

Method for Detection of Chemical Reactions Between Concrete and Deicing Chemicals

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An attempt was made to develop methods that can be used to detect chemical reactions between concrete and deicing chemicals and to determine if they actually occur. The results collected to date provide clear evidence of chemical reactions between concrete and the corrosion-inhibiting deicing salts. The different amounts of precipitates (chemical reaction products) found in the test cells are dependent on the type and the concentration of corrosion-inhibiting deicing salts.

Concrete degradation occurs through a variety of chemical and physical processes. Concrete may be degraded in three different ways distinguished by the prevalent signs of destruction (1,2) such as (a) decomposition of concrete by lime leaching, (b) chemical exchange reactions between hardened cement constituents and a solution, and (c) the accumulation, crystallization, and polymerization of reaction products.

It is well known that the use of deicing salts causes rebar corrosion in concrete and leads to structural failures. Corrosion inhibitors are mixed with plain rock salt (sodium chloride) to reduce or prevent rebar corrosion in concrete. Even though some reports (3-8) indicate the possibility of concrete degradation by deicing chemicals, the effects of the corrosion-inhibiting deicing salts and salt substitutes on concrete degradation are not well understood, and methods for determining the effects of the corrosion-inhibiting deicing salts and salt substitutes on concrete degradation are not available.

The result of previous research (9) suggest that the corrosion-inhibiting deicing salts interact with concrete and produce precipitates through a chemical reaction. If certain ions in the corrosion-inhibiting deicing salts that function as inhibitors are lost by precipitation, the effectiveness of the corrosion-inhibiting deicing salts on rebar corrosion could drop significantly. On the other hand the formation of precipitates in cracks may act as a barrier to the penetration of the salt solutions, thereby acting as an inhibitor. Alternatively some of the precipitates may form in the micro-cracks or pores of concrete and facilitate the propagation of cracks.

In the investigation described here an attempt was made to develop methods that can be used to detect chemical reactions between concrete and deicing chemicals and to determine if they actually occur.

EXPERIMENTAL

Concrete slabs and cone-shaped concrete samples were designed to accelerate the deterioration of concrete in corrosion-inhibiting deicing salt and salt substitute solutions. The physical and chemical changes of the cone-shaped concrete samples are being monitored by visual examination and chemical and mineralogical analyses in an on-going research program.

Concrete Slab Samples

Concrete slabs [30 × 30 × 15 cm (12 × 12 × 6 in.)] [Figure 1(a)] were fabricated by using a 1.5-m³ (2-yd³) mix (183 × 183 × 183 cm) consisting of Portland Cement-Concrete [313 kg (691 lb)] with coarse [797 kg (1,757 lb)] and fine [523 kg (1,154 lb)] aggregates. The bottom halves of all of the slabs were cast from the mix as delivered, and the top halves were cast after adding 9 kg (20 lb) of NaCl to the remaining mix. After casting the slabs were placed in a moist room for a period of 28 days and were then dried in a chamber maintained at a temperature of 43 to 49°C (110 to 120°F) for 45 days. The air content determined by the linear transverse test was 13 percent. Originally the slabs were made for rebar corrosion testing with 3 percent solutions of corrosion-inhibiting deicing salts and salt substitutes.

Concrete slab samples ponded with 3 percent corrosion-inhibiting deicing salts and salt substitute solutions for 484 days were visually examined for rust stains, concrete cracks, and the roughness of the concrete surfaces caused by the corrosion-inhibiting deicing salts.

Cone-Shaped Concrete Samples

Cone-shaped concrete samples [Figure 1(b)] were made by mixing 374 kg (825 lb) of Type III cement, 635 kg (1,400 lb) of sand (Minnesota DOT Specification 3126), and 635 kg (1,400 lb) of quartzite meeting the CA-70 grade (Minnesota DOT Specification 3137). A paper mold was used to make the cone-shaped concrete samples. The cone shape of the samples was chosen to provide a large surface area exposed to the corrosion-inhibiting deicing salt solutions and to accelerate the chemical reactions at the tip. The physical changes in the concrete samples could readily be recognized at the tips. The concrete samples were placed in a moist room for 28 days after fabrication and were then air dried. The compressive strength of the concrete samples was 63.4 MPa (9,190 lb/in²).

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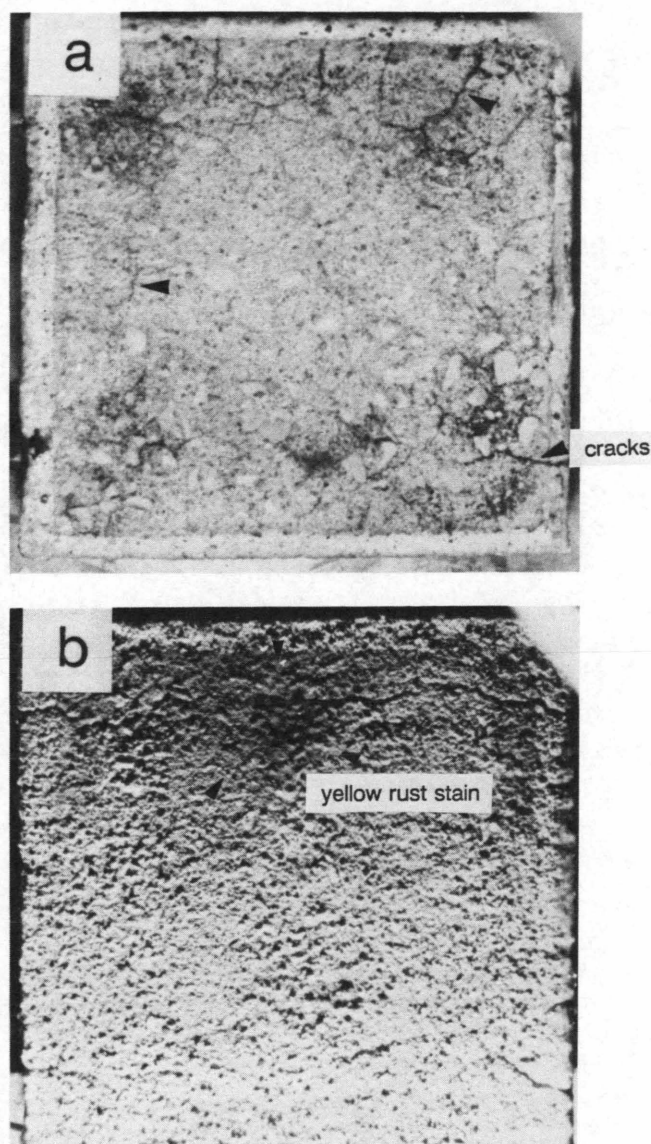


FIGURE 2 Top surfaces of concrete slabs showing (a) numerous concrete cracks and (b) yellow rust stain.

is shown in Figure 3. The slabs tested with CMA and sodium formate solutions contained cracks [Figure 3(a)] but did not show any yellow rust stains on their surfaces [Figure 3(b)]. On the other hand the slab surfaces tested with salt (NaCl) solutions showed signs of rebar corrosion in concrete, but no cracks were observed (Figure 3). Figures 2 and 3 indicate that the cracks in the concrete slabs were created by both rebar corrosion and chemical reactions between deicing chemicals and concrete. These results made it of interest to investigate the concrete degradation caused only by chemical reactions between the deicing media and concrete.

Precipitates in Corrosion-Inhibiting Deicing Salt Solutions

To evaluate the effects of the chemical reaction between corrosion-inhibiting deicing salts and concrete, the cone-shaped concrete sam-

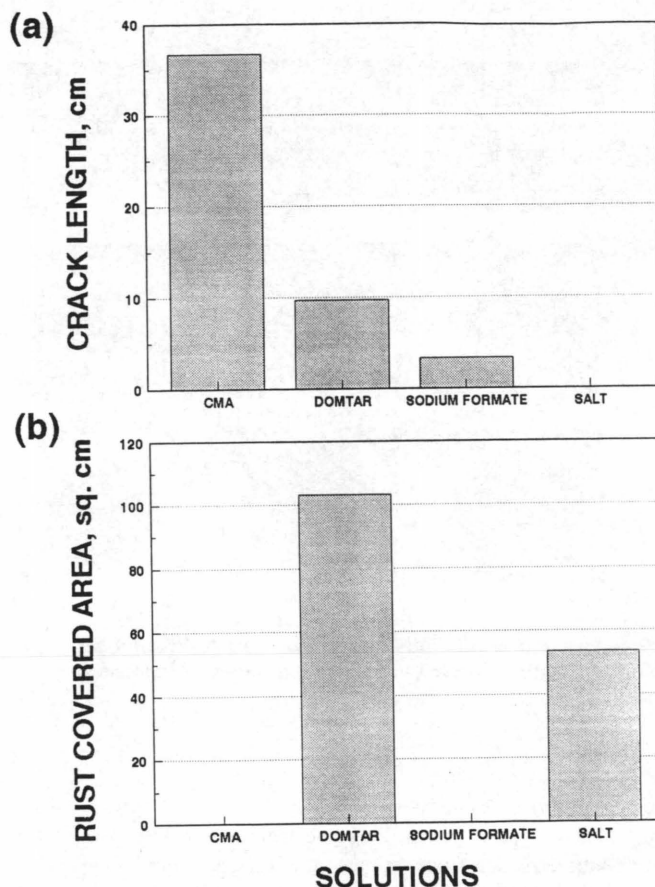


FIGURE 3 Average concrete crack length (a) and average area of yellow rust stains (b) caused by 3 percent corrosion-inhibiting deicing salts and salt substitute.

ples were placed in the 3, 6, and 20 percent corrosion-inhibiting deicing salt and plain sodium chloride solutions. After leaving the concrete samples in the test solutions for a day various amounts of precipitates were found in the test cells depending on the type and the concentration of corrosion-inhibiting deicing salts. Figures 4 and 5 show that the precipitates were formed by chemical reactions between the concrete and the corrosion-inhibiting deicing salts. The precipitates were observed on the concrete sample surfaces, at the bottoms of the test cells, or both. However, no precipitates were found in the test cells containing NaCl (Figure 6) and deionized water (Figure 7). For Deicing Salt A (Figure 4) the amount of precipitates increased with an increased concentration of corrosion-inhibiting deicing salt. For Deicing Salt B (Figure 5) the amount of precipitates decreased with an increased concentration of corrosion-inhibiting deicing salt. It appears that the amount of precipitates increased with time in all cases.

The chemical changes in the test solutions as well as the physical changes in the concrete samples are being monitored as a function of time. The results collected so far provide clear evidence of chemical reactions between concrete and the corrosion-inhibiting deicing salts. The impact of the chemical reactions on concrete degradation can be understood by determining the chemical and mineralogical changes in the concrete caused by the corrosion-inhibiting deicing salts. The chemical changes in the solutions provide part of the necessary information on changes in

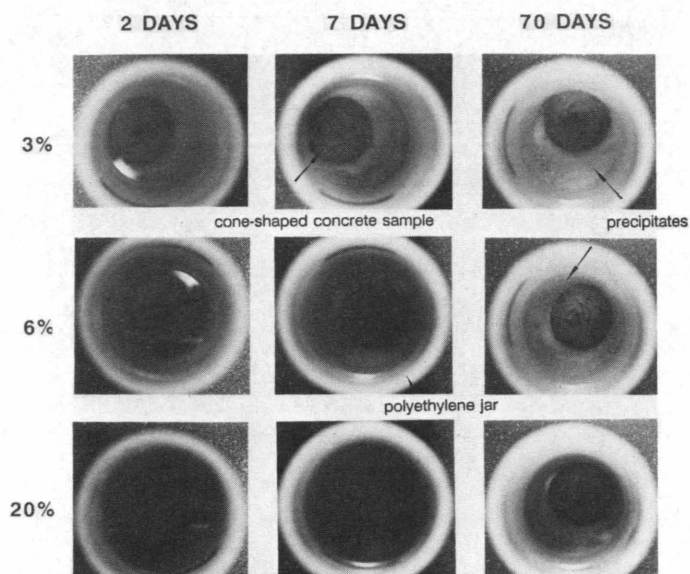


FIGURE 4 Top views of test cells containing 3, 6, and 20 percent corrosion-inhibiting Deicing Salt A. Precipitates increased with increased concentration and as a function of time.

the chemistry and bonding strength of concrete, but the mineralogy of the precipitates must also be determined. The precipitates are being collected from the test cells for quantitative and qualitative chemical and mineralogical analyses to define the chemical reactions.

The physical changes in the concrete samples after 400 days of reaction have not been significant enough (i.e., a minimum of 15 percent weight and dimension changes) to determine the extent of changes by the corrosion-inhibiting deicing salt solutions. The

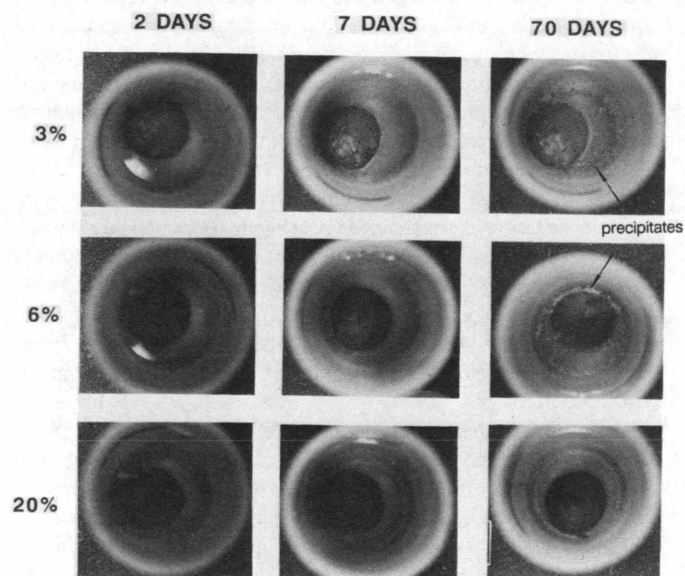


FIGURE 5 Top views of test cells containing 3, 6, and 20 percent corrosion-inhibiting Deicing Salt B. Precipitates decreased with increased concentration.

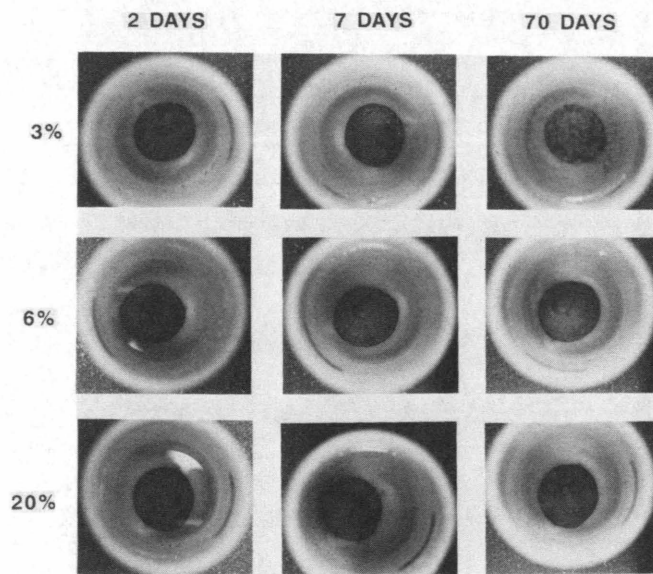


FIGURE 6 Top views of test cells containing 3, 6, and 20 percent NaCl. No precipitate found after 70 days.

physical properties (volume changes on dry-wet and freeze-thaw cycling) of the precipitates will be determined at a later date.

CONCLUSIONS

The results collected to date provide clear evidence of the chemical reactions between concrete and the corrosion-inhibiting deicing salts. The different amounts of precipitates found in the test

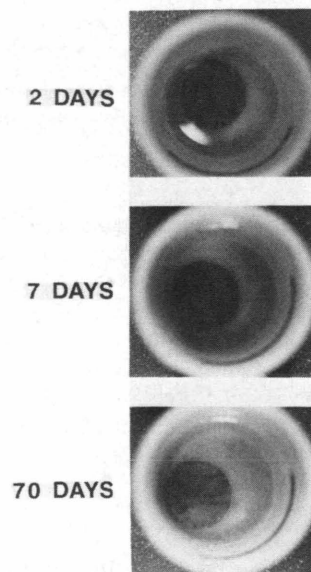


FIGURE 7 Top views of test cells containing deionized water. No precipitate found after 70 days.

However further research is necessary to understand the mechanisms of concrete degradation by corrosion-inhibiting deicing salts. The concrete in the cone-shaped concrete samples are expected to show significant physical changes resulting from the corrosion-inhibiting deicing salts with time. The precipitates must be collected from the test cells for quantitative and qualitative analyses to identify the degree of chemical reaction, the chemical elements involved in the reactions, and the mineralogy of the precipitates. The volume changes in the precipitates in dry-wet and freeze-thaw cycling will indicate the impacts of the precipitates on microcracks in concrete.

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