EFFECT OF DE-ICING CHEMICALS ON AIR-ENTRAINED CONCRETE AT EARLY AGES

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ABSTRACT: Seven newly constructed concrete pavement sections were studied for two winter seasons to observe whether salt, sand, chloride, and various combinations of these agents, would cause pavement scaling. The data collected included the aggregate source, curing method, cement brand and source, air entraining agent, air content, and the de-icing materials used. Based upon the Laboratory's observations, concrete pavement constructed to Department specifications will not scale as a result of early application of de-icing chemicals.

KEY WORDS: deicing, concrete pavement durability, cold weather operations, chemical deicing agents, air entrained concrete.

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This research project, initiated by W. W. McLaughlin on December 13, 1957, was to establish a study of the performance of new concrete pavements subjected to ice removal chemicals.

The resistance of concrete to scaling effects was greatly enhanced with the advent of air-entrained concrete, as evidenced by the laboratory and field experience of the past 25 years. Information for determining the minimum amount of curing required before de-icers become harmful to air-entrained concrete pavements is limited. One reliable detailed laboratory study of this problem has been reported by Kleiger.[1] The results are partially summarized in Table 1 and the statments below:

TABLE 1

Cement Type*	Percent CaCl (accelerator)	Minimum Curing Period, days		
		73F	40F	25F
I	0	7	15	60+
	2	7	7	30
II	0	7	12	35
	2	7	7	28
III	0	7	7	24

*A/E Agent added at mixer to entrain $5\pm1/2$ percent air.

"Considering the 73 F and 40 F temperatures, it is evident that the minimum curing periods for these air-entrained laboratory concretes are approximately the same as normally required by highway departments to insure adequate development of strength before opening to traffic... --These minimum curing periods might be increased somewhat in recommendations for field practice. In special areas, a factor of 3 seems justified to allow for additional influences on field concrete. --A curing temperature below freezing

(25) resulted in excessively long curing periods. In some cases where adequate scale resistance was obtained, the concrete is unacceptable because of low strength." The recommendations set forth in this report seem to be the most comprehensive available.

Varying hypotheses have been advanced as to the exact nature of concrete-scaling. These hypotheses range from strictly a physical or chemical effect to a combination of the two. Evidence is available corroborating all these hypotheses. However, most of the more recent experimental studies agree, that scaling is primarily a physical phenomenon rather than a chemical effect. Two well substantiated observations support this general conclusion:

1. Chemically dissimilar de-icing materials produce the same type of scaling.

2. Intermediate concentrations of de-icing chemicals are more destructive than highly concentrated or very dilute solutions. (2)

Based on the foregoing evidence it seems more likely that the mere presence of de-icing agents contributes more to concrete scaling than their application rates or concentrations.

The decision to revise winter maintenance procedures evolved from a meeting, December 11, 1957, attended by Howard E. Hill, C. A. Weber, C. B. Laird, E. D. Suino, S. W. Dubee, and W. W. McLaughlin, where it was agreed that "..the protection of human life and movement of highway traffic outweigh the possible damage to the surface of concrete pavement by the use of straight chemicals for ice control." Supporting this, W. W. McLaughlin, Testing and Research Engineer, said: "Portland cement concrete pavement cast and properly cured by the end of September will not be adversely affected by ice control chemicals used during the following winter."

District Maintenance Engineers were advised by special instruction letter, dated December 17, 1957, that "... on any portland cement concrete pavements which were completed prior to September 1, normal snow and ice control procedures could be used in the following winter. On sections of pavement, or structures completed after September 1, caution should be used in the application of raw chemicals. Short sections, completed after September 1, but lying in an extensive section of road which was completed prior to September 1 may be treated as the major portion is treated." The foregoing rescinded an earlier instruction dated November 28, 1952 which said: "... only treated abrasives should be used on portland cement concrete pavements during the first year after construction."

Eight newly constructed concrete pavement sections were originally scheduled for study under this Research Project:

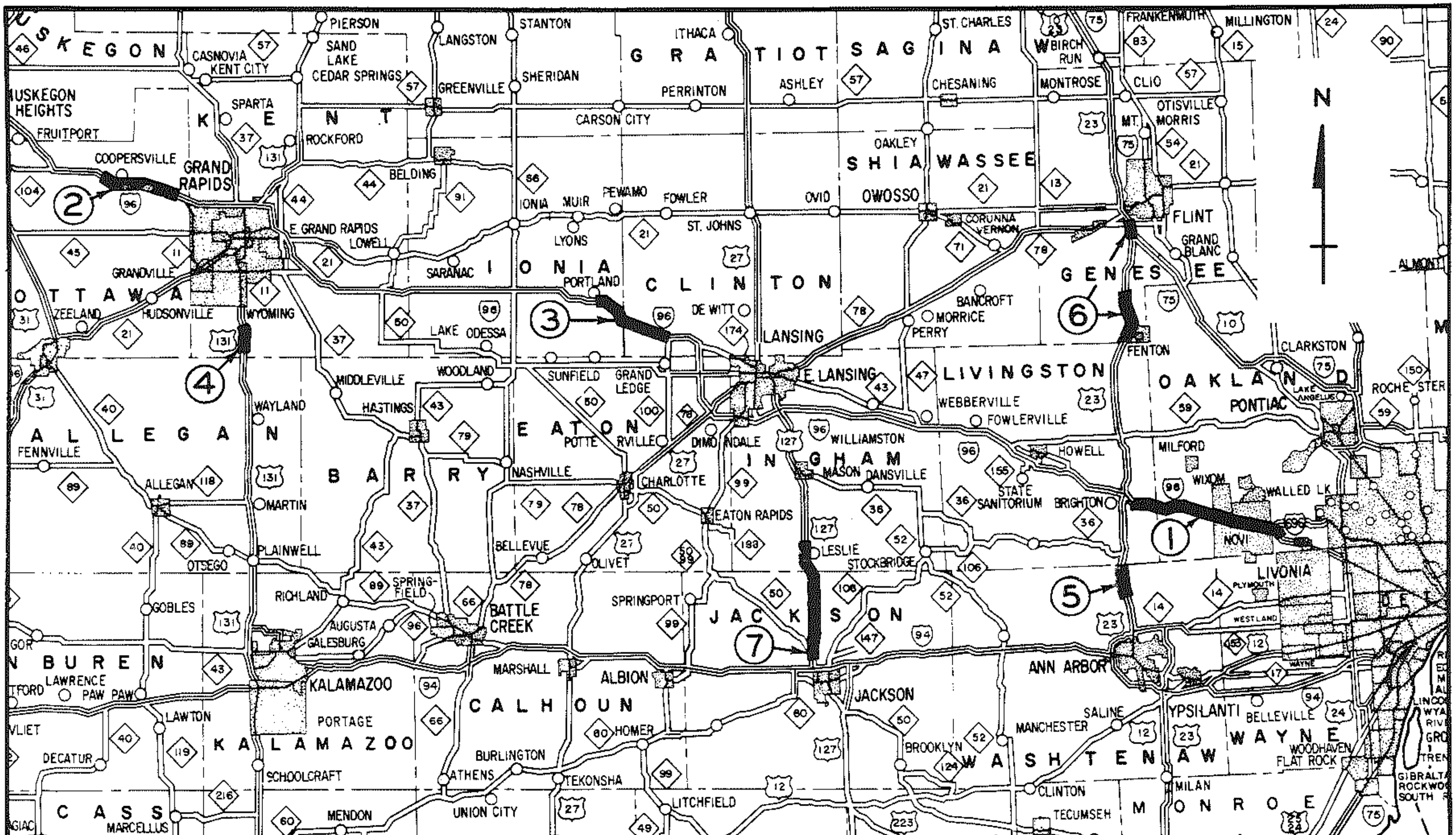
1. I 96, Brighton east to Farmington
2. I 96, Marne west to Coopersville
3. I 96, M100 west to Portland
4. US 131, Grand Rapids 100th St. north to 28th St.
   (data available for pavement from 100th St. north to 76th St.)
5. US 23, Territorial Rd. north to 8 Mile Rd.
6. US 23, Fenton north to M 78
   (data only available for pavement from Jct US 10 and I 75 to north of Bristol Rd, and Fenton north to south of Thompson Rd.)
7. US 127, M 50 north to north of Leslie
8. M 37, Sparta south
   (Section eight not included in the study as it was not completed until the summer of 1958.)

Figure 1 is a layout showing locations of selected test pavements.

Maintenance superintendents of the seven sections were supplied with forms and instructed to record quantities, frequency, and type of treatment for all chemical applications during the first two winter seasons, i.e., 1957-58, and 1958-59. From this information, average rates of chemical application per lane mile (11- or 12-ft wide lanes) were computed and tabulated with other pertinent construction data in Table 2.

Each of these seven pavement sections have been under periodic surveillance by Laboratory personnel since their completion. This surveillance was conducted to note and record changes in the surface condition of the concrete, particularly any indication of surface scaling, the primary concern of this study; scaling being defined as the deterioration, or "peeling away", of the surface of portland cement concrete. After two winter seasons, initial surveys indicated that no scaling existed on the pavement sections under study. A final survey after ten winters of service shows that there is still no scaling.

There was considerable variation between and within test areas with regard to curing time or age of concrete at the date of initial de-icing application. Portions of some projects were actually completed during the 1956 construction season and exposed to a full season (1956-57) of freeze-thaw conditions prior to opening to traffic the following (1957-58) season. Table 3 shows the percentage of concrete surface completed for each project during each month immediately preceding the first winter season (1957-58) when de-icing agents were first applied.



<u>Reference Key</u>

1. I 96 Brighton to Farmington
   IN 63-29, C9R, C10RO & C11RO
   I 63022, C1RN
   I 47064, C2RN
2. I 96 Marne to Coopersville
   I 70063, C1RN, C2UN & C3RN
3. I 96 M 100 to Portland
   BI 19022, C1RN
   BI 34044, C1RN
4. US 131, 100th St. to 76 th St.
   M 41-88, C2
5. US 23, Territorial Rd. to 8 Mile Rd.
   M 81075, C1RN
6. US 23, Fenton to M 78 (part)
   BM 25031, C1RO, C2RO
7. US 127, M 50 to N of Leslie
   BM 38131, C1RN, C2RN & C3RN
   BM 33031, C1RN & C2RN

Figure 1. Project location.

TABLE 2
CONSTRUCTION AND MAINTENANCE DATA

Location	Project Number	Lane		Curing Method	Aggregate Source		Cement Brand and Source	Air-Entraining Agent	Average Air Content(1) percent	Date			De-Icing Material Application Rate (Average Units Per Lane Mile)	
		Length mi	Width ft		Fine	Coarse				Final Pour	Opened to Traffic	Initial De-Icing	Winter 1957-58	Winter 1958-59
I-96 Brighton east to Farmington	IN 63-29, C9R	30.420	12	Trucson Tru-Cure and Spra-Cure	American Agg. Corp., pit no. 47-3	American Agg. Corp., pit no. 47-3	Peerless Vinsol Resin, Detroit Peerless slag, Detroit	Darex	5.5	Sept. '57	Dec. '57	Dec. '57 (2)	0.50 cyds sand (50%) and salt (50%) 0.34 cyds salt 79.1 gal liquid chloride (26%)	1.06 cyds sand (22%), salt (78%) 0.59 cyds sand (93%), chloride (7%) 0.55 cyds salt 71.4 gal liquid chloride (27%)
	IN 63-29, C10RO	21.756	12	Membrane and straw	C. VanEvery & Son, pit no. 47-30 American Agg. Corp., pit no. 47-3	C. Van Every & Son, pit no. 47-30 American Agg. Corp., pit nos. 47-3, 63-4	Huron Servicized, Wyandotte Huron, and Huron IS-A, Wyandotte	Darex and Servicide	5.6	June '57	Dec. '57	Dec. '57		
	IN 63-29, C11RO	8.216	12	Membrane	American Agg. Corp., pit no. 47-3	American Agg. Corp., pit no. 47-3	Wyandotte IS-A, Wyandotte	Darex, Protex and Servicide	5.2	July '57	Dec. '57	Dec. '57		
	I 63022, C1RN	1.828	12	Spra-Cure, white	American Agg. Corp., pit no. 47-3	American Agg. Corp., pit no. 47-3	Huron Vinsol Resin, Wyandotte Huron slag Vinsol Resin, Wyandotte	Protex	5.1	June '57	Dec. '57	Dec. '57		
	I 47064, C2RN	16.504	12	Spra-Cure, white	American Agg. Corp., pit no. 47-3	American Agg. Corp., pit no. 47-3	Huron Vinsol Resin, Wyandotte Huron slag Vinsol Resin, Wyandotte	Protex	5.2	June '57	Dec. '57	Dec. '57		
I-96 Marne east to Coopersville	I 70063, C1RN	8.564	12	Membrane	Postma Gravel Co., pit nos. 41-29, 41-40	Postma Gravel Co., pit nos. 41-29, 41-40 Construction Agg. Corp., pit no. 70-9	Huron AE, Muskegon	Protex	5.0	Nov. '57	Dec. '57	Nov. '57	0.86 cyds sand + 0.91 sacks chloride 2.0 sacks salt 35.7 gals liquid chloride	0.93 cyds sand and chloride (3 sacks per cyd of sand) 53.9 gal liquid chloride
	I 70063, C2UN	8.016	12	Membrane and straw	Postma Gravel Co., pit nos. 41-29, 41-40	Postma Gravel Co., pit nos. 41-29, 41-40 Construction Agg. Corp., pit no. 70-9	Huron AE, Muskegon	Protex	5.1	Nov. '57	Dec. '57	Nov. '57		
	I 70063, C3RN	14.936	12	Membrane and straw	Postma Gravel Co., pit no. 41-40	Postma Gravel Co., pit nos. 41-29, 41-40 Construction Agg. Corp., pit no. 70-9	Huron AE, Muskegon	Protex	5.2	Nov. '57	Dec. '57	Nov. '57		
I-96 M 100 west to Portland	BI 19022, C1RN BI 34044, C1RN	35.444	12	Spra-Cure, white	Pickitt & Schreur pit no. 34-36	Pickitt & Schreur pit no. 34-36	Huron AE, Wyandotte	Protex and Darex	5.7	Oct. '57	Jan. '58	Jan. '58	0.23 cyds sand 0.48 tons salt 0.01 tons chloride	0.45 cyds sand 0.16 tons salt 0.02 tons chloride
US 131 100th St. north to 76th St.	M 41-88, C2	10.705	12	Membrane	Grand Rapids Gravel Co. pit no. 41-1	Grand Rapids Gravel Co., pit no. 41-1	Huron AE, Muskegon	Darex	5.4	May '57	Jan. '58	Jan. '58	0.17 cyds sand + 0.54 sacks salt + 0.50 sacks chloride 1.30 sacks salt 1.01 sacks chloride 74.9 gal liquid chloride	0.26 cyds sand (50%), salt (50%) 0.25 cyds sand (1/3), salt (1/3), chloride (1/3) 1.40 sacks salt 1.35 sacks chloride 46.0 gal liquid chloride
US 23 Territorial Rd. north to Eight Mile Rd.	M 81075, C1RN	14.288	12	White membrane, paper, and straw	American Agg. Corp., pit no. 47-3	American Agg. Corp., pit no. 47-3	Peerless AE, Detroit	--------	4.9	June '57 Dec. '57	all winter Jan. '58	Nov. '57 Dec. '57	0.80 cyds sand and chloride (stockpile mix-37.9 lb add. chloride)(3) 0.41 tons no 2 salt 213.9 gal liquid chloride(4)	0.34 cyds sand and chloride (stockpile mix+16.4 lb add. chloride) 0.47 cyds no 1 salt
US 23 Jct. US 10 and I 75 to north of Bristol Rd.	BM 25031, C1RO	7.036	12	Permite and Straw	Groveland Gravel Co. pit no. 63-54	American Agg. Corp., pit no. 63-4 Groveland Gravel Co., pit no. 63-54 Leffler, pit no. 63-52	Peerless, Port Huron	Darex	5.4	Nov. '57	Dec. '57	Dec. '57	0.45 tons salt + 0.34 sacks chloride 0.56 tons salt 0.20 sacks chloride	0.44 tons salt + 0.12 sacks chloride 0.41 tons salt 0.26 sacks chloride
US 23, Fenton N to S of Thompson Rd.	BM 25031, C2RO	20.884	12	Spra-Cure	American Agg. Corp., pit nos. 47-3, 63-4	American Agg. Corp., pit nos. 47-3, 63-4	Huron, Saginaw Huron, Detroit	Darex	5.3	Oct. '57	Dec. '57	Dec. '57		
US 127, I-94 north to north of Leslie	BM 38131, C1RN	11.592	11	White membrane	Bundy Hill Gravel Co. pit no. 30-35	Bundy Hill Gravel Co., pit no. 30-35	Peninsular, Cement City	Darex	5.9	Oct. '57	Dec. '57	Dec. '57	0.87 cyds sand and chloride 0.96 cyds sand, salt, and chloride 0.32 cyds sand and salt 0.36 cyds salt	0.92 cyds sand and chloride 0.34 cyds sand and salt 0.40 cyds salt
	BM 38131, C2RN	8.028	11	Tru-Cure, white Spra-Cure, white	Bundy Hill Gravel Co. pit no. 30-35	Bundy Hill Gravel Co., pit no. 30-35	Peninsular, Cement City	Darex	5.2	Oct. '57	Dec. '57	Dec. '57		
	BM 38131, C3RN	23.216	11	Spra-Cure, white	Angell Const. Co. pit nos. 33-61, 33-63	American Agg. Corp., pit no. 47-3	Peninsular, Cement City	Darex	5.5	Oct. '57	Dec. '57	Dec. '57		
	BM 33031, C1RN	4.496	11	Spra-Cure, white	Angell Const. Co. pit nos. 33-61, 33-63	American Agg. Corp., pit no. 47-3	Peninsular, Cement City	Darex	4.9	Oct. '57	Dec. '57	Nov. '57		
	BM 33031, C2RN	7.966	11	Spra-Cure, white	Angell Const. Co. pit nos. 33-61, 33-63	American Agg. Corp., pit no. 47-3	Peninsular, Cement City	Darex	5.4	Oct. '57	Dec. '57	Nov. '57		

(1) Construction field test data.
(2) Chemical de-icing materials not applied on that portion of roadway constructed after 9-1-57 until 1-21-58.
(3) The term "stockpile mix", as per S. W. Dubee, Road Maintenance Engineer, normally refers to the ratio of 100 lbs calcium chloride per cyd of sand.
(4) Removing 1/2 inch ice prior to opening.

TABLE 3
CONCRETE PAVEMENT CONSTRUCTION PROGRESS, JULY THROUGH DECEMBER 1957

Project Location and Number	Percent of Completed Surface					
	July	Aug.	Sept.	Oct.	Nov.	Dec.
I 96, Brighton to Farmington.						
IN 63-29, C9R(1)	78	84	92	98	98	98
IN 63-29, C10RO(2)	97	98	100	100	100	100
IN 63-29, C11RO	59	94	97	99	99	99
I 63022, C1RN	97	99	100	100	100	100
I 47064, C2RN	97	99	100	100	100	100
I 96, Marne to Coopersville.						
I 70063, C1RN	--	8	73	90	99	99
I 70063, C2UN	--	8	73	90	99	99
I 70063, C3RN	--	8	73	90	99	99
I 96, M100 to Portland,						
BI 19022, C1RN	--	26	75	92	96	99
BI 34044, C1RN	--	26	75	92	96	99
US 131, 100th St. to 76th St.						
M 41-88, C2	100	100	100	100	100	100
US 23, Territorial Rd. to Eight Mile Rd.						
M 81075, C1RN(3)	82	87	87	94	97	98
US 23, Fenton to M 78.						
BM 25031, C1RO(4)	--	11	11	20	53	53
BM 25031, C2RO	--	--	14	90	97	98
US 127, M 50 to N of Leslie.						
BM 38131, C1RN	--	--	35	90	93	95
BM 38131, C2RN	--	--	--	95	97	98
BM 38131, C3RN	--	20	50	75	85	90
BM 33031, C1RN	--	20	50	75	85	90
BM 33031, C2RN	--	20	50	75	85	90

(1) 78 percent on 10-25-56
(2) 65 percent on 11-29-56
(3) Percentages include project 47011, C1
(4) Percentages include project 25031, C3

Average air contents, reported in Table 2, were weighted on the basis of applicable pour lengths. Some air content values, those which failed to meet allowable tolerances and required adjusting of the concrete batch to comply with specifications, were not considered in computing the mean air content value for any of the test areas. These values were excluded because adjustments were probably made immediately after testing, consequently no weighting factor (length of pour) could be applied. Since test pavements were selected after they were constructed, information reported in the tables was compiled from routine testing and construction reports with no additional or special tests conducted for research information.

The test pavements show some variation in surface texture or shading that is suggestive of light scaling. Upon close inspection these imperfections appear attributable to variable concrete mixes or finishing methods and are confined to small areas within the test pavements. It has been shown that in addition to obtaining proper air-entrainment, the basic fundamentals of quality concrete must be followed to ensure scale-resistant concrete. [3] These include low water-cement ratio, low slump, proper finishing, adequate curing, and the use of sound aggregates. Many of the observed surface imperfections appear to be deficiencies that could fall within one of these categories. Some imperfections were noted on the initial surveys and, as such, cannot be associated in any way with de-icing chemicals.

The most significant variation in surface deterioration noted between test pavements was in pop-out frequency. However, an entirely new and separate study would be required to determine whether there is any association between de-icing chemicals and pop-out occurrences.

Conclusion

Based upon laboratory tests conducted by other states and by field investigations conducted in Michigan, it appears that concrete pavements constructed to Department specifications will not scale as a result of early treatment with de-icing chemicals. However, minimum concrete curing times as given in the preceeding text should elapse before such chemicals are applied.

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