Investigation of PCC Pavement Sections on I-29 in Pottawattamie County

Final Report
for
MLR-06-01

March 2007

Highway Division

Iowa Department Of Transportation

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8. ABSTRACT

Early deterioration has shown up in a number of Iowa PCC pavements placed between 1986 and 1994. Research has shown that inadequate air content and spacing factors have contributed to the deterioration. Ettringite infilling of air voids is nearly always noted in cores obtained from pavements exhibiting deterioration. This research is to document the early deterioration on I-29 in Pottawattamie county from MP 59 to 72 in both directions.

9. KEY WORDS

Air content
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TABLE OF CONTENTS

DISCLAIMER

Introduction and Objective

Early deterioration has shown up in a number of Iowa PCC pavements placed between 1986 and 1994. Research[1,2,7] has shown that inadequate air content and spacing factors have contributed to the deterioration. Infilling of the air voids with ettringite is typically noted on pavements exhibiting deterioration as indicated by previous research[3,4]. This research is to document the early deterioration on I-29 in Pottawattamie County from MP 59 to 72 in both directions.

The northbound pavement placed in 1992 has exhibited staining at the joints since 1998 and some patching has occurred north of milepost 67. The southbound sections placed in 1994 exhibited staining at the joints in 2000 and spalling is now occurring across the joints. A one mile research test section was also placed in 1994 and is in excellent condition. The southbound sections placed in 1995 are also in excellent condition.

Hardened air analysis of cores revealed moderately low air content and borderline spacing factors for the pavement placed in 1992, very low air content and poor spacing factors for the pavement placed in 1994, and the one mile research test section placed in 1994 and the pavement placed in 1995 have excellent air content and spacing factors.

Project Location

The projects are located on I-29 in Pottawattamie county as shown in Figure 1. The northbound pavement was placed in 1992 and the south bound pavement was broken into four sections placed in 1994 and 1995 as shown in Table 1.

Figure 1 Project Location Map

Table 1 I-29 Pavement Sections

Year	Project No.	MP	Dir
1992	IM-29-4(39)56—13-78	57.70 to 72.45	NB
1994	IM-29-3(38)58—13-78	57.70 to 60.80 & 65.50 to 70.84	SB
1995	IM-29-3(52)61—13-78	60.80 to 65.50 & 70.84 to 72.45	SB

Materials

The general mix design and materials used can be found in Table 2. A summary of the plant reports for each project can also be found in the Appendix.

Table 2 Project Material Sources

Year	Mix	Cement	Fly Ash	Fine Aggregate	Coarse Aggregate
1992	C-5WR-C15	Ash Grove I/II	Council Bluffs #3	Oreapolis	Weeping Water
1994	C-6WR-C15 C-3WR	Ash Grove I/II Ash Grove IP*	Council Bluffs #3 N/A	Hartford/Oreapolis Hartford/Oreapolis	Weeping Water Weeping Water
1995	C-4-WR-C10	Ash Grove IP	North Omaha	All Spec	Weeping Water

*Research test section placed Station 282+08 to 231+14 SB.

Pavement Conditions

1992 Pavement Northbound

The pavement placed in 1992 began to exhibit staining at the joints in 1998. Cores were obtained in 1999 to investigate the cause of the staining. In 1999, it was noted that the staining was more prevalent in the sections containing Council Bluffs fly ash from milepost 66 north (Honey Creek interchange). The area with the worst staining occurred at approximately milepost 67.43 and minimal staining was occurring at milepost 69.40. (See Figures 2 to 5) The sections containing Port Neal fly ash did not exhibit staining at that time.

In 1999, cores obtained from the project were subjected to freeze-thaw testing in accordance with ASTM C666 method B. Two of the cores failed at 180 cycles. Failure of cores in freezing and thawing has been noted in previous research[1]. Results may be found in the Appendix.

Figure 2. 1992 NB – MP 67.43 Overall condition 1999


Figure 3. 1992 NB – MP 67.43 Joint close up 1999


Figure 4. 1992 NB – MP 69.40 Overall condition 1999

Figure 5. 1992 NB – MP 69.40 Joint close up condition 1999

In 2006, staining at the joints had progressed in the sections containing Council Bluffs fly ash north of milepost (Honey Creek Interchange). (See Figures 6-7) In the sections containing Port Neal fly ash staining at the joints was beginning to appear. (See Figure 8)

Figure 6. 1992 NB – MP 67.1 Council Bluffs Fly Ash Section Overall condition 2006

Figure 7 1992 NB – MP 67.1 Council Bluffs Fly Ash Section Joint Close-up 2006

Figure 8. 1992 NB – MP 62 Port Neal Fly Ash Section Overall condition 2006

1994 Pavement Southbound

The pavement placed in 1994 began to exhibit staining at the joints in 2000. Cores were obtained in 2002 to investigate the cause of the staining. In 2002, staining was noted throughout both sections placed in 1994. (See Figures 9-10) Some spalling of the joints was also noted in some areas. In 2006, the pavement had deteriorated significantly and many of the joints have had patch repairs. (See Figures 11-14)

Figure 9. 1994 SB – MP 59.4 Joint close up condition 2002

Figure 10. 1994 SB – MP 70.5 Joint close up condition 2002

Figure 11. 1994 SB – MP 70 Overall condition 2006

Figure 12. 1994 SB – MP 70 Joint close up condition 2006

Figure 13. 1994 SB – MP 66 Overall condition 2006

Figure 14. 1994 SB – MP 66 Joint close up condition 2006

1995 Pavement Southbound
The pavement sections placed in 1995 are all in excellent condition with no staining at the joints. (See Figures 15-17)

Figure 15. 1995 SB – MP 65 Joint close up condition 2002

Figure 16. 1995 SB – MP 65 Overall condition 2006

Figure 17. 1995 SB – MP 65 Joint close up condition 2006

Project Data – Plastic Air Content and w/c ratio

Plastic air content was determined on the projects before the paver using the pressure meter. The specification for plastic air content was 6±1% until 1994 and 7±1% from 1995 and later. The w/c ratio is an average for the day reported on the plant report. The w/c ratio specification was a maximum of 0.488 for the mixes used. The average air content and w/c ratio for each project are shown in Table 3.

Table 3. Project Testing Data

Year	Project No.	Dir	Average Plastic Air Content	Average w/c ratio
1992	IM-29-4(39)56—13-78	NB	7.1%	0.384
1994	IM-29-3(38)58—13-78	SB	6.3%	0.425
1995	IM-29-3(52)61—13-78	SB	7.6%	0.471

Hardened Air Analysis

Cores were obtained from the midpanel (MP) and joints (JT). For the 1992 and 1994 projects, areas exhibiting distress were targeted. Samples were obtained from the top (T) and bottom (B) of each core and hardened air analysis was performed by the MARL laboratory at ISU using the scanning electron microscope (SEM) (Figure 18) and image analysis. Infilling of air voids with ettringite was noted in the cores from the 1992 and 1994 pavements and was more prevalent in the top of the cores.

Figure 18. Scanning Electron Microscope (SEM)

Hardened air was measured on core slices obtained from each project. Using a method developed in previous research[4], the SEM is used to sample 20 images at 40X from a polished sample. The images are then analyzed using image analysis software to determine bubble distribution. The hardened air results using the SEM and image analysis are shown in Table 4.

Table 4. Air Content and Spacing Factor by Project

Year/Location	Mortar Air T, %	Mortar Air B, %	Concrete Air T, %	Concrete Air B, %	Spacing Factor T, mm	(in)	Spacing Factor B, mm	(in)
NB 1992 MP 68 JT	6.2	9.3	4.30	6.50	0.194	0.0076	0.168	0.0066
NB 1992 MP 68 MP	8.1	10.4	5.70	7.30	0.184	0.0072	0.147	0.0058
SB 1994 MP 70 JT	1.4	3.8	1.01	2.77	0.383	0.0151	0.285	0.0112
SB 1994 MP 70 MP	5.9	7.5	4.33	5.53	0.198	0.0078	0.185	0.0073
SB 1995 MP 65 JT	11.3	12.7	8.44	9.53	0.133	0.0052	0.117	0.0046
SB 1995 MP 65 MP	8.7	10.2	6.44	7.59	0.099	0.0039	0.089	0.0035

Discussion of Hardened Air Test Results

Concrete by nature is a porous material. In order to make a workable plastic concrete, the total mix water is normally much greater than that needed for hydration. When the original excess mix water not used in the hydration process is lost due to evaporation, voids, or capillary pores remain in the hardened concrete paste. Since the hardened cement paste is a porous solid, it will absorb water. Depending on the degree of saturation, water is typically present in the paste when the concrete is exposed to freezing temperatures. The resistance to freeze-thaw damage depends upon the size and distribution of entrained air bubbles in the paste. The entrained air bubbles act as a pressure relief for the nine percent expansion experienced when ice is formed. The severity is increased in the presence of deicing salts.

The American Concrete Institute (ACI) recommended concrete air content for severe freeze thaw environment is found in Table 5. ACI also recommends a maximum water cement ratio of 0.45 for freezing and thawing in a moist condition or the presence of deicing salts.

Table 5. ACI 318 Table 4.2.1 Total air content for frost resistant concrete

Nominal maximum aggregate size, inches.	Air content, as a percentage of total concrete volume.	
	Severe Exposure	Moderate Exposure
3/8	7.5	6
½	7	5.5
¾	6	5
1	6	4.5
1-1/2	5.5	4.5
2	5	4
3	4.5	3.5

Typical aggregate size is 1 inch and thus, 6% in place air content is required in Iowa. Regardless of aggregate size, the air content in the mortar fraction should be a minimum of 9%. The concrete air content at the top of the cores obtained at the joint in the 1992 (4.3%) and 1994 (1.01%) pavements are lower than the requirement for freeze thaw durability. Concrete air content at the top of the cores obtained at the joint in the 1995 pavement is more than required at 8.44%. The mortar air content at the top of the cores obtained at the joint in the 1992 (6.2%) and 1994 (1.4%) pavements are higher than the requirement for freeze thaw durability. Mortar air content at the top of the cores obtained at the joint in the 1995 pavement is more than required at 11.3%.

Since the expanding water due to freezing cannot travel more than 0.01 inches (0.2mm) in the paste, the bubbles should be small and relatively close together. ASTM C457 recommends a maximum spacing factor of 0.1 to 0.2 mm (0.004 to 0.008 in) for a severe freeze thaw environment. The spacing factors in the top of the cores obtained at the joint in the 1992 pavement (0.194 mm (0.076 in)) is border line to provide freeze thaw durability. The spacing factors in the top of the cores obtained at the joint in the 1994 pavement (0.383mm (0.0151 in)) is completely inadequate to provide freeze thaw durability. The spacing factor at the top of the cores obtained at the joint in the 1995 pavement is lower than required at 0.133 mm (0.0051 in).

Infilling of air voids with ettringite is often associated with these pavements exhibiting early deterioration. Performing hardened air analysis it is often difficult to distinguish infilled air voids from the paste. Thus, the initial air content (total) is often higher than it is after infilling (effective). Previous research[9] has noted that up to 2% of the total air volume may be filled, reducing the effective air content and thus, increasing the spacing factor.

The air content in the top or bottom of 1994 pavement cores at the joint may not be at adequate levels even with a 2% increase in total volume. However, if the air content in the in the top of 1992 pavement cores would have been adequate initially with a 2% increase in total volume, then the air void system may have been compromised by increased saturation and freeze thaw damage, perhaps due to micro-cracking near the surface.

The concrete air contents, mortar air contents, and spacing factors are plotted on figures 19-21.

Figure 19 Hardened Air Content in Concrete - I-29

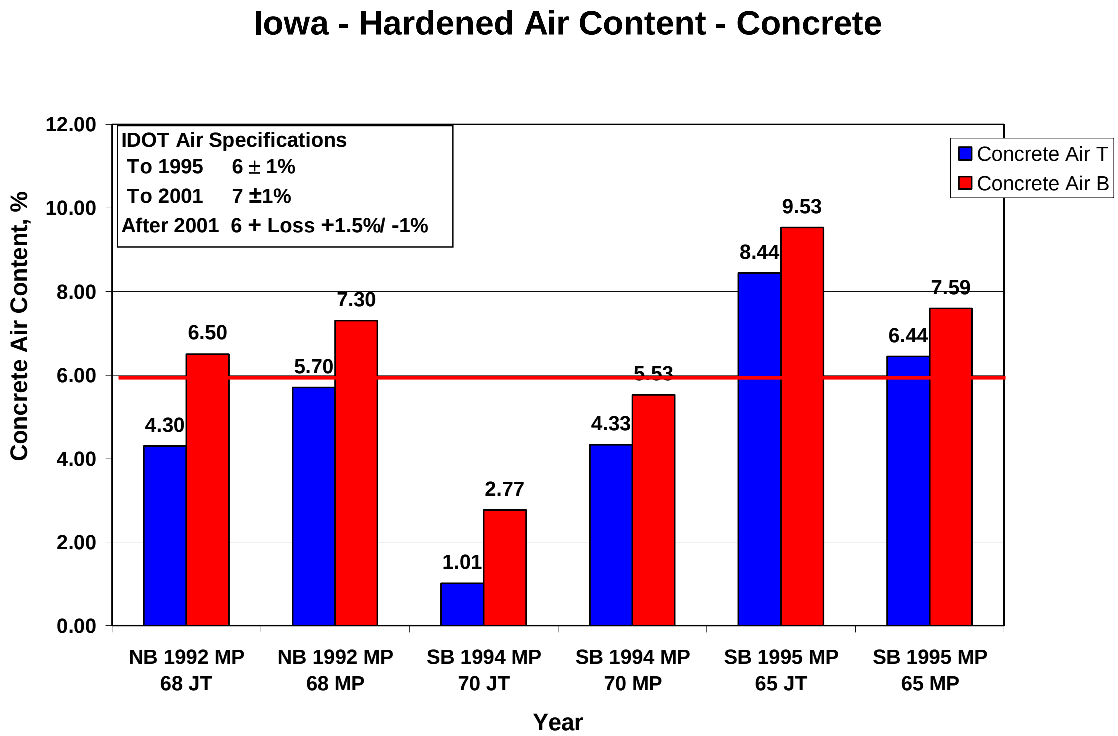


Figure 20 Hardened Air Content in Mortar - I-29

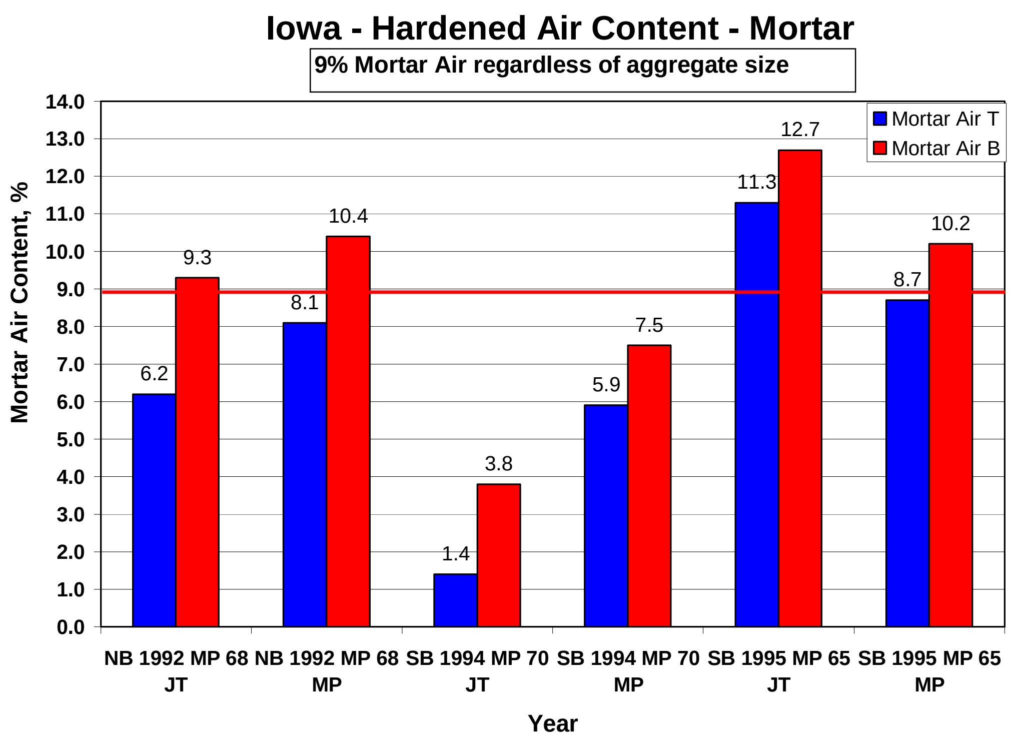
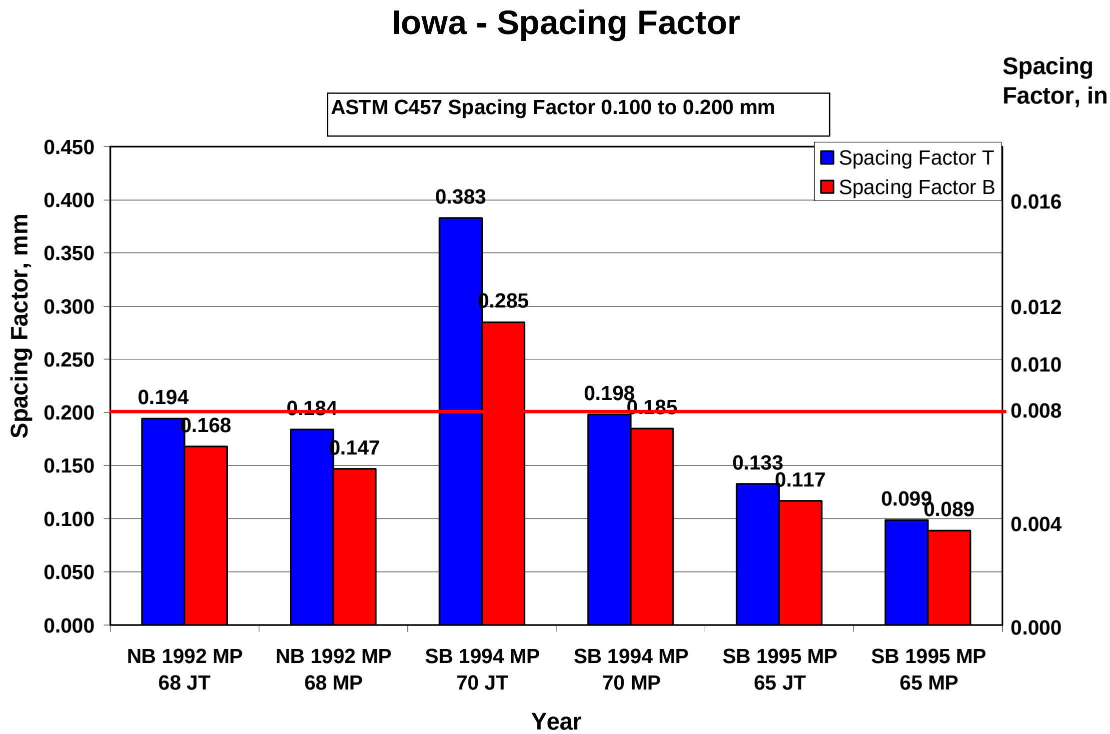


Figure 21. Hardened Air - Spacing Factor I-29



Type IP Research Test Section

A day's run research test section was placed in 1994 using Type IP cement for the first time in Iowa. The Type IP test section is located from Station 282+08 to 231+14 southbound. Note in Figures 22 and 23, the test section is in excellent condition. This ASTM C 595 Type IP cement was produced with 17% calcined clay to eliminate expansion due to alkali silica reactivity (ASR) when Platte River gravels are used in Nebraska. Nebraska Department of Roads considers the Platte River sand-gravel aggregates to be alkali silica reactive. Use of these aggregates has exhibited a map cracking appearance.

Research[7] has shown the plus #4 size aggregate to be somewhat reactive, but not the main cause of map cracking. This research also concluded the limestone sweetening, or use of 30% crushed limestone, was the most effective in eliminating the map cracking associated with the Platte River gravels. The Platte River aggregate used in this pavement was the sand portion with 100% passing the 3/8" sieve. In Iowa, limestone is typically used and the C-6WR mix design contains 40% coarse aggregate as limestone (55% coarse aggregate in the Type IP section with at C-3WR mix design). The sections were checked for evidence of ASR with X-ray mapping using the SEM-EDS.

Figure 22 – Type IP Test Section 1994 at Station 232/MP 59.5 (2006)

Figure 23 – Type IP Test Section 1994 Joint close up at Station 232/MP 59.5 (2006)

Cores were obtained at Station 238 southbound in the Type IP test section. Additional cores were also obtained at Station 195 and 212 in an area exhibiting deterioration for comparison. Hardened air analysis was performed on the cores as well as rapid chloride permeability testing AASHTO T 277.

The permeability of the cores tested using AASHTO T 277 indicated a very low rating in the Type IP test section with an average coulomb rating of 392. The permeability of the cores obtained in the area experiencing deterioration indicated a moderate rating with an average coulomb rating of 2610.

The hardened air results for the Type IP test section are shown in Table 6. The hardened air results in the area exhibiting deterioration are shown in Table 7.

Table 6. Air Content and Spacing Factor – Type IP Test Section Station 282+08 to 231+14 1994 Southbound

Location	Top or Bot	Mortar Air, %	Total Air, %	Avg. Dia. (microns)	Specific Surface (mm-1)	Spacing Factor (mm)	Specific Surface (in-1)	Spacing Factor (in)
238+47	T	14.0	8.71	223	26.906	0.103	683.4	0.004
238+47	B	12.3	7.62	249	24.096	0.125	612.0	0.005
238+57	T	13.2	8.20	223	26.906	0.107	683.4	0.004
238+57	B	13.2	8.20	216	27.778	0.104	705.6	0.004

Table 7. Air Content and Spacing Factor – Areas of Deterioration 1994 Southbound

Location	Top or Bot	Mortar Air, %	Total Air, %	Avg. Dia. (microns)	Specific Surface (mm-1)	Spacing Factor (mm)	Specific Surface (in-1)	Spacing Factor (in)
212+04	T	4.0	2.87	172	34.884	0.154	886.0	0.006
212+04	B	6.9	5.00	342	17.544	0.223	445.6	0.009
195+98	T	4.2	3.02	193	31.088	0.168	789.6	0.007
195+98	B	5.7	4.12	264	22.727	0.193	577.3	0.008

The hardened air results indicate the air content, mortar air content and spacing factor are more than adequate in the Type IP test section. The section experiencing early deterioration has low air content and mortar air content on the top of the cores and borderline spacing factors on the bottom of the cores.

A C-3WR mix with 55% coarse aggregate was used for the Type IP test section. This mix would not be as sandy and sticky as the C-6WR mix with 40% coarse aggregate that was used on the section experiencing deterioration.

Evidence of alkali silica reactivity was not found in either location. This may be due to the use of the sand portion of the Platte river gravel and the use of limestone sweetening. However, note the white spots of sulfur (S) on the Figure 24 (highlighted in red). This is typically noted on all the pavement sections that exhibit early deterioration. Research[2,3] has noted this to be a form of ettringite. Other research[6] has noted the ettringite infilling to be a consequence of cracking and saturation and frost damage. Note on Figure 26, the Type IP section that is in excellent condition, the air voids are free of sulfur (S).

Figure 24. SEM X-RAY Map 100X– Core Obtained in Area Exhibiting Deterioration

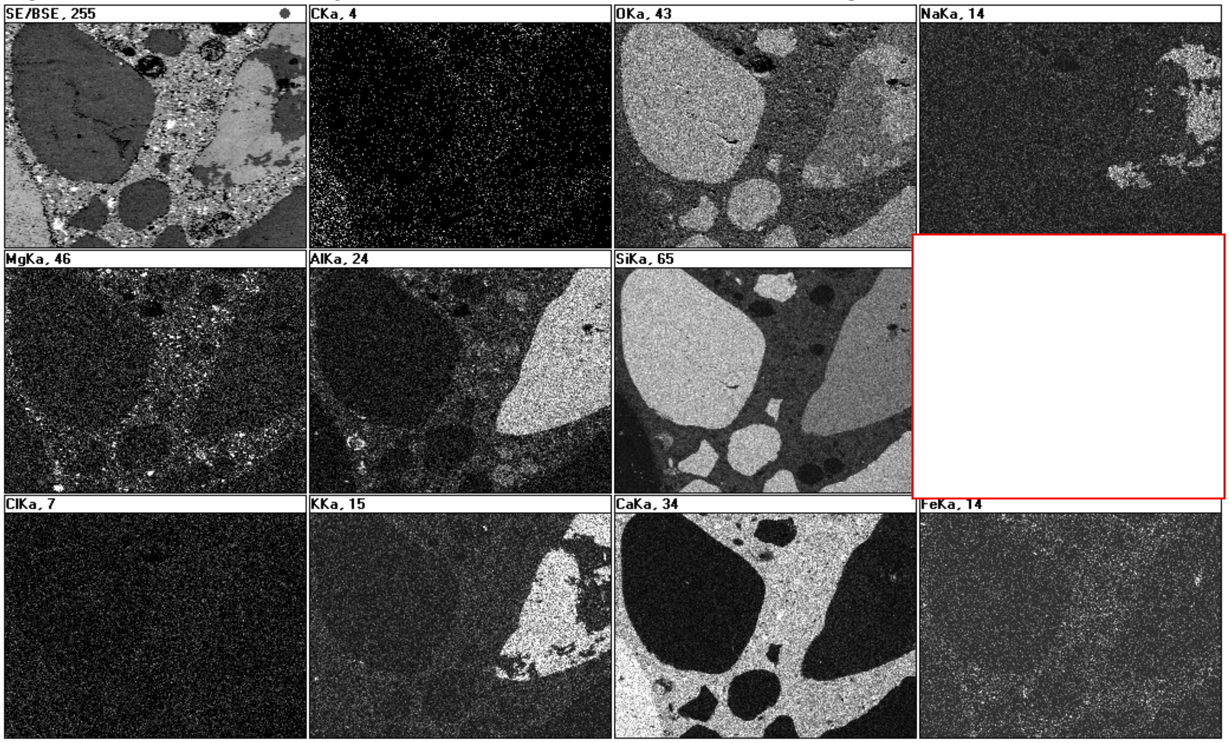
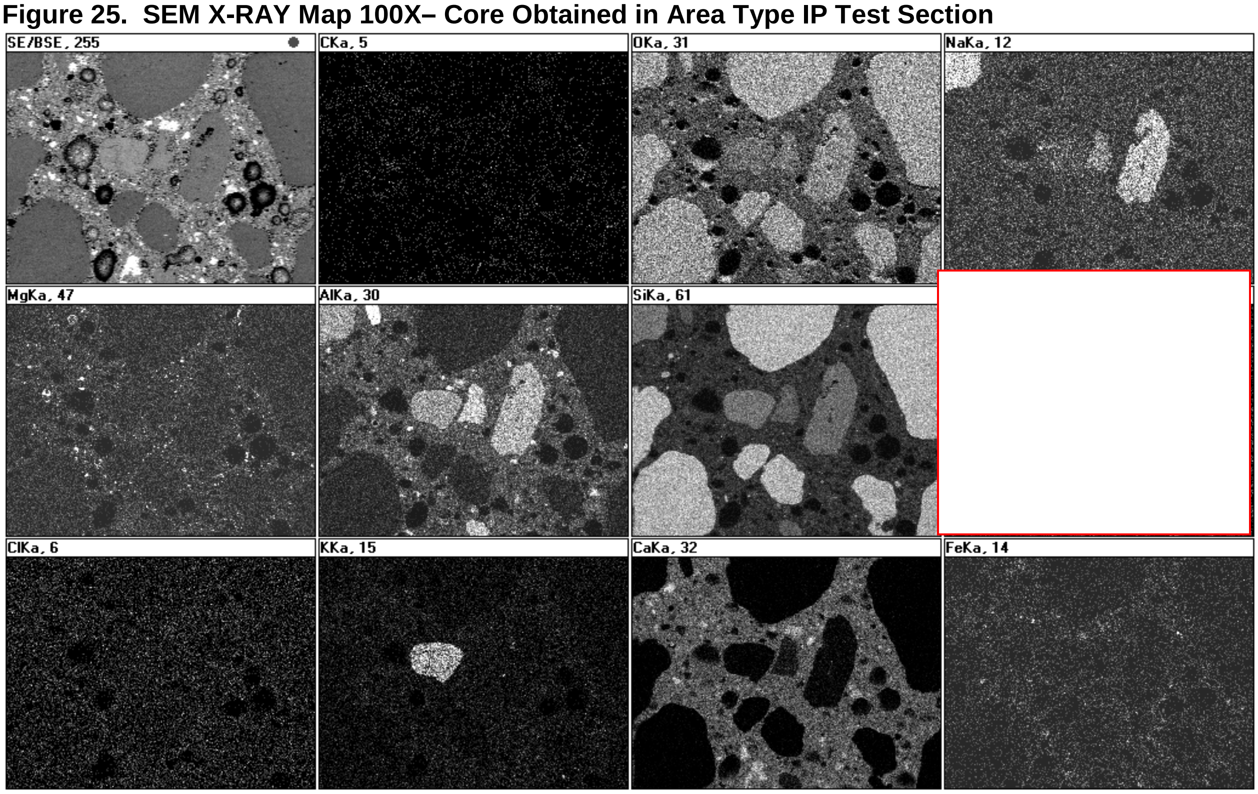


Figure 25. SEM X-RAY Map 100X– Core Obtained in Area Type IP Test Section



Discussion – Iowa DOT Specifications

Iowa DOT specifications regarding air content and vibration changed between 1994 and 1995. The Iowa DOT specifications regarding air and vibration are found in Table 8.

Table 8. Iowa DOT Specifications

Specifications	Before 1995	1995 & Later
Air Content	6±1%	7±1%
Vibration	Minimum of 7000 vpm's	5000 to 8000 vpm's
Supplementary Vibration	Required at Dowel Baskets	N/A

In 2000, the Iowa DOT began to require determining loss of air content through the paving machine. Typical values of air loss are 1.5 to 2.0%. Noting the old required air contents of 6% ±1% coupled with an air loss of up to 2%, it is not difficult to see how air contents could be below 4%.

It has been noted that prior to the mid 1980's, most paving machines were equipped with electric vibrators. These electric vibrators did not have a zone of influence as large as the hydraulic vibrators found on current paving machines. The electric vibrators required higher vibrations to achieve the same consolidation effort as the hydraulic vibrators. Vibration specification limits were not changed to reflect the greater degree of consolidation with hydraulic vibrators.

Research[5,9] has shown that over vibration has been related to early pavement deterioration caused by segregation and excessive air loss in the vibrator trails. Since the air contents and spacing factors just below the surface in many pavements exhibiting early deterioration is typically inadequate, the map cracking may be attributed to frost damage caused by differential dimensional movement between concrete at the surface and the concrete in the area of vibrator depths.

Specifications also required supplemental vibration of dowel baskets from 1984 to 1994. The US 20 project placed in 1987 was the first project in Iowa to exhibit early deterioration due to over vibration and excessive air loss in the pavement. A reinforced pavement section was placed over an old coal mine. Since the section was reinforced, there were no dowel baskets. The person performing supplementary vibration apparently continued as they went through the reinforced section. Staining and cracking was evident on the normal skew of the joint where supplemental vibration had been performed. The section eventually received an overlay. (See Figure 26) It is evident that excess vibration is a contributing factor in the deterioration.

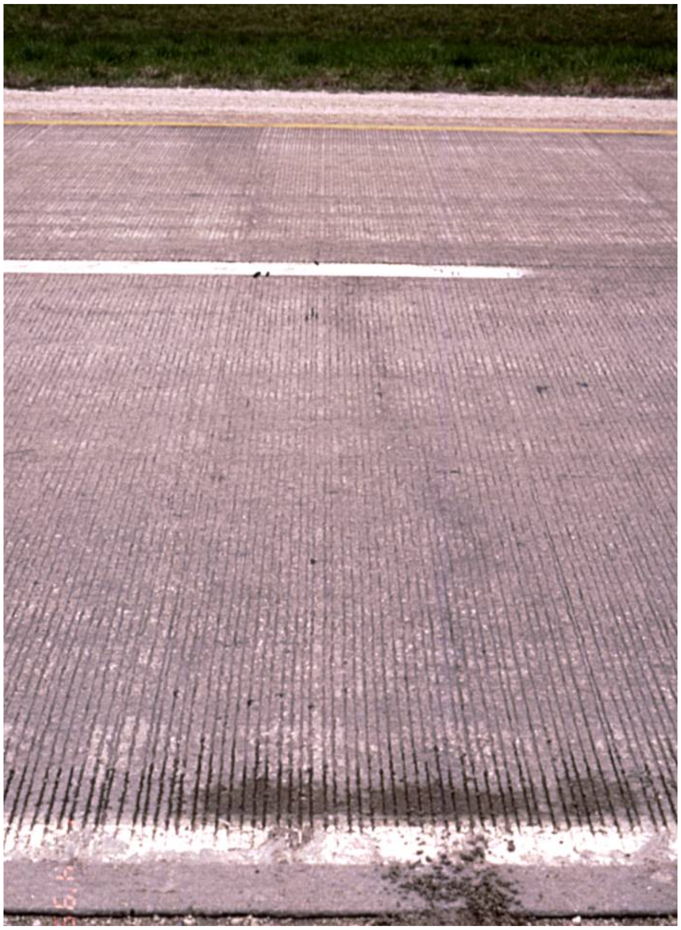


Figure 26 – US 20 Webster county reinforced section (1991) Note staining on skew where joint would be on standard pavement section.

During this time period, there were also problems noted with mix workability and placement problems. It was not unusual for a project to exhibit tearing of the surface which was difficult to close. Often the only alternatives were to add water, increase water reducer admixture dosage, and/or increase vibration. Increased vibration with poor workability and placement problems, whether from mix design or material incompatibilities, compromises the air void system and may cause an increase in micro-cracking. An increase in micro-cracking would allow for increased saturation near the surface.

Conclusions and Recommendations

On the pavements performing well, such as the 1995 pavement and the Type IP test section in the 1994 pavement, the air content and spacing factors were more than adequate. On the 1994 pavement, the air content and spacing factors are inadequate, even with a 2% increase in effective versus total air content. On the 1992 pavement cores, the air content and spacing factors are borderline. The original total air content may have been adequate in the 1992 pavement, but must have been compromised due to infilling of the air voids. Air content and spacing factor play a role in the deterioration of the pavements. This is in agreement with what has been noted in previous research[1,3,5,7].

On all pavements exhibiting deterioration, the presence of ettringite infilling the air voids is always noted. Research[6] has noted this phenomenon to be a consequence of saturation and frost damage. As the paste breaks up, ions go into solution more readily and recrystallize as ettringite in voids.

Micro-cracking in the paste will make the concrete more permeable and open to movement of water. This micro-cracking may be due to freeze thaw damage or perhaps some other mechanism, such as increased micro-cracking or shrinkage from poor workable mixes and over vibration, thereby increasing saturation and potential for freeze thaw damage. Excess vibration from the paver vibrators and supplementary vibration at the joints may compromise the air void system that is not well entrained, or may increase potential for micro-cracking in mixes with poor workability. In either case, it appears that saturation, coupled with inadequate or compromised air void system causes deterioration due to freeze thaw.

The permeability of cores obtained from the section of 1994 pavement experiencing deterioration is much higher than that of the Type IP research test section placed that same year, which is not experiencing deterioration. This increase in permeability may be due in part to micro-cracking.

The conclusions of this research are as follows:

1. Poor placement of concrete coupled with excess vibration from paver vibrators compromises an already poorly entrained air void system. Poor placement may also increase micro-cracking, which increases potential for saturation. With increased saturation, freezing and thawing may cause excess infilling of the air voids, further compromising the air void system.

2. Increased saturation coupled with an entrained air void system that is either inadequate or has been compromised due to infilling causes freeze thaw deterioration. Typically, the first place the deterioration appears is at the joints where saturation is the highest. It also occurs early along the vibrator trails.

3. When a well entrained air void system is found in the concrete, with little infilling, the pavement is freeze thaw durable and experiences no deterioration. When the air void system is inadequate, the pavement experiences deterioration.

The recommendations of this research are as follows:

1. Continue with air checks behind the paver to ensure adequate in place air content.

2. Continue the use of vibration monitoring to prevent over vibration. Over vibrating the concrete leads to excessive air loss and/or increased micro-cracking.

3. Continue to monitor concrete placement to ensure workable mixes are being placed.

4. Continue to monitor hardened air contents.

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Appendix

Figure 1 – Plant Report Summary IM-29-4(39)56—13-78 1992 NB.

1992 IF Jensen IM-29-4(39)56--13-78 NB MP 57.70 to 72.50 Pott./Harrison Counties
Oreapolis Fine (4110) Agg (ANE514), Weeping Water Coarse Agg (ANE002)
WRDA-82 and DARAVAIR R

Date	Station	Mix	Cement	Fly Ash	Fine Aggregate	Coarse Aggregate	Max./Min. Temp.	Slump	Air	W/C Ratio	Report #
7/24/1992	544+00 to 549+00	C-5WR-C15	Ash Grove I/II	Council Bluffs #3	Oreapolis	Weeping Water	65/59	1.0	7.2	0.401	1
7/27/1992	549+00 to 566+15	C-5WR-C15	Ash Grove I/II	Council Bluffs #3	Oreapolis	Weeping Water	88/65	1.75	7.4	0.361	2
8/1/1992	583+32 to 600+94	C-5WR-C15	Ash Grove I/II	Council Bluffs #3	Oreapolis	Weeping Water	80/58	2.0	6.6	0.361	4
8/1/1992	602+05 to 605+12	C-5WR-C15	Ash Grove I/II	Council Bluffs #3	Oreapolis	Weeping Water	80/58	1.25	7.6	0.367	4
8/3/1992	608+41 to 629+23.4	C-5WR-C15	Ash Grove I/II	Council Bluffs #3	Oreapolis	Weeping Water	78/60	1.25	7.2	0.367	5
8/3/1992	628+93 to 634+00	C-5WR-C15	Ash Grove I/II	Council Bluffs #3	Oreapolis	Weeping Water	78/60	1.25	7.0	0.370	5
8/4/1992	634+00 to 655+90	C-5WR-C15	Ash Grove I/II	Council Bluffs #3	Oreapolis	Weeping Water	78/58	1.5	7.1	0.368	6
8/5/1992	655+90 to 682+08	C-5WR-C15	Ash Grove I/II	Council Bluffs #3	Oreapolis	Weeping Water	80/59	1.25	7.0	0.370	7
8/6/1992	682+08 to 711+37	C-5WR-C15	Ash Grove I/II	Council Bluffs #3	Oreapolis	Weeping Water	79/65	1.5	6.3	0.383	8
8/8/1992	711+37 to 729+74	C-5WR-C15	Ash Grove I/II	Council Bluffs #3	Oreapolis	Weeping Water	92/70	1.5	6.8	0.383	9
8/8/1992	731+47 to 737+65	C-5WR-C15	Ash Grove I/II	Council Bluffs #3	Oreapolis	Weeping Water	92/70	1.5	7.2	0.398	9
8/9/1992	737+65 to 764+54	C-5WR-C15	Ash Grove I/II	Council Bluffs #3	Oreapolis	Weeping Water	95/72	1.75	6.5	0.401	10
8/10/1992	764+54 to 768+97	C-5WR-C15	Ash Grove I/II	Council Bluffs #3	Oreapolis	Weeping Water	88/70	1.75	7.6	0.401	11
8/10/1992	770+69 to 786+20	C-5WR-C15	Ash Grove I/II	Council Bluffs #3	Oreapolis	Weeping Water	88/70	1.75	6.8	0.396	11
8/11/1992	786+20 to 829+82	C-5WR-C15	Ash Grove I/II	Council Bluffs #3	Oreapolis	Weeping Water	78/53	1.5	8.0	0.391	12
8/12/1992	812+58 to 828+12	C-5WR-C15	Ash Grove I/II	Council Bluffs #3	Oreapolis	Weeping Water	85/65	2.25	7.7	0.391	13
8/12/1992	829+82 to 838+20	C-5WR-C15	Ash Grove I/II	Council Bluffs #3	Oreapolis	Weeping Water	85/65	1.5	7.3	0.388	13
8/13/1992	838+20 to 855+87	C-5WR-C15	Ash Grove I/II	Council Bluffs #3	Oreapolis	Weeping Water	78/60	2.0	6.9	0.388	14
8/13/1992	857+20 to 858+92	C-5WR-C15	Ash Grove I/II	Council Bluffs #3	Oreapolis	Weeping Water	78/60	1.25	6.9	0.388	14
8/13/1992	857+20 to 858+92	C-5WR-C15	Ash Grove I/II	Council Bluffs #3	Oreapolis	Weeping Water	78/60	1.25	7.5	0.429	14
8/14/1992	858+92 to 863+85	C-5WR-C15	Ash Grove I/II	Council Bluffs #3	Oreapolis	Weeping Water	74/60	1.5	7.2	0.429	16
8/14/1992	867+36 to 872+90	C-5WR-C15	Ash Grove I/II	Council Bluffs #3	Oreapolis	Weeping Water	74/60	1.25	7.6	0.429	16
8/14/1992	873+70 to 885+43	C-5WR-C15	Ash Grove I/II	Council Bluffs #3	Oreapolis	Weeping Water	74/60	1.25	7.6	0.392	16
8/17/1992	885+43 to 888+85	C-5WR-C15	Ash Grove I/II	Council Bluffs #3	Oreapolis	Weeping Water	80/57	1.75	7.2	0.392	18
8/17/1992	889+82 to 902+09	C-5WR-C15	Ash Grove I/II	Council Bluffs #3	Oreapolis	Weeping Water	80/57	1.25	7.5	0.392	18
8/17/1992	903+30 to 912+23	C-5WR-C15	Ash Grove I/II	Council Bluffs #3	Oreapolis	Weeping Water	80/57	1.5	7.5	0.392	18
8/18/1992	912+23 to 916+18	C-5WR-C15	Ash Grove I/II	Council Bluffs #3	Oreapolis	Weeping Water	78/59	1.5	7.6	0.403	19
8/18/1992	921+59 to 922+47	C-5WR-C15	Ash Grove I/II	Council Bluffs #3	Oreapolis	Weeping Water	78/59	1.25	7.5	0.403	19
8/19/1992	928+03 to 931+02	C-5WR-C15	Ash Grove I/II	Port Neal #4 (C)	Oreapolis	Weeping Water	81/60	1.5	6.0	0.391	21
8/19/1992	932+74 to 954+84	C-5WR-C15	Ash Grove I/II	Port Neal #4 (C)	Oreapolis	Weeping Water	81/60	1.0	7.5	0.391	21
8/20/1992	954+84 to 984+75	C-5WR-C15	Ash Grove I/II	Port Neal #4 (C)	Oreapolis	Weeping Water	85/59	1.0	7.0	0.400	22
8/20/1992	984+75 to 1007+84	C-5WR-C15	Ash Grove I/II	Port Neal #4 (C)	Oreapolis	Weeping Water	86/62	1.5	7.2	0.390	24
8/24/1992	1007+84 to 1036+40	C-5WR-C15	Ash Grove I/II	Port Neal #4 (C)	Oreapolis	Weeping Water	84/59	1.25	6.8	0.382	25
8/26/1992	1036+40 to 1054+60	C-5WR-C15	Ash Grove I/II	Port Neal #4 (C)	Oreapolis	Weeping Water	70/56	1.5	6.9	0.386	26
8/27/1992	1054+60 to 1075+75	C-5WR-C15	Ash Grove I/II	Port Neal #4 (C)	Oreapolis	Weeping Water	76/59	1.75	7.4	0.362	27
8/27/1992	1077+12 to 1086+10	C-5WR-C15	Ash Grove I/II	Port Neal #4 (C)	Oreapolis	Weeping Water	76/59	1.0	6.0	0.362	27
8/28/1992	1089+71 to 1102+90	C-5WR-C15	Ash Grove I/II	Port Neal #4 (C)	Oreapolis	Weeping Water	81/58	1.75	7.4	0.365	28
8/28/1992	1103+97 to 1107+02	C-5WR-C15	Ash Grove I/II	Port Neal #4 (C)	Oreapolis	Weeping Water	81/58	1.25	6.6	0.365	28
8/28/1992	1089+71 to 1102+90	C-5WR-C15	Ash Grove I/II	Port Neal #4 (C)	Oreapolis	Weeping Water	81/58	1.75	7.4	0.365	28
8/31/1992	1109+88 to 1130+00	C-5WR-C15	Ash Grove I/II	Port Neal #4 (C)	Oreapolis	Weeping Water	74/56	1.5	7.1	0.373	29
9/1/1992	1109+88 to 1130+00	C-5WR-C15	Ash Grove I/II	Port Neal #4 (C)	Oreapolis	Weeping Water	74/56	1.5	7.1	0.373	29
9/1/1992	855+86 to 857+26	C-5WR-C15	Ash Grove I/II	Port Neal #4 (C)	Oreapolis	Weeping Water	75/63	2.5	6.8	0.394	30
9/2/1992	885+26 to 879+08	C-5WR-C15	Ash Grove I/II	Port Neal #4 (C)	Oreapolis	Weeping Water	82/65	1.5	6.8	0.389	31
9/9/1992	964+80 to 959+90	C-5WR-C15	Ash Grove I/II	Port Neal #4 (C)	Oreapolis	Weeping Water	82/65	1.0	6.5	0.389	31
9/11/1992	134+95 to 156+50	C-5WR-C15	Ash Grove I/II	Port Neal #4 (C)	Oreapolis	Weeping Water	79/55	2.25	7.5	0.371	37
9/12/1992	156+50 to 182+55	C-5WR-C15	Ash Grove I/II	Port Neal #4 (C)	Oreapolis	Weeping Water	82/61	2.5	6.8	0.367	38
9/13/1992	182+55 to 209+25	C-5WR-C15	Ash Grove I/II	Port Neal #4 (C)	Oreapolis	Weeping Water	86/62	1.5	6.8	0.393	39
9/19/1992	209+25 to 226+90	C-5WR-C15	Ash Grove I/II	Port Neal #4 (C)	Oreapolis	Weeping Water	75/45	1.5	6.3	0.379	45
9/20/1992	226+90 to 253+12	C-5WR-C15	Ash Grove I/II	Port Neal #4 (C)	Oreapolis	Weeping Water	75/50	2.0	7.3	0.386	46
9/21/1992	253+12 to 282+45	C-5WR-C15	Ash Grove I/II	Port Neal #4 (C)	Oreapolis	Weeping Water	75/62	1.5	6.8	0.393	47
9/22/1992	287+13 to 312+79	C-5WR-C15	Ash Grove I/II	Port Neal #4 (C)	Oreapolis	Weeping Water	75/60	2.0	7.5	0.390	48
9/23/1992	312+79 to 338+13	C-5WR-C15	Ash Grove I/II	Port Neal #4 (C)	Oreapolis	Weeping Water	75/52	2.0	6.4	0.391	50
9/24/1992	338+13 to 344+02	C-5WR-C15	Ash Grove I/II	Port Neal #4 (C)	Oreapolis	Weeping Water	78/50	1.75	6.8	0.377	51
9/25/1992	363+38 to 375+25	C-5WR-C15	Ash Grove I/II	Port Neal #4 (C)	Oreapolis	Weeping Water	73/50	2.0	6.9	0.389	52
9/25/1992	375+25 to 375+67	C-5WR-C15	Ash Grove I/II	Port Neal #4 (C)	Oreapolis	Weeping Water	73/50	1.75	6.6	0.389	52
10/6/1992	375+75 to 402+18	C-5WR-C15	Ash Grove I/II	Port Neal #4 (C)	Oreapolis	Weeping Water	76/53	2.25	7.5	0.382	60
10/10/1992	402+18 to 406+92.4	C-5WR-C15	Ash Grove I/II	Port Neal #4 (C)	Oreapolis	Weeping Water	59/42	1.5	7.2	0.375	62
10/10/1992	406+92.4 to 426+82	C-5WR-C15	Ash Grove I/II	Port Neal #4 (C)	Oreapolis	Weeping Water	59/42	5		0.375	62
10/11/1992	426+82 to 460+20	C-5WR-C15	Ash Grove I/II	Port Neal #4 (C)	Oreapolis	Weeping Water	65/38	1.25	7.8	0.378	63
10/12/1992	460+20 to 490+91	C-5WR-C15	Ash Grove I/II	Port Neal #4 (C)	Oreapolis	Weeping Water	65/45	2.5		0.373	64
10/13/1992	490+91 to 522+76	C-5WR-C15	Ash Grove I/II	Port Neal #4 (C)	Oreapolis	Weeping Water	72/45	1.5		0.369	65
10/14/1992	522+76 to 544+00	C-5WR-C15	Ash Grove I/II	Port Neal #4 (C)	Oreapolis	Weeping Water	55/46	0.5	7.0	0.367	66
10/16/1992	375+79 to 381+70	C-5WR-C15	Ash Grove I/II	Port Neal #4 (C)	Oreapolis	Weeping Water	44/37	1.5	8.0	0.361	68
								1.62	7.1	0.384	

Figure 2 – Plant Report Summary IM-29-3(38)58—13-78 1994 SB.

IM-29-3(38)58--13-78 SB MP 57.70 to 60.80 & 65.50 to 70.84 Cedar Valley 1994

Date	Station	Mix	Cement	Water Reducer	Fine Aggregate	Coarse Aggregate	Max./Min. Temp.	Slump	Air	W/C Ratio	Report #
06/29/94	809+00 to 799+50	C-6WR-C15	AshGrove I	WRDA-82	Hartford	Weeping Water	88/85	2.5/1.5	6.7/5.8	0.410	3
06/30/94	799+30 to 782+88	C-6WR-C15	AshGrove I	WRDA-82/Daratard	Hartford	Weeping Water	87/76	1.75/2.5	5.8/6.2	0.419	4
07/01/94	782+88 to 766+86	C-6WR-C15	AshGrove I	WRDA-82/Daratard	Hartford	Weeping Water	86/73	1/2.25	5.8/6.2	0.407	5
07/08/94	799+50 to 743+62	C-6WR-C15	AshGrove I	Daratard 17	Hartford	Weeping Water	72/64	1.25/2	6.6/7.4	0.379	8
07/09/94	743+25 to 719+65	C-6WR-C15	AshGrove I	Daratard 17	Hartford	Weeping Water	87/64	2/1.75	6.4/5.6	0.414	9
07/10/94	719+65 to 698+10	C-6WR-C15	AshGrove I	Daratard 17	Hartford	Weeping Water	88/56	1.5	5.5/5.9	0.411	10
07/11/94	698+10 to 675+63	C-6WR-C15	AshGrove I	Daratard 17	Hartford	Weeping Water	90/62	1/1.5	5.5/5.8	0.421	11
07/12/94	675+63 to 667+68	C-6WR-C15	AshGrove I	Daratard 17	Hartford	Weeping Water	90/70	1.5	5.9	0.446	12
07/14/94	667+68 to 639+88	C-6WR-C15	AshGrove I	Daratard 17	Oreapolis	Weeping Water	82/72	1.75/1.25	6/6.5	0.405	14
07/15/94	639+88 to 621+21	C-6WR-C15	AshGrove I	Daratard 17	Oreapolis	Weeping Water	80/60	2.0/1.0	7.1/5.6	0.428	15
07/17/94	621+21 to 599+04	C-6WR-C15	AshGrove I	Daratard 17	Oreapolis	Weeping Water	85/65	1.25/1.5	5.5/6.1	0.436	16
07/18/94	599+04 to 582+38	C-6WR-C15	AshGrove I	Daratard 17	Oreapolis	Weeping Water	89/70	1.5/1.0	6.8/6.2	0.394	17
07/19/94	581+58 to 553+56	C-6WR-C15	AshGrove I	WRDA-82/Daratard	Oreapolis	Weeping Water	92/72	2/1.75	6.6/6.9	0.442	18
07/20/94	553+56 to 544+05	C-6WR-C15	AshGrove I/IP	WRDA-82	Oreapolis	Weeping Water	82/70	1.5/1.25	6.7/6.6	0.451	19
07/21/94	304+00 to 286+68	C-6WR-C15	AshGrove I/IP	WRDA-82	Oreapolis	Weeping Water	82/70	1/1.75	7.0/6.7	0.440	20
07/22/94	282+08 to 256+50	C-3WR-C10	AshGrove IP	WRDA-82	Oreapolis	Weeping Water	70/64	2.0/1.25	5.0/6.6	0.478	21
07/23/94	256+50 to 231+14	C-3WR	AshGrove I/IP	WRDA-82	Oreapolis	Weeping Water	91/60	1.5	6.0/7.0	0.459	22
07/25/94	231+14 to 207+50	C-3WR-C15	AshGrove I	WRDA-82	Oreapolis	Weeping Water	82/65	1.0/1.5	6.8/7.2	0.415	23
07/26/94	207+50 to 182+85	C-6WR-C15	AshGrove I	WRDA-82	Oreapolis	Weeping Water	78/62	0.75	5.5/7.0	0.429	25
07/27/94	182+85 to 155+64	C-6WR-C15	AshGrove I	WRDA-82	Hartford	Weeping Water	78/56	1.75/1.25	6.3/6.0	0.424	26
07/28/94	155+64 to 135+00	C-6WR-C15	AshGrove I	WRDA-82	Oreapolis	Weeping Water	83/54	1.75/1.5	7.0/7.3	0.426	27
									6.3	0.425	

Note: Southbound Lanes. Hartford Fine Aggregate (ANE506) Oreapolis Fine Aggregate (ANE514), & Weeping Water (ANE002) Coarse aggregate, Council Bluffs #3 Flyash (where flyash was used), and Daravair R air entraining agent.

Figure 3 – Plant Report Summary IM-29-3(52)61--13-78 1995SB.

IM-29-3(52)61--13-78 SB MP 60.80 to 65.50 & MP 70.84 to 72.45 1995 Fred Carlson

Date	Dir.	Station	Mix	Cement	Fly ash	Fine	Coarse	Max./Min. Temperature	Slump	Air	W/C Ratio	Report #
07/03/95	SB	1130+00 to 1109+89	C-4WR-C10	Ash Grove IP	N. Omaha	All Spec	Weeping Water	85/60	2/1.25	7.2/7.5	0.464	1
07/05/95	SB	1107+08 to 1078+12	C-4WR-C10	Ash Grove IP	N. Omaha	All Spec	Weeping Water	65/57	1.5/1.75	8/7.8	0.433	2
07/06/95	SB	1076+78 to 1052+40	C-4WR-C10	Ash Grove IP	N. Omaha	All Spec	Weeping Water	82/57	1.25/1.5	7.6/8	0.424	3
07/07/95	SB	1052+40 to 1026+70	C-4WR-C10	Ash Grove IP	N. Omaha	All Spec	Weeping Water	89/62	1.50	8/7.8	0.435	4
07/08/95	SB	1026+70 to 999+65	C-4WR-C10	Ash Grove IP	N. Omaha	All Spec	Weeping Water	95/65	1.87/.75	7.8/7.5	0.469	5
07/10/95	SB	999+65 to 972+50	C-4WR-C10	Ash Grove IP	N. Omaha	All Spec	Weeping Water	93/69	1.5/1.25	7.5/7.8	0.448	6
07/11/95	SB	972+50 to 951+14	C-4WR-C10	Ash Grove IP	N. Omaha	All Spec	Weeping Water	101/71	1.75/1.0	8.0/7.0	0.460	7
07/12/95	SB	951+14 to 928+02	C-4WR-C10	Ash Grove IP	N. Omaha	All Spec	Weeping Water	109/72	1/1.25	7.5	0.478	8
07/14/95	SB	901+52 to 882+43	C-4WR-C10	Ash Grove IP	N. Omaha	All Spec	Weeping Water	100/74	1.25/.75	7.8/6.0	0.458	10
07/15/95	SB	882+43 to 867+16	C-4WR-C10	Ash Grove IP	N. Omaha	All Spec	Weeping Water	90/74	1.25	7.5/8.0	0.472	11
07/17/95	SB	1109+89 to 1106+99	C-4WR-C10	Ash Grove IP	N. Omaha	All Spec	Weeping Water	86/65	1.8/1	7.5/7.2	0.478	12
07/18/95	SB	863+84 to 830+48	C-4WR-C10	Ash Grove IP	N. Omaha	All Spec	Weeping Water	92/64	2.0	8.0/7.0	0.448	13
07/19/95	SB	828+02 to 809+00	C-4WR-C10	Ash Grove IP	N. Omaha	All Spec	Weeping Water	88/63	1.25/1.5	7.4/7.8	0.448	14
07/20/95	SB	932+69 to 932+70	C-4WR-C10	Ash Grove IP	N. Omaha	All Spec	Weeping Water	85/62	.75/1.25	7.5/7.8	0.489	15
07/22/95	SB	931+00 to 922+02	C-4WR-C10	Ash Grove IP	N. Omaha	All Spec	Weeping Water	88/64	4/1.75	8.75/8	0.487	16
07/27/95	SB	917+84 to 828+02	C-4WR-C10	Ash Grove IP	N. Omaha	All Spec	Weeping Water	96/70	2.5/3	8.0	0.480	19
07/28/95	SB	1109+95 to 863+48	C-4WR-C10	Ash Grove IP	N. Omaha	All Spec	Weeping Water	97/65	4.00	8.0	0.476	20
07/31/95	SB	931+00 to 932+70	C-4WR-C10	Ash Grove IP	N. Omaha	All Spec	Weeping Water	85/69	3.8	8.0	0.480	21A
07/31/95	SB	922+28 to 928+02	C-4WR-C10	Ash Grove IP	N. Omaha	All Spec	Weeping Water	85/69	3.75	8.0	0.480	21B
08/01/95	SB	863+48 to 863+63	C-4WR-C10	Ash Grove IP	N. Omaha	All Spec	Weeping Water	78/59	1.5/1.0	7.9/7.8	0.460	22
08/02/95	SB	828+46 to 916+12	C-4WR-C10	Ash Grove IP	N. Omaha	All Spec	Weeping Water	84/64	3.75/1.5	7.8/8.0	0.472	23
08/03/95	SB	864+18 to 864+33	C-4WR-C10	Ash Grove IP	N. Omaha	All Spec	Weeping Water	90/68	2.5	6.8	0.475	24
08/07/95	SB	644+06 to 621+38	C-4WR-C10	Ash Grove IP	N. Omaha	All Spec	Weeping Water	93/68	1.0/1.5	7.4/7.6	0.485	25
08/08/95	SB	521+38 to 493+23	C-4WR-C10	Ash Grove IP	N. Omaha	All Spec	Weeping Water	99/72	1.3	7.8/7.2	0.486	26
08/09/95	SB	493+23 to 462+15	C-4WR-C10	Ash Grove IP	N. Omaha	All Spec	Weeping Water	90/70	1.25/1.5	8.0/7.0	0.488	27
08/10/95	SB	462+15 to 437+50	C-4WR-C10	Ash Grove IP	N. Omaha	All Spec	Weeping Water	94/70	1.0/1.75	7.8/7.4	0.484	28
08/11/95	SB	437+50 to 409+42	C-4WR-C10	Ash Grove IP	N. Omaha	All Spec	Weeping Water	97/72	1.5	7.4/7.6	0.488	29
08/12/95	SB	410+00 to 387+85	C-4WR-C10	Ash Grove IP	N. Omaha	All Spec	Weeping Water	96/74	1.25/1.5	7.6/7.4	0.488	30
08/14/95	SB	387+85 to 366+46	C-4WR-C10	Ash Grove IP	N. Omaha	All Spec	Weeping Water	83/71	2.0/1.0	6.9/8.5	0.468	31
08/16/95	SB	366+46 to 347+05	C-4WR-C10	Ash Grove IP	N. Omaha	All Spec	Weeping Water	86/72	1.75/1.0	8.0/7.6	0.485	32
08/17/95	SB	345+67 to 315+97	C-4WR-C10	Ash Grove IP	N. Omaha	All Spec	Weeping Water	96/70	2.0/1.25	7.4/7.9	0.485	33
08/19/95	SB	315+97 to 303+99	C-4WR-C10	Ash Grove IP	N. Omaha	All Spec	Weeping Water	86/65	1.5	7.7	0.486	35
										7.61	0.471	

SB Lanes. All Spec S&G (ANE540) fine aggregate, Weeping Water (ANE002) coarse aggregate,
Plastocrete 161 water reducer, and Sika AEA air entraining agent.

Figure 4 –Freeze Thaw Durability of Cores from I-29 NB 1999.

Pavement Durability Cycling starts October 11, 1999 ends November 24, 1999

Freeze Thaw Test Cores I-29 NB Pott/Harrison Counties

Core #	***29-1***	***29-5***	***29-9***	***29-13***
Visual Pavement Cracking as of 9/1999	***None***	***Moderate***	***Moderate***	***Moderate***
F-T Cycles	*Fraction of Pulse Velocity*			
0	1.00	1.00	1.00	1.00
9	0.98	1.00	0.93	0.97
33	1.02	1.04	0.97	0.96
43	1.01	0.97	0.89	0.90
76	0.98	0.99	0.90	0.85
85	0.98	0.99	0.87	0.80
95	1.00	0.99	0.82	0.76
115	1.00	0.95	0.82	0.63
147	1.02	0.95	0.53	0.42
157	0.99	0.92	0.52	0.35
180	0.97	0.83	Failed	Failed
190	1.00	0.81		
221	1.01	0.80		
232	0.99	0.78		
242	1.00	0.76		
252	1.00	0.70		
262	1.00	0.76		
302	1.02	0.52		
312	0.99	0.48		
332	0.96	0.27		
364	1.01	Failed		
386	0.99			
406	0.99			
438	1.01			
458	0.99			
509	0.98			
530	0.97			
550	0.97			
585	0.97			
605	0.00			