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I. Executive Summary

The Concrete Freeze-Thaw Durability & Performance Group was formed with industry and Department representatives by SOL 425-06-05. The task was to investigate a possible correlation between concrete pavement and bridge deck performance and low Entrained (hardened) Air test results. The study range was established between 1990 and 2003. A visual survey was conducted of 82 sites using pavement images provided by BOMO's videologging to determine if concrete distress has occurred. The members determined the presence or absence of Freeze-Thaw (F/T) distress using ACI 201.1R-92 definitions and reference photos.

Findings:

1. No Freeze-Thaw distresses were identified by any of the group members (summary sheet attached) of the 82 sites. These sites meet durability and performance expectations.
2. Locations of the core sites were a major obstacle in determining concrete distresses. The difficulty was establishing the core locations' relationships between the construction stationing and the roadway segments/offsets. This was due mainly to incomplete or inaccurate data on the CAMMS reports.
3. Some other observations not related to F/T such as mid-slab cracks and spalled joints are listed on the attachment.

Conclusions:

1. The evaluation of the durability and performance of the concrete reviewed demonstrated no distresses with reference to F/T damage. This statement is based on the fact that no observable distresses were noted at the 82 reviewed sites.
2. The concrete performance of the 34 confirmed core/cylinder sites and the 48 assumed core/cylinder sites indicate the Department's method of Entrained (hardened) Air testing during this period may not be a reliable indicator of F/T performance.

Recommendations:

1. Continue to collect Entrained (hardened) Air testing data and evaluate testing methods to support possible future research and any forensic investigations.
2. Revise CAMMS input data to better capture the location of cores.
3. Consider using GPS technology on construction projects to establish all material core locations for future identification and for project management.
4. Establish a formal committee to investigate the projects with concrete deterioration using a multi-disciplined group of Concrete Industry, FHWA and Department personnel.
5. No specification revisions are proposed from the results of this study.

II. Introduction

The Department's Strike of Letter 425-06-05 established the formation of this investigative study group. The group was formed from Industry, FHWA and Department representatives.

The Concrete Freeze-Thaw Durability and Performance Group reviewed existing concrete elements (pavements, bridges, etc.) where test results indicated low hardened air and document concrete performance. Interpretation of findings, conclusions and recommendations were due by May 31, 2007.

The deadline for completing this effort was extended to September 14, 2007.

Contributing Members:

Robert Prisby, ACPA
Don Ford, Admixtures, Inc
Jack Detz, Hi-Way Paving
Dave Thomas, Golden Triangle
Dave Chilcote, New Enterprise
Dave Cough, FHWA
Neal Fannin, District 2-0
Janice Arellano, BOMO
Pat Miller, BOCM
Joe Robinson, BOCM
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III. Background

A. Scope

SOL 425-06-05 tasked the Concrete Freeze-Thaw Durability & Performance Group with investigating a possible correlation between concrete performance and low entrained (hardened) air test results. A visual survey was conducted using pavement images provided by the Bureau of Maintenance and Operations (BOMO) videologging to determine pavement distress related to Freeze-Thaw (F/T) using ACI 201.1R-92 definitions and reference photos.

The Group expanded the investigation to include both passing and failing entrained air test results.

Technical

Concrete used in the pavements and bridges of Pennsylvania is exposed to severe winter conditions that can initiate and accelerate its deterioration. Two main environmental conditions contribute to the deterioration of pavements and bridge decks.

- The application of large quantities of deicing salts, and
- Freezing and thawing cycles when concrete is in a saturated condition

Concrete freeze/thaw distress become visible in 1-5 years (ref. FHWA 01163). Pennsylvania is located in a severe F/T exposed climate (*1*). The period of F/T exposure of concrete evaluated in this study was 4-17 years.

B. Freeze-Thaw distress, visual identification

The definitions provided by ACI 116R Cement and Concrete Terminology was used and ACI 201.1R-92 in interpreting the visual survey characteristics.

IV. Air Content Measurement and Sampling

A. Measurement Methods

PennDOT Pub. 408, Section 704.1 (c) Design Basis calls for between 3.5% and 8.0% Entrained (hardened) Air volume. PennDOT defines entrained air as bubbles less than 1mm in size and greater than .005mm in diameter.

B. Sampling System

The sampling system used by PennDOT during the survey period is defined in the Publication 408.

V. Field Distress Investigation Survey

A. Sample Population Sites

The Group used a random number system to select 128 sites from all of the sites between 1990 and 2003. This period was selected because the age of the concrete elements could create a high likelihood of F/T distress becoming visibly evident.

The Group determined that the best method of visually surveying for F/T distress was by viewing downward facing videologging images collected by the Bureau of Maintenance and Operations, Roadway Inventory and Testing Section. The core and cylinder field locations were identified from the CAMMS reports for 82 of the 128 randomly selected sites. Images for these sites were collected in June/July

2007. Due to location inaccuracies between the station numbers contained on the CAMMS reports and the segment/offset location, images for 40 sites were not located. An additional six (6) sites were not surveyed because they had received an asphalt overlay.

B. Blind Study Parameters

Approximately half of the test reports, for the 82 sites included in the study, indicated passing $\geq$ 3.5% Entrained (hardened) Air results and the other half were failing <3.5% Entrained (hardened) Air results. Group members were asked to determine the presence or absence of F/T distress caused by low air. These determinations were made without the Group members knowing which sites were related to either CAMMS "passed or failed" test reports (blind study). These survey determinations were made in strict accordance to the ACI 201.1R-92 definitions and reference photos.

Thirty-four (34) of the core holes were visually located on the videologging images. The visual survey was conducted within 15 feet of the core location. This is the location where the sample was retrieved and where deterioration would have occurred.

Where it was not possible to locate the core hole from the information provided on the CAMMS report, a best effort was made to locate the segment/offset that matched the CAMMS location for Twenty-three (23) sites. At these locations, the entire segment/offset related to the CAMMS report was visually surveyed and evaluated.

Twenty-five (25) of the sites were on bridge decks where cylinders locations were used for the examination. The entire bridge deck was visually surveyed and judged for these sites.

VI. Survey Findings

A. No Freeze-Thaw distresses were identified by any of the team members (summary sheet attached) of the 82 sites. These sites meet durability and performance expectations.
B. Locations of the core sites were a major obstacle to determining concrete distresses. The difficulty was establishing the core locations' relationships between the construction stationing and the roadway segments/offsets. This was due mainly to incomplete or inaccurate data on the CAMMS reports.
C. Some other findings not related to F/T such as mid-slab cracks and spalled joints are listed on the attachment

.

VII. Summary of Conclusion

A. The evaluation durability and performance of the concrete reviewed demonstrated no distresses with reference to F/T damage. This statement is based on the fact that no observable distresses were noted at the 82 reviewed sites.
B. The concrete performance of the 34 confirmed core/cylinder sites and the 48 assumed core/cylinder sites leads to the belief that the Department's method of Entrained (hardened) Air testing during this period may not be a reliable indicator of F/T performance.

VIII. Recommendations

A. Continue to collect Entrained (hardened) Air testing data and evaluate testing methods to support possible future research and any forensic investigations.
B. Revise CAMMS input data to better capture the location of cores.
C. Consider using GPS technology on construction projects to establish all material core locations for future identification and for project management.
D. Establish a formal committee to investigate the projects with concrete deterioration using a multi-disciplined group of Concrete Industry, FHWA and Department personnel.
C. No specification revisions are proposed from the results of this study.

IX. References

1. Desai, Dhruv; Tikalsky, Paul, "Hardened Air in Concrete Roadway Pavements and Structures, Research Agreement No. 510401, Work Order 6, Task 1," May 18, 2006, p. 1-4.

X. Appendix

A. Tabulation of Survey Findings