

# Effects of Calcium Magnesium Acetate on Pavements and Motor Vehicles

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The corrosion and deterioration of highway-related and automotive-related materials by chloride-containing deicing chemicals has become a major economic problem in the United States. The FHWA has proposed the use of calcium magnesium acetate (CMA) as an alternative to these chloride-containing chemicals (specifically, sodium chloride). This report describes the comparative effects of CMA and sodium chloride on various highway-related and automotive-related materials. The results of various exposure techniques, which were followed by extensive additional testing, indicate that CMA is much less deleterious to highway-related and automotive-related materials than sodium chloride.

Each year, millions of tax dollars are spent to reconstruct or repair damaged highways and associated highway structures, and millions of private dollars are spent to repair or replace corroded motor vehicles. Additionally, large amounts of money and time are used to assess and correct environmental problems that have resulted from the use of sodium chloride as a deicing chemical.

The FHWA has recognized this problem and has determined that calcium magnesium acetate (CMA) is a suitable alternative deicing chemical. CMA is a mixture of calcium acetate and magnesium acetate, manufactured by reacting acetic acid with dolomitic lime or limestone.

The FHWA wanted a deicing chemical that had deicing capabilities similar to sodium chloride but had less deleterious effects on highway-related and automotive-related materials. The FHWA also wanted to substantiate previous research indicating that CMA was less deleterious to highway-related and automotive-related materials than sodium chloride. This research might also indicate previously unknown effects of CMA on the aforementioned materials. This was the basis for the institution of this study.

At this time, there are no plans for CMA to replace sodium chloride as the United States' primary road deicing chemical. However, it is necessary to have a suitable, effective roadway deicing alternative that can be used in areas where sodium chloride may have significant effects on highway-related and automotive-related materials or great environmental impact.

## DESCRIPTION OF THE STUDY

The purpose of this study was to determine the comparative effects of sodium chloride and calcium magnesium acetate on highway-related and automotive-related materials.

Test material categories for this program were chosen because they include materials commonly used in highway-related and automotive-related applications and also are representative of other products made from similar materials. Specimens totaling 2,240 were tested from 81 categories, including portland cement concrete; asphalt; traffic-marking paint, plastic, and tape; reflective and ceramic pavement markers; pavement-marker adhesives; sign-reflective sheetings and paints; joint-sealant materials; plastic and wood stanchions; bridge-bearing materials; drainage pipe; automotive paints, primers, and undercoatings; automotive exterior adhesives; automotive plastics and elastomers; automotive tires and rubber; brake-lining materials; automotive steels; hydraulic brake-line tubings; automotive aluminum alloys and stainless steels; and automotive combined metals such as chrome, aluminized steel, galvanized steel, terne-coated steel, and nickel-zinc coated steel. The specimens were made from new materials to insure accuracy in testing and reproducibility. It must be noted that the purpose was not to evaluate the test materials' susceptibility to corrosion. Rather, the study sought to evaluate the comparative effects of sodium chloride and calcium magnesium acetate on the various materials tested.

The types of tests performed on the specimens were performed as specified by the ASTM. A total of 6,048 tests were performed on the aforementioned specimens, including salt fog exposure, concrete-compression, abrasion, and scaling-resistance testing; static-loading and impact testing; testing of rubber and light-related properties; paint evaluations; and shear, thickness, indentation/hardness, environmental, friction, adhesion, immersion, exfoliation, and electrochemical testing.

The specimens were exposed to a control solution and four test solutions. The control solution was deionized water and the test solutions were 4 percent by weight sodium chloride acquired from the Maryland State Highway Administration (4 percent NaCl), 1 percent by weight (1 percent CMA<sub>(FHWA)</sub>) and 6.8 percent by weight (6.8 percent CMA<sub>(FHWA)</sub>) calcium magnesium acetate (having a one-to-one molar ratio of calcium and magnesium ions) supplied by the FHWA, and 6.8 percent by weight calcium magnesium acetate made by the contractor by mixing pure calcium acetate and pure magnesium acetate, 4-hydrate (both purchased from American Hoechst Corporation) in a one-to-one molar ratio (6.8 percent CMA<sub>(DAI)</sub>), all in aqueous solution.

Not all of the aforementioned tests were performed on each type of material specimen. Certain tests were performed on certain types of materials.

In the following sections, specimens are comparatively described as more or less affected by the aforementioned test

solutions. It would be unfair to attempt to be more specific about the test results, since each test was repeated only two, three, or four times.

## TESTING OF HIGHWAY-RELATED MATERIALS

### Pavement Materials

The compressive strengths of portland cement concrete and asphalt products were comparatively unaffected by sodium chloride or calcium magnesium acetate solutions. Additionally, scaling did not occur on any asphalt products.

However, some scaling did occur on portland cement concrete. In general, the scaling was severe on specimens exposed to sodium chloride solutions, moderate on specimens exposed to deionized water, and minimal on specimens exposed to calcium magnesium acetate solutions.

The same magnitudes of scaling occurred on joint-sealant-material specimens, but the joint-sealant materials themselves appeared to be comparatively unaffected.

### Guidance Materials

Road-marking materials such as paints, plastic, and tape were affected by both sodium chloride and calcium magnesium acetate solutions. Road-marking paint specimens exposed to solutions of both compounds exhibited chalking, checking, erosion, and flaking. In all cases, the sodium chloride solutions were either more deleterious than the calcium magnesium acetate solutions, or so severely scaled the specimen substrates that no paint remained to be examined. Plastic and tape specimens were similarly affected. Hardness properties appeared to be unaffected, while whiteness of specimens exposed to deionized water and calcium magnesium acetate solutions appeared to be enhanced.

Similarly, hardness properties of pavement markers appeared to be unaffected. Light-related properties were difficult to analyze, since the specimen sizes and configurations inhibited consistent analyses. Although some pavement-marker adhesives exhibited increases or decreases in shear strength and impact resistance over exposure for one year, these were slight, and it appeared that neither solutions of sodium chloride nor solutions of calcium magnesium acetate affected the adhesives.

Sheetings and paints used in directional and informational highway signs that were exposed to sodium chloride and calcium magnesium acetate solutions all appeared to retain adhesion to their aluminum substrates. Light-related properties of the sign materials were either relatively unaffected or similarly affected. Physical degradation of sign paints did not occur.

The light-related properties of plastic road delineators, or stanchions, were either relatively unaffected or similarly affected by the sodium chloride or calcium magnesium acetate solutions. Again, specimen sizes and configurations inhibited consistent analyses. Likewise, hardness properties were also unaffected. Impact resistance of plastic stanchions and shear strengths of wood stanchions appeared to be unaffected.

### Construction Materials

Hardness properties and impact resistance of bridge-bearing materials were unaffected by solutions of sodium chloride or calcium magnesium acetate.

Crushing strengths of concrete, bituminous-coated corrugated metal, and plastic pipes were also unaffected by solutions of sodium chloride or calcium magnesium acetate.

## TESTING OF AUTOMOTIVE-RELATED MATERIALS

### Automotive Paints, Coatings, and Adhesives

The adhesive, light-related, and hardness properties of automotive paints, primers, and undercoatings appeared to be relatively unaffected by solutions of sodium chloride or calcium magnesium acetate. Additionally, no blistering occurred on any of these specimens.

Some paint, primer, and undercoating breakdown and subsequent rusting occurred on both scribed and unscribed specimens. In all cases, however, sodium chloride caused more coating breakdown and more severe rusting than solutions of calcium magnesium acetate.

Some automotive exterior adhesives exhibited increases or decreases in shear strength over exposure for one year, but these were slight, and it appeared that neither solutions of sodium chloride nor solutions of calcium magnesium acetate affected the adhesives.

### Automotive Plastics and Rubber

Solutions of sodium chloride and calcium magnesium acetate caused slight changes in the light-related properties of automotive hard plastics, elastomers, and transparent lens materials, but these changes usually occurred consistently for all materials. One exception was the haze exhibited by the Automotive Transparent Lens Material 1 specimen exposed to the solution of 6.8 percent CMA<sub>(FHWA)</sub>. However, since the same respective specimens exposed to the other calcium magnesium acetate solutions appeared to be unaffected, it was determined that the subject specimen had most likely been damaged prior to the performance of the Test for Haze and Luminous Transmittance of Transparent Plastics (ASTM D1003). Additionally, with the exception of transparent lens materials, most automotive hard plastics and elastomers on automobiles are either painted or are not subjected to light. The specimens were, therefore, considered comparatively unaffected. Accordingly, the hardness properties and impact resistances of these specimens were also considered comparatively unaffected.

The hardness properties of automotive tire materials and rubber compounds exposed to solutions of sodium chloride and calcium magnesium acetate appeared to be unaffected. Compression sets of all specimens increased, although ultimate tensile strengths remained unaffected. The 300-percent moduli and tear resistances of the same specimens were only slightly affected. Some surface cracking appeared on these specimens, but remained consistent throughout the specimen type. Surface cracking, therefore, was not attributable to the exposure to solutions of sodium chloride or calcium magnesium acetate, but rather to the specimen composition.

### Automotive Brake Systems

Solutions of sodium chloride and calcium magnesium acetate appeared to have no effect on the hardness properties of the automotive brake-lining materials. However, specimens exposed to solutions of sodium chloride consistently exhibited lower static and kinetic coefficients of friction.

In general, automotive hydraulic brake-line tubings exposed to solutions of sodium chloride exhibited greater weight losses as a result of corrosion and more rusting and deterioration than the same specimens exposed to solutions of calcium magnesium acetate. No pitting corrosion was observed on any specimens.

### Automotive Metals

Automotive steels exposed to solutions of sodium chloride consistently exhibited greater weight losses as a result of corrosion, more pitting corrosion, and more general corrosion than the same respective specimens exposed to calcium magnesium acetate. Specimens exposed to solutions of sodium chloride were also susceptible to crevice corrosion, whereas the same respective specimens exposed to solutions of calcium magnesium acetate were not.

Automotive aluminum alloys exposed to solutions of sodium chloride consistently exhibited greater weight losses as a result of corrosion and more pitting corrosion than the same respective specimens exposed to calcium magnesium acetate. General corrosion of specimens was either minimal for all solutions or slightly enhanced by solutions of sodium chloride. Susceptibility to crevice corrosion varied from specimen to specimen and solution to solution.

Automotive stainless steels exposed to all solutions exhibited insignificant weight losses and minimal differences in general corrosion. Pitting corrosion was also minimal but did occur in some specimens exposed to solutions of sodium chloride. Specimens exposed to solutions of sodium chloride were also susceptible to crevice corrosion; the same respective specimens exposed to solutions of calcium magnesium acetate were not.

Automotive combined metals exposed to all solutions exhibited minimal pitting corrosion. However, greater resistances to pitting corrosion were prevalent in specimens exposed to the calcium magnesium acetate solutions than in specimens exposed to the sodium chloride solutions. Susceptibility to crevice corrosion varied from specimen to specimen and solution to solution. Chrome-plated steel and stainless steel alloys were only slightly affected by all solutions. Aluminized steel exposed to solutions of sodium chloride exhibited greater weight losses than the same respective specimens exposed to the calcium magnesium acetate solutions. Galvanized steel and terne-coated stainless steel were equally affected by all solutions. Results varied for exposures of nickel-zinc alloy coated steel.

It must be noted that the electrochemical tests were immersion-type tests, which were conducted in a nitrogen environment. Thus, the resulting susceptibilities to general corrosion and corrosion resistance were of limited importance because, under actual highway conditions, automotive metals are in contact with air-saturated environments. It must also be noted that in cases where no general corrosion was detected, as was the case for many metals exposed to deionized water and solutions of sodium chloride, the rate of corrosion would increase exponentially with the degree of aeration. The principal danger to automotive-related materials under actual highway conditions is their susceptibility to localized corrosion (pitting and crevice corrosion). As previously stated, pitting and crev-

ice corrosion were generally more prevalent in specimens exposed to solutions of sodium chloride than in specimens exposed to solutions of calcium magnesium acetate.

### CONCLUSIONS

Asphalts, plastics, elastomers, ceramics, wood, sign sheetings and paints, rubber compounds, sealers, and adhesives appeared to be either unaffected by solutions of sodium chloride or calcium magnesium acetate, or similarly affected.

Road marking paints were affected by both sodium chloride and calcium magnesium acetate solutions. However, it was obvious that sodium chloride solutions were much more deleterious. Road-marking plastics and tapes were affected by both solutions because of the solutions' effects on the portland cement concrete substrates. Again, specimens exposed to sodium chloride solutions were more severely damaged.

Portland cement concrete was affected by both sodium chloride and calcium magnesium acetate solutions. Although the calcium magnesium acetate solutions did minimally affect portland cement concrete, the sodium chloride solutions' effects were much more severe.

Automotive paints and coatings exposed to calcium magnesium acetate solutions exhibited some breakdown, but those same respective specimens exposed to sodium chloride solutions exhibited far greater breakdowns.

Automotive brake-lining materials exposed to sodium chloride solutions consistently exhibited slightly lower static and kinetic coefficients of friction than the same respective specimens exposed to calcium magnesium acetate solutions. However, automotive hydraulic brake-line tubings exposed to sodium chloride solutions consistently exhibited more severe corrosion than the same respective specimens exposed to calcium magnesium acetate solutions.

In general, solutions of sodium chloride cause more severe corrosion in automotive steels, aluminum alloys, stainless steels, and combined metals than solutions of calcium magnesium acetate. This is true for general corrosion, as well as localized corrosion.

Under nitrogen conditions, specimens exposed to solutions of sodium chloride exhibited no passivation, whereas specimens exposed to solutions of calcium magnesium acetate did. Because most sodium chloride solutions exhibit no passivation, in actual highway (aerated) exposures, general corrosion rates of metals caused by exposure to sodium chloride solutions will increase much more rapidly than general corrosion rates caused by solutions of calcium magnesium acetate.

It can also be concluded that in most metals, with the exception of aluminum, solutions of sodium chloride caused more localized corrosion, that is, pitting and crevice corrosion, than solutions of calcium magnesium acetate.

### RECOMMENDATIONS

Results of testing of highway-related materials indicated that the effects of corrosion by salts of sodium chloride and calcium magnesium acetate could be relatively accurately predicted. This condition is probably not as true for automotive-related metallic materials, since new technology is constantly

providing new alloys with enhanced and varying properties. Periodic studies of the susceptibility to corrosion of these new alloys must be performed to ensure the use of the best corrosion-resistant products.

Additionally, further analyses of the effects of sodium chloride and calcium magnesium acetate on the light-reflectance properties of sign sheetings and paints are recommended.

Calcium magnesium acetate was never intended to replace sodium chloride as the United States' primary road deicing chemical. However, it must be noted that, in light of new manufacturing techniques of calcium magnesium acetate leading to lower production costs and its much lower corrosive tendencies, CMA has the potential for significant impact on the commercial and private consumer deicing markets.