Field Deicing Comparison of Calcium Magnesium Acetate and Salt During 1987–1988 in Wisconsin

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During the 1987–1988 winter maintenance season, calcium magnesium acetate (CMA) and CMA-coated sand were applied to the northern half of a 7.5-mile section of four-lane freeway, US-14, located just south of Madison, Wisconsin. Road salt (sodium chloride) was applied to the southern half of the section for comparison purposes. The moderately severe winter, with 52.4 inches of snow during the application period, provided a good basis for comparison of the two deicers. In order to achieve "bare pavement" on US-14, 48 percent more tons of CMA and CMA-coated sand than salt were applied, based on lane-mile-adjusted driver estimates of material used. About one percent less total "effective" or pure CMA (i.e., excluding the weight of the sand) was required compared with salt. The CMA application required 70 percent more miles and 143 percent more hours compared with salt; however, some part of the additional CMA application effort can be attributed to the dedication of a truck to the CMA section while the salt truck had other highway sections to cover. Deicer performance measures were provided by subjective truck driver ratings and by objective field observations. As used in Wisconsin, CMA had distinct disadvantages in handling and transport and somewhat poorer deicing performance than salt, but CMA did provide at least a minimum level of deicing performance. Given the lower level of use of CMA-coated sand and satisfactory performance in all but the coldest conditions, additional research on the economic feasibility of more extensive use of CMA-coated sand may be warranted. Reductions in the cost of CMA-coated sand may be possible by producing the CMA locally and using locally available sand.

The Wisconsin Department of Transportation (DOT) contracted with Bjorksten Research Laboratories, Inc., during the winter of 1986–1987 to evaluate the use of calcium magnesium acetate (CMA) as an alternative to salt for road deicing. The research was conducted on a 6.6-mile section of US-14 in Dane County, just south of the city of Madison. CMA was applied to the southbound two lanes of the four-lane divided highway and salt to the two northbound lanes by the Dane County Highway Department (*1*).

Because the winter of 1986–1987 was unusually mild, with the lightest snowfall since 1981 and the mildest temperatures in 35 years, only about 100 tons of the 300 tons of available CMA was used. The mild temperatures provided limited opportunity to evaluate the effectiveness of CMA under a full range of winter temperatures. Also, 14 of the 18 snowfalls occurred during the morning hours so that there was more traffic on the northbound lanes (where salt was used) than on the southbound lanes.

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For the research conducted during the 1987–1988 winter, the difference in the traffic flows was eliminated by using CMA in both directions on the northern section of US-14 from Badger Road to Irish Lane. Salt was used on the southern section of the four-lane divided portion of US-14, which ends approximately 5,650 feet south of County Highway MM.

For the 1987–1988 winter maintenance season, an estimated 120 tons of CMA and 77 tons of factory produced CMA-coated sand, for a total of 197 tons, were available. The application rates reported by the drivers showed that 110 tons of pure CMA and 85.5 tons of CMA-coated sand, for a total of 195.5 tons, were spread on the northern test section of US-14. Overall, the estimated stockpile tons were within 1 percent of the driver estimates of use. The drivers, however, underreported the CMA spread by 8 percent and overreported the CMA-coated sand used by 11 percent. A total of 127 tons of salt was spread on the southern portion of the test section. The purpose of this paper is to document the data collection procedures and present the results of the evaluation of the effectiveness of pure CMA and CMA-coated sand compared with road salt. A mixture of CMA and sand was not tested, primarily because salt-sand mixtures are not typically used on state highways in southern Wisconsin.

RESEARCH OBJECTIVES

The overall objective of the research was to compare the deicing effectiveness of CMA and CMA-coated sand with that of road salt under a wide range of winter environmental conditions in southern Wisconsin. The specific objectives of the research were the following:

1. To apply CMA and CMA-coated sand to a designated 3.8-mile section of US-14 in Dane County during storm conditions and to compare the deicing characteristics of the CMA with those of road salt applied to the adjoining section of US-14 south of the designated section;
2. To evaluate the results of the comparison treatments, including rate of application, timing of noticeable results, and overall effectiveness, and to modify the CMA treatments as warranted to achieve optimum road deicing results for the CMA (salt applications followed normal application procedures, which varied depending on conditions);
3. To identify specifically the elapsed time from the time of application to brine formation and to bare pavement;

4. To monitor meteorological and pavement sensor data from the test site and correlate these data with the deicing field data;

5. To evaluate the effectiveness of CMA and salt as deicers as a function of temperature, traffic volume, snowfall rate, wind effects, and storm duration (overall CMA/salt application ratios were used as one measure of effectiveness);

6. To identify possible differences in effectiveness on concrete and bituminous surfaces; and

7. To identify possible causes of the darkening of concrete pavement that was observed in 1986–1987.

METHODOLOGY

The research methodology was designed to evaluate the effectiveness of CMA compared with road salt under actual winter storm and roadway conditions that were as similar as possible. Consequently, the roadway configuration shown in Figure 1 was developed. The 7-mile section of four-lane divided, fully access controlled freeway is located just south of the city of Madison, Wisconsin, in gently rolling terrain. It is constructed primarily of portland cement concrete (PCC) pavement with two short sections of bituminous concrete pavement. In order to equalize exposure to traffic, CMA was spread on the 3.84-mile northern section from Badger Road to the bridge over Irish Lane, while road salt was spread on the 3.65-mile southern section from Irish Lane to the end of the four-lane section south of County Highway MM. Operationally, the CMA truck continued spreading CMA southbound across the Irish Lane bridge to a crossover just south of the bridge. Northbound, the CMA truck crossed over the Irish Lane bridge and began spreading at the crossover on the north side of the bridge. The salt truck followed the same procedure to spread salt only on the northbound Irish Lane bridge. Both sections contain standard diamond interchange ramps of approximately equal length, which were treated with CMA and salt, respectively. Including the ramps, the salt section has a total of 15.4-lane miles, while the CMA section is 4.5 percent longer with 16.1-lane miles.

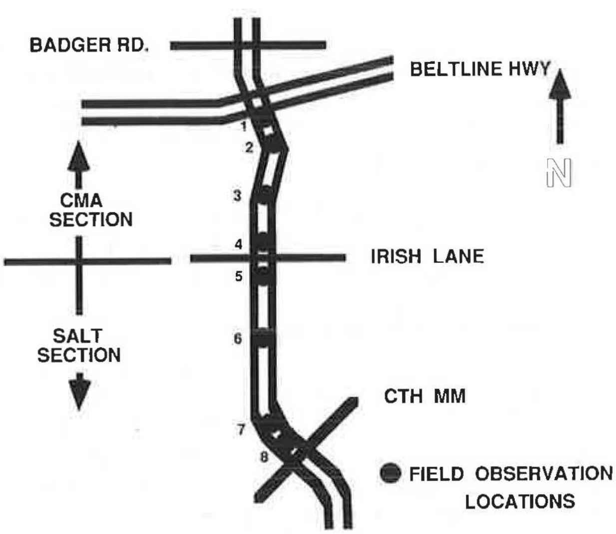

FIGURE 1 Map of US-14 test sections.

Two Dane County Highway Department trucks were dedicated to spreading CMA. The truck boxes were sealed to prevent the CMA from leaking out and full tarps were added to prevent the CMA from blowing out. One truck was used to spread pure CMA, while the second truck was reserved for CMA-coated sand. Two trucks were also assigned to cover the salt test section, but these trucks were also responsible for other sections of highway in the maintenance area. Only one truck at a time was used in both the CMA and salt sections. The drivers were instructed to use their best judgement in deciding when and at what rate to spread the CMA or salt.

While the truck drivers were asked to provide a subjective rating of the overall results of the CMA compared with salt, the primary source of deicer performance data was designed to be field data collected independently at key points. The field data were supplemented with weather and pavement temperature data from a special facility at the Irish Lane overpass, additional weather data from Truax Field in Madison, and traffic counts by lane at Irish Lane.

Initially, the field observations were to be supplemented with 35-mm slides of pavement conditions. Examination of test slides indicated that it was difficult to determine the condition of the snow on the pavement from the slides. Also, the time recording camera equipment needed to correlate the slides to the field observations was not available. Consequently, no further attempt to use 35-mm slides was made. Videotape, however, was used to document the overall test procedure, including the use of CMA under winter storm conditions.

DATA COLLECTION PROCEDURES

Driver Data

The drivers were required to record data on each application of deicer. The key data items obtained from the "driver's report form" are (a) the duration of each application, (b) the estimated miles spread, (c) the estimated tons of deicer used, and (d) the driver's opinion of the results—CMA versus salt on a three point scale of "better," "same," or "poorer." Data on the truck speed, auger setting, and ramps treated were also obtained for each application. The duration of the application does not necessarily imply that deicer was spread continuously during that period.

The "estimated miles spread," in general, was based on the length of the one-way sections covered times the number of passes. The additional miles travelled in covering the ramps were not generally included. Thus, the salt section drivers generally used six miles per "application" with the salt applied down the centerline to cover both lanes in one pass. In contrast, the CMA section drivers generally applied CMA to each lane individually, resulting in 16 miles spread based on a 4-mile section length.

In theory, given the auger calibration data, the amount of deicer used could be computed from the auger setting, the truck speed, and the actual miles spread. In practice, however, the driver's estimate of the tons of deicer used was not always consistent with the other data reported by the driver. The drivers were asked to estimate the tons used based on direct observation of the amount of deicer in the truck box at the beginning and end of each application. The CMA drivers frequently emptied their truck on one application, resulting in a precise estimate of the tons of CMA used. In contrast, the salt trucks typically made one pass ("application") and then worked on other highways before returning to make a second application.

Field Observations

Field observations of the results of the deicer applications were made by students at the eight locations shown in Figure 1. Observations were made in each direction, resulting in a total of 16 observation points with equal numbers in the CMA and salt test sections. Where appropriate, data for both the left and right lanes were collected.

The students used two cars provided by the Wisconsin DOT to travel along the test sections, recording data at each observation point. One round trip required about one-half hour. Thus, by starting the field data collection simultaneously at the northern and southern ends of the overall test section, field data could be obtained at 15-minute intervals for each observation point. For most storms, however, only one car was used, resulting in 30-minute intervals between field observations.

The observation points were selected to cover a ramp, PCC pavement, and bituminous concrete pavement for both the CMA and salt test sections in both directions. In addition, observations were made for the approach and the bridge deck at Irish Lane in order to permit direct correlation with the local weather station and pavement sensor data at Irish Lane.

The students initially collected data on (a) level of "action" of the deicer, (b) average of the left and right wheel track width in feet, (c) average snow depth outside the wheel tracks, (d) type of snow, (e) estimated level of application of the deicer, and (f) comments related to the depth of snow on the shoulder and the presence of drifting. Initial data collection efforts revealed that track width was not always relevant, particularly when only one set of tracks existed for the two lanes. Consequently, a "percent clear" data item was added to supplement and clarify the track width data.

The data on deicer "action" were recorded using the following codes: 1 = no action, 2 = penetration, 3 = brine-begin, 4 = brine-good, 5 = clear-wet, and 6 = clear-dry. The codes represent the full range of steps in the deicing process. First, as melting begins, some degree of penetration of the deicer is observed. At the next stage enough melting and mixing has occurred so that the consistency of the snow has changed (brine-begin), followed by the formation of slush (brine-good). Finally, the slush disappears (clear-wet) and the pavement dries out (clear-dry).

Weather, Pavement Surface, and Traffic Data

Data on air temperature, dew point, and wind speed and direction were available from a special facility located adjacent to the bridges at Irish Lane. The Irish Lane weather station also recorded pavement surface temperatures and moisture conditions for seven sensors located on the approaches and bridge decks of the Irish Lane overpass. An eighth sensor located in the ground 18 inches below Sensor 7 was not used in this research.

The weather station data were stored in computer files, with one file for each sensor. Whenever a change in a sensor condition occurred, the computer wrote all of the weather data plus the new data for that sensor to the appropriate file. A malfunction in the communications link resulted in unusable data for Storms 8 through 12 and Storm 14. For these storms air temperature data from the U.S. Weather Bureau Station at Truax Field in Madison were used. Data on total snowfall by storm were also obtained from the Truax Field weather station.

Traffic count data by lane were available from a continuous, inductive-loop automatic counter located at Irish Lane. The data were summarized by 15-minute intervals. The traffic counter was not functioning during the first storm (November 25).

DATA ANALYSIS

Overview

The basic characteristics of the 28 storms during the winter of 1987–1988 when CMA and CMA-coated sand were applied to US-14 are presented in Table 1. The winter provided a good test of the effectiveness of CMA because of the wide range of temperatures and substantial amount of snowfall. Through the end of December, 6 of the 12 storms had maximum air temperatures at or above the freezing mark, while minimum air temperatures were 24°F or above for all but one storm. During this same period, maximum pavement surface temperatures probably were at or above the freezing mark, although no data were available for the last five storms in December (Storms 8 to 12).

Pavement surface temperatures are critical in the formation of the ice-pavement bond. Both CMA and salt inhibit bond formation down to the 15 to 20°F range. Thus, while air temperatures during January and February were typically in the low 20s and below, temperatures at which CMA in particular is only marginally effective, maximum pavement surface temperatures were still 22°F or above for all but one minor storm. Thus, for at least part of all but one storm both CMA and salt could function as effective deicers, although the speed of deicing was slowed by the cold air temperatures. Mixing by traffic to bring the deicer-snow mixture in contact with the warmer pavement was critical to effective deicing. For most storms there was enough traffic in the right lanes to provide for substantial mixing. In the left lanes, however, traffic was generally much lighter.

Pure CMA was used exclusively through the end of December. With the advent of colder temperatures in January, CMA-coated sand was used almost exclusively until the available supply was exhausted on January 26. The remaining pure CMA was then used during the subsequent three storms with measurable snowfall, despite the limited effectiveness of the pure CMA given the low air temperatures. The pavement surface temperatures, however, were still high enough to permit some deicing to occur.

Driver Application Data

The two principal items of interest recorded by the truck drivers, the total deicer used and the rating of deicing effec-

TABLE 1 BASIC WEATHER, TRAFFIC, AND DEICER EFFECTIVENESS DATA BY STORM

STORM	DATE/DAY OF WEEK	TIME BEGAN	STORM DURATION (Hrs)	SNOWFALL Inches	SNOWFALL Water Equiv.	TEMPERATURE RANGE (F°) AIR (Hi/Low)	TEMPERATURE RANGE (F°) SURFACE[c] (Hi/Low)	PEAK TRAFFIC[a] SOUTH BOUND RL/LL	PEAK TRAFFIC[a] NORTH BOUND RL/LL	TOTAL DEICER CMA (tons)	TOTAL DEICER SALT (tons)	RATING BY:[b] CMA DRIVER	RATING BY:[b] SALT DRIVER
1	NOV 25/WE	2:30	2.5	3.0	0.21	32/31	34/27	--	--	4.5	4.0	2	2
2	DEC 2/WE	22:00	2.0	0.2	0.01	29/28	32/31	62/17	30/5	3.0	3.0	2	3
3	DEC 3/TH	6:15	5.6	2.5	0.28	30/30	34/29	62/15	188/137	9.0	5.0	3	3
4	DEC 6/SU	17:45	4.75	4.3	0.26	32/31	33/30	86/18	45/12	10.0	6.0	3	3
5	DEC 7/MO	4:30	2.0	0.2	0.06	33/32	33/30	22/2	100/31	1.5	4.0	2	2
6	DEC 15/TU	13:00	11.0	13.2	0.87	31/27	34/25	30/6	14/16	15.5	19.0	3	2.5
7	DEC 16/WE	4:00	10.0	T	T	27/25	36/25	63/27	186/125	5.0	8.0	2.5	3
8	DEC 20/SU	2:30	13.25	1.4	0.17	33/30[d]	--	84/15	101/28	13.0	9.5	3	1
9	DEC 22/TU	6:15	1.33	0.3	0.01	33/32[d]	--	65/14	190/98	2.0	3.0	3	3
10	DEC 28/MO	4:10	18.33	9.7	0.79	32/14[d]	--	106/66	169/106	18.5	12.75	3	2.5
11	DEC 29/TU	4:30	6.0	0.0	0.00	27/24[d]	--	50/13	24/253	4.5	6.0	3	--
12	DEC 30/WE	8:00	3.5	T	T	30/26[d]	--	56/18	167/115	1.0	--	2	--
13	JAN 11/MO	6:15	5.25	T	T	25/15	29/7	62/16	197/164	6.0[e]	3.0	2.5	2
14	JAN 13/WE	4:45	0.5	--	--	1.0	--	8/1	11/1	--	--	--	--
15	JAN 18/MO	6:15	3.0	--	--	32/29	38/31	55/16	162/110	5.0[e]	3.0	2.0	2
16	JAN 20/WE	0:30	10.0	0.9	0.11	31/29	36/29	66/10	169/160	10.0[f]	8.5	3	3
17	JAN 21/WE	5:30	4.5	T	T	22/17	32/20	69/41	215/143	2.0[e]	0.5	2	2
18	JAN 22/FR	15:30	7.0	0.4	0.02	24/20	36/24	162/150	84/30	13.0[e]	11.0	3	3
19	JAN 23/SA	17:00	7.0	3.2	0.13	14/10	23/19	95/28	61/6	11.5[e]	--	3	--
20	JAN 24/SU	3:00	9.5	1.2	0.05	19/6	35/11	58/4	77/11	34.0[e]	8.0	3	3
21	JAN 25/MO	5:00	8.25	8.1	0.30	16/9[g]	27/20[g]	204/118	193/162	4.0[e]	1.0	3	--
22	JAN 26/TU	4:30	7.0	T	T	11/2	31/8	49/5	204/97	7.0[h]	6.5	3	3
23	JAN 28/TH	9:00	0.5	T	T	11/5	22/10	45/9	129/54	--	0.5	--	--
24	FEB 1/MO	9:00	9.5	1.1	0.13	18/11	29/19	203/88	144/52	9.5	0.5	3	--
25	FEB 2/TU	8:00	0.5	T	T	4/3	15/11	70/14	232/133	--	0.5	--	3
26	FEB 4/TH	13:35	1.2	0.1	0.01	14/11	28/26	88/11	65/15	2.0	2.0	3	3
27	FEB 5/FR	15:00	0.5[i]	T	T	1/-1	27/20	103/31	65/11	--	--	--	--
28	FEB 8/MO	13:30	3.5	2.6	0.11	15/11	28/25	181/114	76/15	4.0	1.5	3	3
Total			157.96	52.4	3.52	33/-1	38/7	204/150	232/253	195.5	126.75		

[a]Traffic in vehicles per hour per lane (RL - right lane, LL - left lane).
[b]Deicer effectiveness rating: 1 = CMA better, 2 = equal, 3 = salt better.
[c]Pavement surface temperature at approaches to bridge at Irish Lane.
[d]U.S. Weather Bureau temperature at Truax Field. Sensor data not available.
[e]CMA-coated sand.
[f]5.0 tons CMA-coated sand and 5.0 tons pure CMA.
[g]Partial data—lack data for 4:15 to 9:15.
[h]5.0 tons CMA-coated sand and 2.0 tons pure CMA.
[i]Field data collection only.

tiveness, are also summarized by storm in Table 1. A further summary of deicer usage by type of CMA used is presented in Table 2. During the first part of the test period, when pure CMA was used, air temperatures (°F) were typically in the upper 20s to low 30s. The total amount of CMA used to obtain similar deicing performance was only 4 percent greater than the amount of salt. As shown in Table 1, CMA effectiveness compared to salt was viewed at least somewhat positively for 8 of the 12 storms (rating of 2.5 or smaller by at least one of the drivers).

During the second part of the test period, when CMA-coated sand was used nearly exclusively, the total tons of CMA-coated sand plus pure CMA exceeded the tons of salt by over 120 percent, but the effective amount of CMA (subtracting the weight of the sand) was only 65 percent of the salt tonnage based on 25 percent CMA by weight in the CMA-coated sand. The driver ratings for the first half of this time period indicated nearly equal deicing effectiveness between the CMA-coated sand and salt. But with the colder air and pavement surface temperatures of the second half of the time period, salt was uniformly rated as a better deicer than CMA-coated sand.

During the final part of the overall test period, when pure CMA was again used, the level of CMA use exceeded that of salt by nearly three to one. The storm-by-storm ratio of CMA to salt use was highly variable, however, ranging from 19 to 1. Again, the poor performance of the CMA appears to be related to temperature.

The comparison of CMA-coated sand with salt shown in Table 2 must tempered by the inherent differences between a pure deicing material and a mixture of deicer and sand. If the salt had been mixed with sand, the ratios based on total weight as well as on "pure" deicer no doubt would have been quite different.

The overall deicing effectiveness of CMA and CMA-coated sand compared with salt as viewed by the drivers is summarized in Table 3. Considering all storms, the truck drivers rated salt better 64 percent of time, while CMA was rated better only once (2 percent of the time). The salt truck drivers rated CMA slightly more positively (salt better 62 percent of the time) than the CMA drivers. The ratings for CMA-coated sand were similar to salt, rated better 62.5 percent of the time. Again, the salt drivers were somewhat more positive toward CMA (salt better 57 percent of the time).

The detailed data on deicer application by storm as recorded by the drivers are summarized in Table 4. The storms are divided into three groups: (a) early pure CMA, (b) midseason CMA-coated sand, and (c) late pure CMA. As discussed earlier, the deicer use and miles data recorded by the drivers were often estimated rather than measured precisely. Also,

TABLE 2 SUMMARY OF TONS OF DEICER APPLIED BY TYPE

TEST PERIOD STORMS	PURE CMA	CMA-COATED SAND (EFF. CMA)[b]	TOTAL: CMA + SAND[b] (EFF. CMA)[b]	SALT	RATIO OF TOTALS[a] [CMA + SAND]/SALT[b] (Eff. CMA/SALT)[b]
All Storms					
1-12	87.5	--	87.5	80.25	1.04
13-22	7.0	85.5 (21.4)	92.5 (28.4)	41.5	2.13 (0.65)
23-28	15.5	--	15.5	5.0	2.97
All	110.0	85.5 (21.4)	195.5 (131.4)	126.75	1.48 (0.99)
Pure CMA-Storms					
1-12 23-28	103	--	103	85.25	1.21
Only CMA-Coated Sand Storms					
13-15 17-21	--	75.5 (18.9)	75.5 (18.9)	26.5	2.85 (0.71)

[a]Adjusted for the difference in lane-miles between the salt and CMA sections. Salt lane-miles/CMA lane-miles = 15.4/16.1 = 0.957.

[b]Effective or "pure" CMA in CMA-coated sand based on 25 percent by weight.

TABLE 3 TRUCK DRIVER RATINGS OF DEICING EFFECTIVENESS, CMA VERSUS SALT

DEICING EFFECTIVENESS RATING[a]	ALL STORMS			STORMS WITH CMA-COATED SAND		
	CMA DRIVER	SALT DRIVER	BOTH DRIVERS	CMA DRIVER	SALT DRIVER	BOTH DRIVERS
1 - CMA Better	--	1	1	0	0	0
2 - CMA and Salt Equal	6	5	11	2	3	5
2.5 - Salt Marginally Better	2	2	4	1	0	1
3 - Salt Better	16	12	28	6	4	10
Total Observations	24	20	44	9	7	16

[a]Drivers Report Form: Response to question on "Your Opinion of Results: (compared to Salt) _______Better, _______Same, _______Poorer."

an "application" could consist of one or more passes. Thus, the detailed driver data only provided a general indication of differences in deicer use and the level of effort required.

The basic application data shown in Table 4 indicate that much more effort in both hours and miles was expended applying CMA compared with salt. Overall, CMA required 143 percent more hours and 70 percent more miles. The higher level of effort for CMA was consistent across all three time periods.

The application rates shown in Table 4 reveal that CMA was spread at a substantially higher rate per lane-mile, but at a lower rate per hour. The apparent inconsistency in the two rates is explained in part by differences in application procedures. The per lane-mile data presented here assume that the salt was applied to two lanes at once, while the CMA was applied one lane at a time. The much higher application rates per hour for salt compared with CMA reflect both a higher rate for salt from the coverage of two lanes at once by the salt truck and a lower rate for CMA resulting from the nonproductive application hours reported by the CMA drivers.

A fully unbiased comparison of the deicers would require adjustment to account for the slightly smaller number of lane miles in the salt section (15.4 versus 16.1, or 4.3 percent less). The adjustment would make CMA slightly more competitive with salt. The adjustment, however, is not explicitly made here because the impact is overshadowed by the uncertainties in the base data on tons of deicer, miles, and hours.

TABLE 4 SUMMARY OF DEICER APPLICATION DATA

APPLICATION EFFORT[a]				APPLICATION RATES[b]				
MILES		HOURS		(LBS/LANE-MI)			(TONS/HOUR)	
CMA	SALT	CMA	SALT	CMA	SALT	RATIO CMA/SALT	CMA	SALT
Pure CMA Storms--Nov 25 to Dec 30 - 12 Storms								
382	226	47.2	24.1	460	360	1.3	1.8	3.3
CMA-Coated Sand Storms--Jan 11 to Jan 26 - 10 Storms								
241	150	39.2	13.2	770	280	2.8	2.4	3.1
Pure CMA Storms--Jan 28 to Feb 8 - 6 Storms								
69	30	10.6	2.5	450	330	1.4	1.5	2.0
All Storms								
692	406	97.1	39.9	560	310	1.8	2.0	3.2

[a]Vehicle miles and hours of application including plowing reported by the drivers.
[b]Based on driver estimates of the amount of deicer applied.

Field Observations Data

Field observations were recorded for nine storms, but during Storm 27 no deicer was used and only one set of observations was made. For Storm 27 the pavement surfaces were relatively warm (in the 20 to 27°F range) despite very cold air temperatures. In this situation the traffic volumes were sufficient to create essentially clear and dry pavement conditions. The details of the range of pavement conditions observed for the remaining eight storms are presented in Table 5. While the extremes of the observations (lows and highs) presented in Table 5 provide a convenient means of summarizing a much larger set of data, a full understanding of the differences between CMA and salt requires analysis of the complete data set, which relates the field observations to key variables such as air and pavement surface temperatures, wind speeds, traffic volumes, and deicer application rates at 15-minute intervals. The pavement condition data are averages of the three observation points in each section excluding the ramps and considering the Irish Lane location as a single observation point. An alternative format for the complete data base that facilitates comparison of CMA performance by direction as well as salt performance by direction was also developed.

The field observations data cover nearly the full range of winter storm conditions, including both warm and cold pavement surface and air temperatures, low and high wind speeds and traffic volumes, and small and large snowfalls. The type of CMA used, pure CMA versus CMA-coated sand, is another factor to be considered.

TABLE 5 SUMMARY OF FIELD OBSERVATION DATA

Data Item	Southbound Right Lane CMA Low	Southbound Right Lane CMA Hi	Southbound Right Lane Salt Low	Southbound Right Lane Salt Hi	Southbound Left Lane CMA Low	Southbound Left Lane CMA Hi	Southbound Left Lane Salt Low	Southbound Left Lane Salt Hi	Northbound Right Lane CMA Low	Northbound Right Lane CMA Hi	Northbound Right Lane Salt Low	Northbound Right Lane Salt Hi	Northbound Left Lane CMA Low	Northbound Left Lane CMA Hi	Northbound Left Lane Salt Low	Northbound Left Lane Salt Hi
Storm 10 Mon., Dec. 28 9.7 in. snow 14-32°F Began 4:10 Data: 6:08-7:33																
Action[a]	1.0	2.3	1.0	3.0	1.0	1.5	1.5	3.0	2.0	3.0	1.3	2.7	2.0	3.0	1.7	3.0
Tr. Width[b]	0.0	1.1	0.0	2.0	0.0	1.0	0.0	1.0	0.4	1.2	0.0	0.7	0.7	0.8	0.0	1.1
% Clear	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Snow Depth[c]	0.5	0.7	0.5	1.0	0.5	0.8	0.5	2.3	0.5	1.0	0.7	1.2	0.5	1.0	0.7	1.2
Sur. Temp.		--	--			--	--			--	--			--	--	
Traffic		7	36			1	15			79	169			18	106	
Storm 15 Mon., Jan 18 ? in. snow 29-32°F Began 6:15 Data: 8:45-11:45																
Action	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Tr. Width	1.4	3.0	0.5	3.0	0.0	1.3	0.0	0.6	1.0	2.5	0.6	1.8	0.4	1.4	0.0	1.0
% Clear	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Snow Depth	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sur. Temp.		32	36			32	38			34	38			34	36	
Traffic		24	54			2	8			57	102			7	37	
Storm 18 Fri., Jan. 22 0.4 in. snow 20-24° Began 15:30 Data: 15:56-19:58																
Action	4.0	4.3	4.0	5.0	3.3	4.0	4.0	5.0	4.0	4.5	3.7	5.0	2.5	3.5	3.7	5.0
Tr. Width	2.0	4.0	0.0	2.0	1.2	3.3	0.0	1.5	0.0	4.0	0.0	3.7	1.0	2.5	0.0	2.7
% Clear	60	80	75	90	43	67	70	90	45	95	67	100	10	45	47	97
Snow Depth	0.1	0.3	0.1	0.2	0.1	0.3	0.1	0.2	0.1	0.2	0.0	0.1	0.1	0.2	0.0	0.1
Sur. Temp.		25	30			25	31			24	28			24	28	
Traffic		46	162			9	150			21	77			5	14	
Storm 19 Sat., Jan. 23 3.2 in. snow 10-14°F Began 17:00 Data: 18:38-22:06																
Action	3.7	4.0	4.0	4.0	1.0	2.3	1.0	1.0	3.0	4.0	3.7	4.0	1.0	1.0	1.0	1.7
Tr. Width	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
% Clear	47	70	50	75	0	10	0	0	25	50	40	57	0	0	0	0
Snow Depth	0.4	0.4	0.3	0.3	0.8	1.0	1.0	1.0	0.3	0.8	0.4	0.5	1.0	1.0	0.8	1.0
Sur. Temp.		20	20			21	22			19	19			18	18	
Traffic		27	46			0	8			7	43			0	4	
Storm 20 Sun., Jan. 24 1.2 in. snow 6-19°F Began: 3:00 Data: 7:01-10:25																
Action	1.0	4.0	1.0	4.5	1.0	2.3	1.0	4.0	1.0	4.5	1.7	4.3	1.0	3.0	1.7	4.0
Tr. Width	0.0	0.8	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
% Clear	72	87	70	95	0	7	8	50	80	85	57	87	5	25	10	57
Snow Depth	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Sur. Temp.		11	29			13	21			10	23			9	27	
Traffic		3	31			0	1			7	56			0	3	
Storm 21 Mon., Jan. 25 8.1 in snow 9-16°F Began: 5:00 Data: 5:51-7:12																
Action	2.0	3.4	3.0	3.5	1.7	2.5	1.5	3.0	4.0	4.0	4.0	4.0	2.0	3.5	2.0	3.3
Tr. Width	3.7	4.3	1.5	4.5	2.3	3.3	0.5	3.0	4.0	4.5	4.3	5.0	2.5	3.5	3.3	3.3
% Clear	37	43	45	65	15	67	30	95	35	70	17	87	45	80	33	77
Snow Depth	1.0	1.2	1.3	1.5	1.0	2.0	1.5	1.8	1.0	1.0	8.3	8.3	1.0	2.0	1.3	1.30
Sur. Temp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Traffic		13	31			1	3			56	192			1	82	
Storm 24 Mon., Feb. 1 1.1 in. snow 11-18°F Began: 9:00 Data: 10:10-12:52																
Action	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Tr. Width	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0
% Clear	83	90	85	95	22	32	32	65	90	95	95	97	15	25	47	57
Snow Depth	0.0	3.0	0.0	1.5	0.8	5.0	0.5	2.5	1.0	3.0	1.0	1.5	2.0	4.0	0.5	2.3
Sur. Temp.		25	29			24	25			25	26			-	-	
Traffic		43	68			1	6			43	75			2	7	
Storm 28 Mon., Feb. 8 2.6 in. snow 11-15°F Began: 13:30 Data: 13:44-17:50																
Action	4.0	4.0	4.0	4.0	3.0	4.0	3.5	4.0	4.0	4.0	4.0	4.0	3.0	4.0	1.0	4.0
Tr. Width	0.0	0.0	0.0	0.0	0.0	3.3	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
% Clear	86	95	93	95	3	67	15	70	80	95	86	92	10	13	3	37
Snow Depth	0.5	1.7	0.5	2.0	1.7	3.0	2.0	3.0	0.5	3.0	1.0	3.0	3.0	5.0	2.3	4.6
Sur. Temp.		19	24			21	24			18	20			-	-	
Traffic		58	181			2	114			42	67			0	15	

[a] Code: 1 - No Action, 2 - Penetration, 3 - Begin Brine, 4 - Good Brine, 5 - Clear-Wet, 6 - Clear-Dry.
[b] Average of left and right tracks in feet.
[c] In inches.

"Time to Brine" and "Time to Clear and Wet" Evaluation

Field data on two key items of interest, time to brine formation and time to clear and wet pavement conditions, are summarized separately in Table 6. The time and the corresponding "deicer action level" for the first and last field observation are also shown in Table 6. The time recorded is the time from the first application of the specific deicer as reported by the drivers. In general, the applications of CMA and salt did not begin at the same time.

The "time to brine" pavement condition is based on the elapsed time in 15-minute increments until the "deicer action level" exceeds 2.0, which corresponds to "begin brine" conditions on one or more observation points on the section. A careful review of Table 6 reveals that the transition from "no action" to "begin brine" or greater action level was not recorded for every storm. In several storms, the transition had already occurred when field data collection was begun. In one storm brine formation was not observed during the time when field data were being collected.

When pure CMA was spread on relatively warm pavement, with surface temperatures above 22°F, the "time to brine" was generally shorter for the CMA sections. The "time to brine" ranged from 1.0 to 2.0 hours for CMA and 2.0 to 3.25 hours for salt. By contrast, when the CMA-coated sand was spread on colder pavement, the "time to brine" was generally longer for the CMA sections. The "time to brine" ranged from 3.75 to 4.5 hours for salt and 6.75 to 7.25 hours for CMA-coated sand. Some of the variation in "time to brine" appears to be related to traffic volumes. At least one storm, Storm 21, provided evidence of "CMA carryover," in which brine formation is enhanced by residual CMA left from the prior storm. In this case, brine formation occurred before the CMA-coated sand application began. The "time to brine" measured from the start of the salt application, however, was slightly greater for CMA than for salt.

The "time to clear and wet" pavement conditions is based on the elapsed time until the "deicer action level" exceeds 4.0, which corresponds to "clear and wet" conditions on one or more observation points on the section. The focus here is on "clear and wet" conditions rather than "clear and dry" conditions because of the limited number of observations of "clear and dry" conditions. Table 6 shows that, in general, the time to "clear and wet" conditions was longer for CMA-coated sand, with a range of 0.5 to 4.75 hours for salt versus 4.0 to 7.25 hours for CMA-coated sand. For the one storm with shorter times to "clear and wet" conditions for CMA-coated sand, Storm 21, the shorter times may be explained in part by the later start in spreading CMA.

Weather Data

The primary concern in analyzing the weather data is to determine if the temperature at Truax Field is a reasonable surrogate for the local US-14 air temperature. The correlation between the two air temperatures over the 28 storms for which data are available is 0.989. Thus, if the weather station at Irish Lane was not in operation, the Truax Field temperature will provide a good estimate of the local air temperatures.

The Irish Lane air temperature has a moderately high degree of correlation with the pavement surface temperatures, ranging from 0.80 to 0.86, which means that air temperature explains 64 to 74 percent of the variation in pavement surface temperature. The amount of energy from the sun, which is dependent on cloud cover and time of day, is a major reason for differences between pavement and air temperatures. Pavement surface condition, including snow cover, depth, and moisture content, is also an important factor. Traffic volume may be significant under some conditions. At night the degree of cloud cover is important, but this is generally not a factor during storms.

The local wind speed data at Irish Lane typically varied considerably from one 15-minute time period to the next, but the maximum values generally were consistent with wind speeds reported by Truax Field. Local wind speed data provide more precise information on when blowing snow and drifting conditions were likely to have occurred.

SUMMARY AND CONCLUSIONS

The 1987–1988 winter provided a good test of the effectiveness of CMA and CMA-coated sand because of the substantial number of storms with a wide range of temperatures and amount of snowfall. Pavement surface temperatures were high enough to permit significant deicing in all but 1 of the 28 storms.

Based on lane-mile-adjusted driver estimates, 48 percent more tons of CMA and CMA-coated sand than salt were required to achieve "bare pavement" on US-14. Considering only the pure or "effective" amount of CMA used, however, about 1 percent less CMA was required per lane-mile. In contrast, 87 percent more CMA than salt was required on US-14 during the previous winter (1986–1987). The lower amount of pure CMA used, however, was the result of extensive use of CMA-coated sand; no comparable sand-salt mixture was used. CMA-coated sand accounted for 44 percent of the total tons of CMA and CMA-coated sand used.

The application of CMA and CMA-coated sand on US-14 required 70 percent more miles and 143 percent more hours compared with the application of salt. Some part of the additional application effort can be attributed to the dedication of a truck to the CMA section, whereas the salt truck had other highway sections to cover.

The truck drivers rated salt as a more effective deicer in over 60 percent of the storms. In contrast, CMA was rated better only once. The overall driver ratings for CMA compared with CMA-coated sand were about the same. The salt truck drivers rated CMA and CMA-coated sand slightly more positively than the CMA truck drivers did.

Detailed field observations were made for 8 of the 28 storms, covering a reasonable range of temperature and snowfall conditions. Pure CMA was applied during three of the eight "field observations" storms. Overall, the deicing performance of CMA was similar, but often slightly lower than that of salt. Both CMA and salt were more effective with increasing traffic volumes and temperatures. The pavement surface temperature appeared to be more important than air temperature. The performance of CMA was typically lower than that of salt under low-traffic-volume conditions.

TABLE 6 SUMMARY OF TIME TO BRINE AND TIME TO CLEAR AND WET

Data Type	Southbound								Northbound							
	Right Lane				Left Lane				Right Lane				Left Lane			
	CMA		Salt		CMA		Salt		CMA		Salt		CMA		Salt	
	Time[a] (hrs)	Action[b] (1-6)	Time[a] (hrs)	Action[b] (1-6)	Time[a] (hrs)	Action[b] (1-6)	Time[a] (hrs)	Action[b] (1-6)	Time[a] (hrs)	Action[b] (1-6)	Time[a] (hrs)	Action[b] (1-6)	Time[a] (hrs)	Action[b] (1-6)	Time[a] (hrs)	Action[b] (1-6)
Pure CMA STORM 10 -- Mon., December 28 Began: 4:10 @ S. Temp. n.a.																
First Data	0.5	1.0	2.0	1.0	0.5	1.0	2.0	1.5	1.0	2.0	2.0	1.3	1.0	3.0	2.0	3.0
First Brine[c]	1.5	2.3	3.25	3.0	--	--	2.5	3.0	2.0	3.0	2.75	2.7	1.0	3.0	2.0	3.0
Last Data	1.5	2.3	3.25	3.0	1.5	1.5	3.25	2.0	2.0	3.0	2.75	2.7	2.0	2.5	2.75	3.0
CMA/Sand STORM 15 -- Mon., January 18 Began: 6:15 @ S. Temp 31-33																
First Data	2.25	5.0	1.75	5.0	2.25	5.0	1.75	5.0	2.5	5.0	2.25	5.0	2.5	5.0	2.25	5.0
First Cl-Wet[d]	2.25	5.0	1.75	5.0	2.25	5.0	1.75	5.0	2.5	5.0	2.25	5.0	2.5	5.0	2.25	5.0
Last Data	5.25	5.0	4.5	5.0	5.25	5.0	4.5	5.0	5.25	5.0	4.5	5.0	5.25	5.0	4.5	5.0
CMA/Sand STORM 18 -- Fri., January 22 Began: 15:30 @ S. Temp 30-32																
First Data	0.25	4.0	0.5	5.0	0.25	4.0	0.5	5.0	0.75	4.0	0.75	4.7	0.75	2.5	0.75	5.0
First Brine[c]	0.25	4.0	0.5	5.0	0.25	4.0	0.5	5.0	0.75	4.0	0.75	4.7	1.75	3.5	0.75	5.0
First Cl-Wet[d]	4.0	4.3	0.5	5.0	--	--	0.5	5.0	4.25	4.5	3.5	5.0	--	--	0.75	5.0
Last Data	4.0	4.3	4.0	4.5	4.0	3.8	4.0	4.5	4.25	4.5	4.25	4.3	4.25	3.5	4.25	4.3
CMA/Sand STORM 19 -- Sat., January 23 Began: 17:30 @ S. Temp. 18-22																
First Data	1.5	3.7	--	4.0	1.5	2.3	--	1.0	2.25	4.0	--	3.7	2.25	1.0	--	1.7
First Brine[c]	1.5	3.7	--	4.0	1.5	2.3	--	--	2.25	4.0	--	3.7	--	--	--	--
Last Data	4.25	4.0	--	4.0	4.25	1.3	--	1.0	5.0	4.0	--	4.0	5.0	1.0	--	1.0
CMA/Sand STORM 20 -- Sun., January 24 Began: 3:00 @ S. Temp. 15-22																
First Data	4.0	1.0	1.75	1.0	4.0	1.0	1.75	1.0	4.75	1.0	2.0	1.7	4.75	1.0	2.0	1.7
First Brine[c]	6.75	4.0	4.5	4.5	6.75	2.3	3.75	3.5	6.75	3.5	4.0	4.0	7.25	3.0	4.0	4.0
First Cl-Wet[d]	--	--	4.5	4.5	--	--	--	--	7.25	4.5	4.75	4.3	--	--	--	--
Last Data	6.75	4.0	4.5	4.5	6.75	2.3	4.5	4.0	7.25	4.5	4.75	4.3	7.25	3.0	4.75	4.0
CMA/Sand STORM 21 -- Mon., January 25 Began: 5:00 @ S. Temp. n.a.																
First Data	--	2.0	1.0	3.0	--	1.7	1.0	1.5	--	4.0	1.25	4.0	--	2.0	1.25	2.0
First Brine[c]	--	3.4	1.0	3.0	3.0	3.0	1.75	3.0	--	4.0	1.25	4.0	0.0	3.5	2.0	3.3
First Cl-Wet[d]	3.75	6.0	6.0	5.0	--	--	--	--	3.75	5.0	5.5	4.7	4.25	5.0	6.0	4.3
First Cl-Dry[e]	3.75	6.0	7.0	6.0	--	--	--	--	10.0	6.0	6.0	6.0	--	--	--	--
Last Data	10.75	1.0	12.75	1.0	10.75	1.0	12.75	1.0	11.0	1.0	13.0	1.0	11.0	1.0	13.0	1.0
Pure CMA STORM 24 -- Mon., February 1 Began: 9:00 @ S. Temp. 24-25																
First Data	0.5	1.0	1.25	1.0	0.5	1.0	1.25	1.0	0.75	1.0	1.0	1.0	0.75	1.0	1.0	1.0
Last Data	2.75	1.0	3.5	1.0	2.75	1.0	3.5	1.0	3.25	1.0	3.5	1.0	3.25	1.0	3.5	1.0
Pure CMA STORM 28 -- Mon., February 8 Began: 13:30 @ S. Temp. 24																
First Data	0.0	4.0	0.25	4.0	0.0	4.0	0.25	4.0	0.75	4.0	0.25	4.0	0.75	4.0	0.25	1.0
First Brine[c]	0.0	4.0	0.25	4.0	0.0	4.0	0.25	4.0	0.75	4.0	0.25	4.0	0.75	4.0	1.0	3.7
Last Data	3.75	4.0	3.75	4.0	3.75	4.0	3.75	4.0	4.25	4.0	3.75	4.0	4.25	3.0	3.75	3.0

[a] Time from the first application of the specific deicer.
[b] Deicer Action Level: 1-No Action, 2-Penetration, 3-Begin Brine, 4-Good Brine, 5-Clear & Wet, 6-Clear & Dry.
[c] "Deicer action level" exceeds 2.0 so that "begin brine" conditions exist at one or more observation points on the section.
[d] "Deicer action level" exceeds 4.0 so that "clear & wet" conditions exist at one or more observation points on the section.
[e] "Deicer action level" exceeds 5.0 so that "clear & dry" conditions exist at one or more observation points on the section.

Local weather data were available for six of the eight field observation storms. Air temperatures at the U.S. Weather Bureau station at Truax Field were found to be a reasonable surrogate for the local air temperatures. Local air temperatures are correlated with pavement surface temperatures but only explain 64 to 74 percent of the variation in pavement surface temperature. Thus, separate measurement of pavement surface temperatures are needed. Maximum local wind speeds were highly correlated with Truax Field wind speeds, but typically there was considerable variation in wind speed during a storm.

The field observations data provided some information on both the "time to brine formation" and the "time to clear and wet pavement." The amount of data available on "time to brine" was limited because the transition to brine had already occurred before the field data collection was begun. The "time to brine" was found to be shorter for pure CMA being spread on relatively warm pavement, but longer for CMA-coated sand being spread on colder pavement. The level of traffic volumes appeared to influence the time required. In general, the time to "clear and wet" pavement conditions was longer for CMA-coated sand than for salt. No data on the transition to "clear and wet" conditions were available for pure CMA.

Overall, storm duration did not appear to have a significant impact on the relative effectiveness of CMA. CMA received ratings by the drivers of "equal to salt" or better for both short- and long-duration storms. The field observations data did not provide enough information to identify any potential differential impacts of storm duration.

No obvious differences were noted in the deicing effectiveness of either CMA or salt between concrete and bituminous surfaces on US-14. Also, the darkening of concrete pavement by CMA observed in the winter of 1986–1987 was not observed during 1987–1988.

Overall, the comparison of CMA and CMA-coated sand on US-14 demonstrated that CMA can produce results similar to salt, but more deicer and application miles and hours were required. Also, the deicing by CMA tended to occur more slowly, although the differences may not have been noticeable to motorists.

As used in Wisconsin, CMA had distinct disadvantages in handling and transport. CMA was shipped and stored in 1,000- and 1,500-pound fabric bags. Using a mobile crane to hoist the bags over the truck body and then pulling the rip cord to release the CMA was a two-person job. The time-consuming loading of individual bags must be replaced by bulk storage and handling if CMA is to be used more extensively. The tendency of CMA to cake and harden when wet was an annoying but not insurmountable problem.

RECOMMENDATIONS FOR ADDITIONAL RESEARCH

Given the reasonably favorable experience with CMA-coated sand in all but the coldest conditions, an investigation of the economic feasibility of more extensive use of CMA and possibly CMA-sand mixtures may be warranted. A mixture of sand and CMA may have cost advantages over the manufactured CMA-coated sand used in this study. The benefits of reduced corrosion on bridge decks and non coated reinforcing bars in some pavements need to be compared with the higher material and operational costs associated with CMA. Additional field tests are needed to determine the performance of CMA-coated sand and CMA-sand mixtures under the warmer pavement and air conditions typically occurring in November and December. Field trials of CMA-sand mixtures are also needed. Costs for CMA-coated sand may be reduced significantly by producing the CMA in Wisconsin and using local sand.

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