Report No. CDOT-DTD-R-99-2
Quick Study

EFFECT OF MAGNESIUM CHLORIDE ON ASPHALT PAVEMENTS

Werner Hutter

DEPARTMENT OF TRANSPORTATION
RESEARCH

February 1999

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH BRANCH

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by

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Prepared by
Colorado Department of Transportation
Research Branch

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Acknowledgements

The author wishes to give special thanks to personnel from CDOT's Staff Construction and Materials Branch for their diligence in preparing and testing of the laboratory test samples. Special recognition is in order for Tim Aschenbrener who was responsible for completing the stripping potential analysis (Lottman Tests), and Rich Zamora for his work on the Hamburg Wheel Tracking tests. Additionally, the assistance from Region 6 Maintenance for their work on the pavement marking tape tests, and last but not least, Steve Wolford, the representative from Flint Trading for providing the material as well as the installation of the marking tape test samples.

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Background

Magnesium Chloride has been used successfully in a number of states to prevent the formation of ice on roadways. Colorado began using magnesium chloride in the Denver Metropolitan area in 1989. Prior to 1989, salt and sand mixtures had been used exclusively for snow and ice control. As a result of a Strategic Highway Research Program (SHRP) "Test and Evaluate Study" from 1992 to 1993 the Colorado DOT Maintenance Division began to accelerate the use of magnesium chloride with the intent to eventually replace much of the traditional salt and sand mixtures in major metropolitan areas because of the environmental concerns. Salt and sand mixtures tend to be more corrosive, cause sediment loading of streams and ultimately lead to air pollution through the product of dust.

Magnesium chloride has an advantage as it can be applied to the pavement surface prior to a storm to prevent the snow and ice from bonding to the pavement. This is known as the anti-icing method which typically requires less solution (30 to 40 gallons per lane-mile application rates) than de-icing. As much as 100 gallons per lane-mile or more is required to penetrate the snow pack and permit effective snowplow operation. Statewide use of magnesium chloride has grown to nearly 5 Million gallons per year.

Denver metropolitan area maintenance (Region 6) recently noticed stripping on their pavement's surface, and felt this stripping could be attributed to the use of magnesium chloride. They suspected that magnesium chloride remains on the pavement surface and attracts moisture, which could lead to the stripping susceptibility of asphalt pavements.

Additionally, over the last several years it has been observed that there is a distress on newly placed asphalt pavement, which has not been documented before. It has been noted that when a pavement is placed in two lifts, where the first lift is placed late in the fall, followed by the second lift in the subsequent spring, a strong bond is not always obtained between the lifts. The pavement slips, causing crescent-shaped cracking on the surface. It is felt that this lack of bond could be attributed to the magnesium chloride that was placed on the pavement surface during the winter month between the placement of two lifts.

On a project recently placed in Region 6 the thermoplastic paving marking was placed on two separate occasions. The first section was placed immediately after paving, and the second section was placed a short period later. Between the time the first and the second section were placed the road was treated with magnesium chloride.

The first section of thermoplastic marking was placed successfully and remained in place. The second section of thermoplastic marking did not bond to the asphalt mat and was easily removed by snowplows.

Other concerns were raised in regard to crack filling and pothole patching. The lack of material adhesion was thought to be due to a residual presence of magnesium chloride.

As a result of these concerns, the CDOT's Research Branch initiated a research study to investigate the potential problem areas, and report the results before the next paving season begins.

Literature Search and Questionnaires to State Agencies

The first task in this research was to find out if other agencies have experienced the problems that are discussed in the background section of this report. The CDOT library conducted a search on TRIS without success. A request to identify persons or offices that might have familiarity with the topic was e-mailed (see E-Mail Text in Appendix A) to 42 of the US DOT librarians, and the study manager was able to establish a dialogue with 12 individuals. Table 1 shows the results of this effort. It became clear that there was very little information from these sources. One conceivable explanation is the rather short time that most states have been using magnesium chloride (or other chemical deicing material), and as a result, the observed failures were not attributed to chemical deicing. On the other hand, it is quite possible that their snow and ice control with chemicals does not affect the performance of asphaltic pavements.

Table 1

List of DOT Contacts on Effect of Magnesium Chloride on Asphalt Pavements

State	Contact Person	Date	Comments
Colorado	Wayne Lupton	12/10/98	Response on crack filling- must be done prior to MgCl applications
Illinois	Dennis File	12/17/98	Do not use MgCl; NaCl&CaCl
Iowa	Dennis Burkheimer	12/11/98	No MgCl
Maine	Stephen Colson	12/29/98	Use only salt and CaCl; no documented failures
Michigan	David Smiley	12/23/98	Limited use of MgCl; they are aware of some issues ***
Minnesota	Roger Olson	12/16/98	Small amounts of MgCl, some failures, but not attributed to MgCl
Nebraska	Laird Weishahn	12/4/98	Limited use of MgCl
North Dakota	Jerome Horner	12/11/98	No MgCl
Tennessee	Alan Pinson	12/11/98	Don't use MgCl
WSDOT	Linda Pierce	1/4/99	No known problems
Wisconsin	Thomas Martinelli	12/8/98	Limited use (1 winter season), not aware of any problems
Wyoming	Ken Shultz	12/11/98	Isolated use of MgCl; Not aware of any bonding problems

*** from other sources

Other Agencies:			
Strijpe Wright	Janet Tisdall	1/11/99	Work mostly with new overlays; Good surface preparation - important
Inline	Jim Spees	1/11/99	No problem if applied after 1 or more week since last MgCl use

LABORATORY TESTING

Stripping Potential of HBP using CPL-5109, Method B (Lottman test):

As stipulated in the study workplan, the stripping potential of hot bituminous pavement (HBP) was tested in accordance to CPL-5109, Method B. The following section describes this process, and the test results.

In order to determine the effect of Magnesium Chloride on the stripping potential of HBP, a series of tests were conducted using CPL-5109, Method B (Lottman test). This test is used by CDOT to determine the stripping potential of HBP mixtures. Method B uses a 5-minute vacuum saturation and usually has much higher levels of saturation than Method A.

The HBP tested for this study is the Superpave mix design from Kiewit's south plant. This is the same mix that is being used on I-25, between 6th Avenue and Santa Fe. The first lift was placed in Fall 1998 and the second lift was placed in Spring 1999. The first lift was treated with Magnesium Chloride through the winter before the second lift was placed. On the lower lift, a PG 64-22 binder was used. On the upper lift, a PG 76-28 binder was used. This mix was tested in this study with both binders that were used on the project.

The Awet@ control samples were vacuum saturated with water. One control test was conducted with PG 76-28 and one was conducted with PG 64-22. For each test, there were 3 wet and 3 dry specimens.

The Awet@ research test samples were vacuum saturated with a magnesium chloride solution. The solution contains 30% Magnesium Chloride and 70% water just like the solution used by maintenance. Two tests were conducted with PG 76-28, and two tests were conducted with PG 64-22. For each test, there were 3 wet and 3 dry specimens. The results are shown in Table 2.

Table 2. Results of CPL-5109, Method B (Lottman testing) with and without Magnesium Chloride Solution.

Mix with PG 76-28	Saturation (%)	Strengths (psi)		Tensile Strength Ratio
		Dry	Wet	
Control (with water)	76	652	637	1.02
Test (with MgCl)	102	639	633	1.01
Test (with MgCl)	102	743	702	1.06
Mix with PG 64-22				
Control (with water)	75	550	460	120
Test (with MgCl)	102	575	546	1.02
Test (with MgCl)	102	557	561	0.99

Based on the results of the Lottman testing, there appears to be minimal effect on the tensile strength ratio between the samples saturated with Magnesium Chloride or with water. These tests indicate that Magnesium Chloride does not effect the stripping of HBP.

Stripping Potential of HBP using the Hamburg Wheel Tracking Device:

A laboratory study using the Hamburg Wheel Tracking Device (HWTD) was carried out to determine if magnesium chloride liquid deicer has any effect on the stripping potential of hot bituminous pavement (HBP). The experimental matrix for the study is shown in Table 3.

Table 3. Experimental Matrix

Binder Type	Soak Time (30% solution of Magnesium Chloride)		
	No Soak	24 hrs	72 hrs
PG 76-28	2 samples	2 samples	2 samples
PG 64-22	2 samples	2 samples	2 samples

The same aggregate type and gradation were mixed in the laboratory with each binder to produce samples containing 4.9% asphalt cement, by weight of total mix. The samples were compacted in the linear kneading compactor, soaked for the appropriate length of time in a 30% solution of magnesium chloride, and tested according to CPL 5112, "Hamburg Wheel Track Testing of Compacted Bituminous Mixtures". A sample impression less than or equal to 10 mm after 20,000 passes is considered a passing test result. The sample void properties and their associated HWTD test results are shown in Table 4.

Table 4. Test Results

Binder	Soak Time	Air Voids (%)		Test Temperature (°C)	Impression Depth after 20,000 passes (mm)		
		Left	Right		Left	Right	Average
PG 76-28	No Soak	7.1	6.9	55	4.19	3.27	3.73
	24 hrs	7.2	7.0		2.58	3.72	3.15
	72 hrs	6.7	7.5		1.52	1.74	1.63
PG 64-22	No Soak	6.5	6.2	50	14.90	12.06	13.48
	24 hrs	7.4	7.5		14.74	13.12	13.93
	72 hrs	6.6	6.0		24.16	10.47	17.32

Based upon the above data, magnesium chloride appears to have little effect on the stripping potential of HBP, as tested in the HWTD.

Shear Testing of Laboratory produced Core Samples:
This portion of the research was introduced to evaluate the bond strength of an overlay over pavements that had received magnesium chloride for de-icing/anti-icing in a quantitative manner. Although information on bond strength was originally intended to be obtained from field cores, it became apparent that laboratory molded cores would yield better results. Many variables encountered on a paving project can be eliminated, and the test results will truly represent the effects of magnesium chloride on the bond strength of the HBP.

Since no testing device was readily available, a fairly inexpensive apparatus was designed and built by Research personnel and Geology, using a discarded core drill barrel and scrap metal. A sketch of the design can be found in Appendix A.

Two bituminous mixes (Superpave Grading S and SG; see mix specifications in Appendix A) were used to produce the test samples. The 1-1/2 inch lower lifts were compacted in the Gyratory Compactor, and subsequently extracted from the mold. Three samples were prepared for the two mix designs, the two sources of magnesium chloride suppliers (Envirotech and GMCO), and additional three sets for control samples representing the two mix designs. The test samples were placed in the representative solutions of magnesium chloride (30% magnesium chloride and 70% water) for 72 hours at room temperature. After a 72 hour air-drying cycle, the cores were re-inserted into the mold, coated with binder (PG 64-22), and a 1-1/2 inch top lift was compacted. All samples were subsequently air cured at room temperatures for four days before the shear tests were performed.

The following photo shows the test setup on the Instron press, where the samples were loaded to failure.

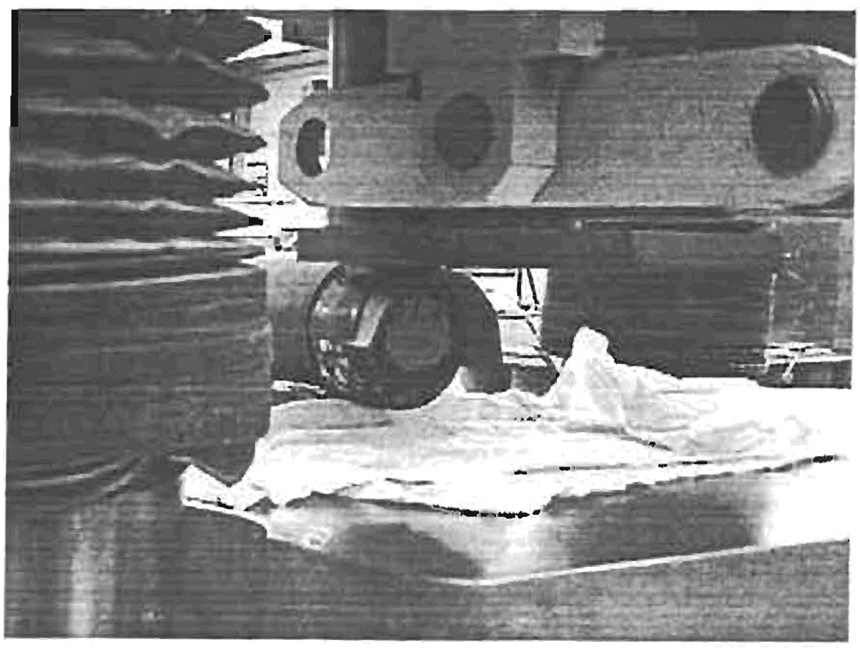


Photo 1: Shear test setup

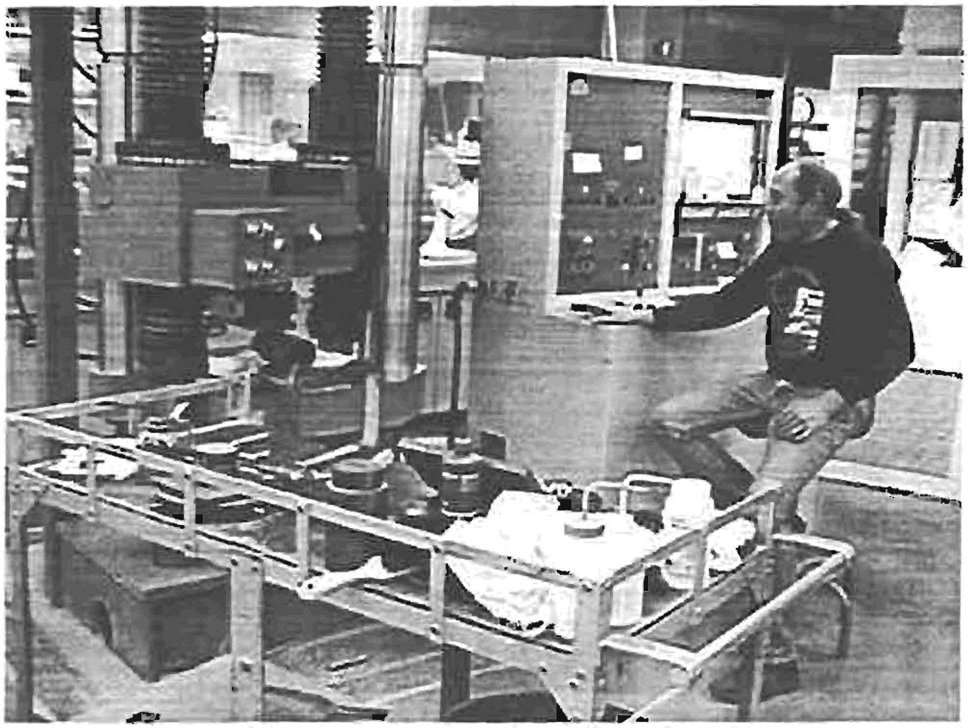


Photo 2: General view of shear testing setup

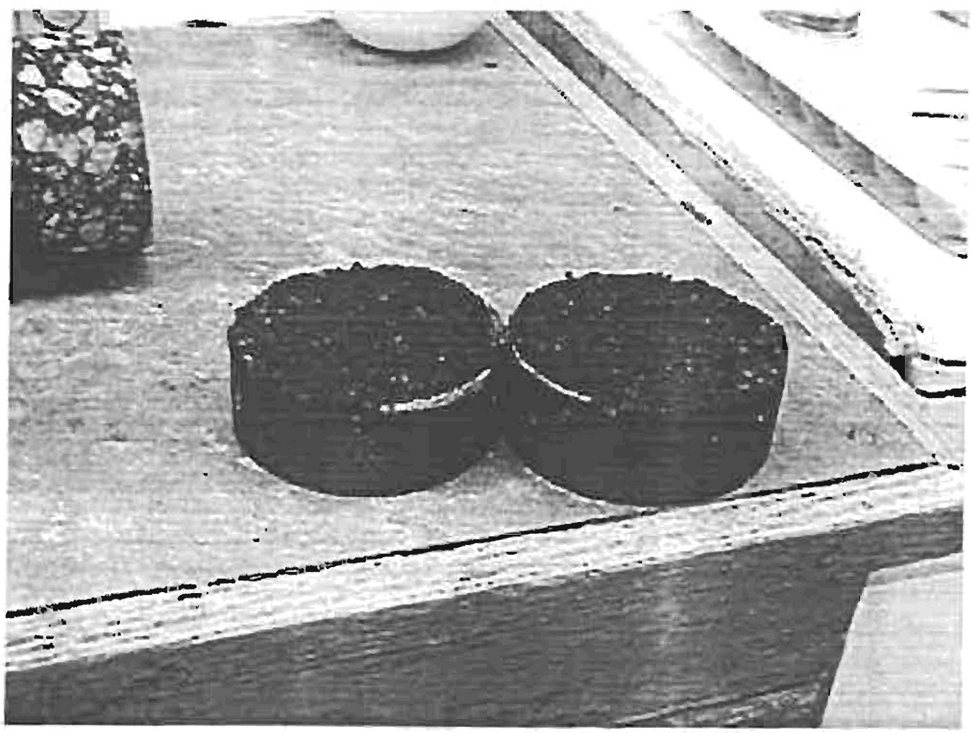


Photo 3: View of a typical sample after failure

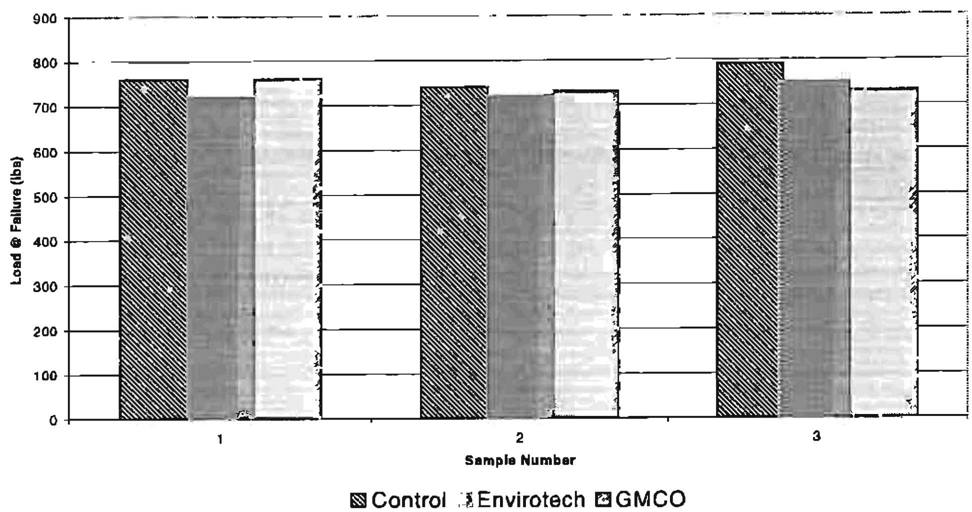
Table 5 below shows the result of the shear tests in tabular form, and figures 1, and 2 give a pictorial representation of these tests.

Table 5: Results of shear test

Mix No 1 334	Load @ Failure (lbs)	Mix No 2 326	Load @ Failure (lbs)
Control No 1	760	Control No 1	770
Control No 2	740	Control No 2	690
Control No 3	790	Control No 3	730
Envirotech No 1	720	Envirotech No 1	700
Envirotech No 2	720	Envirotech No 2	680
Envirotech No 3	750	Envirotech No 3	710
GMCO No 1	760	GMCO No 1	720
GMCO No 2	730	GMCO No 2	730
GMCO No 3	730	GMCO No 3	660

Figure 1

Shear Test for Mix No 1 (334)



Shear Test for Mix No 2 (326)

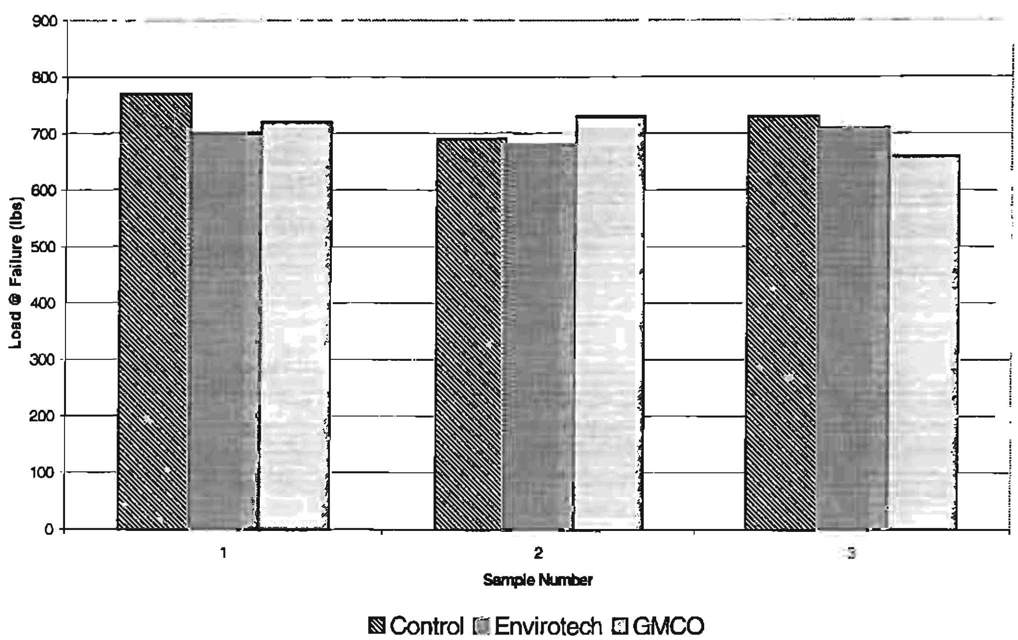


Figure 2

Table 6: Data Overview

	Average load @ failure		Maximum load @ failure		Minimum load @ failure		Range of load @ failure	
	Mix 334	Mix 326	Mix 334	Mix 326	Mix 334	Mix 326	Mix 334	Mix 326
Control	763	730	790	770	740	690	50	80
Envirotech	730	697	750	710	720	680	30	30
GMCO	740	703	760	730	730	660	30	70

Table 7above shows the average, maximum, minimum, and range of loads resulting in failure of the samples. Although the control samples indicate somewhat higher values, the magnitudes of the failure loads do not support the hypothesis that magnesium chloride has a deleterious effect on bond strength of an HBP overlay.

Effect of Magnesium Chloride Deicing Chemicals on Preformed Pavement Marking Tape

Members from Research, CDOT Maintenance, and a representative from the pavement marking tape manufacturer conducted a field test on bonding properties of pavement marking tapes placed on pavements that had previously been treated with chemical deicing material. CDOT personnel had expressed concerns that many failures had occurred when preformed marking tape was installed on asphalt pavements, which had received magnesium chloride for snow and ice control. CDOT has been using the chemical deicing agent for about five years in ever-increasing quantities. Residual magnesium chloride with its high affinity for moisture can lead to bond failures unless installation instructions from the manufacturer are observed. These instructions and guidelines indicate that successful installations are possible after the roadway, which had previously received the chemical, has either been cleansed by several rainstorms, or cleaned with a pressure washing.

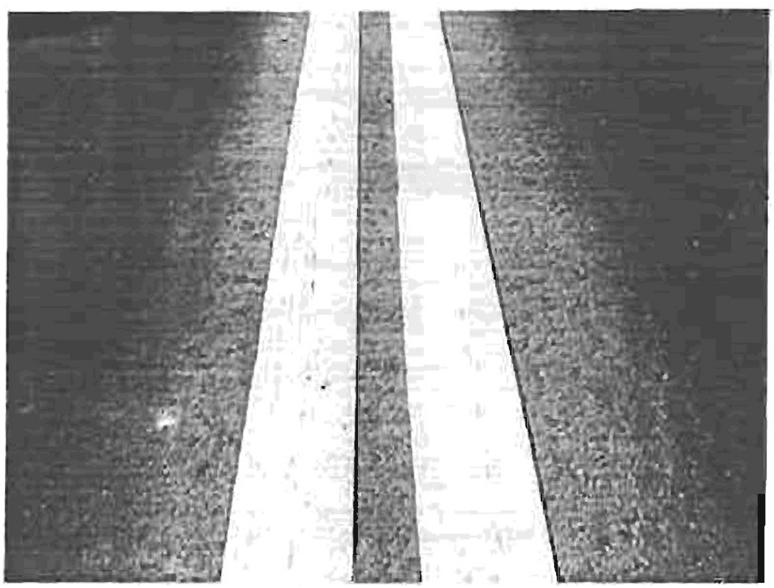
A test section on I-225 was selected for this experiment. A widened roadway section which serves a s temporary truck weighing station was pretreated with magnesium chloride at application rates of 20 and 60 gallons per lane-mile. These application rates represent the typical low and high application rates that are used by CDOT maintenance. The chemical was applied one week prior to the testing.

The photo above shows the magnesium chloride treated section. Minimal amount of water was used to wash several areas to achieve a dilution. Excess water was broomed off and dried before installing the PREMARK 20/20 marking tape, which is used in Colorado.

PREMARK 20/20 marking tape is being tested for bonding property

Surface debris is removed with a blower

A heat lance is used to remove excess moisture from pavement surface



Two types of tape are being installed: PREMARK 20/20 at right
And a new (not approved) metric version of PREMARK

In the photo the "heat indicators" (indentations) are shown which tell the installer when sufficient temperatures are reached. Also the residual magnesium chloride (light area surrounding the tape) is clearly visible, after all moisture has been removed.

Undiluted 60 gal/lane-mile magnesium chloride test section

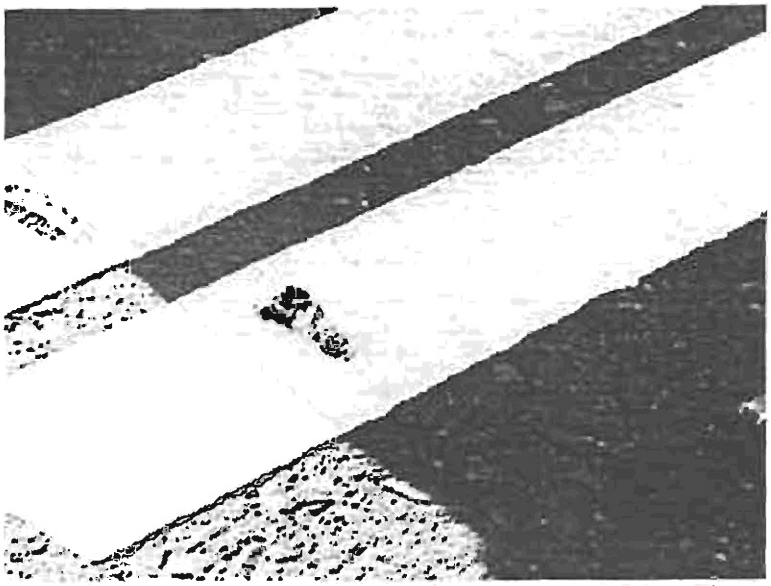
The "Chisel Test" shows a bond failure for the non-approved Metric version of the marking tape.

Marginal bond strength for the PREMARK 20/20(some asphalt aggregate is adhering to the tape) On the 60 gal/lane-mile application rate section

The results of the chisel test for PREMARK 20/20 on the right shows good bonding on the 20 gal/lane-mile undiluted test location. Failure is clear on the metric tape, which has no embedded aggregate on the tape. Note the residual magnesium chloride left after cleaning and drying.

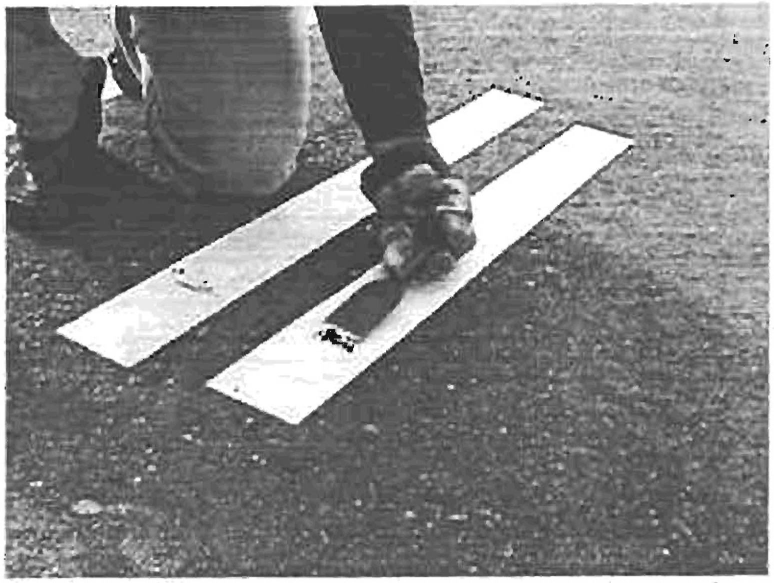
20 gal/lane-mile Test Section (diluted by washing and drying)

"Washed" segment of pavement still shows traces of magnesium chloride
Marking tape is placed between the residual mag chloride area


The washed section shows equally good bond properties

Test Section without magnesium chloride
(This site might have received some chemical during the previous winter season)


Heat lance is used to remove any potential moisture



The resulting chisel test indicates good bond strength
for the PREMARK 20/20. The metric tape shows marginal results
Although relative good bond strength is achieved. The tape itself
Seems to be brittle, and tends to crack.

General Conclusions:

The procedure applied in this testing represents the most severe conditions encountered in the installation of preformed pavement marking tape. In most instances, installation of this pavement marking tape would not normally be done immediately after an application of deicing chemicals. However, if such installation were necessary, dilution of the chemicals using a high-pressure rinse and drying, would diminish the chemical effects. The chisel tests indicate that all segments that were washed prior to the installation of the marking tape were successful. Even the low (20 gal per lane-mile) segment showed reasonable bond strength without washing. Only the high (60 gal per lane-mile) segment had bond failure. Furthermore, the application rates were probably higher than the standard 20 or 60 gal per lane-mile. The reason for this assumption is due to the configuration of the spray nozzles on the magnesium chloride distributor truck. The four nozzles tend to concentrate the spray in the wheelpaths. In an "Anti-icing" application it is assumed that an even distribution occurs over the entire width of a traffic lane. Some of the photos clearly show this heavier concentration (streaking) in the wheelpath area.

Although the metric version of the marking tape was not originally scheduled to be included in this testing, it provides additional information to the manufacturer, as well as to CDOT. Based on the outcome of the tests, it appears that the product is not ready for use at this time.

The results of this test only can be related to the use of magnesium chloride, and cannot be applied to other deicing/anti-icing programs without further investigation. It is assumed that sodium chloride, which is used in Colorado in conjunction with sand, could also lead to bond failures.

Appendix A

E-mail message that was sent to 42 State Dot libraries:

Subject: Effects of magnesium chloride deicing on asphaltic pavements

The Research Branch of the Colorado DOT is currently investigating possible adverse effects of magnesium chloride deicing materials on asphaltic pavements. There is a suspicion those pavements that received magnesium chloride prior to overlay, crack filling, or pavement marking projects, have exhibited failures for the respective treatments. Bond failure in overlays will promote shoving, crack filling material will not adhere, and permanent pavement marking will not adhere properly.
If your agency is using chemical deicing (or anti-icing) practices we would appreciate hearing about your experiences. We will gladly share the results of our investigation, which we plan on completing early next year.
I would appreciate if you could provide me with a contact person (phone number and/or E-mail address) in your organization's Material office who might have knowledge in this matter.

Sincerely,

Werner Hutter
Environmental Research Engineer
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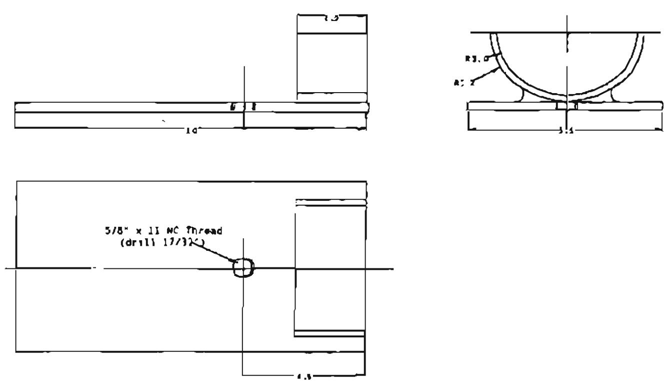
Research Branch
4201 East Arkansas Avenue
Denver, CO 80222
(303) 757-9975
e-mail: werner.hutter@dot.state.co.us

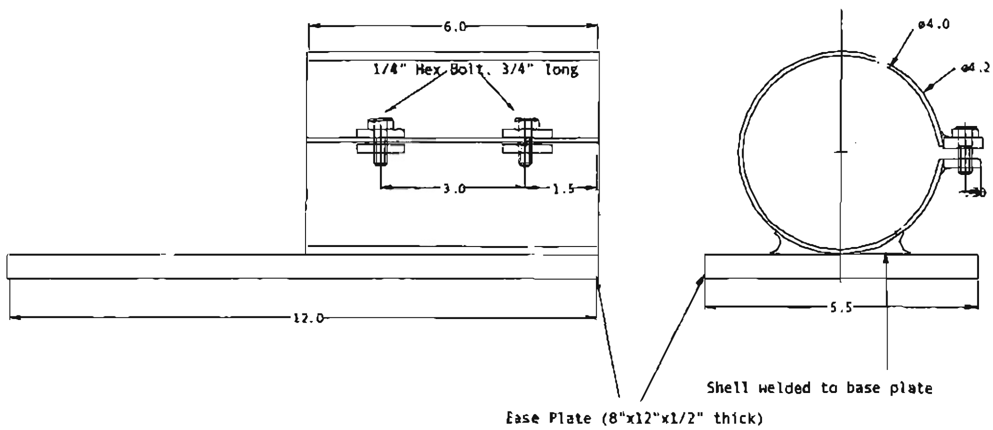
Shear Test Apparatus

Top Plate



Shear Test Jig for Magnesium Chloride Quick Study

Bottom Plate



B326

Colorado Department of Transportation
CDOT Form 360, N(max)
Staff Materials

Date Received: 11/3/199
Field Sample No: 102443
Sample Desc.: 1st Rep

Project No: SP 0761-171
Location: I76/120TH AVE. INTERCHANGE-PHASE 1
SubAccount No: 12055

SUPER PAVE
ITEM 403, PROJECT PRODUCED HOT BITUMINOUS PAVEMENT

Form 43 Date: 8/3/1998
Form 43 Field Sheet No: 105819
SP Grading: S
N(des): (109)

Refinery: FRO/CYN
SP Binder: PG 64-22
Contractor: Asphalt Specialties
Pit: Golden Lyons/Andesite/Del Camino

VOIDS PROPERTIES:
Exclude Specimen No.:

%AC Test Method: Pyrolysis Oven

	Bulk SG:	N(ini):	N(des):	N(max):	Extruded:
Specimen 1:	2.391	68.50	63.30	62.60	62.60
Specimen 2:	2.391	68.60	63.20	62.50	62.50
Specimen 3:	2.388	68.70	63.30	62.60	62.60

	Specimen 1:	Specimen 2:	Specimen 3:	Test Results:	Status:	Specifications:
% Asphalt:	5.70	5.70	5.70	5.70	NG	5.20 +/- 0.30
Max Sp. Gr. T-209:	2.463	2.463	2.463	2.463	OK	2.46 +/- 0.01
Voids @ N(ini):	11.30	11.57	11.67	11.51	OK	> 11.0%
Voids @ N(des):	4.01	4.01	4.14	4.05	OK	2.8 to 5.2
Voids @ N(max):	2.94	2.94	3.06	2.98	OK	> 2.0%
Voids Measured:	2.94	2.94	3.06	2.98	N/A	N/A
VMA @ N(des):	15.6	15.6	15.7	15.6	OK	>= 14.4
VFA @ N(des):	74.2	74.2	73.6	74.0	OK	65.0 to 75.0

GRADATION RESULTS:

Sieve mm (in):	Test Results: % Passing	Status:	Job Mix: % Passing:	Tolerance:
37.5 (1 1/2)				
25.0 (1)				
19.0 (3/4)	100		100	
12.5 (1/2)	89	OK	88	6
9.5 (3/8)	79	OK	79	6
4.75 - #4	67	OK	64	5
2.36 - #8	53	NG	46	5
1.18 - #16	39		31	
600 mic. - #30	26	NG	21	4
300 mic. - #50			13	
150 mic. - #100	10		8	
75 mic. - #200	6.1	OK	5.3	2.0

AGGREGATE PROPERTIES:

N(des): (109)

	Test Result:	Status:	Job Mix:
Angularity CP L-5113:			45 Min.
Bulk SG of Aggregate:	2.640		
Bulk SG of Fine Aggregate:	2.640		

LOTTMAN RESULTS:
Sets Swapped: NO

	Results:	Status:	Job Mix:
Wet Avg. T.S.:	544		
Dry Avg. T.S.:	615	OK	205 Min.
% Voids:	7.36		
% Saturation:	84		
T.S. Retained:	88	OK	70 Min.

STABILITY (For Information Only):

	Results:	Status:	Job Mix:
Stability:			42 Min.
Voids:			2.80 to 5.20

Date Reported: 12/10/199

Region Lab Report

Gary M. Strasser (303) 757-9724
Flexible Pavement Engineer

A-3

SUPERPAVE 98

B334

Colorado Department of Transportation
CDOT Form 360, N(max)
Staff Materials

Date Received:	11/19/199	Project No:	NH 093A-004
Field Sample No:	92697	Location:	SH 93 N.
Sample Desc.:	1st 10K	SubAccount No:	11211

SUPER PAVE
ITEM 403, PROJECT PRODUCED HOT BITUMINOUS PAVEMENT

Form 43 Date:	8/13/1998	Refinery:	FRO/CYN
Form 43 Field Sheet No:	105809	SP Binder:	PG 64-22
SP Grading:	SG	Contractor:	Asphalt Paving
N(des):	(96)	Pit:	AP #1

VOIDS PROPERTIES:

Exclude Specimen No.:

%AC Test Method: Pyrolysis Oven

	Bulk SG:	N(ini):	N(des):	N(max):	Extruded:
			Heights:		
Specimen 1:	2.516	113.20	101.30	100.00	100.00
Specimen 2:	2.519	113.10	101.00	99.70	99.70
Specimen 3:	2.510	113.30	101.60	100.10	100.10

	Specimen 1:	Specimen 2:	Specimen 3:	Test Results:	Status:	Specifications:
% Asphalt:	4.46	4.46	4.46	4.46	OK	4.60 +/- 0.30
Max Sp. Gr. T-209:	2.595	2.595	2.595	2.595	OK	2.59 +/- 0.01
Voids @ N(ini):	14.36	14.42	14.56	14.45	OK	> 11.0%
Voids @ N(des):	4.30	4.17	4.72	4.39	OK	2.8 to 5.2
Voids @ N(max):	3.06	2.92	3.29	3.09	OK	> 2.0%
Voids Measured:	3.06	2.92	3.29	3.09	N/A	N/A
VMA @ N(des):	14.5	14.4	14.8	14.6	OK	>= 13.8
VFA @ N(des):	70.3	71.0	68.2	69.8	OK	65.0 to 75.0

GRADATION RESULTS:

Sieve mm (in):	Test Results: % Passing	Status:	Job Mix: % Passing:	Tolerance:
37.5 (1 1/2)	100		100	
25.0 (1)	94		94	
19.0 (3/4)	90	OK	88	6
12.5 (1/2)	74	OK	75	6
9.5 (3/8)	67	OK	67	6
4.75 - #4	45	OK	45	5
2.36 - #8	29	OK	28	5
1.18 - #16	20		18	
600 mic. - #30	15	OK	13	4
300 mic. - #50			10	
150 mic. - #100	9		7	
75 mic. - #200	7.6	OK	6.0	2.0

LOTTMAN RESULTS:

Sets Swapped: NO

	Results:	Status:	Job Mix:
Wet Avg. T.S.:			
Dry Avg. T.S.:			205 Min.
% Voids:	0.00		
% Saturation:			
T.S. Retained:			70 Min.

AGGREGATE PROPERTIES:

N(des): (96)

	Test Result:	Status:	Job Mix:
Angularity CP L-5113:			45 Min.
Bulk SG of Aggregate:	2.774		
Bulk SG of Fine Aggregate:	2.755		

STABILITY (For Information Only):

	Results:	Status:	Job Mix:
Stability:			0 Min.
Voids:			2.80 to 5.20

Date Reported: 12/7/199

Region Lab Report

Gary M. Strasser (303) 757-9724
Flexible Pavement Engineer

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