Concrete Mix Design and Mix Design Acceptance under the new 2018 PennDOT ASR Specification

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Concrete Mix Design and Mix Design Acceptance under the new 2018 PennDOT ASR Specification

Our Agenda and Panelists for today's Webinar
From the PennDOT / PACA ASR ProTeam:

Introduction
Jim Casilio – PACA

ASR Specification Development and The New ASR Specification
Patricia Baer - PennDOT Bureau of Project Delivery
Construction and Materials Division

Mix Design Examples
Mark Moyer – New Enterprise Stone & Lime Co.

Questions & Answers
Susan Armstrong – Central Builders Supply

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A few Important Facts About ASR:

- PennDOT continues it's leading role among state DOT's for ASR testing and mitigation policy.
- Some of Pennsylvania's aggregates do have the potential for ASR reactivity that can shorten the service life of our highways and bridges.
- As of 2017 of the 374 sources tested 240 are "non reactive" - 64%
- The methods of testing for ASR potential and our understanding of ASR continues to evolve.

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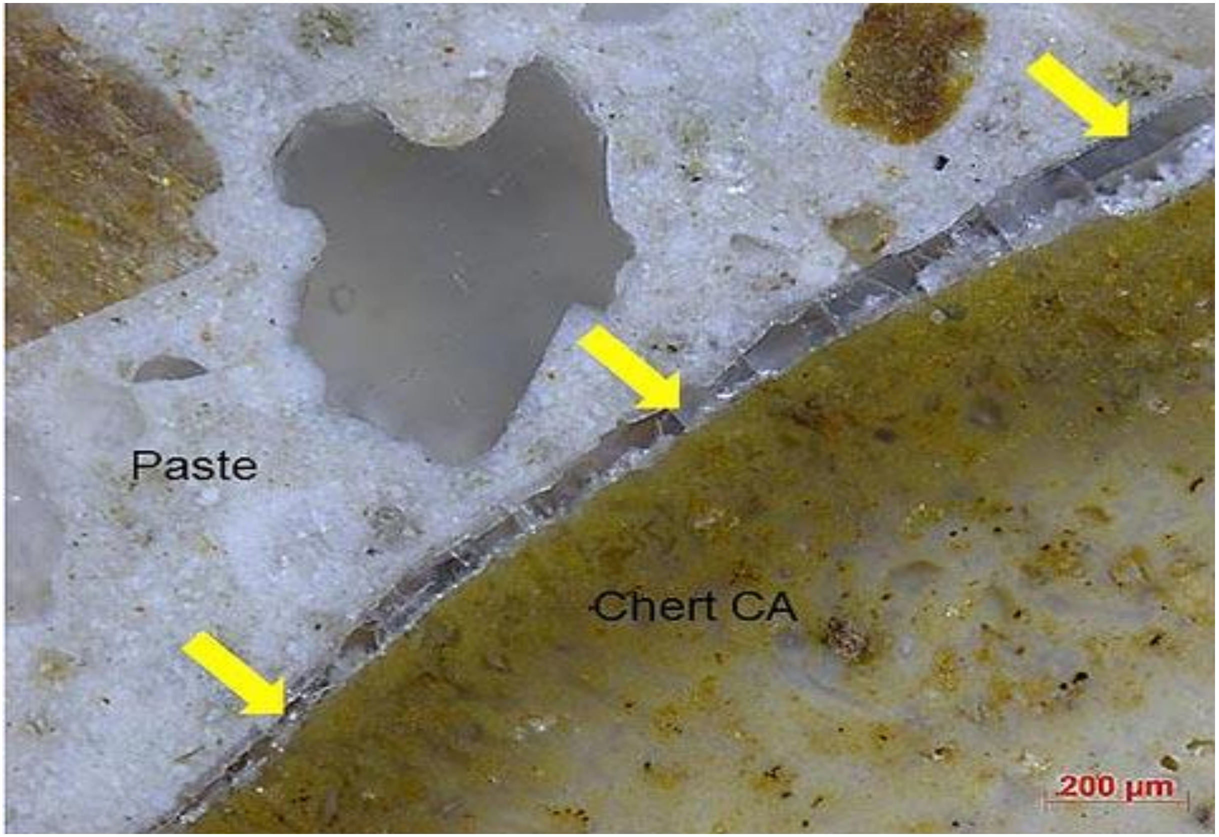
What is ASR

The most common Alkali Aggregate Reaction (AAR)

A – Alkali's (From the cement)
S – Silica (from the aggregates)
R - a reaction forms a gel, that may absorb a lot of water causing detrimental expansion –

ASR Close up



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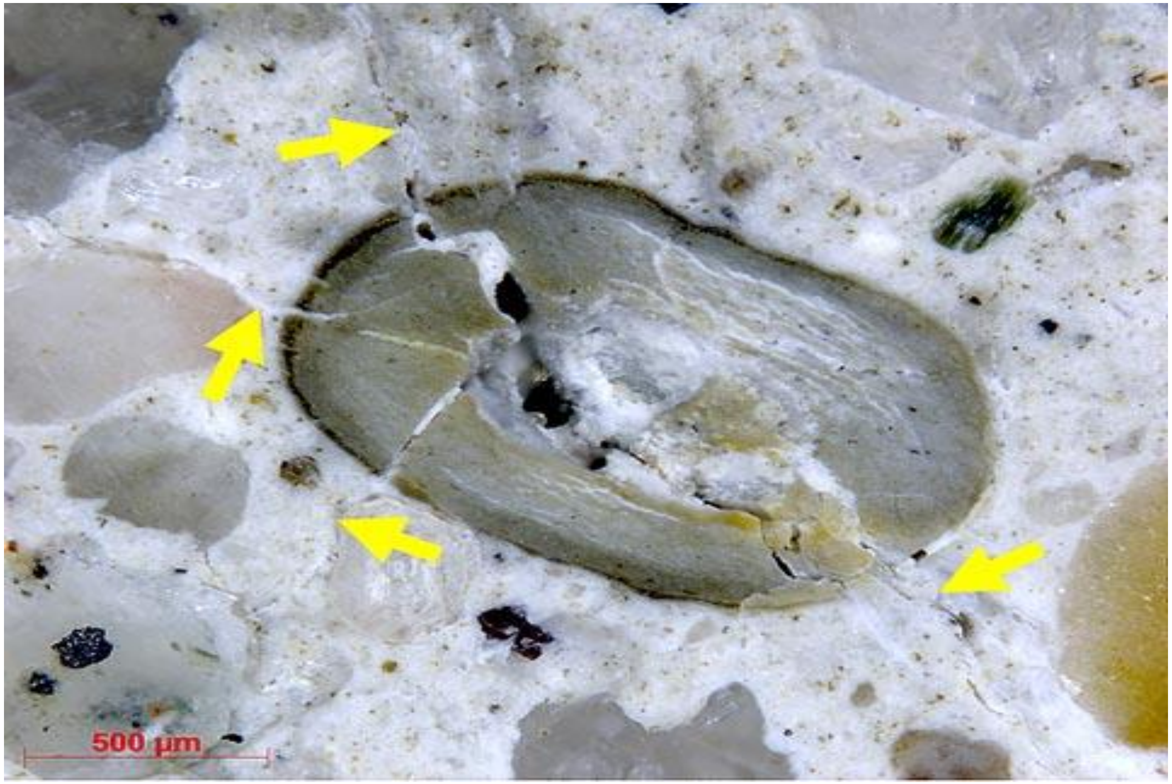

ASR in Pennsylvania

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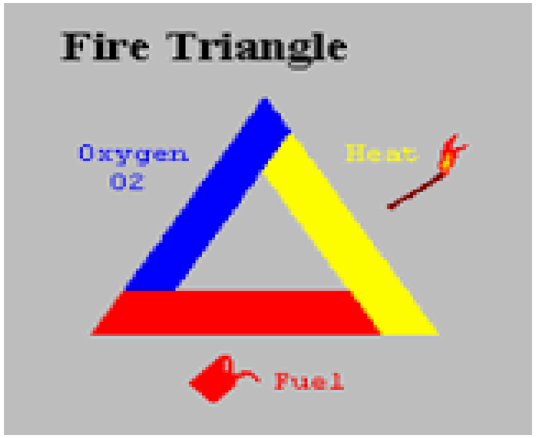
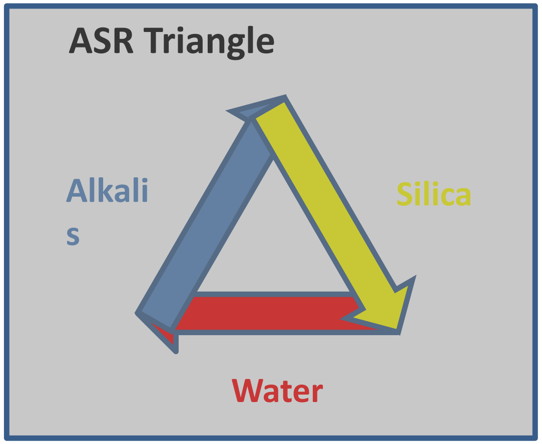
For ASR to occur we need three things - the right kind - and right amount

Alkali's - We need enough of them

Silica – The kind that will be reactive

Water – to "fuel the expansion"





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What ASR looks like in the field

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Pat Baer
Unit Manager
Department of Transportation
Bureau of Project Delivery
Construction and Materials Division
Laboratory Testing Section

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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 investigates this method and 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.

Department Specifications:

- Initially implemented in 1992 via SSP.
- 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

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.

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
- Low alkali (<0.60%) cement
- Independent testing
  - The Department may allow reduced flyash or ground granulated blast furnace slag replacement levels if independent test results show a lesser amount of pozzolan will mitigate ASR to below 0.10%.

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Background of current situation:

- 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.

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What we did:

- Who's been involved in the process – Pro-team
- Short Term solution – Standard Special Provision
- Long Term solution
  - AASHTO PP-65
    - Review of the prescriptive approach
      - Basis for future specification developments

FHWA: PP-65

- 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

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

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Current Policy
AASHTO T-303 Accelerated Mortar Bar Aggregate Evaluation

- Sources initially tested prior to 1992 SSP and Bulletin 14 updated with expansion values.
- <u>Few</u> other than 'new' sources have been re-tested since their initial tests were performed.
  - <u>PennDOT does not currently have any established frequency for re-qualification testing or source QC testing.</u>

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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)

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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.

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Standard Special Provision

- 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.
- SSP comment period ended December 20th
  - **100% approval**
  - Minor comments received were incorporated
  - With FHWA for final approval

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.

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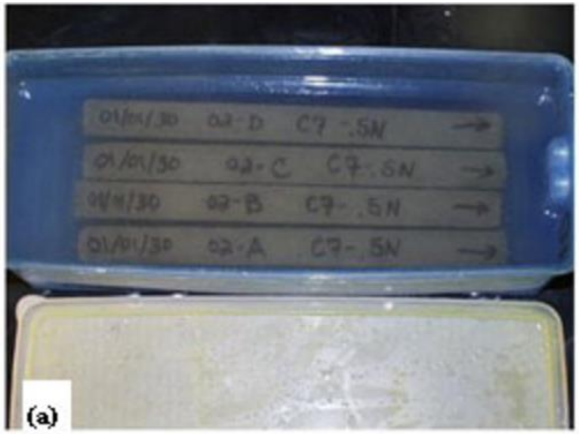
ASTM C1260
Accelerated Mortar Bar



14 Day Test limit - 0.10% at 14 Days
Very aggressive
False Positives – False Negatives

ASTM C1293
Concrete Prism Test

One year Test
0.04% at one year
Length of time is issue
Better but still limited

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.

Draft 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)

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Draft Specification:

- Prescriptive Approach: The Pro-Team made some minor changes to the tables in PP-65
- 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

Draft Specification:

2. Level of ASR Risk: Draft Specification

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

Level of ASR Risk: PP-65

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

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Draft Specification:

- 3. Determining the Level of Prevention: Draft 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: PP-65

-

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.

Draft Specification:

- 4. Structure Classification: PP-65

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

Draft Specification

4. Structure classification- Draft spec:

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

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Draft Specification:

- 5. Minimum Levels of Supplementary Cementitious Materials: Draft 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

Draft 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.

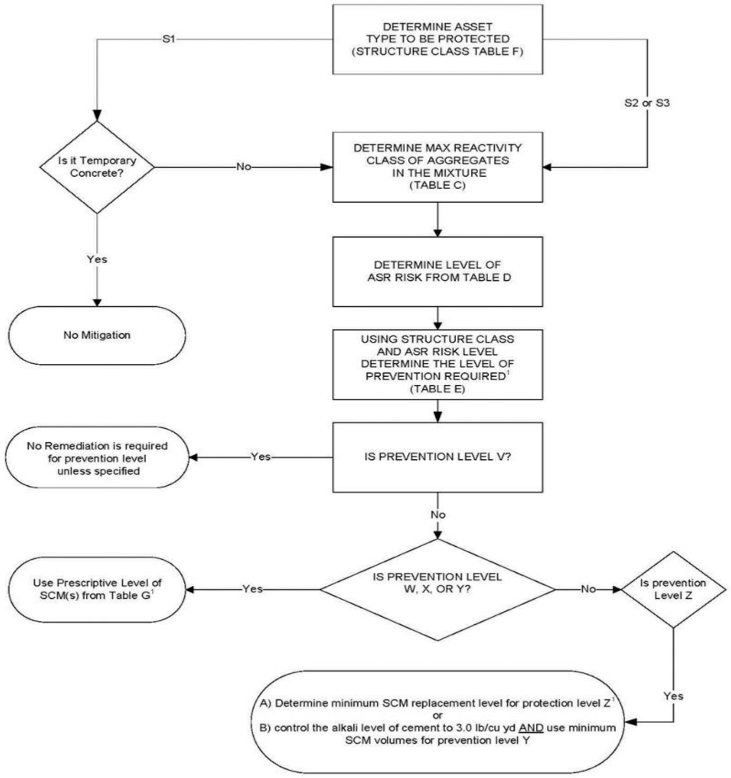
Draft Specification:

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

Draft Specification:



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

Example #1 – using draft 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

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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%

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Mix Design Examples

Mark Moyer
New Enterprise Stone & Lime Co.

R0 example

R0 Example
Prescriptive Approach – Aggregate Reactivity Class

		TABLE C	
Aggregate Reactivity	Description of	1 year Expansion	14 day Expansion
Class	Aggregate Reactivity	ASTM C-1293 (%)	AASHTO T-303 (%)
R0	Non-Reactive	$\leq$ 0.04	$\leq$ 0.10
R1	Moderately Reactive	> 0.04, $\leq$0.12	> 0.10, $\leq$ 0.30
R2	Highly Reactive	> 0.12, $\leq$ 0.24	> 0.30, $\leq$ 0.45
R3	Very Highly Reactive	> 0.24	> 0.45

– Step 1: Determine Aggregate reactivity class (R0-R3)
  - Uses ASTM C1293 OR AASHTO T-303(T-303 is for new material only)
    – If in question of which method to use, contact Pat Baer (717-787-2485)
  - 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 of test is significantly longer (one year).

R0 Example
Prescriptive approach – Level of Risk

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

- Step 2: Determine acceptable level of ASR risk
  - 4 Levels
    - Based on size and exposure conditions

R0 Example
Level of Prevention

	TABLE E		
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

- Step 3
  - Structure class and Risk Level intersect – to determine the replacement level on Table G

R0 Example Structure Class

		TABLE F	
Structure Class		Acceptability of ASR	Structure/Asset Type
S1		Some Deterioration from ASR	Temp Structures, Interior not exposed
S2		Moderate risk of ASR acceptable	Sidewalks, curbs & gutters, inlets, etc.
S3		Minimal risk of ASR acceptable	Structures with a 40-75 years of service life

- Structure class – Determined based on the allowable risk for accepting ASR. You can always use a higher "S" class in lieu of a lower one. Designing at an S3 would cover all classes.

RO Example – Level of SCM

			TABLE G			
Type of SCM (1)	Alkali Level of SCM	Level V	Level W	Level X	Level Y	Level Z
	% Na2Oe (2, 3)		None Needed			
Class F or C Fly Ash (6)	≤ 3.0	–	15	20	25	35
Class F or C Fly Ash (6)	> 3.0, ≤ 4.5	–	20	25	30	40
GGBFS	≤ 1.0	--	25	35	50	65
Silica Fume (7,8)	≤ 1.0	--	1.2 x LBA	1.5 x LBA	1.8 x LBA	2.4 x LBA

- Level of SCM footnotes in SSP
  - NOTE (4) “no remediation is required at Level V unless otherwise directed by specification, eg. Section 530 Long Life Concrete Pavement or AAAP both require pozzolans”

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R0, S3 – Class AA Example:

- Cement Factor, W/C & Air:
  - 588# total
  - No Pozzolan required, but may be used
  - Max. W/C = 0.47
  - 6% air
- ACI 211 Table 6.3.6 (Vol. of Coarse Agg.)
  - 102#/dry rodded (#57)
  - F.M. = 2.80
  - 1” nom. Agg. size
  - 102 x 0.67 x 27 =
  - 1845#/coarse agg./yd.

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R0, S3 – Class AA - continued

- Final Mix Weight is:
  - 588# cement
  - 1845#/#57
  - 276#/H2O
  - 1202#/sand

- Final Mix Volume is:
  - 2.99 of Portland Cement
  - 10.56 of #57 (sg = 2.80)
  - 4.42 of H2O (sg = 1.00)
  - 7.41 of sand (sg = 2.60)
  - 1.62 of air

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R1 example

Utilizing GGBFS

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R1 Example - GGBFS
Prescriptive Approach – Aggregate Reactivity Class

	TABLE C		
Aggregate Reactivity	Description of	1 year Expansion	14 day Expansion
Class	Aggregate Reactivity	ASTM C-1293 (%)	AASHTO T-303 (%)
R0	Non-Reactive	$\leq$ 0.04	$\leq$ 0.10
R1	Moderately Reactive	> 0.04, $\leq$0.12	> 0.10, $\leq$ 0.30
R2	Highly Reactive	> 0.12, $\leq$ 0.24	> 0.30, $\leq$ 0.45
R3	Very Highly Reactive	> 0.24	> 0.45

- Step 1: Determine Aggregate reactivity class (R0-R3)
  - Uses ASTM C1293 OR AASHTO T-303(T-303 is for new material only)
    - If in question of which method to use, contact Pat Baer (717-787-2485)
  - 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 of test is significantly longer (one year).

R1 Example - GGBFS
Prescriptive approach – Level of Risk

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

- Step 2: Determine acceptable level of ASR risk
  - 4 Levels
    - Based on size and exposure conditions

R1 Example – GGBFS -Level of Prevention

		TABLE E	
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

- Step 3
  - Structure class and Risk Level intersect – to determine the replacement level on Table G

R1 Example Structure Class

		TABLE F	
Structure Class		Acceptability of ASR	Structure/Asset Type
S1		Some Deterioration from ASR	Temp Structures, Interior not exposed
S2		Moderate risk of ASR acceptable	Sidewalks, curbs & gutters, inlets, etc.
S3		Minimal risk of ASR acceptable	Structures with a 40-75 years of service life

- Structure class – Determined based on the allowable risk for accepting ASR. You can always use a higher “S” class in lieu of a lower one. Designing at an S3 would cover all classes.

Prescriptive Approach – Level of SCM

TABLE G

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

- Level of SCM footnotes in SSP
  - NOTE (4) “no remediation is required at Level V unless otherwise directed by specification, eg. Section 530 Long Life Concrete Pavement or AAAP both require pozzolans”

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R1, S3 – Class AA 35% GGBFS Example:

- Cement Factor, W/C & Air:
  - 588# total
  - 588 x 35% = 206# GGBFS
  - 588-206=382# Portland cement
  - Max. W/C = 0.47
  - 6% air
- ACI 211 Table 6.3.6 (Vol. of Coarse Agg.)
  - 102#/dry rodded (#57)
  - F.M. = 2.80
  - 1” nom. Agg. size
  - 102 x 0.67 x 27 =
  - 1845#/coarse agg./yd.

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R1, S3 – Class AA 35% GGBFS - continued

- Final Mix Weight is:
  - 382#/Portland cement
  - 206#/GGBFS
  - 1845#/#57
  - 276#/H2O
  - 1188#/sand
- Final Mix Volume is:
  - 1.94 of Portland Cement
  - 1.14 of GGBFS (sg = 2.90)
  - 10.56 of #57 (sg = 2.80)
  - 4.42 of H2O (sg = 1.00)
  - 7.32 of sand (sg = 2.60)
  - 1.62 of air

R2 example

Utilizing GGBFS

R2 Example - GGBFS
Prescriptive Approach – Aggregate Reactivity Class

		TABLE C	
Aggregate Reactivity	Description of	1 year Expansion	14 day Expansion
Class	Aggregate Reactivity	ASTM C-1293 (%)	AASHTO T-303 (%)
R0	Non-Reactive	$\leq$ 0.04	$\leq$ 0.10
R1	Moderately Reactive	> 0.04, $\leq$0.12	> 0.10, $\leq$ 0.30
R2	Highly Reactive	> 0.12, $\leq$ 0.24	> 0.30, $\leq$ 0.45
R3	Very Highly Reactive	> 0.24	> 0.45

- Step 1: Determine Aggregate reactivity class (R0-R3)
  - Uses ASTM C1293 <u>OR</u> AASHTO T-303(T-303 is for new material only)
    - If in question of which method to use, contact Pat Baer (717-787-2485)
  - The ASTM C1293 concrete prism test is <u>much</u> more reliable for determining the true potential of the aggregate to contribute to ASR however the duration of test is significantly longer (one year).

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R2 Example - GGBFS
Prescriptive approach – Level of Risk

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

- Step 2: Determine acceptable level of ASR risk
  - 4 Levels
    - Based on size and exposure conditions

R2 Example - GGBFS
Prescriptive Approach – Level of

	TABLE E		
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

– Structure class and Risk Level intersect – to determine the replacement level on Table G

R2 Example Structure Class

		TABLE F	
Structure Class		Acceptability of ASR	Structure/Asset Type
S1		Some Deterioration from ASR	Temp Structures, Interior not exposed
S2		Moderate risk of ASR acceptable	Sidewalks, curbs & gutters, inlets, etc.
S3		Minimal risk of ASR acceptable	Structures with a 40-75 years of service life

- Structure class – Determined based on the allowable risk for accepting ASR. You can always use a higher "S" class in lieu of a lower one. Designing at an S3 would cover all classes.

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Level of SCM

		TABLE G				
Type of SCM (1)	Alkali Level of SCM	Level V	Level W	Level X	Level Y	Level Z
	% Na2Oe (2, 3)					
Class F or C	$\leq$ 3.0	_	15	20	25	35
Fly Ash (6)						
Class F or C	> 3.0, $\leq$ 4.5	_	20	25	30	40
Fly Ash (6)						
GGBFS	$\leq$ 1.0	--	25	35	50	65
Silica Fume (7,8)	$\leq$ 1.0	--	1.2 x LBA	1.5 x LBA	1.8 x LBA	2.4 x LBA

- Level of SCM footnotes in SSP

R2, S3 – Class AA 50% GGBFS Example:

- Cement Factor, W/C & Air:
  - 588# total
  - 588 x 50% = 294# GGBFS
  - 588-294 =294# Portland cement
  - Max. W/C = 0.47
  - 6% air
- ACI 211 Table 6.3.6 (Vol. of Coarse Agg.)
  - 102#/dry rodded (#57)
  - F.M. = 2.80
  - 1” nom. Agg. size
  - 102 x 0.67 x 27 =
  - 1845#/coarse agg./yd.

R2, S3 – Class AA 50% GGBFS

- Final Mix Weight is:
  - 294#/Portland cement
  - 294#/GGBFS
  - 1845#/#57
  - 276#/H2O
  - 1181#/sand

- Final Mix Volume is:
  - 1.50 of Portland Cement
  - 1.62 of GGBFS (sg = 2.90)
  - 10.56 of #57 (sg = 2.80)
  - 4.42 of H2O (sg = 1.00)
  - 7.28 of sand (sg = 2.60)
  - 1.62 of air

R2 example

TERNARY

NOTE(3) from Table G

"when 2 or more SCM's are used in combination, the minimum mass replacement levels given in Table G for the individual SCM's may be reduced, provided the sum of the parts of each SCM is greater than or equal to one".

IE: the fly ash could be reduced 1/3 provided the GGBFS is 2/3 of the required level given in Table G

R2 Example - TERNARY – Aggregate Reactivity Class

		TABLE C	
Aggregate Reactivity	Description of	1 year Expansion	14 day Expansion
Class	Aggregate Reactivity	ASTM C-1293 (%)	AASHTO T-303 (%)
R0	Non-Reactive	$\leq$ 0.04	$\leq$ 0.10
R1	Moderately Reactive	> 0.04, $\leq$0.12	> 0.10, $\leq$ 0.30
R2	Highly Reactive	> 0.12, $\leq$ 0.24	> 0.30, $\leq$ 0.45
R3	Very Highly Reactive	> 0.24	> 0.45

- Step 1: Determine Aggregate reactivity class (R0-R3)
  - Uses ASTM C1293 OR AASHTO T-303(T-303 is for new material only)
    - If in question of which method to use, contact Pat Baer (717-787-2485)
  - 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 of test is significantly longer (one year).

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R2 Example - Ternary
Prescriptive approach – Level of Risk

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

- Step 2: Determine acceptable level of ASR risk
  - 4 Levels
    - Based on size and exposure conditions

R2 Example - Ternary Prescriptive Approach – Level of

	TABLE E		
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

- Step 3
  - Structure class and Risk Level intersect – to determine the replacement level on Table G

R2 Ternary Example Structure Class

		TABLE F	
Structure Class		Acceptability of ASR	Structure/Asset Type
S1		Some Deterioration from ASR	Temp Structures, Interior not exposed
S2		Moderate risk of ASR acceptable	Sidewalks, curbs & gutters, inlets, etc.
S3		Minimal risk of ASR acceptable	Structures with a 40-75 years of service life

- Structure class – Determined based on the allowable risk for accepting ASR. You can always use a higher "S" class in lieu of a lower one. Designing at an S3 would cover all classes.

R2 Ternary Example – Level of SCM

		TABLE G				
Type of SCM (1)	Alkali Level of SCM	Level V	Level W	Level X	Level Y	Level Z
	% Na2Oe (2, 3)					
Class F or C	< 3.0	_	15	20	25	35
Fly Ash (6)						
Class F or C	> 3.0, < 4.5	_	20	25	30	40
Fly Ash (6)						
GGBFS	< 1.0	--	25	35	50	65
Silica Fume (7,8)	< 1.0	--	1.2 x LBA	1.5 x LBA	1.8 x LBA	2.4 x LBA

- Table G Footnote #3
  - (3) When two or more SCM's (including SCM's in blended cement) are used in combination, the minimum mass replacement levels given in Table G for the individual SCM's may be reduced provided the sum of the parts each SCM is greater than or equal to one. For Example, when Silica Fume and GGBFS are used together, the silica fume may be reduced to one-third of the minimum level given in the table, provided the GGBFS level is at least two-thirds of the minimum slag level required.
  - You may be able to reduce by one-forth and three-fourths as well.

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R2, S3 – Class AA TERNARY Example:

- Cement Factor, W/C & Air:
  - 588# total (reduced by thirds)
  - (1/3 of 25% Fly Ash {F})
  - (2/3 of 50% GGBFS)
  - (0.33 x 25% Fly Ash {F})
  - (0.67 x 50% GGBFS)
  - =8.25% Fly Ash and 33.5% GGBFS

- Cement Factor, W/C & Air:
- 588 x 8.25% Fly Ash (F) = 49#
- 588 x 33.5% GGBFS = 197#
- (588-49) – 197 = 342# Portland cement

R2, S3 – Class AA TERNARY Example:

- ACI 211 Table 6.3.6 (Vol. of Coarse Agg.)
  - 102#/dry rodded (#57)
  - F.M. = 2.80
  - 1” nom. Agg. size
  - 102 x 0.67 x 27 =
  - 1845#/coarse agg./yd.

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R2, S3 – Class AA TERNARY - continued

- Final Mix Weight is:
  - 342#/Portland cement
  - 197#/GGBFS
  - 49#/Fly Ash (F)
  - 1845#/#57
  - 276#/H2O
  - 1181#/sand

- Final Mix Volume is:
  - 1.74 of Portland Cement
  - 1.05 of GGBFS (sg = 2.90)
  - 0.33 of Fly Ash (F) (sg = 2.40)
  - 10.56 of #57 (sg = 2.80)
  - 4.42 of H2O (sg = 1.00)
  - 7.28 of sand (sg = 2.60)
  - 1.62 of air

Concrete Mix Design and Mix Design Acceptance under the new 2018 PennDOT ASR Specification

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