No. 0001-01-01 July 2008

Project Summary

Technology Transfer Outreach Publication

The Deleterious Chemical Effects of Concentrated Deicing Solutions on Portland Cement Concrete

Researcher
Dr. Lawrence Sutter
Professor
Michigan Tech
Transportation Institute

llsutter@mtu.edu
906.487.2268

Sponsor
South Dakota Department of Transportation

Project Title
The Deleterious Chemical Effects of Concentrated Deicing Solutions on Portland Cement Concrete

Project Manager
David L. Huft
SDDOT Research Program Manager

Co-Investigators
Michigan Tech University
Tom Van Dam
Associate Professor

Jianping Dong
Professor

This research project investigated the effects of concentrated brines of magnesium chloride, calcium chloride, sodium chloride, and calcium magnesium acetate on portland cement concrete. Although known to be effective at deicing and anti-icing, the deleterious effects these chemicals may have on concrete have not been well documented. The degradation of concrete used in pavements and bridges that may occur as a result of exposure to these chemicals is the result of an increased concentration of calcium and magnesium ions in the concrete pore water. These free ions are available to combine with materials in the concrete to form expansive or weakened cementitious phases. The possible deleterious effects of these chemicals on concrete must be fully understood if these chemicals are to be used as a mainstay of any deicing or anti-icing strategy.

Research Objectives

1. To determine the long-term effects of concentrated solutions of magnesium, sodium and calcium chloride as well as liquid deicers on durable portland cement concrete.

2. To estimate the potential for reduction in performance and service life for pavements (jointed plain, reinforced and continuously reinforced) and structures subjected to various concentrated deicing brines.

3. To identify alternative protective or deicing/anti-icing strategies that minimize potential impacts to durable portland cement concrete while providing acceptable winter maintenance results.

Research Findings

As a result of this research, it was determined that there is significant evidence that magnesium chloride and calcium chloride chemically interact with hardened portland cement paste in concrete resulting in expansive cracking, increased permeability, and a significant loss in compressive strength. Although the same effects were not seen with sodium chloride brines, it was shown that sodium chloride brines have the highest rate of ingress into hardened concrete. This latter fact is significant with respect to corrosion of embedded steel. The mechanism for attack of hardened cement paste varies with deicer chemical but in general, a chemical reaction between chlorides and cement hydration products results in the dissolution of the hardened cement paste and formation of oxychloride phases, which are expansive.

(continued)

Michigan Tech
Transportation Institute

www.mtti.mtu.edu

University Facts

Total Enrollment	6,550
Graduate Enrollment	916
Number of Faculty	417
Placement Rate	95%

Michigan Tech is located in Houghton, MI on the south shore of Lake Superior. This rural area is known for natural beauty, pleasant summers, abundant snowfall, and numerous all-season outdoor activities. In addition, the University maintains its own downhill and cross-country ski facilities and golf course. There are numerous cultural activities and opportunities on campus and in the community. Michigan Tech has also been rated as one of the safest college campuses in the United States, and the local community provides excellent resources conducive to an outstanding quality of life.

www.mtu.edu

Project Summary

Technology Transfer Outreach Publication

Research Findings (continued)

The chemical attack of the hardened cement paste is significantly reduced if supplementary cementitious materials are included in the concrete mixture. Both coal fly ash and ground granulated blast furnace slag were found to be effective at mitigating the chemical attack caused by the deicers tested. In the tests performed, ground granulated blast furnace slag performed better as a mitigation strategy as compared to coal fly ash. Additionally, siloxane and silane sealants were effective at slowing the ingress of deicing chemicals into the concrete and thereby reducing the observed distress. In general, the siloxane sealant appeared to be more effective than the silane, but both were effective and should be considered as a maintenance strategy.

Implementation

The final report for this project is extensive. To facilitate distribution, the report has been broken down into a number of separate volumes and these are listed below. All research products are available on the South Dakota DOT Office of Research Web Page (http://www.state.sd.us/Applications/HR19ResearchProjects/oneproject_search.asp?projectnbr=SD2002-01).

- Executive Summary – Provides a concise summary of the entire project.
- Final Report – The final technical report with summary results of the literature review, field studies, and laboratory studies.
- Appendix to Final Report – The appendix contains details on specific analytical methods used in the study. Also, the appendix contains an unabridged summary of results for the characterization of field specimens and for all laboratory experiments.
- Full Literature Review – Provides the unabridged version of the literature review.
- Guidelines – A practical guideline document to assist DOT personnel in implementing this research.

Publications

Sutter, L.L., K.R. Peterson, S.H. Touton T.J. Van Dam, and D. Johnston (2006). "Petrographic Evidence Of Calcium Oxychloride Formation In Mortars Exposed to Magnesium Chloride Solution", Cement and Concrete Research, Volume 36, Issue 8, August, pp. 1533-1541.

Sutter, L.L., T.J. Van Dam, K.R. Peterson, and D. Johnston (2006). "Long Term Effects of Magnesium Chloride and Other Concentrated Salt Solutions on Pavement and Structural Portland Cement Concrete – Phase I Results," Journal of the Transportation Research Board, Transportation Research Record 1979, Transportation Research Board. pp. 54-59.

Sutter, L.L., K.R. Peterson, S.H. Touton T.J. Van Dam, and D. Johnston. "Petrographic Evidence Of Calcium Oxychloride Formation In Mortars Exposed To Magnesium Chloride Solution", Proceedings of the 10th Euroseminar on Microscopy Applied to Building Materials, Paisley, Scotland, June 22-25, 2005.

Acknowledgements

This project was conducted as Pooled Fund Study TPF-5 (042) through the cooperation of the Federal Highway Administration and the financial support of California, Colorado, Idaho, Illinois, Iowa, Montana, South Dakota, Texas and Wyoming.

Michigan Tech Transportation Institute

www.mtti.mtu.edu