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Delaware DOT's Use of Slag Cement

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Outline – Slag Cement

- Award Winning SR-1
- Specifications – Current and Future
- Usage
  - ASR Mitigation
  - HPC/Low Permeability Concrete
  - Heat Reduction
- Mix Design
- Placement
- Workability
- Strength and Durability
- Performance

Award Winning SR-1

- 51 mile, new alignment, concrete pavement bypass of Delaware's major north-south corridor (US 13)
- $900 million total cost
- Early action work started in 1987
- Major mainline concrete paving started in late 1992
- Opened in phases; all phases of mainline completed in Spring 2003

Award Winning SR-1

- Most concrete, including structures, had a minimum of 35% Slag Cement up to 50%.
- Almost 750,000 cubic yards of roadway concrete pavement.
- Well over 1,000,000 cubic yards of concrete used on this bypass including structures.
- Estimate over 100,000 tons of Slag Cement used on entire project

Current Specifications

If aggregate is found expansive for ASR, five options in our Specifications:

1. Low Alkali Cement (<0.6%)
2. Fly Ash (20% minimum replacement)
3. Silica Fume (7 - 10% replacement)
4. Lithium admixture
5. Substitution of 35 to 50% of the Portland cement with ground granulated blast furnace slag conforming to AASHTO M 302, Grade 100 or Grade 120

Current Specification

Coarse and Fine Aggregates Evaluation

- Specification Limit – 0.08% Expansion at 14 days
- ASTM C 1260 Mortar Bar Method
- ASTM C 295 Petrographic Examination (optional)
- Field Service Records

Future Proposed Specification

Coarse and Fine Aggregates Evaluation

- More end-result/performance based
- Tests performed by Contractor/Supplier
- Field records relied on heavily regardless of laboratory test results
- Applicable Testing Methods:

Future Proposed Specification

Test	Description	Limit
AASHTO T303	Mortar Bar Expansion	<0.08% at 14 days
ASTM C1293	Concrete Prism Expansion	<0.04% at 1 year

Future Proposed Specification

- If aggregate is found to exceed previous limits, or field records indicate reactivity, mitigation steps must be taken.
- Six different mitigating material options available:

Future Proposed Specification

1. Low Alkali Cement (<0.40%)
2. Blended Hydraulic Cement (ASTM C1157)
3. Silica Fume (AASHTO M307)
4. Fly Ash (AASHTO M295)
5. Lithium Admixtures
6. Ground Granulated Blast Furnace Slag (AASHTO M302, Grade 100 or 120)

Future Proposed Specification

- Dosage rate of mitigating materials is determined by the Contractor based upon their testing.
- Testing labs have to be approved by DelDOT.
- 30 day review period before approval.
- Concrete component testing:

Future Proposed Specification

Procedure	Description	Limit
ASTM C1260 (Modified)	Mortar Bar Expansion	<0.08% at 28 days
ASTM C1293 (Modified)	Concrete Prism Expansion	<0.04% at 2 years

Future Proposed Specification

ASTM MODIFICATIONS

- Low alkali cement can not be evaluated by either method. If L/A cement is proposed with reactive aggregates, total alkali loading from Portland cement can not exceed 2.5 lb/cy.

Future Proposed Specification

ASTM MODIFICATIONS

- Reference to FHWA Publication ‘Guidelines for the Use of Lithium to Mitigate or Prevent Alkali-Silica Reaction’, publication number FHWA-RD-03-047, July 2003, pages 60-62.

Usage

- ASR Mitigation
- HPC/Low Permeability Concrete
- Heat of Hydration Temperature Reduction
  - Indian River Inlet Bridge (Mass Concrete)

ASR Mitigation

- Most cements used in Delaware have an alkali content >0.6%
- Most aggregates used are over the expansion limit of 0.08%
- Need to use a material that mitigates ASR
- Five choices in the current Specifications – Slag Cement is most commonly used.

Low Permeability Concrete

- Extra benefit of Slag Cements use to mitigate ASR.
- Majority of concrete for DelDOT's project have at least 35% slag cement.
- Permeability readings (AASHTO T277) less than 2500 coulombs to as low as 1000 coulombs or lower.
- Slag cement used to meet HPC Specifications

Heat Reduction

- Mass concrete - new Indian River Inlet Bridge.
- Footings and arch base are mass concrete pours (several thousand yard pours each).
- Specification states 75% Slag Cement used in the mix design to try and control heat for concrete mass.


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Mix Design

- Specifications state minimum of 35% Slag Cement to a maximum of 50% Slag Cement for ASR mitigation.
- % use dictated by weather – in the warm weather, we use 50%; in the cooler weather, we use 35%.
- Seen relatively slower strength gains with 50% Slag Cement (28 day strengths are usually still met).

Placement

- Because we've been using Slag Cement in our PCC for approximately 15 years, placement is not an issue.
- Setting times are somewhat slower in the cooler weather.

Workability

- Again, due to our extensive use, contractors do not have issues placing the material.
- Some contractors say the concrete with Slag Cement can be somewhat “sticky” but no major problems.

Strength and Durability

- Slower strength gain in the cooler weather
- Can actually somewhat retard strength gain
- 28 day strengths are usually met
- Big benefit is the low permeability of the concrete which increases durability to the elements.

Performance

- Good performance in the 15 years we've been using it.
- Salt damage has been seen on occasion; but it has been determined that is due to poor construction, not poor materials.

THANK YOU FOR YOUR TIME AND ATTENTION

QUESTIONS????

Websites of Interest

- www.deldot.net
- www.indianriverinletbridge.com

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