Materials Bulletin: Alkali-Silica Reaction (ASR) Brief

Why is ASR Bad?
ASR can cause serious expansion and cracking in concrete. This can result in major structural problems, which can lead to costly removal and replacement. The reaction can occur years after the concrete was placed. Structures most at risk are bridges, hydraulic structures, exposed frames, pavements, and foundations.

What is ASR?
ASR is a reaction between the alkali hydroxides in concrete and reactive forms of silica in the aggregate. The reaction forms a gel that swells when moisture is present. The two step process can be visualized as:

1. Alkali + Silica → Gel reaction Product
2. Gel reaction Product + Moisture → Expansion

Factors Affecting ASR
For the reaction to occur the following three conditions must be present:

1. Sufficiently high alkali content of the cement
2. Reactive forms of silica in aggregate
3. Sufficient Moisture

If one of these three conditions is missing the reaction cannot occur.

How does NC DOT Mitigate the Problem?
The best way to avoid ASR is to take appropriate precautions before the concrete is placed. Section 1024-1 of the NC DOT Standard Specifications for Roads and Structures addresses these precautions.

1. The alkalinity of any cement, expressed as sodium-oxide equivalent, shall not exceed 1.0%.

2. For mix designs that contain non-reactive aggregates and cement with an alkali content less than 0.6%, straight cement or a combination of cement and fly ash, cement and ground granulated blast furnace slag or cement and microsilica may be used. The pozzolan quantity shall not exceed the amount shown below.

3. For mixes that contain cement with an alkali content between 0.6% and 1.0%, use a pozzolan in the amount shown below.

4. For mixes that contain a reactive aggregate documented by the Department, use a pozzolan in the amount shown below.

Class F Fly Ash	20% by weight of required cement content, with 1.2 lbs. Class F fly ash per lb. of cement replaced.
GGBF Slag	35% - 50% by weight of required cement content, with 1 lb. slag per lb. of cement replaced.
Microsilica	4-8% by weight of required cement content, with 1 lb. microsilica per lb. of cement replaced.

Responsibilities
To help alleviate any potential ASR problems the following responsibilities are to be followed:

Cement Producer

1) Abide by the Cement Producer Responsibilities section in the NC Department of Transportation *Hydraulic Cement Acceptance Program*.
2) Submit, to the Materials and Tests Unit, a monthly mill certificate to document that the respective hydraulic cement meets the requirements of AASHTO M85 and all NCDOT specifications.
3) An annual declaration of the anticipated maximum alkali content of the hydraulic cement produced from the respective manufacturing facility.
4) Provide written notification to the Materials and Tests Unit, within 30 days, should the alkali content exceed the maximum stated in the annual declaration.
5) Provide written notification of changes in raw materials or other major production changes.

6) Submit a signed mill certification with each shipment of cement.
7) Submit a "Bill of Lading" (BOL) with every tanker and/or railcar clearly identifying the actual manufacturing location. Note this location will utilize the term "Manufactured In" (city, state (and country if applicable)).

Concrete Producer

1) Obtain a "Bill of Lading" (BOL) and "Mill Certification" for every tanker and/or railcar of cement delivered.
2) Verify that the documentation, location, and type of cement corresponds with the approved NCDOT mix design.
3) Documentation must be kept on hand or easily accessible for at least three years after the project has been completed.
4) Produce concrete per the NC DOT Specifications.
5) Provide the M&T Form 250 pink copies with the first load of concrete delivered to the project and the white copy with the final load delivered to the project.
6) Provide Form 903 with each load of concrete.
7) Verify the materials being used match the materials in the mix design.

NCDOT Materials and Tests Unit

1) Sample cement from each approved concrete facility at least three times per year. One sample will be tested for physical requirements. All samples will be tested chemically and the brand will be verified.
2) Sample fly ash, fine aggregate and coarse aggregate at least annually.
3) Maintain the approved source list.
4) Monitor the sources of cement for alkalinity and track trends.
5) Review, verify and assign concrete mix designs.

NCDOT Project Personnel

1) Verify the material used on the mix design Form 903 match the concrete mix design and sign the bottom of the M&T Form 250. The following items shall be verified on the Form 250:
    - Cement Producer
    - Cement Producer Location
    - Pozzolan Producer
    - Fine Aggregate Source
    - Coarse Aggregate Source
    - Ready Mix Facility & Number
2) Verify the mix design on the M&T Form 903 is approved for use on the particular project.
3) Fill out the bottom portion of the M&T Form 903 with each load of concrete.
4) Provide samples of cement to M&T on Paving and Latex Overlay projects at the following minimum frequency:

- Cement used in Concrete Pavement

Frequency:	One sample per 1,250 tons of cement delivered
Amount:	One Gallon
Submitted To:	Physical Testing Laboratory
Tested For:	Physical and Chemical Requirements
Material Type in HiCAMS:	Cement, Portland Cement for Concrete
Testing Category in HiCAMS:	Acceptance

- Cement used in Latex Modified Concrete

Frequency:	One sample per 100 cubic yards of concrete
Amount:	One Gallon
Submitted To:	Physical Testing Laboratory
Tested For:	Physical and Chemical Requirements
Material Type in HiCAMS:	Cement, Portland
Testing Category in HiCAMS:	Acceptance

APPENDIX A

Owner	Location	Quarry Number
Quarries that have shown ASR in the field and Laboratory		
Hanson	Princeton	CA 64
Martin Marietta	Pomona	CA 51
	Thomasville	CA 102
Vulcan	Gold Hill	CA 85
Quarries that have shown ASR in the Laboratory		
Martin Marietta	Asheboro	CA 30
	Bakers	CA 32
Vulcan	Havre de Grave (Maryland)	CA 345

Table 1: Aggregate Sources That Have Exhibited ASR as Documented by the Department

Producer	Facility	Sodium Oxide Equiv.
Cementos, Argos	Atlanta, GA	0.42
	Harleyville, SC	0.48
	Roberta Plant	0.40
	Knoxville, TN	0.49
Cemex	Knoxville, TN	0.49
Essroc	Speed, IN	0.60
	Martinsburg (LA)	0.57
	Martinsburg (HA)	0.67
Giant	Harleyville, SC	0.46
Holcim	Holly Hill, SC	0.49
	Holly Hill, SC (Slag Modified)	0.46
Lafarge	Ravena, NY	0.69
Lehigh	Union Bridge	0.52
	Leeds	0.49
Roanoke	Cloverdale, VA	0.63

Table 2: Average Sodium Oxide Equivalent values of common cement sources used in North Carolina

Note: **Red designates pozzolan required**
Yellow designates pozzolan required when used with potentially reactive aggregate (see Table 1)
Green designates no pozzolan required