Comparative Field Study of the Operational Characteristics of Calcium Magnesium Acetate and Rock Salt

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A field study was undertaken during the winters of 1986–1987 and 1987–1988 to compare the performance of calcium magnesium acetate (CMA) and rock salt as deicing chemicals. The study included determination of the deicing effectiveness and the handling and storage characteristics of the two chemicals. The CMA was applied to a section of freeway and the adjacent sections of service roads near Beamsville, Ontario. Salt was applied to the adjoining freeway and service roads, which served as the control sections. The CMA and salt were applied at specified rates, and the frequency was dictated by the road conditions. The condition of the test sections was recorded by independent monitors at 1-hr intervals during all winter storms. The CMA was found to be comparable to salt in achieving bare pavement, though more CMA was used than salt. CMA was found to be relatively more effective in longer storms, and there was a residual effect from one storm to another. The storage and handling characteristics of CMA were similar to those of salt. Modifications to equipment were not required, and spreading procedures were changed only slightly. The corrosion of the CMA spreader unit was substantially less than that of the salt spreader unit.

In recent years, the Ontario Ministry of Transportation has attempted to reduce the negative impacts of rock salt used in winter maintenance operations through more judicious application, improved equipment controls, and better storage facilities. Simultaneously, there has been a continuing search for an effective, nonpolluting and noncorrosive alternative to rock salt. A possible alternative is calcium magnesium acetate (CMA), which is a mixture of calcium acetate and magnesium acetate manufactured from dolomitic limestone and acetic acid. CMA was identified in research studies in the late 1970s (*1*) and has been the subject of several laboratory and field investigations to determine its effectiveness as a deicer and its effect on the environment (*2–7*).

In order to assess the potential impact of CMA on the ministry's winter maintenance operations, a field trial was carried out during the winter of 1986–1987. The study was continued with minor modifications during the winter of 1987–1988.

SCOPE OF THE STUDY

The main objective of the study was to investigate the effectiveness of CMA as a deicer. Additional areas of investigation included storage properties, handling and spreading characteristics, and corrosion of the spreading equipment.

The CMA was applied to a 2.4-km section of the Queen Elizabeth Way (QEW) near Beamsville, Ontario, and to the adjacent service roads. The QEW is a four-lane freeway with an average annual daily traffic (AADT) of 38,500; the service roads are used only by local traffic and have an AADT of less than 500. The test section included both the eastbound and westbound lanes to prevent contamination from the adjacent roadway. Further, observations were based on the center 1 km of the test section to avoid the effects of tracking. The 7 km of the freeway and service roads immediately to the east, which were similar to the CMA test site in all aspects of concern (including wind direction and lake effects), were maintained using salt applied in accordance with standard ministry procedures and served as the control sections. All the roads had a bituminous surface.

Prior to the winter of 1986–1987, 200 tonnes of commercially produced CMA meeting FHWA specifications were purchased. The CMA was applied by ministry staff; the salt by a contractor. An additional 180 tonnes of CMA was purchased from the same supplier for use in 1987–1988. During the second winter, ministry staff applied both the CMA and the salt.

The deicing effectiveness was determined through the observations of two independent monitors (each working a 12-hr shift) who rated the condition of the roadway on an hourly basis. Observations with respect to storage, handling, and the condition of the equipment were made by the monitors and the patrol staff.

The CMA was stored under cover in two sheds, one of which contained the neat material and the other the CMA-sand mixture. The salt and salt-sand mixture were also stored under cover according to normal ministry practice.

APPLICATION CRITERIA

The responsibility for determining when deicing chemicals would be applied rested with the patrol supervisor, who based his decision on the condition of the roads and the ministry's Maintenance Quality Standards (*8*).

The standard for the freeway requires that the accumulation of snow not normally be allowed to exceed 25 mm and that bare pavement be achieved as soon as reasonably possible. The standard for the service roads requires that snow not be allowed to accumulate beyond 70 mm, but a snow-packed

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condition is acceptable. In practice, this meant that at the onset of a storm, CMA and salt were applied to the appropriate sections of the freeway at almost the same time. The specified application rate for salt was 130 kg per 2-lane km (130 kg per 2-lane km is equivalent to 230 lb per lane mile). At the beginning of the 1986–1987 winter, CMA was applied at a rate of 221 kg per 2-lane km (or 1.7 times the rate for salt), but this rate was reduced later in the winter. The initial ratio of the application rates of CMA to salt of 1.7 was based on the calculation of theoretically equal deicing performance. Subsequent applications of CMA and salt during the storm were determined by the road conditions. In other words, if the pavement was not bare, a further application of deicing chemical was made at the specified rate. However, no attempt was made to make the same number of applications to the CMA and salt sections, because the chemicals performed differently under different storm conditions.

The decision to use pure deicing chemical or a sand mixture on the freeway was based on weather forecasts and the patrol supervisor's knowledge of local conditions. In general, when there was a reasonable expectation of maintaining bare pavement, neat CMA or salt was applied. At other times, particularly during the most severe storms, or when temperatures were less than the optimum for deicing, or at night, sand mixtures were used to provide traction. Only sand mixtures were used on the service roads.

In 1986–1987, the salt-sand mixture was a manufactured sand and 10 percent salt by mass. The target application rate was 570 kg per 2-lane km. The manufactured sand-salt mixture was used because it was in stockpile from the previous winter. The CMA-sand mixture was a mix of natural sand and 14 percent CMA by mass and was applied at a target application rate of 800 kg per 2-lane km. The CMA content and the application rate for the CMA-sand mixture were calculated from the quantities used in the first storm (the CMA was delivered a few hours before the storm and the spreader was not calibrated until after the first storm). Since it appeared to be effective, the application rate was not changed. In 1987–1988, the salt-sand mixture was natural sand and 15 percent salt by mass, which is an established standard in the geographical area of the patrol. Less salt is used in manufactured sand mixtures than in natural sand mixtures because the former is more abrasive and provides better traction. The CMA-sand mixture was the same as in the first winter.

Because of the very low traffic volumes on the service roads, these had the lowest priority within the patrol area, and sand mixtures were applied as equipment became available during a storm. The primary purpose of applying the sand mixtures to the service roads was to provide traction, and no conscious attempt was made to provide bare pavement. Additional applications were made following plowing or if icy conditions developed.

HANDLING, STORAGE, AND SPREADING CHARACTERISTICS AND EFFECT OF EQUIPMENT

Dusting

Some dusting occurred during loading operations, but not sufficient to require the operators to wear face masks. The amount of dusting of the CMA-sand mixture was greater after a period of prolonged storage (six weeks or more), presumably because the CMA absorbed moisture from the sand. Although the dusting did not constitute a serious handling problem, a well-ventilated storage facility is needed.

Storage

The storage characteristics of the CMA were similar to those of salt, although the angle of repose was somewhat greater. Occasionally, a light crust formed over the stockpile, but this was easily broken and the material became flowable when disturbed by the loader. The principal difference between CMA and salt was in the amount of caking which occurred on the paved apron outside the storage shed. During periods of precipitation, CMA would stick to the wet tires of the loader and was carried out of the shed. This material, together with that spilled during loading, resulted in a thick layer of caked CMA (sometimes up to 75 mm thick) sticking to the apron. This material was allowed to dry, at which time it could be picked up by the loader and was sufficiently friable to be mixed with sand and used as CMA-sand mix.

Sticking

Upon contact with moisture, the CMA became sticky and adhered to the spreader hopper, the dispensing chute, and the spinner. The spreader hopper was smaller than that normally used for salt, and the relatively shallow slope of the hopper sides contributed to the amount of material sticking.

Neat salt is spread by dropping the material through the dispensing chute along the center of the roadway. This was not possible with the CMA because spray from the truck tires caused the CMA to stick and plug the chute. The problem was overcome by discharging the CMA over a slowly-rotating spinner. Although there was a buildup of material on the spinner, this did not affect its functional operation and the CMA was spread evenly in a band approximately 2 m wide along the center of the roadway. Salt-sand and CMA-sand mixtures were spread using the spinner operating at the normal speed of rotation and there was no buildup of material.

In order to limit the amount of CMA sticking in the hopper between loads, either the hopper was emptied or the unit was stored in the equipment garage. Before reloading, the sides of the hopper were struck with a large rubber mallet to loosen the sticking material. The unit was washed following each storm, at which time material sticking to the hopper, chute, and spinner was easily removed. The salt unit was also washed between storms. These procedures were effective in controlling the amount of sticking, which never became serious enough to interfere with normal equipment operations.

Effect on Equipment

An indication of the relative effects of CMA and salt on corrosion was obtained by observation of the spreader units after the first winter. On the unit used for CMA, which was new at the start of the study, exposed metal remained shiny and free from rust. On the salt unit, which was repainted prior to the study, the amount of paint lost was much greater, especially at seams and joints, and exposed metal was rusted. The CMA spinner remained free from rust, whereas the salt spinner became badly rusted.

DEICING PERFORMANCE DURING THE WINTER OF 1986–1987

Overall Observations

Fifteen storms were encountered during the winter. The dates and the weather conditions associated with each storm are given in Table 1. A summary of the number of applications of deicing chemicals, the quantity applied to the QEW during each storm, and the time to achieve bare pavement (the bare and wet condition) are given in Table 2. Table 2 represents the sum of the deicer which was applied neat and the portion of deicer in the appropriate sand mixture. Complete details of when neat deicers and when sand mixtures were applied are given in a ministry report (*9*).

After two months, the ratio of the application rates of CMA to salt of 1.7 seemed excessive and the ratio was reduced to 1.5. The relatively small number of storms later in the winter precluded any conclusions being drawn with respect to the effectiveness of the different application rates.

Table 3 shows the quantity of deicing chemicals applied to the service roads. Because there was no attempt to maintain bare pavement, a comparison of performance similar to that reported in Table 2 for the QEW is not possible. However, the quantities shown were sufficient to maintain the low-

TABLE 1 SUMMARY OF STORMS DURING THE WINTER OF 1986–1987

STORM No.	DATE	AVERAGE TEMPERATURE °C	SNOW cm	RAIN mm	AVERAGE WIND SPEED km/hr
1	NOV 20-21/86	-1.7	14.0	0.0	10.00
2	DEC 8/86	-4.0	7.0	13.4	12.00
3	DEC 11/86	-1.0	0.4	0.6	8.00
4	JAN 2/87	-1.0	9.2	0.6	10.00
5	JAN 10-12/87	-1.9	1.0	0.4	13.00
6	JAN 18/87	-1.0	5.4	0.0	14.00
7	JAN 19-20/87	-4.0	15.0	0.0	10.00
8	JAN 22/87	-3.0	2.0	0.0	18.00
9	JAN 26/87	-7.0	1.0	0.0	6.00
10	JAN 30/86	-3.0	4.8	0.0	8.00
11	FEB 2-3/87	0.0	1.8	0.0	10.00
12	FEB 8/87	-9.3	2.0	2.0	34.00
13	FEB 14/87	-10.0	0.8	0.0	14.00
14	FEB 16/87	-1.4	1.0	0.0	6.00
15	MAR 30-APR 1/87	-2.8	16.5	0.0	10.00

TABLE 2 COMPARISON OF QUANTITIES AND DEICING TIMES FOR CHEMICALS APPLIED TO THE QEW IN 1986–1987

	CMA			SALT		
STORM No.	No. OF APPLIC.	kg/ 2-LANE km APPLIED	TIME TO BARE PAVEMENT H	NO. OF APPLIC.	kg/ 2-LANE km APPLIED	TIME TO BARE PAVEMENT H
1	8	1270	23.50	11	2000	23.50
2	5	1830	14.50	8	1050	14.50
3	2	420	2.00	2	220	2.50
4	8	1520	19.50	12	1420	19.75
5	7	1530	41.00	8	1230	41.00
6	4	1090	6.50	7	1000	6.50
7	5	1340	20.75	9	810	20.75
8	3	770	6.25	3	510	6.25
9	2	170	2.50	4	220	2.50
10	7	1460	23.75	11	1770	23.75
11	2	310	15.00	1	120	15.00
12	2	330	10.00	1	220	10.50
13	2	230	8.25	1	100	9.00
14	2	160	9.00	1	400	9.00
15	8	1450	20.00	9	560	34.00
TOTAL	67	13880		88	11630	

RATIO OF TOTAL QUANTITY USED, CMA:SALT = 1.2:1

TABLE 3 QUANTITIES OF DEICING CHEMICALS APPLIED TO THE SERVICE ROADS IN 1986–1987

	CMA		SALT	
STORM NO.	NO. OF APPLICATIONS	kg/2-LANE km OF MIX APPLIED	NO. OF APPLICATIONS	kg/2-LANE km OF MIX APPLIED
1	4	2690	3	4360
2	3	1640	3	2430
3	1	740	1	1000
4	3	1270	4	3520
5	3	1670	4	3650
6	2	1740	2	2230
7	2	1520	2	1710
8	1	1420	1	1090
9	2	1230	1	1140
10	3	2290	3	2330
11	1	760	1	1140
12	2	1470	2	1640
13	0	0	0	0
14	1	760	1	960
15	2	890	2	2270
TOTAL	30	20090	30	29470
RATIO OF TOTAL QUANITY USED, CMA MIX : SALT MIX = 0.68:1				
CORRECTED RATIO, CMA : SALT = 0.95:1				

volume roads to ministry standards and there were no substantial differences between the condition of the CMA and the salt sections. The ratio of CMA-sand mixture to salt-sand mixture used over the entire season was 0.68. Since the CMA-sand mixture contained 14 percent CMA and the salt-sand mixture contained 10 percent salt, the ratio of CMA to salt used on the service roads was 0.95.

In general, most of the storms occurred when the temperature was between 0 and −5°C, which is typical of winter storm conditions in the Niagara Peninsula. Within this range, temperature did not appear to affect the relative performance of salt and CMA. The storms ranged from a few hours to three days in duration, with the majority lasting less than one day. In some storms, more CMA than salt was used and in others, less. The ratio of CMA to salt usage over the entire winter was 1.2. Fewer applications of CMA than salt were made during the winter (although the application rate was greater), and the difference in the number of applications was most apparent during the storms of longer duration. The times to achieve bare pavement in the CMA and salt sections were comparable and, with one exception, within 45 minutes of each other.

Although the foregoing general observations are useful, it is equally revealing to examine the relative performance of the CMA and salt during individual storms.

Observations During Specific Storms

Storm No. 3, December 11–12, 1986

The time of application of the CMA and salt and the condition of the roadway are shown in Figure 1(a). This storm can be considered a typical illustration of the relative performance of CMA and salt during a storm of short duration. One application of pure material and one application of sand mixture were made at the same time to each section during the storm. The effect of each chemical on pavement condition was the same. The ratio of CMA to salt used was 1.9.

Storm No. 4, January 2–3, 1987

Details of deicer usage and pavement condition throughout the storm are given in Figure 1(b). This storm can be considered representative of the storms of longer duration with significant snowfall. There were six applications of salt, six applications of salt-sand mixture, four applications of CMA, and four applications of CMA-sand mixture. Roadway conditions during the storm were comparable except for a period of about 3 hr when the salt section became snow covered despite three applications of salt in rapid succession. Only one application of CMA in the same period was required to maintain track-bare pavement. The ratio of CMA to salt used during the storm was 1.1.

Storm No. 15, March 30–April 2, 1987

This was the storm having the longest duration and heaviest snowfall of the winter. It was also exceptional in that it was the only time that the performances of the CMA and the salt were not comparable. Six applications of CMA and two of CMA-sand mixture were made over a 32-hr period. As shown in Figure 1(c), the roadway became snow covered for a period of approximately 1 hr on two occasions, but was otherwise track-bare or better. By contrast, the salt section became snow packed such that the application of salt was suspended and maintenance consisted of plowing. Three applications of salt were required after the last application of CMA for a total of three applications of salt and six of salt-sand. The final application of salt was made at 8:00 a.m. on April 2 and is not included in Figure 1(c). Bare pavement was not achieved in the salt section until 14 hr after the CMA section. Since

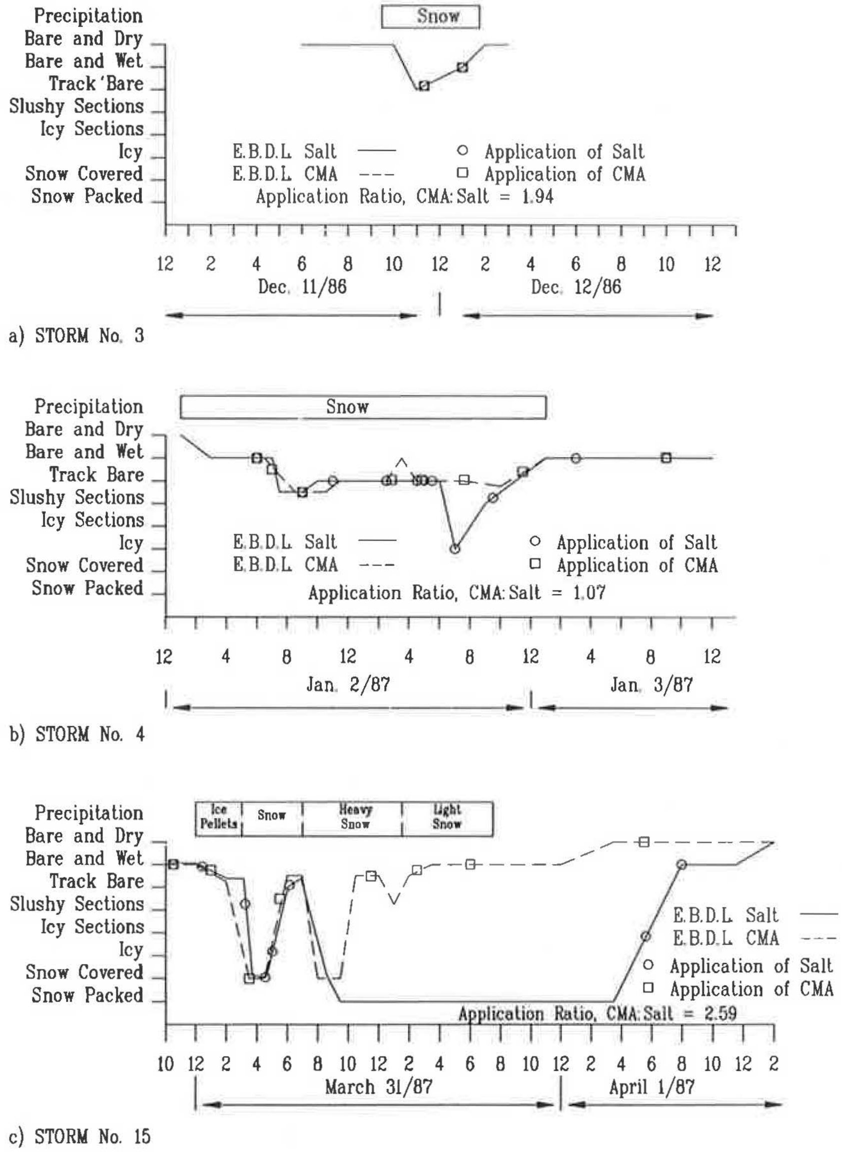


FIGURE 1 Roadway conditions during (a) Storm No. 3 (b) Storm No. 4, and (c) Storm No. 15 in 1986–1987.

CMA continued to be applied throughout the storm, the quantity used was much greater and was 2.6 times as much as the salt.

Effect of Wind During Application

There was no significant difference between the behavior of salt and CMA under windy conditions. It was not found necessary to cover the loads with a tarpaulin. Under strong wind conditions, both deicers were blown after discharge from the hopper, resulting in uneven application.

Retention on the Road Surface

The spreading characteristics of the two materials were similar and, although the CMA was lighter, the particles did not bounce appreciably more than salt particles. Once on the road surface, the two deicers behaved differently. When applied to a moist pavement, the CMA stuck to the pavement surface. The action of traffic embedded the material in the road surface, where the pellets continued to dissolve. As the roadway surface dried, the excess CMA remained bonded to the pavement until there was further precipitation. The salt did not bond to the pavement and was more easily removed from the road surface by traffic, wind, and any subsequent plowing.

The retention of the CMA on the pavement explains two important differences in the performance of CMA and salt. First, it was found that CMA was relatively more effective during the longer storms. As the storm progressed, fewer applications of CMA were needed and the ratio of CMA to salt used was much less during the storms of two to three days duration than in those which lasted a few hours. Second, the CMA had a residual effect from one storm to another, with the result that the ratio of CMA to salt usage tended to decrease through January and February. The presence of CMA embedded in the pavement meant that, at the onset of a storm, a solution formed and prevented icing of the roadway surface. Observations of the pavement up to two weeks after the last application revealed particles of CMA embedded in the surface. The CMA that was retained on the pavement did not attract moisture, and there was no tendency for the pavement to ice as reported in an earlier study (*5*). An extended mild period, during which there were several periods of rain, meant that this residual effect was not apparent during the final storm of the winter.

Penetration Through Snow Pack

The two deicers reacted differently when applied to a snow-packed road surface. The salt formed a brine on the surface of the snow pack. Conversely, the CMA pellets dissolved more slowly and penetrated through the snow pack to the road surface. This was particularly apparent on the service roads. Following plowing, sand and CMA could be found adhering to the pavement. In the salt control section, the sand and salt mixture remained suspended within the snow pack and was scraped off by the plow. The penetration of the CMA meant that it was more effective than salt in breaking up snow pack. The CMA also created a pothole effect in the snow pack, and the rough surface increased pavement noise, which caused drivers to reduce speed. By contrast, the salt tended to glaze the surface, creating an illusion of wet pavement, especially at night.

Acceptance by Patrol Staff

One of the objectives of the study was to determine the impact of the use of CMA on normal patrol operations. Consequently, the reactions of the patrol staff were important. As the winter progressed, the patrol became comfortable with the CMA and confident it would perform as required. Minor irritations such as sticking on the apron and inside the spreader were resolved quickly by the operators at their initiative. Following the full winter's field trial, the overall response of the patrol staff to CMA was favorable.

DEICING PERFORMANCE DURING THE WINTER OF 1987–1988

Overall Observations

The field trial was continued in 1987–1988 with the following minor changes:

- The deicers in both the CMA and the control sections were applied by ministry staff, and
- The salt-sand mixture consisted of natural sand and 15 percent salt by mass.

Following the analysis of the results from the first winter, the decision was made to use an application ratio of 1.4 at the start of the 1987–1988 winter. However, in late January, the patrol staff expressed the view that the performance of the CMA was less than expected and the ratio was increased to 1.7 for the remainder of the winter. The application rates of the CMA-sand and the salt-sand mixtures used in 1987–1988 were the same as those used in 1986–1987.

Twenty separate storms were identified during the 1987–1988 winter, but many of these were very short. The dates of the storms and the weather conditions associated with them are given in Table 4. Summaries of the data for 1987–1988, corresponding to Tables 2 and 3 for 1986–1987, are given in Tables 5 and 6. During Storm No. 20, an equipment breakdown made it necessary to apply CMA to the salt section of the QEW. Consequently, the quantities of deicer used in Storm No. 20 are not included in Table 5.

A major difference between the results of 1986–1987 and 1987–1988 is that in the first winter, the number of applications of CMA was usually less than that of salt in each storm. In the second winter, the number of applications of CMA often exceeded the number of salt applications. This occurred because a truck was dedicated to the short CMA section so that, in all except the worst storm conditions, CMA could be applied when needed. The salt section was longer and more distant from the patrol yard so that not only was the frequency

TABLE 4 SUMMARY OF STORMS DURING THE WINTER OF 1987–1988

STORM NO.	DATE	AVER. TEMP. °C	SNOW cm	RAIN mm	AVERAGE WIND km/h
1	DEC 4/87	-0.1	8.4	0.0	5.0
2	DEC 5/87	-0.4	0.6	0.0	---
3	DEC 15/87	-2.7	5.2	22.0	---
4	DEC 28-29/87	-5.5	8.6	9.0	25.0
5	JAN 4/88	-3.5	0.8	0.0	10.0
6	JAN 14/88	-11.0	1.4	0.0	4.0
7	JAN 21/88	-1.2	0.4	0.2	7.0
8	JAN 23/88	-2.5	2.0	0.0	2.0
9	JAN 25-26/88	-4.5	4.4	0.0	5.0
10	FEB 2-4/88	-3.2	16.2	5.6	10.0
11	FEB 7-8/88	-9.0	1.2	0.0	15.0
12	FEB 9/88	-8.0	0.8	0.0	5.0
13	FEB 11-12/88	-5.0	10.0	0.0	17.0
14	FEB 13/88	-8.0	0.0	6.4	7.0
15	FEB 19/88	-1.0	0.0	12.2	2.0
16	FEB 26/88	-5.0	0.8	0.0	18.0
17	FEB 27/88	-2.0	0.6	0.0	18.0
18	FEB 29/88	0.5	0.2	0.0	12.0
19	MAR 14/88	-2.2	1.2	0.0	5.0
20	MAR 19-20/88	-2.0	4.0	1.2	5.0

--- data not available

TABLE 5 COMPARISON OF QUANTITIES AND DEICING TIMES FOR CHEMICALS APPLIED TO THE QEW IN 1987–1988

	CMA			SALT		
STORM No.	No. OF APPLIC.	kg/ 2-LANE km APPLIED	TIME TO BARE PAVEMENT H	NO. OF APPLIC.	kg/ 2-LANE km APPLIED	TIME TO BARE PAVEMENT H
1	1	170	0.75	1	130	0.75
2	2	350	2.00	1	130	2.00
3	2	290	15.75	2	300	15.75
4	8	1060	17.75	6	980	17.25
5	2	210	1.00	2	280	1.75
6	1	100	4.00	1	90	4.00
7	1	180	N/A	1	150	N/A
8	3	540	4.75	3	480	4.75
9	11	1530	25.50	5	750	25.50
10	11	1700	61.00	10	1470	61.00
11	4	630	13.00	3	310	12.50
12	4	730	8.50	3	390	8.00
13	13	2100	31.25	11	1270	31.25
14	5	340	N/A	6	380	N/A
15	2	310	3.50	1	150	3.50
16	1	110	N/A	1	50	N/A
17	2	310	2.50	2	220	2.50
18	1	200	0.50	1	130	0.50
19	1	180	N/A	1	150	N/A
TOTAL	75	11040		61	7810	

RATIO OF TOTAL QUANTITY USED, CMA MIX : SALT MIX = 1.4:1
N/A NOT APPLICABLE - LOCALIZED DRIFTING ONLY

TABLE 6 QUANTITIES OF DEICING CHEMICALS APPLIED TO THE SERVICE ROADS IN 1987–1988

	CMA		SALT	
STORM NO.	NO. OF APPLICATIONS	kg/2-LANE km OF MIX APPLIED	NO. OF APPLICATIONS	kg/2-LANE km OF MIX APPLIED
1	1	250	0	0
2	1	720	1	500
3	1	700	1	500
4	3	1710	3	1160
5	1	720	1	600
6	1	720	1	780
7	0	0	0	0
8	3	1720	2	780
9	2	1440	3	1500
10	5	3810	5	2400
11	1	790	1	600
12	0	0	0	0
13	3	2140	3	1280
14	2	1510	1	500
15	1	790	0	0
16	0	0	0	0
17	0	0	1	40
18	0	0	0	0
19	0	0	0	0
20	2	1350	1	500
TOTAL	27	18370	24	11140

RATIO OF TOTAL QUANTITY USED, CMA MIX : SALT MIX = 1.6:1
CORRECTED RATIO, CMA : SALT = 1.5:1

of applying salt less than CMA, but a heavier application than the standard sometimes had to be made.

The occurrence of numerous short storms, during which it was often problematical whether deicing chemicals would be needed, also made it more difficult to analyze the results of the second winter than the first. Several "storms" during which there were one or two applications of deicing chemicals could be better described as squalls. In these cases, the patrol supervisor had to decide whether the road would remain serviceable without deicing or whether it was more prudent to apply a deicer. Because the CMA and the salt were not necessarily applied at the same time, and weather conditions often changed rapidly, the ratio of the deicers used in short storms can be misleading. Because the response time to the CMA section was less than to the salt section, more CMA was applied in short storms during which the weather conditions improved. Conversely, when the weather conditions deteriorated, less CMA was used because of its more timely application, and additional applications of salt were sometimes needed to bare the pavement.

Another factor that was more noticeable in 1987–1988 than 1986–1987 was the occurrence of small drifts in the test sections. Under such conditions, sand mixes were applied selectively to the problem areas, but the quantities used were calculated as an average over the appropriate test section. This explains why the quantities shown in Table 5 were sometimes less than the prescribed application rates, as, for example, in Storm Nos. 6 and 16.

To the extent that overall observations can be drawn from the experiences in short storms, the relative performance was the same as that in short storms in the first winter—roadway conditions were comparable throughout the storm, but considerably more CMA than salt was used.

Although the ratio of deicers used in individual short storms can be misleading, the anomalies that resulted from different times of application and drifting conditions tend to cancel out over an entire winter. This averaging effect, together with the fact that much larger quantities of deicers are used in the longer storms, means that the ratio of the total quantities of CMA and salt used is considered to be a reliable indicator of relative performance. The ratio of CMA to salt used on the QEW sections in 1987–1988 was 1.4, compared to 1.2 in 1986–1987. In all other respects, the relative performance of the two deicers in terms of both application and effectiveness during the two winters was very similar.

Table 6 gives the quantities of deicers applied to the service roads. It indicates that considerably more CMA-sand mixture than salt-sand mixture was used. However, the difference is more a reflection of the operational procedures than an indication of relative performance. The CMA truck could carry sufficient CMA-sand mixture to service both the QEW and the service roads, so that sand mix was usually applied to the CMA section early in the storm. After servicing the QEW, the salt truck had to return to the yard to pick up another load of sand mix for the service roads. During severe storms, the truck made another application to the QEW, rather than the service roads, because priority had to be given to maintaining the freeway. In the longer storms there was a substantial difference between the quantity of CMA-sand mixture and salt-sand mixture applied, but a direct comparison is not possible because the CMA section was maintained to a higher standard than the salt section. A much more comparable level of service was provided on the service roads during the first winter, and comparison of the data in Table 3 is more valid than comparisons drawn from Table 6.

Observations During Specific Storms

The experience in short storms has already been discussed, and it is illustrative to take two longer storms, one in which the salt section was in slightly better condition during the storm and the other in which the CMA section was slightly better, as being representative of the relative performance of the two deicers.

Storm No. 4, December 28–29, 1987

The storm began at 8:00 p.m. on December 28 and lasted for 17 hr. The temperature was −3°C at the beginning of the storm and fell to −7°C by the time precipitation ended. The road conditions deteriorated rapidly and icy conditions developed in the first hour. The first application was neat deicer, but as the temperature fell, sand mixtures were used throughout the night. Neat deicers were again applied on the morning of December 29 to remove the remaining slushy sections from the pavement. Details of the usage of the deicers and the condition of the pavement are given in Figure 2(a). The salt section was in slightly better condition than the CMA section for most of the storm and bare, dry pavement was achieved 2 hr sooner. The ratio of the quantities of CMA and salt used during the storm was 1.1.

Storm No. 13, February 11–12, 1988

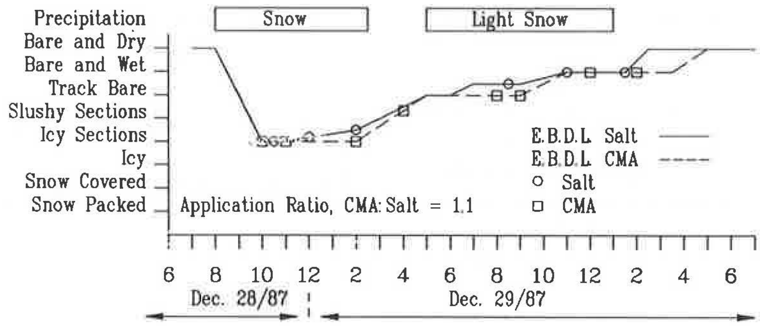
Storm No. 13 was the worst storm of the winter, beginning at 2:00 a.m. on February 11 and lasting for 36 hr. During the storm there were eight applications of CMA and five of CMA-sand mixture, seven applications of salt, and four of salt-sand mixture. Temperatures ranged from −10°C to −1°C. The condition of the roadway is illustrated in Figure 2(b). Except for brief periods when slushy sections developed, the roadway was maintained in a track-bare condition or better throughout the storm. The condition of the CMA section was slightly, though not significantly, better than the salt section. The ratio of the quantities of CMA and salt used in the storm was 1.6.

COSTS

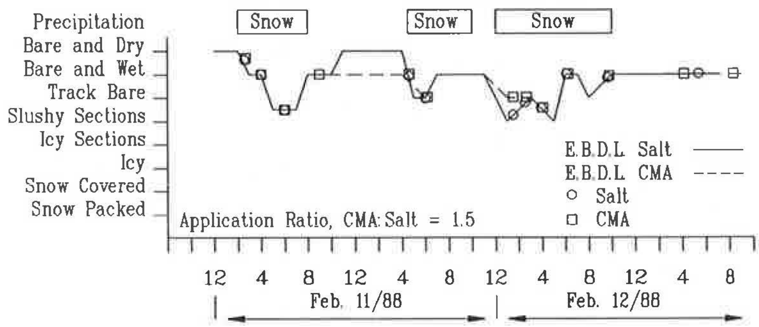
Although an analysis of costs was not within the scope of the current study, it is important to recognize that CMA is only available in limited quantities and at a very high cost. In 1986–1987 the CMA was purchased at $500 (U.S.) per ton f.o.b. plant. The cost at the patrol yard, including freight, duties, and taxes was $1050 (Can.) per tonne. The cost of salt was $29.41 (Can.) per tonne f.o.b. patrol yard. The costs in 1987–1988 were $1060 and $30.20, respectively. A comprehensive analysis of the financial implications of using CMA has been made in a separate study (*10*).

CONCLUSIONS

1. The CMA was used on the test sections throughout two winters. Under the conditions of use, the performance of the CMA was similar to that of salt in achieving bare pavement.



a) STORM No. 4



b) STORM No. 13

FIGURE 2 Roadway conditions during (a) Storm No. 4 and (b) Storm No. 13 in 1987–1988.

2. The initial application rate of CMA of 1.7 times that of salt appeared excessive and an application rate of 1.4 appeared insufficient, but the optimum application rate was not determined.
3. The ratio of the total quantities of CMA and salt used on the freeway test sections was 1.2 in 1986–1987 and 1.4 in 1987–1988.
4. CMA was retained on the pavement longer than salt with the result that it was relatively more effective in longer storms. There was also a residual effect of CMA from one storm to another such that the ratio of CMA to salt used decreased as the winter progressed. This effect was more apparent in 1986–1987 than in 1987–1988.
5. The storage and handling characteristics of CMA were comparable to those of salt.
6. The use of CMA required no changes in equipment and only small changes in normal maintenance procedures. The tendency of the material to stick to equipment and loading areas was a minor inconvenience. Patrol staff readily accepted the CMA.
7. The salt spreader unit exhibited significant corrosion; the CMA unit remained free from rust.

FURTHER RESEARCH

The results from the two winters' field trials have shown that CMA is an effective deicer on both freeway and low-volume roads under the relatively mild conditions of the Niagara Peninsula. Further research is required to determine the optimum application rate for CMA and to evaluate its performance under conditions of lower temperatures, higher snowfall, and on two-lane highways with traffic volumes more representative of highways in Ontario.

REFERENCES

1. S. A. Dunn and R. J. Schenk. *Alternative Highway De-Icing Chemicals.* Report FHWA-RD-79-109. FHWA, U.S. Department of Transportation, 1980.
2. G. Winters. *Environmental Evaluation of Calcium Magnesium Acetate as an Alternative Highway Deicing Chemical.* California Department of Transportation, Sacramento, 1983.
3. B. H. Chollar. *FCP Annual Progress Report, Year Ending September 30, 1984, Project 3C—Calcium Magnesium Acetate (CMA) as an Alternate Deicer.* FHWA, U.S. Department of Transportation, 1984.
4. F. Pianca. *An Assessment of CMA as an Alternative De-Icer.* Report ME-84-02. Ontario Ministry of Transportation and Communications, Downsview, Ontario, Canada, 1984.
5. D. D. Ernst, G. Demich, and T. Wieman. *CMA Research in Washington State.* Washington Department of Transportation, Olympia, Wash., 1984.
6. J. H. Defoe. *Evaluation of Calcium Magnesium Acetate as an Ice Control Agent.* Research Report R-1238. Michigan Transportation Commission, Lansing, Mich., 1984.
7. F. Pianca, K. C. Carter and H. Sedlak. *A Comparison of Concrete Scaling Caused by Calcium Magnesium Acetate and Sodium Chloride in Laboratory Tests.* Report MI-108. Ontario Ministry of Transportation and Communications, Downsview, Ontario, Canada, 1987.
8. *Maintenance Manual Operating Instructions,* Vol. 4. Ontario Ministry of Transportation and Communications, Downsview, Ontario, Canada.
9. D. G. Manning and L. W. Crowder. *A Comparative Field Study of Calcium Magnesium Acetate and Rock Salt During the Winter of 1986–1987.* Report ME-87-16. Ontario Ministry of Transportation and Communications, Downsview, Ontario, Canada, 1987.
10. A. Bacchus. *Financial Implications of Salt vs. CMA as a Deicing Agent.* Report ME-87-23. Ontario Ministry of Transportation and Communications, Downsview, Ontario, Canada, 1987.

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