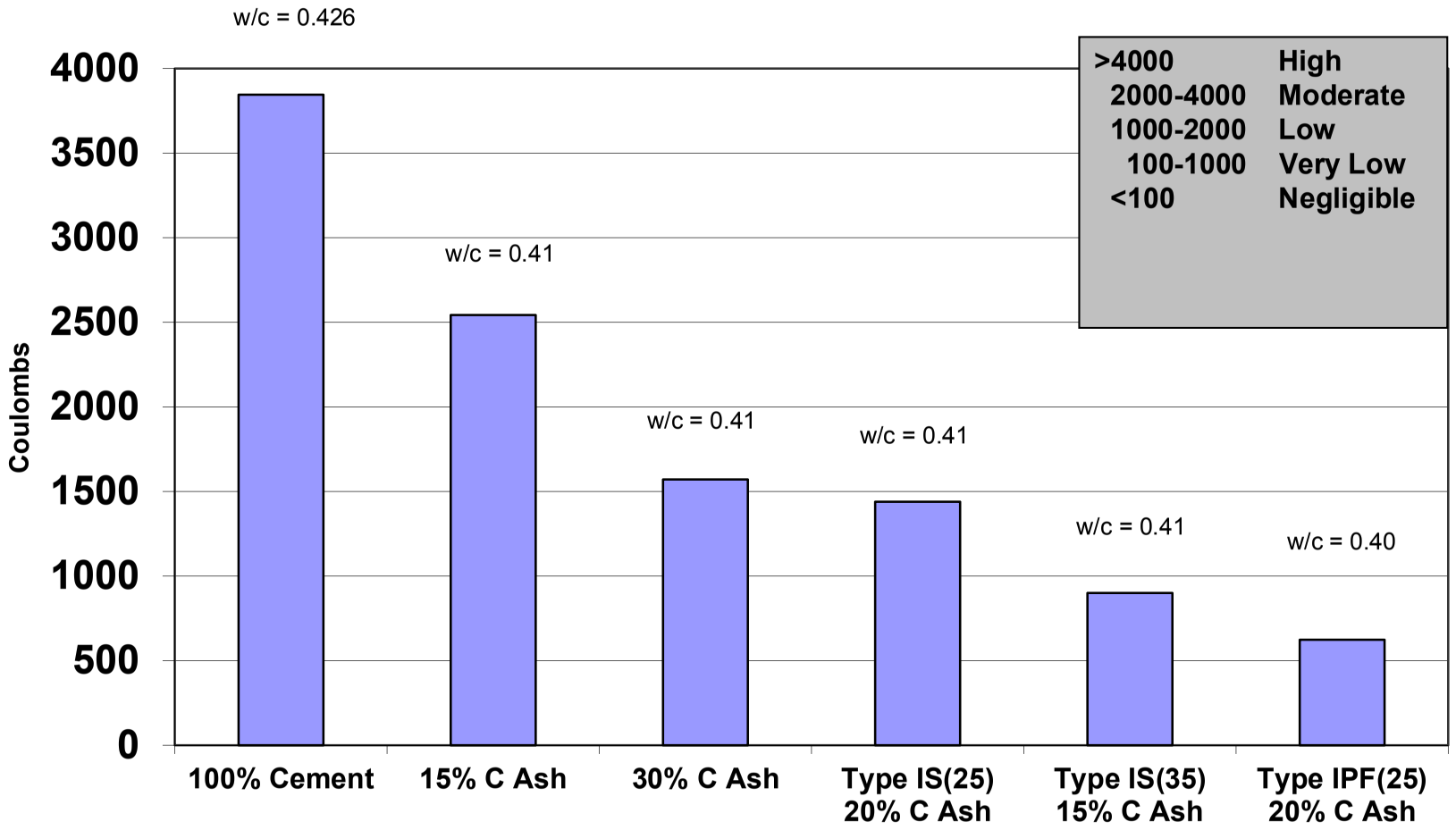
- Florida
- Georgia
- Alabama
- Tennessee
- Kentucky
- Pennsylvania
- Louisiana
- Mississippi
- Colorado

IOWA DOT PERMEABILITY DATA

- Iowa DOT undertook a study on paving performance to measure permeability of all allowed state paving mixtures utilizing SCM available in the market and on current projects.
- Class F is only available locally as a component of a locally produced cement blend. The blend contains 20% class F fly ash.
- Iowa DOT allows for the paving mixture to utilize up to a 40% replacement of cement.
- Local pavers routinely use the 20% F cement blend with 20% Class C fly ash, with the result providing faster set time in cool weather and lower permeability.

Ternary Mix Design - Lab Study

Permeability AASHTO T277 - Virginia Cure Method



SUMMARY OF FINDINGS

- Physical Performance improved on tested ashes.
- Utilization of Marginal Ashes Enhanced.
- ASR Mitigation of Blended C/F fly ashes improved over Class C fly ash alone.
- Permeability's were reduced similar to the use of silica fume.
- Resulting blends of class C and class F fly ashes, meet ASTM C-618.

REFERENCES

- American Concrete Institute. (2008). *Manual of concrete practice: Use of fly ash in concrete committee-232.* Farmington Hills, MI: Author.
- ASTM C 39. (2000). Standard test method for compressive strength of cylindrical concrete specimens. In R. Allen, N. Baldini, E. Gutman, E. Keefe, J. Kramer, & C. Leinweber et al. *Annual Book of ASTM standards*: *Vol. 04.02*. *Concrete and aggregates.* West Conshohocken, PA: American society for testing and materials.
- ASTM C 109. (2000). Standard test method for compressive strength of hydraulic cement mortars (Using 2-in. or [50-mm] cube specimens. In R. Allen, N. Baldini, E. Gutman, E. Keefe, J. Kramer, & C. Leinweber et al. *Annual Book of ASTM standards*: *Vol. 04.01*. *Cement;lime;gypsum.* West Conshohocken, PA: American society for testing and materials
- ASTM C 618. (2000). Standard specification for coal fly ash and raw or calcined natural pozzolan for use as a mineral admixture in concrete. In R. Allen, N. Baldini, E. Gutman, E. Keefe, J. Kramer, & C. Leinweber et al. *Annual Book of ASTM standards*: *Vol. 04.02*. *Concrete and aggregates.* West Conshohocken, PA: American society for testing and materials.
- ASTM C 1012. (2000). Standard test method for length change of hydraulic-cement mortars exposed to a sulfate solution In R. Allen, N. Baldini, E. Gutman, E. Keefe, J. Kramer, & C. Leinweber et al. *Annual Book of ASTM Standards*: *Vol. 04.01. Cement; lime; gypsum*. West Conshohocken, PA: American society for testing and materials.
- ASTM C 1567. (2004). Standard test method for determining the potential alkali-silica reactivity of combinations of cementitious materials and aggregate. *Annual Book of ASTM standards*: *Vol. 04.02*. *Concrete and aggregates.* West Conshohocken, PA: American society for testing and materials
- ASTM C 1697. (2010). Blended supplementary cementitious materials. *Annual Book of ASTM standards*: *Vol. 04.02*. *Cement, lime, gypsum .* West Conshohocken, PA: American society for testing and materials
- Grattan-Bellew, P. E. (1987). *Concrete alkali-aggregate reactions*. Park Ridge, NJ: Noyes Publications.