JOINT TRANSPORTATION RESEARCH PROGRAM

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Investigation of Anti-Icing Chemicals and Their Interactions with Pavement Concretes

Introduction

The increasing costs of deicing chemicals, environmental concerns, and user demands for ice-free pavements all dictate changes in the pavement maintenance strategies used by the Departments of Transportation (DOTs) in the United States of America. As an example, during the last several years, in addition to traditional deicing operations the DOTs also introduced such treatments as anti-icing of pavements and pre-wetting of salt and sand before spreading them on the pavements.

The deicing process involves applying snow and ice control materials directly on the top of already accumulated snow (or ice) layers in order to destroy their bond with pavement surface and thus facilitate easier removal of these materials from the roads.

The anti-icing treatment is defined as a snow and ice control method in which deicing chemicals are applied to the bare pavement surface hours before the expected precipitation to prevent bonding of ice and snow.

The pre-wetting involves application of salt solutions directly on the particles of dry salt (or sand) to increase their initial surface moisture in order to improve their adherence to the pavement and thus ensure reduction in bounce, scatter, and tracking of these materials. The main economic advantages of using the last two methods are reductions in application rates of the snow and ice control chemicals, the decrease in the cost of labor (or materials) during surface treatment operations, and overall lower snow control costs. In addition, there are safety factors which need to be considered, including better adhesion of snow and ice control materials to the road surface and lower accident rates.

For many years, sodium chloride (NaCl), commonly known as rock salt, has been used as an ice and snow control deicing agent with satisfying results. However, due to diminishing salt effectiveness in temperatures below 21°F, other chemicals, such as calcium chloride ($CaCl_2$) and magnesium chloride ($MgCl_2$), were introduced as alternative deicers. These two chemicals have freezing points which are lower than the freezing point of brine made with the rock salt, and thus are more effective at lower temperatures. However, the effect of these alternative chemicals on the long-term durability of concrete surfaces is still not well known and subject to controversy.

The primary objective of this study was to investigate the effects of deicing/anti-icing chemicals commonly used by the Indiana Department of Transportation (INDOT) on the durability of pavement concretes. The chemicals evaluated in this study included: sodium chloride (NaCl), calcium chloride ($CaCl_2$), magnesium chloride ($MgCl_2$), and Ice Ban®.

In order to find a solution to the previously stated problem, the scope of the work included the following four tasks: literature review, selection and testing of deicing chemicals, preparation and testing of laboratory concrete specimens, and data analysis.

Findings

The present study investigated the effects of exposure of plain and fly ash concretes to different deicing solutions while being subjected to wetting/drying (W/D) and freezing/thawing (F/T) regimes. The main observations from the study can be summarized as follows:

1. Overall, the best performance (in terms of reducing the negative impact on concrete) was associated with the use of sodium chloride solutions, followed by the combined solution of sodium chloride with magnesium chloride and sodium chloride with calcium chloride.
2. PC specimens subjected to 28% $CaCl_2$ solution and W/D regime developed very visible surface deterioration and 15% reduction in relative dynamic modulus of elasticity (RDME) after only 154 W/D cycles. By comparison, similar reduction of RDME in specimens subjected to 25% $MgCl_2$ was observed only after about 300 W/D cycles.

3. The SEM-EDX analysis indicated formation of calcium oxychlorides in specimens exposed to 28% $CaCl_2$ solution under W/D regime. The changes in the matrix of specimens exposed to 25% $MgCl_2$ solution involved formation of M-S-H gel and $MgCl_2$ and $Mg(OH)_2$ deposits.
4. The fly ash modified concretes displayed better performance (in terms of lower mass loss and lower reduction in RDME) than plain concretes during the reported period of test in both exposure regimes.
5. The only concrete property that was negatively impacted (although rather mildly) was scaling resistance. Since the rate of scaling can be strongly influenced by w/c values, air-void system parameter, and the concentration of deicers, careful control of these parameters should allow for safe usage of fly ash in concrete subjected to deicers.
6. Freeze/thaw exposure conditions typically resulted in more severe distress than W/D regimes, even though the concentrations of deicers used for F/T tests were about 50% lower than those used during W/D tests.

Implementation

This study provided INDOT with in-depth evaluation of the effects of various deicers on the properties of both plain and fly ash concretes of the composition suitable for usage as a pavement material in the state of Indiana.

Considering the findings from this study, the following implementation actions can be suggested:

1. Sodium chloride immersed specimens showed the best performance under exposure conditions used in the study; hence it is recommended that this deicer should be preferentially used for winter maintenance operation unless the expected temperatures are below 21°F. At the temperature below this limit the effectiveness of this solution will be reduced.
2. The test results indicate that there may be a potential for improving the low temperature effectiveness of NaCl deicer without severely impacting the durability of concrete by pre-treating it with carefully selected amounts of low concentration $MgCl_2$ or $CaCl_2$ solutions.
3. In cases when low temperatures dictate the use of deicers with a lower freezing point than sodium chloride, the application of $MgCl_2$ is likely to be less damaging (in terms of reducing the rate of deterioration) than the application of $CaCl_2$.
4. INDOT should consider using the results of this study to develop a best deicing practices manual which will help the winter maintenance personnel to select the least detrimental method of treatment for the purposes of snow and ice removal.
5. Whenever practical, INDOT should encourage the use of fly ash in all pavement concretes as mixtures containing this material offered higher resistance to degradation processes induced by the use of deicers than mixtures containing plain portland cement.

The benefits of this research include:

- Assemblage of detailed information on the effects of various deicing chemicals on several properties of pavement-type mixtures. This information would be useful to INDOT winter maintenance personnel in the process of selecting the most suitable ice and snow removal applications.
- Generation of fundamental information regarding the potential mechanism and the extent of deterioration resulting from the use of deicing chemicals.
- Increased level of awareness among INDOT's pavement engineers and winter maintenance personnel about how deicers can potentially contribute to damage of concrete pavements.

The implementation of findings from this study will help INDOT to reduce the cost of pavement and bridge deck repairs by improving snow and ice removal practices through increased awareness of potentially detrimental effects of certain deicers.

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