ASR:
Alkali Silica Reactivity

PATRICIA BAER

PENNDOT

BUREAU OF PROJECT DELIVERY

CONSTRUCTION AND MATERIALS DIVISION

History:

In 1990, cores were taken from I-84.

- The pavement was 12 years old and exhibited cracking and centerline deterioration.
- Earliest discovery of ASR on a Department owned pavement.
- Joined the Mid-Atlantic Task Force to form a strategy to detect slowly reacting aggregates.

Task Force came up with a set of documents on:

- How to determine if an aggregate is reactive.
  - Mortar Bar method that originated in South Africa
  - The first SHRP program investigated this method – developed:
    - ASTM P 214 “proposed Test Method for Accelerated detection of Potentially Deleterious Expansion of Mortar Bars Due to Alkali-Silica Reaction”
- Strategies on how to remediate.

History:

1991 Department tested several aggregates

- Results showed a potential for highly reactive aggregates
- A testing program was discussed with the aggregate industry
- Started testing all aggregates in 1992

Results:

- 464 aggregates – 75% had expansion test results over 0.10% linear expansion.

Previous Department Specifications:

Section 704.2(g)

Aggregate Evaluation. The LTS will test aggregates according to AASHTO T 303 and list the results in Bulletin 14. Aggregates that develop expansion greater than 0.10% after 14 days in solution (16 days - age of bar) are considered potentially reactive with cement alkalis. The Contractor may test aggregates according to ASTM C227 to confirm potential reactivity of fine or coarse aggregate, but not to classify an aggregate as “nonreactive.” If ASTMC227 mortar bars are made with cement having an alkali content greater than 0.80%, aggregates are considered to be “reactive” if expansion is greater than 0.05% at 3 months or greater than 0.10% at 6 months. If the expansion result for a coarse aggregate size is not listed in Bulletin 14, use of the expansion result from another coarse aggregate size listed in Bulletin 14 from the same source will be acceptable.

Use aggregates that are deemed potentially reactive only with cements or cement-pozzolan combinations as specified in Section 704.1(g)3. If one or both of the aggregates (coarse or fine) used in a mix is reactive, mitigation is required as specified in Section 704.1(g)3. This requirement applies to all concrete used in paving or permanent structures on Department projects, including latex modified overlays and precast and prestress concrete products.

Previous Department Specifications:

Section 704.3.c(g)

Portland Cement. Conforming to the optional chemical requirement in AASHTO M 85 for a maximum alkali content of 0.60%.

Blended Hydraulic Cement. Type IS or IP, ASTM C595. From a manufacturer listed in Bulletin 15.

Portland Cement-Pozzolan Combination. Furnish a combination of Portland cement with an alkali content no greater than 1.40% and flyash, ground granulated blast furnace slag, or silica fume tested and qualified by the LTS as follows:

- Flyash—Furnish flyash that conforms to the optional chemical requirement in AASHTO M 295 for a maximum alkali content of 1.5% and that produces a 50% minimum reduction in mortar expansion when tested by the LTS according to ASTM C441. Use a quantity of flyash equal to a minimum of 15%, by weight, of the total cementitious material. If flyash is added to reduce alkali-silica reactivity, use a quantity of flyash between 15.0% and 25.0%, by weight, of the total cementitious material. If aggregate expansion, when tested according to AASHTO T 303, is greater than 0.40%, use a quantity of flyash equal to a minimum of 20%, by weight, of the total cementitious material. Flyash may replace no more than 15.0% of the Portland cement; the remaining flyash is to replace the fine aggregate.

- Ground Granulated Blast Furnace Slag—Furnish slag producing a 50% minimum reduction in mortar expansion when tested by the LTS according to ASTM C441. Use a quantity of slag between 25.0% and 50.0%, by weight, of the total cementitious material. If aggregate expansion, when tested according to AASHTO T 303, is greater than 0.40%, use a quantity of ground granulated blast furnace slag equal to a minimum of 40%, by weight, of the total cementitious material.

- Silica Fume—Use a quantity of silica fume between 5% and 10%, by weight, of the total cementitious material. Use of silica fume will be allowed on an experimental basis only, until sufficient experience is gained.

- Mechanically Modified Pozzolan-Cement combinations. Use a quantity equal to or greater than that required for the base pozzolan, as specified above, but not greater than 50% by weight of the total cementitious material.

The Department may waive flyash or ground granulated blast furnace slag requirements if the Contractor presents test results from an independent laboratory showing that a lesser amount of pozzolan will mitigate ASR expansion to below 0.10% when tested according to AASHTO T 303.

Previous Department Specifications:

One or more reactive aggregates (>0.10% expansion):

- Pozzolans as cement replacement (by mass)
  - Flyash
    - 15-25%
    - 20% minimum if expansion is greater than 0.40%
  - GGBFS
    - 25-50%
    - 40% minimum if expansion is greater than 0.40%
  - Silica Fume
    - 5-10%

Blended cements – Type 1S or 1P

Previous Department Specifications:

AASHTO T-303 – Accelerated Mortar Bar Testing

- 14d (in solution) – 0.10% max expansion (AASHTO TP-14 in 1992) Generally good predictive test method and used by many states (or a companion ASTM test method, ASTM C-1260).
  - **Can and does generate inaccurate results**
    - Producer risk: Test positive, – Field negative', i.e. no ASR
    - Department risk: **Test negative**– **Field Positive**, i.e. ASR

Background of situation that prompted change:

Significant ASR deterioration identified in pavement structures

- Districts 4, 6 and 8 (to date)
- Mix designs contained aggregates which were not identified as ‘reactive’, concrete placed after 1992.
- One Example (AASHTO T-303 expansion values)
  - **FA Type A: 0.08%**
  - **CA #57: 0.01%**
- Other Districts have reported preventive maintenance; overlays on concrete pavements less than 10 years old where distress likely was attributable to ASR however no forensic investigation was performed prior to repair and reconstruction.

FHWA development of ASR inventory to assist states

Administration Directive:

Form a ‘pro-team’ to accelerate implementing a corrective action plan.

- Identify any short term/stop gap solutions which can be implemented immediately
- Implement specification revisions to prevent future occurrences.

What we did:

Who’s been involved in the process – Pro-team

Short Term solution – Standard Special Provision

Long Term solution

- AASHTO PP-65 (now – AASHTO R 80)
  - Review of the prescriptive approach
    - Basis for future specification developments

Pro-team

Pro-team developed

- September 5th, 2013 'kick off meeting'

Industry (PACA – ACPA – CABA/PPA)

- PennDOT Central Office, BOMO and District staff
- FHWA
  - Lead ASR researchers made available
    - Dr. Michael Thomas – Univ. of New Brunswick
      participated in the first meeting
    - Dr. Rogers – University Lavalle, Quebec – ASTM C-1293 evaluation assistance for 3rd party testing using Spratt aggregate

Stop Gap Measure - What was considered?

Risk of continuing with our current aggregate testing and ASR remediation is considered too high

- Need to protect future assets!

Most of our aggregates are already considered reactive and when used, remediation required.

Inability to identify aggregates solely via petrographic examination as ‘reactive’ or ‘non-reactive’

Impacts to industry (SCM availability)

Decision – Mitigate all mixtures

Consider all aggregates as reactive until the latest research and remediation strategies can be implemented

- Stop Gap Measure
- Will require more SCM's for use by industry
  - Survey conducted of flyash and GGBFS producers
  - Industry indicated they have sufficient SCM's available for this interim measure.

Standard Special Provision(short term)

Current replacement levels for SCM’s retained

All current ASR remediation methods retained

GGBFS and Flyash (combined) restriction removed

ASTM C-1567 testing for lower SCM volumes (than those prescribed) to be permitted.

Implemented until testing was completed and specification change made

Previous Policy
AASHTO T-303 Accelerated Mortar Bar Aggregate Evaluation

Sources initially tested prior to 1992 SSP and Bulletin 14 updated with expansion values.

Few other than 'new' sources have been re-tested since their initial tests were performed.

- PennDOT does not currently have any established frequency for re-qualification testing or source QC testing.

Verification Testing

AASHTO T-303

- The Department ran T303 for all current aggregate suppliers.
- We looked at the possibility of using a 28 day value instead of the 14 day.

		New ASR Value (28 day)	
Suppler Code	[illegible] Value (14 day)	14 day	28 day
GLA46B14	0.01	0.02	0.02
KIN66A14	0.04	0.02	0.02
CSCNCA14	0.06	0.06	0.09
ALC10D14	0.07	0.03	0.05
YOPMDC14	0.07	0.04	0.12
HEB21C14	0.08	0.06	0.11
VAI21A14	0.08	0.08	0.12
VAI28B14	0.08	0.03	0.06
VAI28A14	0.08	0.08	0.14
HGR16A14	0.08	0.02	0.03
WAMNJB14	0.08	0.05	0.10
TILNJE14	0.08	0.04	0.05
SWBMDA14	0.08	0.04	0.05
MADMDA14	0.08	0.05	0.08
DISMDA14	0.08	0.10	0.19
BIR06A14	0.08	0.04	0.04
PLD23A14	0.09	0.05	
GRS07B14	0.09	0.09	
BLI03A14	0.09	0.02	
ALC37B14	0.09	0.09	0.16
LNDMDD14	0.09	0.06	0.08
NEW05B14	0.10	0.14	
PES36A14	0.10	0.10	
HBMNJD14	0.10	0.08	
AACWVA14	0.10	0.30	0.40
WHINJA14	0.10	0.03	0.05
ICM15A14	0.10	0.08	0.15
REPNJB14	0.10	0.11	0.22

Research and Policy used

Standard Practice for

Determining the Reactivity of Concrete Aggregates and Selecting Appropriate Measures for Preventing Deleterious Expansion in New Concrete Construction

AASHTO Designation: PP 65-11

Researchers: Thomas, Fournier & Folliard

- FHWA-HIF-09-001 (2008)

Document developed under the SAFETEA-LU legislation

Goal: Develop and deploy improved guidance to prevent and mitigate ASR in concrete

Resultant document/practice: AASHTO PP-65-10

- Updated in 2011

FHWA: PP-65 (AASHTO R 80)

History of FHWA ASR Program

- Launched in 2006
- Goal: To increase concrete pavement and structural durability and performance and reduce life-cycle cost through the prevention and mitigation of ASR.
- Guidance Document developed:
  - Report on Determining the Reactivity of Concrete Aggregates and Selecting Appropriate Measures for Preventing Deleterious Expansion in New Concrete Construction (Pub No. FHWA-HIF-09-001)
    - AASHTO PP-65
    - AASHTO R 80
  - Report on Diagnosis, Prognosis and Mitigation of Alkali-Silica Reaction in Transportation Structures (Pub No. FHWA-HIF-09-004)
    - How to diagnose and treat ASR in existing concrete.
- Group will continue researching

Aggregate Evaluation

Letter drafted for Type A aggregate sources

Will allow for their choice of four independent labs

- National Ready Mix Concrete Association
- Concrete Testing Laboratory
- American Engineering Technology
- Bowser-Morner

Provided guidance on sample sizes, coordination with District and sample custody

Sources advised that failure to perform testing would result in loss of use in cement concrete when further specification revisions made

Conduct more definitive concrete prism testing (ASTM C1293) on aggregates.

- Industry and PennDOT to perform testing initially on aggregate sources with T-303 expansions less than or equal to 0.15% a first phase of implementation.

AASHTO PP-65 (AASHTO R 80)

Protocol for Alkali Aggregate Reactivity

- ASR and ACR
- Selecting preventive measures for ASR reactive aggregates
  - Two approaches for ASR prevention:
    - Performance approach – Based on laboratory testing of the aggregates, SCM's or lithium nitrates used to determine the amount required to control deleterious expansion.
      - **Involves a 2 year duration concrete prism test**
      - Looking at field performance as possible approach to how an aggregate performs
    - Prescriptive approach – Involves a number of factors and decision based methods. >This method will be reviewed.

Prescriptive Approach - Assumptions

Level of ASR risk increases with aggregate reactivity, size of structure and availability of moisture in service.

Some structures can tolerate a higher risk than others (i.e. based on service life, safety etc.)

The amount of SCM required, when needed depends on several factors including

- Reactivity of the aggregate
- Max alkali (as Na_2Oe% for SCM's)
- Alkali provided to the concrete by the Portland cement
- Exposure to alkali's in service (Structure type and environment)

Prescriptive Approach – Aggregate Reactivity Class

Table 1. Classification of aggregate reactivity.

Aggregate-Reactivity Class	Description of Aggregate Reactivity	One-Year Expansion in CPT (%)	14-Day Expansion in AMBT (%)
R0	Non-reactive	≤ 0.04	≤ 0.10
R1	Moderately reactive	> 0.04, ≤ 0.12	> 0.10, ≤ 0.30
R2	Highly reactive	> 0.12, ≤ 0.24	> 0.30, ≤ 0.45
R3	Very highly reactive	> 0.24	> 0.45

- Step 1: Determine Aggregate reactivity class (R0-R3)
  - Uses AASHTO C-1260 and C1293
  - The ASTM C1293 concrete prism test is much more reliable for determining the true potential of the aggregate to contribute to ASR however the duration is significantly longer (one year).

Prescriptive approach – Level of Risk

Table 2. Determining the level of ASR risk.

	Aggregate-Reactivity Class			
Size and exposure conditions	R0	R1	R2	R3
Non-massive[2] concrete in a dry[3] environment	Level 1	Level 1	Level 2	Level 3
Massive[2] elements in a dry[3] environment	Level 1	Level 2	Level 3	Level 4
All concrete exposed to humid air, buried or immersed	Level 1	Level 3	Level 4	Level 5
All concrete exposed to alkalis in service[4]	Level 1	Level 4	Level 5	Level 6

Note 4: Examples include highway structures exposed to deicing salts

Step 2: Determine acceptable level of ASR risk

- 6 Levels
  - Based on size and exposure conditions

Prescriptive approach – Level of Prevention

Our 'Risk Level' was 4

Table 3. Determining the level of prevention.

	Classification of Structure (Table 4)			
Level of ASR Risk (Table 2)	**S1**	**S2**	**S3**	**S4**
Risk Level 1	V	V	V	V
Risk Level 2	V	V	W	X
Risk Level 3	V	W	X	Y
Risk Level 4	W	X	Y	Z
Risk Level 5	X	Y	Z	ZZ
Risk Level 6	Y	Z	ZZ	††

†† It is not permitted to construct a Class S4 structure (see Table 4) when the risk of ASR is Level 6. Measures must be taken to reduce the level of risk in these circumstances.

Step 3: Determine the level of prevention required from the structure classification and level of risk from the previous step.

Note that a structure class (S1-S4)is also needed.

Prescriptive Approach – Structure Class

Structure class – Determined based on the allowable risk for accepting ASR. Example structure types are given.

Table 4. Structures classified on the basis of the severity of the consequences should ASR[6] occur (modified for highway structures from RILEM TC 191-ARP).

Class	Consequences of ASR	Acceptability of ASR	Examples[7]
S1	Safety, economic, or environmental consequences small or negligible	Some deterioration from ASR may be tolerated	▪ Non-load-bearing elements inside buildings ▪ Temporary structures (e.g. < 5 years)
S2	Some safety, economic, or environmental consequences if major deterioration	Moderate risk of ASR is acceptable	▪ Sidewalks, curbs, and gutters ▪ Service life < 40 years
S3	Significant safety, economic, or environmental consequences if minor damage	Minor risk of ASR acceptable	▪ Pavements ▪ Culverts ▪ Highway barriers ▪ Rural, low-volume bridges ▪ Large numbers of precast elements where economic costs of replacement are severe ▪ Service life normally 40 to 75 years
S4	Serious safety, economic, or environmental consequences if minor damage	ASR cannot be tolerated	▪ Major bridges ▪ Tunnels ▪ Critical elements that are very difficult to inspect or repair ▪ Service life normally > 75 years

Prescriptive Approach – Option 1

Table 5. Maximum alkali contents in portland cement concrete to provide various levels of prevention.

Prevention Level	Maximum Alkali Content of Concrete (Na_2Oe)	
	lb/yd³	kg/m³
V	No limit	
W	5.0	3.0
X	4.0	2.4
Y	3.0	1.8
Z[8]	Table 8	
ZZ[8]		

Table 8. Using SCM and limiting the alkali content of the concrete to provide exceptional levels of prevention.

Prevention Level	SCM as Sole Prevention	Limiting Concrete Alkali Content Plus SCM	
	Minimum SCM Level	Maximum Alkali Content, lb/yd³ (kg/m³)	Minimum SCM Level
Z	SCM level shown for Level Z in Table 6	3.0 (1.8)	SCM level shown for Level Y in Table 6
ZZ	Not permitted	3.0 (1.8)	SCM level shown for Level Z in Table 6

PP-65 has a number of options in their prescriptive approach at this step.

This option involves controlling the maximum alkali content in the concrete only (where prevention levels are lower)

For prevention level 'Y' in our example, minimum SCM replacement levels are also provided (**presented on next slide, Table 6**).

Prevention Levels Z and ZZ will be shown later as Option 3.

Prescriptive approach – Option 2

Table 6. Minimum levels of SCM to provide various levels of prevention.

Type of SCM[10]	Alkali level of SCM (% Na_2Oe)	Minimum Replacement Level[11] (% by mass of cementitious material)				
		Level W	Level X	Level Y	Level Z	Level ZZ
Fly ash ($CaO \leq 18\%$)	≤ 3.0	15	20	25	35	
	> 3.0, ≤ 4.5	20	25	30	40	
Slag	≤ 1.0	25	35	50	65	
Silica Fume[12] ($SiO_2 \geq 85\%$)	≤ 1.0	1.2 x LBA or 2.0 x KGA	1.5 x LBA or 2.5 x KGA	1.8 x LBA or 3.0 x KGA	2.4 x LBA or 4.0 x KGA	

Table 7

Table 7. Adjusting the minimum level of SCM based on the alkali content in the portland cement.

Cement Alkalis (% Na_2Oe)	Level of SCM
≤ 0.70	Reduce the minimum amount of SCM given in Table 6 by one prevention level[13]
> 0.70, ≤ 1.00	Use the minimum levels of SCM given in Table 6
> 1.00, ≤1.25	Increase the minimum amount of SCM given in Table 6 by one prevention level
> 1.25	No guidance is given

Option 2 – Using SCM's/Cement alkali

Allows for an adjustment of the SCM replacement value indicated based on the alkali level of the cement using Table 7

Prescriptive Approach – requirements for level Z and ZZ

Table 8. Using SCM and limiting the alkali content of the concrete to provide exceptional levels of prevention.

Prevention Level	SCM as Sole Prevention	Limiting Concrete Alkali Content Plus SCM	
	Minimum SCM Level	Maximum Alkali Content, lb/yd^3 (kg/m^3)	Minimum SCM Level
Z	SCM level shown for Level Z in Table 6	3.0 (1.8)	SCM level shown for Level Y in Table 6
ZZ	Not permitted	3.0 (1.8)	SCM level shown for Level Z in Table 6

Higher minimum SCM replacement volumes or limiting the alkali content of the concrete and using SCM's

Used when 'exceptional' levels of prevention are required.

This approach excludes the use of lithium admixtures as a preventive measure (based on research)

AASHTO PP-65 - Program

A free interactive 'program' is available as a download from the FHWA website that takes user inputs, walking through PP65 one step at a time.

http://www.fhwa.dot.gov/pavement/concrete/asr/resources/pp65.cfm

Current Specification:

All fine and coarse aggregates for use in concrete were tested according to ASTM C 1293

New sources that want to be used in concrete will be tested according to AASHTO T 303 and ASTM C 1293.

- The Department has purchased two warm rooms. They have the capacity to test 100 samples.
- The AASHTO T 303 test result will be used for mitigation requirements until the ASTM C 1293 is finished
  - Any new source with an expansion that indicates the aggregate is non-reactive (R0) will initially be listed with an expansion of 0.11% (R1) requiring ASR mitigation until ASTM C 1293 is completed.

A source may opt to do mixture qualification to determine the amount of pozzolan, metakaolin or lithium needed to mitigate.

- This is a two year test (ASTM C 1293).
  - If the expansion of the concrete prism is less than 0.04% after two years, the preventive measure will be deemed effective with the reactive aggregate(s)

Current Specification:

Prescriptive Approach: The Pro-Team made some minor changes to the tables in AASHTO R 80

1. Classification of Aggregate Reactivity :

Aggregate Reactivity Class	Description of Aggregate Reactivity	1-Year Expansion in ASTM C-1293 (percent)	14-d Expansion in AASHTO T-303 (percent)
R0	Non-reactive	≤ 0.04	≤ 0.10
R1	Moderately reactive	>0.04, ≤ 0.12	>0.10, ≤ 0.30
R2	Highly Reactive	>0.12, ≤0.24	>0.30, ≤0.45
R3	Very Highly Reactive	>0.24	>0.45

Current Specification:

2. Level of ASR Risk: Specification

R0	R1	R2	R3
Risk Level 1	Risk Level 2	Risk Level 3	Risk Level 4

Level of ASR Risk: R 80

Table 2. Determining the level of ASR risk.

	Aggregate-Reactivity Class			
Size and exposure conditions	**R0**	**R1**	**R2**	**R3**
Non-massive[2] concrete in a dry[3] environment	Level 1	Level 1	Level 2	Level 3
Massive[2] elements in a dry[3] environment	Level 1	Level 2	Level 3	Level 4
All concrete exposed to humid air, buried or immersed	Level 1	Level 3	Level 4	Level 5
All concrete exposed to alkalis in service[4]	Level 1	Level 4	Level 5	Level 6

Current Specification:

3. Determining the Level of Prevention: Specification

Classification of Structure

Level of ASR Risk	S1	S2	S3
Risk Level 1	V	V	V
Risk Level 2	V	W	X
Risk Level 3	W	X	Y
Risk Level 4	X	Y	Z

Determining the Level of Prevention: R 80

Table 3. Determining the level of prevention.

	Classification of Structure (Table 4)			
Level of ASR Risk (Table 2)	**S1**	**S2**	**S3**	**S4**
Risk Level 1	V	V	V	V
Risk Level 2	V	V	W	X
Risk Level 3	V	W	X	Y
Risk Level 4	W	X	Y	Z
Risk Level 5	X	Y	Z	ZZ
Risk Level 6	Y	Z	ZZ	††

†† It is not permitted to construct a Class S4 structure (see Table 4) when the risk of ASR is Level 6. Measures must be taken to reduce the level of risk in these circumstances.

Current Specification:

4. Structure Classification: R 80

Table 4. Structures classified on the basis of the severity of the consequences should ASR[6] occur (modified for highway structures from RILEM TC 191-ARP).

Class	Consequences of ASR	Acceptability of ASR	Examples[7]
S1	Safety, economic, or environmental consequences small or negligible	Some deterioration from ASR may be tolerated	▪ Non-load-bearing elements inside buildings ▪ Temporary structures (e.g. < 5 years)
S2	Some safety, economic, or environmental consequences if major deterioration	Moderate risk of ASR is acceptable	▪ Sidewalks, curbs, and gutters ▪ Service life < 40 years
S3	Significant safety, economic, or environmental consequences if minor damage	Minor risk of ASR acceptable	▪ Pavements ▪ Culverts ▪ Highway barriers ▪ Rural, low-volume bridges ▪ Large numbers of precast elements where economic costs of replacement are severe ▪ Service life normally 40 to 75 years
S4	Serious safety, economic, or environmental consequences if minor damage	ASR cannot be tolerated	▪ Major bridges ▪ Tunnels ▪ Critical elements that are very difficult to inspect or repair ▪ Service life normally > 75 years

Current Specification:

4. Structure classification: Specification

Structure Class	Consequences	Acceptability of ASR	Structure/Asset type	Publication 408 Sections
S1	Safety and future maintenance consequences small or negligible	Some deterioration from ASR may be tolerated	Temporary structures. Inside buildings. Structures or assets that will never be exposed to water	627, 620, 621, 624, 627, 628 643, 644, 859, 874, 930, 932, 934, 952, 953, 1005
S2	Some minor safety, future maintenance consequences if major deterioration were to occur	Moderate risk of ASR acceptable	Sidewalks, curbs and gutters, inlet tops, concrete barrier and parapet. Typically structures with service lives of less than 40 years	303, 501, 505, 506, 516, 518, 523, 524, 525, 528, 540, 545, 605,607, 615, 618, 622, 623, 630, 633, 640, 641, 658, 667, 673, 674, 675, 676, 678, 714, 875, 852, 875, 910, 948, 951, 1025, 1001, 1040, 1042, 1043, 1086, 1201, 1210, 1230, Miscellaneous Precast Concrete
S3	Significant safety and future maintenance or replacement consequences if major deterioration were to occur	Minimal risk of ASR acceptable	All other structures. Service lives of 40 to 75 years anticipated.	530, 1001, 1006, 1031, 1032, 1040, 1080, 1085, 1107, MSE walls, Concrete Bridge components and Arch Structures

Current Specification:

5. Minimum Levels of Supplementary Cementitious Materials: Specification

Table G:

Type of SCM [1]	Alkali Level of SCM (%Na2Oe) [2] [3]	Level V [4]	Level W	Level X	Level Y	Level Z [5] [11]
Class F or C flyash [6]	≤ 3.0	-	15	20	25	35
Class F or C flyash [6]	>3.0, ≤ 4.5	-	20	25	30	40
GGBFS	≤ 1.0	-	25	35	50	65
Silica Fume [7] [8] [9] [10]	≤ 1.0	-	1.2 LBA	1.5 x LBA	1.8 x LBA	2.4 x LBA

Current Specification:

The minimum replacement levels in Table G are appropriate for use with Portland cements of moderate to high alkali contents (0.70 to 1.25 percent Na2Oe). Table H provides an alternative approach for utilizing SCMs when the alkali content of the portland cement is less than or equal to 0.70%.

Table H – Adjusting the Minimum Level of SCM when using low alkali Portland cement

Cement Alkalis (% Na2Oe)	Level of SCM
≤ 0.70	Reduce the minimum amount of SCM given in Table G by one prevention level. (1)

(1) The replacement levels should not be below those given in Table G for prevention Level W regardless of the alkali content of the Portland cement.

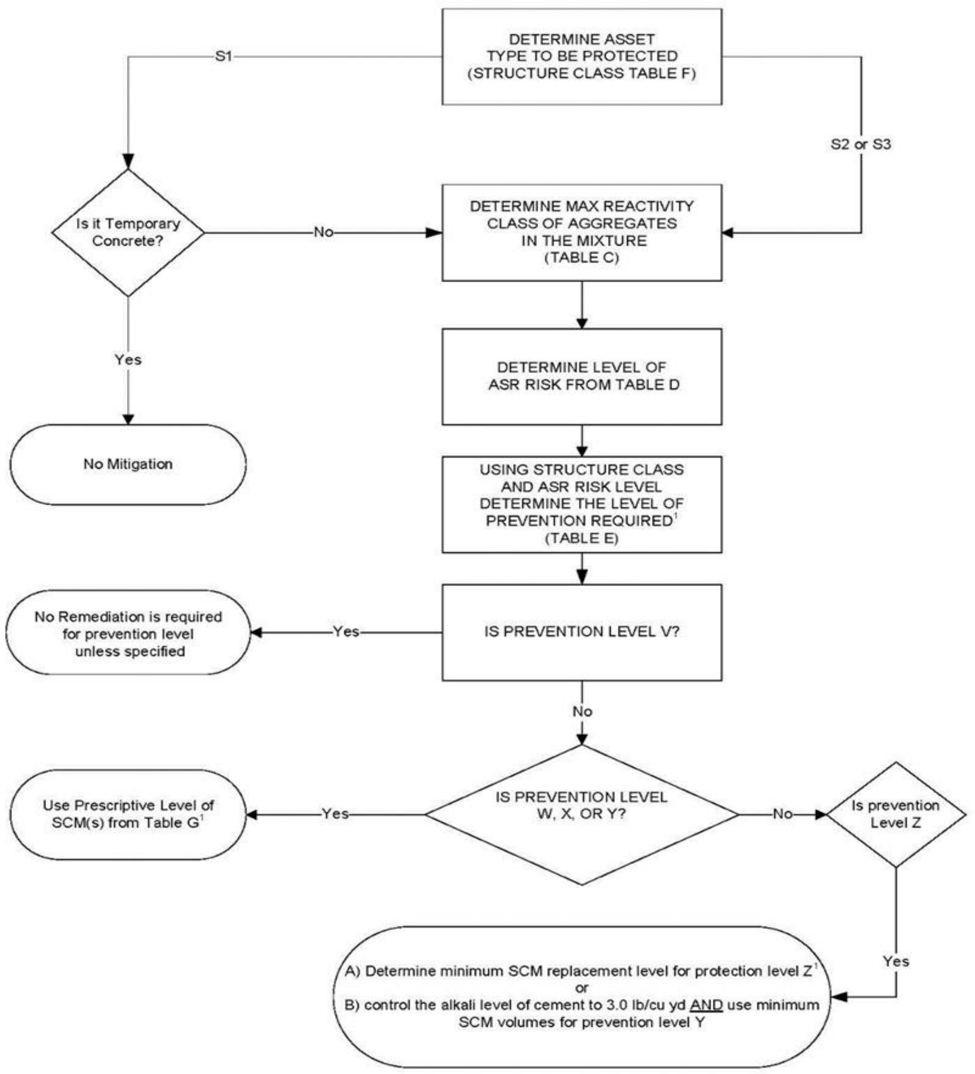
CurrentSpecification:

Requirements for Prevention Level Z – Where prevention Level Z is required, utilize one of the following two options. Use the minimum level of SCM shown in Table G or use the minimum level of SCM and the maximum concrete alkali content indicated in Table I

Table I – Using SCM and limiting the Alkali Content of the Concrete

Prevention Level	SCM as sole prevention	Maximum Alkali Content, (lbs/cy) and Minimum SCM Level
Z	Level Z from Table G	Maximum Alkali Level Content: 3.0 AND minimum SCM Level Y from Table G

Current Specification:



Note 1: The prevention level may be reduced by one level if low alkali cement (≤ 0.70) is used.

Example #1 – using specification

Step #1:

Using a coarse aggregate with a reactivity of 0.18% and a fine aggregate with a reactivity of 0.03%

- According to Table C:

Aggregate Reactivity Class	Description of Aggregate Reactivity	1-Year Expansion in ASTM C-1293 (percent)	14-d Expansion in AASHTO T-303 (percent)
R0	Non-reactive	≤ 0.04	≤ 0.10
R1	Moderately reactive	>0.04, ≤ 0.12	>0.10, ≤ 0.30
R2	Highly Reactive	>0.12, ≤0.24	>0.30, ≤0.45
R3	Very Highly Reactive	>0.24	>0.45

- The coarse aggregate is a R2 reactivity class.
- The fine aggregate is non reactive or R0.
- For mix designs use the highest reactivity level of any aggregates used.

Example #1 continued

Step #2:

The next step is to figure out the level of ASR risk

- According to Table D: Aggregate Reactivity Class

R0	R1	R2	R3
Risk Level 1	Risk Level 2	Risk Level 3	Risk Level 4

- This aggregate would be at a Risk Level 3

Example #1 continued

Step #3:

Determine Level of prevention. The structure classification needs to be know in order to determine the level of prevention.

- See Table F:

If this mix design was for concrete paving under section 506, then the structure class would be S2.

If this mix design was for LLCP- long life concrete pavement under section 530, then the structure class would be S3.

Structure Class	Consequences	Acceptability of ASR	Structure/Asset type	Publication 408 Sections
S1	Safety and future maintenance consequences small or negligible	Some deterioration from ASR may be tolerated	Temporary structures. Inside buildings. Structures or assets that will never be exposed to water	627, 620, 621, 624, 627, 628 643, 644, 859, 874, 930, 932, 934, 952, 953, 1005
S2	Some minor safety, future maintenance consequences if major deterioration were to occur	Moderate risk of ASR acceptable	Sidewalks, curbs and gutters, inlet tops, concrete barrier and parapet. Typically structures with service lives of less than 40 years	303, 501, 505, 506, 516, 518, 523, 524, 525, 528, 540, 545, 605,607, 615, 618, 622, 623, 630, 633, 640, 641, 658, 667, 673, 674, 675, 676, 678, 714, 875, 852, 875, 910, 948, 951, 1025, 1001, 1040, 1042, 1043, 1086, 1201, 1210, 1230, Miscellaneous Precast Concrete
S3	Significant safety and future maintenance or replacement consequences if major deterioration were to occur	Minimal risk of ASR acceptable	All other structures. Service lives of 40 to 75 years anticipated.	530, 1001, 1006, 1031, 1032, 1040, 1080, 1085, 1107, MSE walls, Concrete Bridge components and Arch Structures

Example #1 continued

Step #4: Let's say the design is for concrete pavement (RPS – section 506)

- The Structure Classification would be S2

- From Table E – Determining the level of prevention

	Classification of Structure		
Level of ASR Risk	S1	S2	S3
Risk Level 1	V	V	V
Risk Level 2	V	W	X
Risk Level 3	W	X	Y
Risk Level 4	X	Y	Z

- With a Risk Level of 3 and a S2 classification, this mix needs a prevention level X

Example #1 continued

Step #5:

- Let’s say we are going to pozzolan to mitigate for ASR.
- See Table G for the minimum replacement levels

Type of SCM [1]	Alkali Level of SCM (% Na2Oe) [2] [3]	Level V [4]	Level W	Level X	Level Y	Level Z [5] [11]
Class F or C flyash [6]	≤ 3.0	-	15	20	25	35
Class F or C flyash [6]	>3.0, ≤ 4.5	-	20	25	30	40
GGBFS	≤ 1.0	-	25	35	50	65
Silica Fume [7] [8] [9] [10]	≤ 1.0	-	1.2 LBA	1.5 x LBA	1.8 x LBA	2.4 x LBA

- The mix needs a Level X replacement so the pozzolan replacement levels would be:
  - 20% for a Class F or C flyash with an alkali level of 3.0% or less
  - 25% for a Class F or C flyash with an alkali level greater than 3.0% or less than or equal to 4.5%
  - 35% for GGBFS
  - 1.5 x LBA for Silica Fume but not less than 7%

Example #2 – using current specification

Step #1:

Using a coarse aggregate with a reactivity of 0.10% and fine aggregate with a reactivity of 0.06%

- According to Table C:

Aggregate Reactivity Class	Description of Aggregate Reactivity	1-Year Expansion in ASTM C-1293 (percent)	14-d Expansion in AASHTO T-303 (percent)
R0	Non-reactive	≤ 0.04	≤ 0.10
R1	Moderately reactive	>0.04, ≤ 0.12	>0.10, ≤ 0.30
R2	Highly Reactive	>0.12, ≤0.24	>0.30, ≤0.45
R3	Very Highly Reactive	>0.24	>0.45

- Both aggregates are a R1 reactivity class.

Example #2 continued

Step #2:

The next step is to figure out the level of ASR risk

- According to Table D: Aggregate Reactivity Class

R0	R1	R2	R3
Risk Level 1	Risk Level 2	Risk Level 3	Risk Level 4

- This aggregate would be at a Risk Level 2

Example #2 continued

Step #3:

Determine Level of prevention. The structure classification needs to be know in order to determine the level of prevention.

- See Table F:

If this mix design was for concrete paving under section 506, then the structure class would be S2.

If this mix design was for LLCP- long life concrete pavement under section 530, then the structure class would be S3.

Structure Class	Consequences	Acceptability of ASR	Structure/Asset type	Publication 408 Sections
S1	Safety and future maintenance consequences small or negligible	Some deterioration from ASR may be tolerated	Temporary structures. Inside buildings. Structures or assets that will never be exposed to water	627, 620, 621, 624, 627, 628 643, 644, 859, 874, 930, 932, 934, 952, 953, 1005
S2	Some minor safety, future maintenance consequences if major deterioration were to occur	Moderate risk of ASR acceptable	Sidewalks, curbs and gutters, inlet tops, concrete barrier and parapet. Typically structures with service lives of less than 40 years	303, 501, 505, 506, 516, 518, 523, 524, 525, 528, 540, 545, 605,607, 615, 618, 622, 623, 630, 633, 640, 641, 658, 667, 673, 674, 675, 676, 678, 714, 875, 852, 875, 910, 948, 951, 1025, 1001, 1040, 1042, 1043, 1086, 1201, 1210, 1230, Miscellaneous Precast Concrete
S3	Significant safety and future maintenance or replacement consequences if major deterioration were to occur	Minimal risk of ASR acceptable	All other structures. Service lives of 40 to 75 years anticipated.	530, 1001, 1006, 1031, 1032, 1040, 1080, 1085, 1107, MSE walls, Concrete Bridge components and Arch Structures

Example #2 continued

Step #4: Let’s say the design is for long life concrete pavement (section 530)

- The Structure Classification would be S

- From Table E – Determining the level of prevention

	Classification of Structure		
Level of ASR Risk	S1	S2	S3
Risk Level 1	V	V	V
Risk Level 2	V	W	X
Risk Level 3	W	X	Y
Risk Level 4	X	Y	Z

- With a Risk Level of 2 and a S3 classification, this mix needs a prevention level X

Example #2 continued

Step #5:

- Let’s say we are going to use a pozzolan to mitigate for ASR.
- See Table G for the minimum replacement levels

Type of SCM [1]	Alkali Level of SCM (% Na2Oe) [2] [3]	Level V [4]	Level W	Level X	Level Y	Level Z [5] [11]
Class F or C flyash [6]	≤ 3.0	-	15	20	25	35
Class F or C flyash [6]	>3.0, ≤ 4.5	-	20	25	30	40
GGBFS	≤ 1.0	-	25	35	50	65
Silica Fume [7] [8] [9] [10]	≤ 1.0	-	1.2 LBA	1.5 x LBA	1.8 x LBA	2.4 x LBA

- The mix needs a Level X replacement so the pozzolan replacement levels would be:
  - 20% for a Class F or C flyash with an alkali level of 3.0% or less
  - 25% for a Class F or C flyash with an alkali level greater than 3.0% or less than or equal to 4.5%
  - 35% for GGBFS
  - 1.5 x LBA for Silica Fume but not less than 7%

Pilot Projects:

Pro-team decided that since there was a possibility of high percentages of pozzolans being used on structures and pavements that a pilot project might be beneficial.

- Fall of 2016 projects started
  - Pavement in D-12
  - Sidewalks in D-5
  - Sample of a Sound wall panel, box culvert apron and prestressed beam
- Control section and two section built
  - Control section was a usual concrete mix with pozzolan
  - One section was at a Replacement Level Y
    - 25% Flyash (30%- CaO≤ 18%)
    - 50% GGBFS
  - One section was at Replacement Level Z
    - 35% Flyash (40%- CaO≤ 18%)
    - 65% GGBFS

Pilot Projects:

Projects were built Fall 2017

- Cold weather paving
- Will be monitored for three years

Issues

- Workability problems with higher pozzolan mixes
- After first winter saw some scaling on high GGBFS mix on sidewalk
- Problems getting 28-day strengths during mix design

Next Steps

Currently adopted a five-year frequency of testing.

Started second round of testing in 2020

Running AASHTO T 380 as well as ASTM C 1293

Review of on-going research (mini-concrete prism test, alternate SCM's etc.).

Identify additional ASR affected assets and document using AASHTO ASR inventory tool.

QUESTIONS?