Effects of Calcium Magnesium Acetate on Reinforced Steel Concrete

by

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Introduction

In research aimed at discovering alternative highway deicing chemicals, calcium magnesium acetate (CMA) was identified as a potential alternative deicer to replace salt. (1) This research prompted the Federal Highway Administration (FHWA) to initiate a Federally Coordinated project on CMA as an alternative deicer. (2) The project included four major tasks: (a) evaluate the effects of CMA on environment; (b) determine the feasibility and development of its economical production; (c) determine its physical and chemical properties and deicing ability; and, (d) evaluate its effects on highway and transportation materials.

Early in the research, the FHWA was interested in learning what effect CMA had on highway metals. Preliminary comparative tests were conducted using steel reinforcements immersed in both CMA and salt (NaCl) solutions. The results concluded that steels exposed to CMA solutions corroded much less than those exposed to salt solutions. (1) Besides this, the FHWA also initiated a staff ponding study in 1982 using CMA solutions on reinforced concrete slabs to detect the corrosion susceptibility of CMA under an outdoor environment. More research was conducted in 1984 regarding the effects of CMA on highway metals including ponding studies on small-reinforced concrete slabs. (3) This paper examines the results of the 1982 FHWA–CMA staff ponding study and compares these results with those results of the 1984 study.
Procedures

Ponding studies were started in July 1982. The concrete slabs, 2 ft by 5 ft by 6 in containing a single mat of reinforcing steel were fabricated. The details on mix design, properties of concrete, and construction procedures are described elsewhere. (4) These slabs were fitted with rubber dams and ponded using 3 percent and 5 percent aqueous solutions of CMA for two slabs and 3 percent aqueous salt solution for the third slab. The slabs were ponded twice a week during July 1982 to March 1983, June to September 1984, March to June 1985, and June to September 1986. During the 4-year period, the slabs were exposed to the outdoor environment at the Turner-Fairbank Highway Research Center facility in McLean, Virginia. Using copper-copper sulfate as a reference electrode, electrical potential measurements were made during the first few months and the last 4 months of the 4-year outdoor-exposure period by an ASTM C876-80 procedure. (5)

Results

Laboratory studies and an ASTM standard C876-80 have established that reinforced black steel potentials numerically greater than $-350 \text{ mV}$ with respect to a copper-copper sulfate reference electrode indicate that there is a greater than 90 percent probability that corrosion is occurring in areas of the steel at the time of measurement. (6, 7)

Figures 1 and 2 show the potentials measured for the embedded black steel rebars of the CMA- and salt-ponded slabs over the 4-year period during the test. For the two slabs ponded with the CMA solutions, electrical potentials of black steel rebar varied between 0 to $-60 \text{ mV}$. These potentials are not in the corrosive range. (5)

The potentials of the slab ponded with the salt solution numerically increased from $-100 \text{ mV}$ to $-280 \text{ mV}$ in the first 3 months, and then to $-580 \text{ mV}$ in the next 3.5 years, well within the corrosive range. After 4 years under test, the surface condition of the CMA-ponded slabs showed no signs of surface cracking. On the other hand, for the salt-ponded slabs, after 3 years, concrete cracking was noticeable in areas directly over the rebars. After an additional year, the cracks became wider and rust stains appeared in two areas along the cracks.

The University of Oklahoma study used small reinforced concrete slabs, 14 in by 14 in by 4.5 in, containing two rebar mats, one near the top and the other near the bottom of each slab. (3) These slabs were ponded indoors with CMA and salt solutions for 15 months. There were four duplicate sets of slabs containing bare steel at the top mat. Set one slabs containing uncontaminated concrete were ponded with CMA solution and had top steel potentials in the range $-136$ to $-208 \text{ mV}$; which are not in the corrosion range. The other three sets of duplicate concrete slabs were either fabricated with admixed chloride and then ponded with CMA solution or just ponded with sodium or calcium.
chloride solutions. Some of the slabs in this category did show potentials in the corrosion range; which is not surprising since Cl-ions are known to cause corrosion of reinforcing steel.

All research under this study was conducted in the Materials Division laboratories at the Turner-Fairbank Highway Research Center, McLean, Virginia.

Discussion

Our results show that the potential of the black steel rebars in slabs ponded with salt solutions started increasing numerically within the first 3 months of exposure, while that of rebars in slabs ponded with CMA solution did not increase at all during that time period. The CMA solutions did not cause any significant potential shift or corrosion after 4 years on/off ponding in an outdoor environment. This contradicts the Oklahoma results (3) on this subject, where it was concluded that CMA solutions have a potential to corrode uncoated rebars embedded in portland cement concrete to a somewhat similar extent as salt. This conclusion was based on changes in the electrical potentials for the black steel rebars exposed to simulated pore solutions, embedded in mortar cylinders and concrete slabs. The Oklahoma study did not confirm the corrosion of the rebars for CMA or salt-ponded slabs or cylinders by breaking them and observing the rebars.

Future Studies

Since detailed rebar studies were performed indoors and did not simulate outdoor conditions (3), and since our outdoor exposure studies were very limited, a new outdoor exposure study is planned to resolve questions and differences raised with this limited research. This future study should include destructive evaluation of ponded concrete specimens with a detailed examination of the extracted rebars and the analysis of all aggressive ions in the concrete at various depths. It will decide the rate of diffusion of CMA through the concrete and also conclude if the presence of CMA at the rebar surface will cause any corrosion of the rebar in concretes.

REFERENCES


(2) Federal Highway Administration, Federally Coordinated Project 3C, "Evaluation of Calcium Magnesium Acetate as an Alternate Deicer."


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