Mitigation of Alkali-Silica Reaction While Using Highly Reactive Aggregates with Class C fly ash and Reduction in Water to Cementitious Ratio

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Introduction

Aggregates containing certain siliceous minerals can react with soluble alkalies in concrete, sometimes resulting in detrimental expansion and cracking of concrete structures. Alkali-silica reactivity (ASR), which was first reported in the late 1930's, is now known worldwide. The alkali-silica reaction forms a gel that swells as it draws water from the surrounding cement paste. ASR-induced cracking can exacerbate other deterioration mechanisms such as those that occur in frost, deicer, or sulfate exposures. ASR can be controlled.[1]

Information is presented showing that use of Class C fly ash, with proper proportioning of concrete, can mitigate alkali silica reactivity (ASR). Test results show ASR was mitigated in concretes using highly reactive aggregates and high alkali cement. Pertinent tests were made in certified commercial testing laboratories.

Aggregates, classified as highly alkali reactive tested at significantly greater than 0.2% percent expansion using the ASTM 1260 procedure, Standard Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method)[2]. Cements used were high alkali cements as tested by procedure ASTM C 114.[3]

ASTM C 1567 tests were made with 1:1 substitutions of 30, 35, 40, 50 and 60% Class C fly ash. Subject fly ash typically tests between 1.3 and 1.45% Water Soluble Alkalis by procedure ASTM C 311[4], Sampling and Testing Fly Ash or Natural Pozzolans for Use in Portland-Cement Concrete.

It can be inferred from the test data that ASR can be mitigated by reducing the water to cementitious ratio (W:Cm) in the concrete, a correctly proportioned mixture of highly reactive aggregates, high alkali cement and Class C fly ash having water-soluble alkalis high in the The American Association of Highway and Transportation Officials (AASHTO) acceptable limit.

It has previously been determined that the W:Cm in concrete can be reduced by reducing the amount of fine aggregate while increasing the coarse aggregate.[5] Further, ASR can be mitigated by appropriate level of Class C fly ash in concrete.[6] Pozzolanic reaction consumes alkali, reduces pore size, and mobility of the alkali, thus reduces ASR expansion.[7]

Test Methods

ASTM C 1260, "Standard Test Method for Determining the Potential Alkali Reactivity of Aggregates (Mortar-Bar Method)".

ASTM C 1567,[8] "Standard Test Method for Determining the Potential Alkali Reactivity Combinations of Cementitious Materials and Aggregate (Mortar-Bar Method)."

Compressive strengths, air content, slump, and yield were performed on all the mixtures in the MRT Technology Center in The Woodlands, Texas, following procedures for the appropriate ASTM Test Methods. C1260 and C1567 testing was performed in the TEC Services Laboratory in Lawrenceville, Georgia. TEC Labs is AASHTO (American Association of Highway and Transportation Officials) approved for the tests performed. TEC Labs also participates in the CCRL (Cement and Concrete Reference Laboratory) inspections and ASTM Interlaboratory Sample program.

Test Plan

1. 1:1 substitutions of Class C Fly Ash for portland cement at 0, 30, 35, 40, 50 and 60 percent. A normal amount of water was used in accordance with ASTM C 1260 and C 1567 for the first set of tests.

2. A companion set of C 1567 tests were made using mid range polycarboxylate water reducer to make the adjustment of water to total cementitious –cement plus fly ash - ratio (W:Cm) in ASTM C 1567 to at least minus 0.10 in the "C" mixes (described in Table 2) and maintain consistency within ± 5 flow of the 0.47 W:Cm flow.

3. Known high alkali reactive aggregates (Wright Materials, Robstown, TX) were used.

4. Use 65% coarse and 35% fine in the aggregates portion of the mix.

5. Use 611 lbs per yard of cementitious in all of the mixes.

6. 0.80 Na_20 equivalent portland cement (Buzzi-Taiwan) was used.

7. The fly ashes used were LCRA (LaGrange, Texas) and Labadie, Missouri Class C Fly Ashes produced from use of Powder River Basin Coal.

8. The matrix for the various mixtures is shown in Table 2.

Table 1. Examples of Proportioning with Type I/II portland cement and conventional admix compared to as total cementitious with polycarboxylate admixture, Class C fly ash/portland cement mixes for cementitious.

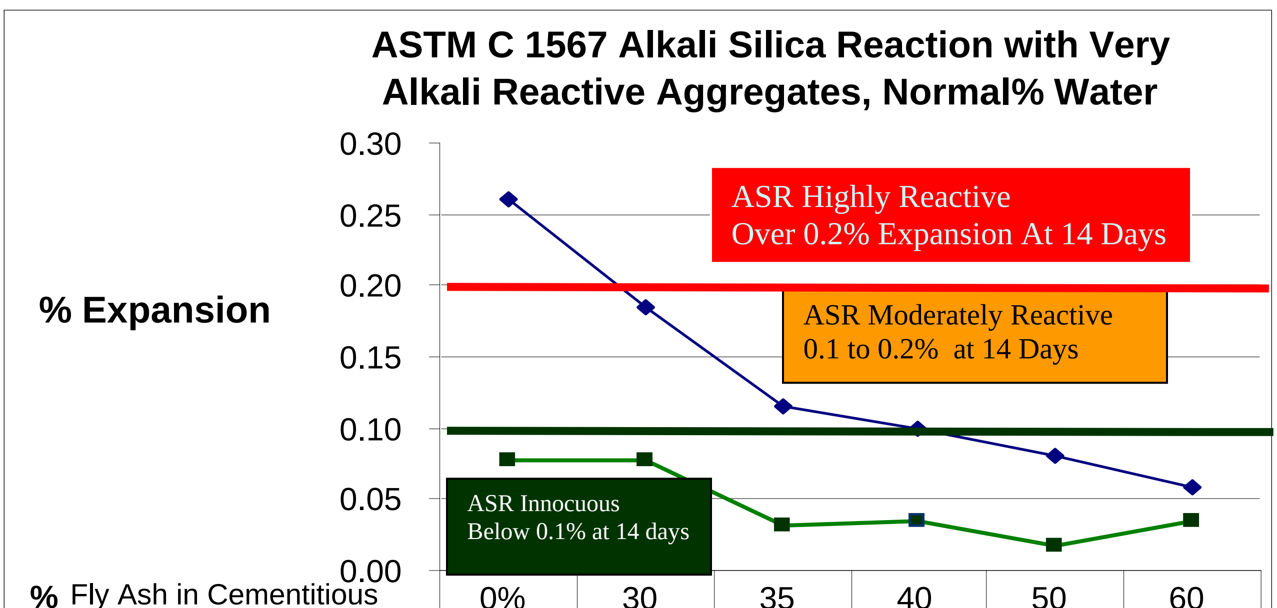
Pounds per Yard Cementitious:			400	400	750
Component			100% Portland / No fly ash	30% Class C	35% Class C
	1" Stone (SSD)	# / yd^3	1917	1917	1900
	Sand (SSD)	# / yd^3	1304	1240	980
	T I/II Portland CEMENT	# / yd^3	400	280	488
	Class C Fly Ash	# / yd^3	0	120	263
Liquid	D-1000 AEA	oz /cwt	0.4	1.2	10.5
Liquid	WRDA 64	oz / cwt	4	0.0	0
Liquid	WR Polycarboxylate 88	oz / cwt	0	6.0	10.5
Liquid	water	# / yd^3	247	206	265
total components		# / yd^3	3868.0	3763.0	3892.5
W/C RATIO			0.62	0.52	0.35
Air Content (%)			4%	3.5%	2.8
Set time 73/90/40 F° (Minutes)			315/240/1275	315/235/1305	300/235/1250
Slump (Inches)			5	4.75	5
	Workability (5 Best)		4	5	5
Compressive Strength	Time (days)	Made on	10/23/2006	11/27/2006	10/4/2005
Compressive Strength	1		1320	1320	3580
Compressive Strength	3		2470	2950	8240
Compressive Strength	7		3420	3890	9790
Compressive Strength	28		4370	5320	10580

Table 2. Matrix Showing the proportions of mixes tested for ASTM C 1012 sulfate resistance.

Per cent Fly ash	Percent Cement					
	100	70	65	40	50	40
0	A					
30		B,C				
35			B,C			
40				B,C		
50					B,C	
60						B,C

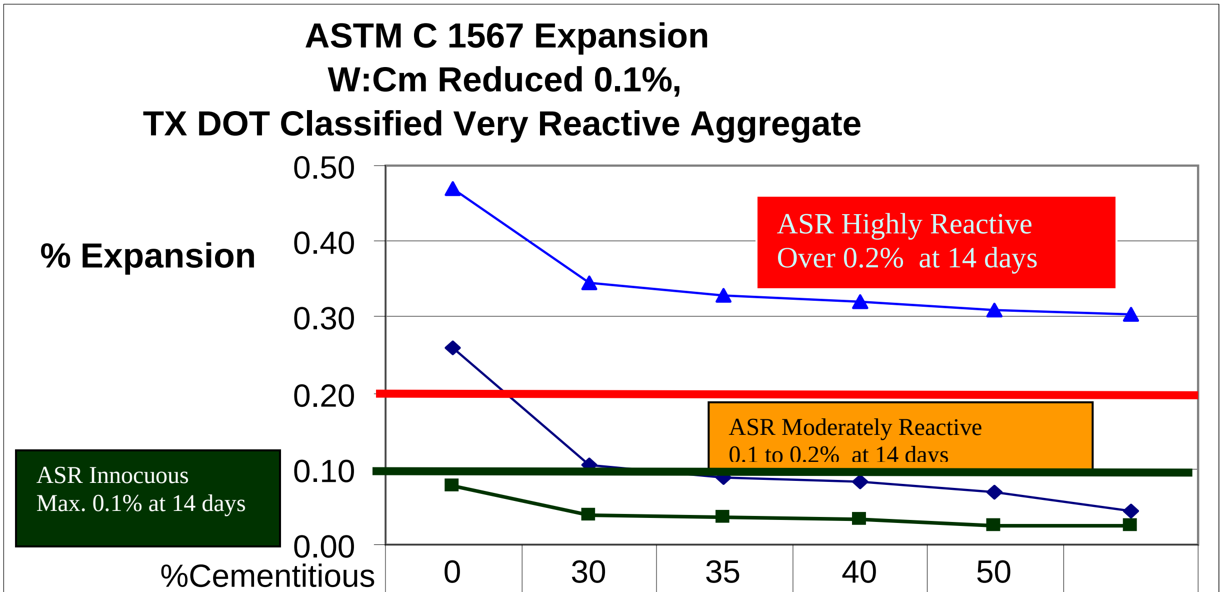
W:Cm Ratios
A = W:Cm of 0.47
B = Water adjusted to provide a Flow within ± 5 of the portland cement only mix.
C = 0.10 W: Cm less than B

Chart 1. ASTM C 1567 Alkali Silica Reaction with Very Alkali Reactive Aggregates and Normal Amount of Water. Seven and 14 Day Expansions.



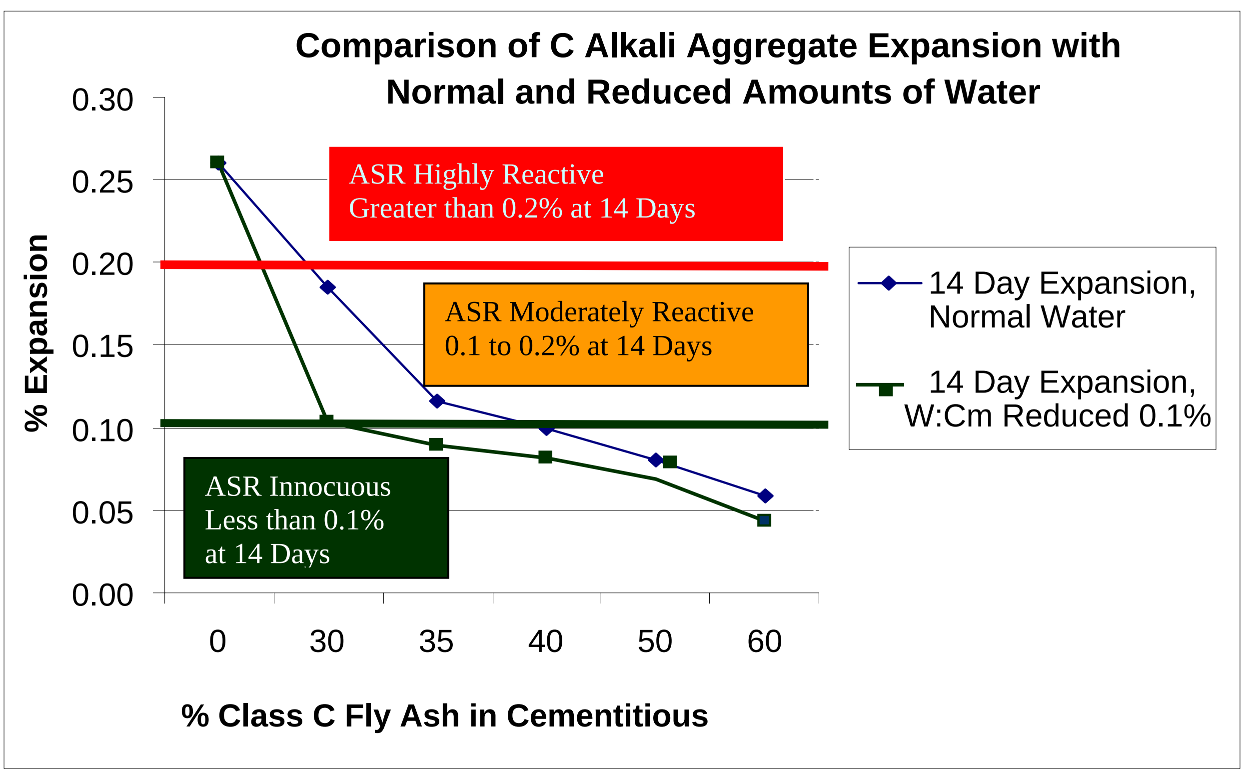
% Fly Ash in Cementitious	0%	30	35	40	50	60
14 Day Expansion	0.26	0.19	0.12	0.10	0.08	0.06
7 Day Expansion	0.08	0.08	0.03	0.03	0.02	0.03

Chart 2. ASTM C 1567 Alkali Silica Reaction with Very Alkali Reactive Aggregates and Reduced Amount of Water. Seven and 14 Day Expansions.



%Cementitious	0	30	35	40	50	
14 Day Expansion	0.26	0.10	0.089	0.08	0.07	0.043
7 Day Expansion	0.08	0.04	0.04	0.033	0.03	0.024
W:Cm	0.47	0.346	0.33	0.3205	0.3091	0.303

Chart 3. ASTM C 1567 Alkali Silica Reaction with Very Alkali Reactive Aggregates, Normal and Reduced Amount of Water. Standard 14 Day Expansions.



Discussion

Salient points gleaned from the tests performed show several positive aspects:

- Mitigation of ASR by the use of additional Class C fly ash was shown by utilizing additional amounts of Class C fly ash as an additive along with reduction in mix water.
- When Class C fly ash was used at over 35 percent, ASR was mitigated to innocuous even with aggregates that tested very highly reactive in conjunction with high alkali portland cement.
- The water used can be accomplished in concrete mixes by combinations of:
  - Reducing sand while increasing coarse aggregates.
  - Use of mid range and high range poly-carboxylate admixes.

Conclusions and Recommendations

It has been shown that reduced W:Cm, in combination with increasing Class C fly ash in mixes, utilization of improved proportioning along with updated admixtures can mitigate ASR in highly reactive aggregates. It is recommended that when ASR is a concern or when Alkali Reactive Aggregates are encountered, that W:Cm be reduced as shown above and sufficient class C fly ash be used to mitigate ASR.

Workability of the concrete mixes with polycarboxylates is achieved by use of reduced sand and increased amounts of fly ash.

REFERENCES

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[3]ASTM C 114 – 05, ASTM International Book of Standards, Volume 04.01 Standard Test Methods for Chemical Analysis of Hydraulic Cement.

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[5] Improved Early Performance of High Volume Class C Fly Ash Concrete, Hicks, J.K., University Of Wisconsin, Recycling Opportunities for Fly Ash and other Coal Combustion Products in Concrete and Construction Materials, February, 2006**.**

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