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## Calcium Magnesium Acetate Research in Washington State

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### ABSTRACT

As part of a pooled-fund research project, the Washington State Department of Transportation was selected to field test approximately 100 tons of calcium magnesium acetate (CMA) to evaluate its potential as a deicing chemical in direct comparison with salt (sodium chloride) and urea. Evaluation included all aspects of storage, handling, use, and performance. CMA was applied whenever necessary at each test site; the same application rates were used as those now used for salt. Typical equipment consisted of front dump trucks with the spinner ahead of the rear axle and rear-discharge hopper trucks. All equipment was used without modification. The use of CMA at the beginning of a storm reduced the amount of bonding of snow to the roadway surface. This effect of keeping the roadway surface bare for longer periods of time reduced the cost of snow fighting. This was accomplished with a chemical application rate of 125 lb per lane mile. The addition of sand to CMA reduced the problems of dust, caking, and uneven distribution. The sand provided moisture and weight to the application, which resulted in a smoother, more even distribution. CMA spread above the ice and snow was excessively dusty, which created problems in the spreading and distribution. CMA is slower to react on compact snow and ice than is salt or urea. This delay in reaction time was not considered a handicap in the overall snow-fighting procedure. The conclusion was that CMA shows promise as a deicing-melting chemical. The problems of dust, light weight, and brittleness need further research and may be significantly alleviated by development of a hydrated compound.

The Washington State Department of Transportation field tested calcium magnesium acetate (CMA) in a wide range of weather conditions and temperatures with standard equipment.

Although slower acting than salt or urea by about 20 min, CMA does break the bond between compact snow or ice and the roadway surface. It is most effective at about 25° F, which is consistent with results for salt and urea. A mixture of CMA and sand proved to have approximately the same results as a similar salt-sand mixture. The sand helps hold the chemical on the roadway until melting action begins. When applied to roadway frost, CMA appeared to cause a steady draw of moisture, which required additional applications. By comparison, salt appeared to melt the ice and allow drying during warmer periods of the day.

The CMA tested was lightweight, which created difficulties in application. The material would blow off a full load, creating a minor visibility problem. The lack of weight also contributed to uneven distribution as the load was reduced through application. CMA would cake on the truck bed and in the spinner assembly whenever moisture interacted with the dust. The excessive dust also created problems in handling.

CMA applied at the beginning of a snowstorm provided the most dramatic results. The application of a small quantity (125 lb per lane mile) of CMA at the beginning of a moderate (1.5-in./hr) snowstorm maintained a compact-free roadway. The CMA was applied at 26° F in moderate traffic. Salt was applied to the opposite lanes at a rate 6 times that of CMA and required continuous plowing to keep the roadway free of slush. If this performance is verified through additional tests, it could greatly reduce the cost of snow and ice control.

The conclusion was that CMA shows promise as a deicing-melting chemical. The problems of dust, light weight, and brittleness need further research and may be significantly alleviated by development of a hydrated compound.

#### COMMENTS FROM MAINTENANCE SUPERINTENDENTS

The maintenance superintendents of the two test areas submitted the following comments about their use of CMA as an alternative deicer:

1. CMA reacted well with snow or ice at temperatures ranging from the mid-20s to 32° F.
2. CMA reacted slower than urea.
3. The chemical was dusty to handle; face masks had to be used.
4. Dusty conditions were created during applications; the spinner assembly on the trucks appeared to break the CMA up, which caused dust problems.
5. The single biggest problem was the drawing of frost in areas of previous applications, which caused continuous use of the chemical. Areas that would normally dry out during daylight hours would stay wet and ice up in late afternoon or early morning.
6. CMA did not react as fast as urea with the snow bottom, which caused excessive chemical movement by traffic.
7. It was believed that 400 to 600 lb per lane mile was not adequate to get the same results as those obtained with 400 to 600 lb of urea.
8. CMA appeared to work best when applied with sand. The sand helped hold the chemical until melting action began.
9. Temperatures below 24° F greatly reduced the melting effects of CMA.
10. No corrosive effects of CMA were noticed in any of the equipment used during the testing.

11. As a traction device, CMA noticeably prevented any ice floor from developing, although this was not the case with salt in this same storm.

12. CMA, when applied to compact snow and ice, generally stayed where contact was made, whereas salt slid off the lane surface.

13. Salt proved more effective in the dissipation of snow and ice in plow berms.

#### PHYSICAL SETTING OF STUDY

Tests were conducted in three separate areas in Washington State:

1. I-90 through the Cascade Mountains from the Snoqualmie Pass Summit at Milepost 52.4 to the western terminus of the Denny Creek viaduct at Milepost 50.4. Salt had never been used on the 3,300-ft-long viaduct and this area was used for test comparison with urea.

2. Another section of I-90 in the Snoqualmie Pass vicinity, Mileposts 56.3 to 57.0, was used for a side-by-side comparison with salt. CMA was applied to the westbound lanes and salt to the eastbound lanes, both with and without abrasives. (The state of Washington was influenced by a Pacific marine flow that resulted in 479 in. of snowfall in the Snoqualmie Pass area during the winter.)

3. The Spokane viaduct section of I-90, Mileposts 279.5 to 285.6, was used for a comparison of salt and CMA without abrasives under drier, colder conditions than are typical at Snoqualmie Pass.

Skid tests, evaluating both CMA and urea, were conducted at the Washington State Patrol Academy test tract on asphalt-concrete pavement and on portland cement concrete on I-5, Mileposts 111 to 112, northbound.

#### TESTING CONDITIONS

During the first quarter of the 1983 test period (ending March 31, 1983), the test areas received below-average snowfall, and chemical deicers were not necessary. However, conditions for the fourth quarter of the 1983 test period (October 1, 1983, through December 31, 1983) provided opportunities for testing CMA in a wide range of conditions and temperatures. Weather during this period included freezing rain, heavy wet snow, dry blowing snow, compact snow and ice, and beginning storm conditions.

The Snoqualmie Pass test area is equipped with eight surface system sensors that are capable of continuously monitoring and recording air and surface temperatures on the Denny Creek viaduct. Avalanche crews monitor and record meteorological data at Snoqualmie Pass on an around-the-clock basis. Drivers recorded the time and rate of application on each load of deicing chemicals; this information was compared with the sensor records to determine the volume of chemicals required to produce satisfactory results at various temperatures.

#### MATERIALS AND METHODS

A storage test was included in which CMA was stored in 200-lb quantities for each of five separate test methods: covered and uncovered in both bagged and bulk form and mixed in a ratio of 5 parts and to 1 part CMA by volume. All urea and salt storage was in bulk form in enclosed sheds.

Equipment consisted of front dump trucks with the spinner ahead of the axle and rear-discharge hopper trucks. The equipment was not modified for CMA.

Equal distribution rates by volume for salt, CMA, and urea were used. It was not deemed important to adjust the application rate of any individual chemical to achieve an equal melt rate. The specific gravity of salt is 2.17, that of urea is 1.33, and that of CMA is 0.83.

#### TEST PROCEDURES

The specific test areas were well defined for control and comparison. They were selected by the local maintenance superintendents for ease of access and application control without sacrifice to either the test program or the primary mission of keeping the highway open to traffic. Applications were performed whenever necessary.

Deicing chemical tests were documented as to application rates, handling techniques, problems encountered in application, air and surface temperatures, rate of penetration (visual comparison), length of melting condition, and general results. In an attempt to standardize the report and the data analysis, slightly modified versions of forms suggested by the Michigan Department of Transportation were used. These forms were reviewed and accepted by field personnel.

Storage testing was monitored on a monthly basis through September 1983, when the storage test site was inadvertently buried under a load of bulk salt.

Each test was documented by the drivers, supervisors, and an observer. The reporting sequence allowed an immediate report from the driver relating any problems in the delivery of CMA, a 15- to 30-min delay report from the supervisor as to reaction time of the chemicals, and a 1-hr delay report from the observer detailing the roadway surface condition.

Application rates varied, depending on weather conditions. At the Spokane site, application rates ranged from 125 lb per lane mile applied at the start of a dry snowfall at 26° F with very slight winds to 400 lb per lane mile on compact snow with 15-mph winds at 28° F. In the Snoqualmie Pass area, application rates varied from 200 to 750 lb per lane mile. The final test application used 15 tons of CMA and sand in the Snoqualmie Pass vicinity, mixed at a proportion of 1 to 5 by volume.

Skid testing was done with a full-scale tire according to ASTM E274-79, using water and various concentrations of CMA and urea as a lubricant at 40 mph on asphalt-concrete pavement and portland cement concrete surfaces.

#### RESULTS AND DISCUSSION

CMA appeared to be more hygroscopic than salt, although a crust would form, resulting in less actual leaching during storage than is typical for salt. CMA cannot be stored in the open under polyvinyl because the film deteriorates either from weather or from reaction to the acetic acid. The storage test area was inadvertently violated by a bulk shipment of salt, which terminated the long-term storage tests after 8 months. Results to the time of termination indicated that both bagged and bulk storage of CMA can be accomplished at a reasonable cost.

The mixing of CMA and sand (1 part CMA to 5 parts sand) in the preparation of stockpiles proved effective in protecting the stockpiles from freezing. The CMA-sand mixture also retained enough chemicals to work as a deicer. This mix ensures that a greater percentage of the material is applied where it is needed and stays there. It also reduces chemical and vehicle use as compared with separate applications and does not contribute to an increase in chloride damage.

CMA was generally about 20 min slower to react than either salt or urea, but it provided the same final reaction of breaking any bonding of the compact snow or ice with the pavement surface.

CMA was tested in weather conditions ranging from freezing fog to heavy snow. This included freezing rain, which dropped as rain but froze when it came in contact with the frozen roadway surface. When CMA was applied, the moisture from the rain assisted the CMA to work at a surface temperature of 19° F and break the bond between the ice and the roadway surface. The rain is assumed to have assisted this action, which occurred at a temperature below the normal range for this deicer. CMA is most effective above 25° F.

At the Spokane site application of CMA at the start of a dry snowstorm resulted in a significant decrease of compacting and far less effort in maintaining a bare pavement as compared with the use of salt during a 10-in. snowfall over a 6-hr period. Some observers independently noted that if CMA is applied at a rather low rate (under 200 lb per lane mile) at the beginning of a storm, it will be unlikely that compact snow and ice will form.

Regarding skid-testing results, CMA and urea were compared by using formulations similar to the Pennsylvania Transportation Institute (PTI) tests. PTI concluded that saturated solutions of CMA did not lower the friction numbers but that urea did lower the skid numbers substantially. The 2-year Washington State field experience with urea did not agree with the PTI report, and skid test results agreed with field experience. Only the first test of urea showed any significant decrease in the friction number when compared with the friction numbers using water. All the other tests showed some slight differences but each was within the limits of test reproducibility for skid numbers. Washington State laboratory personnel and personnel from PTI were unable to determine why different results occurred with duplicate procedures.

Any movement (handling, breaking bags, loading trucks, and spreading) of CMA created excessive dust. Crews had to wear masks during manual handling operations. Bulk delivery and loading would significantly reduce this problem. Dust resulting from application of CMA to the roadway through the spinner may constitute a hazard to passing vehicles because of decreased visibility in some wind conditions. Roadway dust was significantly reduced by mixing CMA and sand together in the same load.

Winds in the mountain pass sometimes blew the CMA off the roadway surface before any melting action could occur. An application of sand immediately following the CMA application provided a partial remedy to this problem. Also because of its light weight, CMA blows off the load in transport. When the load gets low, CMA does not flow smoothly through the flight chain. This results in an uneven distribution toward the end of a load. Minor modifications to the chain would probably take care of this problem if a more dense form of CMA cannot be developed.

CMA tended to cake on the dump truck bodies and in the chute and spinner assemblies. This was especially true on wet equipment or if a partial load of CMA was left in a truck after a run. Cleaning the trucks was difficult; the material had to be chipped off. Using the entire truckload each time generally eliminated clogging problems.

Maintenance crews occasionally used CMA in areas other than the designated test sites when a chemical deicer was required. This usage accelerated the crews' awareness of the effects of CMA under various conditions and indicated their acceptance of CMA as an alternative deicer.

In conclusion, CMA shows promise as a workable de-

icing or melting chemical. The extra cost and effort are believed to be justified in view of the high costs of corrosive damage done by salt to bridge decks and automobile bodies. The current problems of excess dust, light weight, and brittleness are, to some extent, associated with the chemical makeup. Formulation of a hydrated compound of CMA may significantly alleviate these problems.

A synopsis of each application of CMA made during this research project is given in Table 1.

#### CONCLUSIONS AND RECOMMENDATIONS

Although CMA has a slower reaction time on compact snow and ice than either salt or urea, this was not

found unacceptable. The overall effect of a 20-min delay in reaction was not deemed to be critical in a continuous snow-fighting operation.

A mixture of 1 part CMA and 5 parts sand, stored in the open, proved sufficient to retain deicing properties and keep the stockpile from freezing. The effects of mixtures lower than 1 part CMA to 5 parts sand should be investigated. If deicing is maintained, a 1:10 mixture would be more cost-effective. Additional research should be directed toward developing a CMA product that will be more dense and dust-free. The current product is extremely dusty, which created problems in both handling and spreading.

Future testing should pursue the application of limited amounts of CMA (125 to 200 lb per lane mile)

TABLE 1 CMA Research Project

Storm	Test	Temperature (° F)	Surface	Deicing Agent (lb/lane mile)			Results	Comments
				CMA	Salt	Urea		
Snoqualmie Pass								
1	1	29	Compact	375	375	-	CMA slower	CMA slower to break bond than salt, created less moisture, but did break bond about 10 min later
2	1	31	Compact, blowing snow	-	-	650	Slush	Snow bottom broken and with sand provided good traction; urea still working after 9 hr
	1	29	Compact, blowing snow	750	750	750	Bottom broken	Good traction after 30 min; CMA test section at higher elevation than urea; sand and salt worked 15 min faster than either CMA or urea
2	2	29	Compact, poor traction, blowing snow	650	-	650	Good traction	Compact broken; CMA worked faster than urea, but did not maintain good traction for as long a period in snow-storm
3	1	29	Compact	625	-	625	Bottom broken in 30 min with CMA; 15 min with urea	CMA did not respond as fast as urea, but gave good traction after 30 min
4	1	29	Blowing snow, thin ice	525	-	525	After application	In 30 min urea broke bond; CMA did not allow bond to form blowing snow
5	1	26	Compact, snow and ice	375	1,800	-	-	Salt and sand cleared roadway; light weight of CMA made application rate patchy
6	1	24	Thin ice	130	-	-	CMA whipped off by traffic	Heavy traffic whipped CMA off; same effect as salt and urea
7	1	26	Freezing rain	571	-	-	CMA slower	CMA mixed with sand in truck spread evenly and gave good results; slower than salt or sand but gave good traction
7	2	28	Freezing rain	400	400	-	1 hr for re-action	Suggestion made that a lighter application may frequently be better in freezing rain (videotape)
8	2	19	Blowing snow	250	-	-	-	No compact formed; bond of snow never materialized; opposite lane developed compact (no other chemical used)
8	3	24		250	-	-	-	
9	1	30	Compact, snow	1,000	-	-	Good	CMA and sand mixture (1:5) broke bottom
10	1	31	Compact, snow	400	-	-	Good	Strip melting bottom broken
11	1	31	Wet snow	400	-	400	Fair	Slower to work than urea
12	1	31	Compact, snow and ice	1,000	1,000	-	Good	Same as salt when mixed 1:5 with sand
Spokane								
1	1	22	Dry blowing snow	222	-	-	Bad	Plugged chute on truck would not allow distribution; salt and sand applied on same area because of accidents
2	1	22	Blowing snow	200	400	-	None	CMA did not break bond in dry compact; salt applied in same area for 4 hr; trouble with distribution again
3	1	25	Compact, snow	333	333	-	30 min	Penetration to roadway surface in 30 min; problems with application from chute; less moisture evident in CMA lanes than in salt lanes
4	1	25	Compact, snow	666	666	-	Good	Pavement cleared in 1 hr (two lanes); less moisture than in salt lanes; driver thought results better than in salt lanes
5	1	26	Compact, snow	600	-	-	Good	Not much traffic, but penetration to surface in 1½ hr
6	1	27	Blowing snow	200	500	-	Fine	No compact formed on CMA lanes; crews liked salt application better because slush easily removed; however, nothing formed on CMA lanes; therefore, no plowing was required
7	1	30	Black ice	125	-	-	30 min	Remove black ice in 30 min
8	1	30	Ice	416	500	-	Good	Same results as salt, no differences noted; moisture on road from previous snow was freezing; both CMA and salt broke surface bond satisfactorily
9	1	32	Wet snow				Bad	CMA plugged equipment
10	1	14	Dry snow	200	-	-	None	No results; test for lower limits; 14° F below limit of CMA, urea, and salt
11	1	23	Dry snow	400	400	-	Slower	CMA blowing off roadway and trapping snow at sides of lanes

Note: Total chemical used as follows: Snoqualmie Pass—salt, 400 tons (freezing rain, eight storms required bulk of this); urea, 200 tons (Denny Creek Bridge and selected spots); CMA, 60 tons (test area and selected spot use); Spokane—salt, 230 tons; urea, 15 tons; CMA, 38 tons (used in test versus salt).

at the onset of a snowstorm in areas where sand is undesirable. The savings to be realized from decreased plowing, sanding, and sand cleanup would influence overall costs and might significantly narrow the breakeven point between the cost of CMA and salt.

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## Staffing of Maintenance Crews During Winter Months

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#### ABSTRACT

The Pennsylvania Department of Transportation wished to learn whether winter maintenance manpower was being used effectively and developed a research project for this purpose. The objectives of the study were to determine the cost-effectiveness of single- and dual-shift staffing during the winter months, identify maintenance activities that are not snow related and that can be performed during cold weather, estimate the amounts of work that can be accomplished with single and dual shifts, and ascertain optimum winter staffing patterns. Data from actual winters were obtained and computer models were developed to permit the calculation of regular time, premium time, and regular time when there was insufficient light to work and it was not snowing. Other states with weather similar to Pennsylvania's were contacted and furnished information about their use of maintenance manpower during the winter months. In-depth interviews were also conducted with Pennsylvania Department of Transportation personnel at various levels. A winter severity index based on total meteorological data rather than snowfall only was developed during this study to provide a means of approximating the relative severity of winters in terms of labor costs. The computer model permitted the cost-effectiveness of a wide variety of staffing patterns to be evaluated in each county in Pennsylvania. It was determined that dual-shift operation for at least part of the winter season can be more economical than single-shift operation in some districts and counties in Pennsylvania.

A major problem facing every state highway agency in the snow belt is to make winter maintenance operations as cost-effective as possible. On the one hand, safe winter driving conditions must be provided to the public and on the other, expenditures must be kept to a minimum because winter maintenance operations do not provide any lasting improvement to the highway system and can even contribute to its deterioration. The core of the problem usually concerns manpower because labor represents the largest class of expenditure in highway maintenance activities.

A variety of personnel assignment and allocation techniques have been used in an effort to hold labor costs down and to use manpower as effectively as possible. These include

- \* Same working hours as in summer with overtime as necessary,
- \* Reduced regular hours to compensate for increased premium time,
- \* Dual shifts based on storm conditions with reversion to single shifts at the end of the storm, and