Deicer Scaling Resistance of Concrete Pavements, Bridge Decks, and Other Structures Containing Slag Cement

Pooled Fund Project TPF-5(100)

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Overview

• Describe the purpose and goals of the project

• Summarize the field sites and the test results obtained from cores extracted from those sites

• Suggestions for Phase 2
Thanks to the Participants!

- Pool States Include: Iowa (lead), Connecticut, New York, Ohio and Kansas
- Additional States Include: Delaware and Michigan
Background

• Concrete containing slag cement tends to have good to excellent field performance.
• ASTM C 672 test results suggest that concrete mixtures containing slag cement are prone to scaling especially at replacement levels >35-50%.
• The purpose of this research project is to study why this anomalous relationship exists between field concrete and laboratory test methods.
Caveat

- There are a lot of pavements and bridges made with slag cement that are in excellent condition.
- In this study, we focused on sites where some damage was observed so this is not representative of the vast majority of concrete.
Background (continued)

- Pooled fund approach utilizing two phases
  - **Phase 1** - Field study that concentrates on existing concrete containing slag cement
  - **Phase 2** - Lab study that concentrates on scaling test methods
Summary of Phase 1 Sites

- Inspected about 28 potential sites in six different states (IA, NY, MI, DE, KS and CT). Many sites contained fly ash as well as slag.

- Cores were received from all but one of the requested sites (final tally = 6 bridge decks and 6 pavements).

- Three sub-sites were also selected for coring (all pavements) – this was done to provide precision information.
Summary of Phase 1 Site Details

- Slag content varied from 20% to 50%, but was most commonly used at about 30 to 35% replacement

- Ternary mixtures with fly ash and silica fume were most common – only five sites contained binary mixtures of slag and portland cement

- Construction dates ranged from 1990 to 2005 (age from about 2 to 17 yrs)
Condition of field sites

- The majority of the sites looked good to excellent – all were in service
- Scaling was noted on four of the six bridge decks and one of the six pavement sites that were cored
- Scaling was not observed on any of the sub-sites (all pavements) that were cored
Extent of Scaling

- On site 3 the scaling traversed the gutter on the deck
- On site 4 the scaling was only evident in the gutter - the driving lane and passing lanes looked excellent
- Site 5, the scaling was widespread
- On site 8 the scaling progressed across the pavement (10-20% of area)
- Sites 12 and 13 had limited scaling but showed signs of re-tempering.
Site 2: NY, Taconic St. Parkway, SB

Scaling on shoulder but less on driving lanes.
Effect of Curing

• The curing compound projects appeared to have no problems with scaling.
• The wet-curing projects did not fare so well especially in late season construction where there was no drying period.
Summary of Lab Tests

• Petrographic exams and water-cement ratio determinations

• Deicer depth profiling and rapid chloride permeability tests

• Scaling tests were conducted on cores extracted from specific sites – deicer depth profiling was repeated on the samples after the scaling tests
Petrographic Exams

• Only one field site exhibited marginal air void parameters (spacing factor $>0.008''$, hardened air content $\leq 3.5\%$) – all of the other sites had good to very good air void systems

• Water-cement ratios ranged from 0.35 to 0.51 (bridge decks) and 0.38 to 0.50 (pavements)
Depth of carbonation (2-year old concrete—worst case)

Sample ID: N #7
MAG: 10x

Description: Carbonation (unstained) proceeds up to 6 mm (1/4") depth from the top surface along subvertical microcracking.
Carbonation Depth - results

• Carbonation depth was not excessive on most of the cores (typically about 0 to 0.05” in most instances)

• Some of the sites that exhibited scaling did tend to have slightly deeper carbonation depths; however, this could be related to the scaling induced surface damage
Construction Related Issues

• Several of the sites that exhibited scaling also contained petrographic evidence of construction-related issues such as:
  ➢ Retempering or multi-stage batching
  ➢ Petrographic water-cement ratio approximately 0.1 units higher than site batching documentation
Example of retempering

SAMPLE ID: RT 378 4
MAG: 50x
DESCRIPTION: Darker colored, denser paste was observed in the notches of the carbonate coarse aggregate particles.
Scaling Test Results

- Visual ratings tended to stay the same during the scaling tests (most ratings were 0 to 1) with one exception.

- Mass loss values ranged from 0.0 to 0.7 lb/yd² with one exception.

- One site exhibited significant change in visual rating and mass loss (visual rating 2+, mass loss 1.95 lb/yd²).
Chloride Profiling Test Results

- Indicated that the concrete was dense and nearly impenetrable

- Cl diffusion coefficients ranged from about 10E-12 to 10E-13 m²/s

- The scaling tests had little influence on the measured diffusion coefficients
Rapid CI Permeability Test Results

- Values ranged from a low of 590 to a high of 1580

- These values correspond to low or very low ratings as per ASTM C1202

- Slag content appeared to play a role in the observed test results (higher replacements gave lower values)
Summary

• The purpose of this project is to evaluate if slag cement has a major impact on surface scaling of concrete pavements and bridge decks

• Phase 1 consisted of the evaluation of concrete from 13 field sites

• The large majority of the sites that were visited during this project exhibited good field performance - all of the sites were currently in service
Summary (continued)

• Petrographic examinations plus RCP, CI Profile and actual scaling tests indicated that the concrete cores extracted from the field sites generally tended to exhibit good to excellent performance

• Scaling most commonly appeared to be related to field construction issues (retempering, batch discrepancies, etc.) rather than simply slag content
Suggestions for Phase 2

- Need to study scaling resistance of lab concrete mixtures containing 560 and 660 pcy of cement – this would cover nominal pavement and bridge deck mixtures
- Need to evaluate three different levels of slag replacement (e.g. 20%, 35% and 50%)
- Only a single source of coarse aggregate is needed
- A minimum of two different curing strategies need to be studied
The lab. versus the field
Alternative Lab Tests: eg. BNQ Scaling Test

- Like ASTM C 672 with the following differences:
  - Finishing: wood float only
  - Slab cast on filter fabric to allow drainage
  - Salt solution ponded at 28d, but freezing only starts at 35d.

- Appears to better relate to field performance especially with slag and fly ash concretes
Any Questions?