DEPARTMENT OF TRANSPORTATION

Impact of Water/ Cementitious-Based Concrete Mix Design Specification Changes on Concrete Pavement Quality

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July 2018

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Final Report 2018-25

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This research investigated the impact of MnDOT implementing a w/cm-based specification for concrete pavements. Pavement sections constructed before and after the specification implementation were examined to assess permeability, compressive strength and air-void system parameters. Pavement management system data was examined to identify changes in ride quality associated with the specification change. The results show the change to a w/cm-based specification resulted in concrete with lower permeability, higher strength, and increased air content. The ride quality for those pavements appears to be better and the rate of degradation of ride quality appears to be slower.

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IMPACT OF WATER/CEMENTITIOUS-BASED CONCRETE MIX DESIGN SPECIFICATION CHANGES ON CONCRETE PAVEMENT QUALITY

FINAL REPORT

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

Over the past 20 years, there have been significant changes in specifications for concrete mixture designs for pavements constructed in Minnesota. Prior to these changes, achieving a specific design strength was the primary goal and less consideration was given to durability, which is affected more by permeability and other factors.

Some of the identified changes include:

1) Reduction in maximum water-to-cementitious product ratio (*w/cm*) from 0.46 to 0.40
2) Optimization of gradations from the gap graded to the well-graded aggregate
3) Increased pozzolan substitution for Portland cement to lower the risk of alkali-silica reaction (ASR)
4) Improved curing materials and practices
5) Increase in plastic air content

To establish the effectiveness of these specification changes, MnDOT undertook this research in cooperation with American Engineering Testing. Thirty-six pavement projects were identified for core sampling. Although a number of specification changes were made over the past 20 years, the *w/cm* specification is considered the most significant and was used to delineate projects for this research.

The projects for investigation were not selected on a statistical basis or with intent to establish a specific experimental matrix. Projects were identified with respect to age, seeking a good representation of both pre- and post-*w/cm* specification projects (i.e., construction date of the pavements ranged from 1991 – 2004), and with respect to geographic distribution.

The laboratory tests performed were selected to characterize key properties that were expected to change with the described changes in specifications. These properties are permeability, compressive strength, and air-void system parameters.

In addition to laboratory testing, MnDOT provided pavement management data for each project and that data was also examined in this research to identify trends occurring between pre- and post-*w/cm* projects.

A total of 27 projects were examined in accordance with ASTM C1202 (RCPT test) to establish the relative permeability of each specimen as represented by the electrical charge passed through the specimens during the test. The results indicate a clear distinction between pre- and post-*w/cm* concrete with post-*w/cm* concrete having a significantly lower permeability.

The results indicate an approximate five-fold difference between pre-*w/cm* and post-*w/cm* charge transfer, indicating a distinct difference in permeability between the two groups of samples. Also of interest is the scatter in results for each individual project. Although the number of samples analyzed per project was small, there appears to be a trend of more scatter between pre-*w/cm* as compared to post-*w/cm.* This suggests that not only are the post-*w/cm* pavements sampled less permeable, but there is also less variability in this important material property.

A total of 20 projects were examined in accordance with ASTM C1152 to establish the degree of chloride ingress into the concrete pavements sampled. The results of these tests were confounded by multiple factors affecting chloride penetration.

Surface resistivity was measured in accordance with AASHTO T 358 on the same core samples used to measure compressive strength. These cores represented 26 of the projects studied. The results indicate a clear distinction between pre- and post-*w/cm* concrete with post-*w/cm* concrete having a significantly higher resistivity indicating a lower permeability.

Samples from the same 26 projects studied for resistivity were tested in accordance with ASTM C39 to establish the compressive strength of the concrete in place. The results indicate a clear distinction between pre- and post-*w/cm* concrete with post-*w/cm* concrete having a higher compressive strength.

The air-void system parameters were measured for 31 projects. These measurements were performed in accordance with ASTM C457 Procedure A-Linear Traverse. The results indicate an increase in air content between pre- and post-*w/cm* concrete of approximately 1% volume, which will positively impact freezing and thawing durability.

In addition to measuring changes in the key material properties the researchers investigated differences in pavement condition and ride quality as measured by standard MnDOT pavement management procedures. To examine this, International Roughness Index (IRI), Ride Quality Index, (RQI), Pavement Quality Index (PQI), and Surface Rating (SR) data were obtained from the MnDOT Pavement Management System (PMS) and analyzed. The results suggest that post-*w/cm* pavements appear to have an improved ride quality at any given year of pavement life and the rate of ride quality degradation appears to be slower for post-*w/cm* pavements, in both cases when compared to pre-*w/cm* specified concrete.

It is concluded that laboratory test results from this study strongly indicate the changes in specifications enacted have led to a lower permeability concrete as well as higher strength concrete with higher air contents, the latter improving resistance to freezing and thawing deterioration.

Key recommendations for future work include suggestions for a statistical based approach to experimental design, improvements on sample selection, and laboratory testing to focus on key properties such as establishing the formation factor for the various mixtures pre- and post-*w/cm* specification. The latter effort may assist in adoption of new performance engineered mixture specifications. It is recommended that any future study include selected pavements from this study, depending on the overall scope of the follow-up study.

CHAPTER 1: INTRODUCTION

Over the past 20 years, there have been significant changes in the processes and outcomes of concrete mixture designs for pavements constructed in Minnesota. Prior to these changes, achieving a specific design strength was the primary goal and less consideration was given to durability, which is affected more by permeability and other factors.

Based on research and local trials, in 1995 the Minnesota Department of Transportation (MnDOT) moved from a strength-based specification to a water-to-cementitious material ratio (*w/cm*) specification for acceptance. The goal was to construct more durable and longer lasting concrete pavements.

Some of the identified changes include:

1) Reduction in maximum *w/cm* ratio from 0.46 to 0.40
2) Optimization of gradations from the gap graded to the well-graded aggregate
3) Increased pozzolan substitution for portland cement to lower the risk of alkali-silica reaction (ASR)
4) Improved curing materials and practices
5) Increase in plastic air content

MnDOT has been collecting ASTM C1202 Rapid Chloride Permeability (RCPT) data dating back to the early 2000s. This testing was performed on thickness verification cores taken from concrete paving projects. Testing has been performed at approximately 60 days from concrete placement. The RCPT data indicate that at early ages (i.e., 60 days) the permeability was typically below 1500 coulombs for most of the pavements evaluated. In addition, visual examination of the pavements in service has indicated no premature failure as compared to pavement constructed in the early 1980s.

This research studied the difference in concrete properties resulting from changes in concrete mixture designs driven by changes in MnDOT construction specifications. In this study, concrete mixtures are delineated as either *pre-w/c* (i.e., prior to the *w/*c specification promulgation in 1996) or *post-w/c* (i.e., following the *w/*c specification promulgation in 1996). The goal of this research project was to ascertain, based on examination of pavement core samples and analysis of pavement management system data (e.g., IRI, RQI, PQI, SR), the effectiveness of the identified specification changes on pavement durability and performance.

CHAPTER 2: BACKGROUND

The three principal factors that guide current MnDOT Concrete Paving Specifications are:

1) Mixture Design for Durability
2) Incentives/Disincentives
3) Curing Practices

2.1 - MIXTURE DESIGN FOR DURABILITY

Previous to 1995, MnDOT supplied all concrete paving mixture designs to the paving contractors. These historical-based mixtures were designed on a "cement to voids" ratio method that ensured a mixture with compressive design strength of 3900 psi. Almost all mixture designs consisted of the following proportions:

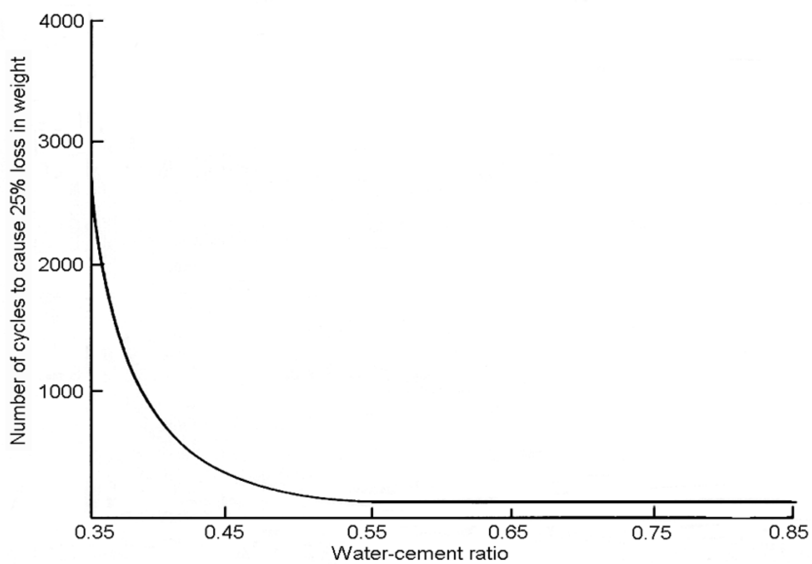
1) Design *w/cm* ratio of 0.46.
2) Minimum cementitious content of 530 pounds, typically consisting of 450 pounds of cement (i.e., specification minimum) and 80 pounds of fly ash (i.e., specification maximum, 15%).
3) 244 pounds of water.
4) 1200 pounds of fine aggregate.
5) Specified air content of 5.5 volume %.
6) Remaining volume made up of coarse aggregate to equal a volume of 27.0 cubic feet of which the coarse aggregate was required to meet the following gradation:

Table 2.1 Historical Required MnDOT Coarse Aggregate Gradation

Sieve	Percent Passing
2"	100
1-1/2"	95-100
¾"	35-70
3/8"	10-30
#4	0-7

These mixtures served MnDOT well over the years, but in the early 1990's agency engineers noted an increase in early pavement distresses, which initiated a review of possible causes and solutions. Previously, MnDOT had performed research on early joint deterioration caused by D-cracking and had developed a specification in the late 1980's that effectively controlled D-cracking. In the case of the newly observed failures, most of the deterioration seemed to be freezing and thawing durability related, affecting the cement paste.

MnDOT performed research to identify potential causes for the freezing and thawing related deterioration. One potential cause was identified as alkali-silica reactivity (ASR). As MnDOT was performing their research during the mid-1990's, the agency initiated a very aggressive ASR testing program to ensure the aggregates used in concrete pavements were not susceptible to ASR and if they were, the agency required increased amounts of supplementary cementitious materials (SCM) in the concrete mixtures using those aggregates to mitigate the ASR reaction. The typical SCM substitutions were 25–30% fly ash, and in certain areas of the state with more reactive aggregates, fly ash sources that exhibited properties closer to Class F fly ash were required. Several concrete research papers and text books referenced lower *w/cm* ratio as a good starting point to ensure durable concrete which was the basis of the direction MnDOT decided to take the new specification. Figure 2.1 shows the relationship between *w/cm* ratio and the number of cycles to cause 25% loss in mass. MnDOT's historical mixture designs had a *w/cm* ratio of approximately 0.46. Published research suggested that a maximum *w/cm* ratio for freeze-thaw durable concrete was in the range of 0.40 to 0.45.



"Chemical Admixtures for Concrete" 2nd Edition by M.R. Rixom and N.P. Mailvaganam

Figure 2.1. Relationship between *w/cm* ratio and the number of cycles to cause 25% loss in weight.

2.2 - FHWA INITIATIVE FOR STATISTICALLY BASED PERFORMANCE RELATED SPECIFICATIONS

During the same time period that MnDOT was reviewing their specification for possible enhancements, the Federal Highway Administration (FHWA) was also looking to enhance concrete pavement durability and consistency. The FHWA developed several pilot programs to work with statistical-based performance-related specifications. MnDOT experimented with these pilot specifications from 1992 to 1993, focusing on concrete strength and air content, pavement thickness, and pavement smoothness.

After completing the FHWA pilot projects on performance-related specifications, MnDOT did not believe the attributes being focused on would ensure durable pavement. The agency continued with their internal review and research to develop a specification that would better serve MnDOT's need to address concrete pavement durability.

2.3 - ADDITION OF WATER REDUCERS

Between 1993 and 1995, MnDOT determined they needed to reduce the water content in pavement concrete mixtures as the means to achieve their goal of a lower *w/cm* ratio. Select pilot projects were initiated where MnDOT provided an ASTM C494 Type A water reducer for specific contracts. The goal was to allow paving contractors the opportunity to gain experience with water reducers, as well as test the effectiveness of water reducers at reducing the water content.

2.4 - CREATION OF A NEW SPECIFICATION

After these pilot projects, and in cooperation with the concrete paving industry, it was agreed to establish a new specification for a maximum *w/cm* of 0.40 and a maximum cementitious value of 600 pounds per cubic yard. The cementitious value was also amended to allow for up to a maximum replacement of 25% of the portland cement with fly ash. Prior to this, MnDOT did not allow water reducers other than in low-slump concrete bridge deck overlays.

Table 2.2 outlines the specification changes for *w/cm* ratio, air content, and use of admixtures seen over the transition to low *w/cm* ratio mixture designs. Table 2.3 outlines the cementitious changes seen over the transition to low *w/cm* ratio mixture designs.

Table 2.2. MnDOT concrete mixture design history for *w/cm* ratio, target air content, use of admixtures.

Year	Maximum *w/cm* Ratio	Minimum *w/cm* Ratio for Incentive	Maximum *w/cm* Ratio for Incentive	Target Air Content (+/- 1.5%)	Admixtures Allowed
Pre-1996	0.46	NA	NA	5.5%	None Allowed
1996	0.40	0.35	$4.00	6.5%	Type A Water Reducers
2000	0.40	0.35	$4.00	7.0%	Type A and Type A Mid Range Water Reducers
2010	0.40	0.35	$4.00	7.0%	Viscosity Modifying Admixtures (VMA) and Hydration Stabilizers
2011	0.40	0.37	$3.00	7.0%	
2015	0.40 with fly ash 0.42 with slag/ternary	0.37 with fly ash 0.39 with slag/ternary	$3.00	7.0% (+2%/-1%)	

Table 2.3. MnDOT concrete mixture design history for cementitious content.

Year	Minimum Cement	Minimum Cementitious	Maximum Cementitious	% Fly Ash Allowed	% Slag Allowed	% Ternary Allowed
Pre-1996	450	530	850	15	35	N/A
1996	450	530	600	25	35	N/A
2000	450/420	530	600	25/30**	35	N/A
2002	400/385**	530	600	30**	35	N/A
2015	400/385**	530	600	33	35	35

Total Alkalis ($Na_2O + 0.658\ K_2O$) in Cement	0.6%
Total Alkalis in Cementitious Material	5.0 lbs/yd^3
**Total Alkalis in Cementitious Material when using Quartzite or Gneiss Coarse Aggregate	4.17 lbs/yd^3 Changed to require 30% Type F Fly Ash or 35% Slag

2.5 - CONCRETE STRENGTH PRE- AND POST-W/CM SPECIFICATION

Historically, MnDOT designed mixtures achieved the required strength of 3000 psi in 7 days, while high-early strength mixtures achieved 3000 psi in 3 days. The new low *w/cm* mixtures were achieving the required strength in 3 days. The contractors were designing high-early mixtures that easily achieved opening times in 24 hours.

In-place concrete pavement strength, assessed by testing concrete cores, has been measured back to the early 1900's. MnDOT designed mixtures were achieving an average core strength of approximately 4500 psi at 60 days of age. Contractor designed low *w/cm* mixtures were achieving an average core strength of greater than 6000 psi at 60 days of age.

2.6 - MNDOT'S EXPERIENCE WITH INCENTIVES

At the time MnDOT explored the use of incentives for smoothness, such action was not supported by the FHWA. However, MnDOT had previously seen the benefits of incentives for smoothness and felt concrete-mixture-related incentives would allow innovation by the contractor at a lower cost.

Incentives can provide an advantage to quality contractors, which in turn provides a better final product for MnDOT. MnDOT believed that once a contractor understood how they could utilize incentives, contractors would:

1) When bidding work, potentially buy new equipment.

2) Expend the time and money necessary to better understand their concrete mixture designs.

3) Give extra attention to grade preparation.

4) Utilize double stringline.

5) Optimize their operations.

2.6.1 - Incentives/Disincentives for w/cm

The new specification not only specified the maximum *w/cm* ratio, it also provided an incentive to the contractor to lower the *w/cm* ratio further. MnDOT believed that getting a *w/cm* ratio even lower than 0.40 would provide an even greater opportunity for long life, durable pavements. MnDOT also believed specifying a *w/cm* ratio assured quality, performance, and increased strength in advance, and advantageously provided immediate results as compared to waiting 28 days for strength test results.

MnDOT implemented AASHTO T 318, "*Method of Test for Water Content of Freshly Mixed Concrete Using Microwave Oven Drying*" to estimate the water content in the contractor's mixture. Although this test method was not accurate enough to establish incentive pay, its usefulness was in checking the uniformity of the concrete mixture (i.e., quality control). In several instances, the microwave oven test indicated either higher or lower water contents in the mixture, prompting further investigation of the batching equipment (i.e., water meter) by the contractor and facilitated corrective actions.

2.6.2 - Well-Graded Aggregate Optional Incentives

As part of the new specification approach, MnDOT also focused on gradation changes to help minimize the water demand of the mixtures and to enhance workability. As with the mixture design, MnDOT had historically specified a gradation for all paving mixtures. The required gradations were gap graded and not necessarily water demand or finisher friendly.

The new specification included an optional incentive to encourage the contractor to acheive a "well graded" gradation. If the Contractor met the well-graded gradation, they earned an incentive. If they did not meet the well-graded gradation, there was no disincentive. For a short period of time, MnDOT required an optimized gradation on 60-year high performance concrete paving projects and alternate bid projects.

Over time, the Contractor's saw a benefit to optimizing gradations and also found they achieved smoother riding pavements in addition to reduced water demand and enhanced workability.

Table 2.4 summarizes the evolution of well-graded aggregate incentives as MnDOT transitioned from the Shilstone "haystack" gradation (i.e., 8–18 % gradation), to use of the workability and coarseness factor, to finally the "Tarantula Curve". These various methodologies are illustrated graphically in Figure 2.2.

Table 2.4. Changes in well-graded aggregate incentives for MnDOT construction.

Year	Optional 8–18 % Retained	Optional 7–18 % Retained	Required HPC 8–18 % Retained	Required Alternate Bid 6 – 18% Retained	Optional Workability and Coarseness Factor – Zone II-A	Optional Tarantula Curve
1996	$0.50	NA	NA	NA	NA	NA
1998	$2.00	NA	NA	NA	NA	NA
2000	$2.00	$0.50	-$5.00	NA	NA	NA
2010	$2.00	$0.50	NA**	-$2.00	$2.00	NA
2015	NA	NA	NA	NA	NA	$2.00

**Eliminated HPC paving specifications

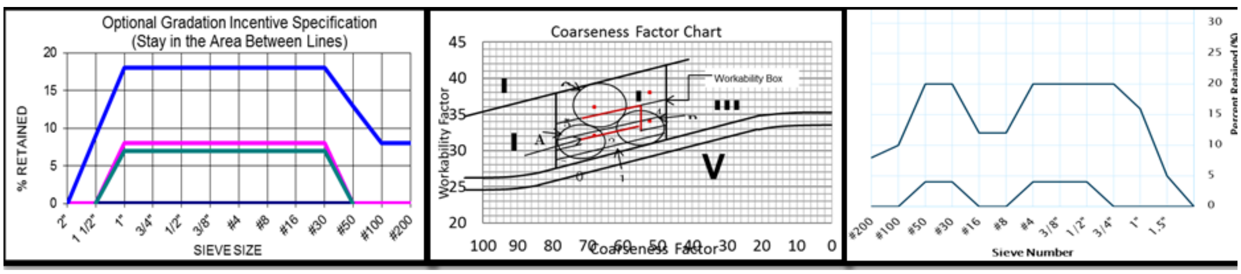


Figure 2.2. Graphical examples of various gradation methodologies (left to right), Haystack 8-18 %), Workability and Coarseness Factor, Tarantula Curve

2.6.3 - Incentives/Disincentives for Aggregate Quality

By incentivizing enhanced aggregate durability, MnDOT also expected to increase pavement life and reduce life cycle costs. Any coarse aggregate sources that met the MnDOT aggregate quality specification were not disallowed. However, the agency did provide an incentive to the contractor to use a high quality aggregate for a given project. Table 2.5 shows the aggregate quality incentives, which have remained primarily unchanged since they were implemented.

Table 2.5. Changes in aggregate quality incentives for MnDOT construction.

Year	Class A Granites, Gneiss, Quartzites	Class B Carbonates, Dolostones	Class C Natural Gravels
1997 – present	$1.00/cu. yd.	$1.00/cu. yd.	$1.00/cu. yd.
2000 HPC Specification Only	$1.90/cu. yd.	$1.90/cu. yd.	$1.90/cu. yd.
Only pay on the two (2) largest fractions of coarse aggregate			
Class A – Automatic incentive			
Class B – Lower % absorption in aggregate (1.75% Max)		~Ave 1.40% or less	
Class C – Reduced % carbonate in aggregate (30% Max)		~Ave 20.0% or less	

2.7 - IMPROVED CURING REQUIREMENTS

Another issue identified shortly after the new specifications were implemented was the need for better control on curing practices. With the lower *w/cm* ratio, (i.e., 0.38 typical compared to 0.46, or about 20% lower) and the lower overall water (i.e., 210 pounds vs. 244 pounds, or about 15% less) there was far less bleed water available to aid in curing. Most curing compound manufacturers recommended applying the curing compound as soon as the bleed water has dissipated. The new mixtures had minimal bleed water and curing became more critical because a larger fraction of the water in the mixture was consumed to hydrate the cementitious material in the mixture.

Between 1997 and 1998, MnDOT conducted research on curing compounds and considered changes to curing specifications (Vandenbossche 1999). Based on the experience of other agencies such as Caltrans, it was determined that a version of poly-alpha methyl styrene (AMS) would be introduced as MnDOT's specified curing compound base material. Part of this specification included adding a requirement for a maximum 24-hour water loss of 0.15 kg/m^3 [0.25 lb/yd^3]. The agency believed a 24-hour water loss requirement would help ensure the concrete pavement continued to hydrate during the critical very early ages. Table 2.6 shows the changes to types of curing compounds used over time.

Table 2.6. Changes in MnDOT specifications for curing compound used for MnDOT construction.

Year	Type of Curing Compound Specified	Comments
Pre-1999	Water Based Curing Compound	
1999	Non-Water Based Only	
2000 - present	Poly-alpha methyl styrene (AMS)	
2005-present	Poly-alpha methyl styrene (AMS)	Apply homogeneously to provide a uniform solid white opaque coverage on all exposed concrete surfaces (equal to a white sheet of typing paper)

2.8 - CHANGES TO PAVEMENT SMOOTHNESS

The last major overhaul of the MnDOT concrete pavement specification was related to pavement smoothness. Prior to 1983, MnDOT only required a straightedge for acceptance. The agency was concerned the ride on new construction projects was degrading compared to previous years as contractors were paving with equipment used to build the original interstate system in the 1960's.

Over time there was a shift in ideology and methodology for measuring pavement smoothness. As part of that change, MnDOT believed they would be better served by having an incentive for the contractor to achieve better than specified smoothness. As with the other specifications, this specification has evolved with time leading to increased incentives and smoother pavements. Figure 2.3 shows historical MnDOT smoothness at initial concrete pavement construction over time with use of the different ride measuring equipment and specifications. Table 2.7 summarizes the evolution of the MnDOT smoothness specifications up to present time.

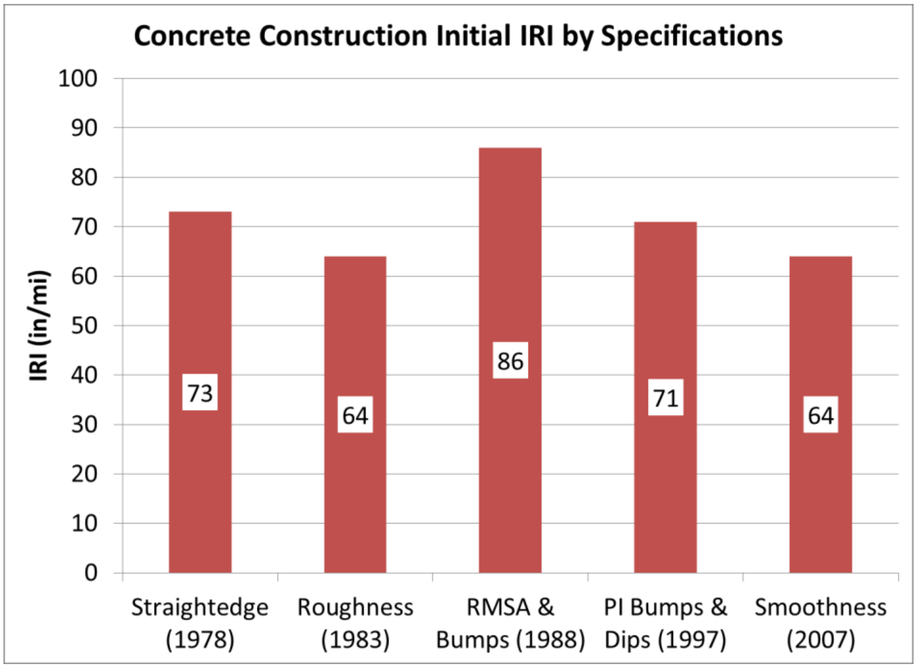


Figure 2.3. Changes in IRI correlated to methods of measurement used.

Table 2.7. Changes in MnDOT specifications for smoothness of concrete pavements as placed.

Item	1978-1982	1983-1987	1988-1996	1997-2006	2007-present
Equipment	Straight Edge	GM Profilometer	GM Profilometer	California Profilograph	Inertial Profiler
Measurement	N/A	Roughness (in/mi)	Root Mean Square Acceleration (RMSA)	Profile Index (in/mi)	International Roughness Index (IRI/MRI)
Who Performs	N/A	MnDOT	MnDOT	Contractor	Contractor
Max. Incentive $/SY	N/A	$0.50	$0.50	$1.12	$1.26
Max. Disincentive $/SY	N/A	-$2.00	-$2.00	-$1.00	-$1.07
Max. Incentive $/0.1 mile	N/A	$352	$352	$788.48	$890
Max. Disincentive $/0.1 mile	N/A	-$1408	-$1408	-$704	-$750

2.9 - OTHER SPEC CHANGES TO ENHANCE QUALITY

With the shift in responsibility for mixture design to the contractor, MnDOT assumed a reduced process-control testing role and transferred the quality control testing to the contractor. MnDOT intended that as a result of this change, contractors would become more educated on how closely they can control the uniformity of the paving mixtures and make adjustments as necessary to improve the concrete mixture design.

MnDOT has instituted several other changes in specifications over the years, not discussed here, to increase durability, increase pavement life, and reduce life-cycle costs. These changes include:

1) Vibration monitoring requirements for slipform paving applications
2) Testing before and after paver to determine the air loss due to consolidation
3) Dowel bar alignment testing using the MIT Scan T2

2.10 - THE PROCESS OF SPECIFICATION CHANGE

As new specifications were implemented in the mid to late 1990's, both MnDOT and the contractors became aware of the need to allow for change in the specifications. MnDOT needed to clearly communicate expectations to the contractor and allow them an opportunity to learn what worked and what did not. There were items that needed to be updated to allow for the specifications to succeed and allow the contractor to provide the best concrete mixture possible. Specifications and incentives have been tweaked over the last 15 years as needed to continue to improve the durability of the concrete paving mixture. Table 2.8 includes some of the pilot projects that utilized specification enhancements during development of the new specification.

Table 2.8. Pilot projects that utilized specification enhancements during development of the new specification

Year Built	Project Number	Roadway/ Location	Specification Enhancement	Incentive	Comments
1994	2102-41	I-94 Alexandria	Coarse Aggregate Quality	$1.00 per cubic yard	Class A Low Absorption Class B Low Carbonate Class C
1994	4208-36	TH 59 Marshall	Thickness		Needed to add maximum thickness
1994	1013-58	TH 212 Cologne	Coarse Aggregate Quality	$1.00 per cubic yard	Class A Low Absorption Class B Low Carbonate Class C
			Optimized Gradations	none	Gradation Methods i. Shilstone mixture (very easy to place and included 3/8”- material) ii. SHRP mixture (very coarse with 2/3 typical sand and 1.5 times ¾”+ coarse aggregate, segregated with belt placer, difficult to finish, slump meter couldn’t measure accurately while batching)
1995	0712-32	TH 169 Garden City	Strength	$2.25 per cubic yard	
			Optional Contractor Mixture Design*	Contractor Elected to use MnDOT designs with adjustments	Maximum *w/cm* ratio = 0.42 i. Type A Water Reducer ii. Gradation Control iii. Cementitious addition at a minimum of 1 pounds of cement to 3 pounds of fly ash
			Contractor Testing	none	Process Control Testing i. moisture contents ii. batch weight adjustments iii. gradations iv. air contents v. flexural strengths vi. slump testing Agency Acceptance Testing i. gradation ii. air content iii. slump testing

* The Contractor received the full bonus for all the sections we have results for, but one of the purposes of this incentive program was to require Contractor mixture design. This gave the Contractor the first look at risk analysis in this area and making an economic decision on the concrete mixture design so it served its purpose.

CHAPTER 3: RESEARCH APPROACH

To establish the effectiveness of the specification changes described in Section 2, MnDOT undertook this research in cooperation with American Engineering Testing. Thirty-six pavement projects were identified for core sampling. These projects are summarized in Table 3.1. Table 3.3 organizes the selected projects with respect to implementation of the *w/cm* specification in 1996. Although a number of specification changes were made as described in Section 2, the *w/cm* specification is considered the most significant and is used to delineate projects for this research.

The projects for investigation were selected to capture the wide range of materials and exposure conditions found throughout the state. Projects were identified with respect to age, seeking a good representation of both pre- and post-*w/cm* specification projects (i.e., construction date of the pavements ranged from 1991 – 2004), and with respect to geographic distribution. The specific locations cored and the number of cores per project were determined by the coring crews in the respective maintenance districts 1-8 and Metro. Each crew attempted to capture both mid-panel and jointed core samples. The desire was to have a randomly sampled population for analysis. A state map indicating the various districts referenced in Table 3.1 is presented in Figure 3.1. Mixture design parameters for the pavements sampled are provided in Table 3.3.

The cores were delivered to American Engineering Testing and selected cores were identified for the various tests performed. Not all tests were performed on cores representing each project; the cores selected are identified in the various data tables presented in this report. The laboratory tests performed were selected to characterize key properties that were expected to change with the described changes in specifications. These properties are permeability, compressive strength, and air-void system parameters. Regarding permeability, a number of different tests were performed as presented in Section 4.

In addition to laboratory testing, MnDOT provided pavement management data for each project and that data was also examined in this research to identify trends occurring between pre- and post *w/cm* projects.

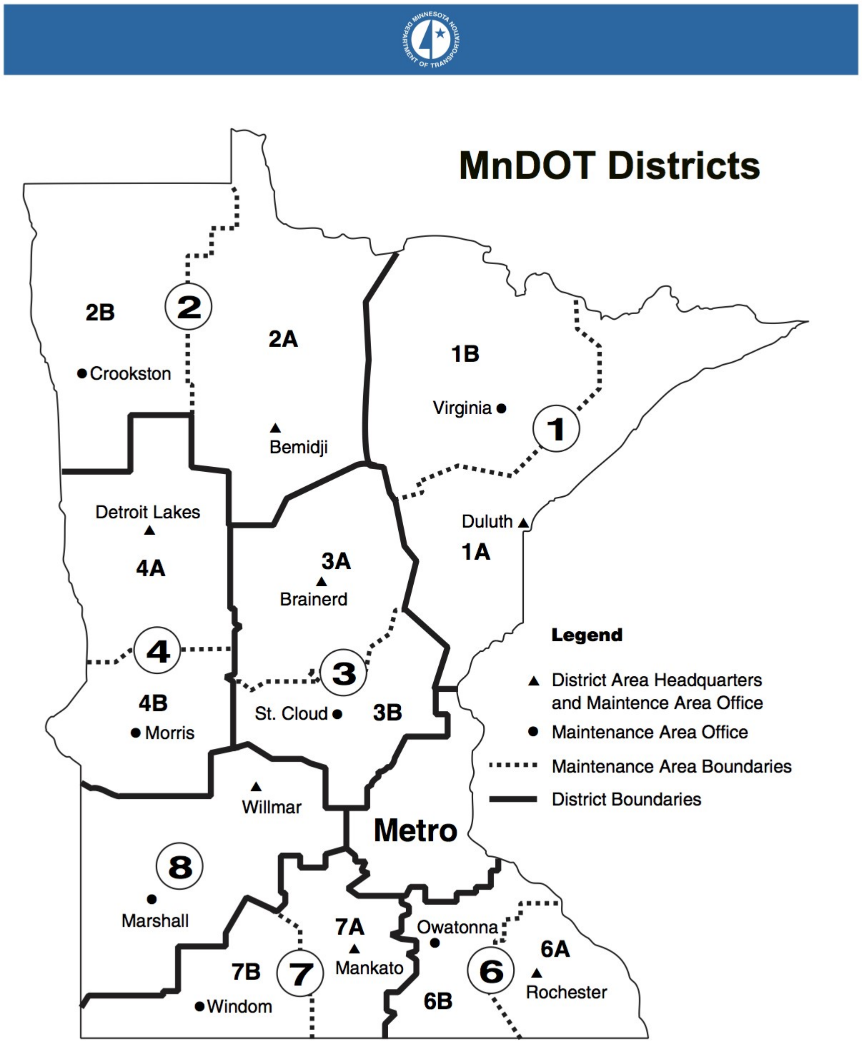


Figure 3.1. Map of Minnesota showing the various districts referenced in Table 3.1 and throughout this document.

Table 3.1. Pavement projects sampled for this research.

District	SP Project Number	Route	Maintenance Area	County Code	Year Built	Contractor
1	0980-127	I-35	1A	9	1992	PCI
1	3805-67	MN-61	1A	38	1997	Shafer
2	6019-22	US-2	2B	60	2000	PCI
3	7380-199	I-94	3B	73	1999	PCI
3	7380-200	I-94	3B	73	1999	PCI
4	1480-131	I-94	4A	14	1998	PCI
4	2180-78	I-94	4A	21	1994	PCI

District	SP Project Number	Route	Maintenance Area	County Code	Year Built	Contractor
4	5680-111	I-94	4A	56	1997	PCI
4	8480-26	I-94	4A	84	1993	Shafer
4	8480-27	I-94	4A	84	1994	PCI
4	2180-71	I-94	4B	21	1993	Diamond Surfaces
4	2180-80	I-94	4B	21	1998	PCI
M	1907-53	US-55/52	9B	19	1995	Shafer
M	1907-54	US-55	9B	19	1995	PCI
M	2782-268	I-35W	5A	27	2000	Shafer
M	2786-115	I-94	5A	27	2004	Shafer
M	2786-116	I-94	5A	27	2004	PCI
M	2786-117	I-94	5A	27	2004	McCrossan
M	0280-049a	I-35W	9A	2	2000	Shafer
6	2313-13	US-63	6A	23	1996	PCI
6	5507-47	US-52	6A	55	1992	PCI
6	2480-88	I-35	6B	24	1998	PCI
6	2480-91	I-35	6B	24	2000	PCI
7	0702-98	US-14	7A	51	1997	PCI
7	0712-30	US-169	7A	7	1992	PCI
7	0712-32	US-169	7A	7	1995	PCI
7	2208-35	US-169	7A	22	1992	Castlerock
7	2208-36	US-169	7A	22	1991	PCI
7	4013-41	US-169	7A	40	1995	PCI
7	5306-37	MN-60	7A	38	1997	PCI
7	6507-04	MN-19	7A	65	1993	PCI
7	7204-13	MN-19	7A	72	1992	Diamond Surfaces
7	3204-59	MN-60	7B	32	2003	PCI
7	3204-62	MN-60	7B	76	2001	Cape
8	4705-30	US-12	8A	47	1996	Shafer
8	6404-32	MN-19	8A	65	1998	Shafer

Table 3.2. Pavement projects sampled for this research delineated as pre- or post-*w/cm* specification, which was fully implemented in 1996.

Year Completed	Project Number	Pre or Post *w/cm* Specification	Year Completed	Project Number	Pre or Post *w/cm* Specification
1991	2208-36	PRE	1995	0712-32	POST
1992	0712-30	PRE	1996	2313-13	POST
1992	0980-127	PRE	1997	0702-98	POST
1992	2208-35	PRE	1997	3805-67	POST

Year Completed	Project Number	Pre or Post *w/cm* Specification	Year Completed	Project Number	Pre or Post *w/cm* Specification
1992	5507-47	PRE	1997	5306-37	POST
1992	7204-13	PRE	1997	5680-111	POST
1993	2180-71	PRE	1998	1480-131	POST
1993	6507-04	PRE	1998	2180-80	POST
1993	8480-26	PRE	1998	2480-88	POST
1994	2180-78	PRE	1998	6404-32	POST
1994	8480-27	PRE	1999	7380-199	POST
1995	4013-41	PRE	1999	7380-200	POST
1995	1907-53	PRE	2000	0280-49a	POST
1995	1907-54	PRE	2000	2480-91	POST
1996	4705-30	PRE	2000	2782-268	POST
			2000	6019-22	POST
			2001	3204-62	POST
			2003	3204-59	POST
			2004	2786-115	POST
			2004	2786-116	POST
			2004	2786-117	POST

Table 3.3. Mixture design specifications for the projects included in this study.

	Coarse (lbs)										
SPNO	1.5"	3/4"	3/8"	Grit (lbs)	Natural Sand (lbs)	Water (lbs)	Cement (lbs)	Fly Ash (lbs)	Slag (lbs)	Cement Source	Fly Ash/Slag Source
2208-36 (0712-34)		1578			1200	290	512	90	0	Lehigh	Unknown
2208-36 (0712-34)	939	939			1200	244	451	79	0	Lehigh	Unknown
0712-30		1669			1200	260	472	111	0	Lehigh	NSP @ Eagan
0980-127	579	1343			1200	244	451	79	0	Lafarge @ Alpena, MI	NSP @ Eagan
2208-35	1003	729			1200	257	468	82	0	Lehigh	Lehigh
5507-47	1113	740			1200	244	493	87	0	Lehigh	Portage Unit #2, CL C
7204-13		1698			1200	260	472	111	0	Lehigh	Genoa #3, CL F
2180-71	815	982			1200	260	472	83	0	Unknown	Unknown
6507-04		1616			1200	282	502	88	0	Lehigh, Mason City	NSP @ Eagan
8480-26		1678			1200	260	472	83	0	Lafarge @ Alpena, MI	Unknown
2180-78	750	1118			1200	260	472	83	0	Missassauga @ St. Lawrence	NSP @ Eagan
1907-53		1703			1200	260	472	83	0	Unknown	Unknown
1907-54		1710			1200	260	472	83	0	Unknown	Unknown
0702-98	845	1030			1190	218	450	125	0	Holnam, Mason City	NMC/NSP Eagan
5306-37	908	927			1216	222	450	135	0	Holnam, Mason City	NMC/NSP Eagan
5680-111	950	950			1245	203	450	115	0	Lafarge/Exshaw	Coal Creek
1480-131	950	950			1215	208	450	130	0	Lafarge/Exshaw	Coal Creek
2180-80	860	1020			1220	212	450	140	0	Lafarge	JTM/Coal Creek
2480-88	850	1040			1220	216	450	150	0	Lehigh, Mason City	Coal Creek (Mineral Solutions)
6404-32	930	930			1174	228	450	150	0	Holnam/Mason City	NSP @ Eagan
7380-199	650	1125	310		1075	208	450	130	0	Holnam, Siam City	Coal Creek (Mineral Solutions)
0280-049	603	1078	412		1078	209	450	100	0	Holman Siam	NSP @ Eagan
2480-91	860	1021			1210	224	450	140	0	Holnam, Siam City	Edgewater (Mineral Solutions)
2782-268	575	800	350	440	950	220	384	0	206	Lafarge, Davenport	Holnam, Grancem 100
6019-22	880	1075			1170	208	450	130	0	LaFarge, Exshaw	LaFarge, Coal Creek
7380-200	770	910	390		1100	208	450	130	0	Holnam, Siam City	JME/ISG, Coal Creek
3204-62	1153	738			1159	230	377	0	203	Holnam, Siam City	Holnam, Grancem 100

SPNO	Coarse (lbs) 1.5"	3/4"	3/8"	Grit (lbs)	Natural Sand (lbs)	Water (lbs)	Cement (lbs)	Fly Ash (lbs)	Slag (lbs)	Cement Source	Fly Ash/Slag Source
3204-59	770	890	310		1120	207	403	172	0	Holcim, Mason City	ISG Coal Creek
8480-27	1955				1200	225	459	79	0	Lafarge	NMC Unit #1
0712-32		1683			1200	260	472	83	0	Holnam @ Mason City	Genoa #3, CL F
4013-41	1670				1190	232	450	130	0	Lehigh	NSP @ Eagan
2313-13	745	1115			1255	222	450	120	0	Holnam	Portage Unit #1
4705-30	1210	760			1100	232	450	130	0	Unknown	Unknown
3805-67	852	1046			1220	228	450	150	0	Missassauga @ St. Lawrence	NMC/NSP Eagan

Table 3.3. Mixture design specifications for the projects included in this study (cont.)

SPNO	Maximum Aggregate Size	1.5" Coarse Source	1.5" Aggregate Type	3/4" Coarse Source	3/4" Coarse Aggregate Type	3/8" Coarse Source	GRIT Source	Natural Sand Source
2208-36 (0712-34)	3/4		NONE	152003	Recycled/Quartzite			107002
2208-36 (0712-34)	3/4		NONE	152003	Recycled/Quartzite			107002
0712-30	3/4	152003	Quartzite	152003	Recycled/Quartzite			107002
0980-127	1 1/2	109001	Gravel	109001	Gravel			109001
2208-35	3/4			152003	Recycled/Quartzite			107002
5507-47	1 1/2	179091	Limestone	179091	Limestone			155204
7204-13	3/4			152003	Recycled/Quartzite			110001
2180-71	1 1/2	121055	Gravel	121055	Gravel			121055
6507-04	3/4			164065	Gravel/Recycled			108002
8480-26	3/4			Recycled	Recycled			103081
2180-78	1 1/2	173006	Granite	173006	Granite			121055
1907-53	3/4			Recycled	Recycled			182001
1907-54	3/4			Recycled	Recycled			182001
0702-98	1 1/2	152003	Quartzite	152003	Quartzite			107002

SPNO	Maximum Aggregate Size	1.5" Coarse Source	1.5" Aggregate Type	3/4" Coarse Source	3/4" Coarse Aggregate Type	3/8" Coarse Source	GRIT Source	Natural Sand Source
5306-37	1 1/2	117001	Quartzite	117001	Quartzite			167001
5680-111	1 1/2	156003	Gravel	156003	Gravel			156003
1480-131	1 1/2	103081	Gravel	103081	Gravel			103081
2180-80	1 1/2	173006	Granite	173006	Granite			161072
2480-88	1 1/2	193018	Limestone	193018	Limestone			124041
6404-32	1 1/2	165065	Gneiss	165065	Gneiss			165001
7380-199	1 1/2	173006	Granite	173006	Granite	177095		177095
0280-049	1 1/2	173006	Granite	127003	Gravel	182001		113004
2480-91	1 1/2	193018	Limestone	193018	Limestone			124069
2782-268	1 1/2	127003	Gravel	127003	Gravel	127004	119004	119004
6019-22	1 1/2	160003	Gravel	160003	Gravel			160003
7380-200	1 1/2	173006	Granite	173006	Granite	177095	OR 173002	173002
3204-62	1 1/2	164064	Gravel	187002	Gravel			117071
3204-59	1 1/2	117001	Gravel	117001	Gravel	167001		167001
8480-27	1 1/2	156003	Gravel	156003	Gravel			114073
0712-32	3/4			Recycled	Recycled			107002
4013-41	1 1/2	140002	Gravel	Recycled	Recycled			140002
2313-13	1 1/2	193018	Limestone	193018	Limestone			123011
4705-30	1 1/2	173006	Granite	173006	Granite			186001
3805-67	2	169004	Gravel	138001	Gravel			138001

CHAPTER 4: EXPERIMENTAL METHODS

The laboratory procedures used to examine the selected cores are summarized in Table 4.1.

Table 4.1 Summary of laboratory tests performed on selected cores.

Property	Test Method	Comments
Permeability	ASTM C1202 *Standard Test Method for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration*	In most cases, a minimum of three measurements were made for each project. Measurements typically came from different cores.
Permeability	ASTM C1152 *Standard Test Method for Acid-Soluble Chloride in Mortar and Concrete*	Samples obtained at three depths from each core: ¼" – 1", 1" – 2", 2" – 3". Chloride content determined by potentiometric titration of chloride with silver nitrate.
Permeability	AASHTO T 358 *Standard Method of Test for Surface Resistivity Indication of Concrete's Ability to Resist Chloride Ion Penetration*	Each core for strength was tested. Cores were kept in moist room until testing. Surface was wiped dry with a towel prior test, two measurements on opposite sides.
Compressive Strength	ASTM C39/C39M *Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens*	Specimens tested were core samples of varying dimensions. Measured compressive strengths were corrected for geometric effects using the procedure outlined in the Calculation section of ASTM C39. MnDOT performed all ASTM C39 testing.
Air-Void System Parameters	ASTM C457/C457M *Standard Test Method for Microscopical Determination of Parameters of the Air-Void System in Hardened Concrete*	Determined using Procedure A – Linear Traverse.
Other Properties	ASTM C856 *Standard Practice for Petrographic Examination of Hardened Concrete*	Selected cores were analyzed for general properties and attributes. The complete results are summarized in Appendix A of this report.

CHAPTER 5: RESULTS & DISCUSSION

5.1 - PERMEABILITY – ASTM C1202 (RCPT)

A total of 27 projects were examined in accordance with ASTM C1202 to establish the relative permeability of each specimen as represented by the electrical charge passed through the specimens during the test. The results are presented in Table 5.1 and Figure 5.1. In most cases at least three separate samples were analyzed, typically from two or more cores. The error bars shown in Figure 5.1 represent the high and low values of the samples analyzed for that project. The filled circle data points in Figure 5.1 indicate the average of all samples analyzed for that project.

The results indicate an approximate five-fold difference between pre-*w/cm* and post-*w/cm* charge transfer, indicating a distinct difference in permeability between the two groups of samples. Also of interest is the scatter in results for each individual project. Although the number of samples analyzed per project was small, there appears to be a trend of more scatter between pre-*w/cm* as compared to post-*w/cm.* This suggests that not only are the post-*w/cm* pavements sampled less permeable, there is also less variability in this important material property.

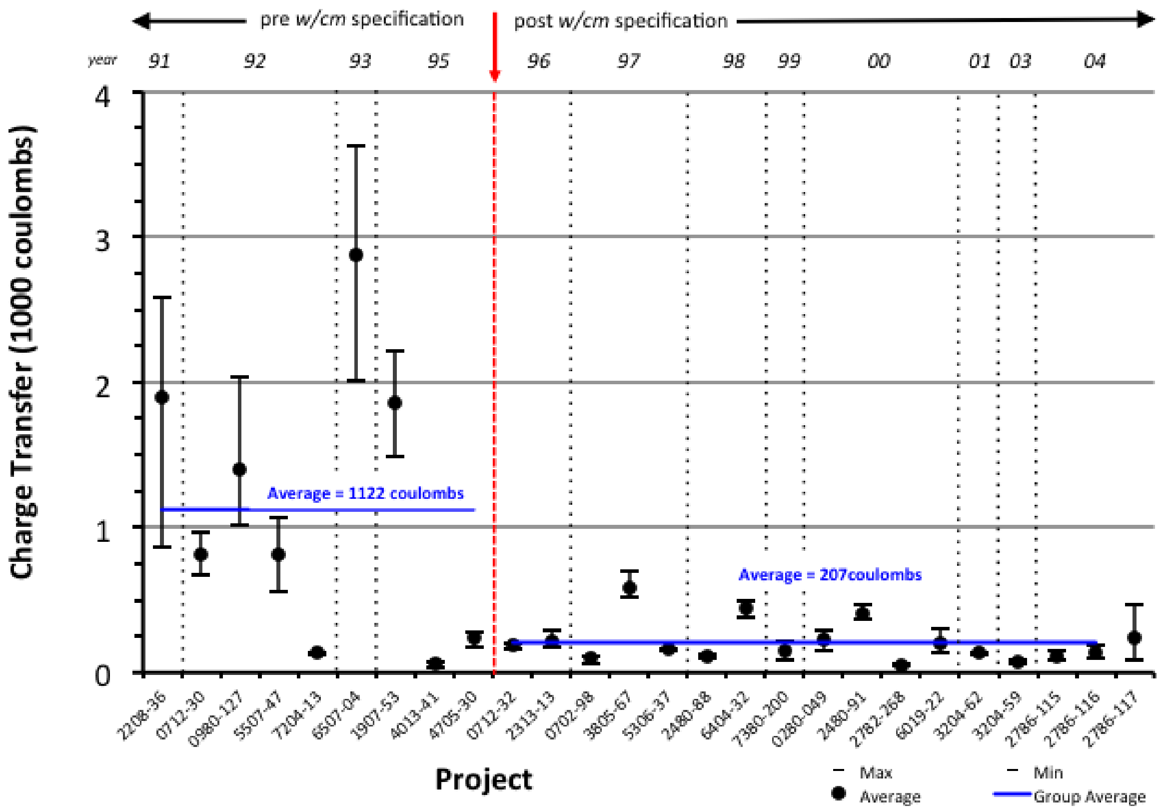


Figure 5.1. Results of ASTM C1202 (Rapid Chloride Ion Test, RCPT) from 27 different pavement projects. The error bars shown represent the high and low values of the samples analyzed for each project. The filled circle data points indicate the average of all measured values for each project. The blue line represents the average of all pre-w/cm analyses and the average of all post-w/cm analyses, respectively.

Table 5.1. Results of ASTM C1202 (Rapid Chloride Ion Test, RCPT) from 27 different pavement projects.

Project #	Core	Coulombs	Project #	Core	Coulombs	Project #	Core	Coulombs
2208-36	G	2249	2313-13	M004	295	2782-268	C-05	56
	G	870		M005	180		C-05	46
	H	2580		M005	171			
0712-30	L	960	4705-30	3	171	6019-22	5	299
	L	828		6	274		8	139
	M	668		6	278		11	156
0980-127	2C	1160	0702-98	2	114	3204-62	4	125
	2C	2032		2	114		4	140
	3C	1012		3	65		4	125
5507-47	M006	1063		3	108		4	140

Project #	Core	Coulombs
	M006	562
7204-13	29	142
	29	119
	30	140
6507-04	23	3630
	23	2007
	24	3005
4705-30	3	171
	6	274
	6	278
0712-32	4	192
	4	192
	5	201
	5	167
	5	201
	5	167
1907-53	C-02	1486
	C-02	2218
4013-41	4	40
	4	63
	4	40
	4	63
	5	77
	5	77

Project #	Core	Coulombs
	3	65
	3	108
3805-67	6A	534
	7A	525
	7A	696
5306-37	4	162
	4	149
	4	162
	4	149
	5	162
	5	162
2480-88	M006	100
	M006	110
	M006	125
6404-32	11	442
	11	379
	12	497
7380-200	7001	211
	7004	86
	7007	168
0280-049	C-05	156
	C-05	287
2480-91	M013	467
	M013	370
	M013	370

Project #	Core	Coulombs
	5	140
	5	140
3204-59	5	63
	5	81
	5	63
	5	81
	6	70
	6	70
2786-115	5MP	109
	5MP	91
	5MP	145
2786-116	1MP	185
	1MP	114
	1MP	99
2786-117	6MP	91
	6MP	165
	6MP	474

5.2 - PERMEABILITY – ASTM C1152 (CHLORIDE PROFILING)

The chloride concentration profile, perpendicular from an exposed surface towards the interior of the slab, is often used as an indicator of permeability. The source of the chloride is deicer salts used for winter maintenance. As permeability increases, the chloride ions diffuse to a greater depth, as compared to concrete with lower permeability and the same chloride exposure conditions. Also with higher permeability, the chloride concentration at a specific depth (e.g., one inch) will be greater than measured at the same depth for concrete with lower permeability and the same chloride exposure conditions. ASTM C1152 is used to determine the acid-soluble chloride concentration in a given sample and provides an estimate of the total chloride concentration in the sample at a specific depth. A total of 20 projects were examined in accordance with ASTM C1152 to establish the degree of chloride ingress. The selected cores were obtained near mid-panel of each site, away from any transverse or longitudinal joint. The results are presented in Table 5.2 and Figure 5.2.

The chloride profiles in Figure 5.2 fall into three distinct groupings. These are summarized in Table 5.3.

Table 5.2. Results of ASTM C1152 (Acid Soluble Chloride) from 20 different pavement projects. One core was analyzed from each project and three samples, at increasing depths, were obtained from each core.

Project #	Core	Chloride Concentration (ppm)		
		1/4" - 1"	1" - 2"	2" - 3"
2208-36	H	2820	840	230
0712-30	M	1950	990	190
0980-127	3C	7700	4680	1550
5507-47	M006	5880	2360	970
7204-13	30	4300	220	
6507-04	24	2060	200	140
4013-41	NB 4	2290	154	123
0712-32	SB 4	3450	20	272
2313-13	M004	2720	160	170
4705-30	3	2300	100	78
3805-67	6A	3060	230	65
5306-37	5	4170	20	58
0702-98	2	2220	20	80
2480-88	M006	2870	150	110
6404-32	12	3030	170	110
7380-200	7004	2240	84	81
2480-91	M013	2150	100	160
6019-22	11	1860	180	70
3204-62	5	2080	20	129
3204-59	6	3450	66	97

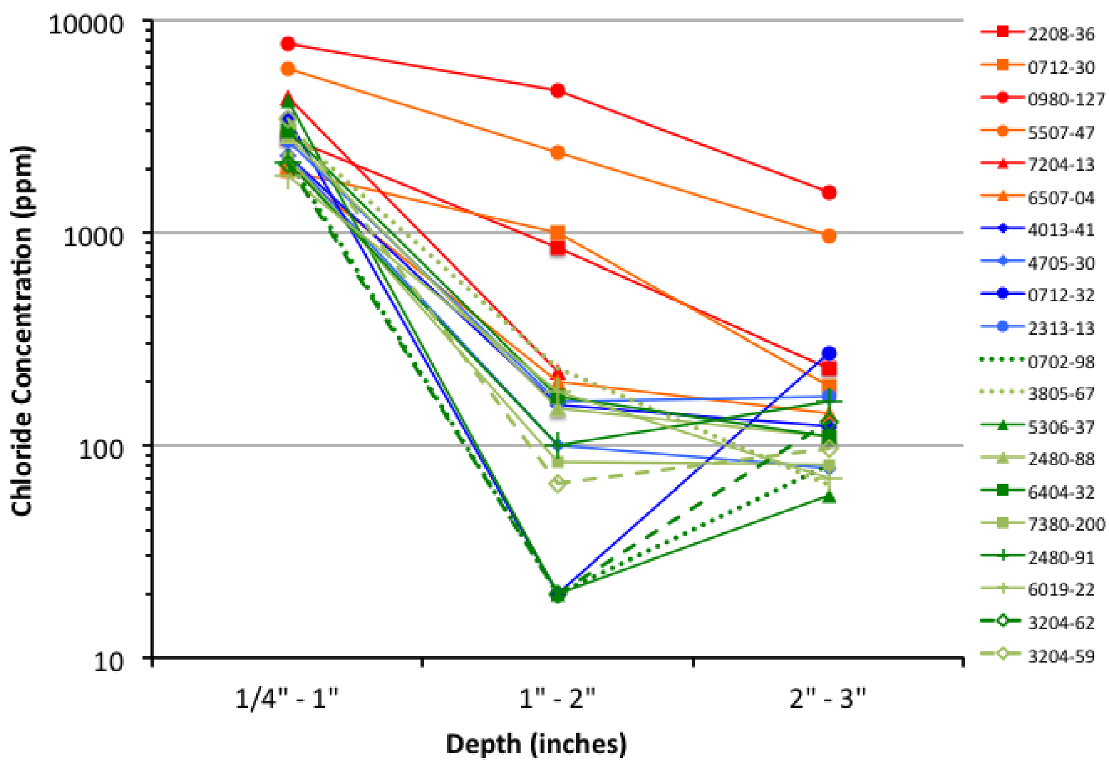


Figure 5.2. Results of ASTM C1152 (Acid Soluble Chloride) from 20 different pavement projects. One core was analyzed from each project and three samples, at increasing depths, were obtained from each core. Data is color coded red & orange is 1991 – 1995 (pre-*w/cm*), blue is 1996-1997 (transition period), and green is 1998 – present (post-*w/cm*). Concentration data shown on log scale to visually enhance differences.

Table 5.3. Grouping of results presented in Figure 5.2.

Lower Group			*Middle Group*			*Upper Group*		
Project Number	**Date Built**	**District**	**Project Number**	**Date Built**	**District**	**Project Number**	**Date Built**	**District**
0712-32	1995	7	7204-13	1992	7	2308-36	1991	7
5306-37	1997	7	6507-04	1993	7	0712-30	1992	7
0702-98	1997	7	4013-41	1995	7	0980-127	1992	1
3204-62	2001	7	2313-13	1996	6	5507-47	1992	6
			4705-30	1996	8			
			3805-67	1997	1			
			2480-88	1998	6			
			6404-32	1998	8			
			7380-200	1999	3			
			2480-91	2000	6			
			6019-22	2000	2			
			3204-59	2003	7			

As stated, chloride diffusion can be used as a relative measure of permeability when exposure conditions are the same. In this case, the pavements range in age and the older pavements simply have been exposed to chlorides for a longer period of time. Further, the salt exposure associated with winter maintenance varies by district and the maintenance practices required for that portion of the state. Therefore, the data from these analyses is confounded and it is not possible to draw any absolute conclusions based on this data. As a further explanation, note the upper grouping are all pavements built in 1991 and 1992, the oldest pavements in this study. These show the highest chloride ingress and the highest concentrations at a given depth, which is consistent with a longer exposure time, or higher permeability, or a higher exposure condition, or any combination of these factors. Likewise, the two highest concentration profiles in the middle group (i.e., 7204-13 and 6507-04) are the next oldest pavements sampled. The trends noted are easily due to just pavement age.

5.3 - PERMEABILITY – AASHTO T 358 (RESISTIVITY)

Surface resistivity provides a quick measurement that correlates well with the ASTM C1202 measurement of the same concrete. Many DOTs currently use surface resistivity as a measure of concrete permeability. Surface resistivity was measured in accordance with AASHTO T 358 on the same core samples used to measure compressive strength. These cores represent 26 of the projects studied. The surface resistivity results are presented in Table 5.4, Table 5.5 and Figure 5.3. The error bars shown in Figure 5.3 represent the high and low values of the samples analyzed for that project. The filled circle data points in Figure 5.3 indicate the average of all samples analyzed for that project. The blue line represents the average of all pre-*w/cm* analyses and the average of all post-*w/cm* analyses, respectively.

A clear trend can be seen where samples representing the post-*w/cm* projects have a higher resistivity than measured on cores representing the pre-*w/cm* projects, indicating a lower permeability. Unlike the ASTM C1202 measurements, there appears to be a trend of more scatter between post-*w/cm* samples from the same project as compared to pre-*w/cm* samples from the same project. This suggests more variability in the post-*w/cm* permeability. With out a third independent measurement of paste density, it is not possible to determine if the variability observed in both tests is a true measure of variability or if it is an artifact of the testing method. It is reasonable to suspect that bound chlorides, as measured in the ASTM C1152 tests, could affect either permeability measurement. The RCPT test relies on movement of chloride ions though the concrete while the surface resistivity is measuring conductivity, which in turn would be affected by chloride ions bound in the cement paste matrix. Given the known correlation between surface resistivity and the RCPT test, it appears that a difference in permeability exists between pre-*w/cm* as compared to post-*w/cm* projects, but it is not possible to comment with confidence on the variability of permeability for a given project.

Table 5.4. Resistivity data measured in accordance with AASHTO T 358 and compressive strength measured in accordance with ASTM C39

Project	Core	Resistivity (kohm-cm)	Capped Length (inch)	Diameter (inch)	L/D	Measured Compressive Strength	Geometry Correction Factor	Corrected Compressive Strength
2208-36	J	28	6.86	4.66	1.47	8292	0.9573	7938
0712-30	K	22	7.27	4.66	1.56	7490	0.9649	7227
0980-127	1A	29.4	7.07	3.67	1.93	5779	1.0000	5779
	1C	32.7	6.84	3.69	1.85	5792	1.0000	5792
2208-35	C	21.6	6.41	4.67	1.37	7023	0.9469	6650
	D	15.4	6.42	4.65	1.38	6038	0.9480	5724
5507-47	M002	42	7.69	3.93	1.96	9985	1.0000	9985
	M003	37.6	7.61	3.92	1.94	7963	1.0000	7963
	M009	44.7	7.50	3.91	1.92	8923	1.0000	8923
7204-13	32	46	7.33	3.96	1.85	6400	1.0000	6400
	33	43.9	7.40	3.95	1.87	5645	1.0000	5645
	36	81.3	7.31	3.96	1.85	7436	1.0000	7436
2180-71	2	68.3	7.64	3.97	1.92	5043	1.0000	5043
	5	61.8	6.95	3.99	1.74	6624	0.9790	6485
6507-04	20	35.9	6.97	3.98	1.75	6951	0.9799	6811
	26	19.5	7.48	3.98	1.88	6226	1.0000	6226
8480-26	2	235.3	7.20	3.71	1.94	5002	1.0000	5002
	3	25.9	7.24	3.72	1.95	5732	1.0000	5732
	6		4.28	3.70	1.16	5266	0.9129	4807
	8	25.96	7.16	3.74	1.91	5595	1.0000	5595
	9	24.5	7.17	3.72	1.93	4579	1.0000	4579
2180-78	2	27.2	7.12	3.72	1.91	5873	1.0000	5873
	4	27.6	6.47	3.73	1.73	5880	0.9782	5752
	9	26.7	7.19	3.70	1.94	6250	1.0000	6250
8480-27	2	63.9	6.99	3.73	1.87	6817	1.0000	6817

Project	Core	Resistivity (kohm-cm)	Capped Length (inch)	Diameter (inch)	L/D	Measured Compressive Strength	Geometry Correction Factor	Corrected Compressive Strength
	5	50.5	7.08	3.75	1.89	6070	1.0000	6070
	9	64.5	7.10	3.74	1.90	7217	1.0000	7217
1907-54	C-2	26.2	8.70	4.64	1.88	6354	1.0000	6354
	C-3	22.4	8.81	4.62	1.91	6436	1.0000	6436
	C-5	32	8.77	4.63	1.89	5690	1.0000	5690
	C-8	14.5	7.81	4.64	1.68	5909	0.9742	5756
	2	82.5	7.88	3.99	1.97	7759	1.0000	7759
	8	108.6	7.86	3.98	1.97	8983	1.0000	8983
4705-30	9	116.8	7.87	4.00	1.97	8968	1.0000	8968

Table 5.5. Resistivity and compressive strength data (cont.).

Project	Core	Resistivity (kohm-cm)	Capped Length (inch)	Diameter (inch)	L/D	Measured Compressive Strength	Geometry Correction Factor	Corrected Compressive Strength
0712-32	N	96.9	7.02	4.67	1.50	8617	0.9599	8272
	P	48.9	7.16	4.67	1.53	6902	0.9625	6643
2313-13	M006	151.7	7.86	3.95	1.99	8080	1.0000	8080
	M009	124	7.79	3.92	1.99	6753	1.0000	6753
3805-67	6B	56.6	7.30	3.95	1.85	6864	1.0000	6864
	7B	45.3	7.31	3.98	1.84	7468	1.0000	7468
	8A	75.8	7.66	4.00	1.92	7308	1.0000	7308
5680-111	2	184.3	7.20	3.68	1.95	7951	1.0000	7951
	7	241.4	7.23	3.72	1.94	6912	1.0000	6912
	9	258.9	7.10	3.73	1.90	7756	1.0000	7756
1480-131	1	91.2	7.06	3.73	1.89	6099	1.0000	6099
	7	155.6	6.87	3.75	1.83	6131	1.0000	6131
	9	191.9	7.21	3.72	1.94	7174	1.0000	7174
2180-80	2	326.4	7.14	3.73	1.91	8528	1.0000	8528
	5	277.5	7.13	3.73	1.91	6896	1.0000	6896
	6	330.9	7.18	3.72	1.93	9233	1.0000	9233
	8	239.5	7.84	3.99	1.96	8008	1.0000	8008
2480-88	M002	222.3	7.88	3.93	2.01	8856	1.0000	8856
	M003	233	7.61	3.94	1.99	8597	1.0000	8597
	M004	138.8	7.85	3.92	2.00	7593	1.0000	7593
	M007	143.2	7.86	3.92	2.01	8623	1.0000	8623
6404-32	14	101	7.85	4.01	1.96	6651	1.0000	6651

Project	Core	Resistivity (kohm-cm)	Capped Length (inch)	Diameter (inch)	L/D	Measured Compressive Strength	Geometry Correction Factor	Corrected Compressive Strength
	17	266.8	7.85	4.00	1.96	9099	1.0000	9099
	18	250.6	7.87	4.00	1.97	8968	1.0000	8968
7380-199	7010	122.6	7.20	3.75	1.92	8088	1.0000	8088
	7011	106.9	7.17	3.70	1.95	7020	1.0000	7020
	7014	133.5	7.17	3.69	1.94	6440	1.0000	6440
	7016	199.9	7.16	3.71	1.93	7197	1.0000	7197
	7017	155.7	4.38	3.69	1.18	8371	0.9171	7677
0280-049	C-08	326.5	7.95	4.62	1.72	7779	0.9776	7605
7380-200	7002	295.9	7.10	3.72	1.91	6383	1.0000	6383
	7005	237.4	7.36	3.70	1.98	7001	1.0000	7001
	7006	56.9	7.35	3.70	1.99	8637	1.0000	8637
	7008	266	7.10	3.73	1.90	7197	1.0000	7197
	7020	254.8	7.12	3.70	1.92	6485	1.0000	6485
2480-91	M011	64.6	7.85	3.92	2.00	8157	1.0000	8157
	M015	54.1	7.90	3.93	2.01	7926	1.0000	7926
	M016	69.3	7.83	3.91	2.00	8429	1.0000	8429
	M017	107.9	7.85	3.91	2.01	7759	1.0000	7759
6019-22	3	208.2	7.17	3.69	1.91	7903	1.0000	7903
	4	226.9	7.20	3.78	1.90	7921	1.0000	7921
	7001	225.4	7.17	3.75	1.91	7662	1.0000	7662

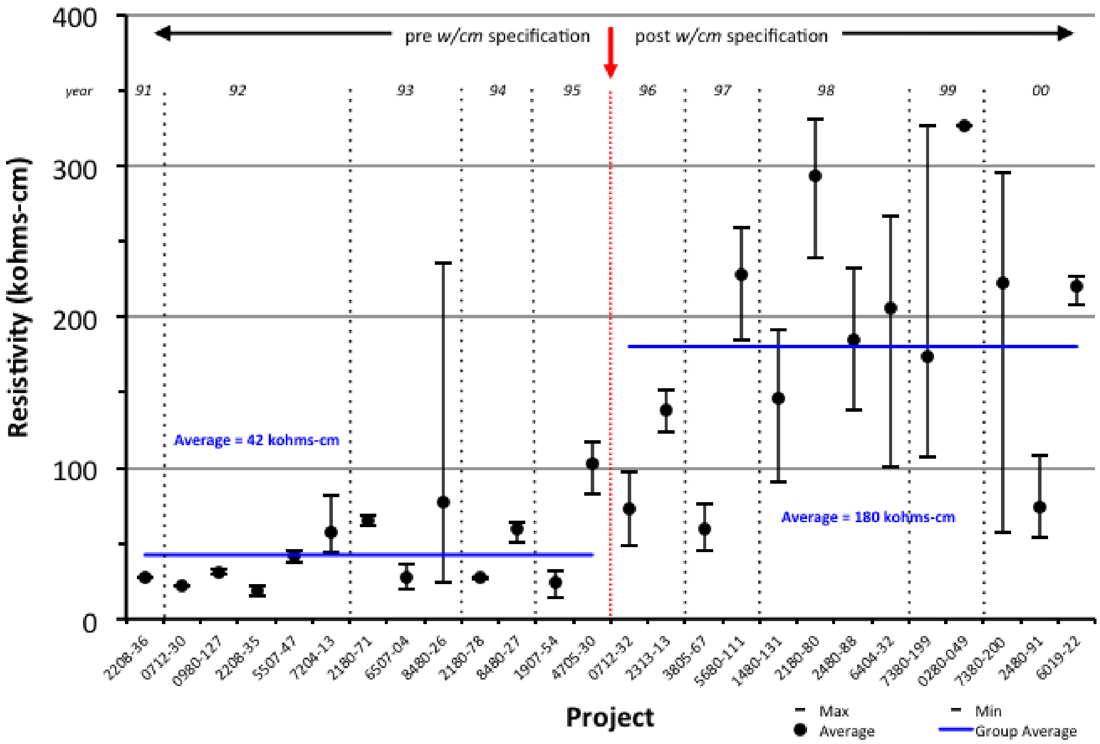


Figure 5.3. Resistivity data measured in accordance with AASHTO T 358. The error bars shown represent the high and low values of the samples analyzed for each project. The filled circle data points indicate the average of all measured values for each project. The blue line represents the average of all pre-*w/cm* analyses and the average of all post-*w/cm* analyses, respectively.

5.4 - COMPRESSIVE STRENGTH – ASTM C39

Cores representing 26 of the projects studied were tested in accordance with ASTM C39 to establish the compressive strength of the concrete in place. The results of this testing are presented in Table 5.4, Table 5.5 and Figure 5.4. The error bars shown in Figure 5.4 represent the high and low values of the samples analyzed for that project. The filled circle data points in Figure 5.4 indicate the average of all samples analyzed for that project. The blue line represents the average of all pre-*w/cm* analyses and the average of all post-*w/cm* analyses, respectively. The testing results suggest on average an approximate 900 psi increase in strength between the pre-*w/cm* projects and the post-*w/cm* projects. This observation is consistent with a decreased *w/cm*.

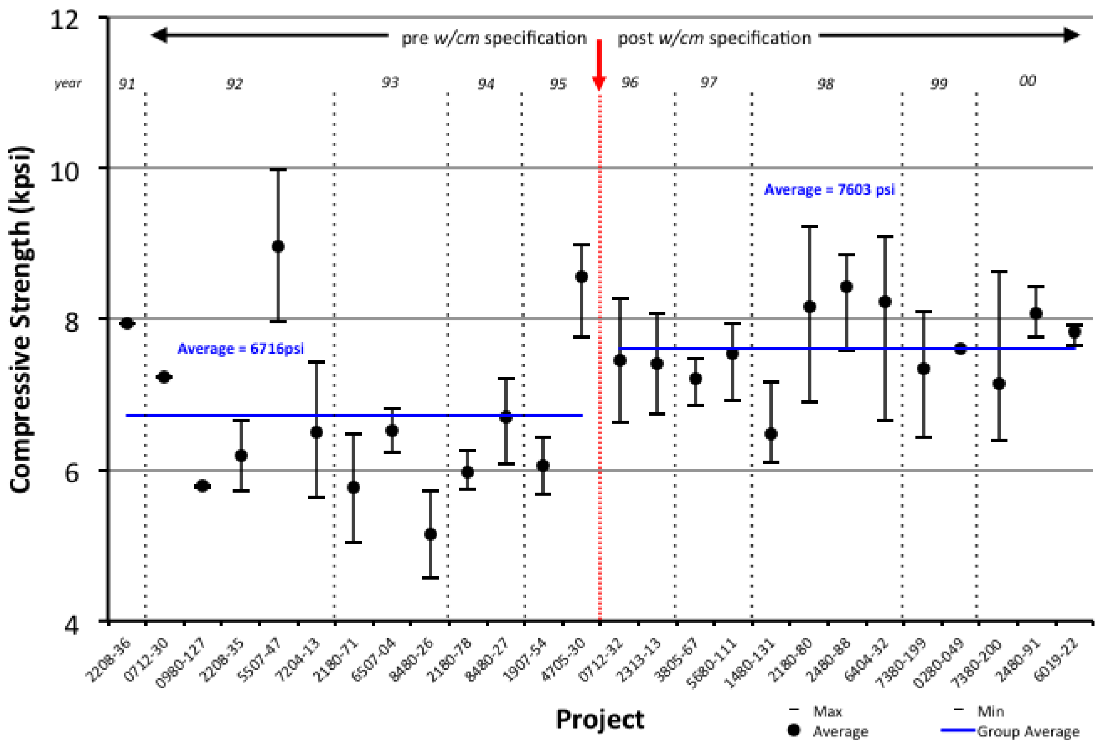


Figure 5.4. Compressive strength data measured in accordance with ASTM C39. The error bars shown represent the high and low values of the samples analyzed for each project. The filled circle data points indicate the average of all measured values for each project. The blue line represents the average of all pre-*w/cm* analyses and the average of all post-*w/cm* analyses, respectively.

5.5 - AIR VOID SYSTEM PARAMETERS – ASTM C457 PROCEDURE A – LINEAR TRAVERSE

The air-void system parameters were measured for 31 projects. These measurements were performed in accordance with ASTM C457 Procedure A-Linear Traverse. The results are presented in Table 5.6 and Table 5.7, and Figure 5.5 through Figure 5.7. There is an approximate 1 % volume increase in entrained air content when comparing the average of all pre-*w/cm* analyses with the average of all post-*w/cm* analyses. Notably, a number of the post-*w/cm* projects had what could be considered an excessively high air content (i.e., > 8 % volume) whereas neither scenario, pre-*w/cm* or post-*w/cm*, indicated an excessively low air content. The data suggests that specification changes have led to an increased air content but attention should be paid to not driving the air content to high. As part of the water reduction in post-*w/cm* specification mixtures, a water reducer was introduced. Water reducers, especially modern high range water reducers, have been known to interact with air entraining agents in a manner that leads to excessive air contents. Not addressed in this report are recent changes to MnDOT testing and specifications that calls for sampling behind the paver to determine air content. This practice is well advised and should help reduce the occurrences of excessive air content.

In terms of the other parameters, the entrapped air remained constant, as would be expected. The measured spacing factor, shown in Figure 5.7, dropped commensurate with the increased air content. In all cases, the measured spacing factor is consistent with an air-void system that should provide adequate freezing and thawing durability.

Table 5.6. Air-void system parameters for 31 projects measured in accordance with ASTM C457 Procedure A–Linear Traverse.

Project	Core	Total Air Content (volume%)	Entrained Air Content (volume %)	Entrapped Air Content (volume %)	voids/inch	Specific Surface (inch^{-1})	Spacing Factor	Paste Content (volume %)
0980-127	3A	4.9	3.7	1.2	10.0	810	0.006	
	3B	6.7	4.0	2.7	10.2	610	0.006	
5507-47	M004	6.3	5.4	0.9	12.7	790	0.005	
	M005	5.1	4.2	0.9	9.4	740	0.006	
7204-13	28	5.3	4.2	1.1	9.3	690	0.007	
2180-71	1	5.9	3.8	2.1	11.9	800	0.005	24.1
	3	5.1	3.6	1.5	6.8	530	0.008	22.7
6507-04	22	7.4	5.5	1.9	11.7	630	0.006	
8480-26	1	10	7.5	2.5	16.1	640	0.004	23.4
	4	5.5	4.0	1.5	8.5	610	0.007	23.9
	5	5.9	3.7	2.2	7.9	540	0.008	24.3
2180-78	3	4.7	4.2	0.5	11.6	990	0.005	
	5	5.9	4.5	1.4	9.0	620	0.006	22.5
8480-27	3	4.1	3.1	1.0	7.5	720	0.007	24.5
	7	6.6	5.1	1.5	16.4	990	0.004	
	8	5.2	4.2	1.0	8.9	680	0.007	24.1
0712-32	1	7.3	3.9	3.4	15.3	840	0.005	32.0
1907-53	C-04	7.3	5.3	2.0	13.8	760	0.005	30.0
1907-54	C-1A	7.8	5.8	2.0	16.6	850	0.004	
	C4	5.8	3.9	1.9	6.7	470	0.010	27.8
	C7	6.9	5.6	1.3	10.5	610	0.005	21.9
4013-41	1	9.6	7.0	2.6	21.5	890	0.002	16.0

Project	Core	Total Air Content (volume%)	Entrained Air Content (volume %)	Entrapped Air Content (volume %)	voids/inch	Specific Surface (inch^{-1})	Spacing Factor	Paste Content (volume %)
2313-13	M001	5.4	4.4	1.0	11.4	850	0.005	
	M002	5.3	3.2	2.1	8.8	670	0.007	
4705-30	#4	9.6	6.9	2.7	15.3	640	0.004	
	#7	6.7	4.3	2.4	8.7	520	0.007	

Table 5.7. Air-void system parameters (cont.)

Project	Core	Total Air Content (volume%)	Entrained Air Content (volume %)	Entrapped Air Content (volume %)	voids/inch	Specific Surface (inch^{-1})	Spacing Factor	Paste Content (volume %)
0702-98	5	8	5.8	2.2	16.8	840	0.003	23.0
3805-67	7C	6.7	5.9	0.8	14.5	870	0.004	
	8C	5.6	5.0	0.6	11.2	800	0.006	
5306-37	3	6.3	4.7	1.6	13.1	830	0.003	18.0
5680-111	4	7.6	5.6	2.0	16.6	880	0.004	
1480-131	2	4.5	3.9	0.6	11.6	1030	0.004	
	3	8.6	7.2	1.4	16.0	740	0.004	
	5	8.3	5.8	2.5	13.0	630	0.005	23.8
2180-80	1	9.2	7.2	2.0	20.0	870	0.003	
	4	9.8	7.4	2.4	15.0	610	0.004	22.6
2480-88	M001	5.5	4.1	1.4	9.2	660	0.007	
7380-199	7009	7.0	4.9	2.1	11.5	660	0.006	
	7012	11.0	8.2	2.8	15.4	570	0.004	
0280-049	C-04	9.7	8.4	1.3	21.5	880	0.003	23.0
2480-91	M018	6.7	5.7	1.0	12.6	750	0.005	
2782-268	C-04	7.0	10.4	2.7	33.7	1040	0.002	23.0
6019-22	9	6.9	5.1	1.8	12.7	740	0.005	

Project	Core	Total Air Content (volume%)	Entrained Air Content (volume %)	Entrapped Air Content (volume %)	voids/inch	Specific Surface (inch^{-1})	Spacing Factor	Paste Content (volume %)
	12	8.7	5.4	3.3	13.4	610	0.005	
3204-62	1	5.5	4.6	0.9	12.3	910	0.005	23.5
3204-59	3	5.5	4.7	0.8	13.2	950	0.004	21.0
2786-115	3J	7.0	6.6	0.4	16.0	910	0.004	23.7
2786-116	1J	9	6.8	2.2	26.6	1180	0.002	16.0
2786-117	6J	10	8.6	1.4	20.6	820	0.002	16.0

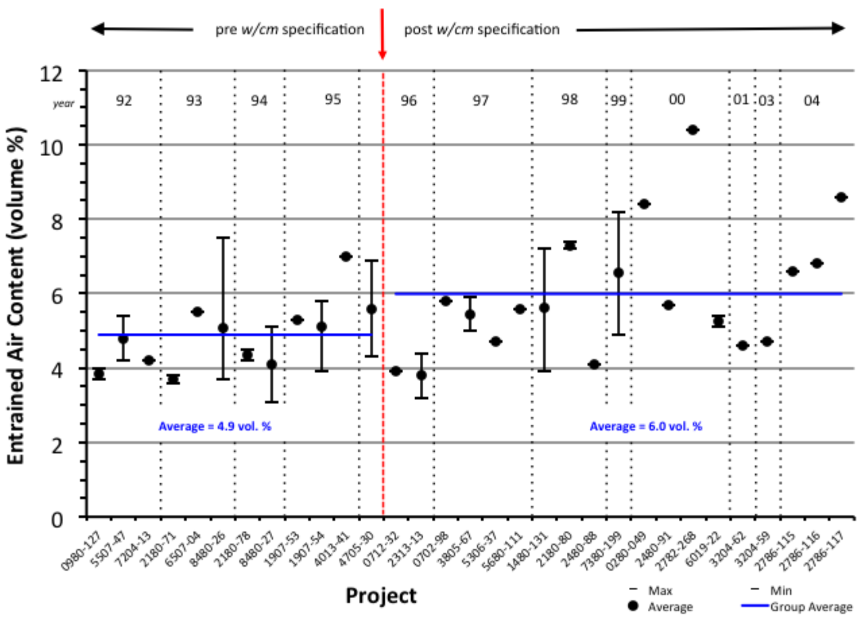


Figure 5.5. Entrained air content measured in accordance with ASTM C457. The error bars shown represent the high and low values of the samples analyzed for each project. The filled circle data points indicate the average of all measured values for each project. The blue line represents the average of all pre-*w/cm* analyses and the average of all post-*w/cm* analyses, respectively.

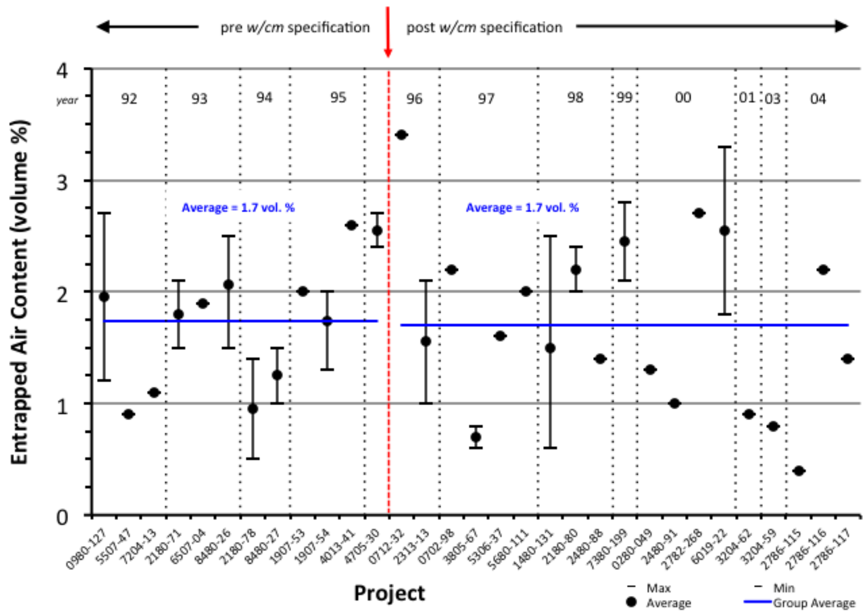


Figure 5.6. Entrapped air content measured in accordance with ASTM C457. The error bars shown represent the high and low values of the samples analyzed for each project. The filled circle data points indicate the average of all measured values for each project. The blue line represents the average of all pre-*w/cm* analyses and the average of all post-*w/cm* analyses, respectively.

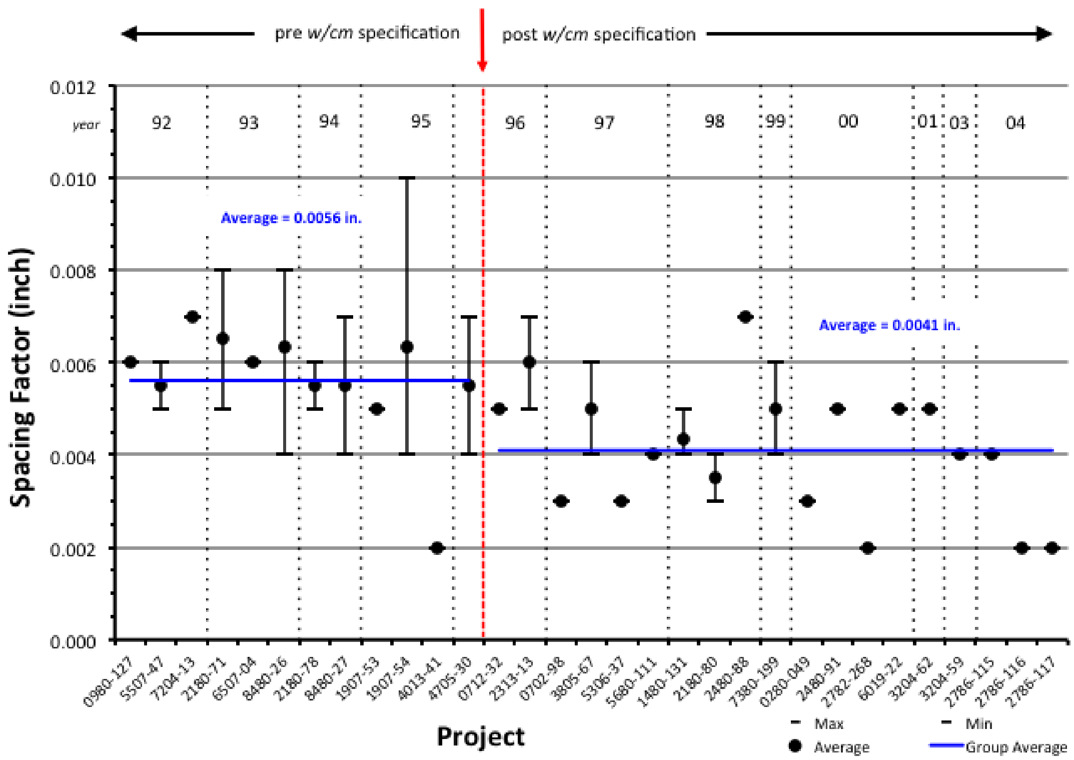


Figure 5.7. Spacing factor measured in accordance with ASTM C457. The error bars shown represent the high and low values of the samples analyzed for each project. The filled circle data points indicate the average of all measured values for each project. The blue line represents the average of all pre-*w/cm* analyses and the average of all post-*w/cm* analyses, respectively.

5.6 - PETROGRAPHY – ASTM C856

Petrographic analysis was performed on core samples from 36 pavements. The results for all analyses are included in Appendix A of this report. Not all cores received a full petrographic analysis. In total, 67 cores were examined and 50 full petrographic analyses were performed. For the remainder of the cores, photo documentation was provided only. The information from the petrographic analyses provided context for other observations and some specific data will be incorporated in discussions associated with other testing reported herein.

5.7 - ANALYSIS OF PAVEMENT MANAGEMENT SYSTEM DATA

In addition to changes in the key material properties already discussed, changes in concrete pavement specifications should lead to a measurable difference in pavement condition and ride quality as measured by standard MnDOT pavement management procedures. To examine this, International Roughness Index (IRI), Ride Quality Index, (RQI), Pavement Quality Index (PQI), and Surface Rating (SR) data were obtained from the MnDOT Pavement Management System (PMS). The combined data for all projects examined in this study are compiled in Appendix B of this report.

In the absence of a clear protocol to analyze this data, it was decided to examine the rate of change in the ride quality indices mentioned. Referring to the data in Appendix B, for practically any selected project, trends in pavement quality are equally represented by either IRI, RQI, or PQI. The SR data, in general, showed no demonstrable trend with respect to time, with a few notable exceptions. Therefore, for simplicity, the analyses presented all examine the change in IRI with respect to pavement age.

To conduct the analysis, the PMS data for each section of a project was shifted from an annual basis to a pavement life basis. In other words, regardless if the pavement was constructed in 1992 or 2002, or any year, the analysis looks at pavement condition at a given pavement age (i.e., Year 1, Year 2, etc.). Each project has multiple sections and the PMS data values for each section were averaged to determine an average IRI value for the project for each year. In many cases the PMS data captures pavement condition prior to a construction activity such as an overlay or rehabilitation (e.g., See Figure B1 – B7 of Appendix B) and after the activity, the various ride quality indices exhibit a step change towards better quality, as would be expected. However, this step change hampered the analysis process. Therefore, analysis of the change in ride quality used as the starting point the IRI after the step change, but retained the age parameter. So in the case of the example cited (i.e., Project 0980-127, Figure B1 – B7 of Appendix B), the data analysed would start with the fourth available data point, which is Year 7 of pavement life.

The over-arching questions for each project are, a) what is the absolute value of the IRI at a given pavement age, and b) at what rate is the pavement ride quality degrading? To further simplify presentation of the data, the various projects are color-coded. Red is used to indicate pavements from 1991 – 1995, or pre-*w/cm*. Green is used to indicate pavements from 1998 – 2004, or post-*w/cm*. Blue is used to indicate pavements from 1996 and 1997 which is considered the transition period from pre-*w/cm* to post-*w/cm* specification. All data presented below is tabled and shown by individual project and segment in Appendix B.

Figure 5.8 presents the pavement management system data used for analysis for all projects included in this study. Clearly in this form the data provides little information. In Figure 5.9 the data for the transition years is not included and a general trend begins to emerge where the majority of post-*w/cm* data tends to show a lower IRI at any given age (i.e., the majority of green lines plot below the majority of red lines).

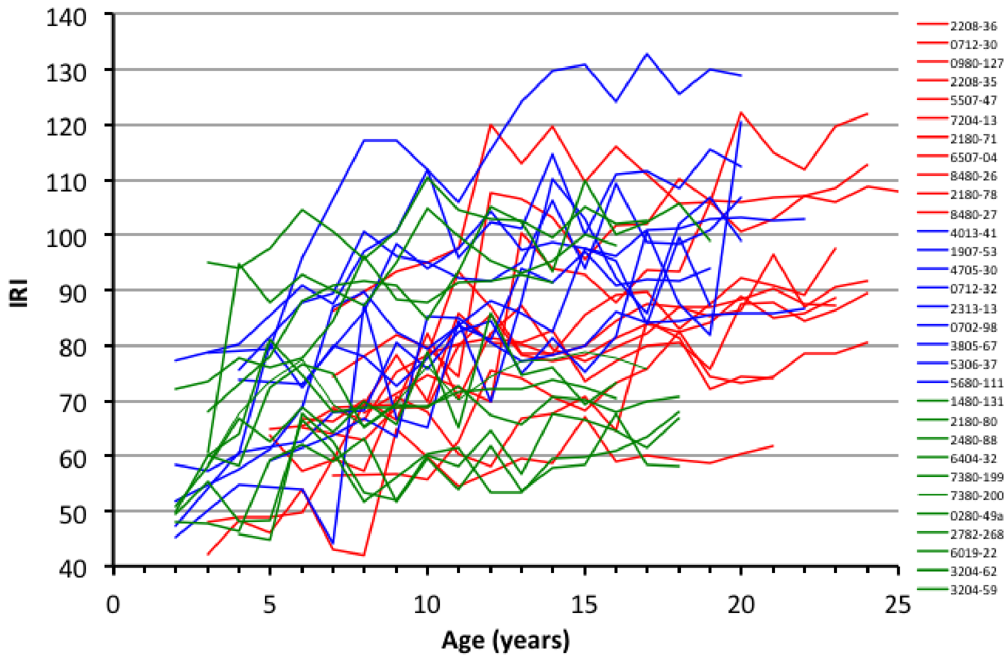


Figure 5.8. Raw pavement management system data used for analysis for all projects included in this study.

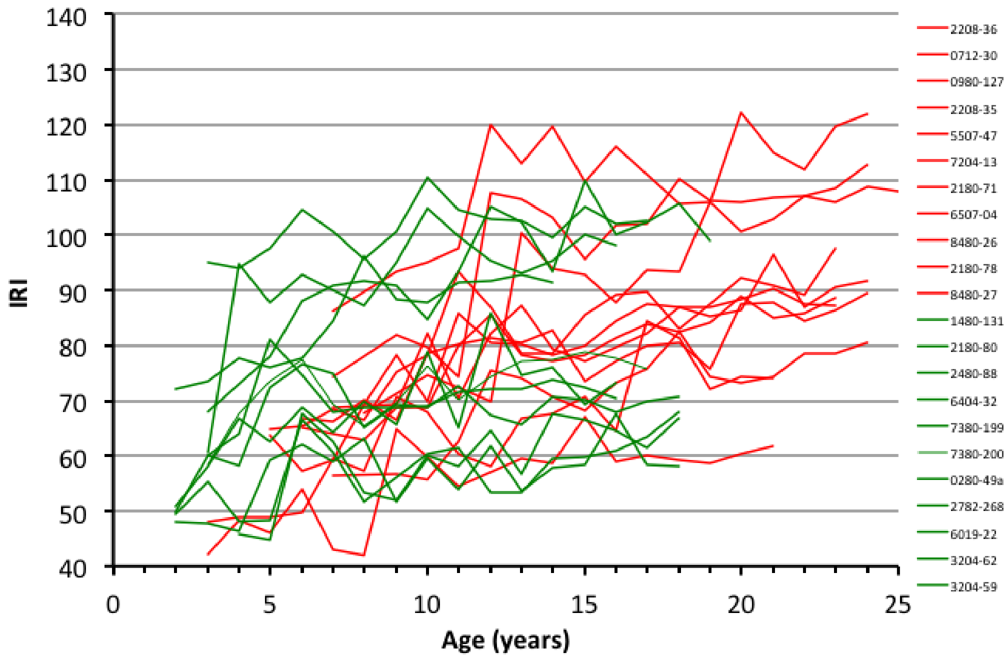


Figure 5.9. Raw pavement management system data used for analysis for all projects included in this study except those built in 1996 or 1997.

To clarify trends, a linear regression fit was performed for all data. The results are shown in Figure 5.10. In Figure 5.11, the linear regression lines are shown for only the pre-*w/cm* data and post-*w/cm* data. Referring first to Figure 5.10., it is interesting to note the transition years (i.e., blue lines) tend to have higher slopes, indicating a faster rate of degradation, and the absolute value of IRI for the pavements constructed in the transition years tends to be among the highest of all pavements. Regarding the slope values, Figure 5.12 presents the slope of each regression line in Figure 5.10 and shows the pre-*w/cm* data and post-*w/cm* data essentially have the same slope (i.e., a similar rate of degradation) while the transition year pavements show on average an increased slope, taken to represent increased rate of degradation. In Figure 5.11, the general trend between pre-*w/cm* data and post-*w/cm* data is more clearly identified. There is a central grouping of trend lines that are predominantly pre-*w/cm* data (i.e., red lines). The post-*w/cm* data (i.e., green lines) predominantly plot below this central core, indicating a lower IRI at any given pavement age. As stated, the slopes of these lines are similar indicating a similar rate of degradation, but the post-*w/cm* data are starting that process at a point of better ride quality and therefore the IRI at later ages is commensurately lower as compared to the pre-*w/cm* projects.

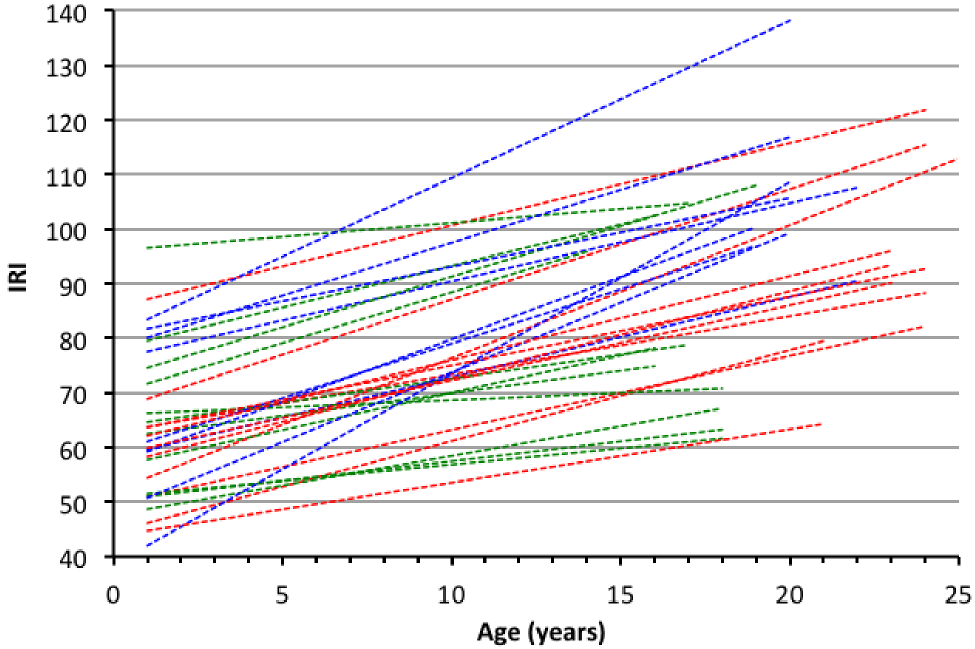


Figure 5.10. Linear regression fit lines for raw pavement management system data used for analysis for all projects included in this study.

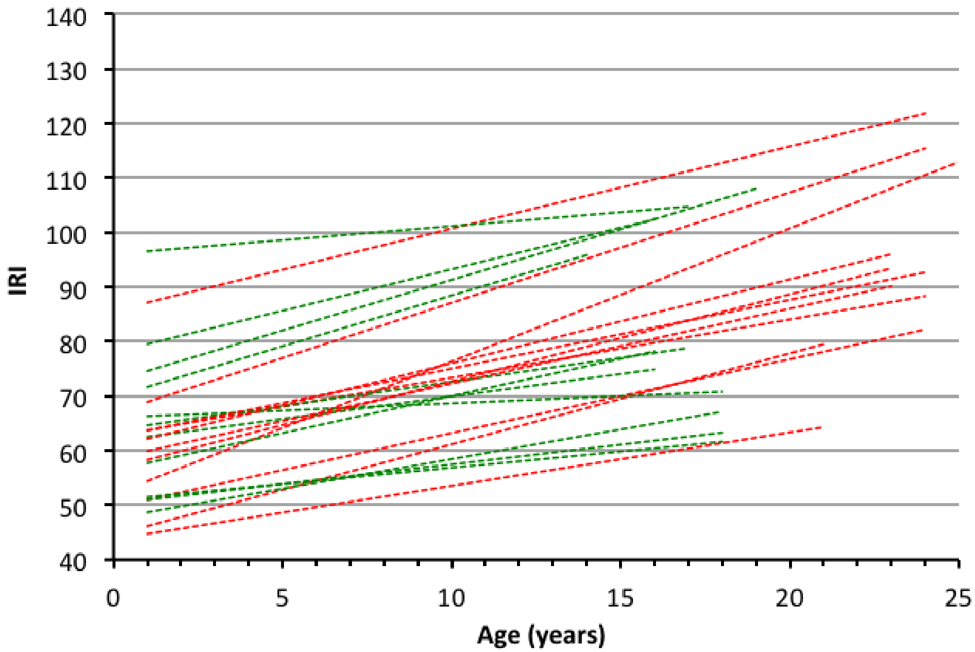


Figure 5.11. Linear regression fit lines for raw pavement management system data used for analysis for all projects included in this study except those built in 1996 or 1997.

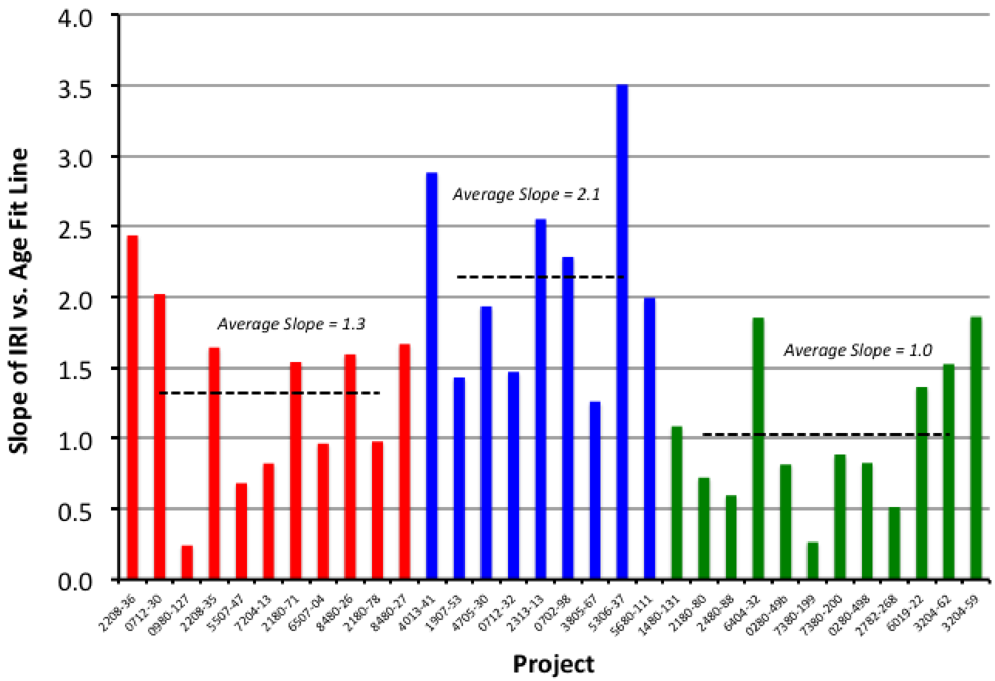


Figure 5.12. Summary of slopes of best-fit linear regression lines shown in Figure 5.10.

5.8 - ANALYSIS OF SELECTED PROJECTS

Examining Figure 5.10 and Figure 5.11, there are four post-*w/cm* projects whose regression lines plot in the upper portion of the graph with the pre-*w/cm* regression lines. Conversely there are three pre-*w/cm* projects whose regression lines plot in the lower portion of the graph with the post-*w/cm* regression lines. In other words, some pavements that were expected to perform well performed poorly, and vice versa. For clarity these projects are isolated in Figure 5.13.

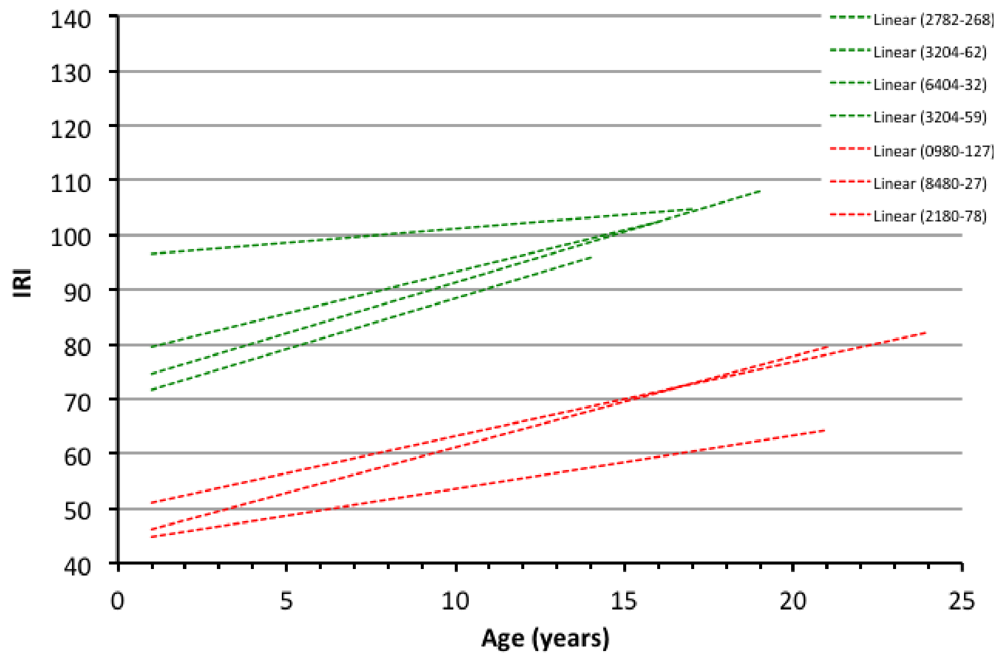


Figure 5.13. Same data as Figure 5.10 with projects showing unexpected performance isolated.

An attempt was made to identify why these particular pavements appeared to perform in an unexpected manner. The data obtained from laboratory testing of these projects is summarized in Table 5.8.

The data set for these projects is incomplete making a definitive analysis not possible. For the data available, the properties of the pre-*w/cm* projects that performed better than expected are consistent with the general properties seen for all pre-*w/cm* projects. Likewise, the properties of the post-*w/cm* projects that performed worse than expected are consistent with the general properties seen for all post-*w/cm* projects. This suggests other factors may be impacting the performance of these pavements. In the case of the post-*w/cm* projects that performed worse than expected, this could be a number of common maladies such as sub-grade engineering or excessive loading. In the case of pre-*w/cm* projects that performed better than expected, it is not clear what factors have affected performance and it would be of value to further investigate these pavements to understand more fully the factors contributing to their performance.

Table 5.8. Summary of known material properties for post-*w/cm* pavements that performed poor and pre-*w/cm* performed well. A dash indicates no data was available.

Performance	Project	Year Built	Average Spacing Factor	Average RCPT	Average Resistivity	Average Compressive Strength (psi)	*w/cm* Estimated
Post-*w/cm* Performed Poor	6404-32	1998	-	222	206	8240	0.40-0.45
	2782-268*	2000	0.002	51	-	-	-
	3204-59	2003	0.004	71	-	-	0.43-0.48
	3204-62	2003	0.005	135	-	-	-
Pre-*w/cm* Performed Well	0980-127	1992	0.006	1401	31	5785	0.42-0.47
	2180-78	1994	0.006	-	27	6000	0.43-0.48
	8480-27	1994	0.006	-	60	6700	0.43-0.48

* This project was MnDOT's first 60-year high performance concrete pavement, and it contained slag cement.

5.9 - ANALYSIS OF PROJECTS FROM INDIVIDUAL CORRIDORS

The same process described above for all data was applied to selected projects that occur in proximity on the same highway corridor. The projects within these corridors see similar traffic counts, used similar materials for construction, and undergo the same winter maintenance. Therefore, it should be possible to compare pavements constructed pre- and post-*w/cm* specification and look for differences in performance. Table 5.9 summarizes the individual projects to be compared. The same color code approach as used above is continued in this section of the analysis. The source data for comparison are the PMS data, specifically the IRI data processed as has been already introduced. There is insufficient data from the laboratory materials testing for making comparisons.

Table 5.9. Projects selected for comparing performance within a given corridor.

Highway	Pre-*w/cm* Comparison Project	Year Built	Transition Period Comparison Project	Year Built	Post-*w/cm* Comparison Project	Year Built
TH60			5306-37	1997	3204-59 3204-62	2003 2001
TH169	2208-36 2208-35 0712-30	1991 1992 1992	0712-32	1995		
TH94	8480-26 8480-27	1993 1994	5680-111	1997	1480-131	1998
TH94	2180-71	1993			2180-80 7380-199 7380-200	1998 1999 1999

5.9.1 - Highway TH60

The comparison of average IRI data for TH60 is presented in Figure 5.14 and Figure 5.15 Examples of the individual section data for the projects being compared are presented in Figure 5.16 through Figure 5.18. As seen in Figure 5.14 as well as Figure 5.10, the IRI versus age regression line for project 5306-37 has a steeper slope than almost every other data set, with the exception of project 4013-41. In both of these cases, the anomalous rate of degradation is not explained. There is no strength data for these projects and the RCPT results show low permeability. Consulting the petrographic examinations for these projects in Appendix A, there are no outstanding features indicating early deterioration. The petrography reports (Appendix A) state the *w/cm* for 3204-59 and 5306-37 is in the range of 0.43 – 0.48. No value is reported for 3204-62. Overall, the post-*w/cm* projects indicated a higher average IRI, but the rate of degradation of 5306-37 implies its IRI will soon surpass the other pavements.

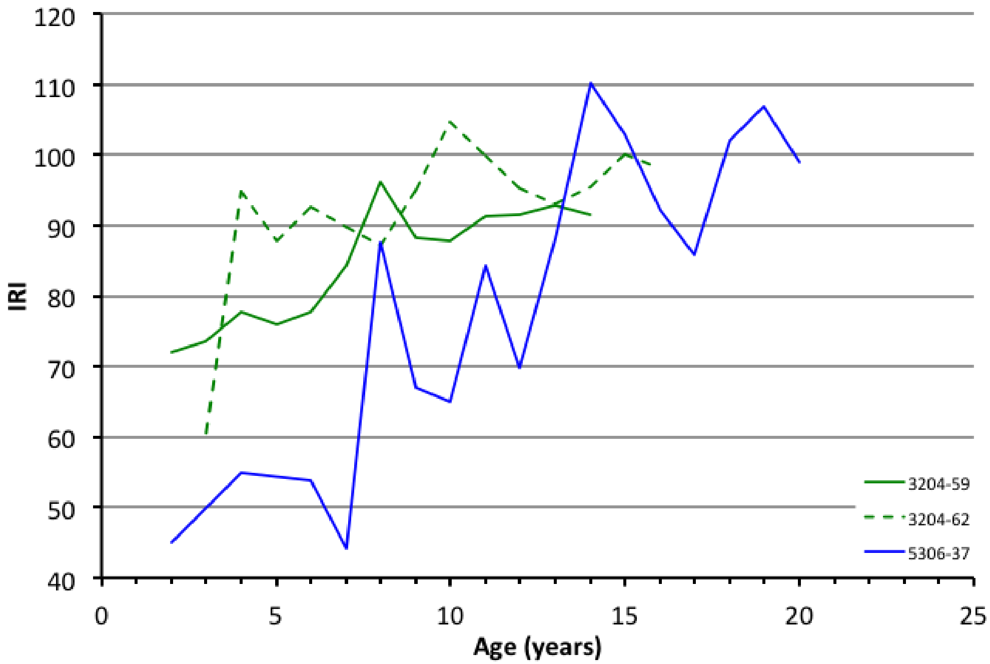


Figure 5.14. Raw IRI data for projects on TH60.

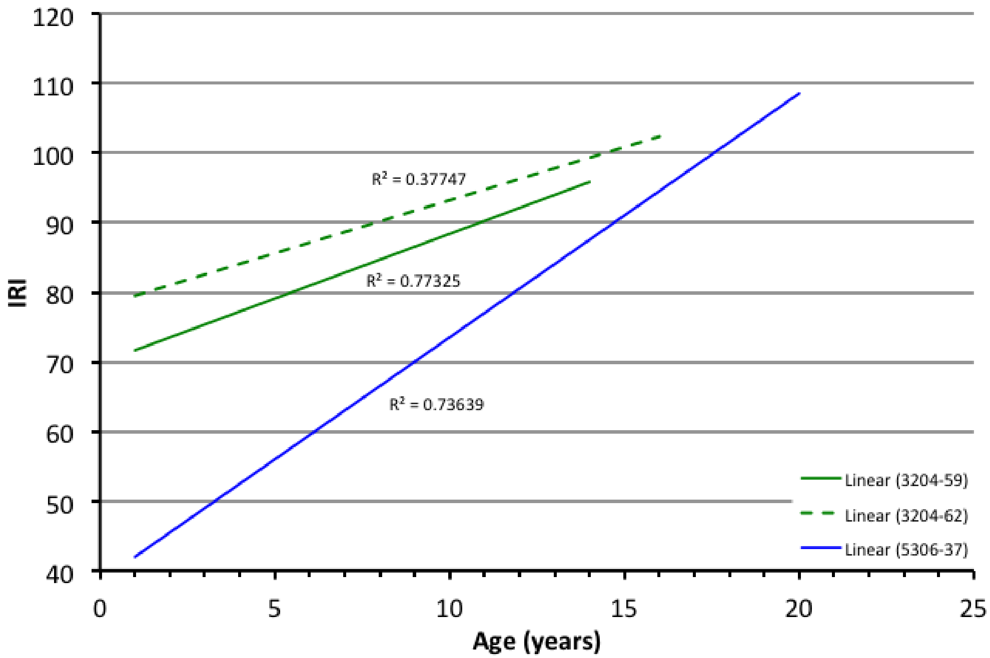


Figure 5.15. Linear regression fit lines for IRI data for projects on TH60.

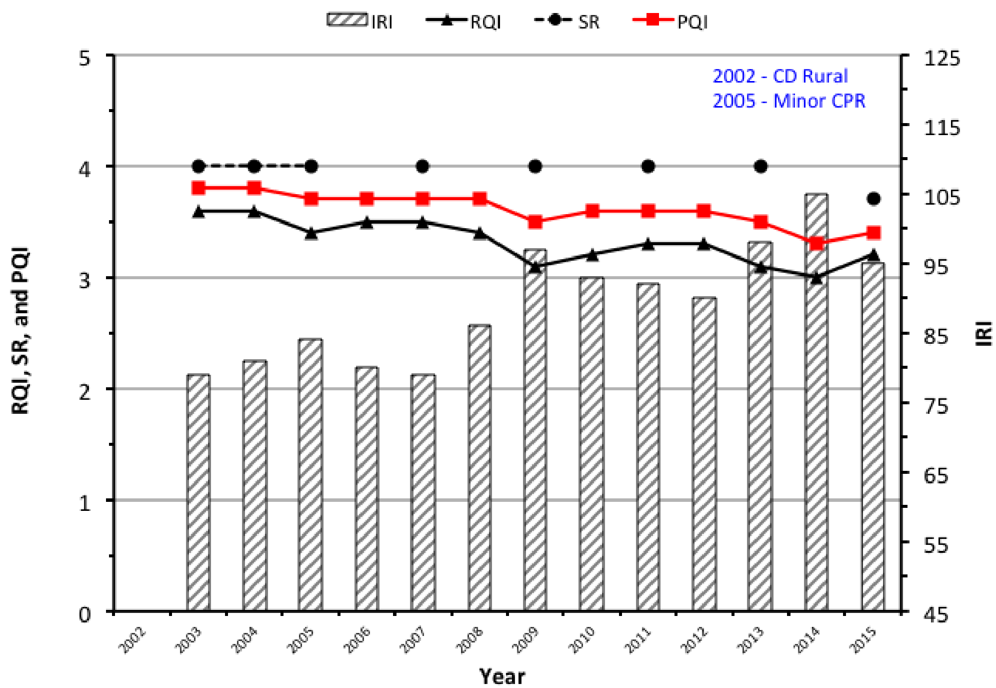


Figure 5.16. Example PMS data from project 3204-59, RP 35+0.000.

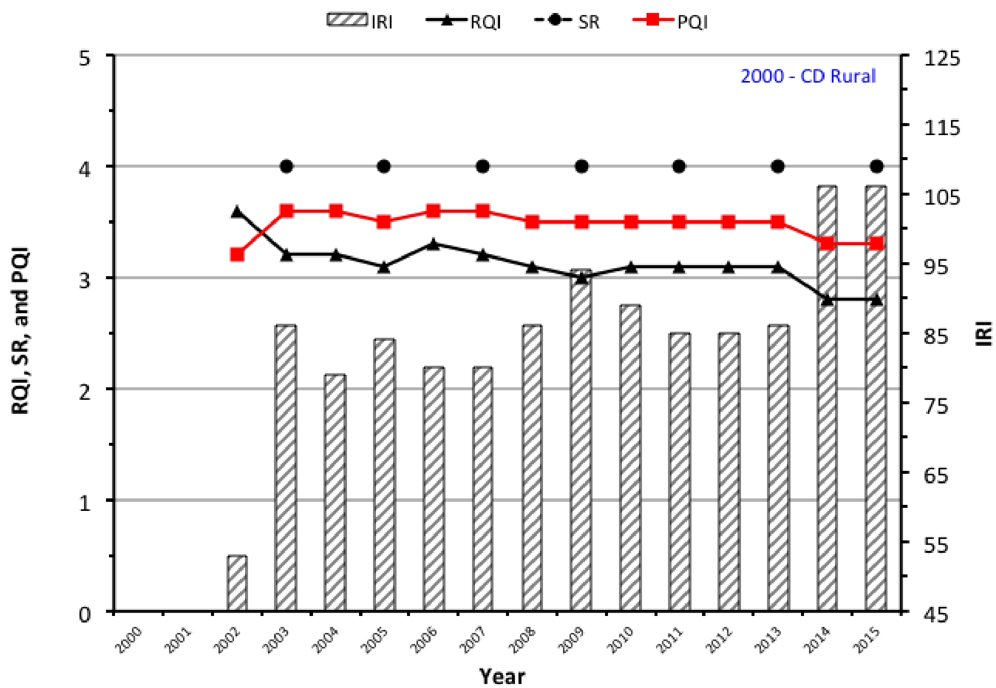


Figure 5.17. Example PMS data from project 3204-62, RP 23+0.000.

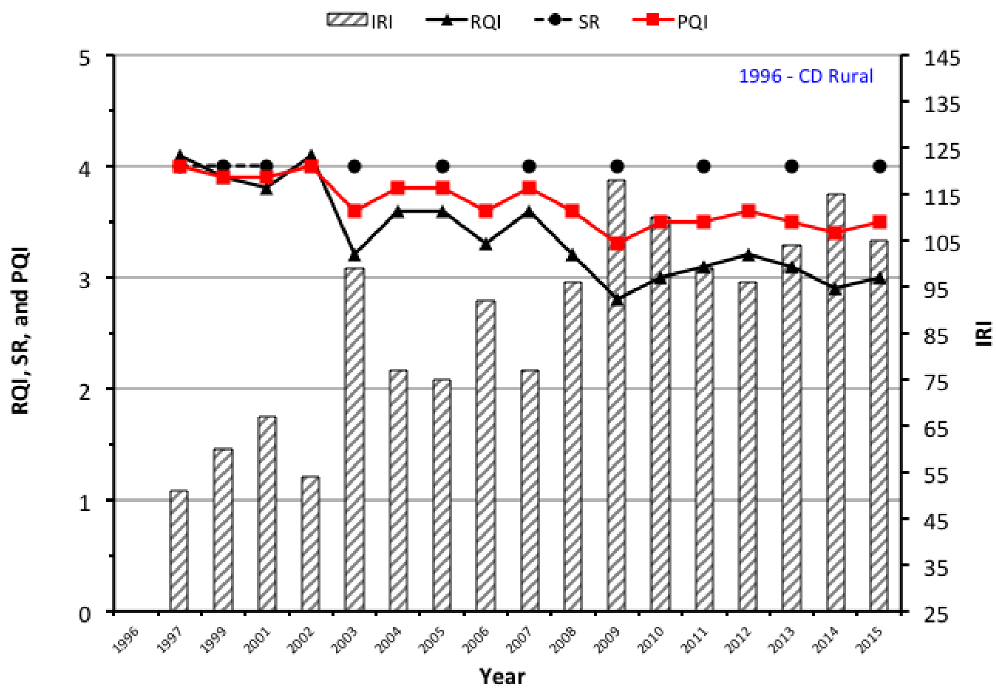


Figure 5.18. Example PMS data from project 5306-37, RP 17+0.000.

5.9.2 - Highway TH169

The comparison of average IRI data for TH169 is presented in Figure 5.19 and Figure 5.20. Examples of the individual section data for the projects being compared are presented in Figure 5.21 through Figure 5.24. Project 0712-32 is listed with a 1995 construction date but was actually the first project constructed using a maximum *w/cm* specification which MnDOT purchased the water reducer for the Contractor to use in the concrete mix. As seen in the petrography reports in Appendix A, this section does exhibit some joint deterioration associated with unbounded silicone sealers. Otherwise there are no remarkable features noted. The petrography reports (Appendix A) state the *w/cm* for 0712-32 is in the range of 0.43 – 0.48. No value is reported for the other projects.

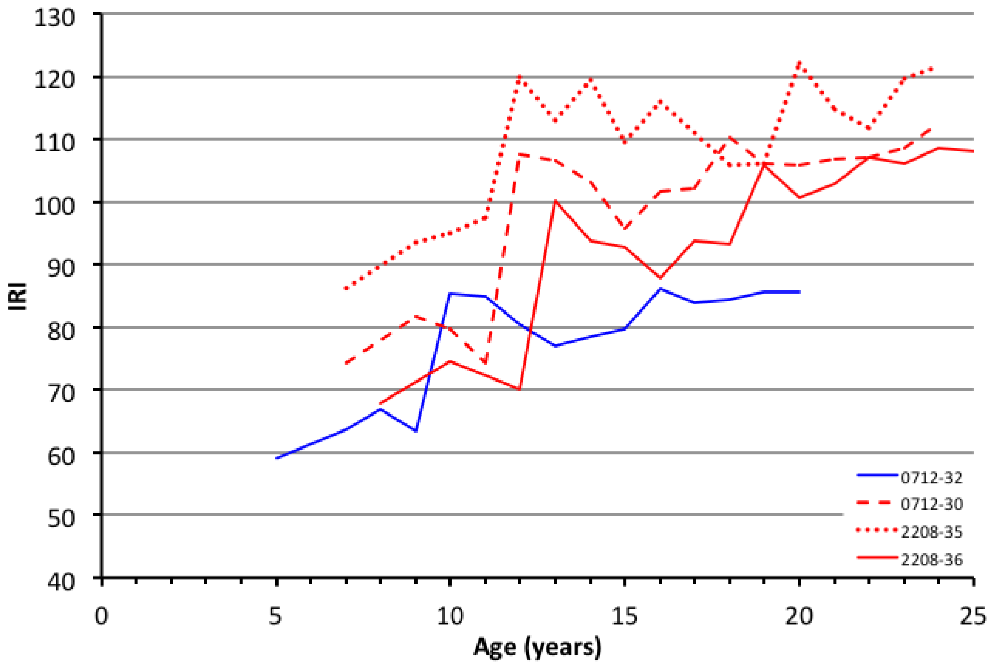


Figure 5.19. Raw IRI data for projects on TH169.

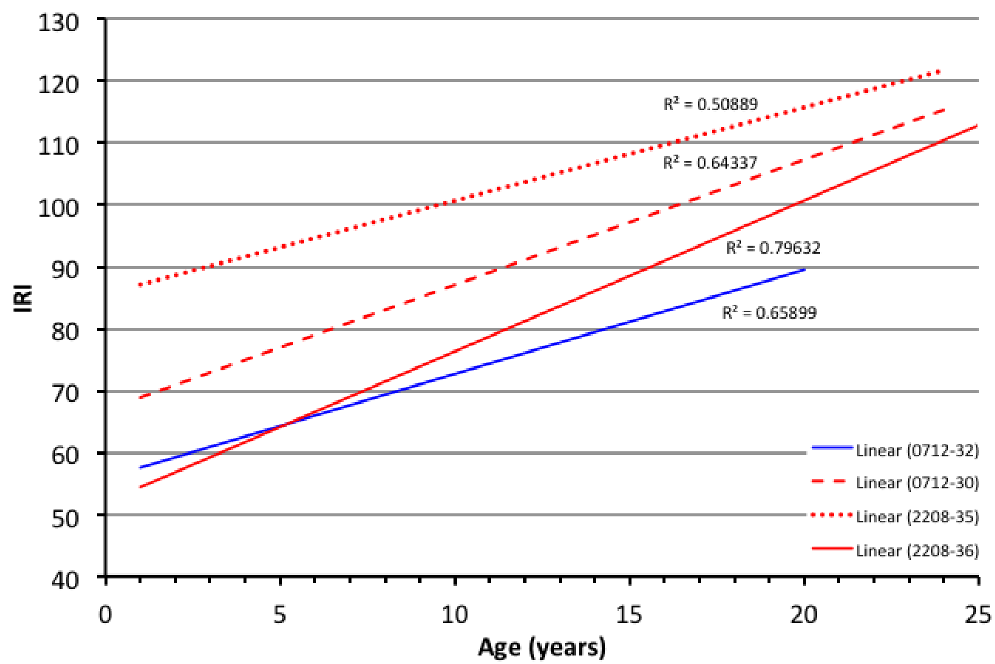


Figure 5.20. Linear regression fit lines for IRI data for projects on TH169.

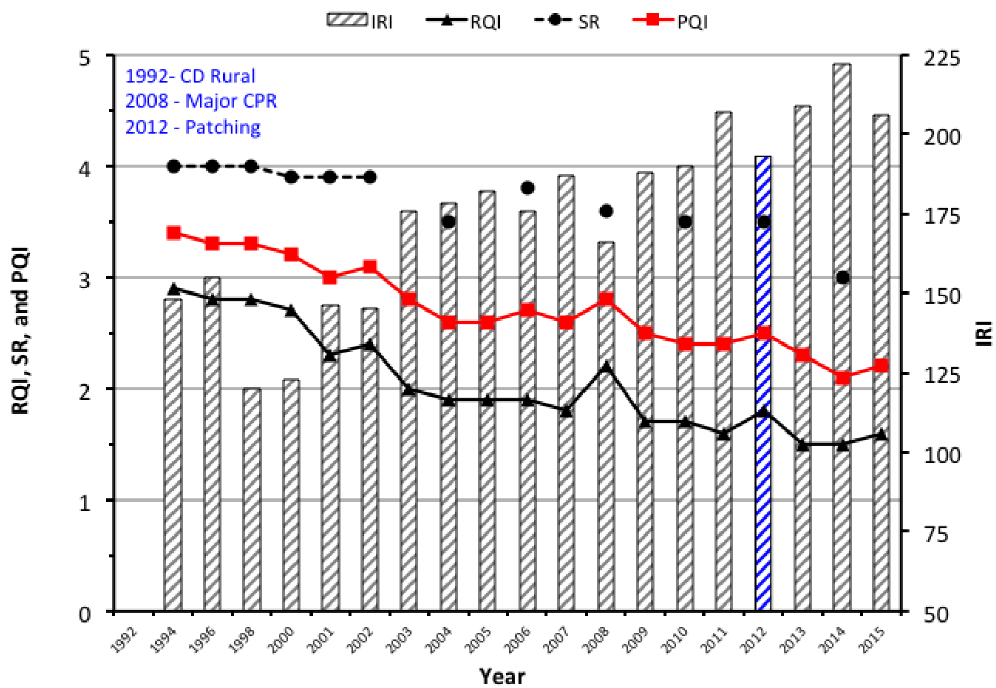


Figure 5.21. Example PMS data from project 2208-35, RP 20+0.000.

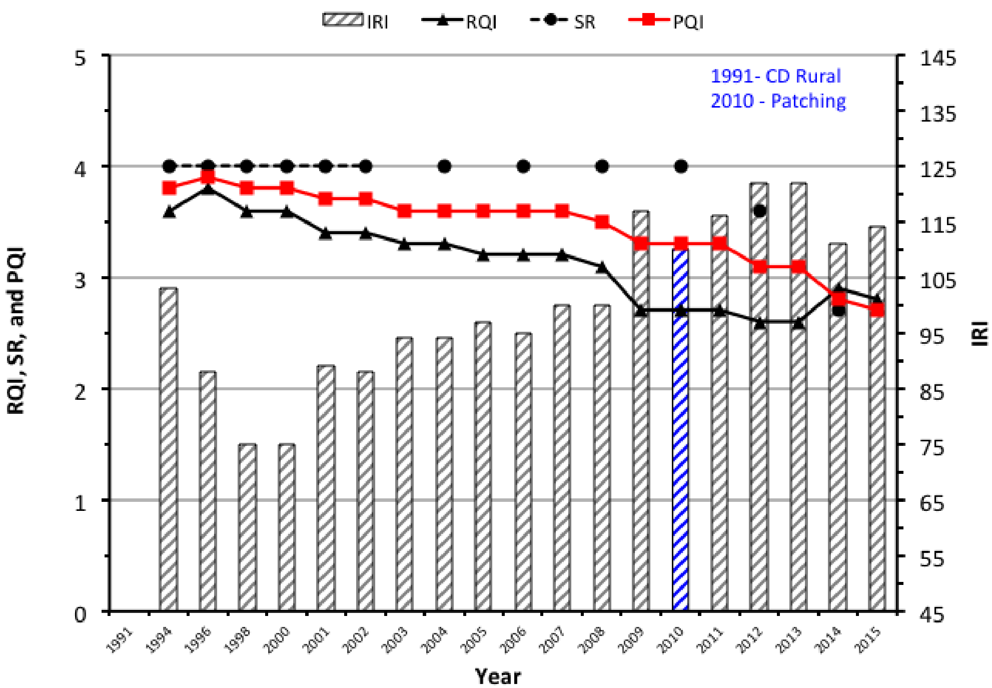


Figure 5.22. Example PMS data from project 2208-36, RP 21+0.000.

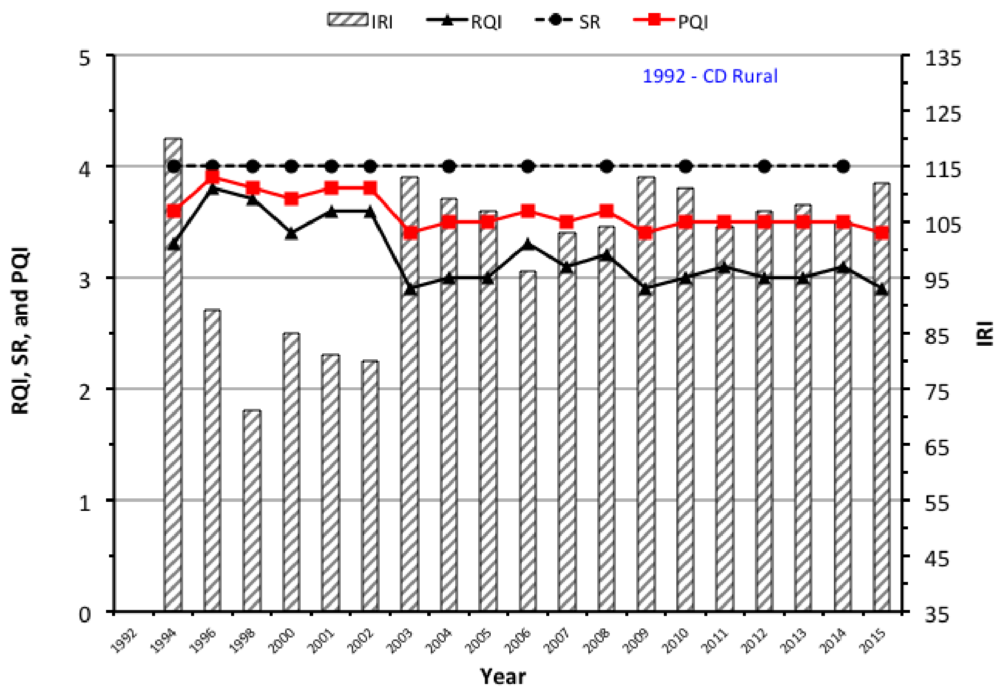


Figure 5.23. Example PMS data from project 0712-30, RP 32+0.000.

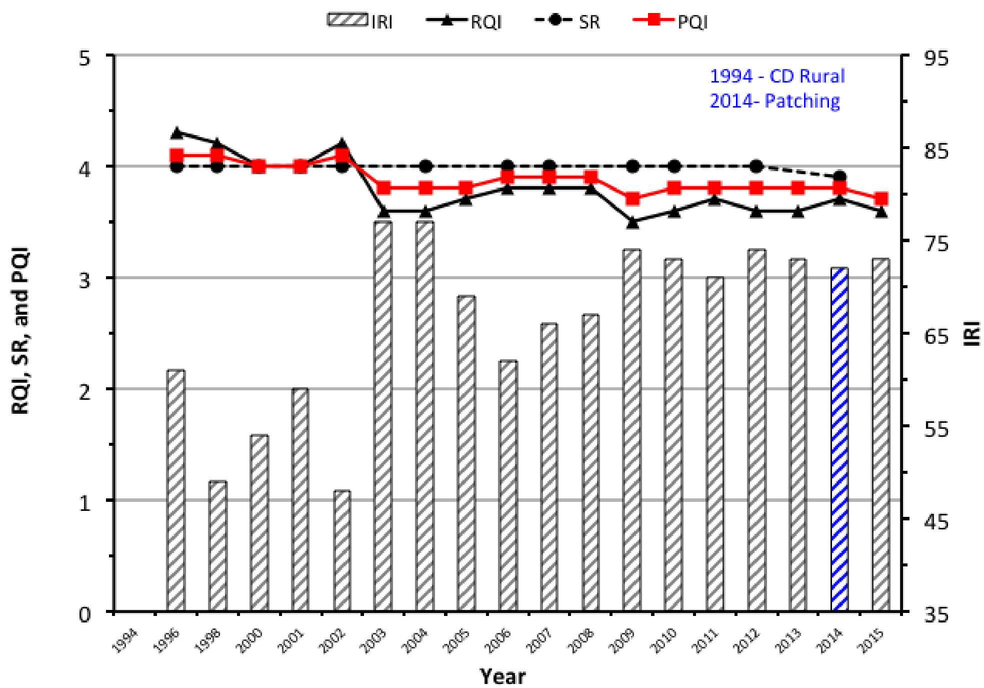


Figure 5.24. Example PMS data from project 0712-32, RP 46+0.000.

5.9.3 - Highway TH94

For TH94 two comparisons are presented. The first comparison is for the projects presented in Figure 5.25 and Figure 5.26. The second comparison is for the projects presented in Figure 5.31 and Figure 5.32. Examples of the individual section data for the projects being compared are presented in Figure 5.28 through Figure 5.30 for the first comparison, and Figure 5.33through Figure 5.36 for the second.

The IRI versus age relationship shown in Figure 5. and Figure 5. typifies the overall suite of projects. Each project has a similar slope to the regression line, with the post-*w/cm* fit having a slightly lower slow (i.e., slower rate of degradation). The project constructed in the transition years has the highest average IRI and the projects constructed pre-*w/cm* fall between the transition projects and the post-*w/cm* project. The difference in slope of the regression lines for post-*w/cm* projects, as compared to pre-*w/cm* projects, is even more clearly seen in Figure 5.26 and Figure 5.32. Likewise, the same trends can be observed in the raw data presented in Figure 5.27 through Figure 5.36. That is, the post-*w/cm* projects appear to hold their ride quality longer than the pre-*w/cm* projects. Clearly this study was not a statistical based method of analysis so such observations must be considered as simply that, observations. The petrography reports in Appendix A reports the following values for *w/cm*: 1480-131 – 0.36 to 0.41; 5680-111 – 0.36 to 0.41; 8480-26 (three cores) – 0.39 to 0.44, 0.42 to 0.47, and 0.42 to 0.47; 2180-71 - 0.40 to 0.45; 2180-80 – 0.34 to 0.39; 7380-199 – 0.40 to 0.45; 7380-200 – none. The petrography reports indicate no remarkable features for any of the identified project cores except for 2180-71, which had an above average level of erosion in the joint cavity.

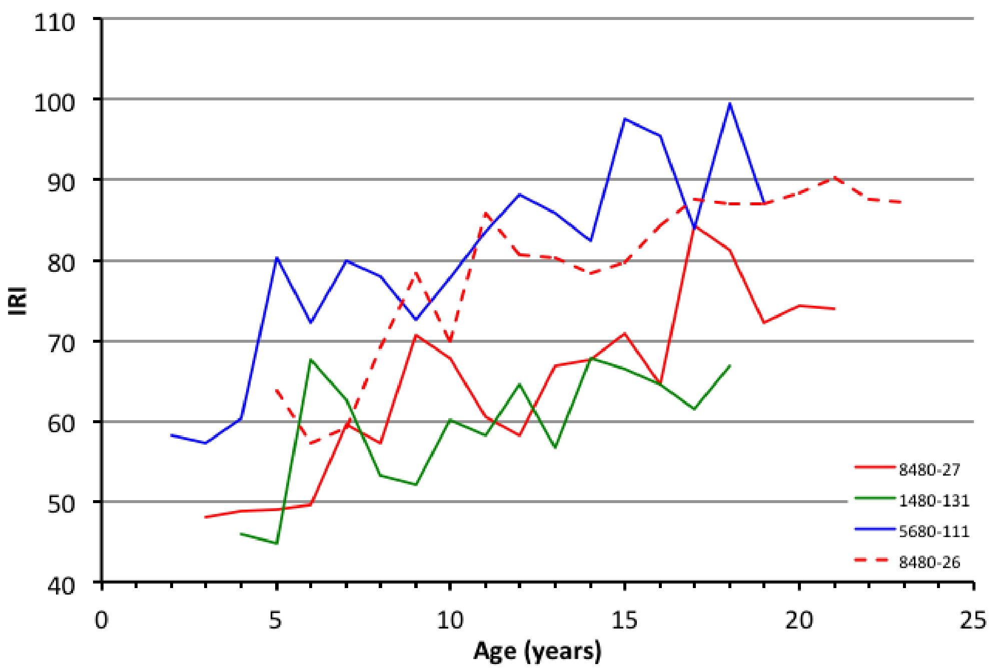


Figure 5.25. Raw IRI data for projects on TH94.

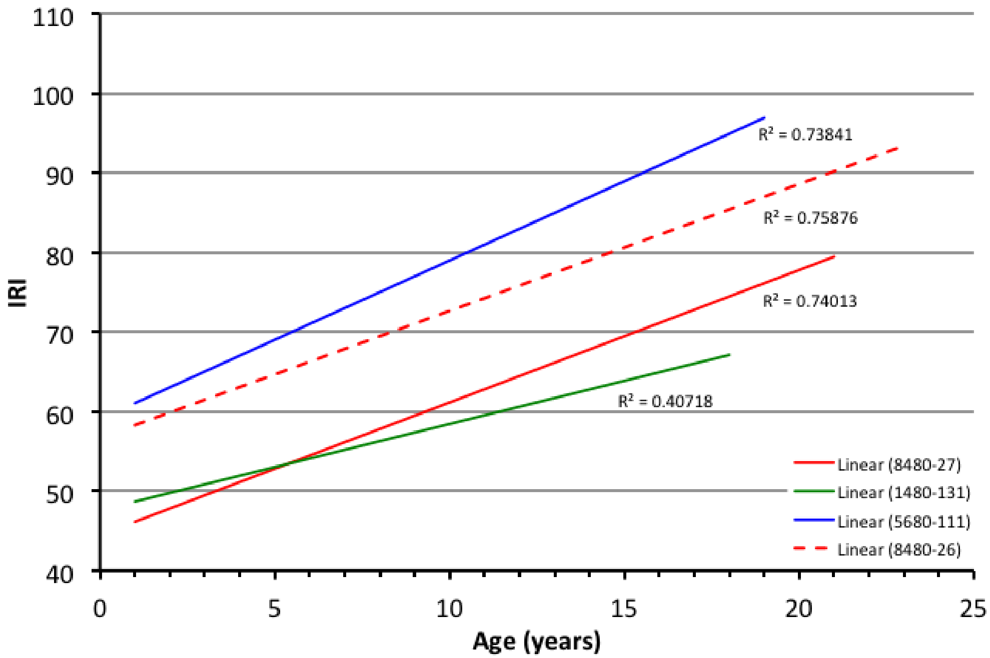


Figure 5.26. Linear regression fit lines for IRI data for projects on TH94.

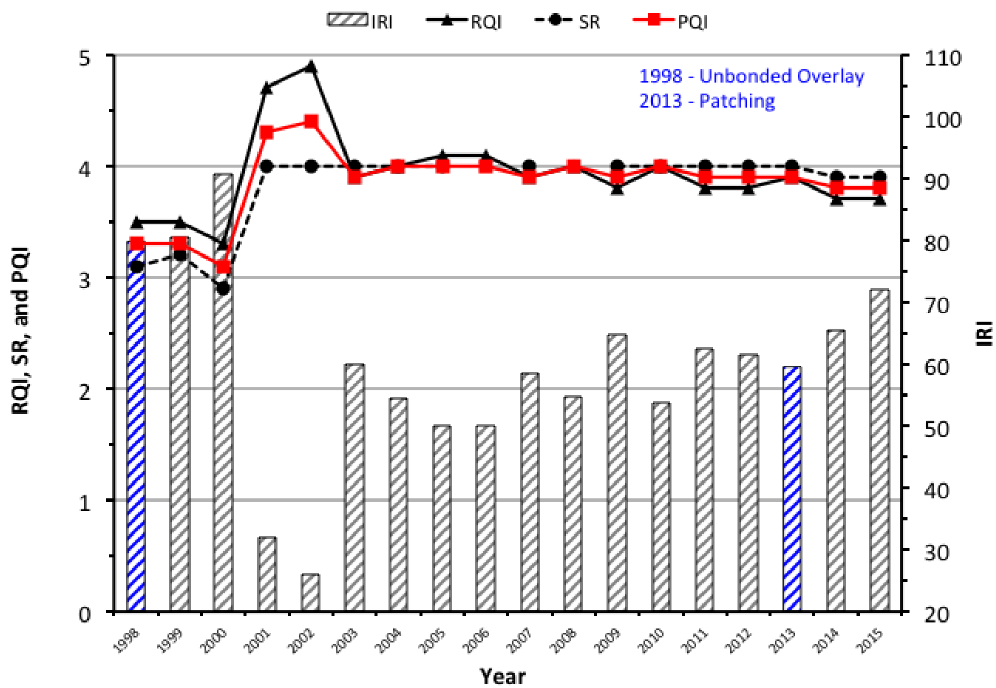


Figure 5.27. Example PMS data from project 1480-131, RP 27+0.000.

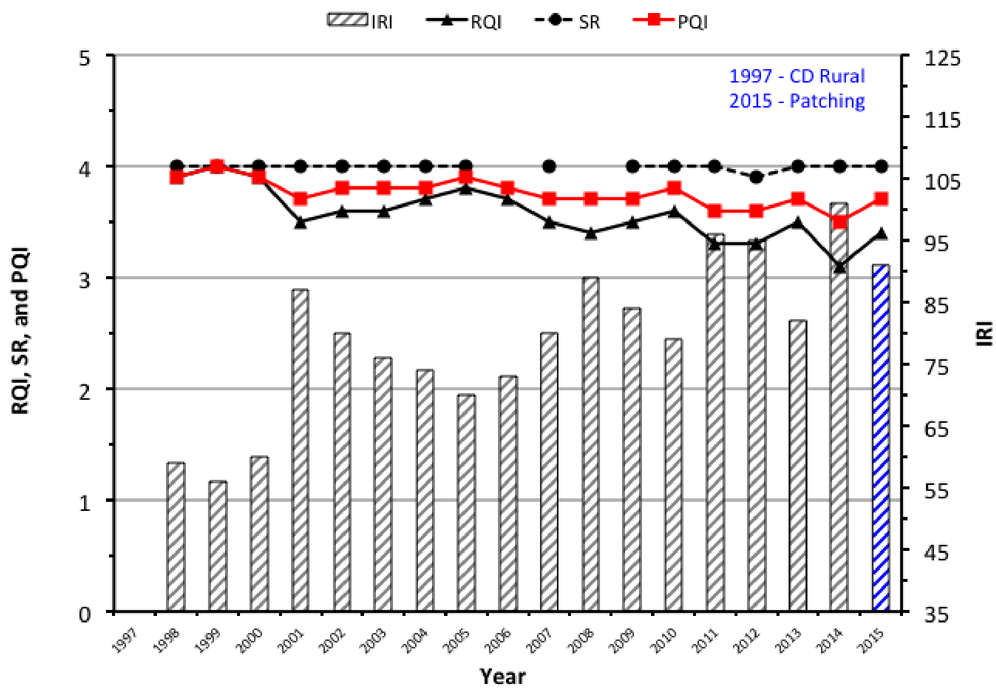


Figure 5.28. Example PMS data from project 5680-111, RP 41+0.000.

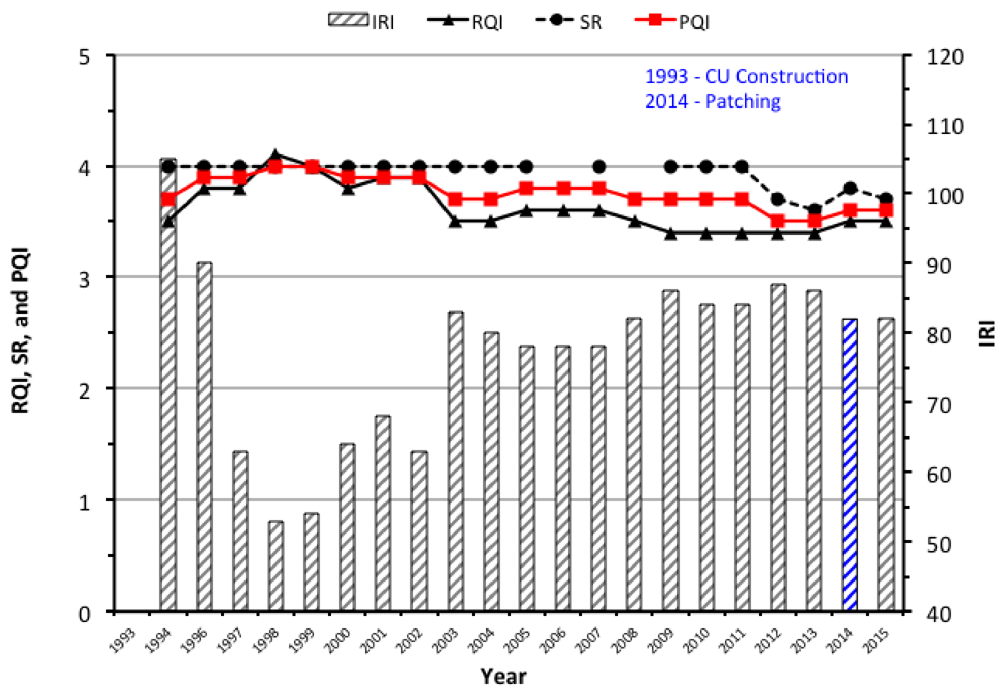


Figure 5.29. Example PMS data from project 8480-26, RP 34+0.000.

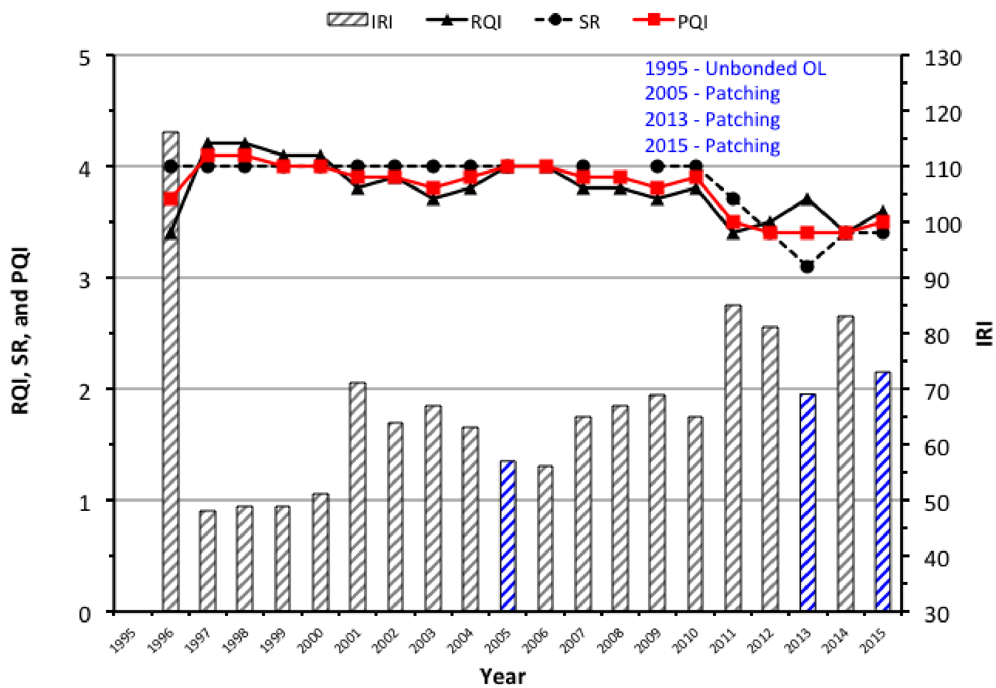


Figure 5.30. Example PMS data from project 8480-27, RP 36+0.000.

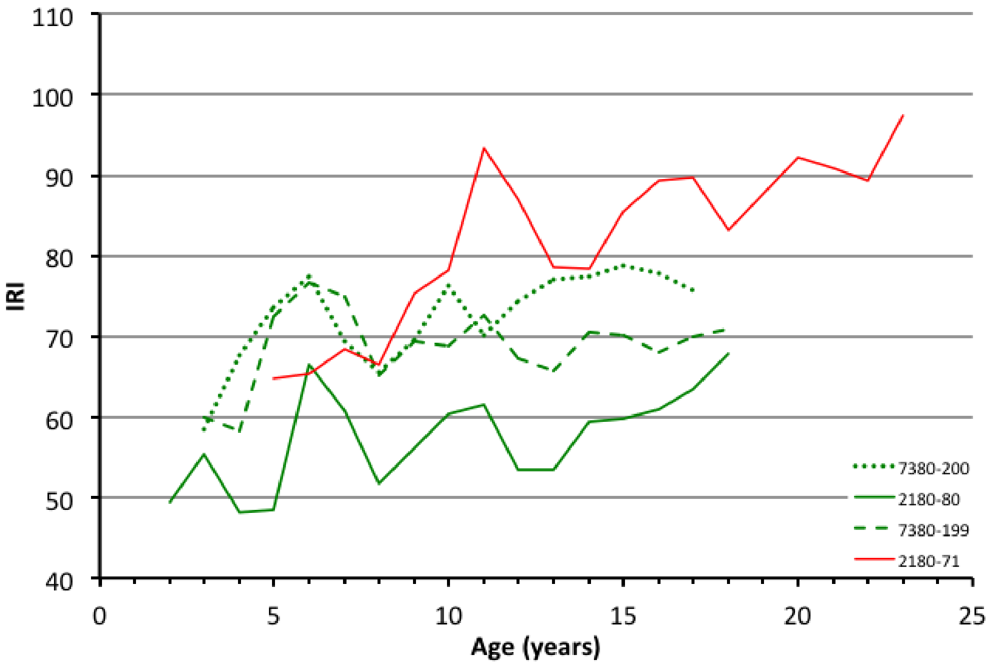


Figure 5.31. Raw IRI data for projects on TH94.

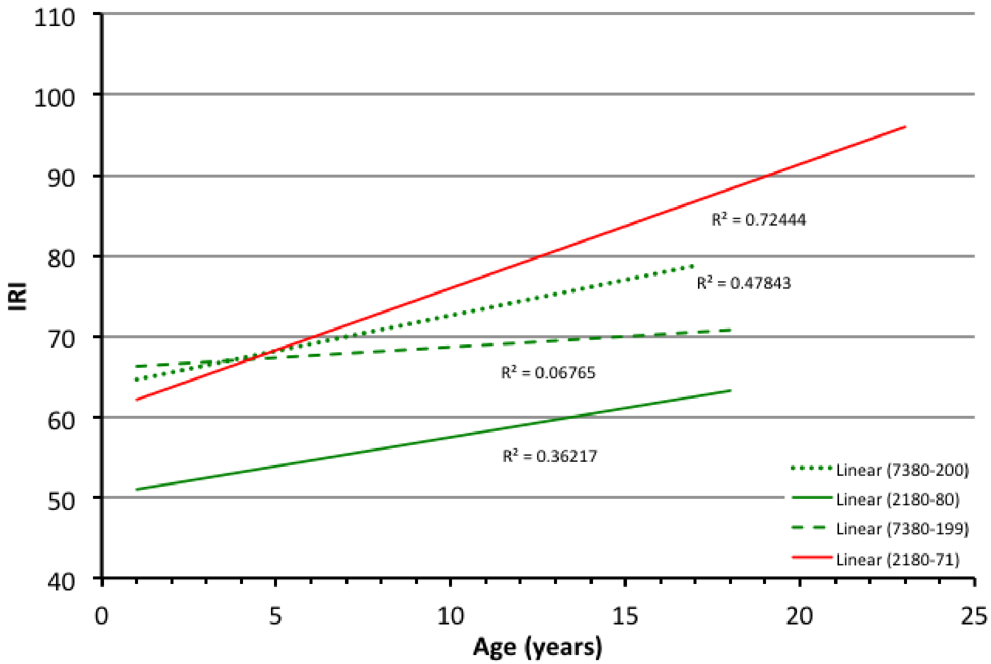


Figure 5.32. Linear regression fit lines for IRI data for projects on TH94.

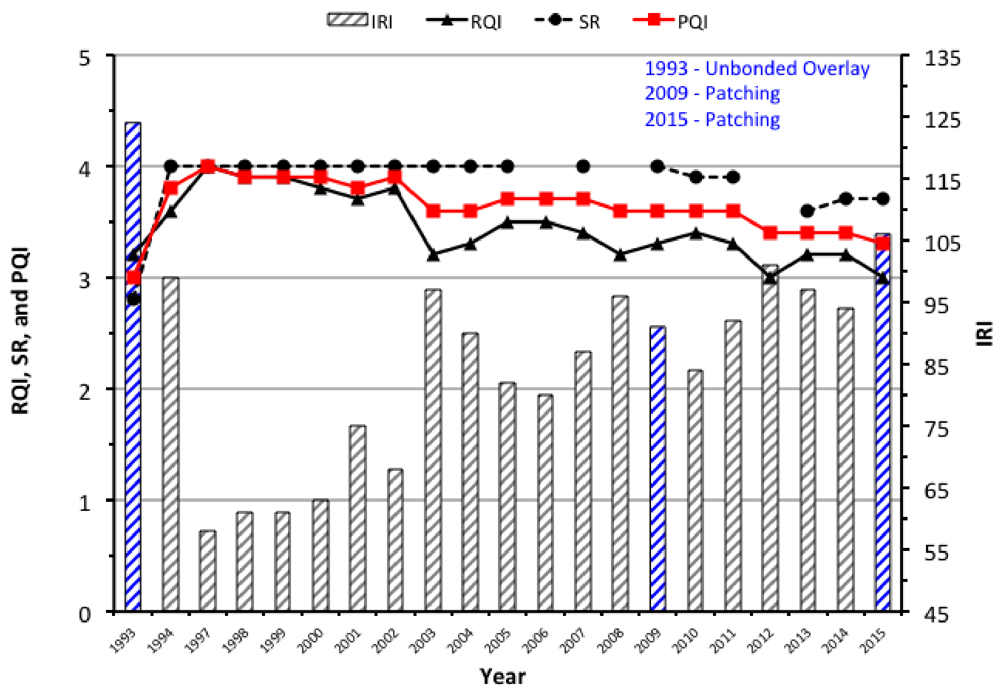


Figure 5.33. Example PMS data from project 2180-71, RP 101+0.000.

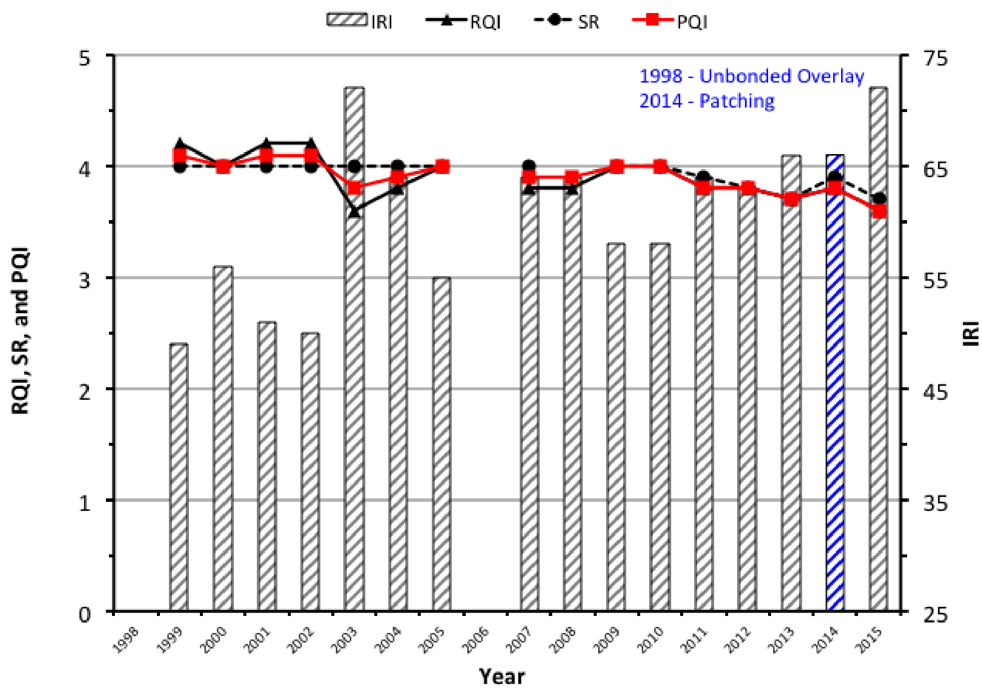


Figure 5.34. Example PMS data from project 2180-80, RP 105+0.000.

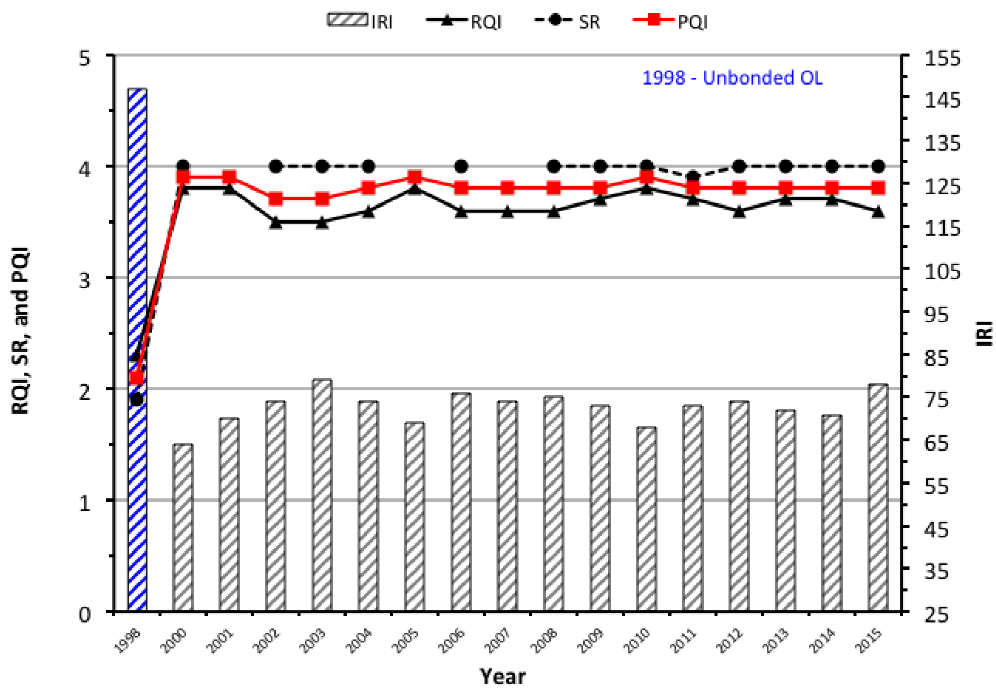


Figure 5.35. Example PMS data from project 7380-199, RP 115+0.283

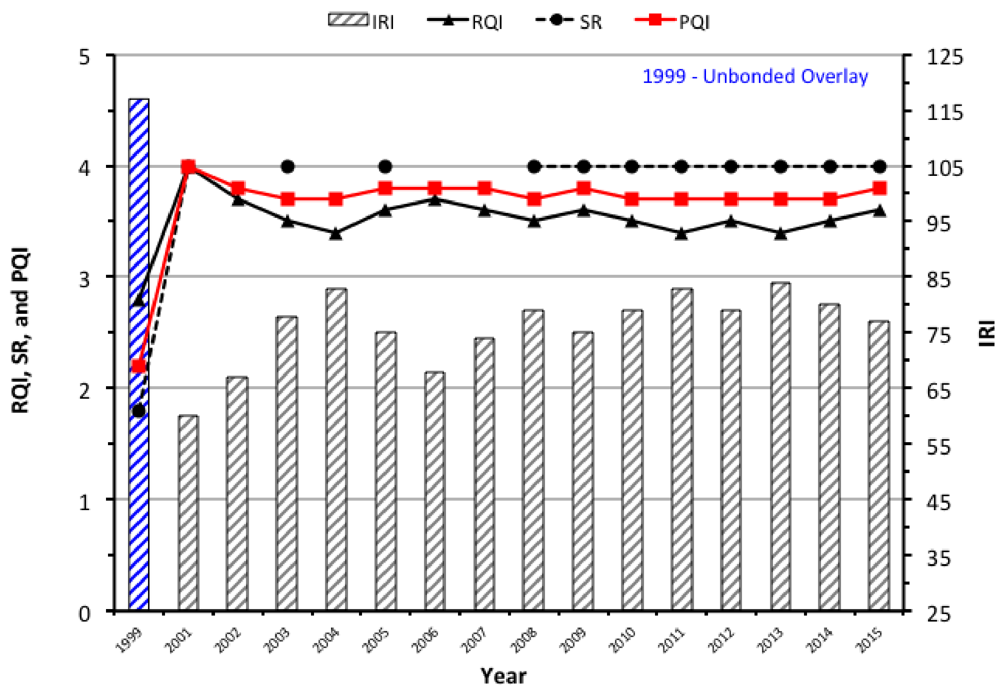


Figure 5.36. Example PMS data from project 7380-200, RP 120+0.000.

CHAPTER 6: CONCLUSIONS

Based on this study, the following conclusions are presented.

- Laboratory testing of cores from 36 pavement projects (i.e., 15 projects constructed prior to the *w/cm* specification, 21 projects constructed using the *w/cm* specification as well as other specification changes) provides strong evidence the specification changes have led to concrete with lower permeability and higher strength.
    - Testing using ASTM C1202 *Standard Test Method for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration* supports this conclusion. On average, lower coulomb values are seen for post-*w/cm* specification concrete as compared to pre-*w/cm* specification concrete.
    - Testing using AASHTO T 358 *Standard Method of Test for Surface Resistivity Indication of Concrete's Ability to Resist Chloride Ion Penetration* supports this conclusion. On average, higher resistivity values are seen for post-*w/cm* specification concrete as compared to pre-*w/cm* specification concrete.
    - Testing using ASTM C39/C39M *Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens* supports this conclusion. Higher compressive strength values are seen for post-*w/cm* specification concrete as compared to pre-*w/cm* specification concrete.
- Laboratory testing of cores using ASTM C457/C457M *Standard Test Method for Microscopical Determination of Parameters of the Air-Void System in Hardened Concrete* indicates that specification changes have resulted, on average, in an increase in air content and an improved air-void system, which leads to an improved resistance to freezing and thawing deterioration.
- Laboratory testing of cores using ASTM C1152 *Standard Test Method for Acid-Soluble Chloride in Mortar and Concrete* is inconclusive. The results are confounded by multiple effects on chloride ingress.
- Analysis of MnDOT pavement management system data suggests that pavements constructed using the *w/cm* specification have on average, better ride quality at a given year of pavement life, and a slower rate of ride quality degradation, as compared to pavements constructed prior to the *w/cm*.
- Some unexplained anomalous performance was identified in the analysis of the pavement management system data, and there was insufficient information to identify the reasons for this performance. The data analysis suggests factors other than those measured in this study are positively or negatively affecting performance.

CHAPTER 7: FUTURE WORK

The following recommendations are made for future work examining the impacts of specification changes on pavement concrete.

- Any future study should begin with a statistical based experimental matrix designed to elicit the specific information sought, with a predictable level of certainty. The proposed matrix would most likely be a partial factorial design. This study was hampered, in some cases by incomplete information and in some cases, pavement projects were over sampled.

- Given the desire to isolate and study the impact of specifications, it is recommended that any core samples extracted for laboratory analysis be taken mid-panel only. Sampling at or near a joint confounds any analysis by ingress of deicers or deterioration from other sources. Mid-panel concrete will most accurately represent the concrete as placed.

- Laboratory testing must take on a more specific focus. ASTM C1202 seems to be applicable although the scatter seen in some samples needs explanation. The same is true for resistivity. Compressive strength testing seems logical and simple and should be considered, but applied on a statistical basis as previously mentioned. Another measure of permeability that should be considered is the ultra-violet (UV) dye method of thin section preparation and examination. In addition to statistically sampling to select cores, multiple UV thin sections will be required from each core sample analyzed. A minimum of 16 thin sections should be analyzed per core if the UV dye method is employed.

- New research should focus on examination of the formation factor, which entails measurement of bulk resistivity. This information will help support adoption of the performance engineered mixtures (PEM) specification.

- Pavement management data appears to offer an extraordinary opportunity to investigate performance and correlate that performance with specification changes. Combining PMS data with construction data would enhance this analysis. A clear protocol for analysis of the PMS data needs to be established. There are a number of trends observed in the analysis presented herein that could serve as the basis for that protocol. Analysis of the PMS data would be greatly enhanced by moving the data to a query-accessible relational database that can be used to easily associate key variables. Michigan Tech has developed an open-source data base solution that meets these criteria and has implemented it with the Michigan DOT for analyzing fly ash data. The same platform can be adopted for analysis of PMS data.

- Closer examination of pre-*w/cm* pavements that performed well may identify other design parameters or maintenance practices that contribute to long life pavements.

REFERENCES

Rixom, R.M. and N.P. Mailvaganam. (1986). *Chemical Admixtures for Concrete, 2nd edition*. E. & F. N. Spon, Ltd. 29 West 35th Street, New York, New York 10001. 306 pp. ISBN-13 9780419126300

Vandenbossche, J.M. (1999). *A Review of the Curing Compounds and Application Techniques Used by the Minnesota Department of Transportation for Concrete Pavements*. Final Report 2001-06. Minnesota Department of Transportation. St. Paul, MN. November 1999. http://dotapp7.dot.state.mn.us/research/pdf/200106.pdf. Accessed April 1, 2018.

APPENDIX A – PETROGRAPHIC DATA

Appendix A - Petrographic Reports

Introduction

Included in this Appendix are the field notes and coring information provided by coring crews and the complete petrographic reports for the selected cores analyzed from each project. The projects and core identifications for the data included in this appendix are summarized in Table A.1. Core samples from a total of 36 projects were examined. In select cases as noted, only core pictures are presented. Full petrographic analyses were not performed in these select cases. For many of the projects, the reports appended here include photographic documentation of cores receive but not analyzed by petrography. This additional information is presented at the end of the last petrographic report for a given project.

Table A.1. List of cores examined by petrography sorted by district and project number.

District	Project Identification	Core Identification	District	Project Identification	Core Identification
1	0980-127	3A, 3B	6	2313-13	M001, M002
1	3805-67	7C, 8C	6	2480-88	M001
2	6019-22	9, 12	6	2480-91	M018
3	7380-199	7009, 7012	6	5507-47	M004, M005
3	*7380-200	7000, 7003, 7006, 7018,	7	0702-98	5
4	1480-131	2, 3, 5	7	*0712-30	K, L, M
4	2180-71	1, 3	7	0712-32	1
4	2180-78	3, 5	7	*2208-35	A, B, C
4	2180-80	1, 4	7	*2208-36	D, E, F, G, H
4	5680-111	4	7	3204-59	3
4	8480-26	1, 4, 5	7	3204-62	1
4	8480-27	3, 7, 8	7	4013-41	1
M	0280-049a	C-4	7	5306-37	3
M	1907-53	C04	7	6507-04	22
M	1907-54	C-1A, C-4, C-7	7	7204-13	28
M	2782-268	C4	8	4705-30	4, 7
M	2786-115	3J	8	*6404-32	11, 12
M	2786-116	1J, 2J			
M	2786-117	6J			

* Indicates core documentation only.

Field Notes and Petrographic Reports for Project 0980-127, Cores 3A, 3B

Table A.2. Field notes for SP Number 0980-127, I-35.

Core	Location from Joint	RP	Station	Direction	Lane	Offset	Thickness
1A	-2.3'	214.247		NB	PA	-10.8'	8.000"
1C	2.5'	214.247		NB	PA	-10.8'	8.000"
2A	-1.1'	214.520		NB	PA	-11.0'	7.750"
2C	2.0'	214.520		NB	PA	-11.0'	7.750"
3A	-1.8'	214.540		NB	PA	-10.2'	7.750"
3B	ON	214.540		NB	PA	-10.2'	7.500"
3C	1.8'	214.540		NB	PA	-10.2'	7.500"

00 LAB 001 Petrographic Examination of Hardened Concrete
ASTM: C-856

Project No.	28-00337	Date:	January 4, 2012
Sample ID:	3A, SP0980-127	Performed by:	G. Moulzolf

I. General Observations

1. Sample Dimensions: Our analysis was performed on both lapped sides of a 205mm (8") x 93mm (3 5/8") x 39mm (1 ½") thick section, a 205mm (8") x 83mm (3 ¼") x 27mm (1") thick section, and a 76mm (3") x 52mm (2") wide thin section that were sawcut and prepared from the original 93mm (3 5/8") diameter x 205mm (8") long core.

2. Surface Conditions:
   Top: Rough screeded and tined surface with traffic wear exposing several coarse aggregate surfaces.
   Bottom: Rough, irregular, formed surface; placed on asphalt-stabilized sub-base.

3. Reinforcement: None observed.

4. General Physical Conditions: The core exhibits fair to good overall condition. The rough screeded and tined top surface of the core exhibits moderate traffic wear; exposing several truncated coarse aggregate surfaces. The concrete was well consolidated, with no voidspaces observed in excess of 12mm in diameter in the core. The concrete was purposefully air entrained and contains a well-distributed air void system considered freeze-thaw resistant under severe exposure conditions.

II. Aggregate

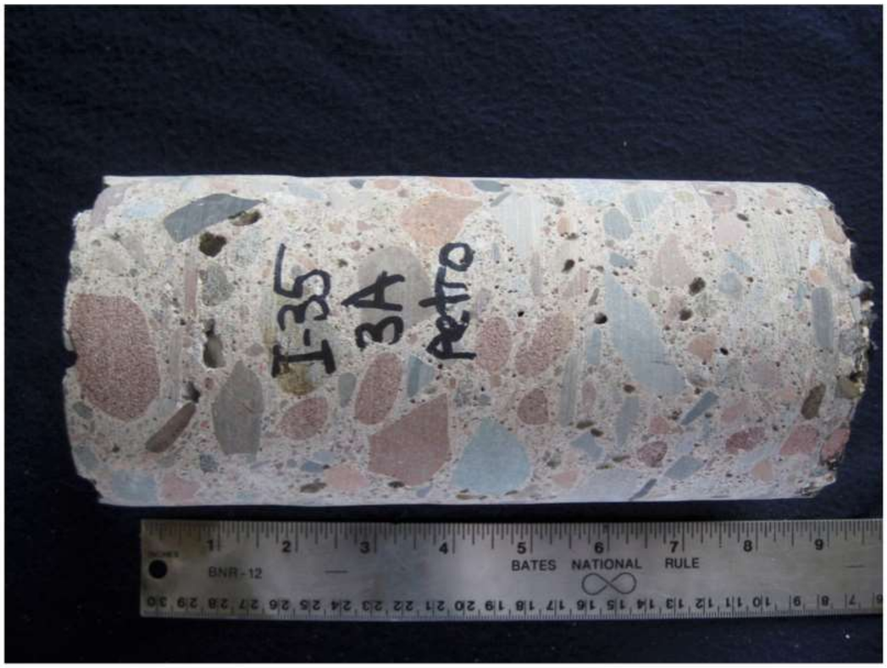
1. Coarse: 25mm (1") nominal sized natural glacial gravel composed chiefly of rhyolite, basalt, gabbro, sandstone, graywacke, and granite; with some iron oxide and chert. The coarse aggregate appeared well graded and exhibited good overall distribution.

2. Fine: Natural quartz, feldspar, and lithic sand. The lithic grains are consistent with composition of the coarse aggregate. The grains were mostly sub-rounded with many smaller sub-angular particles. The fine aggregate appeared fairly graded and exhibited good overall uniform distribution.

III. Cementitious Properties

1. Air Content: 4.9% total
2. Depth of carbonation: Ranges from negligible up to 8mm depth from the top surface of the core; along sub-vertical drying shrinkage microcracking.
3. Pozzolan presence: Flyash was observed.
4. Paste/aggregate bond: Fair to good.
5. Paste color: Similar to Light Brownish Gray (Munsell® 5YR 6/1).
6. Paste hardness: Moderately hard (Moh's 3)
7. Microcracking: A few, fine, sub-vertical drying shrinkage microcracks proceed up to 6mm depth from the top surface; one proceeds to 17mm depth. No other microcracking was evident in the core.
8. Secondary deposits: White ettringite partly fills many of the finest entrained sized air voids scattered throughout the paste between the carbonated top surface paste and approx. 60mm depth in the sample; and in the bottom approx. 3mm of the core.
9. w/cm: Estimated at between 0.42 and 0.47 with approximately 4 to 6% residual portland cement clinker particles and an amount of flyash visually consistent with a 15 to 25% replacement of portland cement.
10. Cement hydration: Alites: Mostly fully.
    Belites: Well to fully.

PHOTO: 7



SAMPLE ID: 0980-127, 3A **DESCRIPTION:** "Mid-panel" core sample selected for petrographic analysis.

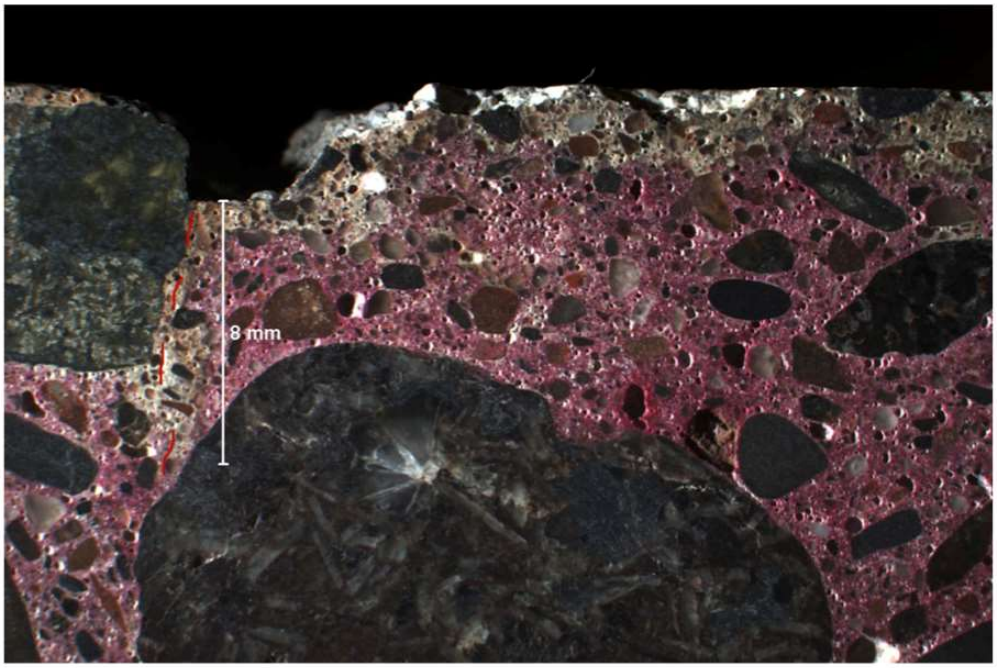
PHOTO: 8

SAMPLE ID: 0980-127, 3A **DESCRIPTION:** Rough screeded and tined top surface of the core with traffic wear exposing coarse aggregate surfaces.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

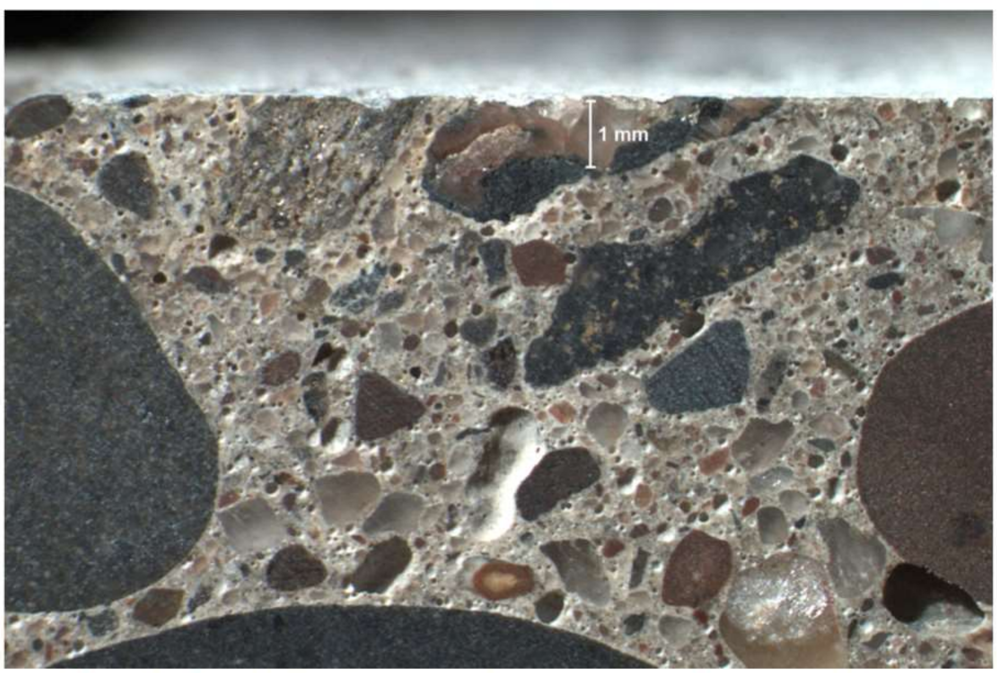
PROJECT: W/CM Study
Phase 1

PHOTO:
98



SAMPLE ID: 0980-127, 3A **DESCRIPTION:** Carbonation (unstained paste) ranged from negligible up to 8mm depth from the top surface; along sub-vertical drying shrinkage microcracking mapped in red ink. A freshly sawcut and lapped cross section of core exposed to phenolphthalein pH indicator.
MAG: 5x

PHOTO:
99



SAMPLE ID: 0980-127, 3A **DESCRIPTION:** The air void system proximate to the top surface of the core is free of secondary ettringite.
MAG:

00 LAB 001 Petrographic Examination of Hardened Concrete
ASTM: C-856

Project No.	28-00337	Date:	January 6, 2012
Sample ID:	3B, SP0980-127	Performed by:	G. Moulzolf

I. General Observations

1. Sample Dimensions: Our analysis was performed on both lapped sides of a 190mm (7 ½") x 65mm (2 ½") x 20mm (¾") thick section, a 192mm (7 ¾") x 60mm (2 ³/₈") x 37mm (1 ³/₈") thick section , a 165mm (6 ½") x 33mm (1 ¼") x 20mm (¾") thick section, and two 76mm (3") x 52mm (2") wide thin sections that were sawcut and prepared from the original 93mm (3 ⁵/₈") diameter x 205mm (8") long core taken directly through a distressed sawcut joint. The thin sections were located at between 12mm (½") and 90mm (3 ½") depth and 120mm (4 ¾") and 191mm (7 ¾") depth in the core from the top surface; directly adjacent to the distressed joint surface.

2. Surface Conditions:
Top: Rough screeded and traffic worn surface; exposing fine aggregate surfaces.
Bottom: Rough, irregular, formed surface; placed on a natural aggregate sub-base.
Joint: One side of the core exhibits evidence of the first sawcut to 53mm depth before severe vertical scaling/ spalling exposes larger coarse aggregate fairly clean of paste below. A second "reservoir" sawcut is evident to 33mm depth. The adjacent sawcut surfaces on the other side of the joint are missing and completely spalled away. Some loose sand and apparent fine concrete debris line the joint plane.

3. Reinforcement: None observed.

4. General Physical Conditions: The core was taken directly through a severely distressed pavement joint. An unattached 90mm long and 10mm wide section of silicon joint sealant was included with the sample. The joint surfaces are vertically scaled/spalled away, leaving an up to approx. 25mm (1") diameter void in the joint between 35 and 85mm depth from the top surface. The void is approx. 10mm wide between 85 and 120mm depth; with some thinner paste loss and residual interlock between the two halves of core below 120mm depth. Concentrated sub-vertical microcracks (incipient spalling) were observed generally within the paste-only and within 12mm of the distressed joint surface between the top and bottom surfaces of the core. A few schist aggregate particles and softer graywackes exhibit spalling and some internal microcracking.

The rough screeded top surface of the core exhibits moderate traffic wear; exposing fine aggregate surfaces. The concrete was well consolidated, with no voidspaces observed in excess of 12mm in diameter in the core. The concrete was purposefully air entrained and originally contained a well-distributed air void system considered freeze-thaw resistant under severe exposure conditions. Original air void parameters include a 4.0% entrained-sized void volume and a 0.006" spacing factor. Secondary ettringite, with some portlandite, fills many of the smaller entrained sized voidspaces throughout the depth of the core apart from the partly carbonated top approx. 7mm. Void fillings decrease with depth from the vertical distressed joint surfaces. Actual measured air void parameters, excluding the ettringite void fillings, in a band between approx. 25mm and 52mm (1-2") depth from the distressed joint surface, are 2.7% entrained volume and a 0.008" spacing factor. Measured empty air void parameters in a band between approx. 0mm and 25mm (1") depth from the distressed joint surface are 2.7% entrained air volume and a 0.009" spacing factor.

II. Aggregate

1. Coarse: 25mm (1") nominal sized natural glacial gravel, consistent with Superior Lobe glacial deposits, is composed chiefly of rhyolite, basalt, gabbro, sandstone, graywacke, and granite; with some iron oxide and chert. The coarse aggregate appeared well graded and exhibited good overall distribution.

2. Fine: Natural quartz, feldspar, and lithic sand. The lithic grains are consistent with the composition of the coarse aggregate. The grains were mostly sub-rounded with many smaller sub-angular particles. The fine aggregate appeared fairly graded and exhibited good overall uniform distribution.

III. Cementitious Properties

1. Air Content: 6.7% total original air void. 4.9% actual air voidspace between 25mm and 52mm depth from the distressed joint. 3.5% between the distressed joint surface and 25mm depth in the core.
2. Depth of carbonation: Ranges from negligible up to 5mm depth from the top surface of the core; along sub-vertical drying shrinkage microcracking.
3. Pozzolan presence: Flyash was observed.
4. Paste/aggregate bond: Fair to good.
5. Paste color: Similar to Light Brownish Gray (Munsell® 5YR 6/1).
6. Paste hardness: Moderately hard (Moh's 3)
7. Microcracking: Some concentrated sub-vertical microcracks (incipient spalling) were observed generally within the paste-only and within 12mm of the distressed joint surface between the top and bottom surfaces of the core. A few fine, sub-vertical drying shrinkage microcracks proceed up to 5mm depth from the top surface.
8. Secondary deposits: White, generally acicular grown ettringite along with some clear platelets of portlandite fills most of the finer entrained sized air voids scattered throughout the paste from the top partly carbonated 7mm of paste through the depth of the core. Void fillings become less abundant with distance greater than approx. 25mm from the distressed joint surface. A few rare "mats" of white ettringite partly fill incipient spalls on the joint plane.
9. w/cm: Estimated at between 0.42 and 0.47 with approximately 4 to 6% residual portland cement clinker particles and an amount of flyash visually consistent with a 15 to 25% replacement of portland cement.
10. Cement hydration: Alites: Mostly fully.
    Belites: Well to fully.

PROJECT: W/CM Study
Phase 1

PHOTO: 9

SAMPLE ID: 0980-127, 3B **DESCRIPTION:** Severely distressed joint core sample selected for petrographic analysis.

PHOTO: 10

SAMPLE ID: 0980-127, 3B **DESCRIPTION:** Rough screeded top surface of the core with mortar erosion/ traffic wear exposing some coarse aggregate surfaces. Note compromised sealant.

PROJECT: W/CM Study
Phase 1

PHOTO:
11

SAMPLE ID: 0980-127, 3B **DESCRIPTION:** Severely distressed joint plane exhibits mostly sound aggregates protruding from distressed paste.

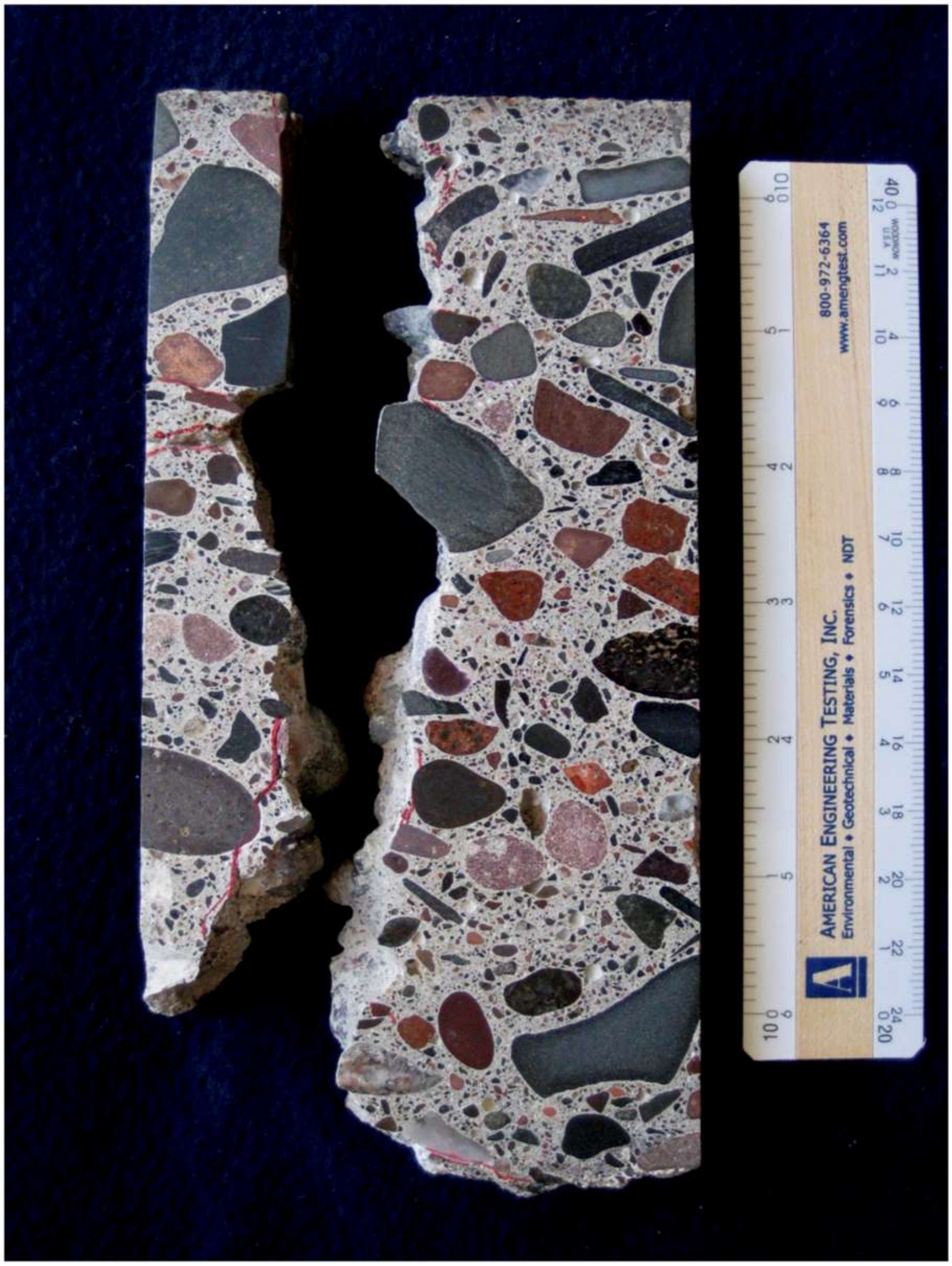
PHOTO:
12

SAMPLE ID: 0980-127, 3B **DESCRIPTION:** The other side of the severely distressed joint exhibits much of the original sawcut joint and a loosely adhered silicon sealant.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 1

PHOTO:
83

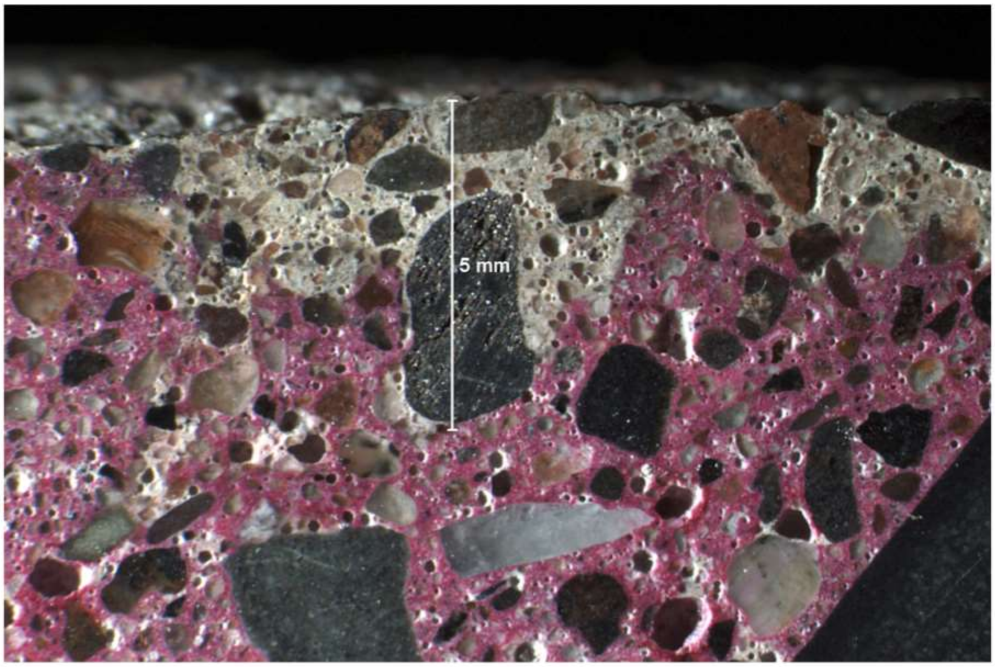


SAMPLE ID: 0987-127, 3B **DESCRIPTION:** Sawcut and lapped cross section of core exhibits significant mass loss along the joint plane. Incipient spalling is mapped in red ink.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 1

PHOTO:
100



SAMPLE ID: 0980-127, 3B **DESCRIPTION:** Carbonation (unstained paste) ranged from negligible up to 5mm depth from the top surface.
MAG: 5x

PHOTO:
101

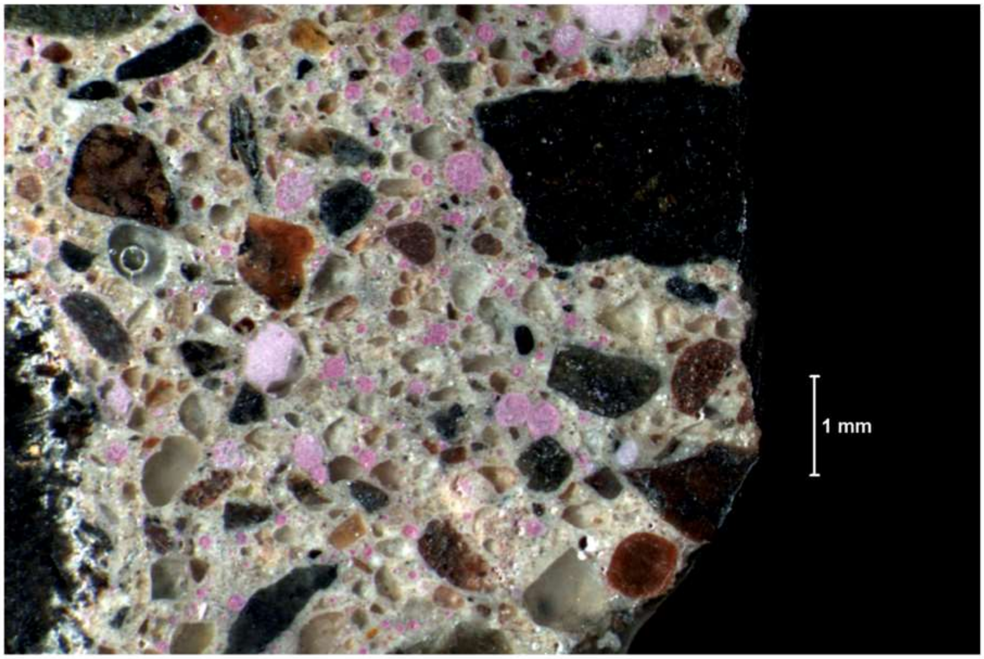
SAMPLE ID: 0980-127, 3B **DESCRIPTION:** Ettringite-filled air voids present on the spalled joint surface of the core.

MAG: 10x

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

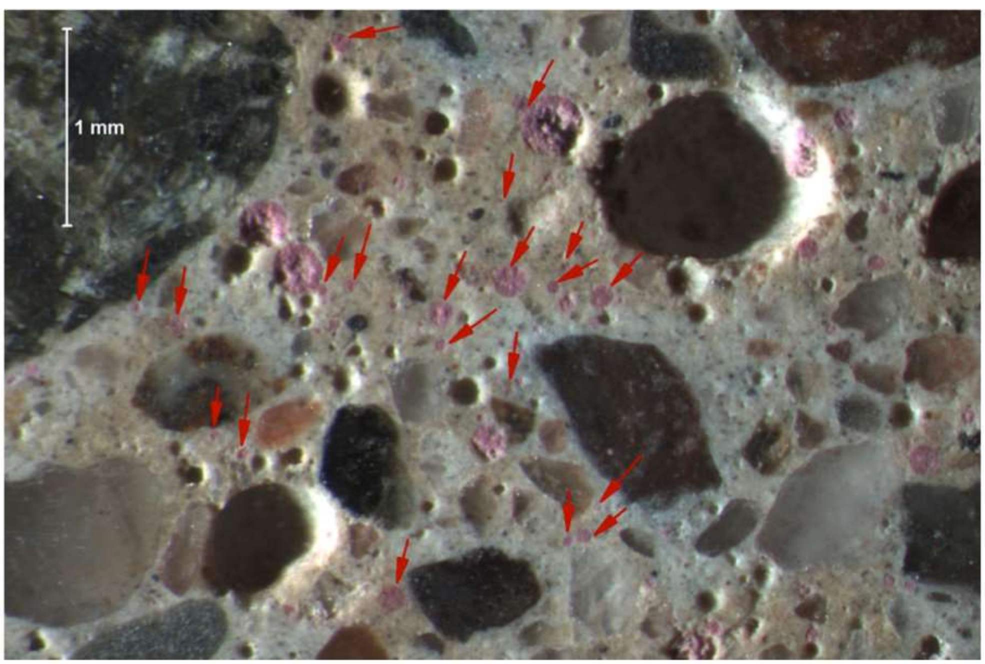
PROJECT: W/CM Study
Phase 1

PHOTO:
102



SAMPLE ID: 0980-127, 3B **DESCRIPTION:** Most of the entrained air void spaces proximate to the distressed joint plane is filled with secondary ettringite; stained purple.
MAG: 15x

PHOTO:
103

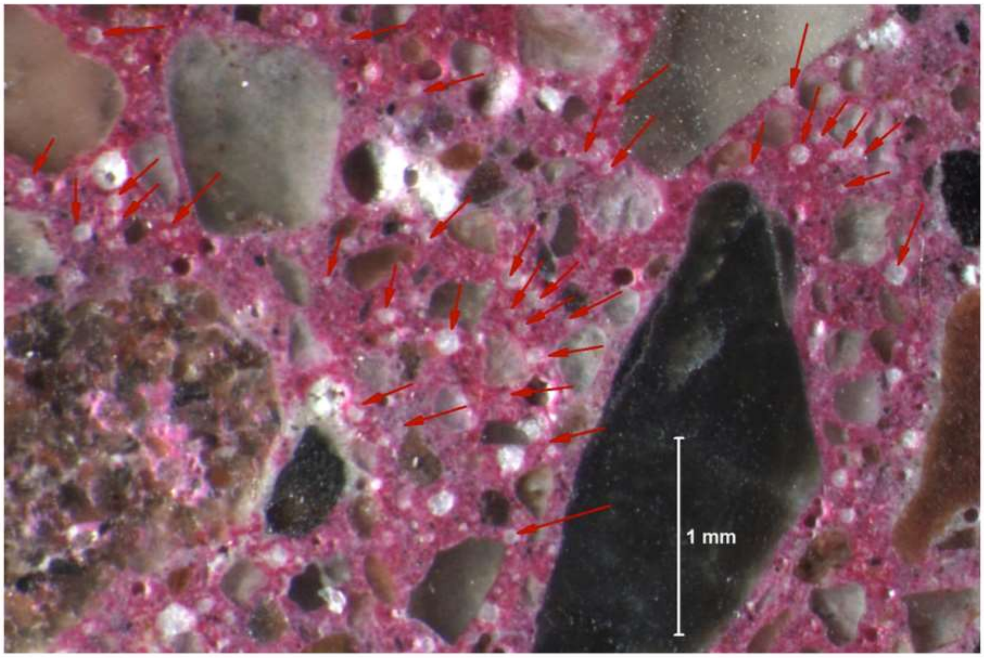


SAMPLE ID: 0980-127, 3B **DESCRIPTION:** Ettringite-filled air void spaces (stained) at 38mm depth in the concrete and 30mm depth from the joint plane.
MAG: 10x

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

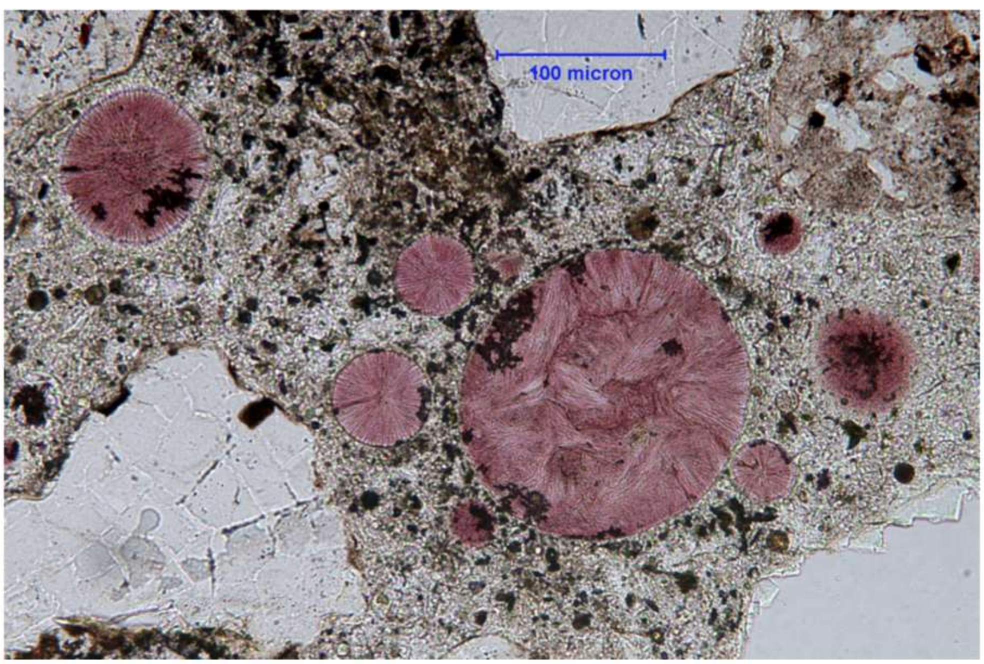
PROJECT: W/CM Study
Phase 1

PHOTO:
104



SAMPLE ID: 0980-127, 3B **DESCRIPTION:** Most of the entrained air void spaces at 180mm depth in the core and 45mm from the distressed joint plane is filled with secondary ettringite; in phenolphthalein-stained paste.
MAG: 30x

PHOTO:
105



SAMPLE ID: 0980-127, 3B **DESCRIPTION:** Ettringite-filled air void spaces (stained) in thin section of concrete adjacent to the joint plane; under plane polarized light.
MAG: 200x

Field Notes and Petrographic Reports for Project 3805-67, Cores 7C, 8C

Table A.3. Field notes for SP Number 3805-67, MN-61.

Core	Location from Joint	RP	Station	Direction	Lane	Offset	Thickness
6A	OFF	35.700		NB			8.000"
6B	OFF	35.700		NB			8.000"
7A	OFF	35.700		NB			8.000"
7B	OFF	35.700		NB			8.000"
7C	ON	35.700		NB			8.000"
8A	OFF	35.700		NB			8.250"
8B	OFF	35.700		NB			8.250"
8C	ON	35.700		NB			8.250"

00 LAB 001 Petrographic Examination of Hardened Concrete
ASTM: C-856

Project No.	28-00337	Date:	January 22, 2012
Sample ID:	7C, SP3805-67	Performed by:	D. Hunt, G. Moulzolf

I. General Observations

1. Sample Dimensions: The core was taken directly through a sealed, sawcut and cracked pavement joint. Our analysis was performed on both lapped sides of a cross section (two pieces) of core sawcut "normal" to a sawcut and cracked joint measuring 207mm (8 1/8") x 92mm (3 5/8") x 38mm (1 ½") thick, a 207mm (8 1/8") x 92mm (3 5/8") x up to 45mm (1 ¾") thick section (in two pieces), and two 76mm (3") x 52mm (2") wide thin sections that were sawcut and prepared from the original 100mm (3 7/8") diameter x 207mm (8 1/8") long core. The thin sections were located between 24mm and 98mm depth from the top surface and 135mm and 207mm depth in the core; in cross section and along the sawcut and cracked portions of the joint.

2. Surface Conditions:
   Top: Rough screeded and textured surface with minor mortar erosion exposing many fine aggregates.
   Bottom: Rough, irregular, formed surface; placed on grade.

3. Reinforcement: A 25mm (1") diameter epoxy-coated, steel dowel rod was observed at below 97mm depth from the top surface. Minor corrosion product was observed isolated to the center portion of the bottom half of the dowel, aligned with the joint crack. The epoxy coating has been deformed.

4. General Physical Conditions: The core was taken through a sealed pavement joint. The joint was characterized by an approx. 4mm wide sawcut proceeding 51mm (2") depth from the top surface and an approx. 10mm wide reservoir cut to 32mm (1 ¼") depth; in-filled with foam backer rod. The light gray silicone joint sealant appears well bonded to both sides of the sawcut joint. The joint plane is characterized by a relatively clean fracture with no discernible loss of paste. The fracture intersects consolidation voids at the approximate depth of the steel dowel. A few sub-vertical microcracks splay from the joint between 55mm and 90 mm depth from the top surface. The core exhibits a tight, residual interlock between the two halves of the core; with a few coarse aggregate bisected by the joint at depth in the core. A sub-horizontal fracture proceeds across the entire diameter of the core between 108mm and 121mm depth from the top surface, approximately aligned with the center depth of the steel dowel. A sub-horizontal microcrack proceeds across approximately half the diameter of the core within 10mm of the bottom surface, on one side of the joint. The coarse gabbro aggregate appeared sound. No evidence of ASR associated with the coarse or fine aggregate was observed.

   The rough screeded top surface of the core exhibits minor mortar erosion/traffic wear; exposing many fine aggregate surfaces. The concrete overall was fairly well consolidated with the exception of a few large, sub-vertically orientated, consolidation voids up to 25mm wide by 70mm long located between 90mm and 155 depth from the top surface, proximate to the steel dowel. The concrete was purposefully air entrained and contained a well-distributed air void system considered freeze-thaw resistant under severe exposure conditions. Air void parameters include a 5.9% entrained-sized void volume and a 0.004" spacing factor. Secondary ettringite, with some portlandite, fills a few of the smaller entrained sized voidspaces within approx. 2mm of the joint plane/surface. Void fillings decrease with depth from the joint plane.

II. Aggregate

1. Coarse: 25mm (1") nominal sized crushed gabbro. The coarse aggregate appeared well graded and exhibited good overall distribution.

2. Fine: Natural, local igneous lithic sand with some quartz and feldspar grains. The grains were mostly sub-rounded with many smaller sub-angular particles. The fine aggregate appeared fairly graded and exhibited good overall uniform distribution.

III. Cementitious Properties

1. Air Content: 4.3% original entrained air content. 2.5% "actual" un-filled entrained air between 0mm and at least 20mm depth from the distressed joint (below 57mm depth).

2.	Depth of carbonation:	Negligible up to 9mm depth from the top surface of the core along a sub-vertical microcrack. Ranged from 1mm up 4mm along the sawcut joint. Ranged from mostly negligible up to 2mm depth from the distressed joint surface.
3.	Pozzolan presence:	Flyash was observed.
4.	Paste/aggregate bond:	Good.
5.	Paste color:	Mottled Light Gray (Munsell® N7) to tan.
6.	Paste hardness:	Hard (Moh's >3)
7.	Microcracking:	Few sub-vertical microcracks were observed along the joint (cracked) surface between 55mm and 90mm depth from the top surface of the core. A horizontal microcrack was observed proceeding across the entire width of on one side of the joint within 10mm of the bottom surface of the core. A few fine, sub-vertical drying shrinkage microcracks proceed up to 9mm depth from the top surface.
8.	Secondary deposits:	White, generally acicular grown ettringite fills a few of the finer entrained sized air voids between the joint surface and approx. 2mm depth into the core. Void fillings become less abundant with distance from this zone.
9.	w/cm:	Estimated at between 0.40 and 0.45 with approximately 3 to 5% residual portland cement clinker particles, <1% residual slag cement particles, and an amount of flyash visually consistent with a 15 to 25% replacement of portland cement.
10.	Cement hydration:	Alites: Mostly fully. Belites: Well to fully. Slag: Mostly fully.

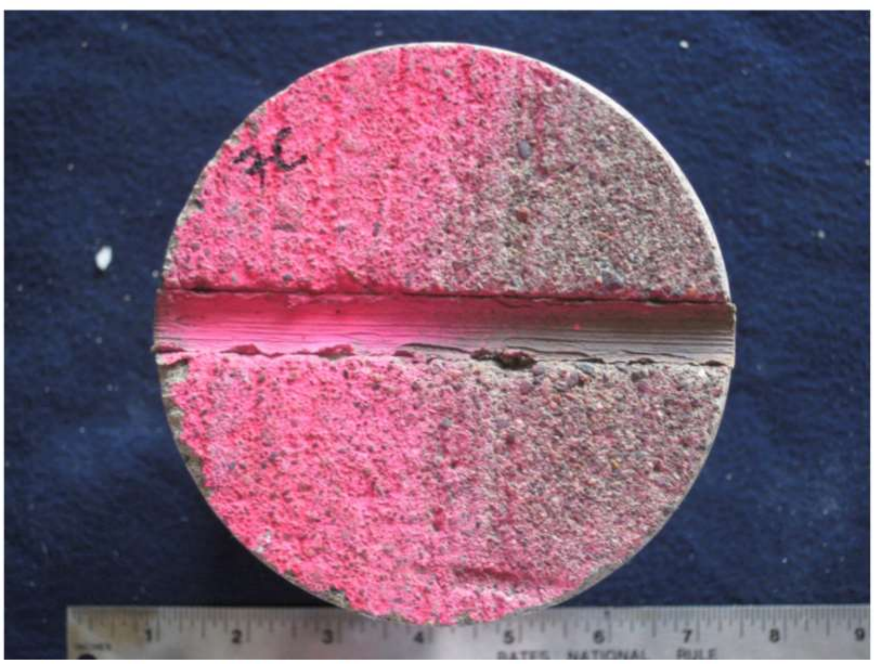
AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 1

PHOTO:
37

SAMPLE ID: 3805-67, 7C **DESCRIPTION:** Overall view of the jointed core utilized for petrographic analysis. The top surface is left.

PHOTO:
38



SAMPLE ID: 3805-67, 7C **DESCRIPTION:** Rough screeded and jointed top surface of the core with silicone sealant.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 1

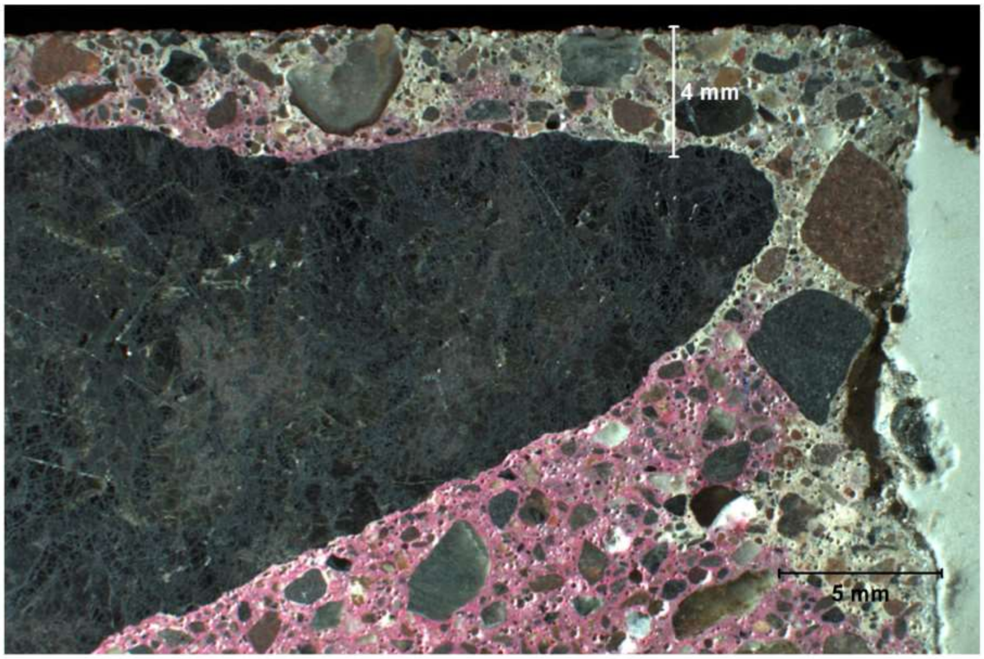
PHOTO:
87

SAMPLE ID: 3805-67, 7C **DESCRIPTION:** Sawcut and lapped cross section of core. The core exhibits tight interlock of the joint crack and intersects an epoxy-coated dowel exhibit the initiation of corrosion. The silicone was well-bonded to both side of the sawcut.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

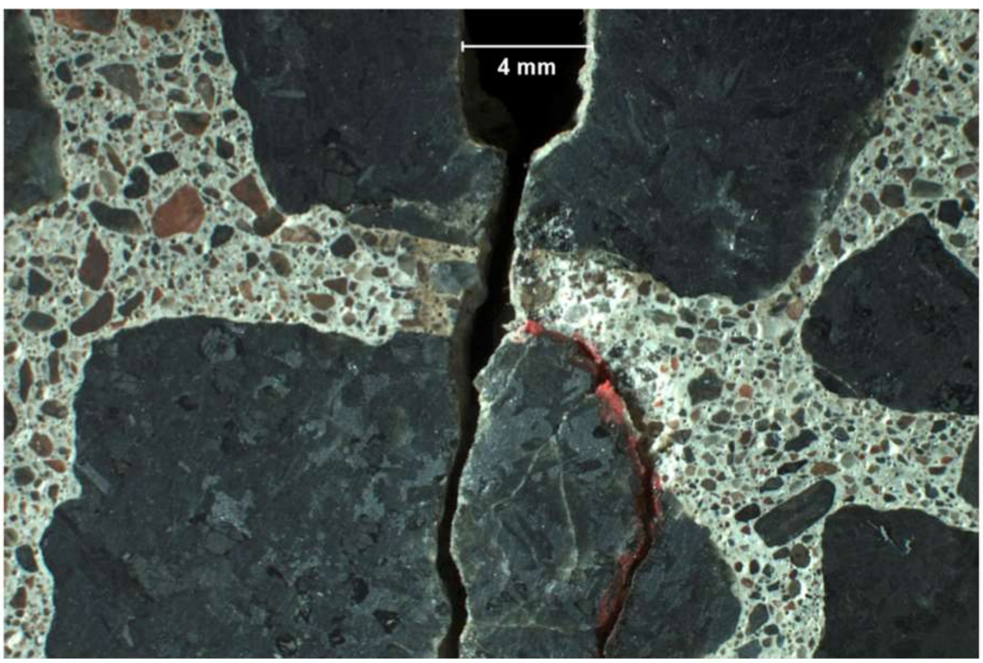
PROJECT: W/CM Study
Phase 1

PHOTO:
118



SAMPLE ID: 3805-67, 7C **DESCRIPTION:** Carbonation (unstained paste) ranged from negligible up to 4mm from the top surface (in this view).
MAG: 5x

PHOTO:
119



SAMPLE ID: 3805-67, 7C **DESCRIPTION:** The relatively tight, un-distressed joint proceeds through a coarse aggregate particle below the sawcut.
MAG: 5x

00 LAB 001 Petrographic Examination of Hardened Concrete
ASTM: C-856

Project No.	28-00337	Date:	January 23, 2012
Sample ID:	8C, SP3805-67	Performed by:	D. Hunt, G. Moulzolf

I. General Observations

1. Sample Dimensions: The core was taken directly through a sawcut and cracked pavement joint. Our analysis was performed on both lapped sides of a cross section (two pieces) of core sawcut "normal" to a sawcut and cracked joint measuring 215mm (8 ⅝") x 97mm (3 ¾") x 33mm (1 ¼") (in two pieces), and two 76mm (3") x 52mm (2") wide thin sections that were sawcut and prepared from the original 97mm (3 ¾") diameter x 215mm (8 ⅝") long core. The thin sections were located between 0mm and 71mm depth from the top surface and 145mm and 215mm depth in the core; in cross section and along the sawcut and cracked portions of the joint.

2. Surface Conditions:
Top: Fairly smooth traffic-worn surface with minor mortar erosion exposing many fine aggregate surfaces.
Bottom: Rough, irregular, formed surface; placed on grade.

3. Reinforcement: None observed.

4. General Physical Conditions: The core was taken through a sawcut pavement joint. The joint was characterized by an approx. 5mm wide, un-sealed sawcut proceeding 65mm (2 ½") depth from the top surface. Several sub-vertical microcracks (incipient scaling/spalling), observed in the paste-only, were observed between 65mm and 210mm depth in the cracked joint surface and incorporates between a few mm and 5mm of total concrete paste between the two sides of the joint crack. The joint plane is characterized by several relatively "clean" and un-distressed gabbro coarse aggregates protruding from the concrete joint. A loss of concrete paste in a "vertical oval shape" and up to 20mm in width "centers" between 80mm and 135mm depth from the top surface. Below this point, the core exhibits relatively tight, residual interlock between the two halves of core; with a few coarse aggregate bisected by the joint at depth in the core. The coarse gabbro aggregate appeared sound. No evidence of ASR associated with the coarse or fine aggregate was observed.

   The traffic-worn top surface of the core exhibits minor mortar erosion; exposing many fine aggregate surfaces. The concrete was fairly well consolidated, with only a few entrapped voidspace observed up to 7mm in diameter in the mid-section of the core. The concrete was purposefully air entrained and originally contained a well-distributed air void system considered freeze-thaw resistant under severe exposure conditions. Original air void parameters include a 5.0% entrained-sized void volume and a 0.006" spacing factor. Secondary ettringite, with some portlandite, fills most of the smaller entrained sized voidspaces within approx. 20mm of the joint plane/surface; below the depth of the sawcut. Void fillings decrease with depth from the joint plane. Actual measured air void parameters, which excludes the ettringite void fillings, in a band between approx. 0mm and at least 20mm (0-0.75") depth from the joint surface (below 62mm depth in the core), are 3.9% entrained volume and a 0.009" spacing factor.

II. Aggregate

1. Coarse: 25mm (1") nominal sized crushed gabbro. The coarse aggregate appeared well graded and exhibited good overall distribution.

2. Fine: Natural quartz, feldspar, and lithic sand. The grains were mostly sub-rounded with many smaller sub-angular particles. The fine aggregate appeared fairly graded and exhibited good overall uniform distribution.

III. Cementitious Properties

1. Air Content: 5.0% original entrained air content. 3.9% "actual" un-filled entrained air between 0mm and at least 20mm depth from the distressed joint (below 62mm depth).
2. Depth of carbonation: Up to 5mm depth from the top surface of the core. Negligible up to 2mm depth along the sawcut joint. Ranged from 3mm up to 12mm depth from the distressed joint surface with ingress of carbonation along paste/aggregate boundaries up to 30mm.

3.	Pozzolan presence:	Flyash was observed.
4.	Paste/aggregate bond:	Fair.
5.	Paste color:	Mottled Medium Light Gray (Munsell® N6) to tan.
6.	Paste hardness:	Moderately hard (Moh's 3)
7.	Microcracking:	Several sub-vertical microcracks (incipient spalling) were observed along the joint (cracked) surface between 65mm and 210mm depth from the top surface of the core. A few fine, sub-vertical drying shrinkage microcracks proceed up to 5mm depth from the top surface.
8.	Secondary deposits:	White, generally acicular grown ettringite along with some clear platelets of portlandite fills most of the finer entrained sized air voids between the joint surface and approx. 20mm depth into the core. Void fillings become less abundant with distance from this zone.
9.	w/cm:	Estimated at between 0.40 and 0.45 with approximately 3 to 5% residual portland cement clinker particles, < 1% residual slag cement particles, and an amount of flyash visually consistent with a 15 to 25% replacement of portland cement.
10.	Cement hydration:	Alites: Mostly fully. Belites: Well to fully. Slag: Mostly fully.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 1

PHOTO:
39

SAMPLE ID: 3805-67, 8C **DESCRIPTION:** Overall view of the jointed core utilized for petrographic analysis. The top surface is left. Developing "tunneling" is marked in red.

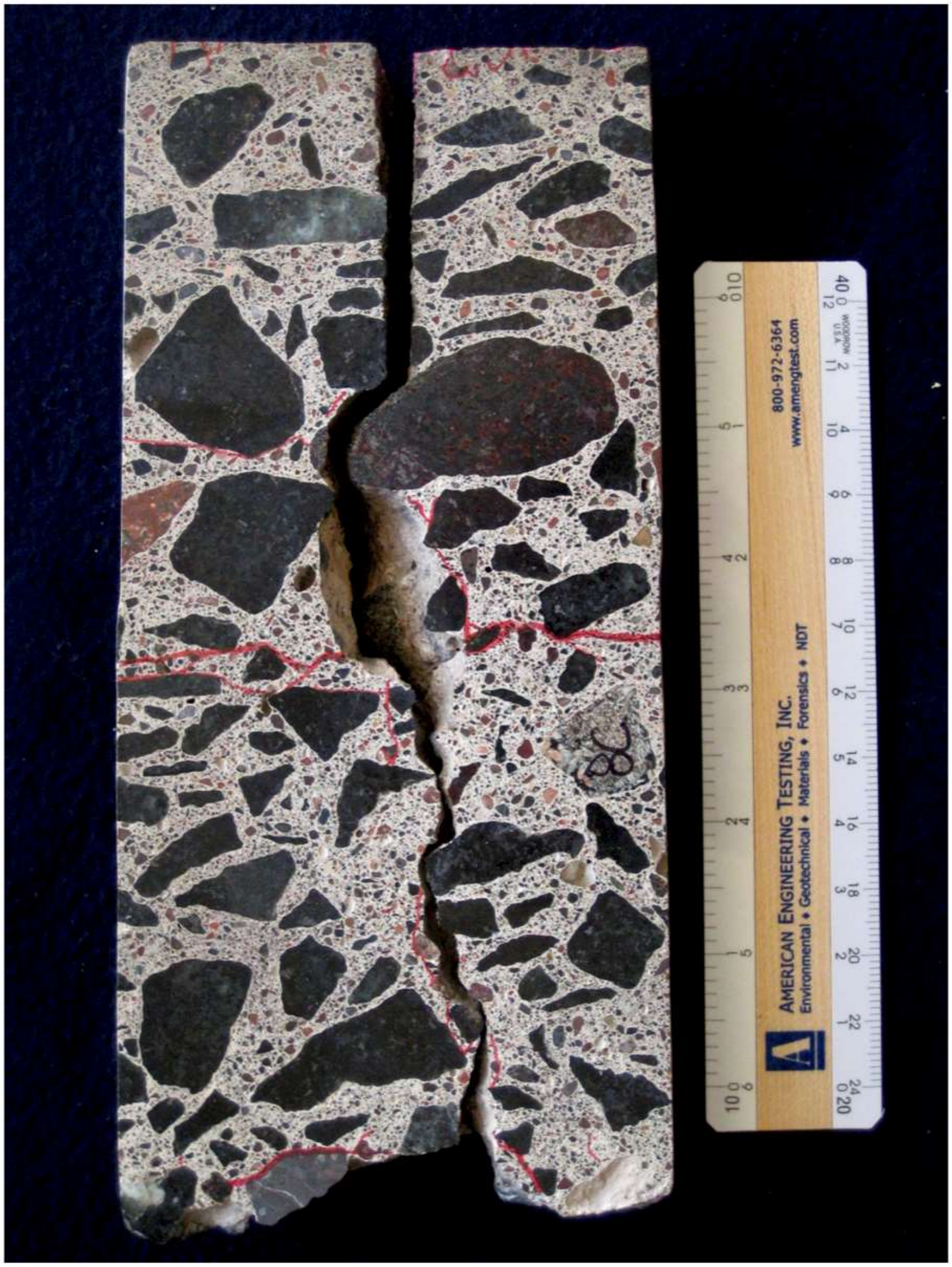
PHOTO:
40

SAMPLE ID: 3805-67, 8C **DESCRIPTION:** Rough screeded and (un-sealed) jointed top surface of the core.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 1

PHOTO:
88

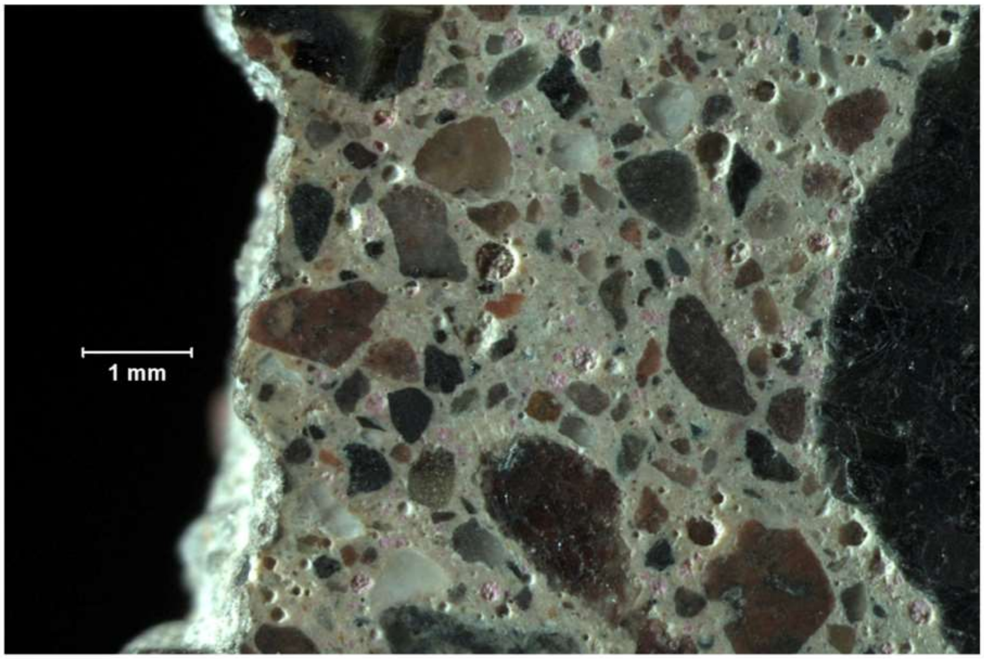


SAMPLE ID: 3805-67, 8C **DESCRIPTION:** Sawcut and lapped cross section of core. The core exhibits somewhat tight interlock of the unsealed joint crack. Incipient vertical spalling was present between 65mm and 210mm depth in the joint. Missing concrete below sawcut in this image may be related to fracturing and loss during sample preparation.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

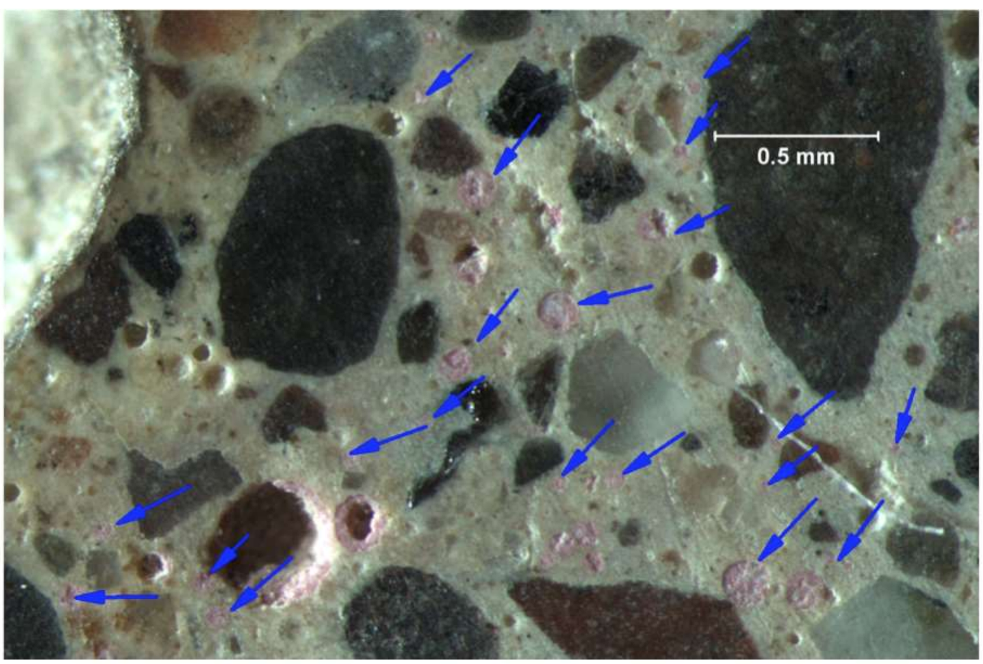
PROJECT: W/CM Study
Phase 1

PHOTO:
120



SAMPLE ID: 3805-67, 8C **DESCRIPTION:** Air void system below 45mm depth from the top surface and at the distressed joint plane appears low in volume.
MAG: 15x

PHOTO:
121

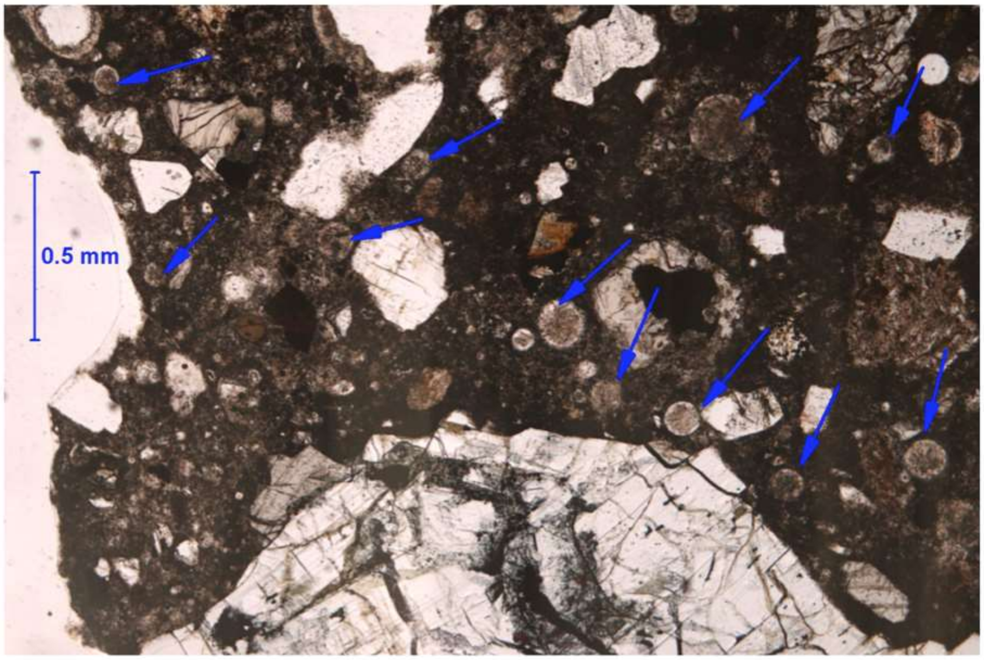


SAMPLE ID: 3805-67, 8C **DESCRIPTION:** Most of the finest entrained air voidspaces proximate to the distressed joint plane (left) are filled with (stained) secondary ettringite.
MAG: 50x

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

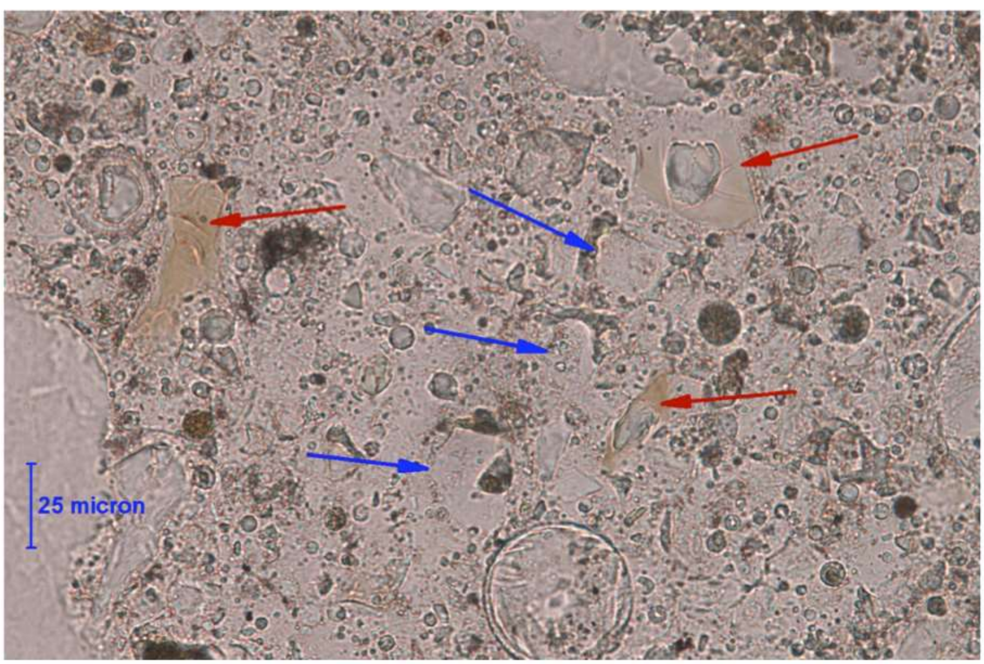
PROJECT: W/CM Study
Phase 1

PHOTO:
122



SAMPLE ID: 3805-67, 8C **DESCRIPTION:** Air void system along the distressed joint surface is filled with secondary ettringite (arrows);in thin section under plane polarized light.
MAG: 40x

PHOTO:
123



SAMPLE ID: 3805-67, 8C **DESCRIPTION:** Fully hydrated alite portland cement clinker relicts (blue arrows) and well to fully hydrated slag cement grains (red) in thin section of concrete paste under plane polarized light.
MAG:400x

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 1

PHOTO:
35

SAMPLE ID: 3805-67, 6A **DESCRIPTION:** Overall view of the jointed core utilized for rapid chloride permeability testing. The top surface is left.

PHOTO:
36

SAMPLE ID: 3805-67, 6A **DESCRIPTION:** Rough screeded and tined top surface of the core with minor mortar erosion.

Field Notes and Petrographic Reports for Project 6019-22, Cores 9, 12

Table A.4. Field notes for SP Number 6019-22, US-2.

Core	Location from Joint	RP	Station	Direction	Lane	Offset	Thickness
7001	EAST	1.733		EB	DR	8.0'	9.000"
7003	WEST	1.734		EB	PA	8.0'	9.000"
7004	WEST	1.736		EB	PA	8.0'	9.000"
7005	EAST	1.737		EB	PA	8.0'	9.250"
7008	EAST	1.770		EB	DR	8.0'	10.500"
7009	ON	1.776		EB	DR	9.0'	10.500"
7010	WEST	1.780		EB	DR	8.0'	10.750"
7011	EAST	1.781		EB	DR	8.0'	10.750"
7012	ON	1.781		EB	DR	8.0'	10.750"

00 LAB 001 Petrographic Examination of Hardened Concrete
ASTM: C-856

Project No.	28-00337	Date:	December 30, 2012
Sample ID:	9, SP6019-22	Performed by:	G. Moulzolf

I. General Observations

1. Sample Dimensions: The core was taken directly through a sealed pavement joint. Our analysis was performed on both lapped sides of a cross section (two pieces) of core, sawcut "normal" to a distressed joint, measuring 271mm (10 ⅝") x 96mm (3 ¾") x 32mm (1 ¼") thick, a 273mm (10 ¾") x 96mm (3 ¾") x 25mm (1") thick section (in two pieces), and three approx. 76mm (3") x 52mm (2") wide thin sections that were sawcut and prepared from the original 96mm (3 ¾") diameter x 273mm (10 ¾") long core. The thin sections were located between 25mm and 102mm depth, 5mm and 80mm, and 100mm and 180mm depth in the core (from the top surface); along the sawcut and "crack" portions of the joint.

2. Surface Conditions:
   Top: Rough screeded surface now traffic worn relatively smooth.
   Bottom: Rough, irregular, formed surface; placed on natural gravel sub-base.

3. Reinforcement: None observed.

4. General Physical Conditions: The core exhibits good overall condition. The core was taken through a silicon-sealed pavement joint. The joint was characterized by a 3mm vertical sawcut proceeding to 68mm (2 ⅝") depth from the top surface and a 9mm wide reservoir cut to 28mm depth. The joint was sealed with a foam backer rod and approx. 12mm of light gray silicon. A sub-vertical crack proceeds the length of the core, proceeding through paste and a few dolostone coarse aggregates. A single sub-vertical microcrack was observed between 145mm and 180mm depth, within the paste and a dolostone coarse aggregate within 12mm of the joint crack surface.

   The originally rough screeded top surface of the core exhibits moderate traffic wear; producing a fairly smooth surface. The concrete was fairly well consolidated, with a few entrapped voidspace observed in excess of 12mm in diameter scattered in the core. The concrete was purposefully air entrained and contained a well-distributed air void system considered freeze-thaw resistant under severe exposure conditions. The air void parameters include a 6.9% entrained-sized void volume and a 0.005" spacing factor. Acicular grown secondary ettringite fills some of the finest entrained sized air voids in the paste within 6mm of the joint crack starting below the sawcut.

II. Aggregate

1. Coarse: 37mm (1 ½") nominal sized natural glacial gravel composed of granites, gneisses, schists, dolostone, and basalts. The coarse aggregate appeared well graded and exhibited good overall distribution.

2. Fine: Natural quartz, feldspar, and lithic sand. The grains were mostly sub-rounded with many smaller sub-angular particles. The fine aggregate appeared fairly graded and exhibited good overall uniform distribution.

III. Cementitious Properties

1. Air Content:	6.9% total.
2. Depth of carbonation:	Ranges from negligible up to 10mm depth, intermittently, from the top surface of the core; along sub-vertical drying shrinkage microcracks. Carbonation proceeds to 4mm depth from the sawcut joint and up to 2mm depth from the joint crack below the sawcut.
3. Pozzolan presence:	Flyash was observed.
4. Paste/aggregate bond:	Fair to good.
5. Paste color:	Similar to Medium Light Gray (Munsell® N6).
6. Paste hardness:	Moderately hard (Moh's 3)
7. Microcracking:	A few fine, sub-vertical drying shrinkage microcracks proceed up to 5mm depth from the top surface.
8. Secondary deposits:	White, generally acicular grown ettringite fills some of the finest entrained sized air voids in the paste within 6mm of the joint crack below the sawcut. Calcium carbonate, after ettringite, fills some fine voids within the carbonated joint crack paste
9. w/cm:	Estimated at between 0.37 and 0.42 with approximately 8 to 10% residual portland cement clinker particles and an amount of flyash visually consistent with a 10 to 20% replacement of portland cement.
10. Cement hydration:	Alites: Well. Belites: Low.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 1

PHOTO:
59

SAMPLE ID: 6019-22, 9 **DESCRIPTION:** Overall view of the jointed core utilized for petrographic analysis. The top surface is left.

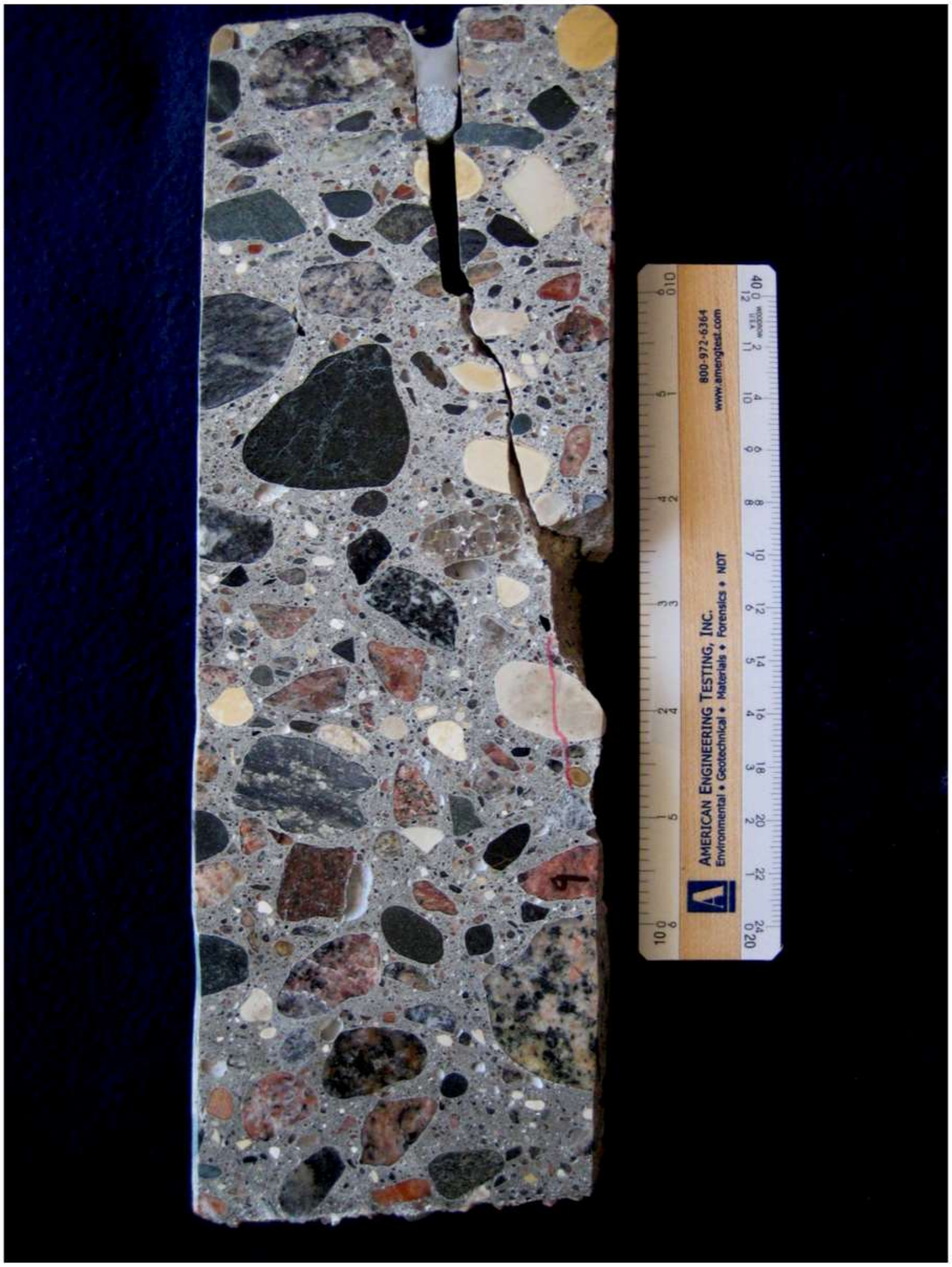
PHOTO:
60

SAMPLE ID: 6019-22, 9 **DESCRIPTION:** Joint crack plane exposed at depth in the core.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

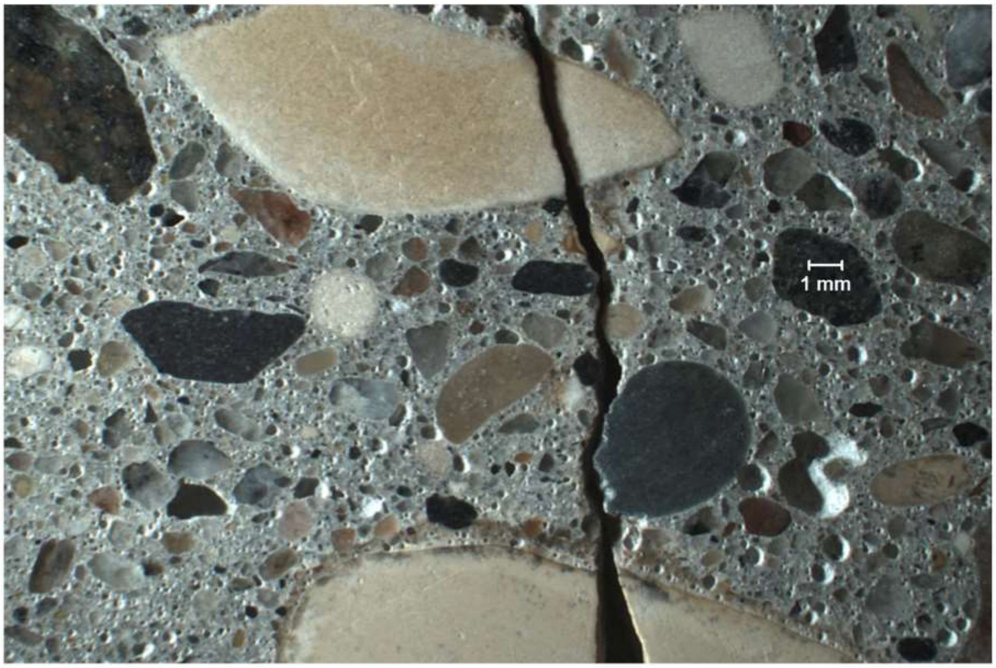
PROJECT: W/CM Study
Phase 1

PHOTO:
92



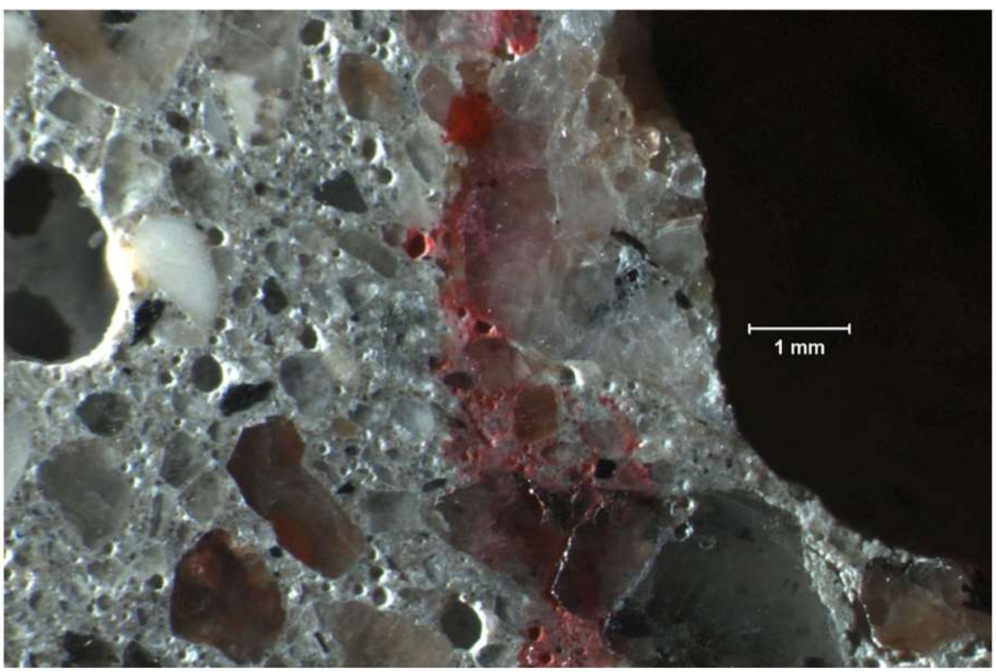
SAMPLE ID: 6019-22, 9 **DESCRIPTION:** Sawcut and lapped cross section of core. The silicone sealant was bonded to both sides of the sawcut. Note the apparent later-aged cracking bisects coarse aggregates.

PHOTO:
140



SAMPLE ID: 6019-22, 9 **DESCRIPTION:** Relatively tight, un-distressed joint crack proceeds through coarse aggregates below the sawcut.
MAG: 5x

PHOTO:
141

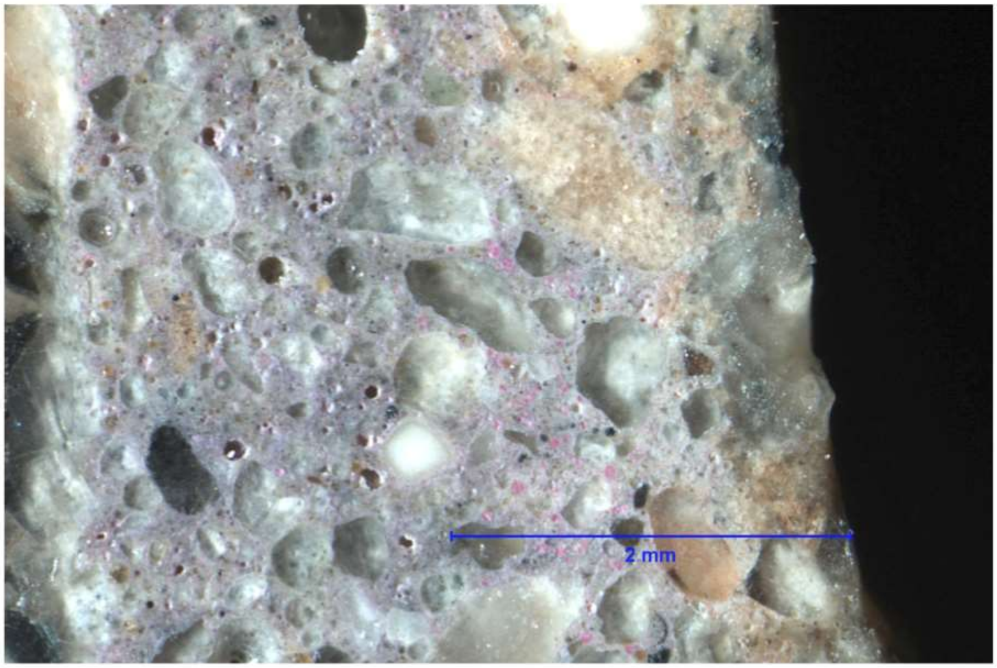


SAMPLE ID: 6019-22, 9 **DESCRIPTION:** Ettringite lined or filled entrained air voidspaces are concentrated at the base of the sawcut control joint.
MAG:100x

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

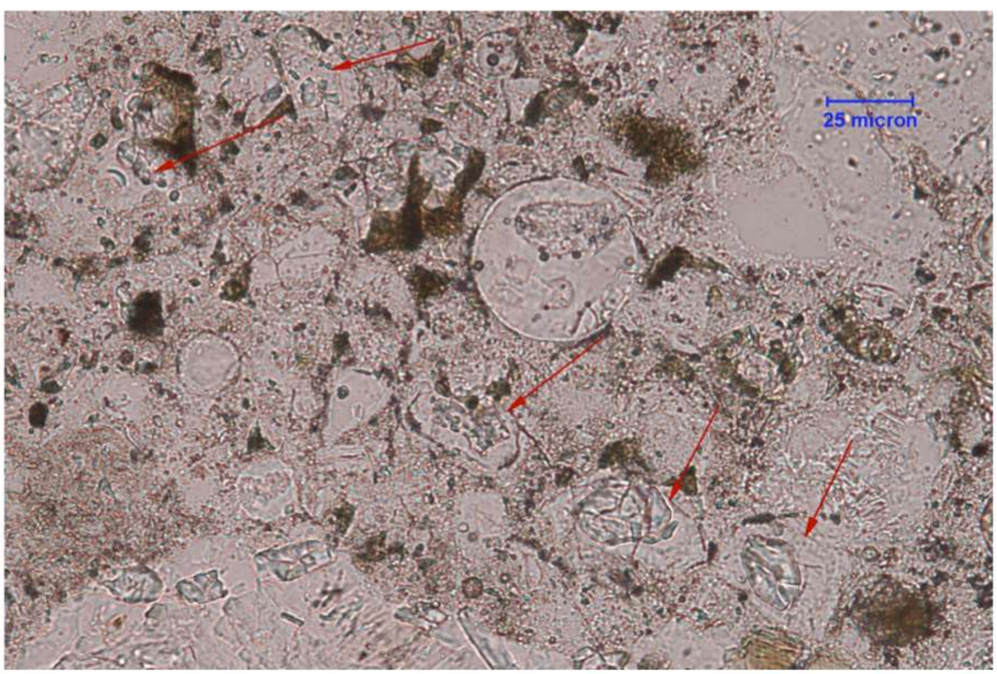
PROJECT: W/CM Study
Phase 1

PHOTO:
142



SAMPLE ID: 6019-22, 9 **DESCRIPTION:** Fine entrained-sized air void spaces directly adjacent to the joint crack plane are mostly filled with secondary ettringite; stained purple.
MAG: 5x

PHOTO:
143



SAMPLE ID: 6019-22, 9 **DESCRIPTION:** Well hydrated alite portland cement clinker particles in thin section of concrete paste under plane polarized light. Note spherical flyash pozzolan particles.
MAG: 400x

00 LAB 001 Petrographic Examination of Hardened Concrete
ASTM: C-856

Project No.	28-00337	Date:	December 30, 2012
Sample ID:	12, SP6019-22	Performed by:	G. Moulzolf

I. General Observations

1. Sample Dimensions: The core was taken directly through a sealed pavement joint. Our analysis was performed on both lapped sides of a cross section (two pieces) of core, sawcut "normal" to a distressed joint, measuring 239mm (9 $^3/_8$") x 96mm (3 ¾") x 36mm (1 $^3/_8$") thick, a 239mm (9 $^3/_8$") x 96mm (3 ¾") x 25mm (1") thick section (in two pieces), and three approx. 76mm (3") x 52mm (2") wide thin sections that were sawcut and prepared from the original 96mm (3 ¾") diameter x 273mm (10 ¾") long core. The thin sections were located between 0mm and 80mm depth, and 80mm to 155mm depth in the core (from the top surface); along the sawcut and "crack" portions of the joint.

2. Surface Conditions:
   Top: Rough screeded surface; now traffic worn very smooth.
   Bottom: Rough, irregular, fractured surface.

3. Reinforcement: None observed.

4. General Physical Conditions: The core was taken through a silicon-sealed pavement joint. The joint was characterized by a 3mm vertical sawcut proceeding to 66mm (2 $^5/_8$") depth from the top surface and a 9mm wide reservoir cut to 30mm depth. The joint was sealed with a foam backer rod and approx. 10mm of light gray silicon. The silicon was detached from one side of the joint; leaving thin remnants of silicon adhered to the concrete. A sub-vertical crack proceeds the length of the core from the bottom of the sawcut, proceeding through the paste-only. An apparent loss of paste and fine aggregate occurs up to 8mm wide along the crack below approx. 80mm depth in the joint. Sub-vertical microcracking was observed up to 6mm depth from the distressed crack plane in the adjacent concrete paste generally below 100mm depth. The concrete is sub-horizontally fractured and micro-cracked numerous times below 68mm depth in the core. Aged, stained macrocracks were obvious at approx. 170mm, 190mm, and 210mm depths. A fresh crack, most likely produced during the coring procedure, was located at approx. 75mm depth – on one side of the core. Further sub-horizontal microcracking was observed below 85mm depth

   The originally rough screeded top surface of the core exhibits moderate traffic wear; producing a smooth surface. The concrete was fairly consolidated, with several entrapped voidspaces observed in excess of 12mm in diameter scattered throughout the core. The concrete was purposefully air entrained and contained a well-distributed air void system considered freeze-thaw resistant under severe exposure conditions. The air void parameters include a 5.4% entrained-sized void volume and a 0.005" spacing factor. Acicular grown secondary ettringite fills or partly fills some of the finest entrained sized air voids scattered in the paste, generally starting below 52mm depth in the concrete. Secondary ettringite void fillings become more concentrated in the concrete paste within a few mm of the distressed joint plane; starting below approx. 60mm depth in the joint.

II. Aggregate

1. Coarse: 37mm (1 ½") nominal sized natural glacial gravel composed of granites, gneisses, schists, dolostone, and basalts. The coarse aggregate appeared well graded and exhibited good overall distribution.

2. Fine: Natural quartz, feldspar, and lithic sand. The grains were mostly sub-rounded with many smaller sub-angular particles. The fine aggregate appeared fairly graded and exhibited good overall uniform distribution.

III. Cementitious Properties

1. Air Content: 8.7% total.
2. Depth of carbonation: Ranges from negligible up to 5mm depth from the top surface of the core; along sub-vertical drying shrinkage microcracks. Carbonation ranges from negligible up to 2mm depth from the sawcut and cracked joint.
3. Pozzolan presence: Flyash was observed.
4. Paste/aggregate bond: Fair to good.
5. Paste color: Similar to Medium Light Gray (Munsell® N6).
6. Paste hardness: Moderately hard (Moh's 3)

7. Microcracking: A few fine, sub-vertical drying shrinkage microcracks proceed up to 5mm depth from the top surface.

8. Secondary deposits: White, generally acicular grown ettringite fills or partly fills some of the finest entrained sized air voids in the paste scattered below 52mm in the core. Also, ettringite and some portlandite fills most entrained sized voids generally within 3mm of the joint crack, below the depth of the sawcut. Calcium carbonate, after ettringite, fills some fine voids and sub-vertical microcracks within the carbonated joint crack paste (generally up to 1mm depth). White to clear ASR gel lines a couple of scattered air voidspaces adjacent to isolated alkali-silica reactive fine aggregate particles.

9. w/cm: Estimated at between 0.37 and 0.42 with approximately 8 to 10% residual portland cement clinker particles and an amount of flyash visually consistent with a 10 to 20% replacement of portland cement.

10. Cement hydration: Alites: Well.
Belites: Low.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 1

PHOTO:
63

SAMPLE ID: 6019-22, 12 **DESCRIPTION:** Overall view of the jointed core utilized for petrographic analysis. The top surface is left. Note failed silicon sealant.

PHOTO:
64

SAMPLE ID: 6019-22, 12 **DESCRIPTION:** Joint plane exhibits loss of paste and exposure of sound coarse aggregates.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 1

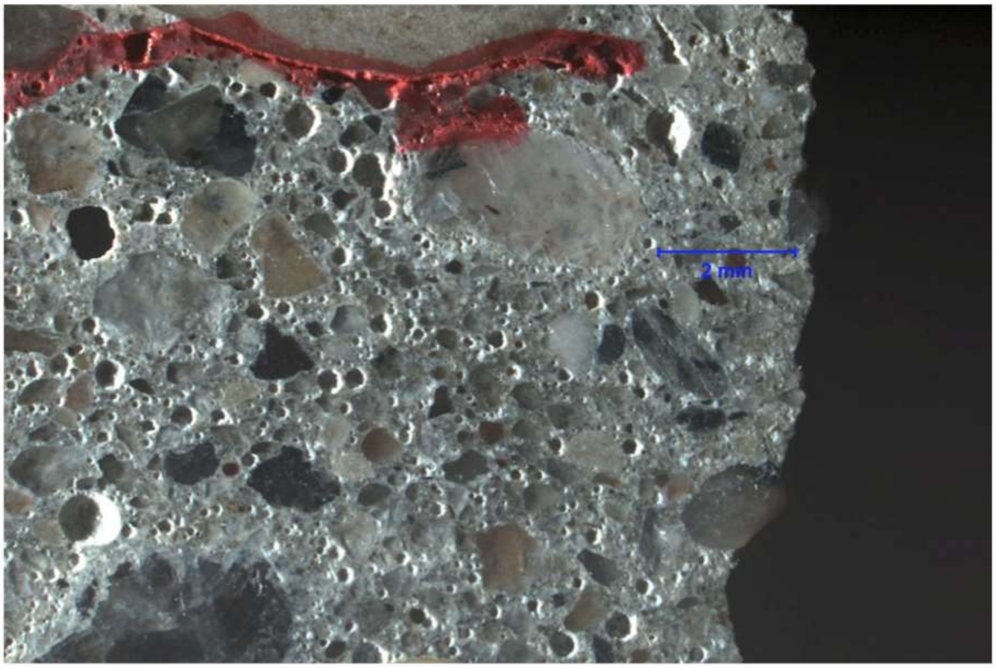
PHOTO:
93

SAMPLE ID: 6019-22, 12 **DESCRIPTION:** Sawcut and lapped cross section of core. The silicone sealant was de-bonded from one side of the joint. Sub-horizontal fractures, macrocracks, and microcracks are mapped in red ink. Some were pre-existing; Some were likely produced during coring and preparation. Concrete mass loss was to 8mm wide along the length of the joint crack.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

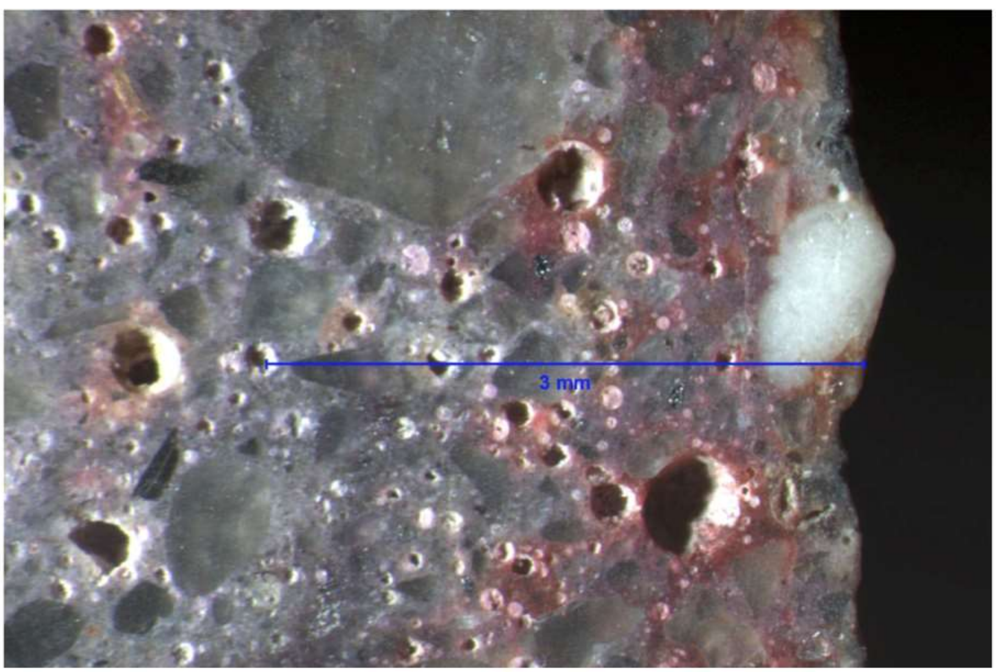
PROJECT: W/CM Study
Phase 1

PHOTO:
144



SAMPLE ID: 6019-22, 12 **DESCRIPTION:** Fine entrained-sized air void spaces directly adjacent to the joint crack plane are mostly filled with secondary ettringite; at 130mm depth from the top surface.
MAG: 10x

PHOTO:
145

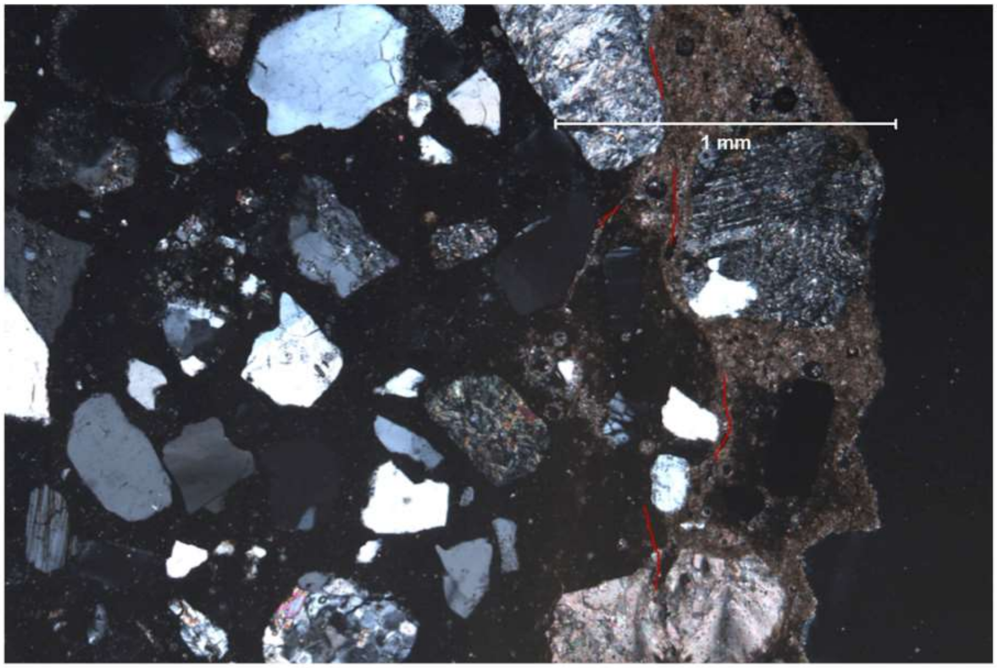


SAMPLE ID: 6019-22, 12 **DESCRIPTION:** Fine entrained-sized air void spaces directly adjacent to the joint crack plane are mostly filled with secondary ettringite; at 203mm depth from the top surface.
MAG: 30x

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

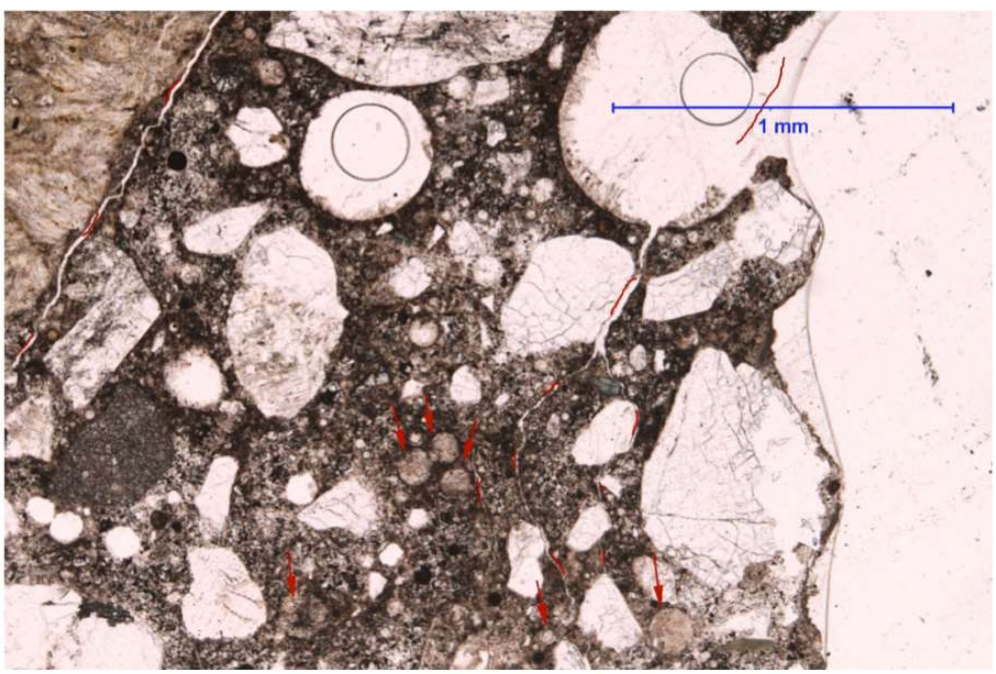
PROJECT: W/CM Study
Phase 1

PHOTO:
146



SAMPLE ID: 6019-22, 12 **DESCRIPTION:** Carbonation (lighter colored paste) proceeds to 1mm depth from the joint crack plane at 98mm depth from the top surface. Microcracking is mapped in red dashed line.
MAG: 40x

PHOTO:
147



SAMPLE ID: 6019-22, 12 **DESCRIPTION:** Fine entrained-sized air void spaces directly adjacent to the joint crack plane are mostly filled with secondary ettringite (red arrows); in thin section under plane polarized light at 145mm depth from the top surface.
MAG: 40x

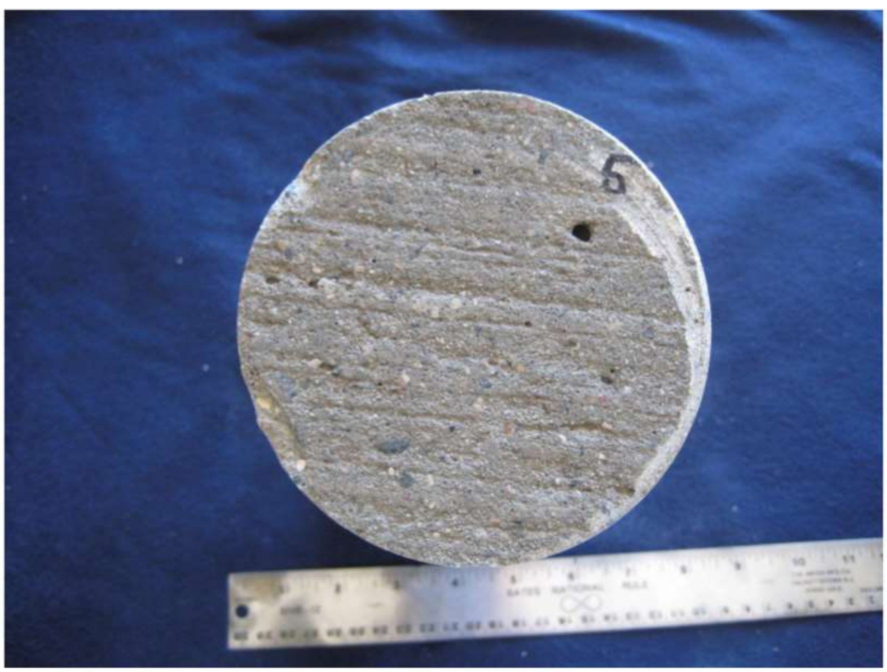
AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 1

PHOTO:
55

SAMPLE ID: 6019-22, 5 **DESCRIPTION:** Overall view of the mid-panel core utilized for rapid chloride permeability. The top surface is left.

PHOTO:
56



SAMPLE ID: 6019-22, 5 **DESCRIPTION:** Fairly rough screeded top surface of the core with minor mortar erosion.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 1

PHOTO:
57

SAMPLE ID: 6019-22, 8 **DESCRIPTION:** Overall view of the mid-panel core utilized for rapid chloride permeability. The top surface is left.

PHOTO:
58

SAMPLE ID: 6019-22, 8 **DESCRIPTION:** Fairly smooth screeded top surface of the core with traffic wear.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 1

PHOTO:
61

SAMPLE ID: 6019-22, 11 **DESCRIPTION:** Overall view of the mid-panel core utilized for rapid chloride permeability. The top surface is left.

PHOTO:
62

SAMPLE ID: 6019-22, 11 **DESCRIPTION:** Rough screeded top surface of the core; with some spalling apparently created during sampling.

Field Notes and Petrographic Reports for Project 7380-199, Cores 7009, 7012

Table A.5. Field notes for SP Number 7380-199, I-94.

Core	Location from Joint	RP	Station	Direction	Lane	Offset	Thickness
7009	ON	116.000		EB	DR	6.0'	9.750"
7010	1'E	116.000		EB	DR	6.0'	9.750"
7011	5'E	116.000		EB	DR	6.0'	9.750"
7012	ON	120.000		EB	DR	6.0'	10.000"
7013	1'E	120.000		EB	DR	6.0'	10.000"
7014	5'E	120.000		EB	DR	6.0'	10.000"
7016	1'E	124.000		EB	DR	6.0'	9.000"
7017	5'E	124.000		EB	DR	6.0'	9.250"

00 LAB 001 Petrographic Examination of Hardened Concrete
ASTM: C-856

Project No.	28-00337	Date:	February 29, 2012
Sample ID:	7009, SP7380-199	Performed by:	G. Moulzolf

I. General Observations

1. Sample Dimensions: The core was taken directly through a sealed, sawcut and cracked pavement joint. Our analysis was performed on both lapped sides of a cross section (two pieces) of core sawcut "normal" to a sawcut and cracked joint measuring 247mm (9 ¾") x 95mm (3 ¾") x 33mm (1 ¼") thick, a 247mm (9 ¾") x 86mm (3 ³/₈") x up to 26mm (1") thick section (in two pieces), and two 76mm (3") x 52mm (2") wide thin sections that were sawcut and prepared from the original 95mm (3 ¾") diameter x 247mm (9 ¾") long core. The thin sections were located between 80mm and 155mm depth and 157mm and 235mm depth in from the top surface of the core; in cross section and along the sawcut and cracked and distressed portions of the joint.

2. Surface Conditions:
   Top: Rough screeded and tined surface with minor mortar erosion exposing fine aggregate surfaces.
   Bottom: Rough, irregular, formed surface of unknown composition.

3. Reinforcement: None observed.

4. General Physical Conditions: The core was taken through a sealed pavement joint. The light gray silicone joint sealant was completely de-bonded from one side of the sawcut joint. The joint was characterized by a partially intact approx. 3-4mm wide sawcut proceeding 77mm (3") depth from the top surface and an approx. 10mm wide reservoir cut to 28mm (1 ¹/₈") depth; with the resulting joint crack proceeding the depth of the core. A foam backer rod was present. A loss of concrete paste in a "vertical oval shape" and up to 22mm in width "centers" around the lower approx. 40mm of the pilot sawcut. A loss of paste occurs from between the base of the reservoir cut and up to approx. 90mm depth along the joint. Below this point, the crack is relatively tight and intimate and proceeds through several coarse aggregate, as opposed to around them. The distressed joint plane is characterized by several relatively "clean" and un-distressed or sawcut granitic gneiss coarse aggregates protruding from the distressed concrete paste. Some, fine, concentrated sub-vertical microcracking (incipient scaling/spalling), proceeding through the paste-only, were observed proximate to the distressed zone. Incipient sub-vertical spalling (micro and macrocracking), proceeding through the paste only, occurs on both sides of the joint and within 20mm of the joint plane; between 120mm depth and the bottom surface of the core.

   The coarse granitic gneiss aggregate was hard, sound, and durable. No evidence of ASR associated with the coarse aggregate was observed.

   The rough screeded and tined top surface of the core exhibits moderate mortar erosion/traffic wear; exposing many fine aggregate surfaces. The concrete was fairly well consolidated, with only a few entrapped voidspace observed up to 12mm in diameter in the mid-section of the core. The concrete was purposefully air entrained and originally contained a well-distributed air void system considered freeze-thaw resistant under severe exposure conditions. Original air void parameters include a 4.9% entrained-sized void volume and a 0.006" spacing factor. Secondary ettringite, with some portlandite, fills most of the smaller entrained sized voidspaces within approx. 10mm of the joint plane/crack surface. Void fillings decrease with depth from this zone. Actual measured air void parameters, which excludes the ettringite void fillings, in a band between approx. 0mm and at most 25mm (0-1.0") depth from the joint surface (starting below 35mm depth in the core), are a 3.4% actual, unfilled entrained volume and a 0.010" spacing factor. At between approx. 25mm and 37mm depth from the joint, the air void parameters improve to a 4.4% entrained volume and a 0.008" spacing factor.

II. Aggregate

1. Coarse: 38mm (1 ½") nominal sized crushed granitic gneiss. The coarse aggregate appeared well graded and exhibited good overall distribution.

2. Fine: Natural quartz, feldspar, and lithic sand. The grains were mostly sub-rounded with many smaller sub-angular particles. The fine aggregate appeared fairly graded and exhibited good overall uniform distribution.

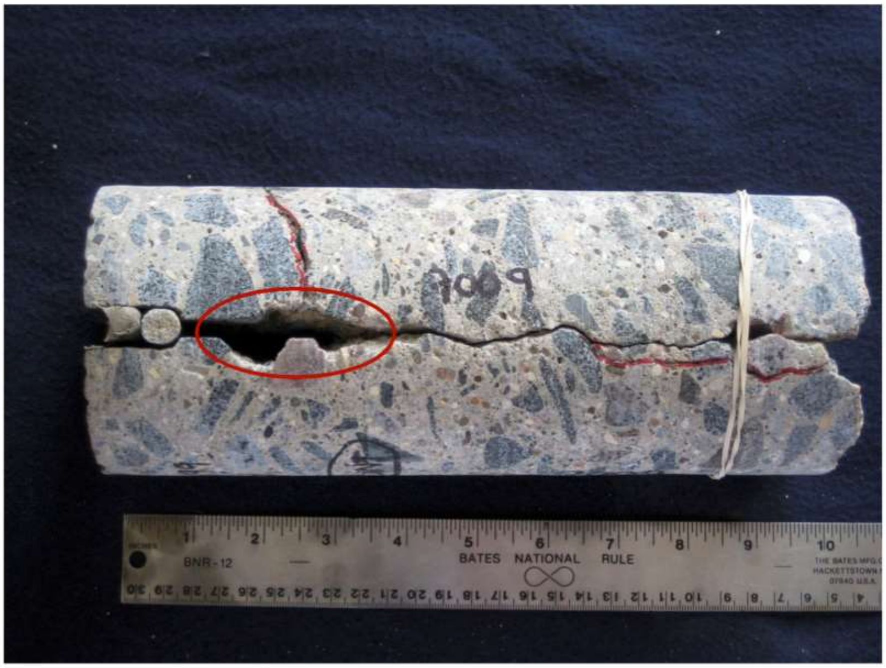
III. Cementitious Properties

1. Air Content: 4.9% original entrained air content. 3.9% "actual" un-filled entrained air between 0mm and at most 25mm depth from the distressed joint (below 35mm depth from the top surface). 4.4% "actual" unfilled air void content between approx. 25mm and 37mm depth from the distressed joint.
2. Depth of carbonation: Ranged from negligible up to 5mm depth from the top surface of the core; along fine sub-vertical drying shrinkage microcracking and consolidation voidspaces. Ranged from negligible up to 3mm depth from the sawcut joint surface and from negligible up to approx. 6mm depth from the distressed joint surface. Negligible below 175mm depth in the joint.
3. Pozzolan presence: Flyash was observed.
4. Paste/aggregate bond: Fair.
5. Paste color: Similar to Medium Gray (Munsell® N5).
6. Paste hardness: Moderately-hard (>Moh's 3)
7. Microcracking: Sub-vertical macro/microcracks (incipient spalling) were observed (in the paste-only) oriented sub-parallel to the joint (cracked) surface and within 20mm of the joint; below 120mm depth from the top surface of the core. Numerous other microcracks were observed sub-parallel and proximate (within a few mm) of the distressed region of the joint between approx. 35mm and 90mm depth from the top surface.
8. Secondary deposits: White ettringite, along with some scattered occurrences of clear platelets of portlandite, fills most of the entrained sized air voids between the sawcut and distressed joint surface (and generally below 30mm depth from the top surface along the sawcut) and approx. 10mm depth into the core. Void fillings become less abundant with distance from this zone.
9. w/cm: Estimated at between 0.35 and 0.40 with approximately 8 to 10% residual portland cement clinker particles and an amount of flyash visually consistent with a 15 to 25% replacement of portland cement.
10. Cement hydration: Alites: Well.
    Belites: Moderate.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 1

PHOTO:
75



SAMPLE ID: 7380-199, 7009 **DESCRIPTION:** Overall view of the jointed core utilized for petrographic analysis. Note developing tunneling at the base of the sawcut. The top surface of the core is left.

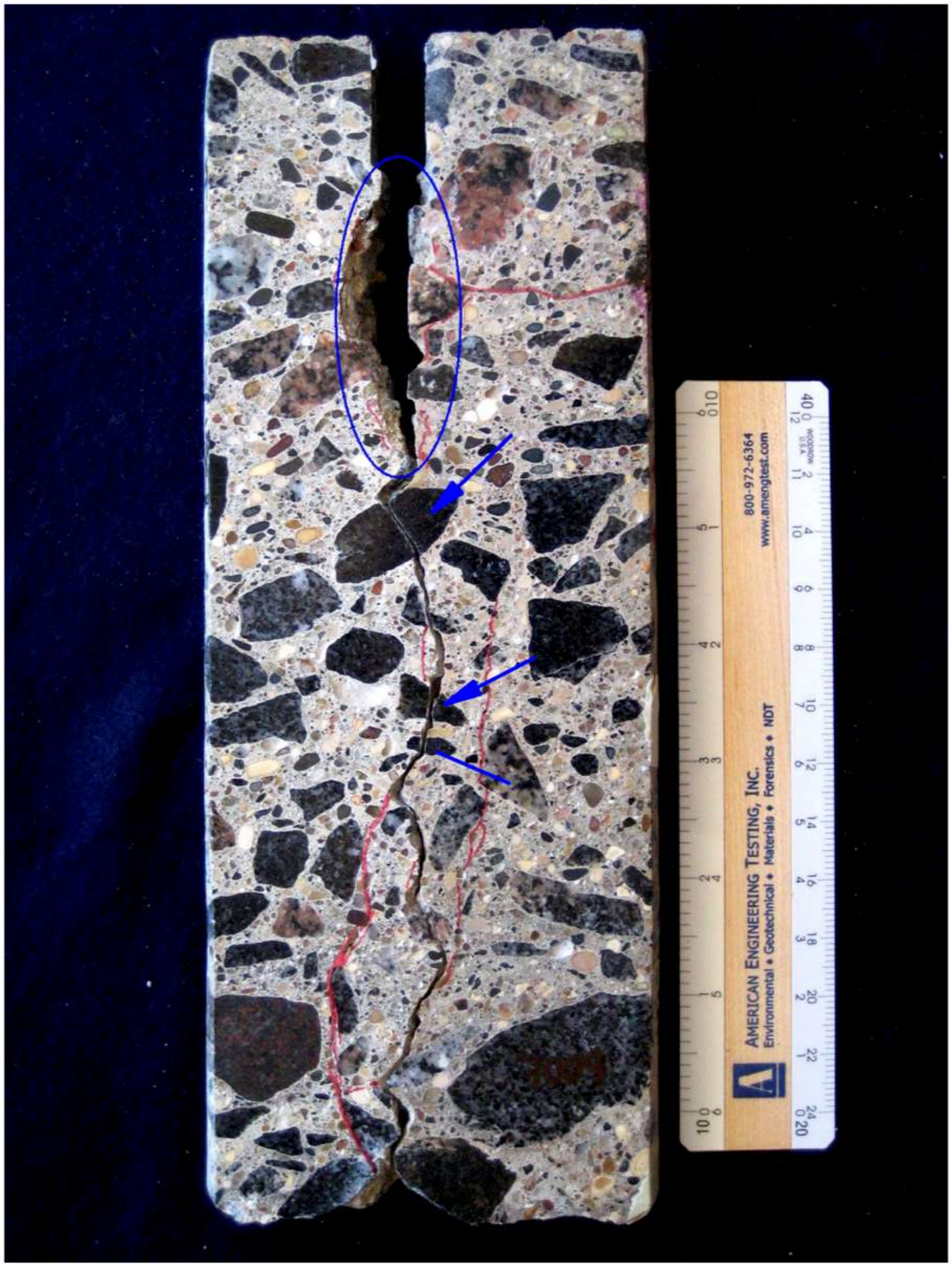
PHOTO:
76

SAMPLE ID: 7380-199, 7009 **DESCRIPTION:** Top surface of the core exhibiting a compromised sealant.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 1

PHOTO:
96

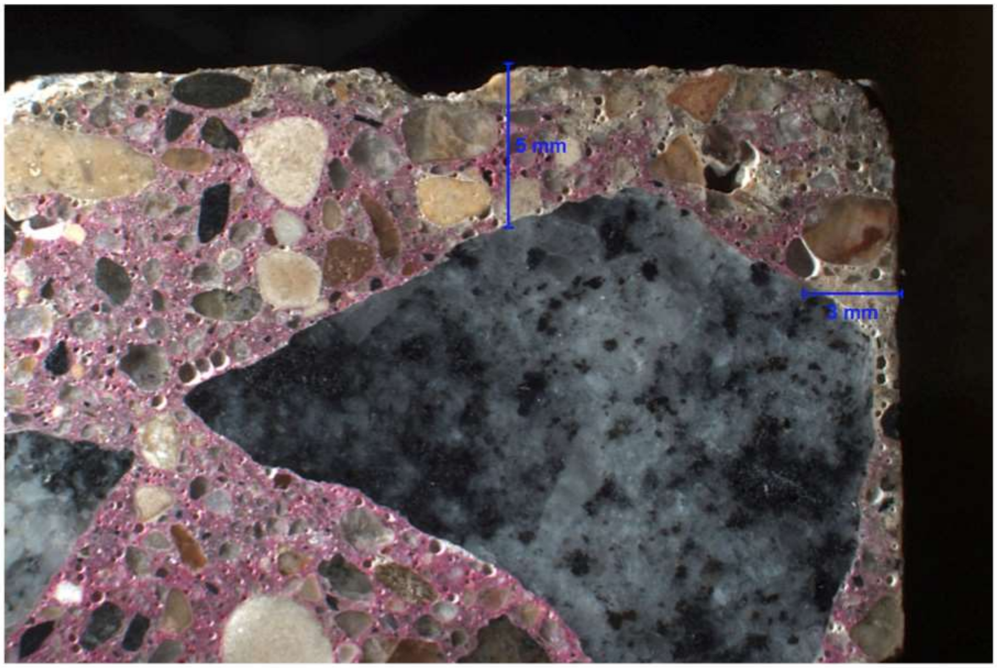


SAMPLE ID: 7380-199, 7009 **DESCRIPTION:** Sawcut and lapped cross section of core. The silicone sealant was completely de-bonded from one side of the joint. Sub-vertical microcracks adjacent to the joint crack are mapped in red ink. Note bisected coarse aggregates (arrows) suggesting late crack activation. Mass loss (tunneling) occurs directly below the sawcut (circled).

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

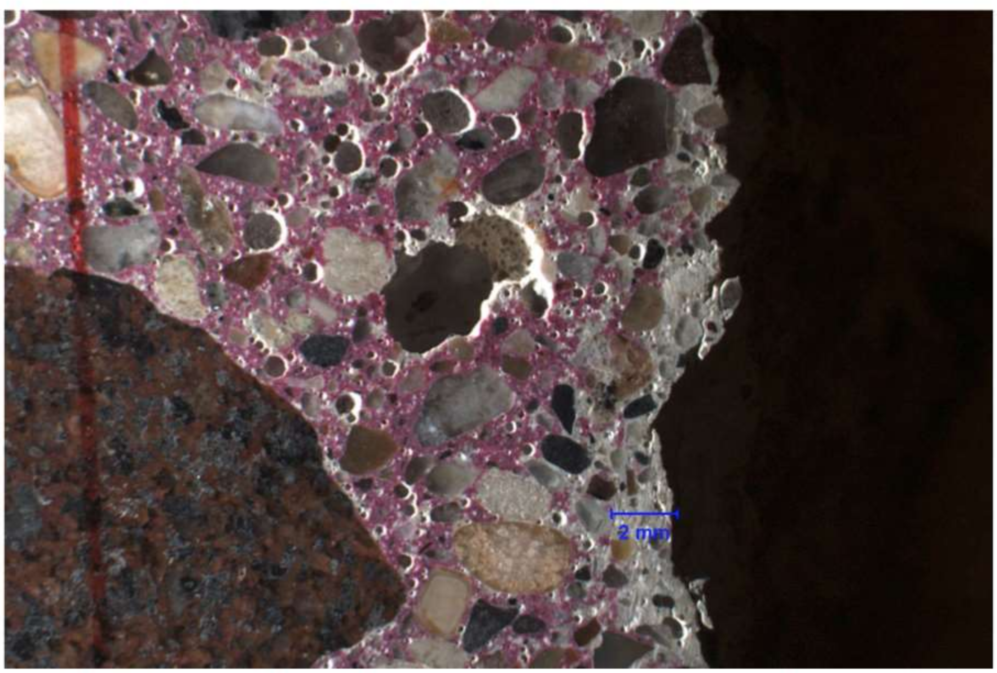
PROJECT: W/CM Study
Phase 1

PHOTO:
154



SAMPLE ID: 7380-199, 7009 **DESCRIPTION:** Carbonation (unstained) proceeds up to 5mm depth from the top surface and up to 3mm depth from the sawcut joint surface; in this view of sawcut and lapped cross section of core **ex**posed to phenolphthalien pH indicator.
MAG: 5x

PHOTO:
155

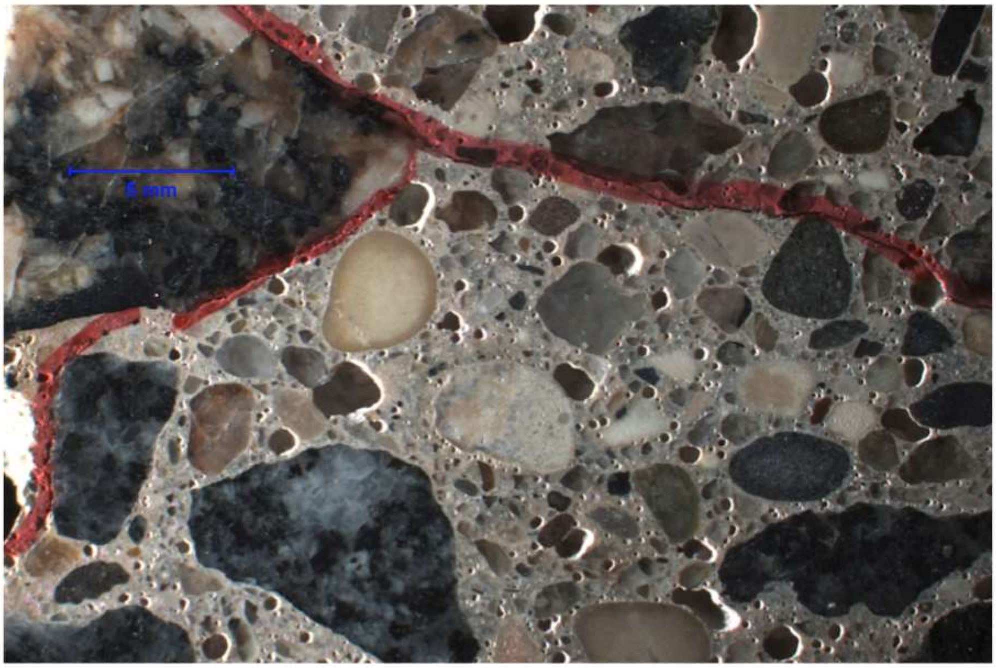


SAMPLE ID: 7380-199, 7009 **DESCRIPTION:** Carbonation (unstained paste) proceeds up to 2mm depth from the distressed joint plane at 100mm depth in the core.
MAG: 5x

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

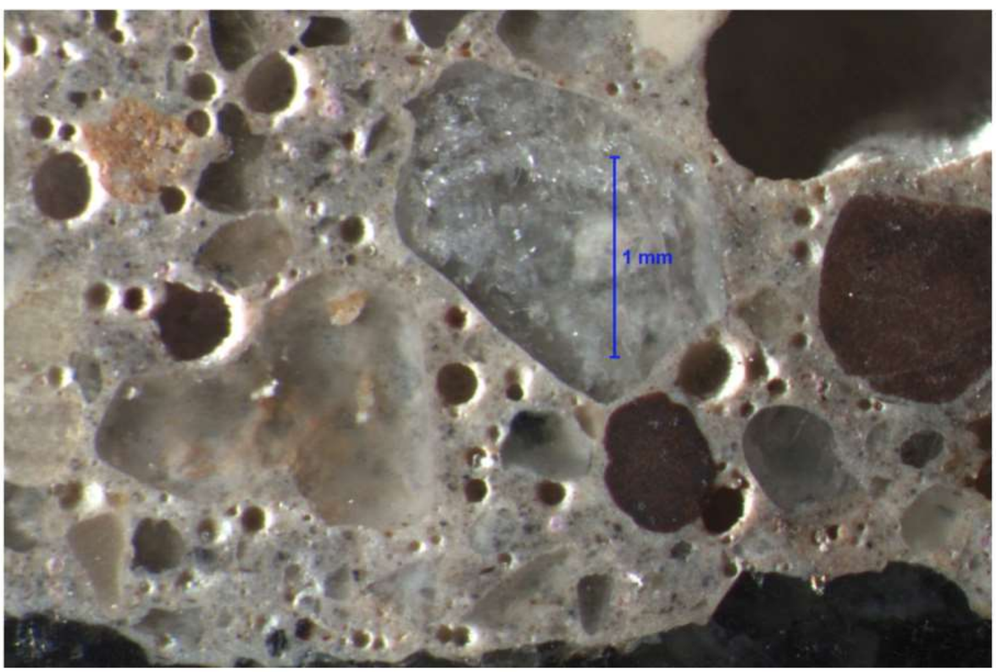
PROJECT: W/CM Study
Phase 1

PHOTO:
156



SAMPLE ID: 7380-199, 7009 **DESCRIPTION:** Overall view of air void system at 60mm depth in the core. Not loss of fine air void spaces on left 1/3 of image from secondary ettringite fillings.
MAG: 5x

PHOTO:
157

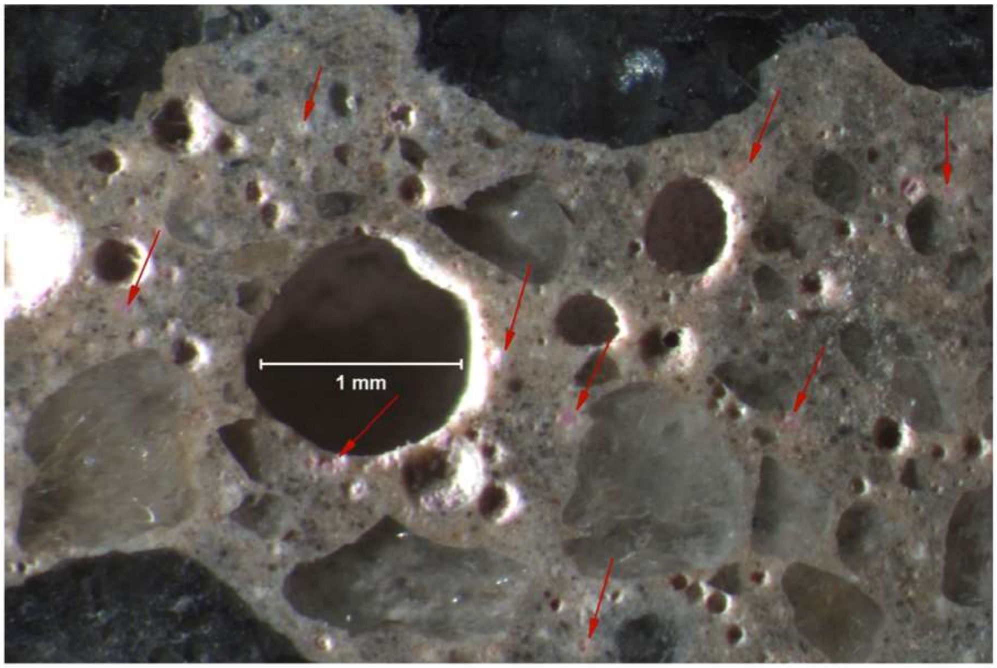


SAMPLE ID: 7380-199, 7009 **DESCRIPTION:** Air void system at 70mm depth in the core and 45mm depth from the distressed joint plane.
MAG: 30x

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

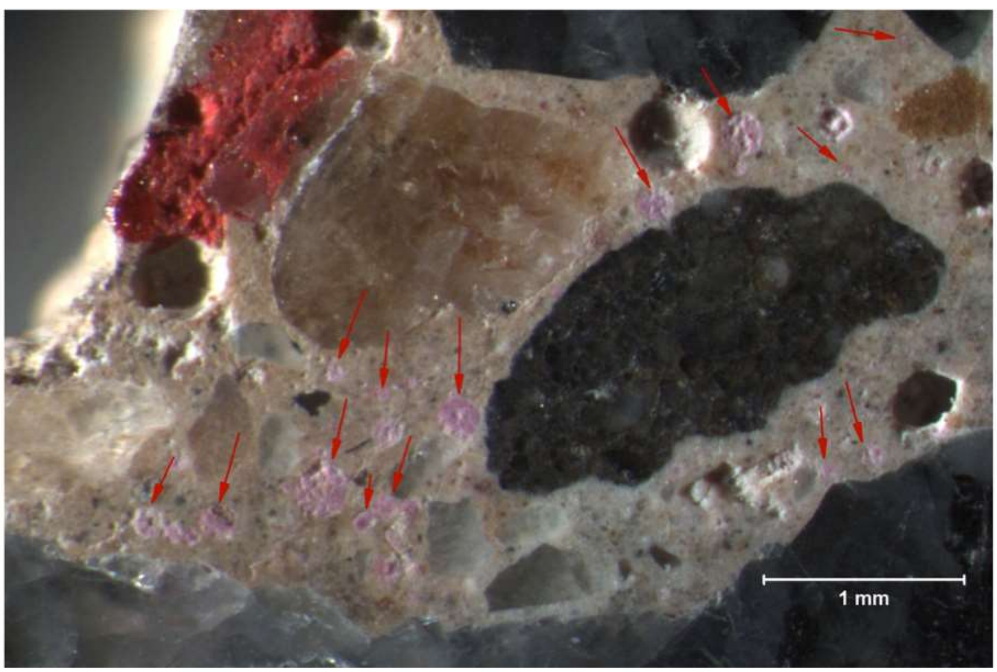
PROJECT: W/CM Study
Phase 1

PHOTO:
158



SAMPLE ID: 7380-199, 7009 **DESCRIPTION:** Overall view of air void system at 70mm depth in the core and 25mm from the distressed joint plane. Note (stained) ettringite-filled air voidspaces (arrows).
MAG: 15x

PHOTO:
159

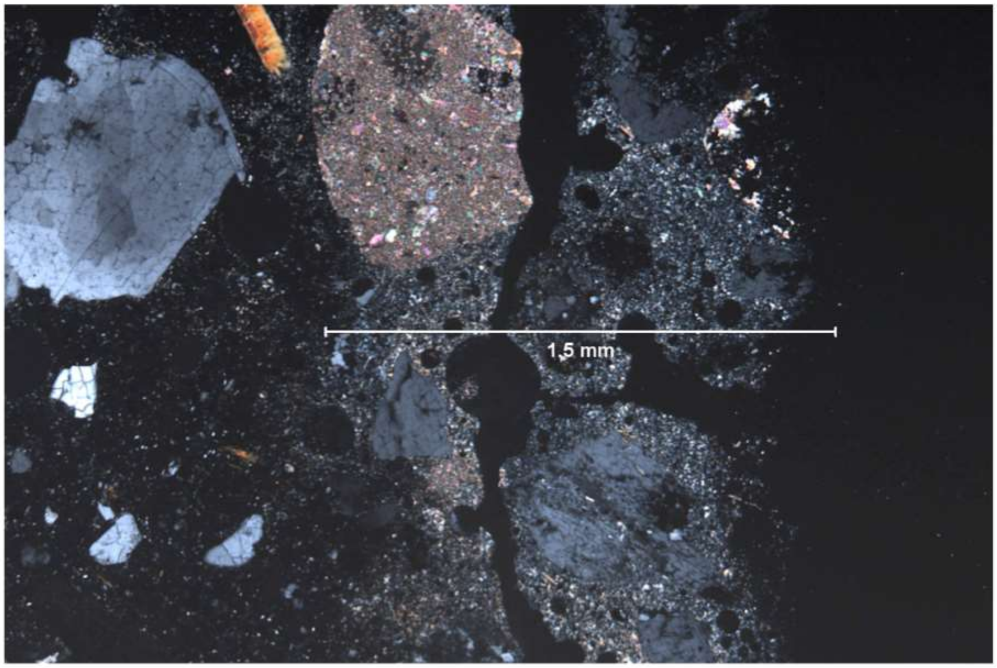


SAMPLE ID: 7380-199, 7009 **DESCRIPTION:** Air void system at 70mm depth in the core and at the distressed joint plane (L). Note stained ettringite-filled voidspaces marked with arrows.
MAG: 30x

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

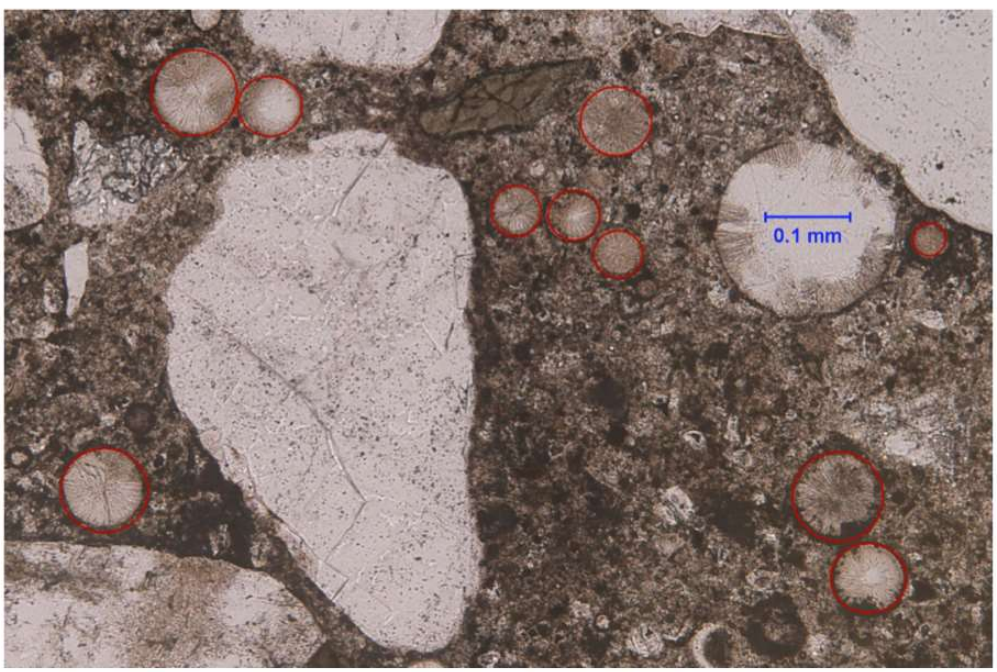
PROJECT: W/CM Study
Phase 1

PHOTO:
160



SAMPLE ID: 7380-199, 7009 **DESCRIPTION:** Overall view of brightly colored carbonated paste to 1.5mm depth from the distressed joint plane; in thin section of concrete under cross polarized light.
MAG: 40x

PHOTO:
161



SAMPLE ID: 7380-199, 7009 **DESCRIPTION:** Ettringite-filled voidspaces, outlined in red, in thin section of concrete paste adjacent to the distressed joint plane, under plane polarized light.
MAG: 100x

00 LAB 001 Petrographic Examination of Hardened Concrete
ASTM: C-856

Project No.	28-00337	Date:	February 29, 2012
Sample ID:	7012, SP7380-199	Performed by:	G. Moulzolf

I. General Observations

1. Sample Dimensions: The core was taken directly through a sealed, sawcut and cracked pavement joint. Our analysis was performed on both lapped sides of a cross section (two pieces) of core sawcut "normal" to a sawcut and cracked joint measuring 255mm (10") x 95mm (3 ¾") x 3mm (1 ¼") thick, a 255mm (10") x 86mm (3 3/8") x up to 28mm (1 1/8") thick section (in two pieces), and three 76mm (3") x 52mm (2") wide thin sections that were sawcut and prepared from the original 95mm (3 ¾") diameter x 255mm (10") long core. The thin sections were located between 5mm and 85mm depth, 100mm depth and 175mm, and 180mm and 250mm depth in from the top surface of the core; in cross section and along the sawcut and cracked and distressed portions of the joint.

2. Surface Conditions:
   Top: Rough screeded and tined surface with minor mortar erosion exposing fine aggregate surfaces.
   Bottom: Rough, irregular, formed surface, placed upon apparent asphalt-stabilized base.

3. Reinforcement: None observed.

4. General Physical Conditions: The core was taken through a sealed pavement joint. The light gray silicone joint sealant was well bonded to both sides of the sawcut joint and was forcibly torn during handling of the core. The joint was characterized by an approx. 3mm wide sawcut proceeding 82mm (3 ¼") depth from the top surface and an approx. 10mm wide reservoir cut to 32mm (1 ¼") depth; with the resulting joint crack proceeding the depth of the core. A foam backer rod was present. The crack is relatively tight and intimate and proceeds through several coarse aggregate, as opposed to around them. The coarse granitic gneiss aggregate was hard, sound, and durable. No evidence of ASR associated with the coarse aggregate was observed.

   The rough screeded and tined top surface of the core exhibits moderate mortar erosion/traffic wear; exposing many fine aggregate surfaces. The concrete was fairly well consolidated, but contains at least 2 entrapped voidspaces observed to 12mm in diameter in the mid-section of the core. The concrete was purposefully air entrained and contained a well-distributed air void system considered freeze-thaw resistant under severe exposure conditions. The original air void parameters include a 9.2% entrained-sized void volume and a 0.004" spacing factor. In general, secondary ettringite fills some of the smaller entrained sized voidspaces within approx. 3 of the joint plane/crack surface; with a concentration of void fillings in the surrounding paste at the base of the sawcut.

II. Aggregate

1. Coarse: 36mm (1 ½") nominal sized crushed granitic gneiss. The coarse aggregate appeared well graded and exhibited good overall distribution.

2. Fine: Natural quartz, feldspar, and lithic sand. The grains were mostly sub-rounded with many smaller sub-angular particles. The fine aggregate appeared fairly graded and exhibited good overall uniform distribution.

III. Cementitious Properties

1. Air Content:	9.2% original entrained air content. 8.2% "actual" un-filled entrained air between 0mm and at least 25mm depth from the distressed joint (below 98mm depth from the top surface).
2. Depth of carbonation:	Ranged from negligible up to 3mm depth from the top surface of the core; along fine sub-vertical drying shrinkage microcracking and consolidation voidspaces. Ranged from negligible up to 5mm depth from the sawcut joint surface and from negligible up to approx. 3mm depth from the joint surface. Negligible below 140mm depth in the joint.
3. Pozzolan presence:	Flyash was observed.
4. Paste/aggregate bond:	Fair.
5. Paste color:	Similar to Medium Gray (Munsell® N5).
6. Paste hardness:	Moderately-hard (>Moh's 3)
7. Microcracking:	A single, fine microcrack was observed at a low angle and oriented sub-parallel to the joint crack at the base of the sawcut. A few, very fine sub-vertical drying shrinkage microcracks proceed to 2mm depth from the top surface.

8. Secondary deposits: Small, white, acicular clumps of ettringite grows on the lining of most air voids at depth in the concrete. Ettringite fills a small amount of the finest entrained sized air voids scattered throughout the depth of the core; with some concentration within a few mm of the joint crack and at the base of the pilot sawcut.
9. w/cm: Estimated at between 0.35 and 0.40 with approximately 8 to 10% residual portland cement clinker particles and an amount of flyash visually consistent with a 15 to 25% replacement of portland cement.
10. Cement hydration: Alites: Well
Belites: Moderate

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 1

PHOTO:
77

SAMPLE ID: 7380-199, 7012 **DESCRIPTION:** Overall view of the jointed core utilized for petrographic analysis. Note joint crack bisecting a coarse aggregate particle outlined in black marker. The top surface of the core is left.

PHOTO:
78

SAMPLE ID: 7380-199, 7012 **DESCRIPTION:** Top surface of the core exhibiting an intact sealant.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 1

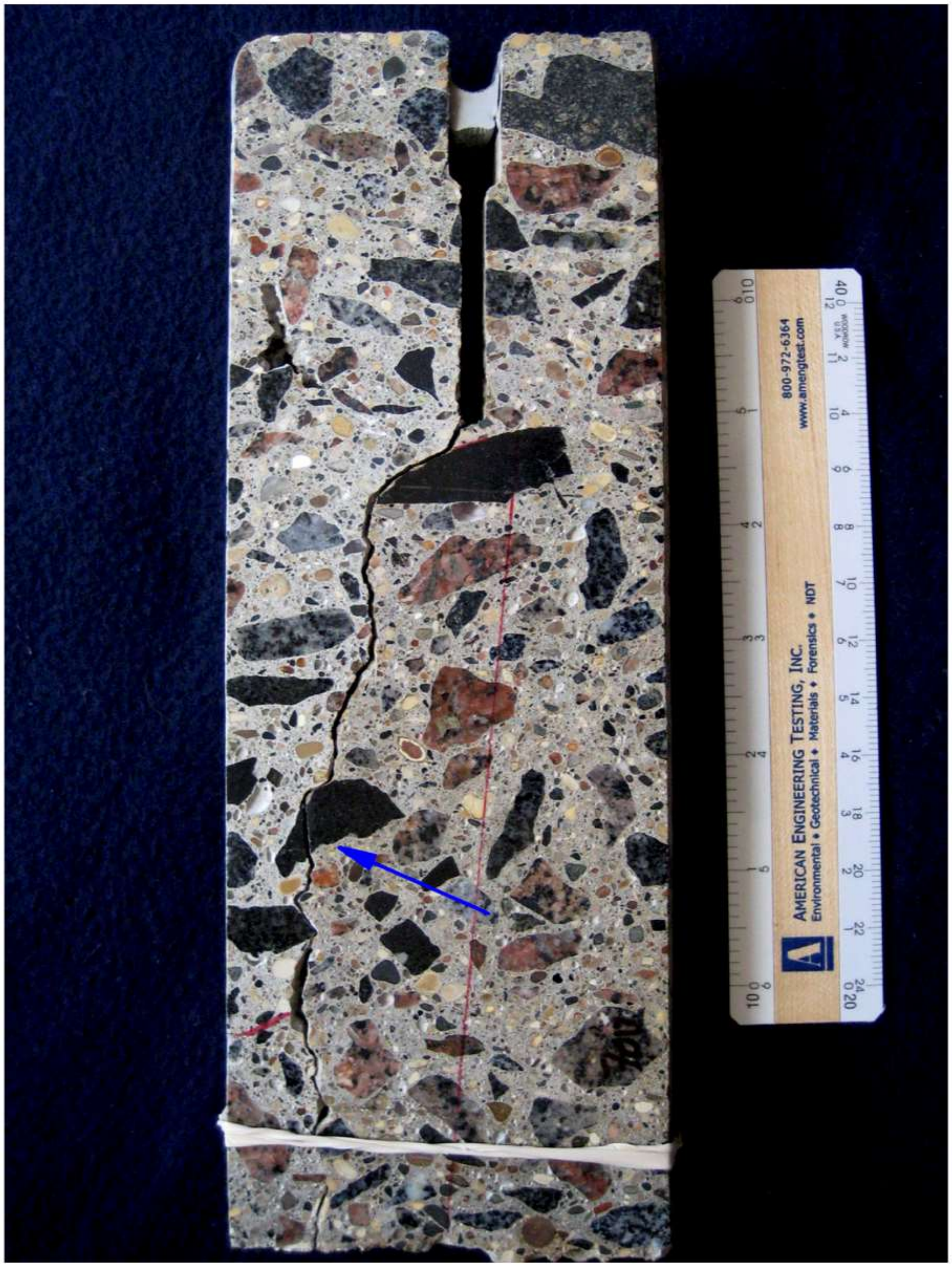


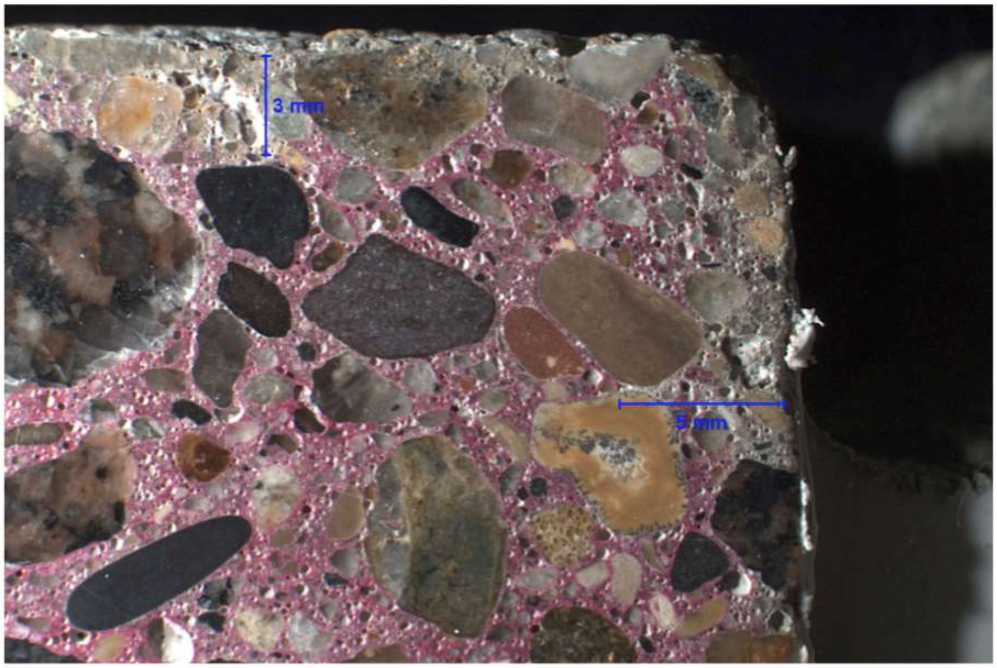
PHOTO:
97

SAMPLE ID: 7380-199, 7012 **DESCRIPTION:** Sawcut and lapped cross section of core. The silicone sealant was well bonded to both sides of the joint. Note bisected coarse aggregate (arrow) suggesting late crack activation. No mass loss was detected.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

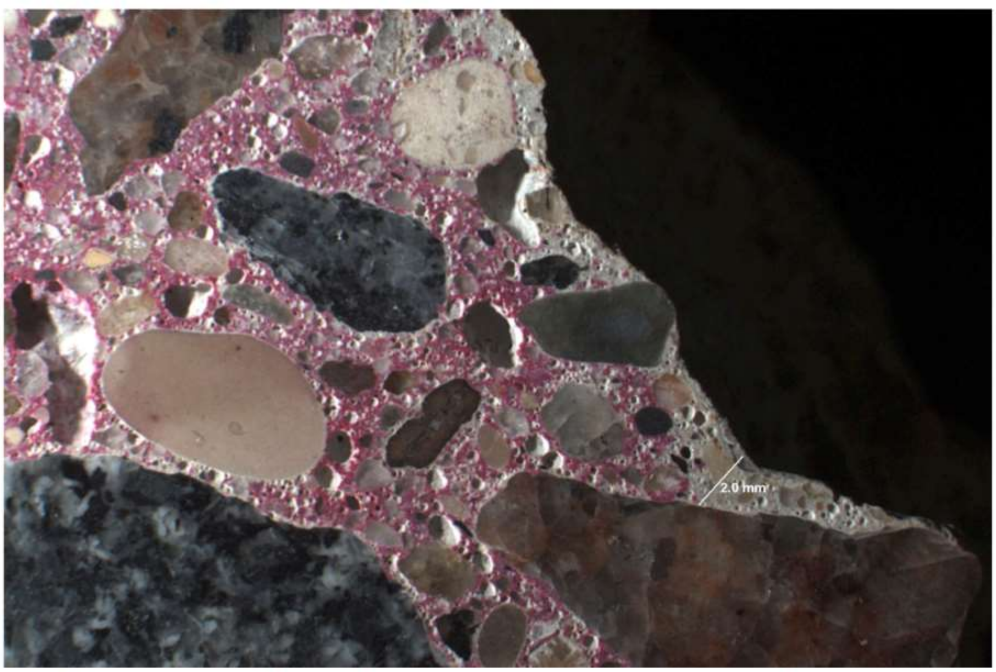
PROJECT: W/CM Study
Phase 1

PHOTO:
162



SAMPLE ID: 7012, 7380-199 **DESCRIPTION:** Carbonation (unstained) ranged from negligible up to 3mm depth from the top surface and ranged from negligible up to 5mm depth from the sawcut joint surface; in this view of sawcut and lapped cross section of core exposed to phenolphthalien pH indicator.
MAG:5x

PHOTO: 163

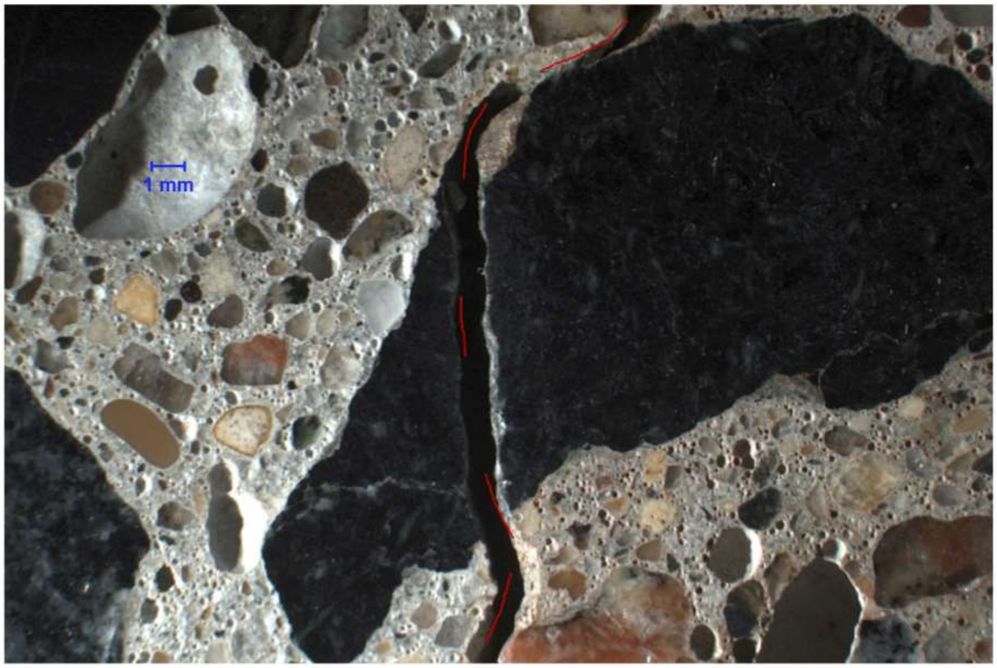


SAMPLE ID: 7012, 7380-199 **DESCRIPTION:** Carbonation (unstained paste) proceeds up to 2mm depth from the stressed joint plane at 105mm depth in the core.
MAG: 5x

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 1

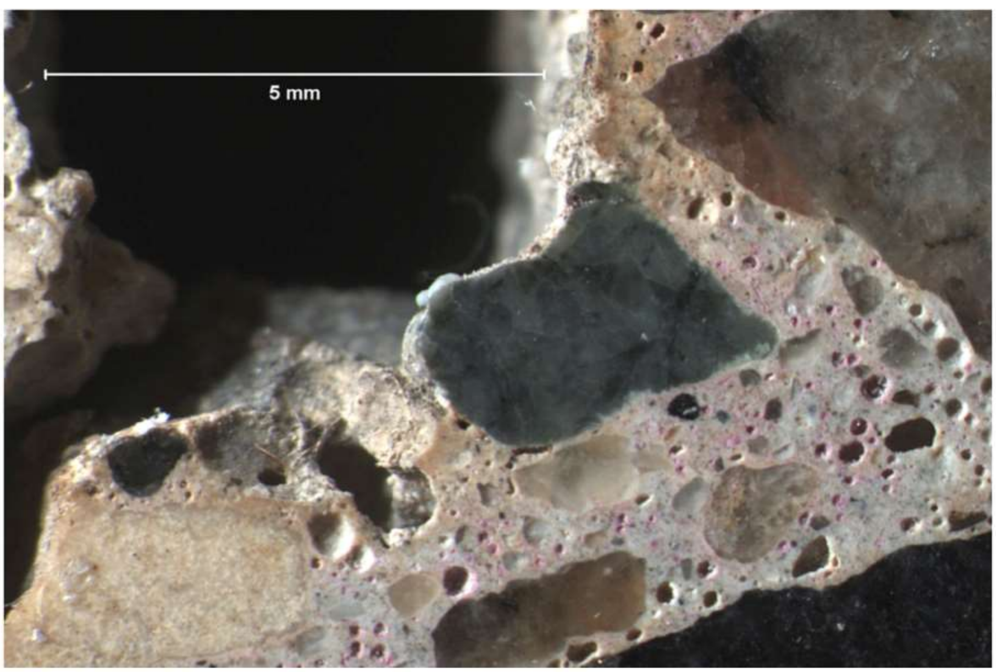
PHOTO:
164



SAMPLE ID: 7380-199, 7012 **DESCRIPTION:** Cracked coarse aggregate at 165mm depth in the joint crack.

MAG: 5x

PHOTO:
165

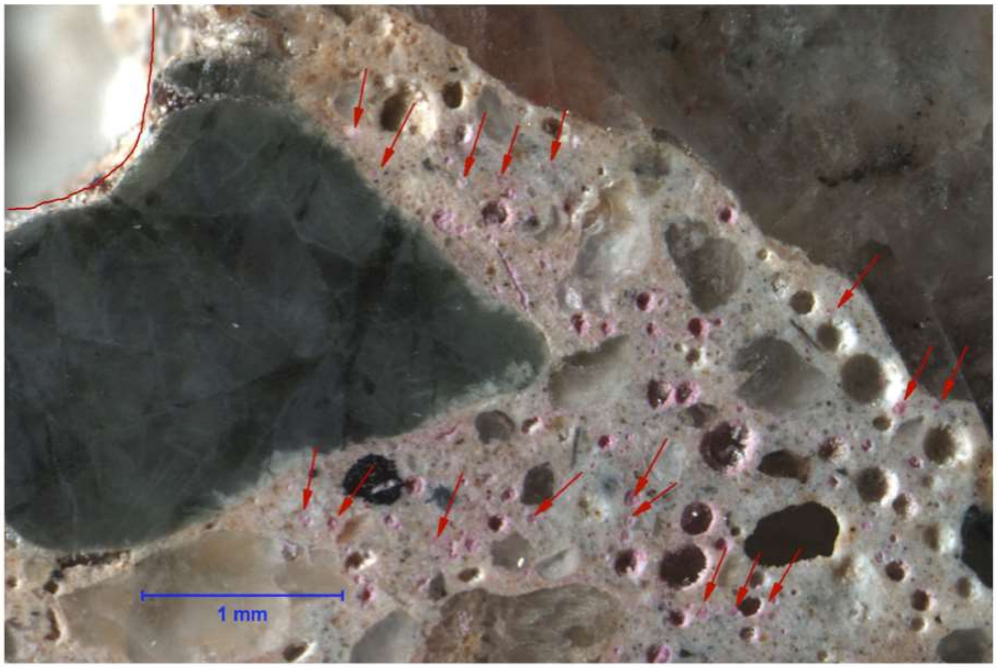


SAMPLE ID: 7380-199, 7012 **DESCRIPTION:** A concentration of magenta-stained, ettringite-filled voidspaces at the base of the sawcut control joint.
MAG: 5x

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 1

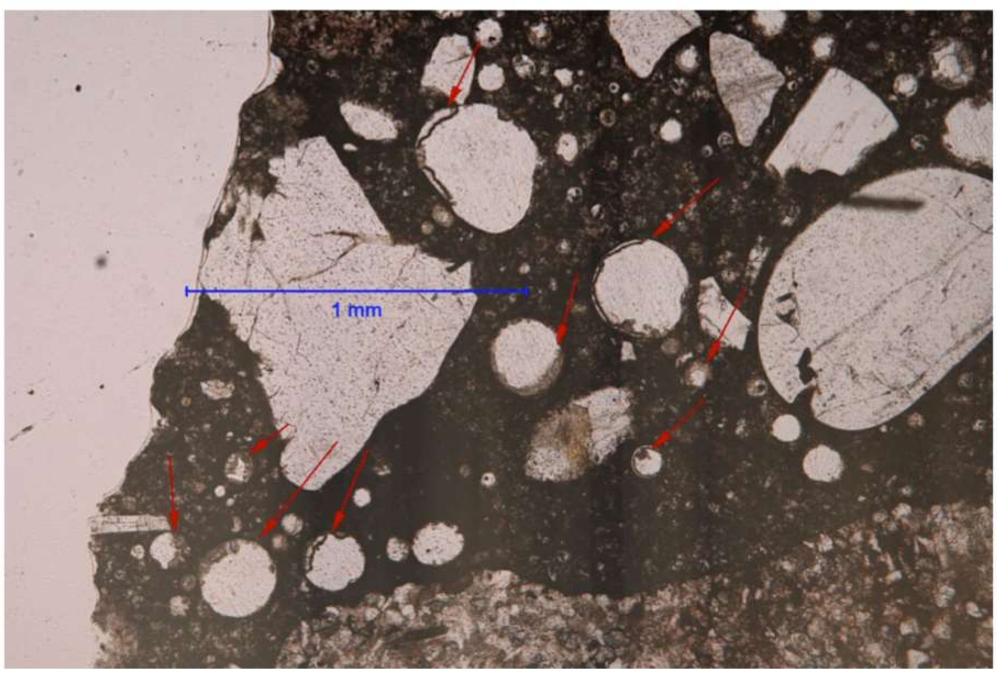
PHOTO:
166



SAMPLE ID: 7012, 7380-199 **DESCRIPTION:** Closer view of fine, ettringite-filled voids at the base of the sawcut.

MAG: 30x

PHOTO:
167

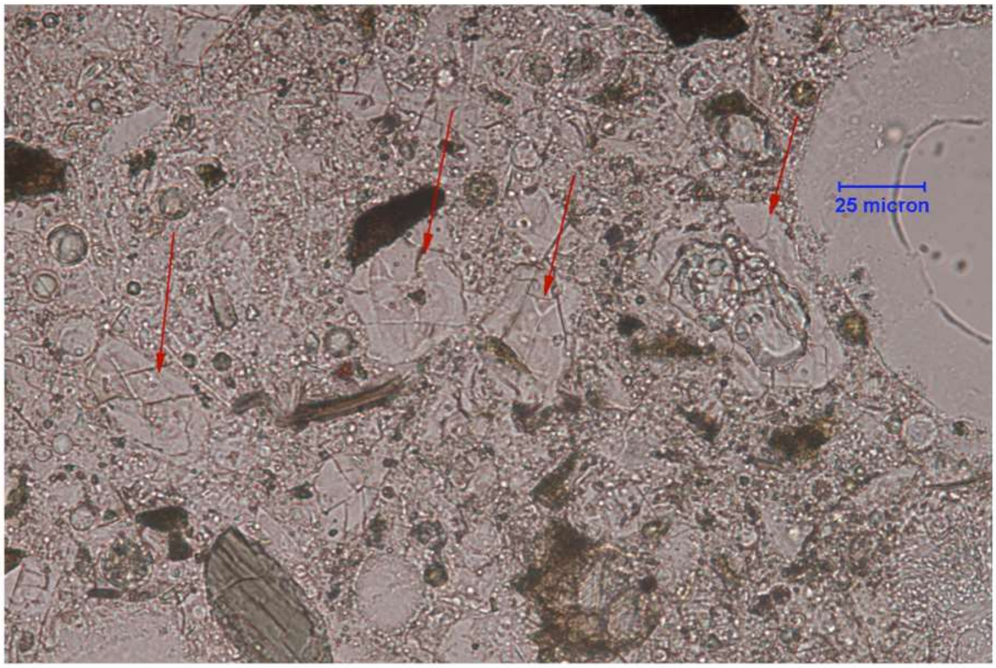


SAMPLE ID: 7012, 7380-199 **DESCRIPTION:** Occurrences of ettringite on the linings of voidspaces at 140mm depth and directly adjacent to the joint crack (L).
MAG: 40x

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

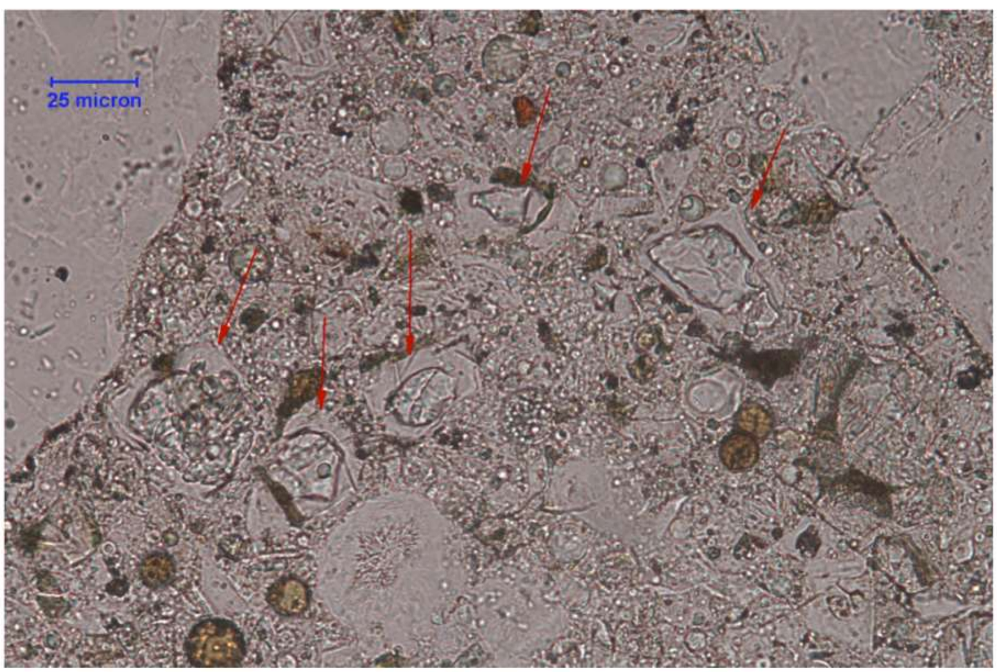
PROJECT: W/CM Study
Phase 1

PHOTO: 168



SAMPLE ID: 7380-199, 7012 **DESCRIPTION:** Well to fully hydrated alite portland cement clinker particles in thin section of concrete paste under plane polarized light. Note abundant spherical flyash pozzolan particles.
MAG: 400x

PHOTO: 169



SAMPLE ID: 7380-199, 70012 **DESCRIPTION:** Well hydrated alite portland cement clinker particles in thin section of concrete paste under plane polarized light. Note abundant spherical flyash pozzolan particles.
MAG: 400x

Field Notes and Petrographic Reports for Project 7380-200, Cores 7000, 7003, 7006, 7018

Table A.6. Field notes for SP Number 7380-200, I-94.

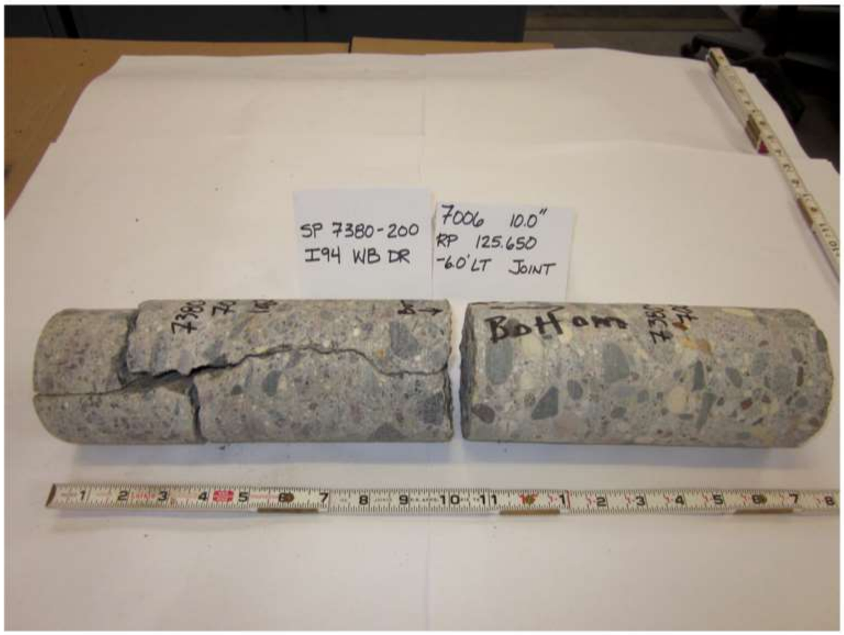
Core	Location from Joint	RP	Station	Direction	Lane	Offset	Thickness
7001	1.0'	125.493		WB	DR	-6.0'	9.500"
7002	5.0'	125.493		WB	DR	-6.0'	9.500"
7004	1'W	121.000		WB	DR	-5.1'	11.500"
7005	5'W	121.000		WB	DR	-5.1'	11.500"
7006	ON	125.650		WB	DR	-6.0'	10.000"
7007	1'W	125.649		WB	DR	-6.0'	10.000"
7008	5'W	125.645		WB	DR	-6.0'	10.000"
7018	1'W	125.553		WB	DR	-6.0'	9.750"
7020	5'W	125.549		WB	DR	-6.0'	9.750"


7380-200
7000
SP 7380-200
I94 WB DR
7000 9.5"
RP 125.493
-6.0' LT JOINT


SP 7380-200
I94 WB DR
7000 9.5"
RP 125.493
-6.0' LT JOINT


SP 7380-200
I94 WB DR
7003 11.5"
RP 121.000
-5.1' LT JOINT


SP 7380-200
I94 WB DR
7003 11.5"
RP 121.000
-5.1' LT JOINT


SP 7380-200
I94 WB DR
7006 10.0"
RP 125.650
-6.0'LT JOINT
Bottom


SP 7380-200
I94 WB DR
7006 10.0"
RP 125.650
-6.0'LT JOINT


SP 7380-200
I94 WB DR
7018 9.75"
RP 125.554
-60' LT - JOINT


SP 7380-200
I94 WB DR
7018 9.75"
RP 125.554
-60' LT - JOINT

Field Notes and Petrographic Reports for Project 1480-131, Cores 2, 3, 5

Table A.7. Field notes for SP Number 1480-131, I-94.

Core	Location from Joint	RP	Station	Direction	Lane	Offset	Thickness
1	3.0'	31.000	1936+00	WB	DR	5.0'	8.500"
2	ON	31.000	1935+97	WB	DR	6.0'	8.750"
3	ON	29.000	1830+33	WB	DR	4.5'	9.000"
4	2.7'	29.000	1830+30.4	WB	DR	5.0'	8.750"
5	ON	27.000	1725+21	WB	DR	4.5'	8.250"
6	2.3'	27.000	1725+23	WB	DR	5.0'	8.500"
7	2.7'	26.000	1672+50	WB	DR	5.0'	8.250"
8	2.2'	25.000	1619+47	WB	DR	5.0'	8.500"
9	2.7'	24.150	1567+04	WB	DR	5.0'	9.250"

00 LAB 001 Petrographic Examination of Hardened Concrete
ASTM: C-856

Project No.	28-00337	Date:	August 22, 2012
Sample ID:	1480-131, 2	Performed by:	D. Hunt, G. Moulzolf

I. General Observations

1. Sample Dimensions: Our analysis was performed on both lapped sides of a 230mm (9") x 89mm (3 1/2") x 37mm (1 1/2") thick section (in two pieces), a 230mm (9") x 82mm (3 1/4") x 25mm (1") thick section (in two pieces), and two 76mm (3") x 52mm (2") wide thin sections that were sawcut and prepared from the original 95mm (3 3/4") diameter x 230mm (9") long core taken directly through a distressed sawcut joint. The thin sections were located at between 76mm and 150mm depth and 153mm and 229mm depth in the core from the top surface; directly adjacent to the distressed joint surface.

2. Surface Conditions:
   Top: Fairly rough, textured, and mortar eroded/traffic worn surface; exposing many fine aggregate surfaces.
   Bottom: Rough, irregular, formed surface; placed on a bituminous sub-base.

3. Reinforcement: None observed.

4. General Physical Conditions: The core was taken directly through a sealed pavement joint. A silicone joint sealer was observed well attached to both sides of the sawcut joint between 1mm and 16mm depth from the top surface. The joint sealer was placed on a 12mm diameter foam backer rod. The joint was characterized by an approx. 5mm wide sawcut proceeding 65mm (2 1/2") depth from the top surface and an approx. 10mm wide reservoir cut to 31mm (1 1/4") depth; with the resulting joint crack proceeding the entire depth of the core. The joint crack proceeds around coarse aggregate particles it encounters and exhibits tight residual interlock between the two core halves. In general, no loss of concrete due to freeze-thaw action was documented. The coarse aggregate appeared sound. No evidence of ASR associated with the coarse aggregate was observed. Numerous alkali-silica "reacted" shale fine aggregate were present in the core. The "reacted" shale particles exhibit internal cracking that propagates into the paste. Alkali-silica reaction gel was observed partially lining to filling a few air voids proximate to the reactive shale particles.

   The fairly rough textured top surface of the core exhibits significant mortar erosion/traffic wear; topographic highs have been worn smooth with exposed fine and coarse aggregate particles exhibiting worn surfaces. The concrete was well consolidated, with no voidspaces observed in excess of 6mm in diameter in the core. The concrete was purposefully air entrained and originally contained a well-distributed air void system considered freeze-thaw resistant under severe exposure conditions. Original air void parameters include a 3.9% entrained-sized void volume and a 0.004" spacing factor. Secondary ettringite occurs on the linings on many entrained sized voidspaces throughout the depth of the core and appears to fills some concentrations of the finest voids directly adjacent to the crack plane.

II. Aggregate

1. Coarse: 25mm (1") nominal sized gravel consisting predominately of granite, carbonates, basalt and chert. The aggregate is of Des Moines glacial lobe outwash. The coarse aggregate appeared well graded and exhibited good overall distribution.

2. Fine: Natural quartz, feldspar, and lithic sand (granite, chert, carbonates, basalt, siltstone and shale.) The grains were mostly sub-rounded with many smaller sub-angular particles. The fine aggregate appeared fairly graded and exhibited good overall uniform distribution.

III. Cementitious Properties

1. Air Content: 4.5% total original air void.
2. Depth of carbonation: Ranged from 1mm up to 6mm depth from the top surface of the core. Carbonation ranged from negligible up 7mm depth from sawcut joint face. Carbonation was observed intermittently along the joint crack plane ranging in depth from negligible up to 6mm.
3. Pozzolan presence: Flyash was observed.
4. Paste/aggregate bond: Fair.
5. Paste color: Similar to Medium Light Gray (Munsell® N6)
6. Paste hardness: Moderately hard (Moh's >3)

7. Microcracking: Several randomly oriented microcracks occur in the paste only to 29mm depth from the top surface; present on one side of the joint only. A sub-horizontal fracture occurred between 160mm and 169mm depth from the top surface on one side of the joint only.
8. Secondary deposits: White, generally acicular grown ettringite along occurs on the linings of most voids scattered throughout the paste with some concentration of fine void fillings along the length of the joint crack. Calcite fills or lines voids directly adjacent to the joint crack. Clear ASR gel was observed filling to partially lining a few air voids proximate to reactive shale fine aggregate particles.
9. w/cm: Estimated at between 0.36 and 0.41 with approximately 7 to 9% residual portland cement clinker particles and an amount of flyash visually consistent with a 20 to 30% replacement of portland cement.
10. Cement hydration: Alites: Well to fully.
    Belites: Well.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 2

PHOTO: 1

SAMPLE ID: 1480-131, 2 **DESCRIPTION:** Jointed core sample utilized for petrographic analysis. Top surface is right.

PHOTO: 2

SAMPLE ID: 1480-131, 2 **DESCRIPTION:** Rough screeded and mortar eroded top surface of the core with intact silicone joint sealant.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 2

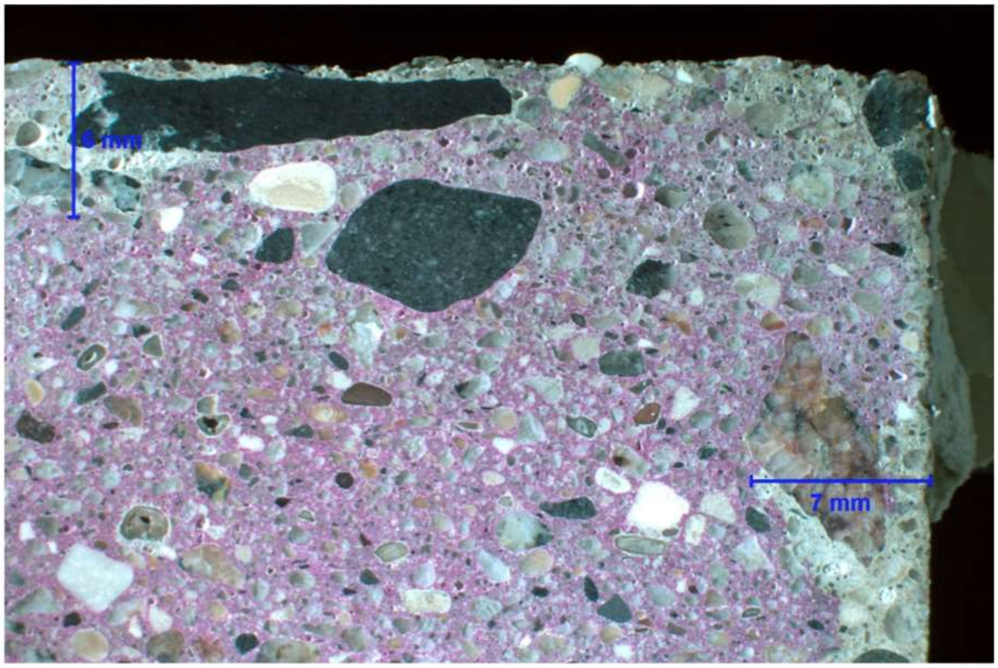
PHOTO:
57

SAMPLE ID: 1480-131, 2 **DESCRIPTION:** Sawcut and lapped cross section of core. The core exhibits tight interlock and no distress of the joint crack.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

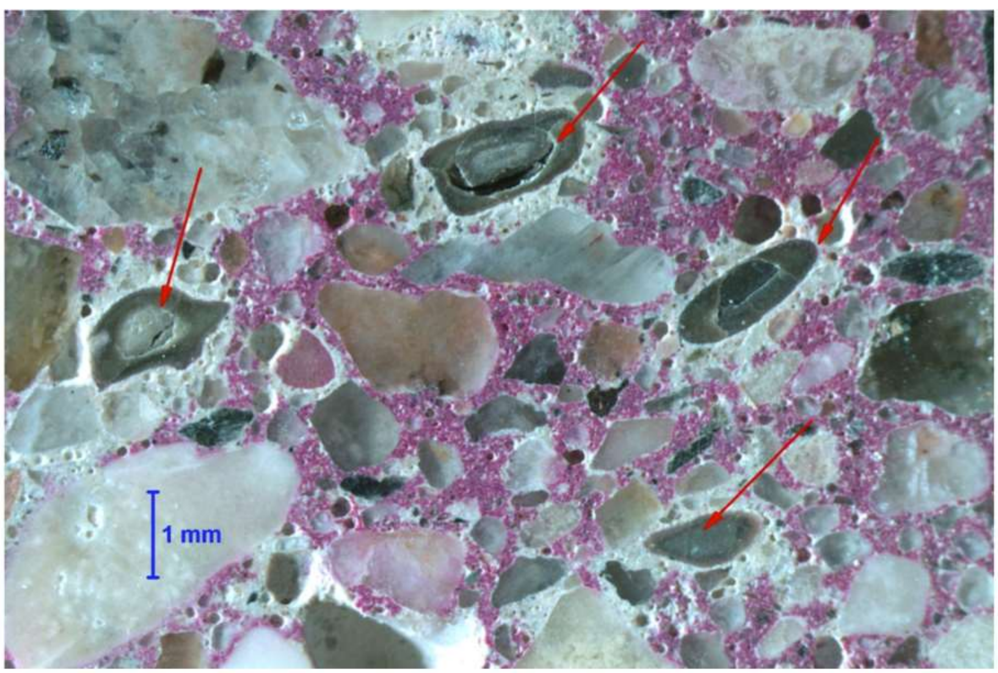
PROJECT: W/CM Study
Phase 2

PHOTO: 76



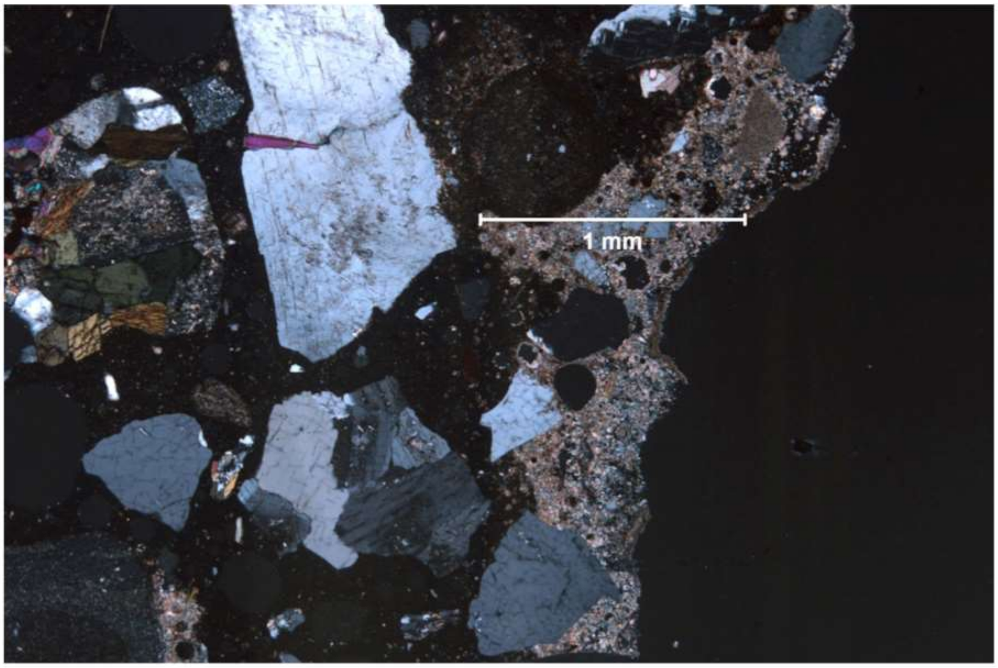
SAMPLE ID: 1480-131, 2 **DESCRIPTION:** Carbonation (unstained paste) ranged from negligible up to 6mm depth from the top surface and negligible up to 7mm depth from the sawcut joint face.
MAG: 5x

PHOTO: 77



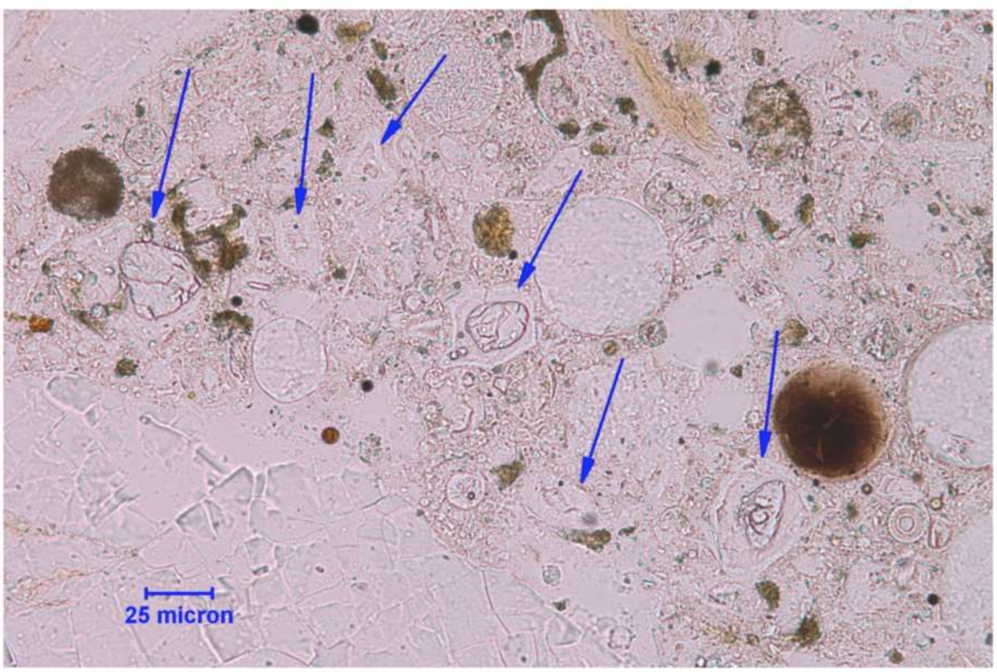
SAMPLE ID: 1480-131, 2 **DESCRIPTION:** Four alkali silica reactive shale fine aggregate particles at depth in the sawcut and lapped cross section of core.
MAG: 15x

PHOTO: 78



SAMPLE ID: 1480-131, 2 **DESCRIPTION:** Carbonation (brightly colored paste) proceeded to 1mm depth from the joint crack plane (black, isotropic) on the right side of the image. Thin section of concrete at mid-depth in the joint under cross polarized light.
MAG: 40x

PHOTO: 79



SAMPLE ID: 1480-131, 2 **DESCRIPTION:** Well to fully hydrated alite portland cement clinker particles (arrows) in thin section of concrete paste under plane polarized light. Note abundant spherical flyash pozzolan particles,
MAG: 400x

00 LAB 001 Petrographic Examination of Hardened Concrete
ASTM: C-856

Project No.	28-00337	Date:	September 4, 2012
Sample ID:	1480-131, 3	Performed by:	D. Hunt, G. Moulzolf

I. General Observations

1. Sample Dimensions: Our analysis was performed on both lapped sides of a 225mm (8 3/4") x 90mm (3 1/2") x 29mm (1 1/8") thick section (in two pieces), a 225mm (8 3/4") x 90mm (3 1/2") x 29mm (1 1/8") thick section (in two pieces), and two 76mm (3") x 52mm (2") wide thin sections that were sawcut and prepared from the original 95mm (3 3/4") diameter x 225mm (8 3/4") long core taken directly through a sawcut joint. The thin sections were located at between 65mm and 140mm depth and 145mm and 220mm depth in the core from the top surface; directly adjacent to the distressed joint surface.

2. Surface Conditions:
   Top: Fairly rough, textured, tined, and mortar eroded/traffic worn surface; exposing many fine aggregate surfaces.
   Bottom: Rough, irregular, formed surface; placed on a granular gravel base.

3. Reinforcement: None observed.

4. General Physical Conditions: The core was taken directly through a sealed pavement joint. A silicone joint sealer was observed between 1mm and 14mm depth from the top surface. The joint sealant was well bonded to one side of the sawcut joint along most of its 14mm thickness. The sealant was poorly adhered to the other side of the joint; with generally only a thin bond along the tooled "meniscus" of the material. The joint sealant was placed on a foam backer rod. The joint was characterized by an approx. 4mm wide pilot sawcut proceeding to 73mm depth from the top surface and an approx. 8mm wide reservoir cut to 29mm depth; with the resulting joint crack proceeding the entire depth of the core. The joint crack proceeds around all coarse aggregate particles it encounters. In general, a loss of concrete mass (up to 17mm maximum width) occurs along the entire depth of the joint crack. Several sub-vertical microcracks (incipient scaling/spalling) were observed generally within the paste-only and within 3mm of the distressed joint surface below the sawcut joint. The cracked joint plane is characterized by several relatively "clean" and un-distressed coarse aggregates protruding from the concrete joint. Residual interlock between the two halves of core occurs mainly with the protruding coarse aggregate particles interlocking with their corresponding sockets below 73mm depth. Three sub-horizontal, apparent coring induced, fractures were observed at approx. 85mm and 122mm depth from the top surface on one side the joint crack and at 150mm depth from the top surface on the opposite side of the joint crack. The coarse aggregate appeared sound. No evidence of ASR associated with the coarse aggregate was observed. Abundant alkali-silica "reacted" shale fine aggregate particles were present in the core. The "reacted" shale particles exhibit internal cracking that propagates into the paste. Alkali-silica reaction gel was observed partially lining to filling a few air voids proximate to the reactive shale particles.

   The fairly rough top surface of the core exhibits significant traffic wear; topographic highs have been worn smooth with exposed fine and coarse aggregate particles exhibiting worn surfaces. The concrete was well consolidated, with a few voidspaces up to 10mm in diameter in the core. The concrete was purposefully air entrained and contains a well-distributed air void system considered freeze-thaw resistant under severe exposure conditions. Air void parameters include a 7.2% entrained-sized void volume and a 0.004" spacing factor. Secondary ettringite with some portlandite tablets fill numerous entrained sized voidspaces within 3mm of the cracked joint. Void fillings are scares outside of 3mm.

II. Aggregate

1. Coarse: 38mm (1 1/2") nominal sized crushed gravel consisting predominately of granite, gneiss, carbonate, basalt and gabbro. The aggregate is of Des Moines glacial lobe outwash. The coarse aggregate appeared well graded and exhibited good overall distribution.

2. Fine: Natural quartz, feldspar, and lithic sand (granite, chert, carbonates, basalt, siltstone, iron oxide and shale.) The grains were mostly sub-rounded with many smaller sub-angular particles. The fine aggregate appeared fairly graded and exhibited good overall uniform distribution.

III. Cementitious Properties

1. Air Content: 8.6% total.
2. Depth of carbonation: Ranged from 1mm up to 11mm depth from the top surface of the core and up to 17mm depth from the joint crack plane; along consolidation voidspace. "Carbonation" or pH loss was observed thinly around the perimeter of carbonate aggregate particles throughout the depth of the core.
3. Pozzolan presence: Flyash was observed.
4. Paste/aggregate bond: Fair.
5. Paste color: Similar to Medium Light Gray (Munsell® N6)
6. Paste hardness: Moderately hard (Moh's <3) with areas of moderately soft paste (Moh's 2) within 2mm of the joint crack.
7. Microcracking: A few sub-vertical microcracks (incipient spalling) were observed generally within the paste-only and within 3mm of the distressed joint surface below the sawcut joint. Several sub-horizontal microcracks were observed in the paste between 117mm and 180mm depth within one side of the joint cross section. Microcracking was observed at a moderate angle in the paste; oriented sub-parallel to and within 10mm of the angled distress at the bottom of the joint crack.
8. Secondary deposits: Secondary ettringite with some portlandite tablets fill numerous entrained sized voidspaces within 3mm of the cracked joint. Void fillings decrease drastically with further depth from the joint crack. ASR gel was observed filling to partially lining to filling a few air voids proximate to abundant reactive shale fine aggregate particles.
9. w/cm: Estimated at between 0.37 and 0.42 with approximately 6 to 8% residual portland cement clinker particles and an amount of flyash visually consistent with a 10 to 20% replacement of portland cement.
10. Cement hydration: Alites: Mostly fully.
    Belites: Well.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 2

PHOTO: 3

SAMPLE ID: 1480-131, 3 **DESCRIPTION:** Jointed core sample utilized for petrographic analysis. Note some mass lost along the length of the joint. The top surface is right.

PHOTO: 4

SAMPLE ID: 1480-131, 3 **DESCRIPTION:** Rough screeded and tined top surface of the core with mortar erosion. Note failed silicone joint sealant.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 2

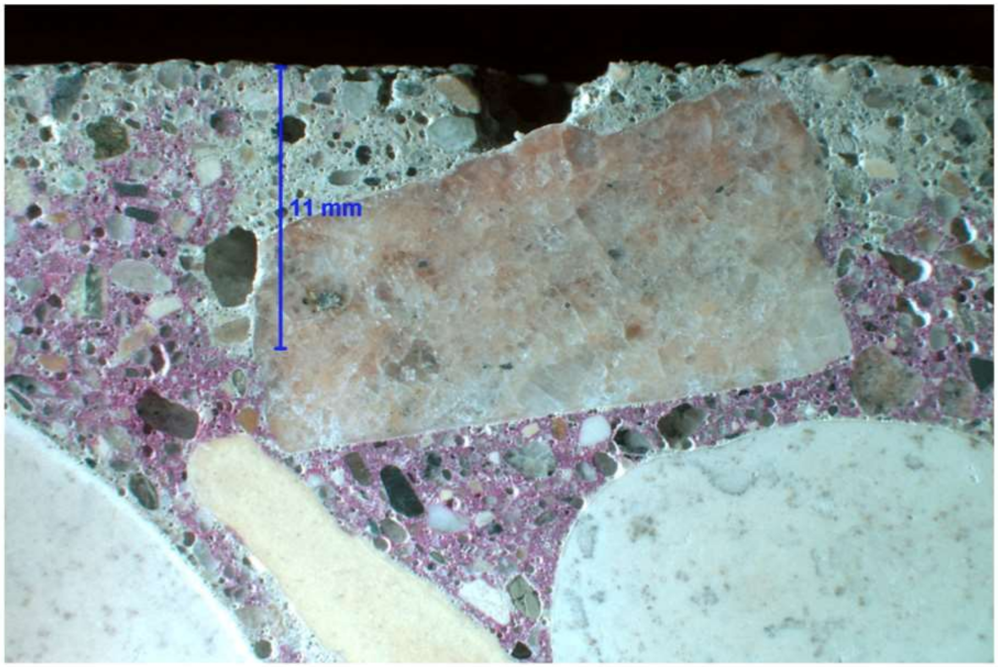
PHOTO:
58

SAMPLE ID: 1480-131, 3 **DESCRIPTION:** Sawcut and lapped cross section of core. The core exhibits significant loss of paste along the joint crack. Microcracking is mapped in red ink.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

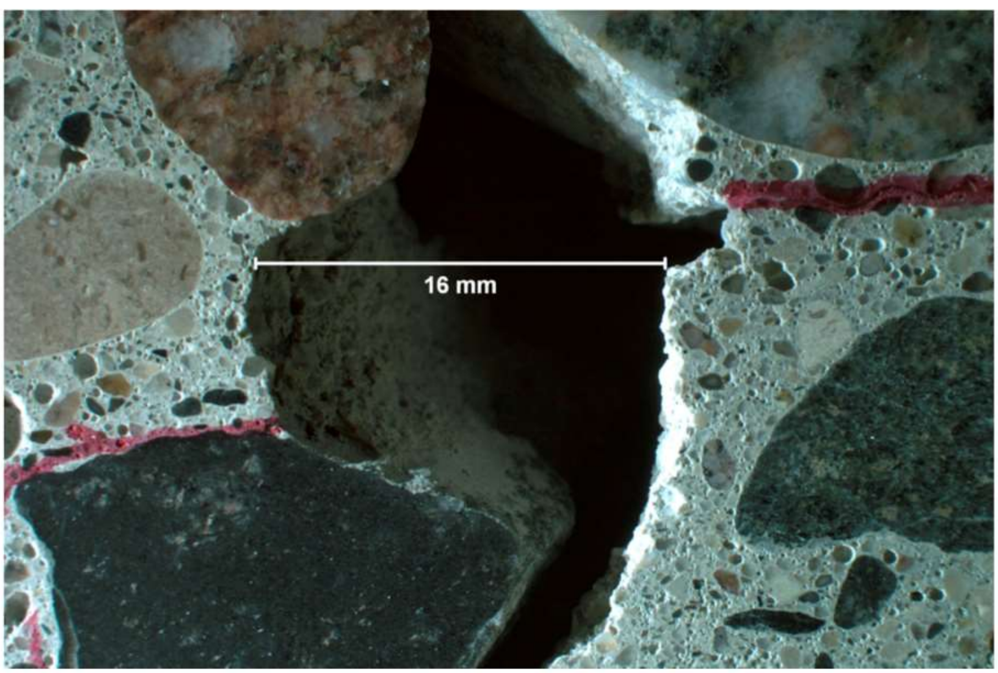
PROJECT: W/CM Study
Phase 2

PHOTO: 80



SAMPLE ID: 1480-131, 3 **DESCRIPTION:** Carbonation (unstained paste) ranged from 1mm up to 11mm depth from the top surface of the core.
MAG: 5x

PHOTO: 81



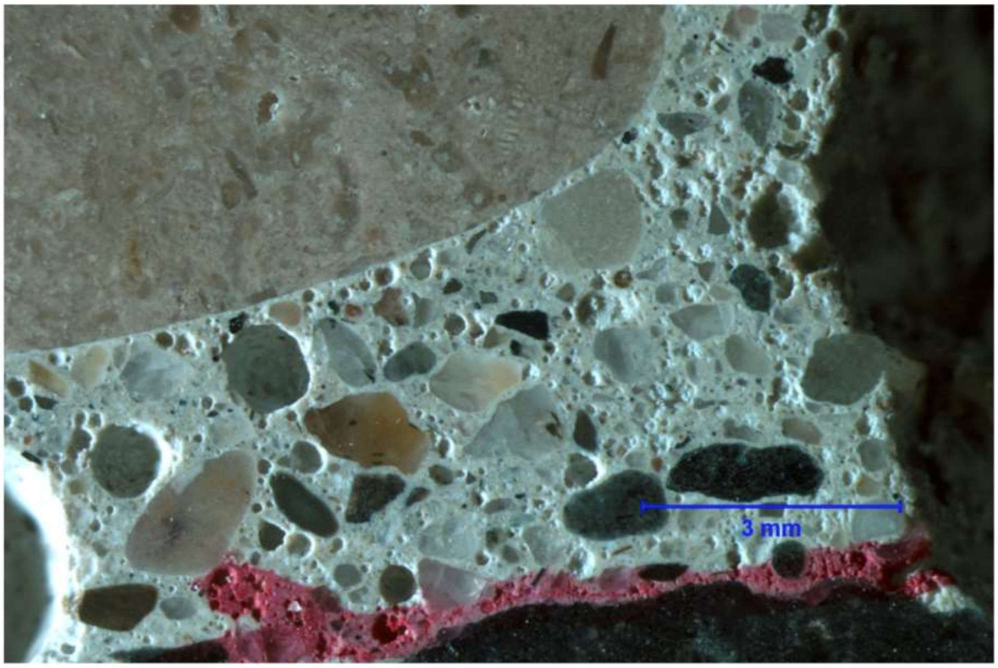
SAMPLE ID: 1480-131, 3 **DESCRIPTION:** 16mm of mass loss between the two side of the joint crack at below 80mm depth in the joint.

MAG: 5x

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

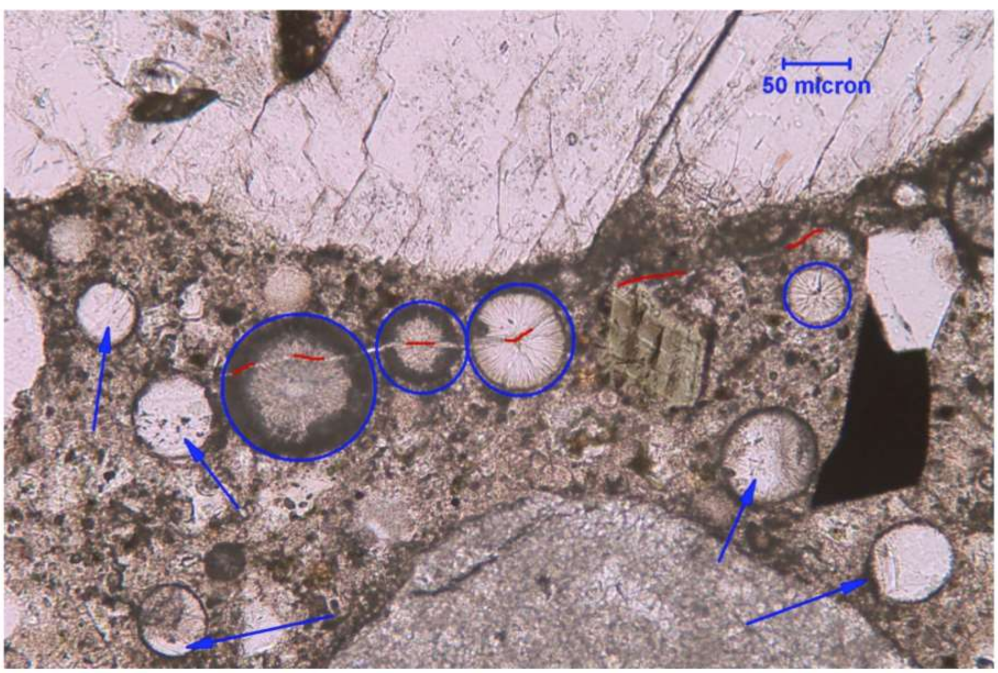
PROJECT: W/CM Study
Phase 2

PHOTO: 82



SAMPLE ID: 1480-131, 3 **DESCRIPTION:** Fine entrained sized air void spaces within 3mm of the joint crack surface (R) are mostly filled with secondary ettringite. Image at below 90mm depth in the joint.
MAG: 15x

PHOTO: 83



SAMPLE ID: 1480-131, 3 **DESCRIPTION:** Spherical ettringite-filled air void spaces in thin section of concrete paste adjacent to the joint face; in thin section under plane polarized light. Note microcracking bisecting previously filled voids; mapped in red dashed line.
MAG: 200x

00 LAB 001 Petrographic Examination of Hardened Concrete
ASTM: C-856

Project No.	28-00337	Date:	September 6, 2012
Sample ID:	1480-131, 5	Performed by:	D. Hunt, G. Moulzolf

I. General Observations

1. Sample Dimensions: Our analysis was performed on both lapped sides of a 219mm (8 1/2") x 88mm (3 1/2") x 31mm (1 1/4") thick section (in two pieces), a 219mm (8 1/2") x 85mm (3 3/8") x 29mm (1 1/8") thick section (in two pieces), and two 76mm (3") x 52mm (2") wide thin sections that were sawcut and prepared from the original 92mm (3 5/8") diameter x 219mm (8 1/2") long core taken directly through a sawcut joint. The thin sections were located at between 60mm and 136mm depth and 140mm and 216mm depth in the core from the top surface; directly adjacent to the distressed joint surface.

2. Surface Conditions:
   Top: Fairly rough, textured and traffic worn surface; exposing many fine aggregate surfaces.
   Bottom: Rough, irregular, formed surface; placed on a bituminous base.

3. Reinforcement: None observed.

4. General Physical Conditions: The core was taken directly through a sealed pavement joint. A silicone joint sealer was well adhered to both sides of the sawcut joint through its entire thickness. The silicone joint sealer was adhered between approximately 3mm and 18mm depth from the top surface of the core. The joint sealer was placed on a foam backer rod. The joint was characterized by a 4mm wide pilot sawcut proceeding 57mm depth from the top surface and an approx. 11mm wide reservoir cut to 35mm depth; with the resulting joint crack proceeding the depth of the core. No vertical scaling/spalling was observed along the joint crack. In general, loss of concrete is minimal to non-existent along the entire depth of the joint crack . The cracked joint plane is characterized by a relatively "clean" surface with no debris lining the joint plane. The joint crack proceeds around nearly all but through a one coarse aggregate particle. The core exhibits tight residual interlock between the two halves of core along the entire depth of the joint crack; with no apparent distress or paste loss. The coarse aggregate appeared sound. No evidence of ASR associated with the coarse aggregate was observed. Abundant alkali-silica "reacted" shale and chert fine aggregate were present in the core. The "reacted" shale particles exhibit internal cracking that propagates into the paste. Alkali-silica reaction gel was observed partially lining to filling a few air voids proximate to the reactive particles.

   The fairly rough top surface of the core exhibits significant traffic wear; topographic highs have been worn smooth with exposed fine and coarse aggregate particles exhibiting worn surfaces. The concrete was fairly well consolidated, with one consolidation void measuring up to 20mm in diameter. The concrete was purposefully air entrained and contains a well-distributed air void system considered freeze-thaw resistant under severe exposure conditions. Air void parameters include a 5.8% entrained-sized void volume and a 0.005" spacing factor. Secondary ettringite fills many entrained sized voidspaces within 1mm of the cracked joint. Void fillings decrease with depth from the joint crack.

II. Aggregate

1. Coarse: 25mm (1") nominal sized gravel consisting predominately of granite, carbonate, basalt and gabbro. The aggregate is of Des Moines lobe glacial outwash. The coarse aggregate appeared well graded and exhibited good overall distribution.

2. Fine: Natural quartz, feldspar, and lithic sand (granite, chert, carbonates, basalt, siltstone and shale.) The grains were mostly sub-rounded with many smaller sub-angular particles. The fine aggregate appeared fairly graded and exhibited good overall uniform distribution.

III. Cementitious Properties

1. Air Content: 8.3% total.
2. Depth of carbonation: Ranged from negligible up to 3mm depth from the top surface of the core; spiking to 6mm depth along a sub-vertical microcrack. Carbonation ranged from negligible up 5mm depth from joint crack.

3.	Pozzolan presence:	Flyash was observed.
4.	Paste/aggregate bond:	Fair.
5.	Paste color:	Similar to Medium Light Gray (Munsell® N6)
6.	Paste hardness:	Moderately hard (Moh's >3)
7.	Microcracking:	A few sub-vertical drying shrinkage microcracks proceed up to 7mm depth from the top surface of the core.
8.	Secondary deposits:	Secondary ettringite fills many of the smaller entrained sized voidspaces within 1mm of the cracked joint. Void fillings decrease with depth from the joint crack. ASR gel was observed filling to partially lining a few air voids proximate to reactive shale fine aggregate particles.
9.	w/cm:	Estimated at between 0.36 and 0.41 with approximately 7 to 9% residual portland cement clinker particles and an amount of flyash visually consistent with a 10 to 20% replacement of portland cement.
10.	Cement hydration:	Alites: Mostly fully. Belites: Well.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 2

PHOTO: 7

SAMPLE ID: 1480-131, 5 **DESCRIPTION:** Jointed core sample utilized for petrographic analysis. The top surface is right.

PHOTO: 8

SAMPLE ID: 1480-131, 5 **DESCRIPTION:** Rough screeded top surface of the core with mortar erosion. Note silicone joint sealant.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 2

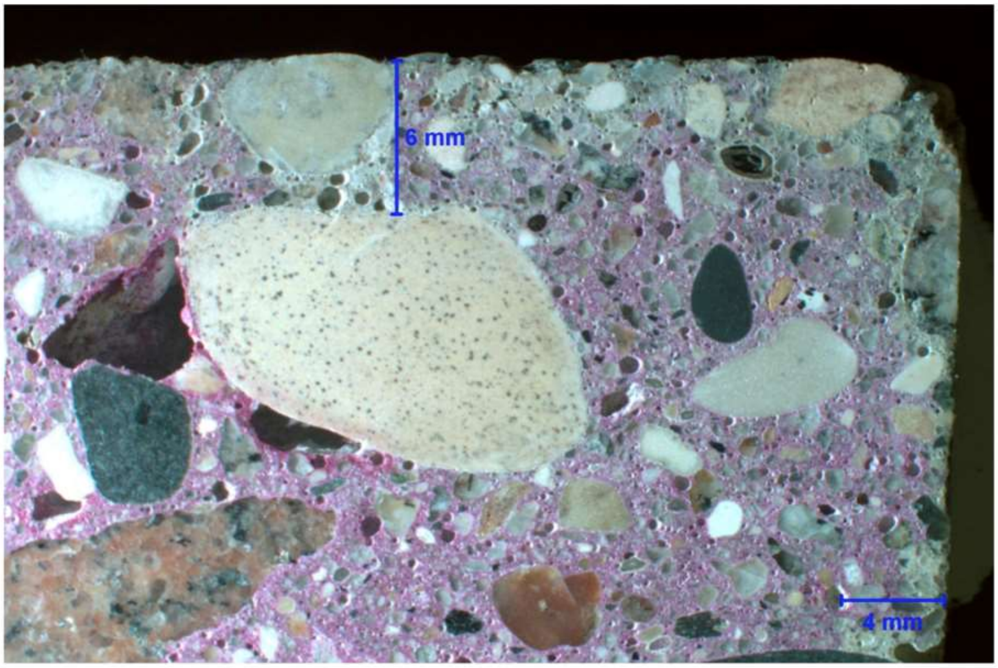
PHOTO:
59

SAMPLE ID: 1480-131, 5 **DESCRIPTION:** Sawcut and lapped cross section of core. The joint crack exhibits no distress.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

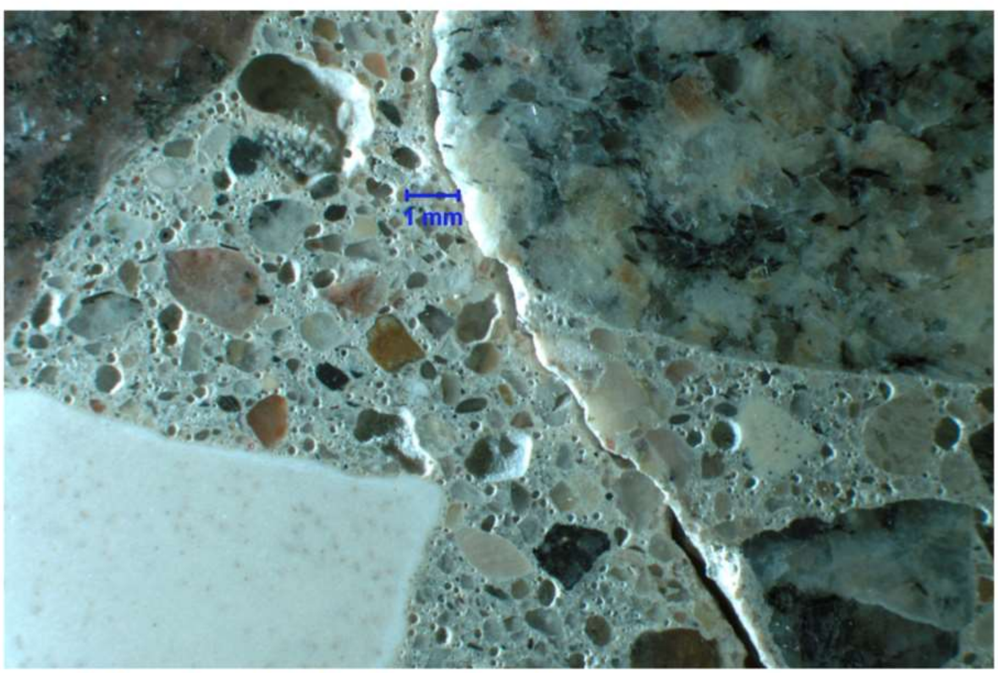
PROJECT: W/CM Study
Phase 2

PHOTO: 84



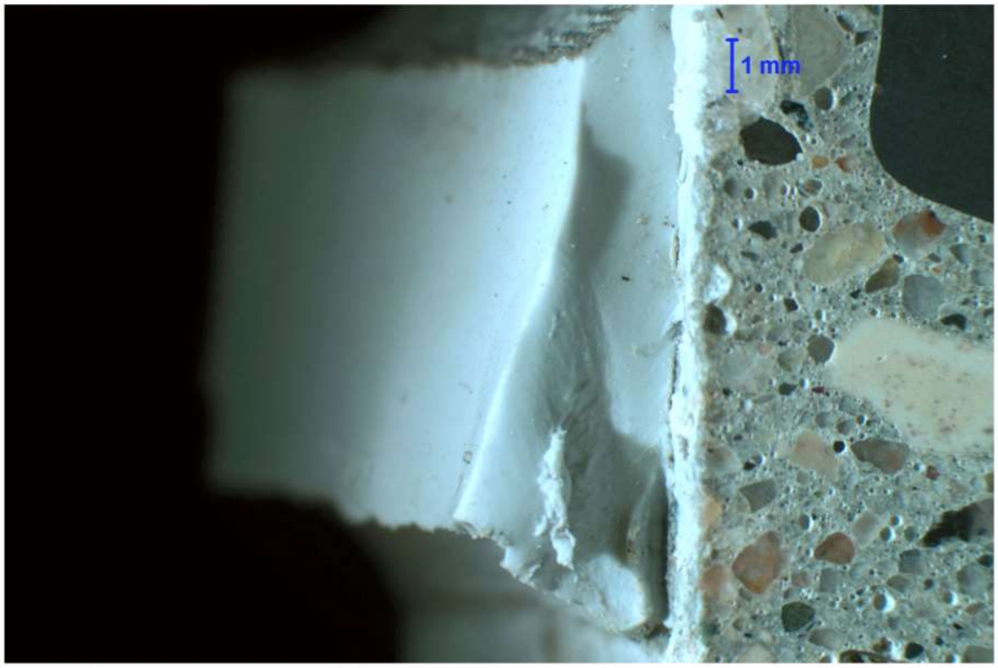
SAMPLE ID: 1480-131, 5 **DESCRIPTION:** Carbonation (unstained) ranged from negligible up to 6mm depth from the top surface and from negligible up to 4mm depth), in this image, from the sawcut joint surface. A freshly sawcut and lapped cross section of concrete core exposed to phenolphthalein pH indicator.
MAG: 5x

PHOTO: 85



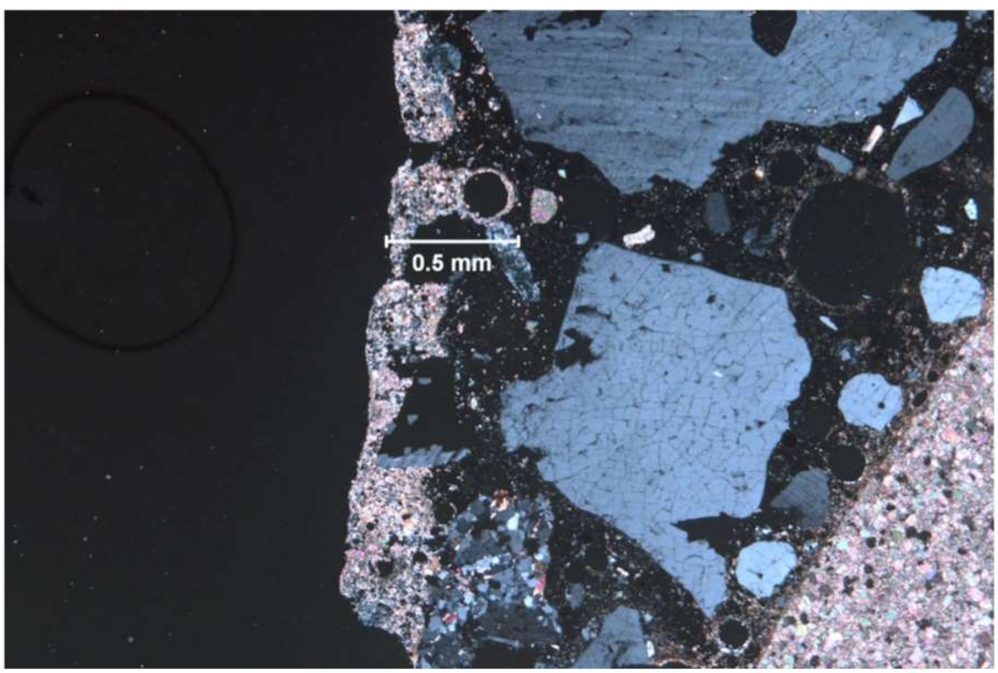
SAMPLE ID: 1480-131, 5 **DESCRIPTION:** Tight residual interlock between the two core halves along the joint crack; below 145mm depth in this image. Note fine, unfilled, entrained sized air voidspaces.
MAG: 10x

PHOTO: 86



SAMPLE ID: 1480-131, 5 **DESCRIPTION:** Well bonded silicone joint sealant was cut from the core half for preparation of the concrete surface.
MAG: 10x

PHOTO: 87



SAMPLE ID: 1480-131, 5 **DESCRIPTION:** Brightly colored layer of carbonated paste along the joint crack plane; in thin section under cross polarized light.
MAG: 40x

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 2

PHOTO: 5

SAMPLE ID: 1480-131, 4 **DESCRIPTION:** Mid-panel core sample utilized for rapid chloride permeability testing. The top surface is right.

PHOTO: 6

SAMPLE ID: 1480-131, 4 **DESCRIPTION:** Rough screeded and tined top surface of the core with mortar erosion.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 2

PHOTO: 9

SAMPLE ID: 1480-131, 6 **DESCRIPTION:** Mid-panel core sample utilized for rapid chloride permeability testing. The top surface is right.

PHOTO: 10

SAMPLE ID: 1480-131, 6 **DESCRIPTION:** Rough screeded and tined top surface of the core with mortar erosion.

Field Notes and Petrographic Reports for Project 2180-71, Cores 1, 3

Table A.8. Field notes for SP Number 2180-71, I-94.

Core	Location from Joint	RP	Station	Direction	Lane	Offset	Thickness
1	ON	102.000	3534+68	WB	DR	-5.0'	8.250"
2	2.0'	102.000	3534+70	WB	DR	-6.0'	8.500"
3	ON	101.000	3481+90	WB	DR	-6.0'	8.750"
4	2.0'	101.000	3481+92	WB	DR	-5.5'	9.000"
5	2.5'	100.000	3429+18	WB	DR	-5.0'	8.000"
6	2.3'	99.000	3376+44	WB	DR	-6.0'	5.750"

00 LAB 001 Petrographic Examination of Hardened Concrete
ASTM: C-856

Project No.	28-00337	Date:	August 24, 2012
Sample ID:	2180-71, 1	Performed by:	D. Hunt, G. Moulzolf

I. General Observations

1. Sample Dimensions: Our analysis was performed on both lapped sides of a 217mm (8 1/4") x 98mm (3 7/8") x 23mm (7/8") thick section (in two pieces), a 217mm (8 1/4") x 95mm (3 3/4") x 33mm (1 1/4") thick section (in two pieces), and two 76mm (3") x 52mm (2") wide thin sections that were sawcut and prepared from the original 100mm (4") diameter x 217mm (8 1/4") long core taken directly through a distressed sawcut joint. The thin sections were located at between 130mm and 215mm depth in the core from the top surface; directly adjacent to the distressed joint surface.

2. Surface Conditions:
   Top: Fairly rough, textured and tined surface with traffic wear exposing many fine aggregate and a few coarse aggregate surfaces.
   Bottom: Rough, irregular, formed surface; placed on a natural granular sub-base.

3. Reinforcement: None observed.

4. General Physical Conditions: The core was taken directly through a distressed pavement joint. A silicone joint sealant was observed well bonded to one side of the sawcut joint between 3mm and 13mm depth from the top surface. The sealant was originally poorly bonded to the other side of the joint and is now completely de-bonded. The joint sealer was placed on a 12mm diameter foam backer rod. The joint was characterized by an approx. 5mm wide pilot sawcut to 61mm depth from the top surface and an approx. 10mm wide reservoir cut to 30mm depth with the resulting joint crack proceeding the depth of the core. Vertical scaling/spalling begins at approx. 50mm depth from the top surface of the core, along the pilot sawcut. The joint surfaces are vertically scaled/spalled away, leaving an approx. 10mm to 25mm (1") wide void through the entire depth of the core. The distressed joint plane is characterized by several relatively "clean" and un-distressed coarse aggregate particles protruding from the distressed concrete paste. Sub-vertical microcracks (incipient spalling) were observed proceeding through the paste and several carbonate aggregate particles within 18mm of the distressed joint surface between 48mm and 205mm depth from the top surface of the core. Sub-horizontal fractures were observed proceeding through both halves of the core between approx. 90mm and 130mm depth in the core. ASR gel was observed lining a few air voids proximate to abundant reactive shale fine aggregate particles.

   The originally rough textured top surface of the core exhibits significant traffic wear; topographic highs have been worn smooth with exposed fine and coarse aggregate particles exhibiting worn surfaces. The concrete was well consolidated, with no voidspaces observed in excess of 12mm in diameter in the core. The concrete was purposefully air entrained and contains a well-distributed air void system considered freeze-thaw resistant under severe exposure conditions. Original air void parameters include a 3.9% entrained-sized void volume and a 0.007" spacing factor. Secondary ettringite, with some portlandite, fills many of the smaller entrained sized voidspaces below approx. 55mm depth from the top surface. Entrained sized void fillings are concentrated within approx. 7mm of the distressed joint face. Void fillings decrease with depth from the vertical distressed joint surfaces.

II. Aggregate

1. Coarse: 25mm (1") nominal sized gravel consisting predominately of carbonates, chert, basalt, rhyolite, and granite. The aggregate was of Des Moines glacial lobe outwash. The coarse aggregate appeared well graded and exhibited good overall distribution.

2. Fine: Natural quartz, feldspar, and lithic sand (granite, carbonates, basalt). The grains were mostly sub-rounded with many smaller sub-angular particles. The fine aggregate appeared fairly graded and exhibited good overall uniform distribution.

III. Cementitious Properties

1. Air Content:	5.2% total original air void.
2. Depth of carbonation:	Ranged from 1mm up to 8mm depth from the top surface of the core. Ranged from negligible up to 5mm depth from the sawcut and distressed joint surfaces.
3. Pozzolan presence:	Flyash was observed.
4. Paste/aggregate bond:	Fair.
5. Paste color:	Similar to Medium Light Gray (Munsell® N6).
6. Paste hardness:	Moderately hard (Moh's >3)
7. Microcracking:	Numerous sub-vertical microcracks (incipient spalling) were observed generally proceeding through the paste and carbonate aggregate particles within 18mm of the distressed joint surface between 48mm and 205mm depths from the top surface of the core. A few fine, sub-vertical drying shrinkage microcracks proceed up to 6mm depth from the top surface.
8. Secondary deposits:	White, generally acicular grown ettringite along with some clear platelets of portlandite fills many of the finer entrained sized air voids scattered below approx. 55mm depth from the top surface. Entrained sized void fillings are concentrated within approx. 7mm of the distressed joint face. Void fillings decrease with depth from the vertical distressed joint surfaces. Alkali silica reaction gel lines or fills air voidspaces proximate to abundant reactive shale fine aggregate particles.
9. w/cm:	Estimated at between 0.40 and 0.45 with approximately 6 to 8% residual portland cement clinker particles and an amount of flyash visually consistent with a 5 to 15% replacement of portland cement.
10. Cement hydration:	Alites: Well to fully. Belites: Well.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 2

PHOTO: 17

SAMPLE ID: 2180-71, 1 **DESCRIPTION:** Jointed core sample utilized for petrographic analysis. The sealed top surface is right. Note mass lost along much of the length of the joint crack.

PHOTO: 18

SAMPLE ID: 2180-71, 1 **DESCRIPTION:** Rough screeded and tined top surface of the core with traffic wear. The sealant was completely de-bonded from one side of the joint.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 2

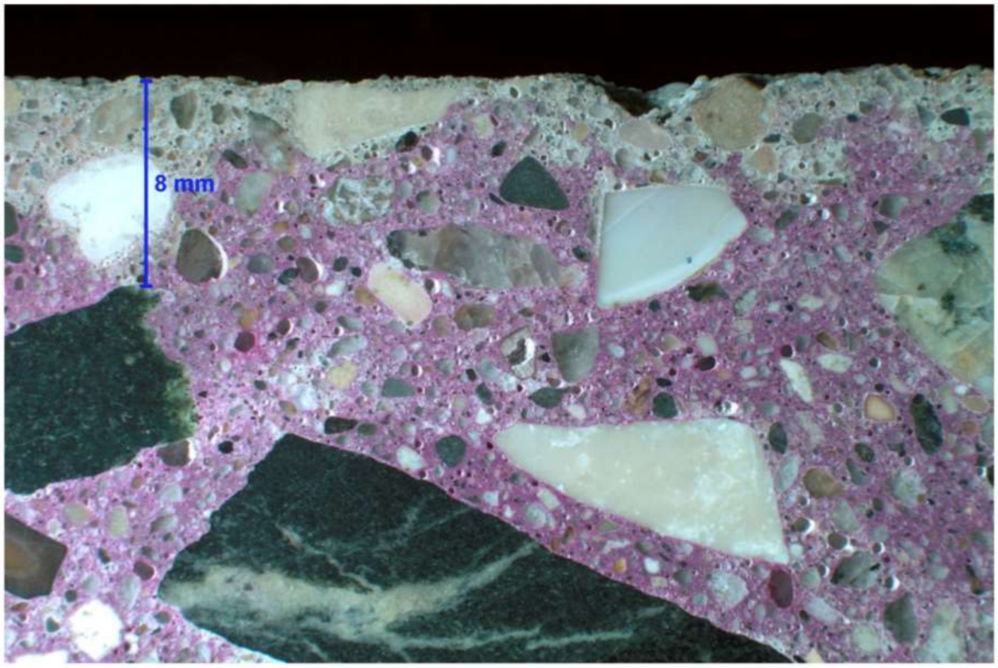
PHOTO:
63

SAMPLE ID: 2180-71, 1 **DESCRIPTION:** Sawcut and lapped cross section of core. The joint crack exhibited significant incipient distress in the paste and carbonate coarse aggregates. Microcracking is mapped in red ink.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

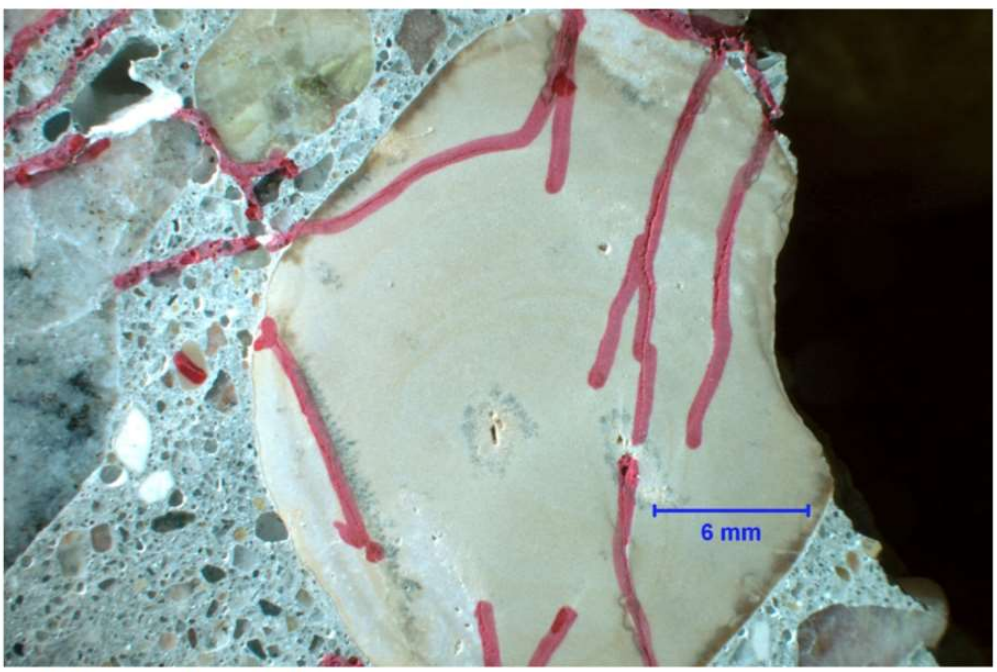
PROJECT: W/CM Study
Phase 2

PHOTO: 98



SAMPLE ID: 2180-71, 1 **DESCRIPTION:** Carbonation (unstained) ranged from 1mm up to 8mm depth from the top surface.
MAG: 5x

PHOTO: 99

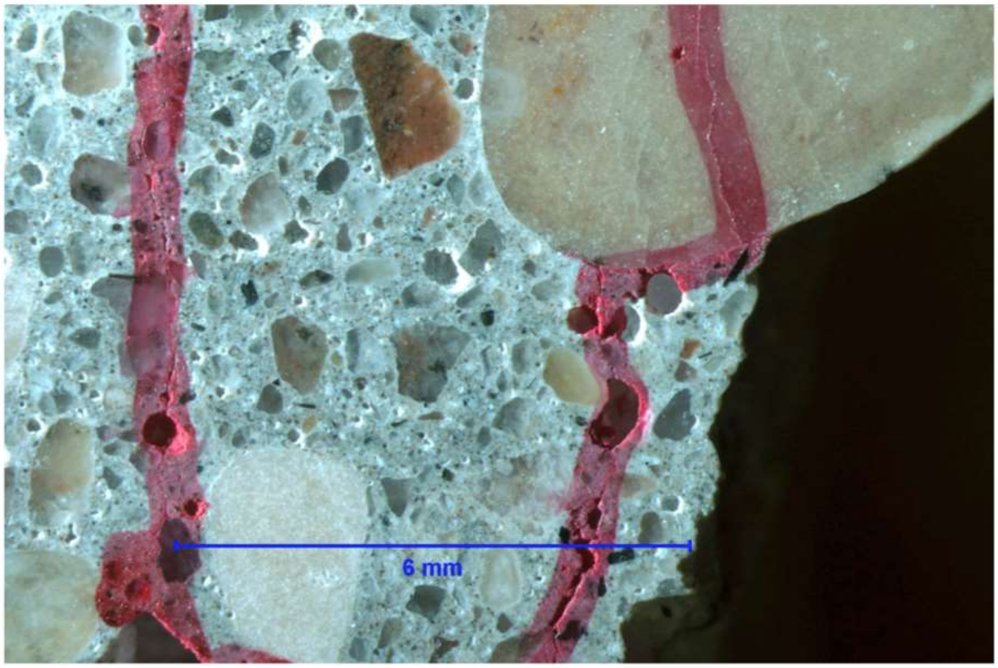


SAMPLE ID: 2180-71, 1 **DESCRIPTION:** The coarse carbonate aggregate particle is participating in the incipient distress along the joint at below 140mm depth in the core.
MAG: 5x

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 2

PHOTO:
100



SAMPLE ID: 2180-71, 1 **DESCRIPTION:** A noticeable loss of entrained air voidspaces in the paste adjacent to the distressed joint face at 115mm depth in the concrete. Sub-vertical microcracking (incipient spalling) is mapped in red ink.
MAG: 15x

PHOTO:
101

SAMPLE ID: 2180-71, 1 **DESCRIPTION:** White to clear secondary ettringite-filled entrained air voidspaces adjacent to the distressed joint plane (left) at 108mm depth from the top surface.
MAG: 50x

00 LAB 001 Petrographic Examination of Hardened Concrete
ASTM: C-856

Project No.	28-00337	Date:	August 29, 2012
Sample ID:	2180-71, 3	Performed by:	D. Hunt, G. Moulzolf

I. General Observations

1. Sample Dimensions: Our analysis was performed on both lapped sides of a 230mm (9") x 100mm (4") x 29mm (1 1/8") thick section (in two pieces), a 230mm (9") x 92mm (3 1/2") x 29mm (1 1/8") thick section (in two pieces), and two 76mm (3") x 52mm (2") wide thin sections that were sawcut and prepared from the original 100mm (4") diameter x 230mm (9") long core taken directly through a sawcut joint. The thin sections were located at between 76mm and 150mm depth and 153mm and 229mm depth in the core from the top surface; directly adjacent to the distressed joint surface.

2. Surface Conditions:
   Top: Fairly rough, textured and traffic worn surface; exposing many fine aggregate surfaces.
   Bottom: Rough, irregular, formed surface; placed on natural granular base.

3. Reinforcement: None observed.

4. General Physical Conditions: The core was taken directly through a sealed pavement joint. A silicone joint sealant was originally placed between 1mm and 18mm depth from the top surface. The joint sealer was fully de-bonded from one side of the sawcut joint and mostly de-bonded from the other side of the joint. The joint sealant was placed on a 12mm diameter foam backer rod. The joint was characterized by an approx. 5mm wide pilot sawcut proceeding to 78mm depth from the top surface and an approx. 10mm wide reservoir cut to 40mm depth; with the resulting joint crack proceeding the depth of the core. Thin paste loss with little residual interlock between the core halves occurs along the length of the core; ranging from negligible to 5mm loss between 78mm and 112mm from the top surface and up to 12mm loss the remaining depth of the core. Incipient vertical scaling/spalling occurs in the paste within 3mm of the sawcut and joint crack beginning at approx. 73mm depth from the top surface, through the remaining depth of the core. The cracked joint plane is characterized by several relatively "clean" and un-distressed coarse aggregates protruding from the concrete joint. The coarse aggregate appeared sound. No evidence of ASR associated with the coarse aggregate was observed. A few alkali-silica "reacted" shale fine aggregate particles were present in the core. The "reacted" shale particles exhibit internal cracking that propagates into the paste. Alkali-silica reaction gel was observed partially lining to filling a few air voids proximate to the reactive shale particles.

   The fairly rough textured top surface of the core exhibits significant traffic wear; topographic highs have been worn smooth with exposed fine and coarse aggregate particles exhibiting worn surfaces. The concrete was well consolidated, with a few voidspaces up to 22mm in diameter in the core. The concrete was purposefully air entrained and contains a well-distributed air void system considered freeze-thaw resistant under severe exposure conditions. Air void parameters include a 3.6% entrained-sized void volume and a 0.008" spacing factor. Secondary ettringite fills most of the finer entrained sized voidspaces within 12mm of the cracked joint. Void fillings decrease with depth from the joint crack.

II. Aggregate

1. Coarse: 25mm (1") nominal sized crushed gravel consisting predominately of granite, carbonate, basalt and gabbro. The aggregate is of Des Moines lobe glacial outwash. The coarse aggregate appeared well graded and exhibited good overall distribution.

2. Fine: Natural quartz, feldspar, and lithic sand (granite, chert, carbonates, basalt, siltstone, iron oxide and shale.) The grains were mostly sub-rounded with many smaller sub-angular particles. The fine aggregate appeared fairly graded and exhibited good overall uniform distribution.

III. Cementitious Properties

1. Air Content: 5.1% total.

2. Depth of carbonation: Ranged from <1mm up to 12mm depth from the top surface of the core. Carbonation ranged from negligible up 10mm depth from the distressed joint crack plane.
3. Pozzolan presence: Flyash was observed.
4. Paste/aggregate bond: Fair.
5. Paste color: Similar to Medium Light Gray (Munsell® N6).
6. Paste hardness: Moderately hard (Moh's >3)
7. Microcracking: A few sub-vertical microcracks (incipient spalling) were observed generally within the paste-only and within 3mm of the distressed joint surface below the sawcut joint. Sub-horizontal microcracking proceeds across the diameter of the core between 95mm and 112mm. The microcrack swarm proceeds through a carbonate coarse aggregate particle. Other, generally sub-horizontal microcracking occurs mostly along paste-coarse aggregate boundaries in one side of the joint, below 172mm depth in the core. A few fine sub-vertical drying shrinkage microcracks proceed up 12mm depth from the top surface
8. Secondary deposits: Secondary ettringite fills numerous entrained sized voidspaces within 12mm of the cracked joint. Void fillings decrease with depth from the joint crack. ASR gel was observed filling to partially lining a few air voids proximate to reactive shale fine aggregate particles.
9. w/cm: Estimated at between 0.41 and 0.46 with approximately 5 to 7% residual portland cement clinker particles and an amount of flyash visually consistent with a 10 to 15% replacement of portland cement.
10. Cement hydration: Alites: Well to fully.
    Belites: Well.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 2

PHOTO: 19

SAMPLE ID: 2180-71, 3 **DESCRIPTION:** Jointed core sample utilized for petrographic analysis. The sealed top surface is right. Note mass lost along much of the length of the joint crack.

PHOTO: 20

SAMPLE ID: 2180-71, 3 **DESCRIPTION:** Rough textured top surface of the core with traffic wear. The sealant was completely de-bonded from one side of the joint and poorly bonded to the other.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 2

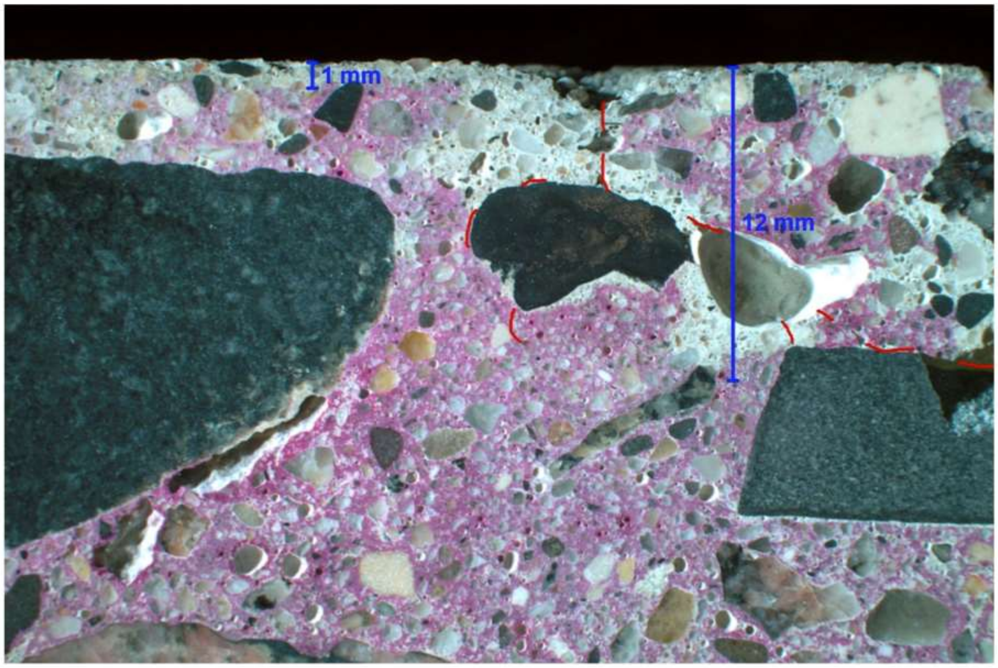
PHOTO:
64

SAMPLE ID: 2180-71, 3 **DESCRIPTION:** Sawcut and lapped cross section of core. The joint crack exhibited mass loss and incipient distress in the paste and carbonate coarse aggregates. Microcracking is mapped in red ink.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

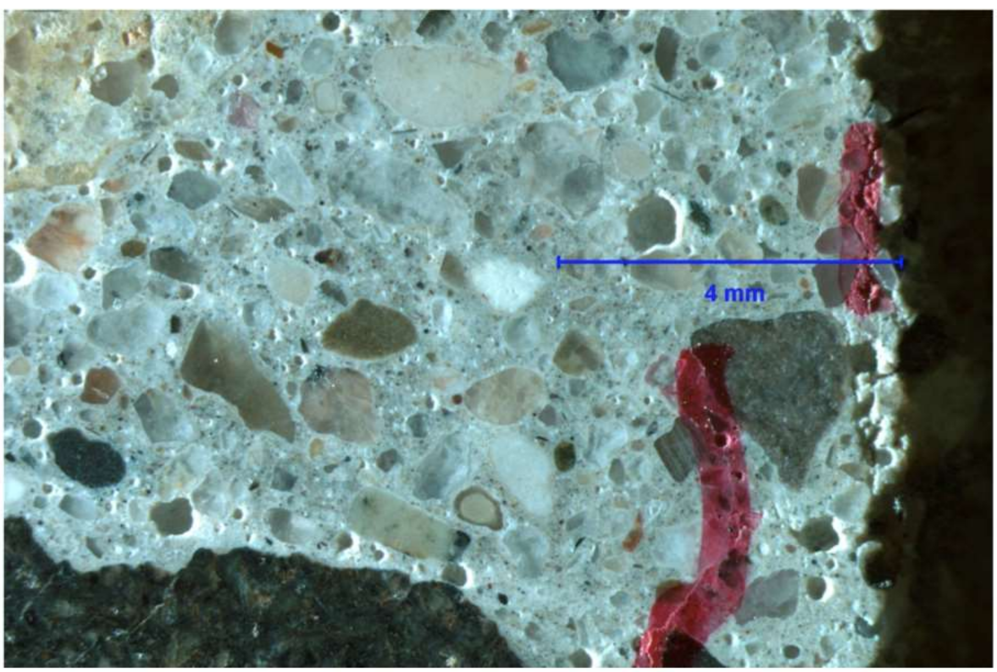
PROJECT: W/CM Study
Phase 2

PHOTO:
102



SAMPLE ID: 2180-71, 3 **DESCRIPTION:** Carbonation (unstained paste) ranged from 1mm up to 12mm depth from the top surface; proceeding along microcracking mapped in red dashed line and consolidation void space.
MAG: 5x

PHOTO:
103



SAMPLE ID: 2180-71, 3 **DESCRIPTION:** Note a significant loss of entrained air voidspaces within 4mm of the joint plane (right) at 90mm depth from the top surface. Incipient spalling is mapped in red ink.
MAG: 15x

Field Notes and Petrographic Reports for Project 2180-78, Cores 3, 5

Table A.9. Field notes for SP Number 2180-78, I-94.

Core	Location from Joint	RP	Station	Direction	Lane	Offset	Thickness
1	ON	110.040	3956+93	EB	DR	4.5'	3.250"
2	2.0'	110.040	3956+91	EB	DR	5.0'	8.500"
3	ON	111.000	4009+50	EB	DR	5.5'	7.750"
4	2.0'	111.000	4009+48	EB	DR	5.0'	7.750"
5	ON	112.000	4062+33	EB	DR	5.0'	8.000"
6	2.0'	112.000	4062+31	EB	DR	6.0'	8.000"
7	2.0'	113.000	4115+12	EB	DR	6.0'	8.500"
8	2.2'	114.000	4167+80	EB	DR	6.0'	8.250"
9	2.0'	115.000	4220+90	EB	DR	6.0'	8.250"

00 LAB 001 Petrographic Examination of Hardened Concrete
ASTM: C-856

Project No.	28-00337	Date:	November 2, 2012
Sample ID:	2180-78, 3	Performed by:	D. Hunt, G. Moulzolf

I. General Observations

1. Sample Dimensions: Our analysis was performed on both lapped sides of a 200mm (8") x 92mm (3 5/8") x 25mm (1") thick section (in two pieces), a 200mm (8") x 91mm (3 5/8") x 25mm (1") thick section (in two pieces), and two 76mm (3") x 52mm (2") wide thin sections that were sawcut and prepared from the original 92mm (3 5/8") diameter x 200mm (8") long core taken directly through a distressed sawcut joint. The thin sections were located at between 120mm and 190mm depth in the core from the top surface; directly adjacent to the distressed joint surface.

2. Surface Conditions:
   Top: Fairly rough textured and traffic worn surface; exposing many fine and a few coarse aggregate surfaces.
   Bottom: Rough, irregular, formed surface; apparently placed on a natural granular base.

3. Reinforcement: A 25mm (1") diameter epoxy coated steel dowel rod was observed at below 88mm (3 1/2") depth from the top surface. Severe corrosion product was observed on the length of the steel dowel; deepest where the epoxy coating appears to have been exposed and initially compromised. Corrosion product was observed on the resulting steel rebar impression.

4. General Physical Conditions: The core was taken directly through a distressed pavement joint. A silicone joint sealant was observed well bonded to one side of the sawcut joint, only, between 1mm and 13mm depth from the top surface. The sealant was originally poorly bonded to the other side of the joint; with a little residual tooled meniscus remaining adhered to the sawcut surface. The joint sealant was placed on a foam backer rod. The joint was characterized by a 5mm wide pilot sawcut proceeding to 62mm depth and an approx. 10mm wide reservoir cut to 30mm depth; with the resulting joint crack proceeding the depth of the core. The joint crack appears to split at approx. 80mm depth, proceeds around the steel dowel, converging into a single crack at approx. 135mm depth. The resulting, approximately 55mm long by 35mm wide, section of concrete is missing along the joint crack. Several pieces of the core are missing proximate to the steel dowel, likely lost during procurement of the core. Blackish Red (Munsell® 5R 2/2) corrosion product lined the steel dowel impression and both sides of the joint crack below 88mm depth from the top surface. A few millimeters of vertical scaling/spalling in the paste only along the joint begins along the initial sawcut at approx. 30mm depth from the top surface. Little apparent paste loss with good residual interlock between the core halves was observed below 145mm depth from the top surface. A few sub-vertical microcracks (incipient spalling) were observed generally within the paste-only and within 3mm of the distressed joint surface between 60mm 165mm depth from the top surface of the core. The joint crack plane is characterized by a few relatively "clean" and un-distressed coarse aggregates protruding from the concrete joint between 60mm and 88mm depth from the top surface. Sub-horizontal fractures proceed through the entire diameter of the core between 90mm and 115mm depth from the top surface, intersecting the corroded steel dowel. Several sub-vertical microcracks were observed radiating up to 12mm from both sides of the steel dowel impression. The coarse aggregate appeared sound. No evidence of ASR associated with the crushed granitic coarse aggregate was observed. Abundant alkali-silica "reacted" shale fine aggregate particles were present in the core. The "reacted" shale particles exhibit internal cracking that propagates into the paste. Alkali-silica reaction gel was observed lining a few air voids and filling a few microcracks proximate to the reactive shale particles.

   The fairly rough top surface of the core exhibits significant traffic wear; topographic highs have been worn smooth with exposed fine and coarse aggregate surfaces exhibiting worn surfaces. The concrete was well consolidated, with no voidspaces observed in excess of 6mm in diameter in the core. The concrete was purposefully air entrained and contains a well-distributed air void system considered freeze-thaw resistant under severe exposure conditions. Original air void parameters include a 4.2% entrained-sized void volume and a 0.005" spacing factor. Secondary ettringite fills many of the finest entrained sized voidspaces throughout the depth of the core; with greater concentration with depth from the top surface and proximity to the joint.

II. Aggregate

1. Coarse: 25mm (1") nominal sized crushed granitic rock. The coarse aggregate appeared well graded and exhibited good overall distribution.

2. Fine: Natural quartz, feldspar, and lithic sand (granite, chert, carbonates, basalt, siltstone and shale.) The grains were mostly sub-rounded with many smaller sub-angular particles. The fine aggregate appeared fairly graded and exhibited good overall uniform distribution.

III. Cementitious Properties

1. Air Content: 4.7% total original air void.
2. Depth of carbonation: Ranged from 2mm up to 5mm depth from the top surface of the core. Carbonation proceeding from the joint crack ranged from <1mm up to 10mm. Mottled carbonation was observed throughout the depth of the core.
3. Pozzolan presence: Flyash was observed.
4. Paste/aggregate bond: Fair.
5. Paste color: Similar to Very Light Gray (Munsell® N8).
6. Paste hardness: Moderately hard (Moh's >3)
7. Microcracking: Few sub-vertical microcracks (incipient spalling) were observed generally within the paste-only and within 3mm of the distressed joint surface between 60mm 165mm depth from the top surface of the core. A few microcracks occur within the paste proximate to reactive fine aggregate particles. A few fine, sub-vertical drying shrinkage microcracks proceed up to 8mm depth from the top surface.
8. Secondary deposits: Secondary ettringite fills many of the finest entrained sized voidspaces throughout the depth of the core; with greater concentration with depth from the top surface and proximity to the joint. Alkali silica reaction gel lines a few air voids fills a few microcracks proximate to reactive shale fine aggregate particles.
9. w/cm: Estimated at between 0.43 and 0.48 with approximately 3 to 5% residual portland cement clinker particles and an amount of flyash visually consistent with a 10 to 20% replacement of portland cement.
10. Cement hydration: Alites: Fully.
    Belites: Well to fully.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 2

PHOTO: 21

SAMPLE ID: 2180-78, 3 **DESCRIPTION:** Jointed core sample utilized for petrographic analysis. The sealed top surface is right. Note mass lost along much of the length of the joint crack and the presence of a corroded rebar.

PHOTO: 22

SAMPLE ID: 2180-78, 3 **DESCRIPTION:** Rough textured top surface of the core with traffic wear. The silicone sealant was completely de-bonded from one side of the joint.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 2

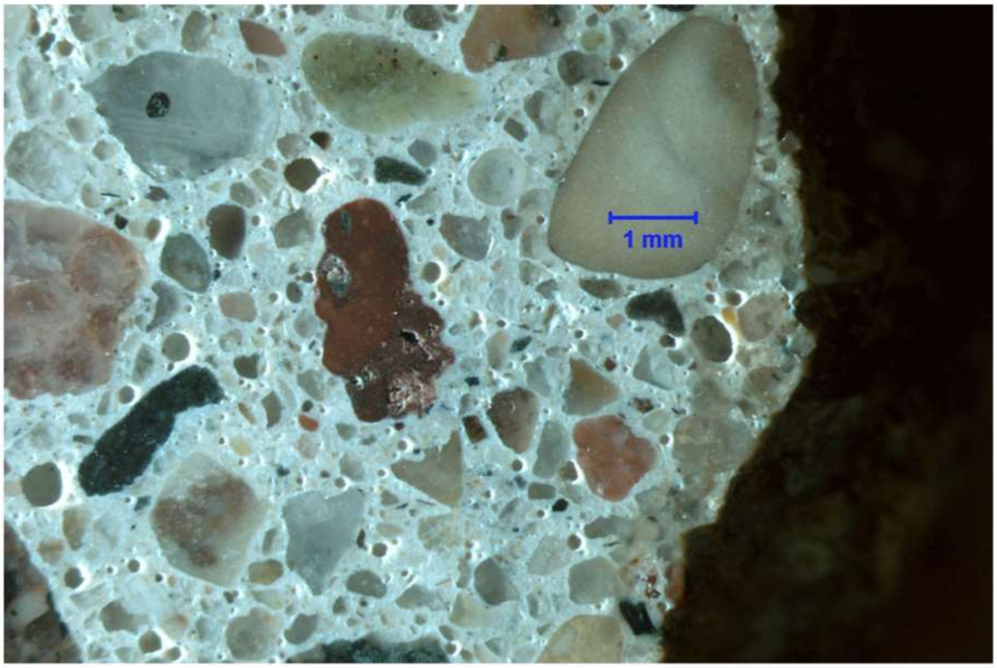
PHOTO:
65

SAMPLE ID: 2180-78, 3 **DESCRIPTION:** Sawcut and lapped cross section of core. The joint crack exhibited no distress. Missing mass was corroded dowel and concrete likely lost during coring. Fractures (wide) and microcracking is mapped in red ink.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

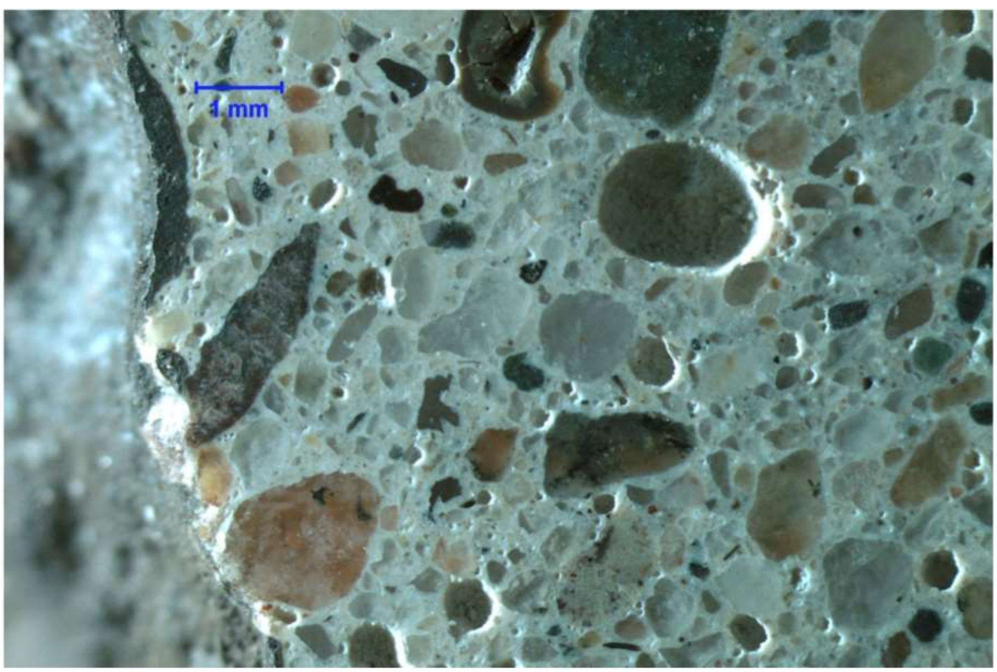
PROJECT: W/CM Study
Phase 2

PHOTO:
104



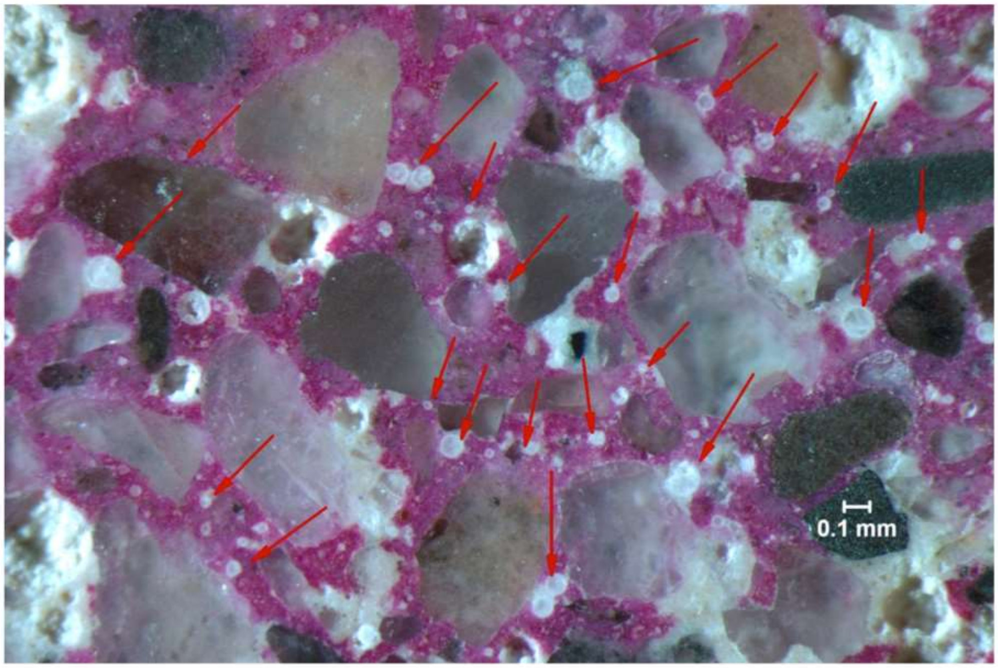
SAMPLE ID: 2180-78, 3 **DESCRIPTION:** Fine entrained air voidspaces are obvious in the paste adjacent to the un-distressed joint face at 70m depth in the concrete.
MAG: 15x

PHOTO:
105



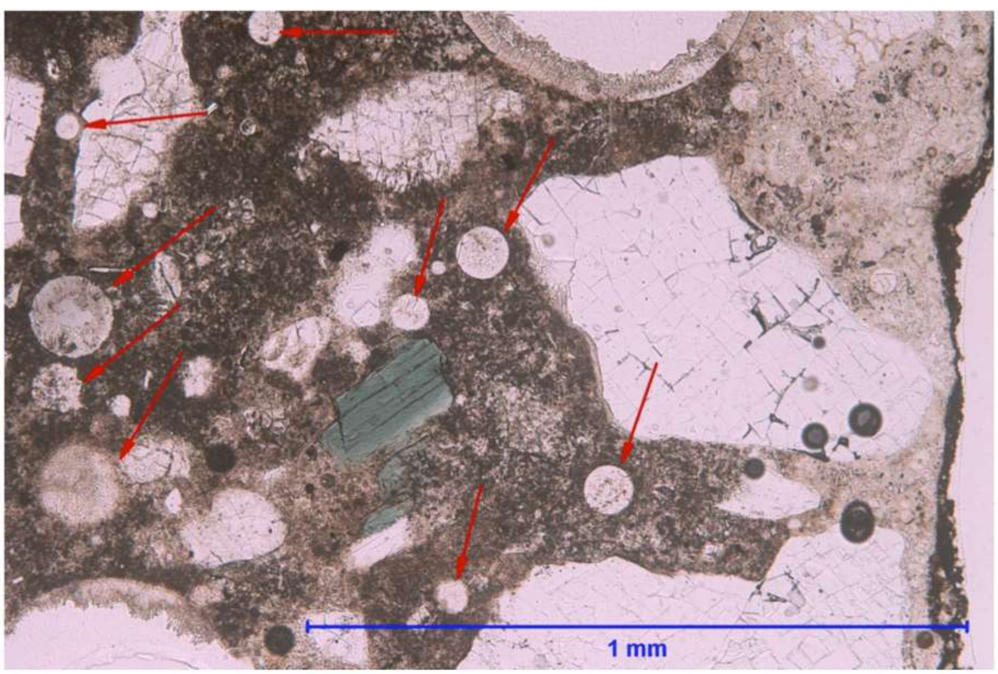
SAMPLE ID: 2180-78, 3 **DESCRIPTION:** Note significantly less obvious entrained air voidspaces adjacent to the joint plane (left) at 148mm depth from the top surface.
MAG: 15x

PHOTO:
106



SAMPLE ID: 2180-78, 3 **DESCRIPTION:** Fine entrained air voidspaces filled with white secondary ettringite are obvious in paste stained with phenolphthalein at 10mm from the joint and 167mm depth from the top surface.
MAG: 50x

PHOTO:
107



SAMPLE ID: 2180-78, 3 **DESCRIPTION:** Ettringite-filled, entrained sized air voidspaces in the concrete paste directly adjacent to the distressed joint face (right) in thin section, under plane polarized light, at mid-depth in the core.
MAG: 100x

00 LAB 001 Petrographic Examination of Hardened Concrete
ASTM: C-856

Project No.	28-00337	Date:	September 10, 2012
Sample ID:	2180-78, 5	Performed by:	D. Hunt, G. Moulzolf

I. General Observations

1. Sample Dimensions: Our analysis was performed on both lapped sides of a 219mm (8 1/2") x 90mm (3 1/2") x 28mm (1 1/8") thick section (in two pieces), a 219mm (8 1/2") x 88mm (3 1/2") x 29mm (1 1/8") thick section (in two pieces), and two 76mm (3") x 52mm (2") wide thin sections that were sawcut and prepared from the original 92mm (3 5/8") diameter x 219mm (8 1/2") long core taken directly through a sawcut joint. The thin sections were located at between 60mm and 136mm depth and 140mm and 216mm depth in the core from the top surface; directly adjacent to the joint surface.

2. Surface Conditions:
   Top: Fairly rough textured and traffic worn surface; exposing many fine and a few coarse aggregate surfaces.
   Bottom: Rough, irregular, formed surface; apparently placed on a natural granular base.

3. Reinforcement: None observed.

4. General Physical Conditions: The core was taken directly through a sealed pavement joint. A silicone joint sealant was fairly well bonded to both sides of the sawcut joint only within a few millimeters of the top surface, within the "meniscus" of the tooled sealant surface. The silicone joint sealant was observed between approximately 1mm and 13mm depth from the top surface of the core. The joint sealant was placed on a foam backer rod. The joint was characterized by a 4mm wide pilot sawcut proceeding 60mm depth from the top surface and an approx. 8mm wide reservoir cut to 30mm depth; with the resulting joint crack proceeding the depth of the core. The joint crack appeared to split into two cracks at 184mm depth resulting in the loss of a section of concrete up to 40mm wide near the bottom surface of the core. No vertical scaling/spalling was observed along the joint crack. The cracked joint plane is characterized by a light brownish gray, somewhat "dirty" surface with some debris lining the joint plane. A thin band of Moderate Yellowish Brown (Munsell® 10YR 5/4) paste was observed within 1mm of the joint crack, occasionally preceded by relatively softer paste adjacent to the joint crack. The joint crack proceeds around most but proceeds through a few coarse aggregate particles. The core exhibits tight residual interlock between the two halves of core along the entire depth of the joint crack. The coarse aggregate appeared sound. No evidence of ASR associated with the coarse aggregate was observed. Abundant alkali-silica "reacted" shale and fine aggregate were present in the core. The "reacted" shale particles exhibit internal cracking that propagates into the paste. Alkali-silica reaction gel was observed lining or filling air voids proximate to the reactive shale particles. One side of the core was fractured sub-horizontally at approx. 85mm and 109mm depth in the core; likely produced during coring or preparation.

   The fairly rough textured top surface of the core exhibits significant traffic wear; topographic highs have been worn smooth with exposed fine and coarse aggregate particles exhibiting worn surfaces. The concrete was fairly well consolidated, with a few consolidation voids measuring up to 10mm in diameter. The concrete was purposefully air entrained and contains a well-distributed air void system considered freeze-thaw resistant under severe exposure conditions. Air void parameters include a 4.5% entrained-sized void volume and a 0.006" spacing factor. Secondary ettringite fills many of the smaller entrained sized voidspaces within a few millimeters of the cracked joint generally below 75mm depth in the core. Void fillings decrease with depth from the joint crack and increase in propensity along the crack plane with depth below 75mm depth.

II. Aggregate

1. Coarse: 25mm (1") nominal sized crushed granitic rock. The coarse aggregate appeared well graded and exhibited good overall distribution.

2. Fine: Natural quartz, feldspar, and lithic sand (granite, chert, carbonates, basalt, siltstone and shale.) The grains were mostly sub-rounded with many smaller sub-angular particles. The fine aggregate appeared fairly graded and exhibited good overall uniform distribution.

III. Cementitious Properties

1. Air Content: 5.9 % total.

2.	Depth of carbonation:	Ranged from 1mm up to 3mm depth from the top surface of the core; spiking to 6mm depth along a sub-vertical microcrack. Carbonation ranged from negligible up 10mm depth from joint crack. Mottled carbonation occurs throughout the depth of the core.
3.	Pozzolan presence:	Flyash was observed.
4.	Paste/aggregate bond:	Fair.
5.	Paste color:	Similar to Medium Light Gray (Munsell® N6) becoming similar to Pale Yellowish Orange (Munsell® 10YR 8/6) within the carbonated areas.
6.	Paste hardness:	Moderately hard (Moh's >3) with a few areas of softer paste (Moh's 2.5) along the joint crack.
7.	Microcracking:	A few sub-vertical drying shrinkage microcracks proceed up to 6mm depth from the top surface of the core.
8.	Secondary deposits:	Secondary ettringite fills many of the smaller entrained sized voidspaces within a few millimeters of the cracked joint generally below 75mm depth in the core. Void fillings decrease with depth from the joint crack and increase in propensity along the crack plane with depth below 75mm depth. ASR gel was observed lining or filling scattered air voids proximate to abundant reactive shale fine aggregate particles.
9.	w/cm:	Estimated at between 0.43 and 0.48 with approximately 3 to 5% residual portland cement clinker particles and an amount of flyash visually consistent with a 10 to 20% replacement of portland cement.
10.	Cement hydration:	Alites: Fully. Belites: Mostly fully.

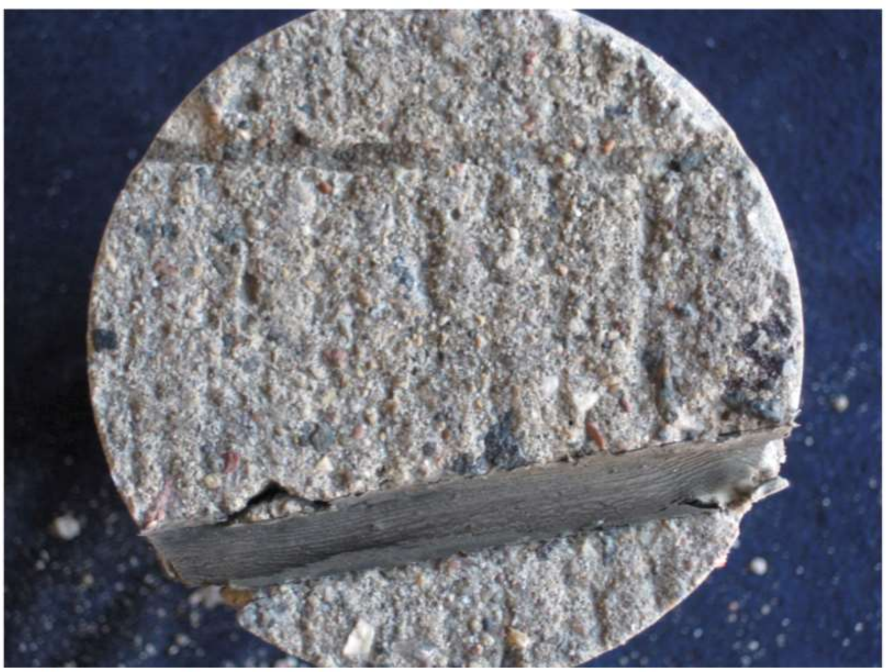
AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 2

PHOTO: 23

SAMPLE ID: 2180-78, 5 **DESCRIPTION:** Jointed core sample utilized for petrographic analysis. The sealed top surface is right.

PHOTO: 24



SAMPLE ID: 2180-78, 5 **DESCRIPTION:** Rough textured top surface of the core with traffic wear. The silicone sealant was fairly well bonded to both sides of the joint.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 2

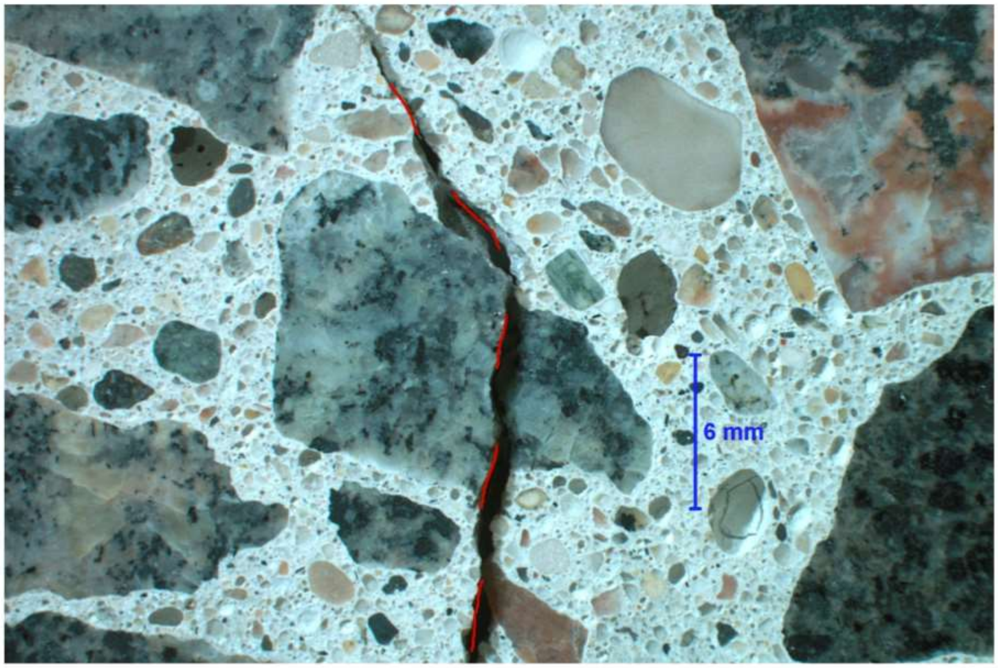
PHOTO:
66

SAMPLE ID: 2180-78, 5 **DESCRIPTION:** Sawcut and lapped cross section of core. The joint crack exhibited no distress. Note joint crack bisects two coarse aggregates in the lower third of the core.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

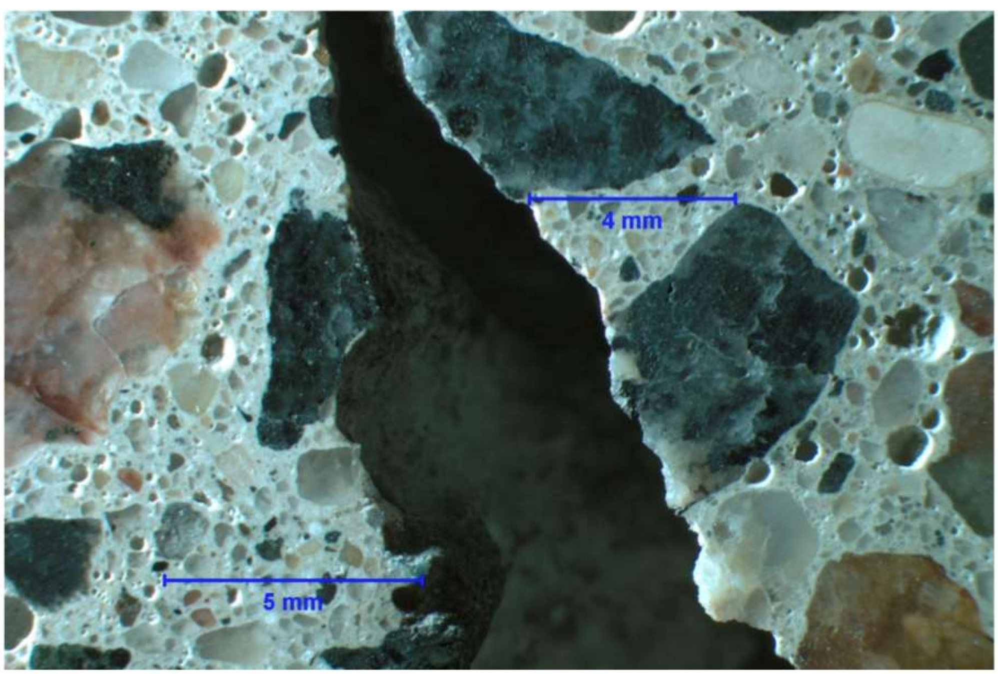
PROJECT: W/CM Study
Phase 2

PHOTO:
108



SAMPLE ID: 2180-78, 5 **DESCRIPTION:** A coarse aggregate was bisected by the joint crack at below 131mm depth from the top surface.
MAG: 5x

PHOTO:
109



SAMPLE ID: 2180-78, 5 **DESCRIPTION:** Significant air loss was documented in the concrete paste directly adjacent to the divergent joint faces at the bottom surface of the core.
MAG: 5x

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 2

PHOTO: 25

SAMPLE ID: 2180-78, 6 **DESCRIPTION:** Mid-panel core sample utilized for rapid chloride permeability testing. The top surface is right.

PHOTO: 26

SAMPLE ID: 2180-78, 6 **DESCRIPTION:** Rough textured top surface of the core with traffic wear.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 2

PHOTO: 27

SAMPLE ID: 2180-78, 7 **DESCRIPTION:** Mid-panel core sample utilized for rapid chloride permeability testing. The top surface is right.

PHOTO: 28

SAMPLE ID: 2180-78, 7 **DESCRIPTION:** Rough textured top surface of the core with traffic wear.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 2

PHOTO: 25

SAMPLE ID: 2180-78, 6 **DESCRIPTION:** Mid-panel core sample utilized for rapid chloride permeability testing. The top surface is right.

PHOTO: 26

SAMPLE ID: 2180-78, 6 **DESCRIPTION:** Rough textured top surface of the core with traffic wear.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 2

PHOTO: 27

SAMPLE ID: 2180-78, 7 **DESCRIPTION:** Mid-panel core sample utilized for rapid chloride permeability testing. The top surface is right.

PHOTO: 28

SAMPLE ID: 2180-78, 7 **DESCRIPTION:** Rough textured top surface of the core with traffic wear.

Field Notes and Petrographic Reports for Project 2180-80, Cores 1, 4

Table A.10. Field notes for SP Number 2180-80, I-94.

Core	Location from Joint	RP	Station	Direction	Lane	Offset	Thickness
1	ON	104.000	3640+55	EB	DR	4.5'	9.750"
2	1.8’	104.000	3640+53	EB	DR	5.0’	9.500”
3	2.0'	105.000	3693+10	EB	DR	5.0'	9.000"
4	ON	105.000	3693+08	EB	DR	4.0'	9.000"
5	2.2'	106.000	3745+60	EB	DR	5.0'	8.750"
6	2.0'	107.000	3798+63	EB	DR	6.0'	8.500"
7	ON	107.000	3798+61	EB	DR	6.0'	4.250"
8	7.2'	108.000	3851+20	EB	DR	5.0'	9.500"
9	1.8'	109.000	3904+02	EB	DR	5.0'	8.750"

00 LAB 001 Petrographic Examination of Hardened Concrete
ASTM: C-856

Project No.	28-00337	Date:	October 24, 2012
Sample ID:	2180-80, 1	Performed by:	D. Hunt, G. Moulzolf

I. General Observations

1. Sample Dimensions: Our analysis was performed on both lapped sides of a 242mm (9 1/2") x 92mm (3 5/8") x 31mm (1 1/4") thick section (in two pieces), a 242mm (9 1/2") x 87mm (3 3/8") x 31mm (1 1/4") thick section (in two pieces), and two 76mm (3") x 52mm (2") wide thin sections that were sawcut and prepared from the original 92mm (3 5/8") diameter x 242mm (9 1/2") long core taken directly through a sawcut joint. The thin sections were located at between 100mm and 176mm depth and 180mm and 242mm depth in the core from the top surface; directly adjacent to the joint surface.

2. Surface Conditions:
   Top: Fairly rough textured and traffic worn surface; exposing many fine and a few coarse aggregate surfaces.
   Bottom: Rough, irregular, formed surface; placed on asphaltic base.

3. Reinforcement: None observed.

4. General Physical Conditions: The core was taken directly through a sealed pavement joint. A silicone joint sealant was well bonded to both sides of the sawcut joint. The silicone joint sealant bond encompasses between approximately 1mm and 17mm depth from the top surface of the core. The joint sealant was placed on a foam backer rod. The joint was characterized by a 5mm wide sawcut proceeding 68mm depth from the top surface and an approx. 10mm wide reservoir cut to 30mm depth; with the resulting joint crack proceeding the depth of the core. No vertical scaling/spalling was observed along the joint crack. The cracked joint plane is characterized by a light brownish gray, somewhat “dirty” surface with some debris lining the joint plane. An intermittent thin band of Moderate Yellowish Brown (Munsell® 10YR 5/4) paste was observed within 1mm of the joint crack. The joint crack proceeds around coarse aggregate particles; as opposed to through them. The core exhibits tight residual interlock between the two halves of core along the entire depth of the joint crack. Two "fresh", coring induced, sub-horizontal fractures were observed between 66mm to 76mm depth from the top surface on one side of the joint crack and 102mm to 110mm depth from the top surface on the other side of the joint crack. The coarse aggregate appeared sound. No evidence of ASR associated with the coarse aggregate was observed. A few alkali-silica “reacted” shale and fine aggregate were present in the core. The “reacted” shale particles exhibit internal cracking that propagates into the paste. Alkali-silica reaction gel was observed lining a few air voids proximate to the reactive shale particles.

   The fairly rough top surface of the core exhibits significant traffic wear; topographic highs have been worn smooth with exposed fine and coarse aggregate particles exhibiting worn surfaces. The concrete was fairly well consolidated with a few irregular shaped consolidation voids measuring up to 14mm in diameter. The concrete was purposefully air entrained and contains a well-distributed air void system considered freeze-thaw resistant under severe exposure conditions. Air void parameters include a 7.2% entrained-sized void volume and a 0.003" spacing factor. Secondary ettringite lines or fills scattered entrained sized voidspaces within a few millimeters of the joint crack plane, generally below 155mm depth in the core; becoming more concentrated within 20mm of the bottom surface of the core. Secondary ettringite presence decreases with depth from the joint crack.

II. Aggregate

1. Coarse: 25mm (1") nominal sized crushed granitic rock with some basalt. The coarse aggregate appeared well graded and exhibited good overall distribution.

2. Fine: Natural quartz, feldspar, and lithic sand (granite, chert, carbonates, basalt, siltstone and shale.) The grains were mostly sub-rounded with many smaller sub-angular particles. The fine aggregate appeared fairly graded and exhibited good overall uniform distribution.

III. Cementitious Properties

1. Air Content: 9.2 % total.
2. Depth of carbonation: Ranged from 2mm up to 5mm depth from the top surface of the core. Carbonation ranged from 1mm up 4mm depth from joint crack.

3. Pozzolan presence: Flyash was observed.
4. Paste/aggregate bond: Fair.
5. Paste color: Similar to Medium Light Gray (Munsell® N6)
6. Paste hardness: Moderately hard (Moh's >3) with a few areas of softer paste (Moh's 2.5) along the joint crack.
7. Microcracking: Few, fine sub-vertical drying shrinkage microcracks proceed up to 7mm depth from the top surface of the core. Internal microcracking of reactive shale particles propagates into the surrounding paste.
8. Secondary deposits: Secondary ettringite lines or fills scattered entrained sized voidspaces within a few millimeters of the joint crack plane, generally below 155mm depth in the core; becoming more concentrated within 20mm of the bottom surface of the core. Secondary ettringite presence decreases with depth from the joint crack. ASR gel was observed lining a few air voids proximate to reactive shale fine aggregate particles.
9. w/cm: Estimated at between 0.34 and 0.39 with approximately 9 to 11% residual portland cement clinker particles and an amount of flyash visually consistent with a 10 to 20% replacement of portland cement.
10. Cement hydration: Alites: Well.
    Belites: Moderate to low.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 2

PHOTO: 29

SAMPLE ID: 2180-80, 1 **DESCRIPTION:** Jointed core sample utilized for petrographic analysis. The sealed top surface is right.

PHOTO: 30

SAMPLE ID: 2180-80, 1 **DESCRIPTION:** Rough textured top surface of the core with traffic wear. The silicone sealant was fairly well-bonded to both sides of the joint.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 2

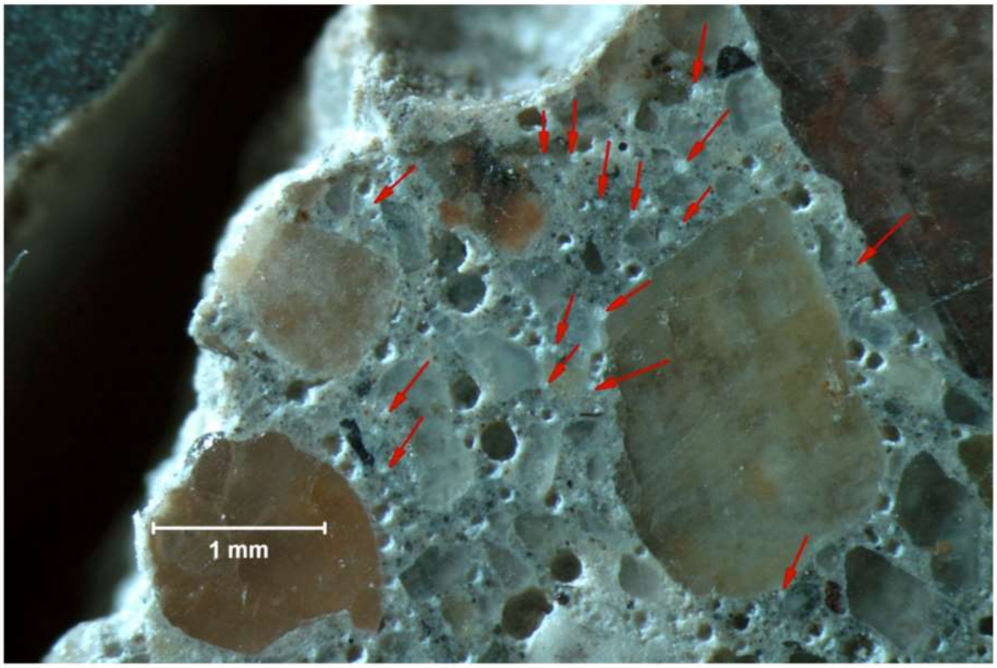
PHOTO:
67

SAMPLE ID: 2180-80, 1 **DESCRIPTION:** Sawcut and lapped cross section of core. The joint crack exhibited no distress. Sub-horizontal fractures are mapped in red ink.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

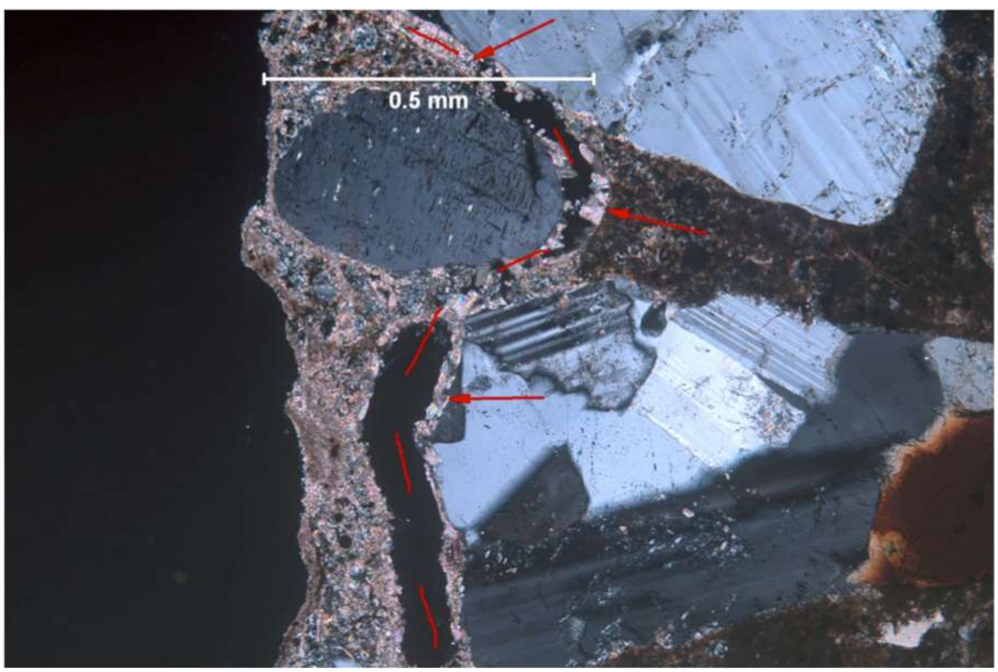
PROJECT: W/CM Study
Phase 2

PHOTO:
110



SAMPLE ID: 2180-80, 1 **DESCRIPTION:** Much of the entrained air voidspaces within a few mm of the joint face at 222mm depth in the core are filled with secondary ettringite.
MAG: 30x

PHOTO:
111



SAMPLE ID: 2180-80, 1 **DESCRIPTION:** A sub-vertical microcrack in brightly colored, carbonated paste along the joint face; is mapped in red dashed line. Note secondary calcite crystals lining the microcrack (arrows).
MAG: 40x

00 LAB 001 Petrographic Examination of Hardened Concrete
ASTM: C-856

Project No.	28-00337	Date:	August 28, 2012
Sample ID:	2180-80, 4	Performed by:	D. Hunt, G. Moulzolf

I. General Observations

1. Sample Dimensions: Our analysis was performed on both lapped sides of a 230mm (9") x 90mm (3 1/2") x 25mm (1") thick section (in two pieces), a 230mm (9") x 90mm (3 1/2") x 33mm (1 1/4") thick section (in two pieces), and two 76mm (3") x 52mm (2") wide thin sections that were sawcut and prepared from the original 95mm (3 3/4") diameter x 230mm (9") long core taken directly through a distressed sawcut joint. The thin sections were located at between 76mm and 150mm depth and 153mm and 229mm depth in the core from the top surface; directly adjacent to the distressed joint surface.

2. Surface Conditions:
   Top: Fairly rough textured and traffic worn surface; exposing many fine aggregate surfaces.
   Bottom: Rough, irregular, formed surface; apparently placed upon a granular base.

3. Reinforcement: None observed.

4. General Physical Conditions: The core was taken directly through a sealed pavement joint. The silicone joint sealant was de-bonded from both sides of the sawcut joint. Continuous, well adhered, remnant "strips" of the silicone joint sealant were observed on both sides of the sawcut joint between the top surface and approximately 8mm depth into the joint. The joint sealer was placed upon a 12mm diameter foam backer rod. The joint was characterized by an approx. 5mm wide pilot sawcut proceeding 60mm depth from the top surface and an approx. 10mm wide reservoir cut to 31mm depth; with the resulting joint crack proceeding the depth of the core. The joint crack proceeds through several coarse aggregates; as opposed to around them. Vertical scaling/spalling occurs along a portion of the sawcut joint beginning at as shallow as 40mm depth from the top surface. An up to approximately 5mm loss of concrete was observed along the sawcut joint surface between 40mm and 60mm depths from the top surface. In general, the widest loss of concrete, of at least 10mm, occurs between 60mm and 70mm depth (developing "tunneling"). Abundant sub-vertical microcracks (incipient spalling) were observed, generally within the paste-only, within 3mm of the distressed joint surface; below the sawcut joint. The cracked joint plane is characterized by several relatively “clean” and un-distressed coarse aggregates protruding from the concrete joint. The core exhibits significant residual interlock between the two halves of core below 85mm depth. The coarse aggregate appeared sound. No evidence of ASR associated with the coarse aggregate was observed. Numerous alkali-silica “reacted” shale and chert fine aggregate were present in the core. The “reacted” shale particles exhibit internal cracking that propagates into the paste. Alkali-silica reaction gel was observed partially lining to filling a few air voids proximate to the reactive shale and chert particles.

   The fairly rough textured top surface of the core exhibits significant traffic wear; topographic highs have been worn smooth with exposed fine and coarse aggregate particles exhibiting worn surfaces. The concrete was fairly well consolidated, with a few relatively large voidspaces observed up to 22mm in diameter in the core. The concrete was purposefully air entrained and contains a well-distributed air void system considered freeze-thaw resistant under severe exposure conditions. Air void parameters include a 7.4% entrained-sized void volume and a 0.004" spacing factor. Secondary ettringite fills most of the finest entrained-sized voidspaces generally within 12mm of the joint crack plane; below 45mm depth in the joint. Void fillings decrease greatly with further depth from the joint crack.

II. Aggregate

1. Coarse: 25mm (1") nominal sized crushed granite. The coarse aggregate appeared well graded and exhibited good overall distribution.

2. Fine: Natural quartz, feldspar, and lithic sand (granite, chert, carbonates, basalt, siltstone and shale.) The grains were mostly sub-rounded with many smaller sub-angular particles. The fine aggregate appeared fairly graded and exhibited good overall uniform distribution.

III. Cementitious Properties

1. Air Content: 9.8% total.

2.	Depth of carbonation:	Ranged from 3mm up to 8mm depth from the top surface of the core. Carbonation ranged from 2mm up 5mm depth from joint crack.
3.	Pozzolan presence:	Flyash was observed.
4.	Paste/aggregate bond:	Fair.
5.	Paste color:	Similar to Medium Gray (Munsell® N5)
6.	Paste hardness:	Moderately hard (Moh's >3)
7.	Microcracking:	A few sub-vertical microcracks (incipient spalling) were observed generally within the paste-only and within 3mm of the distressed joint surface below the sawcut joint.
8.	Secondary deposits:	Secondary ettringite fills most of the finest entrained-sized voidspaces generally within 12mm of the joint crack plane; below 45mm depth in the core. Void fillings decrease greatly with further depth from the joint crack. ASR gel was observed filling to partially lining a few air voids proximate to reactive shale and chert fine aggregate particles.
9.	w/cm:	Estimated at between 0.35 and 0.40 with approximately 8 to 10% residual portland cement clinker particles and an amount of flyash visually consistent with a 10 to 20% replacement of portland cement.
10.	Cement hydration:	Alites: Well Belites: Moderate to low.

PHOTO: 33

SAMPLE ID: 2180-80, 4 **DESCRIPTION:** Jointed core sample utilized for petrographic analysis. The top surface is right. Note "tunneling" (mass lost) at base of sawcut.

PHOTO: 34

SAMPLE ID: 2180-80, 4 **DESCRIPTION:** Rough textured top surface of the jointed core with traffic wear. The silicone sealant had been forcibly de-bonded from both sides of the joint.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 2

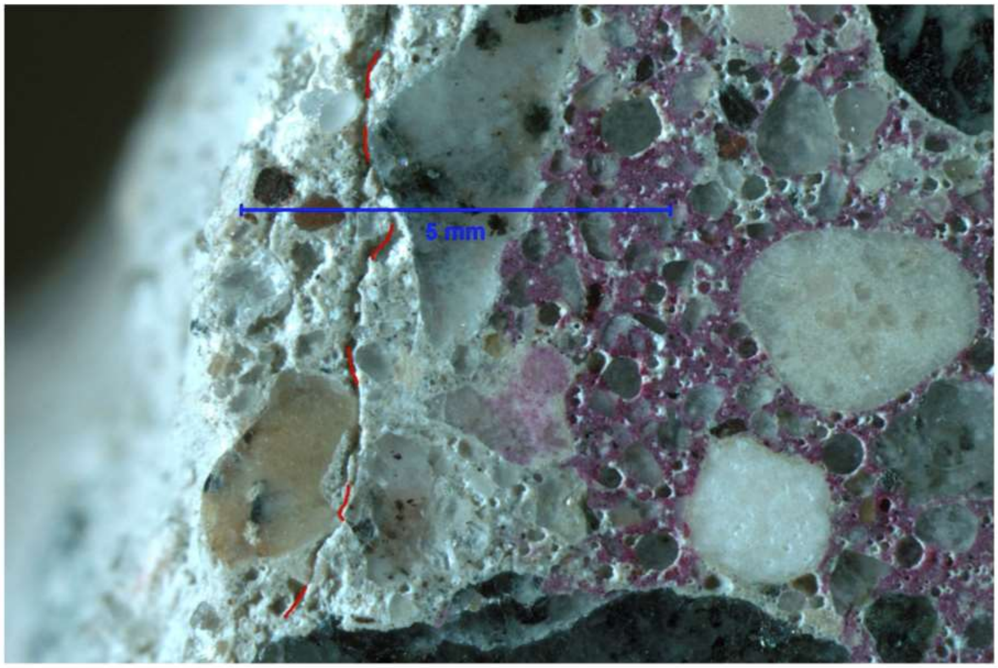
PHOTO:
68

SAMPLE ID: 2180-80, 4 **DESCRIPTION:** Sawcut and lapped cross section of core. The joint crack exhibited some mass loss and incipient distress mapped in red ink. Sub-horizontal fractures are also mapped in thicker red ink.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

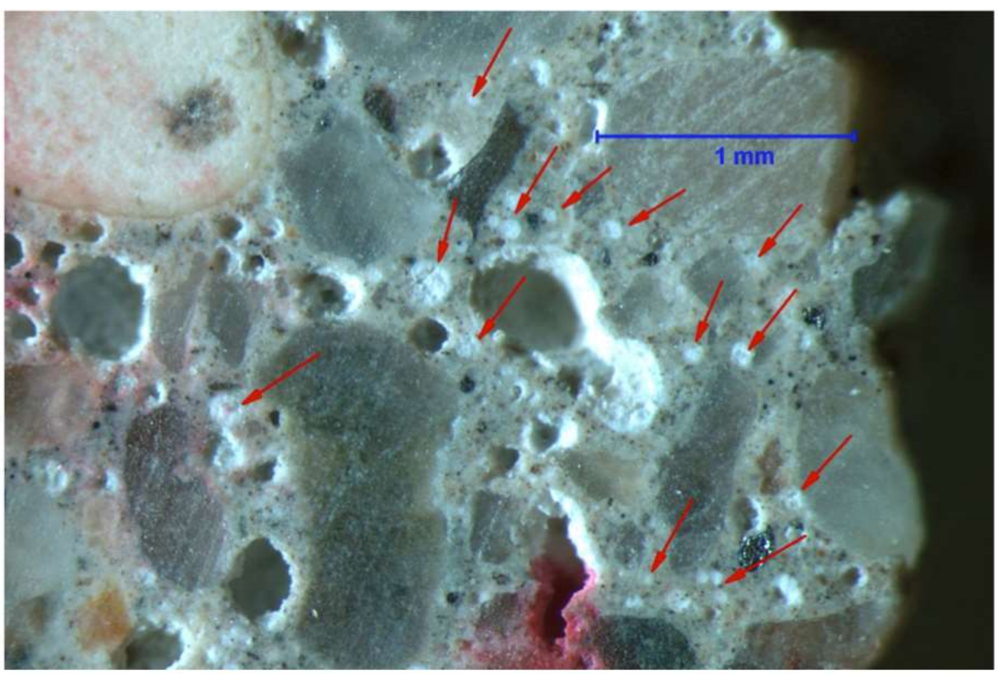
PROJECT: W/CM Study
Phase 2

PHOTO:
112



SAMPLE ID: 2180-80, 4 **DESCRIPTION:** Much of the entrained air voidspaces within a few mm of the joint face at 145mm depth in the core are filled with secondary ettringite.
MAG: 15x

PHOTO:
113

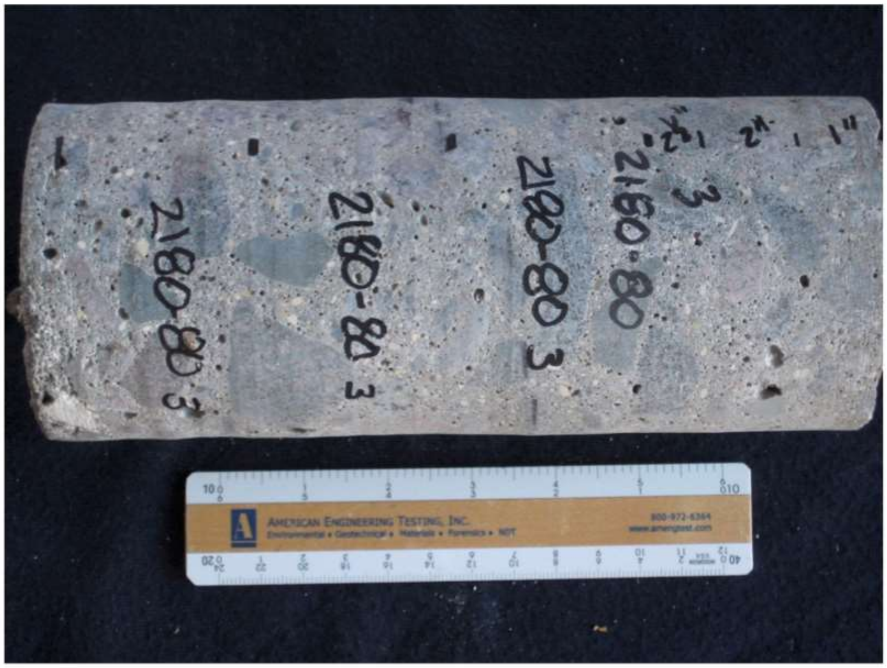


SAMPLE ID: 2180-80, 4 **DESCRIPTION:** Secondary ettringite-filled entrained sized voidspaces in the paste within a few millimeters of the distressed joint face (right) at 210mm depth in the core.
MAG: 50x

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

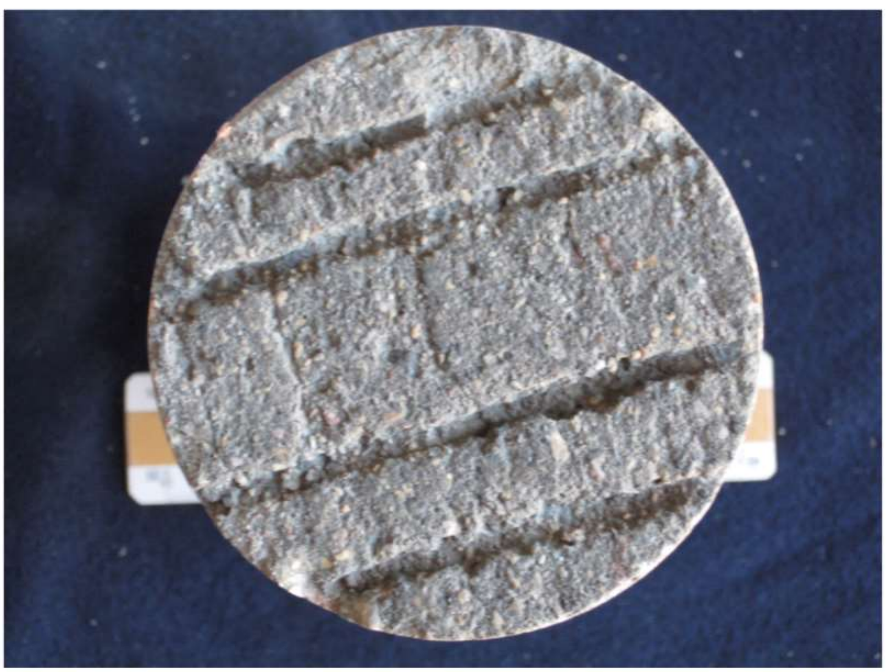
PROJECT: W/CM Study
Phase 2

PHOTO: 31



SAMPLE ID: 2180-80, 3 **DESCRIPTION:** Jointed core sample utilized for rapid chloride permeability testing. The top surface is right.

PHOTO: 32

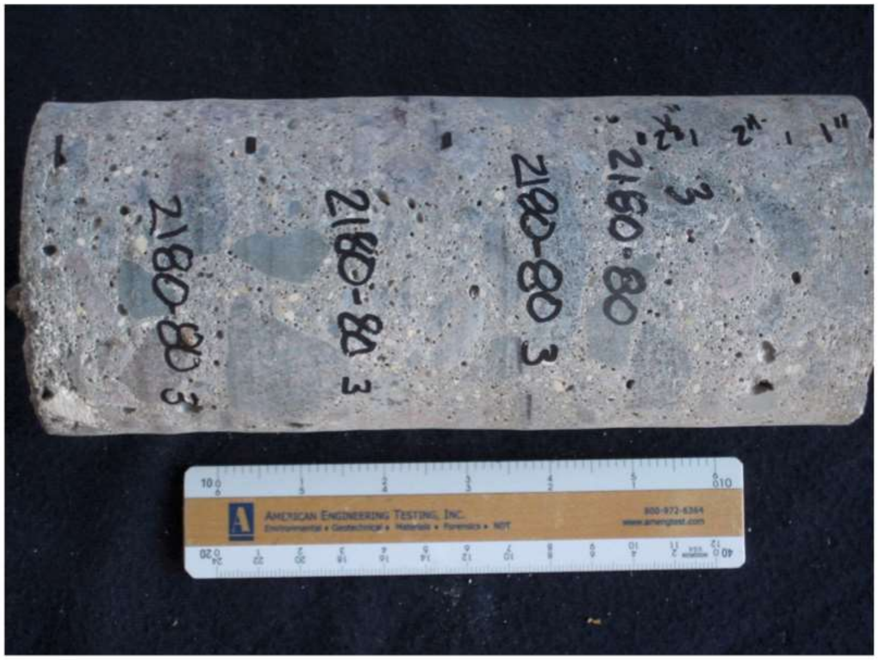


SAMPLE ID: 2180-80, 3 **DESCRIPTION:** Rough textured top surface of the core with traffic wear. The silicone sealant was fairly well bonded to both sides of the joint.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

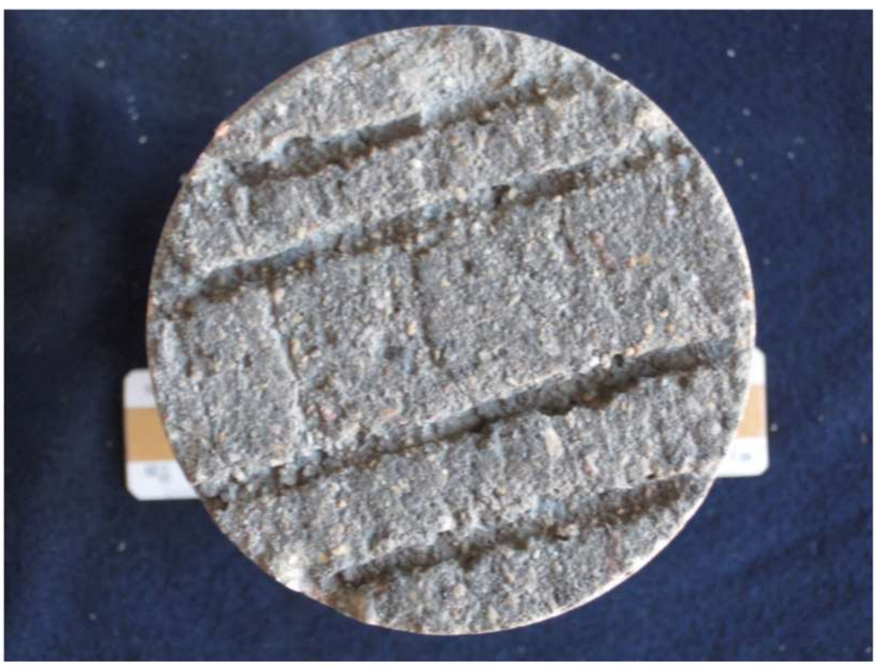
PROJECT: W/CM Study
Phase 2

PHOTO: 31



SAMPLE ID: 2180-80, 3 **DESCRIPTION:** Jointed core sample utilized for rapid chloride permeability testing. The top surface is right.

PHOTO: 32



SAMPLE ID: 2180-80, 3 **DESCRIPTION:** Rough textured top surface of the core with traffic wear. The silicone sealant was fairly well bonded to both sides of the joint.

Field Notes and Petrographic Reports for Project 5680-111, Core 4

Table A.11. Field notes for SP Number 5680-111, I-94.

Core	Location from Joint	RP	Station	Direction	Lane	Offset	Thickness
1	ON	49.000	738+44	WB	DR	-6.0'	7.000"
2	2.5'	49.000	738+78	WB	DR	-6.0'	10.750"
3	2.0'	47.000	633+31	WB	DR	-7.0'	11.250"
4	ON	47.000	632+90	WB	DR	-6.0'	11.750"
5	2.0'	45.000	527+85	WB	DR	-6.0'	11.500"
6	ON	45.000	527+41	WB	DR	-6.0'	11.250"
7	2.5'	43.000	421+80	WB	DR	-6.0'	11.000"
8	2.0'	41.000	316+25	WB	DR	-6.5'	11.000"
9	2.3'	39.000	238+38	WB	DR	-6.0'	11.000"

00 LAB 001 Petrographic Examination of Hardened Concrete
ASTM: C-856

Project No.	28-00337	Date:	October 29, 2012
Sample ID:	5680-111, 4	Performed by:	D. Hunt, G. Moulzolf

I. General Observations

1. Sample Dimensions: Our analysis was performed on both lapped sides of a 305mm (12") x 93mm (3 5/8")x 28mm (1 1/8") thick section (in two pieces), a 305mm (12") x 91mm (3 5/8") x 36mm (1 3/8") thick section (in two pieces), and two 76mm (3") x 52mm (2") wide thin sections that were sawcut and prepared from the original 95mm (3 3/4") diameter x 305mm (12") long core taken directly through a sawcut joint. The thin sections were located at between 85mm and 161mm depth and 190mm and 276mm depth in the core from the top surface; directly adjacent to the joint surface.

2. Surface Conditions:
   Top: Fairly rough, mortar eroded/traffic worn surface; exposing many fine and a few coarse aggregate surfaces.
   Bottom: Rough, irregular, formed surface; placed on a (cement stabilized?) granular base.

3. Reinforcement: None observed.

4. General Physical Conditions: The core was taken directly through a sealed pavement joint. The silicone joint sealant was fairly well bonded to one side of the sawcut joint, but mostly in the thin tooled "meniscus" in the sealant. The silicone joint sealant was placed between approximately 1mm and 15mm depth from the top surface of the core. The sealant was fully de-bonded from the opposite side; torn from its partly bonded meniscus still adhered to the sawcut joint face. The joint sealant was placed upon a foam backer rod. The joint was characterized by a 5mm wide pilot sawcut proceeding 80mm depth from the top surface and an approx. 10mm wide reservoir cut to 30mm depth; with the resulting joint crack proceeding the depth of the core. Several sub-vertical microcracks (incipient spalling), observed in the paste and some carbonate aggregates, occur between 70mm and 305mm depth in the cracked joint surface and within 3mm of the joint plane. Distress, in the form of mass lost, generally incorporates up to 4mm of total concrete between the two sides of the joint crack below 130mm depth in the core. The joint plane is characterized by numerous relatively "clean" and un-distressed coarse aggregate particles protruding from the concrete joint. The widest loss of concrete, between 10mm and 18mm in width, (tunneling) occurs between 90mm and 130mm depth in the concrete from the top surface. The joint crack generally proceeds around coarse aggregate particles; but does bisect a few at depth in the core. The core exhibits residual interlock between the two halves of core below 135mm depth from the top surface. The coarse aggregate appeared sound. No evidence of ASR associated with the coarse aggregate was observed. A few alkali-silica "reacted" shale fine aggregates were present in the core. The "reacted" shale particles exhibit internal cracking that propagates into the paste. Alkali-silica reaction gel was observed lining a few air voids proximate to the reactive shale particles.

   The fairly rough top surface of the core exhibits significant mortar erosion/traffic wear; topographic highs have been worn smooth with exposed fine and coarse aggregate particles exhibiting worn surfaces. The concrete was fairly well consolidated, with a few consolidation voids measuring up to 10mm in diameter. The concrete was purposefully air entrained and contains a well-distributed air void system considered freeze-thaw resistant under severe exposure conditions. Air void parameters include a 5.6% entrained-sized void volume and a 0.004" spacing factor. Secondary ettringite fills much of the entrained sized voidspaces within 5mm of the joint plane; below 35mm depth in the core. Void fillings decrease with depth from the distressed joint faces.

II. Aggregate

1. Coarse: 38mm (1 1/2") nominal sized glacial gravel consisting predominately of granite, carbonates, chert, basalt, and rhyolite. The coarse aggregate was of Des Moines lobe glacial outwash. The coarse aggregate appeared well graded and exhibited good overall distribution.

2. Fine: Natural quartz, feldspar, and lithic sand (granite, chert, carbonates, basalt, siltstone and shale.) The grains were mostly sub-rounded with many smaller sub-angular particles. The fine aggregate appeared fairly graded and exhibited good overall uniform distribution.

III. Cementitious Properties

1. Air Content:	7.6 % total.
2. Depth of carbonation:	Ranged from mostly negligible up to 2mm depth from the top surface of the core. Carbonation ranged from negligible up 5mm depth from joint crack.
3. Pozzolan presence:	Flyash was observed.
4. Paste/aggregate bond:	Fair.
5. Paste color:	Similar to Medium Light Gray (Munsell® N6).
6. Paste hardness:	Moderately hard (Moh's >3) with a few areas of softer paste (Moh's 2.5) along the joint crack.
7. Microcracking:	Several sub-vertical microcracks (incipient scaling/spalling) were observed within 4mm of the joint crack and between 70mm and 305mm depth in the joint. An area of concentrated sub-vertical microcracks was observed along the joint between approx. 70mm and 105mm depth from the top surface. Few, reactive, shale particles exhibit internal cracking that propagates into the paste. A few sub-vertical drying shrinkage microcracks proceed up to 2mm depth from the top surface of the core.
8. Secondary deposits:	Secondary ettringite fills many of the smaller entrained sized voidspaces within 5mm of the distressed joint plane and 35mm depth in the core. Void fillings decrease with depth from the distressed joint faces. ASR gel was observed lining air voids proximate to few reactive shale fine aggregate particles.
9. w/cm:	Estimated at between 0.36 and 0.41 with approximately 7 to 9% residual portland cement clinker particles and an amount of flyash visually consistent with a 15 to 25% replacement of portland cement.
10. Cement hydration:	Alites: Well to fully. Belites: Well.

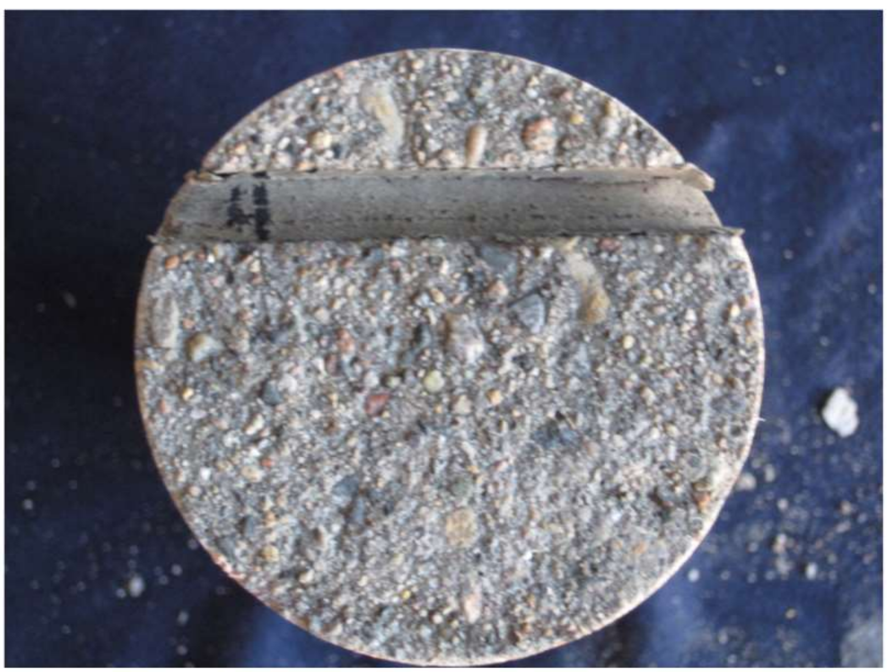
AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 2

PHOTO: 37

SAMPLE ID: 5680-111, 4 **DESCRIPTION:** Jointed core sample subjected to petrographic analysis. The silicone sealed top surface is right. Note "tunneling" directly below the base of the sawcut.

PHOTO: 38



SAMPLE ID: 5680-111, 4 **DESCRIPTION:** Rough textured and mortar-eroded top surface of the core. The silicone sealant was well adhered to one side of the joint, only.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 2

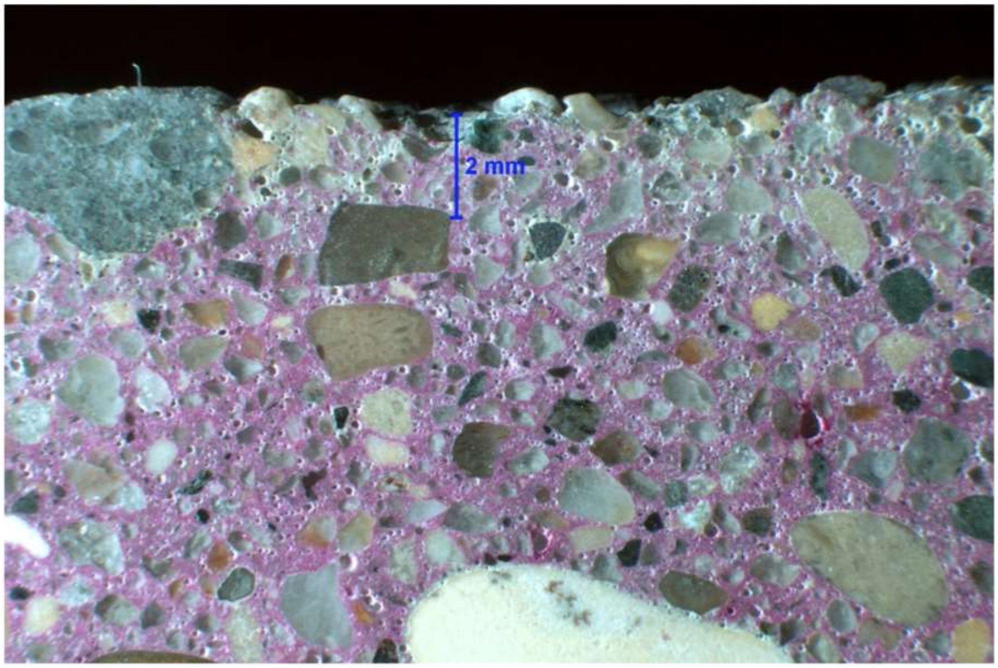
PHOTO:
69

SAMPLE ID: 5680-111, 4 **DESCRIPTION:** Sawcut and lapped cross section of core. The joint crack exhibited "tunneling" around the base of the sawcut.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

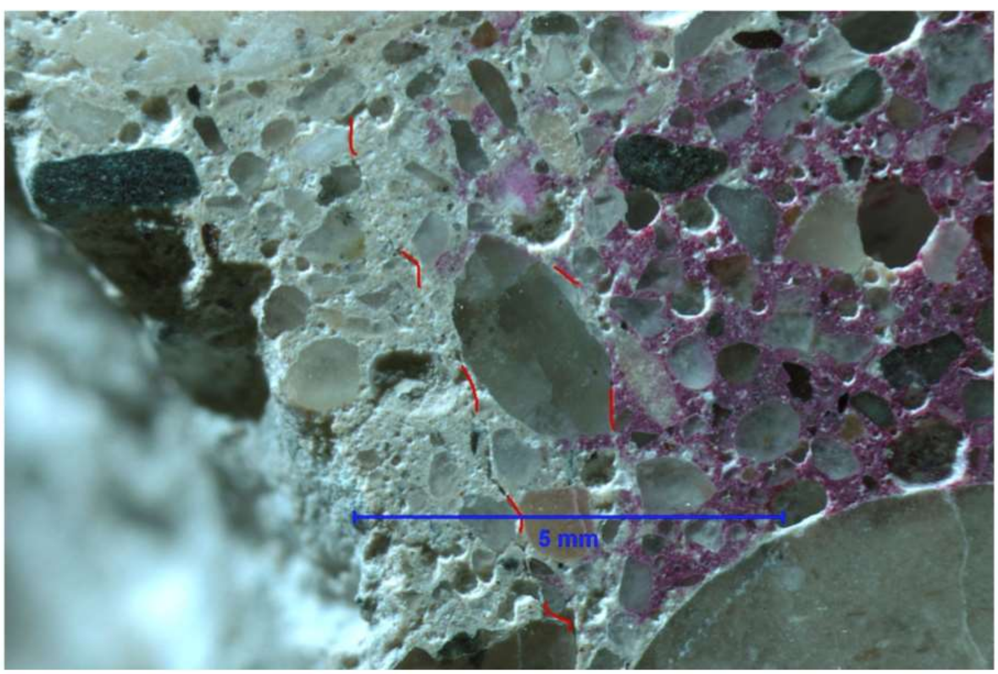
PROJECT: W/CM Study
Phase 2

PHOTO:
114



SAMPLE ID: 5680-111, 4 **DESCRIPTION:** Carbonation (unstained paste) ranged from negligible up to 2mm depth from the top surface.
MAG: 5x

PHOTO:
115

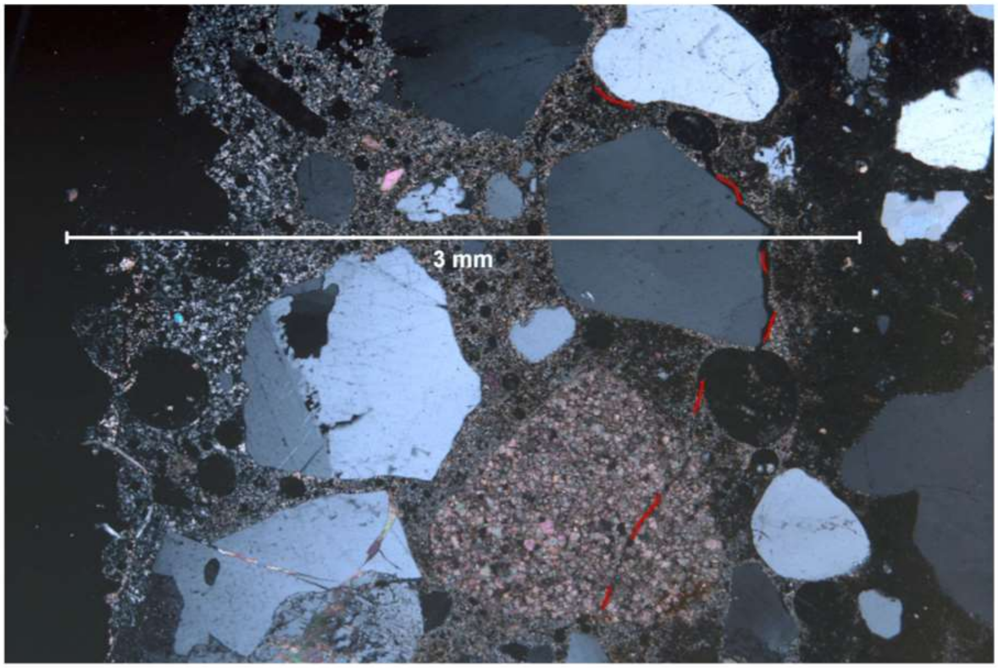


SAMPLE ID: 5680-111, 4 **DESCRIPTION:** Secondary ettringite-filled entrained sized voidspaces in the paste within a several millimeters of the distressed joint face (left) at 228mm depth in the core.
MAG: 15x

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

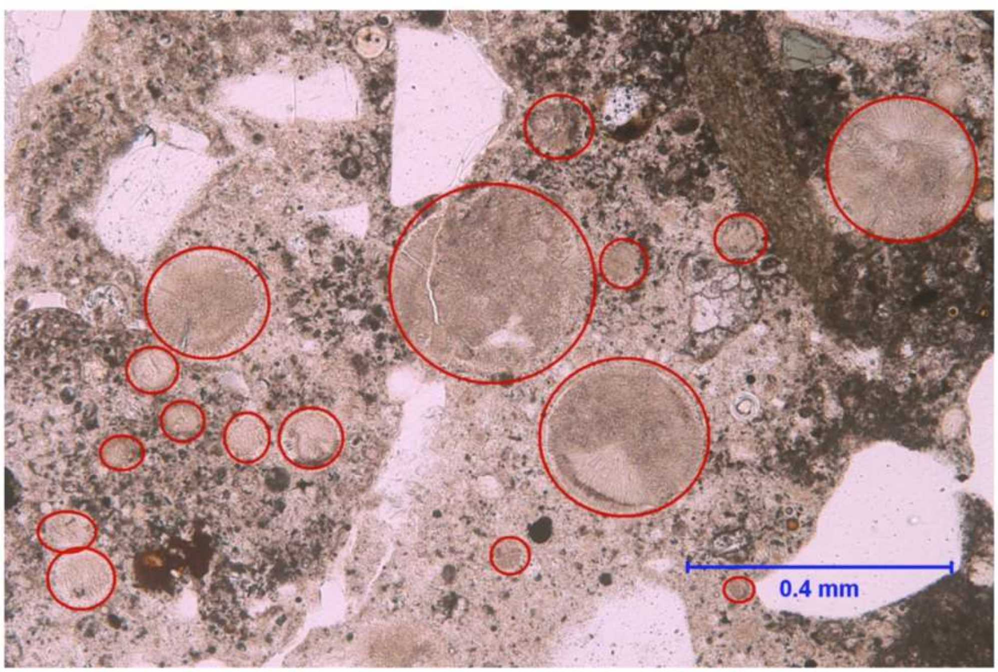
PROJECT: W/CM Study
Phase 2

PHOTO:
116



SAMPLE ID: 5680-111, 4 **DESCRIPTION:** Carbonation (brightly colored paste) proceeded to 3mm depth from the joint surface (left); in thin section under cross polarized light. Sub-vertical, incipient spalling is mapped in red dashed line.
MAG: 40x

PHOTO:
117



SAMPLE ID: 5680-111, 4 **DESCRIPTION:** Secondary ettringite-filled entrained sized voidspaces in the paste within 3mm of the distressed joint face; in thin section under plane polarized light, at mid-depth in the core.
MAG: 100x

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 2

PHOTO: 35

SAMPLE ID: 5680-111, 3 **DESCRIPTION:** Mid-panel core sample held from analysis. The top surface is right.

PHOTO: 36

SAMPLE ID: 5680-111, 3 **DESCRIPTION:** Rough textured and mortar-eroded top surface of the core.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 2

PHOTO: 39

SAMPLE ID: 5680-111, 5 **DESCRIPTION:** Mid-panel core sample subjected to rapid chloride permeability testing. The top surface is right.

PHOTO: 40

SAMPLE ID: 5680-111, 5 **DESCRIPTION:** Rough textured and mortar-eroded top surface of the core.

Field Notes and Petrographic Reports for Project 8480-26, Cores 1, 4, 5

Table A.12. Field notes for SP Number 8480-26, I-94.

Core	Location from Joint	RP	Station	Direction	Lane	Offset	Thickness
1	ON	30.000	1883+35	EB	DR	-6.0'	10.500"
2	2.0'	30.000	1883+33	EB	DR	-6.0'	10.000"
3	2.0'	32.000	1989+00	EB	DR	-5.0'	10.500"
4	ON	32.000	1989+02	EB	DR	-5.0'	10.500"
5	ON	34.000	2094+72	EB	DR	-5.0'	10.500"
6	2.0'	34.000	2097+70	EB	DR	-5.0'	10.750"
7	2.0'	35.000	2147+54	EB	DR	-4.5'	10.000"
8	2.0'	36.000	2200+13	EB	DR	-5.0'	10.500"
9	2.5'	37.000	2252+63	EB	DR	-6.0'	10.250"

00 LAB 001 Petrographic Examination of Hardened Concrete
ASTM: C-856

Project No.	28-00337	Date:	October 25, 2012
Sample ID:	8480-26, 1	Performed by:	D. Hunt, G. Moulzolf

I. General Observations

1. Sample Dimensions: Our analysis was performed on both lapped sides of a 260mm (10 1/4") x 90mm (3 1/2") x 25mm (1") thick section (in two pieces), a 260mm (10 1/4") x 85mm (3 3/8 ") x 30mm (1 1/4") thick section (in two pieces), and three 76mm (3") x 52mm (2") wide thin sections that were sawcut and prepared from the original 90mm (3 1/2") diameter x 260mm (10 1/4") long core taken directly through a severely distressed sawcut joint. The thin sections were located at between 65mm and 140mm depth, 170mm and 245mm depth in the core from the top surface; directly adjacent to the severely distressed joint surface.

2. Surface Conditions:
   Top: Rough textured, and mortar eroded/traffic worn surface; exposing many fine aggregate surfaces.
   Bottom: Rough, irregular, formed surface; placed on base.

3. Reinforcement: None observed.

4. General Physical Conditions: The core was taken directly through a severely distressed pavement joint. The silicone joint sealant was generally well bonded to both sides of the sawcut joint between 1mm and up to 15mm depth from the top surface. The joint sealer was placed on a foam backer rod. The joint was characterized by an approx. 4mm wide pilot sawcut to 64mm depth from the top surface and an approx. 9mm wide reservoir cut to 30mm depth; with the resulting joint crack proceeding the depth of the core. Vertical scaling/spalling begins along the sawcut joint at approx. 49mm depth. A maximum of approximately 20mm of mass loss occurs along the joint between 50mm and 85mm depth from the top surface. Thinner paste loss (<10mm) with some residual interlock between the core halves occurs along the remainder of the joint crack. Several sub-vertical microcracks (incipient spalling) were observed generally within the paste-only and within 7mm of the distressed joint surface below 37mm depth from the top surface of the core. The cracked joint plane is characterized by several relatively "clean" and un-distressed coarse aggregates protruding from the concrete joint. Three sub-horizontal fractures of unclear origin were observed at approx. 70mm and 190mm depth along one side of the core and approx. 150mm depth on the other side of the core. The coarse aggregate appeared hard, sound, and durable. No evidence of alkali silica reaction (ASR) associated with the coarse aggregate was observed. Abundant alkali-silica "reacted" shale fine aggregate particles were present in the core. The "reacted" shale particles exhibit internal cracking that propagates into the paste. ASR gel was observed lining to partially filling a few air voids proximate to the reactive shale particles

   The fairly rough top surface of the core exhibits traffic wear with some topographic highs worn smooth, exposing many fine aggregate surfaces. The concrete was fairly consolidated, with voidspaces observed in up to 17mm in size. Many sub-horizontally elongated voidspaces were observed between 22mm and 145mm depth from the top surface. The concrete was purposefully air entrained and originally contained an air void system considered freeze-thaw resistant under severe exposure conditions. Original air void parameters include a 7.5% entrained-sized void volume and a 0.004" spacing factor. Secondary ettringite fills many of the finer entrained sized voidspaces within approx. 4mm of the cracked joint; below 18mm depth into the joint. Void fillings gradually decrease with depth from the joint crack plane. The air void system within the top approx. 25mm of the core was significantly finer than the remainder of the concrete.

II. Aggregate

1. Coarse: 38mm (1 1/2") nominal sized gravel consisting predominately of carbonates, chert, basalt, and granite. The coarse aggregate was of Des Moines glacial lobe outwash. The coarse aggregate appeared well graded and exhibited good overall distribution.

2. Fine: Natural quartz, feldspar, and lithic sand (granite, chert, carbonates, basalt, siltstone and shale.) The grains were mostly sub-rounded with many smaller sub-angular particles. The fine aggregate appeared fairly graded and exhibited good overall uniform distribution.

00 LAB 001 Petrographic Examination of Hardened Concrete
ASTM: C-856

Project No.	28-00337	Date:	October 25, 2012
Sample ID:	8480-26, 1	Performed by:	D. Hunt, G. Moulzolf

I. General Observations

1. Sample Dimensions: Our analysis was performed on both lapped sides of a 260mm (10 1/4") x 90mm (3 1/2") x 25mm (1") thick section (in two pieces), a 260mm (10 1/4") x 85mm (3 3/8 ") x 30mm (1 1/4") thick section (in two pieces), and three 76mm (3") x 52mm (2") wide thin sections that were sawcut and prepared from the original 90mm (3 1/2") diameter x 260mm (10 1/4") long core taken directly through a severely distressed sawcut joint. The thin sections were located at between 65mm and 140mm depth, 170mm and 245mm depth in the core from the top surface; directly adjacent to the severely distressed joint surface.

2. Surface Conditions:
   Top: Rough textured, and mortar eroded/traffic worn surface; exposing many fine aggregate surfaces.
   Bottom: Rough, irregular, formed surface; placed on base.

3. Reinforcement: None observed.

4. General Physical Conditions: The core was taken directly through a severely distressed pavement joint. The silicone joint sealant was generally well bonded to both sides of the sawcut joint between 1mm and up to 15mm depth from the top surface. The joint sealer was placed on a foam backer rod. The joint was characterized by an approx. 4mm wide pilot sawcut to 64mm depth from the top surface and an approx. 9mm wide reservoir cut to 30mm depth; with the resulting joint crack proceeding the depth of the core. Vertical scaling/spalling begins along the sawcut joint at approx. 49mm depth. A maximum of approximately 20mm of mass loss occurs along the joint between 50mm and 85mm depth from the top surface. Thinner paste loss (<10mm) with some residual interlock between the core halves occurs along the remainder of the joint crack. Several sub-vertical microcracks (incipient spalling) were observed generally within the paste-only and within 7mm of the distressed joint surface below 37mm depth from the top surface of the core. The cracked joint plane is characterized by several relatively "clean" and un-distressed coarse aggregates protruding from the concrete joint. Three sub-horizontal fractures of unclear origin were observed at approx. 70mm and 190mm depth along one side of the core and approx. 150mm depth on the other side of the core. The coarse aggregate appeared hard, sound, and durable. No evidence of alkali silica reaction (ASR) associated with the coarse aggregate was observed. Abundant alkali-silica "reacted" shale fine aggregate particles were present in the core. The "reacted" shale particles exhibit internal cracking that propagates into the paste. ASR gel was observed lining to partially filling a few air voids proximate to the reactive shale particles

   The fairly rough top surface of the core exhibits traffic wear with some topographic highs worn smooth, exposing many fine aggregate surfaces. The concrete was fairly consolidated, with voidspaces observed in up to 17mm in size. Many sub-horizontally elongated voidspaces were observed between 22mm and 145mm depth from the top surface. The concrete was purposefully air entrained and originally contained an air void system considered freeze-thaw resistant under severe exposure conditions. Original air void parameters include a 7.5% entrained-sized void volume and a 0.004" spacing factor. Secondary ettringite fills many of the finer entrained sized voidspaces within approx. 4mm of the cracked joint; below 18mm depth into the joint. Void fillings gradually decrease with depth from the joint crack plane. The air void system within the top approx. 25mm of the core was significantly finer than the remainder of the concrete.

II. Aggregate

1. Coarse: 38mm (1 1/2") nominal sized gravel consisting predominately of carbonates, chert, basalt, and granite. The coarse aggregate was of Des Moines glacial lobe outwash. The coarse aggregate appeared well graded and exhibited good overall distribution.

2. Fine: Natural quartz, feldspar, and lithic sand (granite, chert, carbonates, basalt, siltstone and shale.) The grains were mostly sub-rounded with many smaller sub-angular particles. The fine aggregate appeared fairly graded and exhibited good overall uniform distribution.

AET PROJECT NO: 28-00337 DATE: December 31, 2012

PROJECT: W/CM Study
Phase 2

PHOTO: 41

SAMPLE ID: 8480-26, 1 **DESCRIPTION:** Jointed core sample subjected to petrographic analysis. The silicone sealed top surface is right. Note "tunneling" directly below the base of the sawcut.

PHOTO: 42

SAMPLE ID: 8480-26, 1 **DESCRIPTION:** Rough textured and mortar-eroded top surface of the core. The silicone sealant was well adhered to one side of the joint, only.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 2

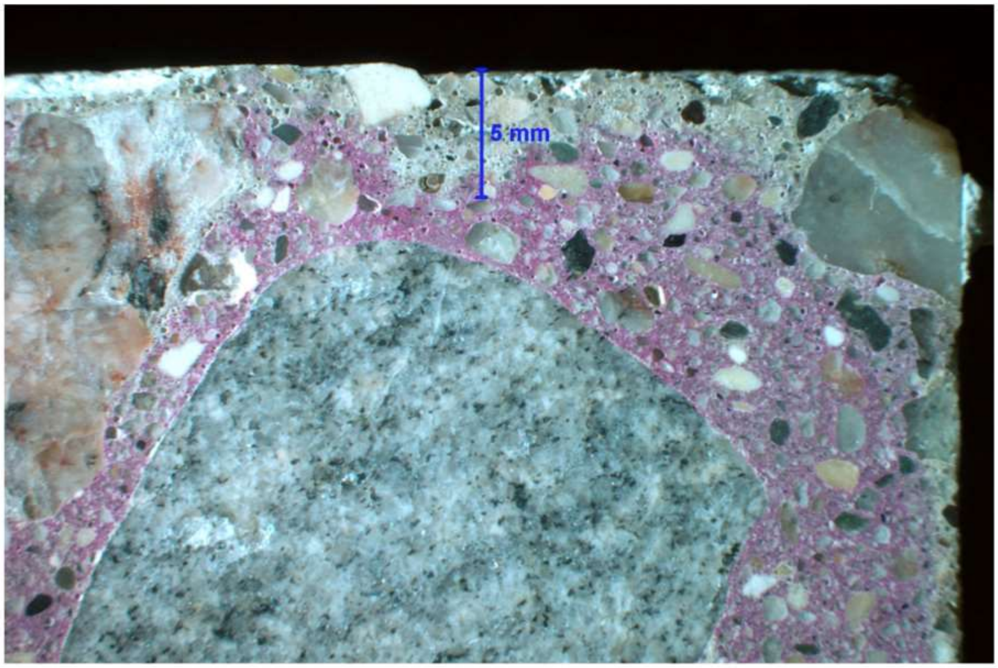
PHOTO:
70

SAMPLE ID: 8480-26, 1 **DESCRIPTION:** Sawcut and lapped cross section of core. The joint crack exhibited emerging "tunneling" around the base of the sawcut. Pre-existing sub-horizontal fractures are mapped in red ink.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 2

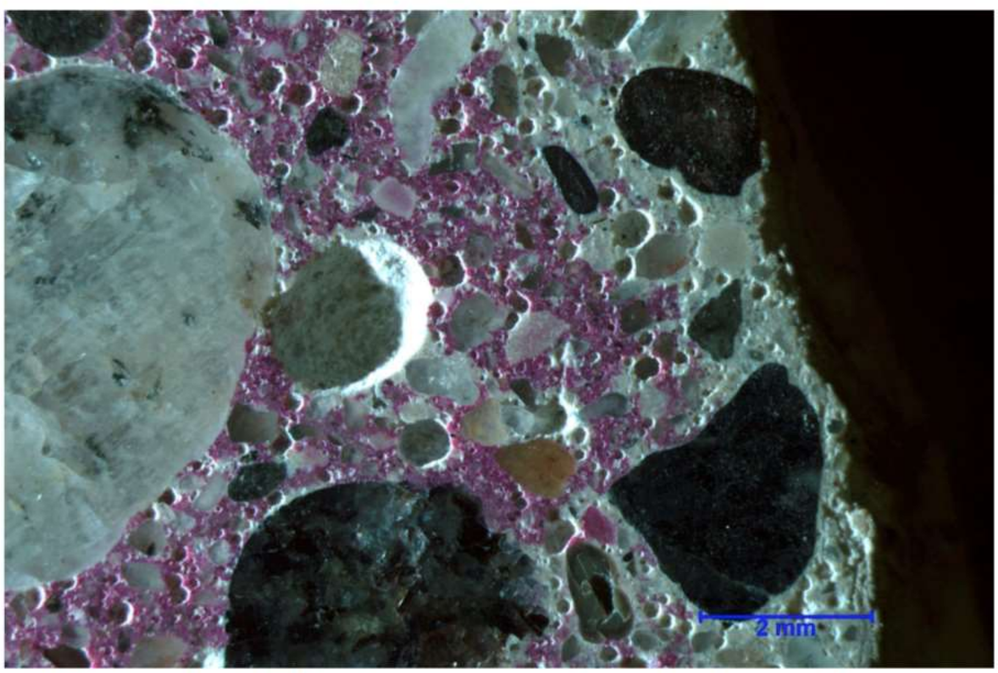
PHOTO:
118



SAMPLE ID: 8480-26, 1 **DESCRIPTION:** Carbonation (unstained paste) proceeded up to 5mm depth from the top surface.

MAG: 5x

PHOTO:
119



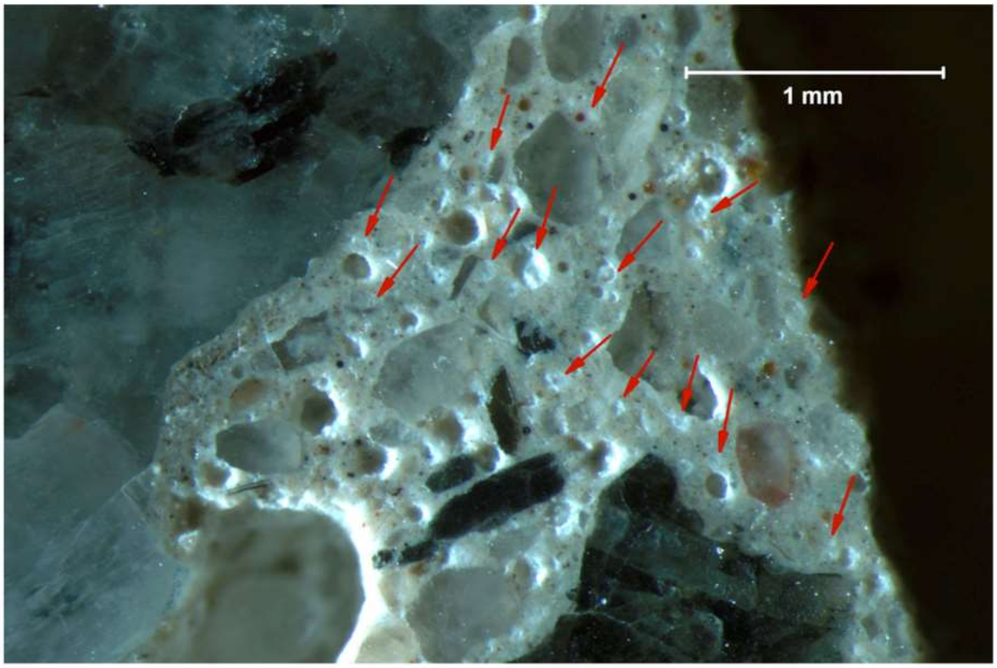
SAMPLE ID: 8480-26, 1 **DESCRIPTION:** Carbonation (unstained paste) to 2mm depth from the joint face at 210mm depth in the core.

MAG: 15x

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

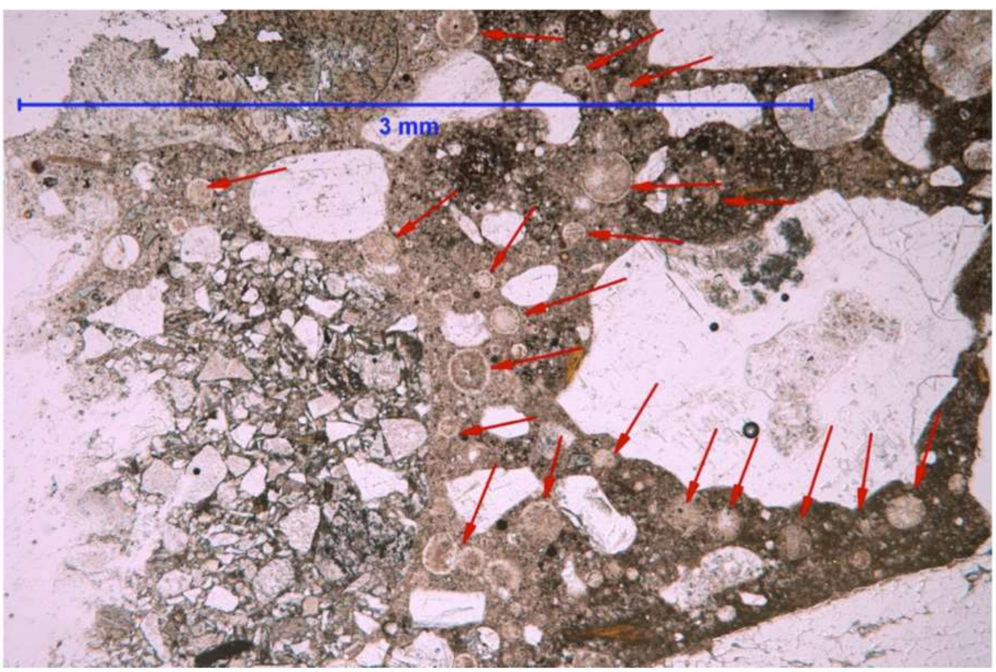
PROJECT: W/CM Study
Phase 2

PHOTO:
120



SAMPLE ID: 8480-26, 1 **DESCRIPTION:** Secondary ettringite-filled voids within a few millimeters of the distressed joint face at 165mm depth from the top surface.
MAG: 50x

PHOTO:
121



SAMPLE ID: 8480-26, 1 **DESCRIPTION:** Secondary ettringite-filled voidspaces within a few millimeters of the distressed joint face (left); in thin section of concrete at mid-depth in the core, under plane polarized light.
MAG: 40x

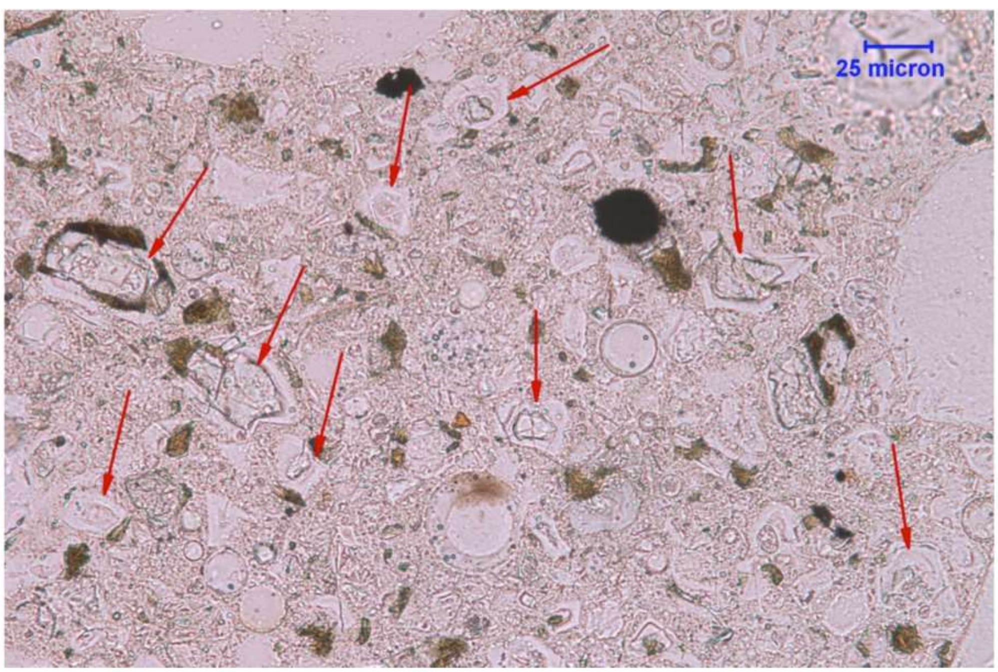
AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 2

PHOTO:
122

SAMPLE ID: 8480-26, 1 **DESCRIPTION:** Brown reactive shale particle (upper left) and clear ASR gel product lining void space (center) in thin section of concrete under plane polarized light.
MAG: 40x

PHOTO:
123



SAMPLE ID: 8480-26, 1 **DESCRIPTION:** Well to fully hydrated alite portland cement clinker particles in thin section of concrete under plane polarized light (red arrows). Note abundant spherical flyash particles.
MAG: 400x

00 LAB 001 Petrographic Examination of Hardened Concrete
ASTM: C-856

Project No.	28-00337	Date:	October 8, 2012
Sample ID:	8480-26, 4	Performed by:	D. Hunt, G. Moulzolf

I. General Observations

1. Sample Dimensions: Our analysis was performed on both lapped sides of a 266mm (10 1/2") x 89mm (3 1/2") x 25mm (1") thick section (in two pieces), a 266mm (10 1/2") x 89mm (3 1/2") x 25mm (1") thick section (in two pieces), and two 76mm (3") x 52mm (2") wide thin sections that were sawcut and prepared from the original 90mm (3 1/2") diameter x 266mm (10 1/2") long core taken directly through a sawcut joint. The thin sections were located at between 66mm and 143mm depth and 150mm and 226mm depth in the core from the top surface; directly adjacent to the cracked joint surface.

2. Surface Conditions:
   Top: Fairly rough, mortar eroded/traffic worn surface; exposing many fine aggregate surfaces.
   Bottom: Rough, irregular, formed surface; placed on a granular (possibly cement stabilized) base.

3. Reinforcement: None observed.

4. General Physical Conditions: The core was taken directly through a sealed pavement joint. A silicone joint sealant was poorly bonded to one side of the sawcut joint in the "meniscus" in the sealant between 1mm and 6mm depth from the top surface of the concrete. The sealant was completely de-bonded from the other side of the joint leaving some residual silicone bonded to the joint face between 1mm and 6mm depth. The joint sealant was placed on a 12mm diameter foam backer rod. The joint was characterized by an approx. 4mm wide pilot sawcut proceeding 67mm depth from the top surface and an approx. 9mm wide reservoir cut to 32mm depth; with the resulting joint crack proceeding the depth of the core. Several sub-vertical microcracks (incipient scaling/spalling), observed in the paste only, occur between 75mm and 260mm depth in the cracked joint surface and incorporates up to 5mm of total concrete paste on either side of the joint crack. The joint plane is characterized by numerous relatively "clean" and un-distressed coarse aggregate particles protruding from the concrete joint. The widest loss of concrete (10mm to 15mm) occurs between 90mm and 170mm depth in the concrete from the top surface. The core exhibits relatively tight, residual interlock between the two halves of the core between 67mm and 90mm depths from the top surface of the core. No evidence of ASR associated with the coarse aggregate was observed. Abundant alkali-silica "reacted" shale fine aggregate were present in the core; in the concrete and within the recycled concrete aggregate. The "reacted" shale particles exhibit internal cracking that propagates into the paste. Alkali-silica reaction gel was observed partially lining to filling a few air voids proximate to the reactive shale particles. The core was fractured sub-horizontally between approx. 129mm and 15mm depth in the core. The fracture exhibits staining and age.

   The fairly rough top surface of the core exhibits significant traffic wear; topographic highs have been worn smooth with exposed fine and coarse aggregate particles exhibiting worn surfaces. The concrete was well consolidated, with no voidspaces observed in excess of 7mm in diameter in the core. The concrete was purposefully air entrained and originally contained a well-distributed air void system considered freeze-thaw resistant under severe exposure conditions. Original air void parameters include a 4.0% entrained-sized void volume and a 0.007" spacing factor. Secondary ettringite fills most entrained-sized air voids within 5mm of the joint crack and fills many of the smallest entrained-sized voids throughout the lower half of the core. Void fillings decrease slightly with depth from the joint crack and decrease with proximity to the top surface of the core. Recycled concrete aggregates were generally air entrained. However, a few particles were not. In addition, many of the air void spaces are filled with secondary ettringite; esp. proximate to the joint faces.

II. Aggregate

1. Coarse: 12mm (1/2") nominal sized recycled concrete and natural gravel consisting predominately of granite, carbonates, basalt and chert. The coarse aggregate was of Des Moines glacial lobe outwash. The coarse aggregate appeared well graded and exhibited good overall distribution.

2. Fine: Natural quartz, feldspar, and lithic sand (granite, chert, carbonates, basalt, siltstone and shale.) The grains were mostly sub-rounded with many smaller sub-angular particles. The fine aggregate appeared fairly graded and exhibited good overall uniform distribution.

III. Cementitious Properties

1. Air Content: 5.5% total original air void.
2. Depth of carbonation: Ranged from 1mm up to 7mm depth from the top surface of the core and from the sawcut or distressed joint face.
3. Pozzolan presence: Flyash was observed.
4. Paste/aggregate bond: Fair.
5. Paste color: Similar to Light Gray (Munsell® N7)
6. Paste hardness: Moderately hard (Moh's >3)
7. Microcracking: Several sub-vertical microcracks (incipient spalling), observed in the paste only, occur between 75mm and 260mm depth in the cracked joint surface and incorporates up to 5mm of total concrete paste between the two sides of the joint crack. Several sub-horizontal microcracks occur sub-parallel and proximate to a sub-horizontal fracture, between 110mm and 160mm depth in the core. A sub-vertical microcrack of unclear origin proceeds from the sub-horizontal fracture to the bottom surface of the core; at approx. 35mm depth from the joint crack.
8. Secondary deposits: Secondary ettringite fills most entrained-sized air voids within 5mm of the joint crack and fills many of the smallest entrained-sized voids throughout the lower half of the core. Void fillings decrease slightly with depth from the joint crack and decrease with proximity to the top surface of the core. ASR gel was observed filling to partially lining a few air voids proximate to reactive shale fine aggregate particles in the concrete and the recycled concrete aggregate particles.
9. w/cm: Estimated at between 0.42 and 0.47 with approximately 4 to % residual portland cement clinker particles and an amount of flyash visually consistent with a 10 to 20% replacement of portland cement.
10. Cement hydration: Alites: Fully.
    Belites: Well to fully.

00 LAB 001 Petrographic Examination of Hardened Concrete
ASTM: C-856

Project No.	28-00337	Date:	August 30, 2012
Sample ID:	8480-26, 5	Performed by:	D. Hunt, G. Moulzolf

I. General Observations

1. Sample Dimensions: Our analysis was performed on both lapped sides of a 272mm (10 3/4") x 89mm (3 1/2") x 25mm (1") thick section (in two pieces), a 272mm (10 3/4") x 89mm (3 1/2") x 25mm (1") thick section (in two pieces), and two 76mm (3") x 52mm (2") wide thin sections that were sawcut and prepared from the original 90mm (3 1/2") diameter x 272mm (10 3/4") long core taken directly through a sawcut joint. The thin sections were located at between 65mm and 135mm depth and 140mm and 215mm depth in the core from the top surface; directly adjacent to the cracked joint surface.

2. Surface Conditions:
Top: Fairly rough, traffic worn surface; exposing many fine aggregate surfaces.
Bottom: Rough, irregular, formed surface; placed on a gravel base.

3. Reinforcement: None observed.

4. General Physical Conditions: The core was taken directly through a sealed pavement joint. A silicone joint sealant was mostly well bonded to one side of the sawcut joint between 1 mm and 16mm depth from the top surface. The sealant was intermittently bonded to the other side of the joint; with evidence of fresh, unstained, sealant torn from the surface. The joint sealer was placed on a 12mm diameter foam backer rod. The joint was characterized by an approx. 4mm wide pilot sawcut proceeding 65mm depth from the top surface and an approx. 9mm wide reservoir cut to 31mm depth; with the resulting joint crack proceeding the depth of the core. The cracked joint plane proceeds around most coarse mineral aggregate particles and some recycled concrete aggregates and exhibits significant residual interlock between the two core halves. In general, negligible to minimal paste loss was observed along the length of the joint crack. Several pervasive sub-vertical microcracks were observed within 12mm of the joint crack between 140mm and 240mm depth from the top surface. No evidence of ASR associated with the coarse aggregate was observed. Abundant alkali-silica "reacted" (ASR) shale fine aggregate were present in the core. The "reacted" shale particles exhibit internal cracking that propagates into the paste. ASR gel was observed partially lining to filling air voids proximate to the reactive shale particles. The core sections were fractured sub-horizontally during sawcutting and preparation.

   The fairly rough textured top surface of the core exhibits significant traffic wear/mortar erosion. Topographic highs have been worn smooth with exposed fine and coarse aggregate particles exhibiting worn surfaces. The concrete was well consolidated, with no voidspaces observed in excess of 10mm in diameter in the core. The concrete was purposefully air entrained and originally contained a well-distributed air void system considered freeze-thaw resistant under severe exposure conditions. Original air void parameters include a 3.7% entrained-sized void volume and a 0.008" spacing factor. Secondary ettringite fills many of the smaller entrained sized voidspaces throughout the depth of the core; below 30mm from the top surface. Concentrations of ettringite filled fine entrained air void spaces were observed within 3mm of the joint crack; again below 30mm. The spacing factor and resulting freeze-thaw durability was likely adversely affected by the fillings.

II. Aggregate

1. Coarse: 12mm (1/2") nominal sized recycled concrete and natural gravel consisting predominately of granite, carbonates, basalt and chert. The coarse aggregate was of Des Moines glacial lobe outwash. The coarse aggregate appeared well graded and exhibited good overall distribution.

2. Fine: Natural quartz, feldspar, and lithic sand (granite, chert, carbonates, basalt, siltstone and shale.) The grains were mostly sub-rounded with many smaller sub-angular particles. The fine aggregate appeared fairly graded and exhibited good overall uniform distribution.

III. Cementitious Properties

1. Air Content: 5.9% total original air void.
2. Depth of carbonation: Ranged from 1mm up to 9mm depth from the top surface of the core and from negligible up to 9mm depth from the sawcut joint along consolidation voidspace.

3.	Pozzolan presence:	Flyash was observed.
4.	Paste/aggregate bond:	Fair.
5.	Paste color:	Similar to Light Gray (Munsell® N7)
6.	Paste hardness:	Moderately hard (Moh's >3)
7.	Microcracking:	A few fine sub-vertical drying shrinkage microcracks proceed up to 3mm depth from the top surface. A sub-horizontal microcrack proceeds along a coarse aggregate particle between 4mm and 7mm depth from the top surface.
8.	Secondary deposits:	White, generally acicular grown ettringite along fills many of the finer entrained sized air voids scattered throughout the paste below 30mm depth in the core. Ettringite and calcite lines or fills sub-vertical microcracking below 140mm depth in the core. ASR gel was observed filling to partially lining a few air voids proximate to reactive shale fine aggregate particles.
9.	w/cm:	Estimated at between 0.42 and 0.47 with approximately 4 to 6% residual portland cement clinker particles and an amount of flyash visually consistent with a 10 to 20% replacement of portland cement.
10.	Cement hydration:	Alites: Fully. Belites: Well to fully.

Field Notes and Petrographic Reports for Project 8480-27, Cores 3, 7, 8

Table A.13. Field notes for SP Number 8480-27, I-94.

Core	Location from Joint	RP	Station	Direction	Lane	Offset	Thickness
1	ON	37.000	2252+83	WB	DR	-5.0'	8.000"
2	2.0'	37.000	2252+85	WB	DR	-5.0'	8.000"
3	ON	35.000	2147+54	WB	DR	-4.0'	8.500"
4	2.0'	35.000	2147+56	WB	DR	-5.0'	9.000"
5	2.5'	34.000	2094+72	WB	DR	-5.0'	8.500"
6	2.0'	32.000	1989+00	WB	DR	-5.0'	8.000"
7	ON	32.000	1989+02	WB	DR	-5.5'	8.000"
8	ON	31.500	1962+62	WB	DR	-5.0'	8.500"
9	2.0'	31.500	1962+64	WB	DR	-5.5'	8.500"

00 LAB 001 Petrographic Examination of Hardened Concrete
ASTM: C-856

Project No.	28-00337	Date:	October 29, 2012
Sample ID:	8480-27, 3	Performed by:	D. Hunt, G. Moulzolf

I. General Observations

1. Sample Dimensions: Our analysis was performed on both lapped sides of a 200mm (8") x 92mm (3 5/8") x 25mm (1") thick section (in two pieces), a 200mm (8") x 8mm (3 1/4") x 25mm (1") thick section (in two pieces), and two 76mm (3") x 52mm (2") wide thin sections that were sawcut and prepared from the original 95mm (3 3/4") diameter x 200mm (8") long core taken directly through a distressed sawcut joint. The thin sections were located at between 130mm and 200mm depth in the core from the top surface; directly adjacent to the distressed joint surface.

2. Surface Conditions:
Top: Fairly rough textured and mortar eroded/traffic worn surface; exposing many fine aggregate surfaces.
Bottom: Rough, irregular, formed surface; placed on a natural granular (?) sub-base.

3. Reinforcement: A 25mm (1") diameter epoxy coated steel dowel rod was observed at 95mm (3 ¾") depth from the top surface. Severe corrosion product was observed on half the steel dowel where the epoxy coating appears to have been compromised directly below the joint crack. Corrosion product was observed on the resulting steel rebar impression on one side of the joint crack.

4. General Physical Conditions: The core was taken directly through a distressed sealed pavement joint. A silicone joint sealant was originally well bonded to both sides of the sawcut joint between 1mm and 15mm depth from the top surface. The joint sealant was placed on a foam backer rod. The joint was characterized by a 5mm wide pilot sawcut to 50mm depth and an approx. 10mm wide reservoir cut to 30mm depth with the resulting joint crack proceeding the depth of the core. The joint crack bisects several coarse aggregates; as opposed to proceeding around them. Vertical spalling along the joint begins at approx. 25mm depth and incipient spalling (sub-vertical microcracking) was observed generally within the paste and some coarse aggregates within 10mm of the joint faces between 60mm 195mm depth from the top surface of the core. Much of the mass lost appears to have occurred due to late activation of the crack and a joint crack that splayed apart due to proximity and restraint from the intersected dowel. Up to approximately 12mm of paste loss occurs along the joint between 80mm and 125mm depth from the top surface. Good residual interlock between the core halves occurs along the entire length of the joint crack farthest from the steel dowel. In general, the widest loss of paste occurs between 60mm and 125mm depth from the top surface along the portion of the joint crack closest to the steel dowel. Sub-horizontal fractures, likely induced by dowel corrosion and coring, proceed through the entire diameter of the core between 105mm and 120mm depth from the top surface, proximate to the steel dowel. The coarse aggregate appeared sound. No evidence of ASR associated with the coarse aggregate was observed. Abundant alkali-silica "reacted" (ASR) shale fine aggregate particles were present in the core. The "reacted" shale particles exhibit internal cracking that propagates into the paste. ASR gel was observed lining a few air voids and filling a few microcracks proximate to the reactive shale particles

   The fairly rough top surface of the core exhibits significant traffic wear; topographic highs have been worn smooth with exposed fine aggregate surfaces exhibiting worn surfaces. The concrete was well consolidated, with no voidspaces observed in excess of 10mm in diameter in the core. The concrete was purposefully air entrained and contains a well-distributed air void system considered freeze-thaw resistant under severe exposure conditions. Original air void parameters include a 3.1% entrained-sized void volume and a 0.007" spacing factor. Secondary ettringite fills many entrained sized voidspaces within 2mm of the cracked joint. Void fillings decrease with depth from the joint crack.

II. Aggregate

1. Coarse: 25mm (1") nominal sized natural gravel consisting predominately of carbonates, chert, basalt, and granite. The coarse aggregate was of Des Moines glacial lobe outwash. The coarse aggregate appeared well graded and exhibited good overall distribution.

2. Fine: Natural quartz, feldspar, and lithic sand (granite, chert, carbonates, basalt, siltstone and shale.) The grains were mostly sub-rounded with many smaller sub-angular particles. The fine aggregate appeared fairly graded and exhibited good overall uniform distribution.

III. Cementitious Properties

1. Air Content: 4.1% total original air void.
2. Depth of carbonation: Ranged from <1mm up to 5mm depth from the top surface of the core. Carbonation proceeding from the joint crack ranges from <1mm up to 15mm. Mottled carbonation was observed throughout the depth of the core.
3. Pozzolan presence: Flyash was observed.
4. Paste/aggregate bond: Fair.
5. Paste color: Similar to Light Gray (Munsell® N7).
6. Paste hardness: Moderately hard (Moh's >3)
7. Microcracking: Several sub-vertical microcracks (incipient spalling) were observed within the paste and and several coarse aggregate within 10mm of the distressed joint surface between 60mm 190mm depth from the top surface of the core. Fine shrinkage microcracks occur within the paste proximate to and within abundant reactive fine aggregate particles. A few fine, sub-vertical drying shrinkage microcracks proceed up to 5mm depth from the top surface.
8. Secondary deposits: Secondary ettringite fills many entrained sized voidspaces within 2mm of the joint crack. Void fillings decrease with depth from the joint crack and above 40mm depth in the core. Alkali silica reaction gel lines air voids fills a few microcracks proximate to abundant reactive shale fine aggregate particles.
9. w/cm: Estimated at between 0.43 and 0.48 with approximately 3 to 5% residual portland cement clinker particles and an amount of flyash visually consistent with a 10 to 20% replacement of portland cement.
10. Cement hydration: Alites: Well to mostly fully.
    Belites: Well to fully.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 2

PHOTO: 49

SAMPLE ID: 8480-27, 3 **DESCRIPTION:** Jointed core sample subjected to petrographic analysis. The silicone sealed top surface is right. Note intersected dowel and loss of concrete along much of the length of the joint.

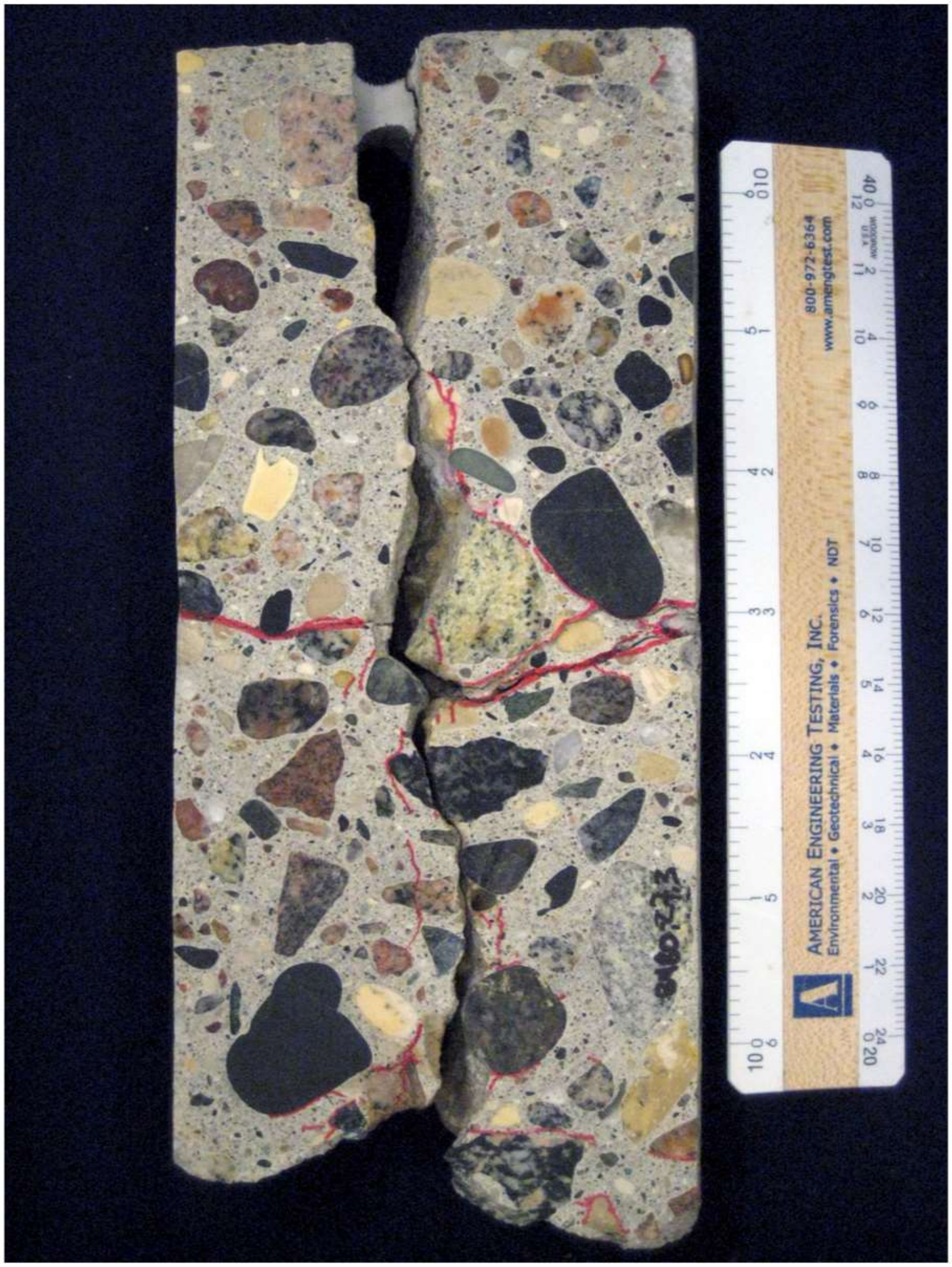
PHOTO: 50

SAMPLE ID: 8480-27, 3 **DESCRIPTION:** Textured and worn top surface of the core as received. Note the forcibly distressed silicone sealant.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 2

PHOTO:
73

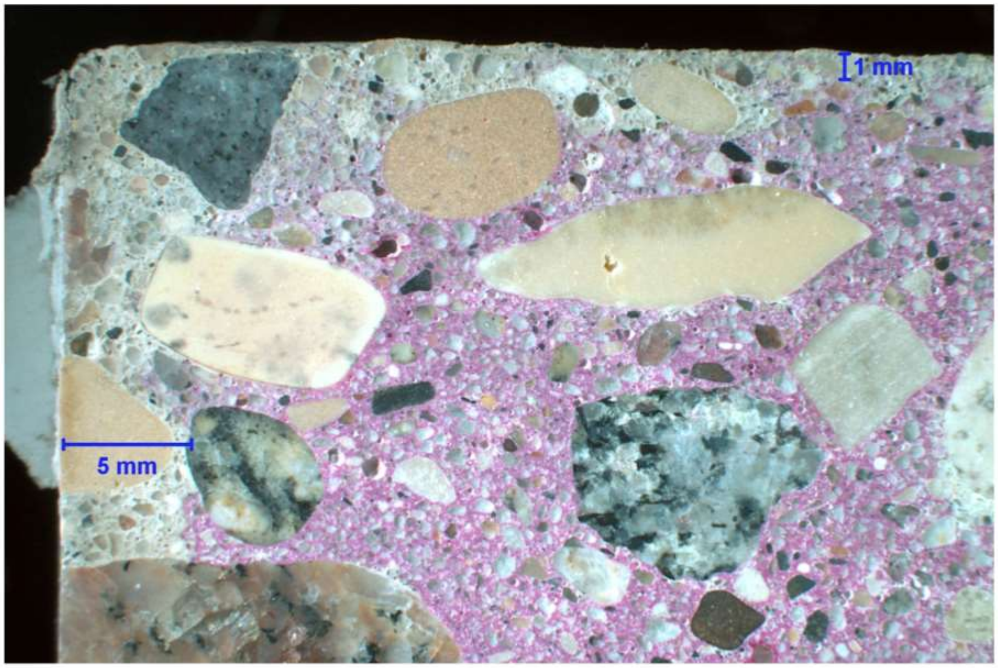


SAMPLE ID: 8480-27, 3 **DESCRIPTION:** Sawcut and lapped cross section of core. The joint crack exhibited some splayed micro-cracking along the joint crack. Pre-existing sub-horizontal fracturing intersecting a corroded dowel is mapped in red ink.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

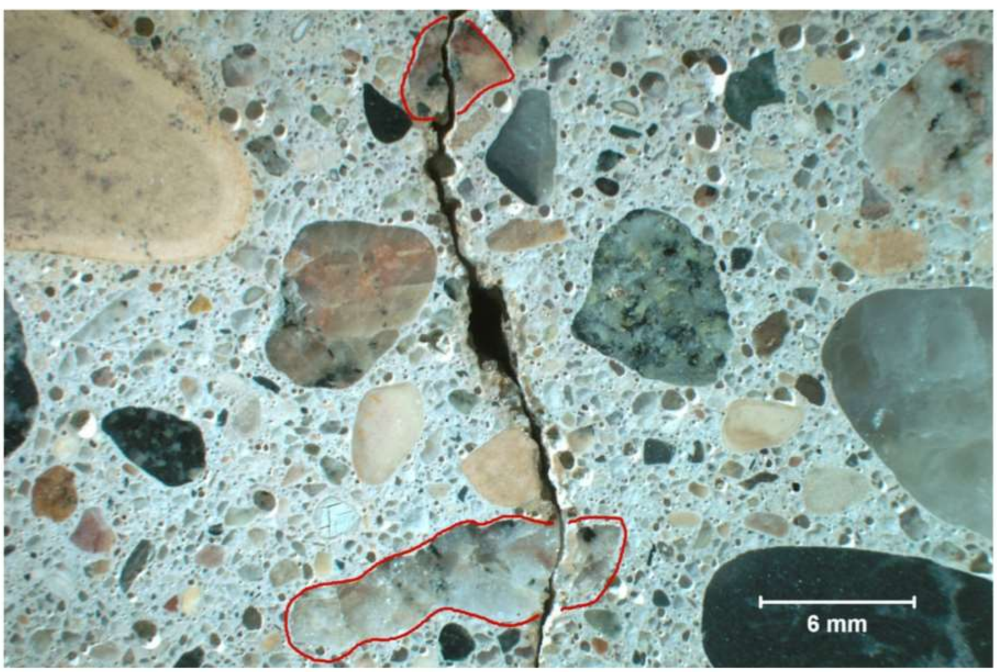
PROJECT: W/CM Study
Phase 2

PHOTO:
130



SAMPLE ID: 8480-27, 3 **DESCRIPTION:** Carbonation (unstained paste) proceeded at least 1mm depth from the top surface and proceeded to 5mm depth from the sawcut joint; in this image.
MAG: 5x

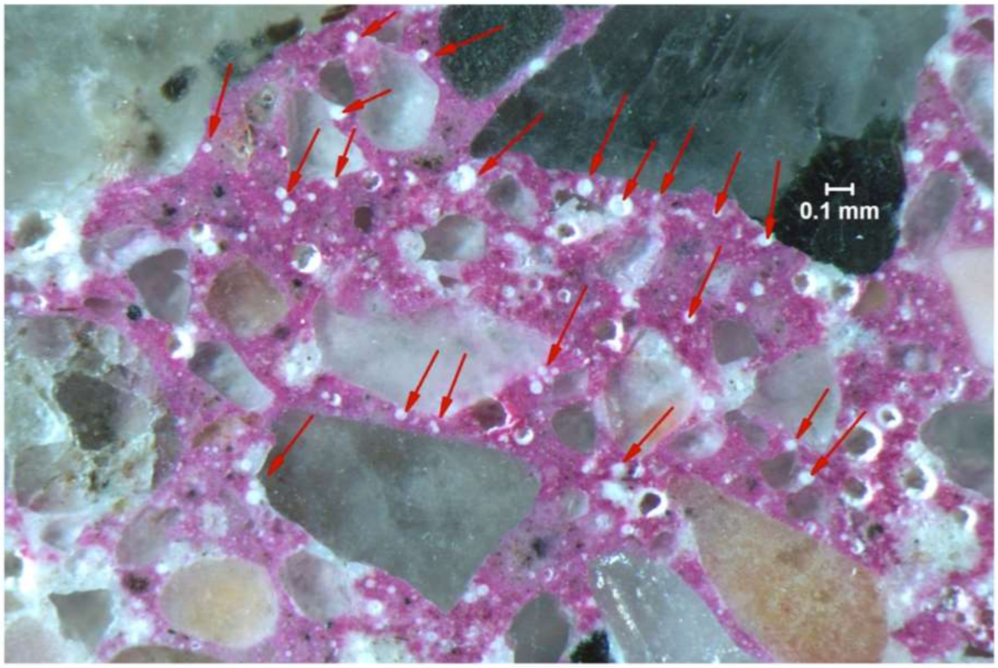
PHOTO:
131



SAMPLE ID: 8480-27, 3 **DESCRIPTION:** The joint crack bisects coarse aggregate particles, outlined in red, at depth in the core.

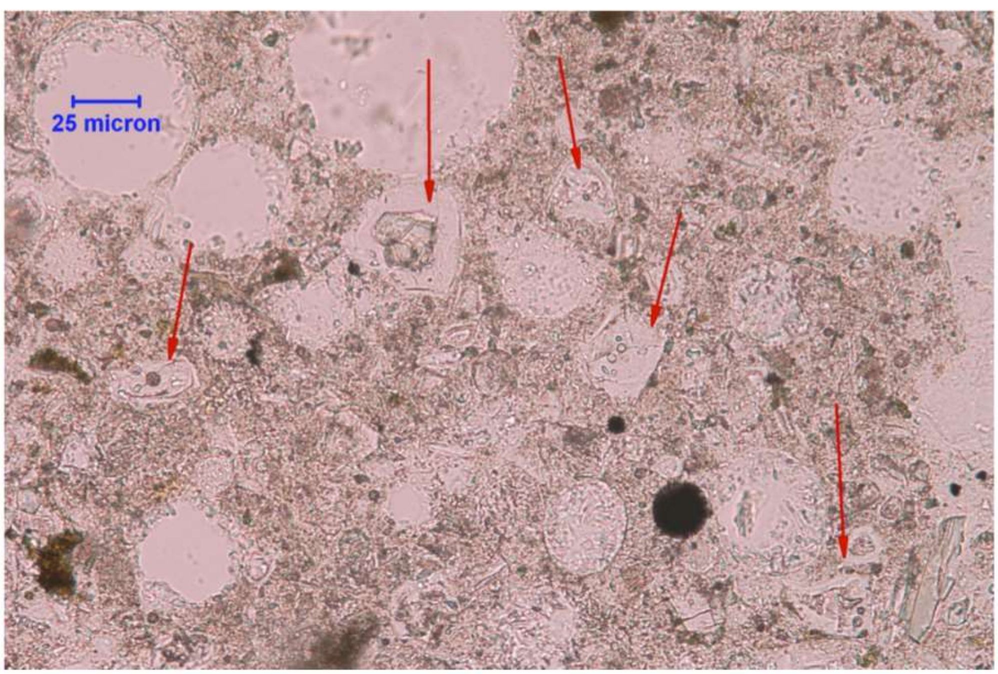
MAG: 5x

PHOTO:
132



SAMPLE ID: 8480-27, 3 **DESCRIPTION:** Fine, entrained-sized, secondary ettringite-filled voidspaces in the phenolphthalein-stained paste at 100mm depth from the top surface and 13mm depth from the joint crack.
MAG: 50x

PHOTO:
133



SAMPLE ID: 8480-27, 3 **DESCRIPTION:** Well to fully hydrated alite portland cement clinker particles (arrows) in thin section of concrete paste under plane polarized light.
MAG: 400x

00 LAB 001 Petrographic Examination of Hardened Concrete
ASTM: C-856

Project No.	28-00337	Date:	October 31, 2012
Sample ID:	8480-27, 7	Performed by:	D. Hunt, G. Moulzolf

I. General Observations

1. Sample Dimensions: Our analysis was performed on both lapped sides of a 210mm (8 1/4") x 91mm (3 5/8") x 19mm (3/4") thick section (in two pieces), a 210mm (8 1/4") x 91mm (3 5/8") x 33mm (1 1/4") thick section (in two pieces), and two 76mm (3") x 52mm (2") wide thin sections that were sawcut and prepared from the original 94mm (3 3/4") diameter x 210mm (8 1/4") long core taken directly through a sawcut joint. The thin sections were located at between 25mm and 100mm depth and 100mm and 175mm depth in the core from the top surface; directly adjacent to the cracked joint surface.

2. Surface Conditions:
   Top: Fairly rough textured and mortar eroded/traffic worn surface; exposing many fine and few coarse aggregate surfaces.
   Bottom: Rough, irregular, formed surface; placed on an asphalt-stabilized base.

3. Reinforcement: None observed.

4. General Physical Conditions: The core was taken directly through a sealed pavement joint. A silicone joint sealant was generally well bonded to both sides of the sawcut joint between 1mm and 17mm depth from the top surface. The joint sealant was placed on a 12mm diameter foam backer rod. The joint was characterized by an approx. 4mm wide pilot sawcut proceeding 52mm depth from the top surface and an approx. 10mm wide reservoir cut to 29mm depth; with the resulting joint crack proceeding the depth of the core. The cracked joint plane proceeds around coarse aggregate particles, as opposed to through them, and exhibits "tight" interlock between the two core halves. No distress was observed along the length of the joint crack. A few sub-vertical microcracks (incipient scaling/spalling) were observed within 2mm of the joint crack between 125mm and 150mm depth from the top surface. A thin band of Moderate Yellowish Brown (Munsell® 10YR 5/4) colored carbonated paste was observed within 1mm of the joint crack. The coarse aggregate appeared sound. No evidence of ASR associated with the coarse aggregate was observed. Abundant alkali-silica "reacted" (ASR) shale fine aggregate were present in the core. The "reacted" shale particles exhibit internal cracking that propagates into the paste. Alkali-silica reaction gel was observed partially lining to filling a few air voids proximate to the reactive shale particles.

   The fairly rough top surface of the core exhibits significant traffic wear; topographic highs have been worn smooth with exposed fine and coarse aggregate particles exhibiting worn surfaces. The concrete was well consolidated, with no voidspaces observed in excess of 9mm in diameter in the core. The concrete was purposefully air entrained and originally contained a well-distributed air void system considered freeze-thaw resistant under severe exposure conditions. Original air void parameters include a 5.1% entrained-sized void volume and a 0.004" spacing factor. Secondary ettringite lines or partly fills some of the smallest entrained sized voidspaces within 2mm of the joint crack. Void fillings generally decrease with depth from the joint crack.

II. Aggregate

1. Coarse: 25mm (1") nominal sized glacial gravel consisting predominately of granite, carbonates, basalt and chert. The coarse aggregate was of Des Moines glacial lobe outwash. The coarse aggregate appeared well graded and exhibited good overall distribution.

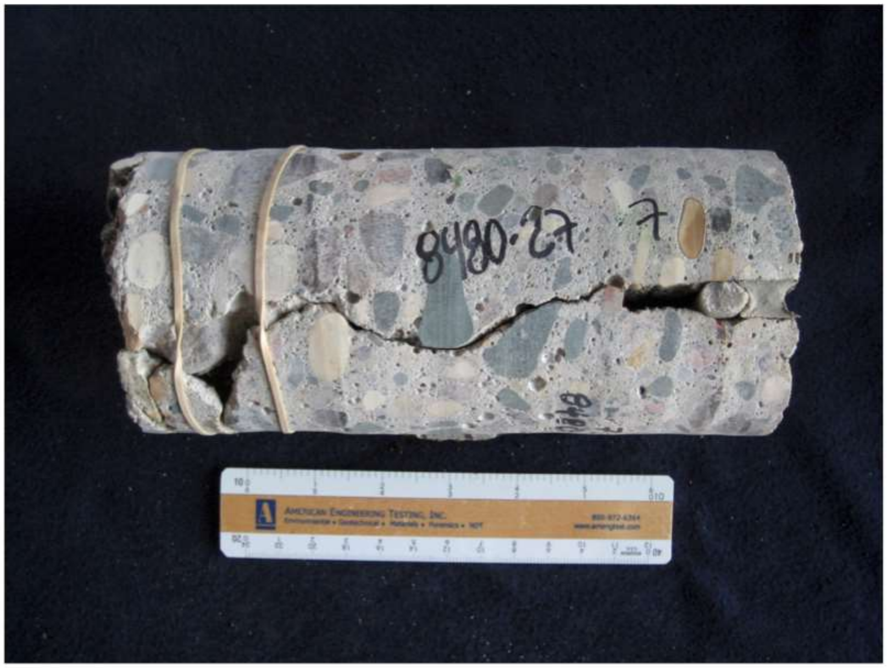
2. Fine: Natural quartz, feldspar, and lithic sand (granite, chert, carbonates, basalt, siltstone and shale.) The grains were mostly sub-rounded with many smaller sub-angular particles. The fine aggregate appeared fairly graded and exhibited good overall uniform distribution.

III. Cementitious Properties

1. Air Content: 6.6% total original air void.

2.	Depth of carbonation:	Ranged from 1mm up to 7mm depth from the top surface of the core. Ranged from 3mm up to 13mm depth from the sawcut joint and ranged from negligible up to 7mm depth along the joint crack.
3.	Pozzolan presence:	Flyash was observed.
4.	Paste/aggregate bond:	Fair.
5.	Paste color:	Similar to Light Gray (Munsell® N7).
6.	Paste hardness:	Moderately hard (Moh's >3) with areas of moderately soft paste (Moh's 2.5) along the joint crack.
7.	Microcracking:	A few fine sub-vertical drying shrinkage microcracks proceed up to 3mm depth from the top surface. Two sub-vertical microcracks splay and re-enter the joint crack between 75mm and 165mm depth in the concrete. A sub-horizontal microcrack proceeds across the diameter of the core, in the paste only, at between approx. 157mm and 177mm depth from the top surface.
8.	Secondary deposits:	White, generally acicular grown ettringite and calcium carbonate line or partly fills many of the finest entrained sized air voids within 2mm of the joint crack. Ettringite presence generally decreases with distance from the joint. Calcium carbonate also lines of partly fills microcracking sub-parallel to the joint crack. ASR gel was observed filling to partially lining a few air voids proximate to reactive shale fine aggregate particles.
9.	w/cm:	Estimated at between 0.43 and 0.48 with approximately 3 to 5% residual portland cement clinker particles and an amount of flyash visually consistent with a 10 to 20% replacement of portland cement.
10.	Cement hydration:	Alites: Well to mostly fully. Belites: Well to fully.

PHOTO: 53



SAMPLE ID: 8480-27, 7 **DESCRIPTION:** Jointed core sample subjected to petrographic analysis. The silicone sealed top surface is right. Minimal paste loss was apparent along the length of the joint.

PHOTO: 54

SAMPLE ID: 8480-27, 7 **DESCRIPTION:** Textured and worn top surface of the core as received. Note the de-bonded silicone joint sealant.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 2

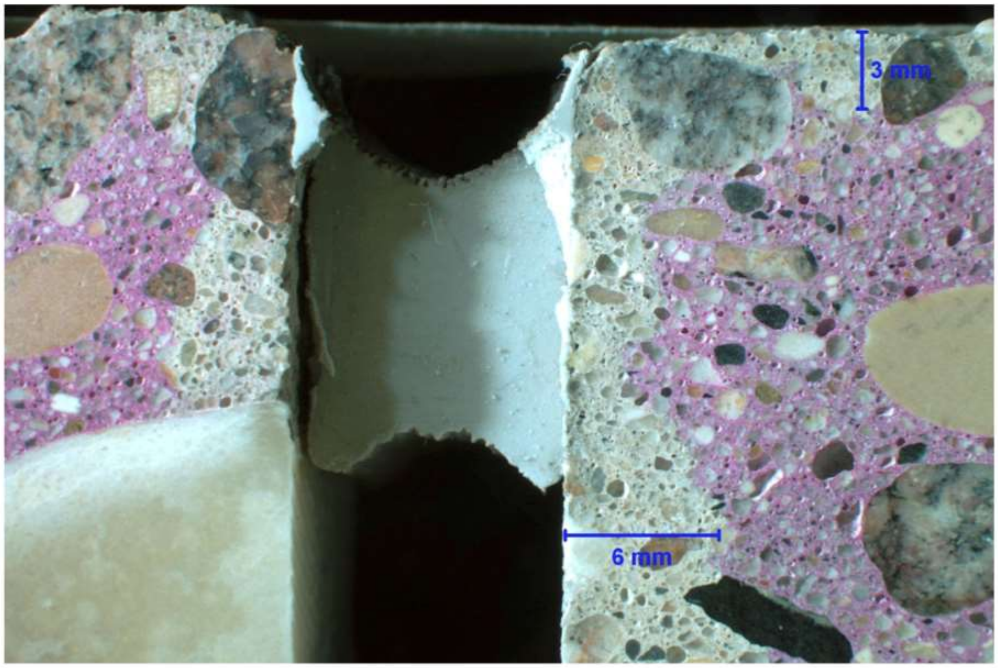
PHOTO:
74

SAMPLE ID: 8480-27, 7 **DESCRIPTION:** Sawcut and lapped cross section of core. The joint crack exhibited no distress.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

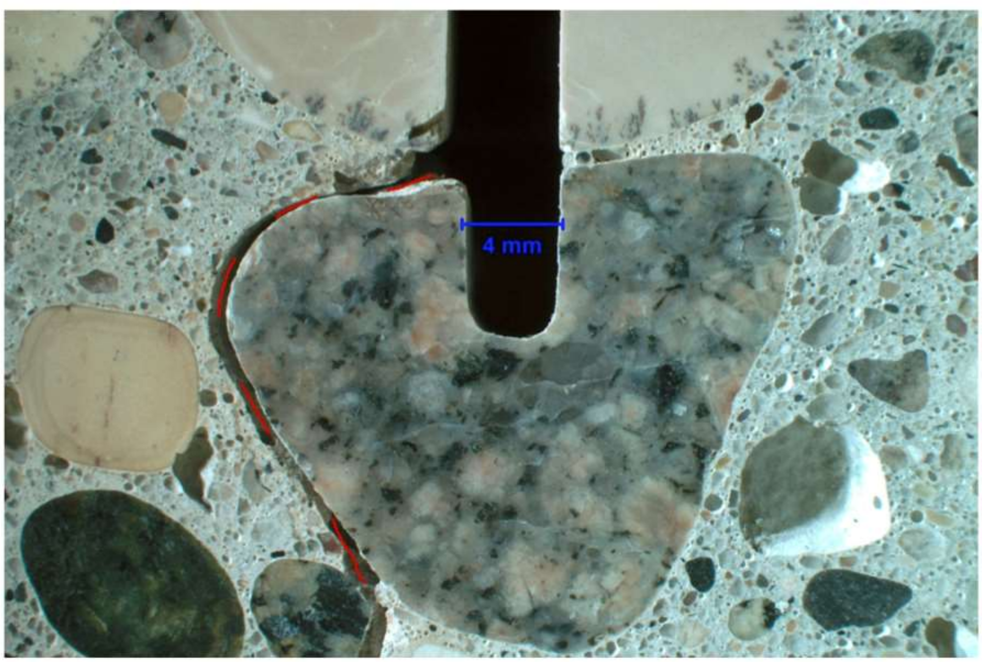
PROJECT: W/CM Study
Phase 2

PHOTO:
134



SAMPLE ID: 8480-27, 7 **DESCRIPTION:** Carbonation (unstained paste) proceeded to 3mm depth from the top surface and to 6mm depth from the sawcut and sealed joint; in this image. The joint sealant was generally originally well bonded to both sides of the joint.
MAG: 5x

PHOTO:
135



SAMPLE ID: 8480-27, 7 **DESCRIPTION:** Image of the resulting joint crack proceeding around the sawcut-intersected coarse aggregate.
MAG: 5x

00 LAB 001 Petrographic Examination of Hardened Concrete
ASTM: C-856

Project No.	28-00337	Date:	September 12, 2012
Sample ID:	8480-27, 8	Performed by:	D. Hunt, G. Moulzolf

I. General Observations

1. Sample Dimensions: Our analysis was performed on both lapped sides of a 217mm (8 1/2") x 95mm (3 3/4") x 29mm (1 1/8") thick section (in two pieces), a 217mm (8 1/2") x 88mm (3 1/2") x 29mm (1 1/8") thick section (in two pieces), and three 76mm (3") x 52mm (2") wide thin sections that were sawcut and prepared from the original 95mm (3 3/4") diameter x 217mm (8 1/2") long core taken directly through a severely distressed sawcut joint. The thin sections were located at between 15mm and 91mm depth, 95mm and 171mm depth, and 140mm and 216mm depth in the core from the top surface; directly adjacent to the severely distressed joint surface.

2. Surface Conditions:
   Top: Fairly smooth, textured and traffic worn surface; exposing many fine aggregate surfaces.
   Bottom: Rough, irregular, formed surface; placed on base.

3. Reinforcement: None observed.

4. General Physical Conditions: The core was taken directly through a distressed pavement joint. A silicone joint sealant was intermittently bonded to both sides of the sawcut joint between 1mm and 13mm depth from the top surface. The joint sealant was placed upon a foam backer rod. The joint was characterized by an approx. 4mm wide pilot sawcut, partially vertically scaled/spalled away, measurable to 55mm depth from the top surface, and an approx. 10mm wide reservoir cut to 30mm depth. The resulting joint crack proceeded the depth of the core and bisects at least three coarse aggregates. A shallow spall, approximately 13mm by 28mm by up to 12mm deep was observed well adhered to the silicone joint sealer on the top surface near the cored edge of the sample. Vertical scaling/spalling along the joint begins as shallow as approx. 26mm depth; with a slight loss of paste along a portion of the reservoir cut. Up to approximately 20mm of paste loss occurs along the joint between 45mm and 130mm depth from the top surface. Thin paste loss with some residual interlock between the core halves occurs between 130mm and 217mm from the top surface. In general, the widest loss of paste occurred between 45mm and 105mm depth from the top surface. This zone is characterized by several relatively "clean" and un-distressed coarse aggregates protruding from the concrete joint faces. Several sub-vertical microcracks (incipient spalling) were observed generally within the paste-only and within 12mm of the distressed joint surface between 70mm and 217mm depth from the top surface of the core. A few sub-horizontal microcracks proceed up to 20mm depth from the joint between 35mm and 114mm depths from the top surface. Two sub-horizontal fractures in the cores were present when received; occurring between 100mm and 108mm depth on one side of the joint crack and between 130mm and 135 mm depth on the other side of the joint crack. Several other sub-horizontal microcracks of unclear origin occur in the paste throughout the top 110mm of the core. The coarse aggregate appeared sound. No evidence of ASR associated with the coarse aggregate was observed. Abundant alkali-silica "reacted" (ASR) shale fine aggregate particles and one coarse aggregate were present in the core. The "reacted" shale particles exhibit internal cracking that propagates into the paste. ASR gel was observed partially filling a few air voids proximate to the reactive shale particles

   The fairly smooth textured top surface of the core exhibits significant traffic wear; topographic highs have been worn smooth with exposed fine aggregate particles exhibiting worn surfaces. The concrete was well consolidated, with no voidspaces observed in excess of 10mm in diameter in the core. The concrete was purposefully air entrained and contains a well-distributed air void system considered freeze-thaw resistant under severe exposure conditions. Original air void parameters include a 4.2% entrained-sized void volume and a 0.007" spacing factor. Secondary ettringite fills numerous entrained sized voidspaces within 5mm of the distressed joint faces; below 45mm depth in the core. Void fillings decrease with depth from the joint faces.

II. Aggregate

1. Coarse: 25mm (1") nominal sized gravel consisting predominately of carbonates, chert, basalt, and granite. The coarse aggregate is of Des Moines glacial lobe outwash. The coarse aggregate appeared well graded and exhibited good overall distribution.

2. Fine: Natural quartz, feldspar, and lithic sand (granite, chert, carbonates, basalt, siltstone and shale.) The grains were mostly sub-rounded with many smaller sub-angular particles. The fine aggregate appeared fairly graded and exhibited good overall uniform distribution.

III. Cementitious Properties

1. Air Content: 5.2% total original air void.
2. Depth of carbonation: Ranged from 1mm up to 3mm depth from the top surface of the core. Carbonation proceeding from the joint crack ranges from 1mm up to 15mm.
3. Pozzolan presence: Flyash was observed.
4. Paste/aggregate bond: Fair.
5. Paste color: Similar to Light Gray (Munsell® N7) becoming Yellowish Gray (Munsell® 5Y 8/1) within the top 3mm of the core.
6. Paste hardness: Moderately hard (Moh's >3)
7. Microcracking: Some sub-vertical microcracks (incipient spalling) were observed generally within the paste-only and within 3mm of the distressed joint surface between 150mm 180mm depth from the top surface of the core. A few sub-horizontal microcracks proceed up to 20mm of the joint between 35mm and 114mm depths from the top surface. A few fine, sub-vertical drying shrinkage microcracks proceed up to 3mm depth from the top surface.
8. Secondary deposits: Secondary ettringite fills numerous entrained sized voidspaces within 5mm of the cracked joint; below 45mm depth from the top surface. Void fillings decrease with depth from the joint faces. Alkali silica reaction gel partially fills air void spaces proximate to abundant reactive shale fine aggregate particles.
9. w/cm: Estimated at between 0.43 and 0.48 with approximately 3 to 5% residual portland cement clinker particles and an amount of flyash visually consistent with a 10 to 20% replacement of portland cement.
10. Cement hydration: Alites: Mostly fully.
    Belites: Well to fully.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 2

PHOTO: 55

SAMPLE ID: 8480-27, 8 **DESCRIPTION:** Jointed core sample subjected to petrographic analysis. The silicone sealed top surface is right. Significant "tunneling" was present directly beneath the sawcut joint.

PHOTO: 56

SAMPLE ID: 8480-27, 8 **DESCRIPTION:** Textured and worn top surface of the core as received. Note the de-bonded silicone joint sealant.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 2

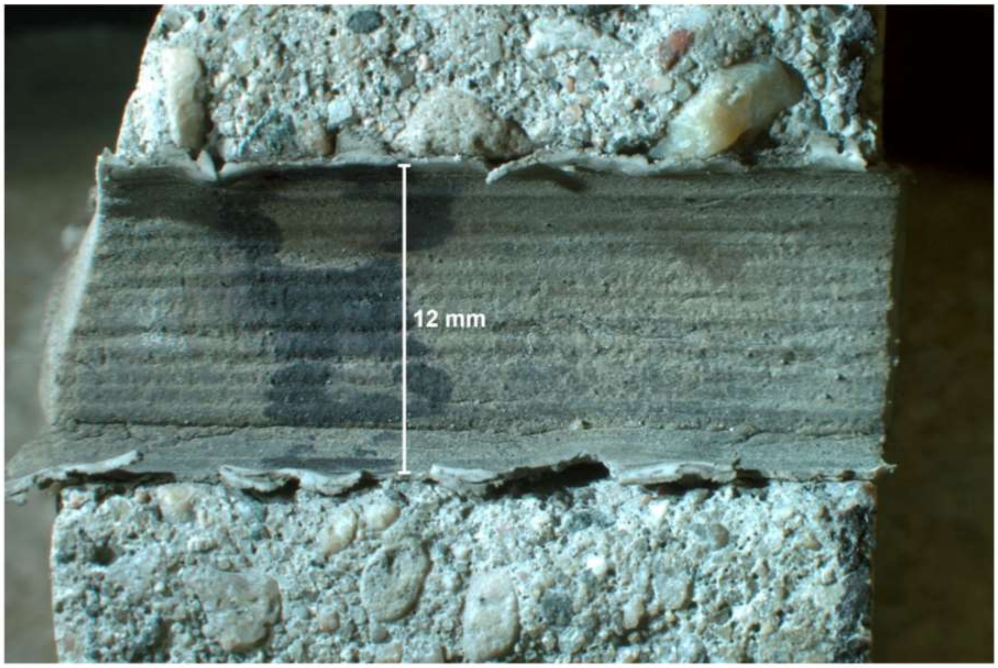
PHOTO:
75

SAMPLE ID: 8480-27, 8 **DESCRIPTION:** Sawcut and lapped cross section of core. The joint crack exhibited significant mass loss below the base of the sawcut (tunneling). Microcracking and sub-horizontal microcracking (thicker) is mapped in red ink.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

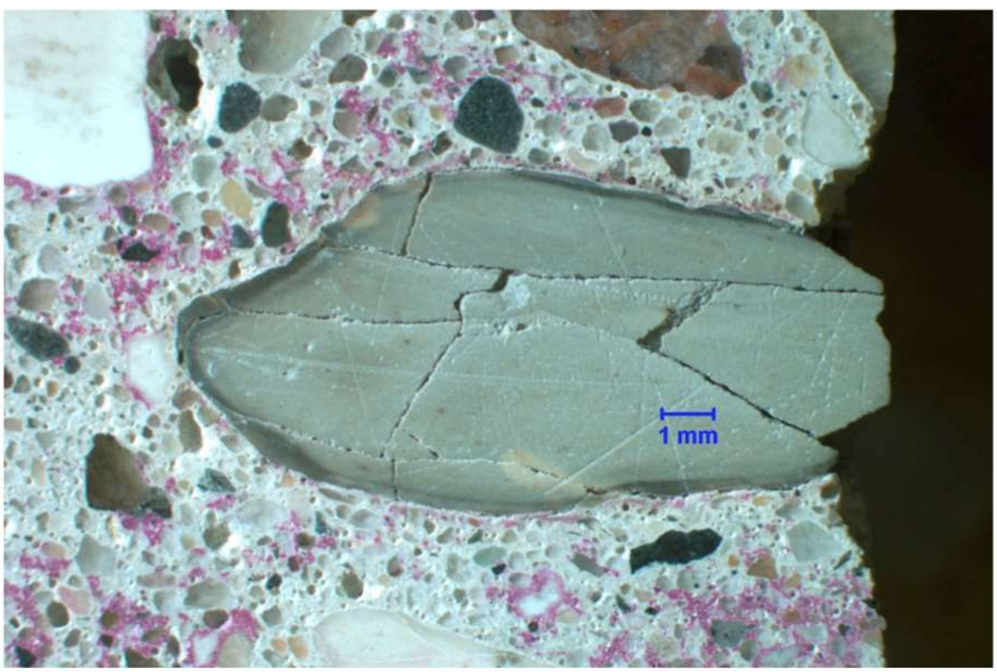
PROJECT: W/CM Study
Phase 2

PHOTO:
136



SAMPLE ID: 8480-27, 8 **DESCRIPTION:** The joint sealant was intermittently bonded to the sawcut joint . Note mortar erosion of the top surface.
MAG: 5x

PHOTO:
137

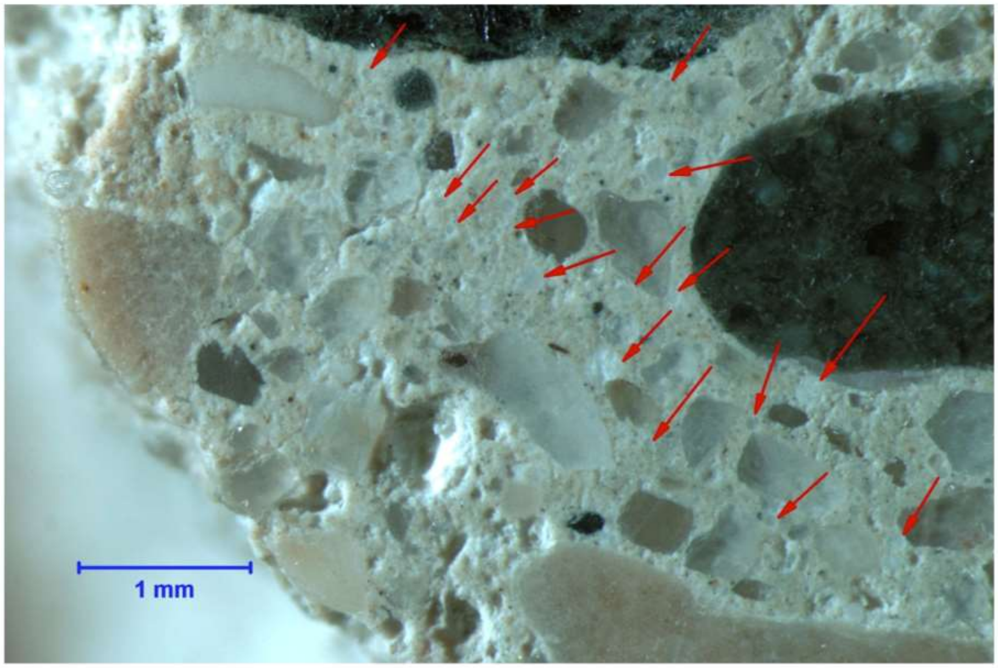


SAMPLE ID: 8480-27, 8 **DESCRIPTION:** Deleterious shale coarse aggregate particle intersected by the joint crack plane (right).
MAG: 5x

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

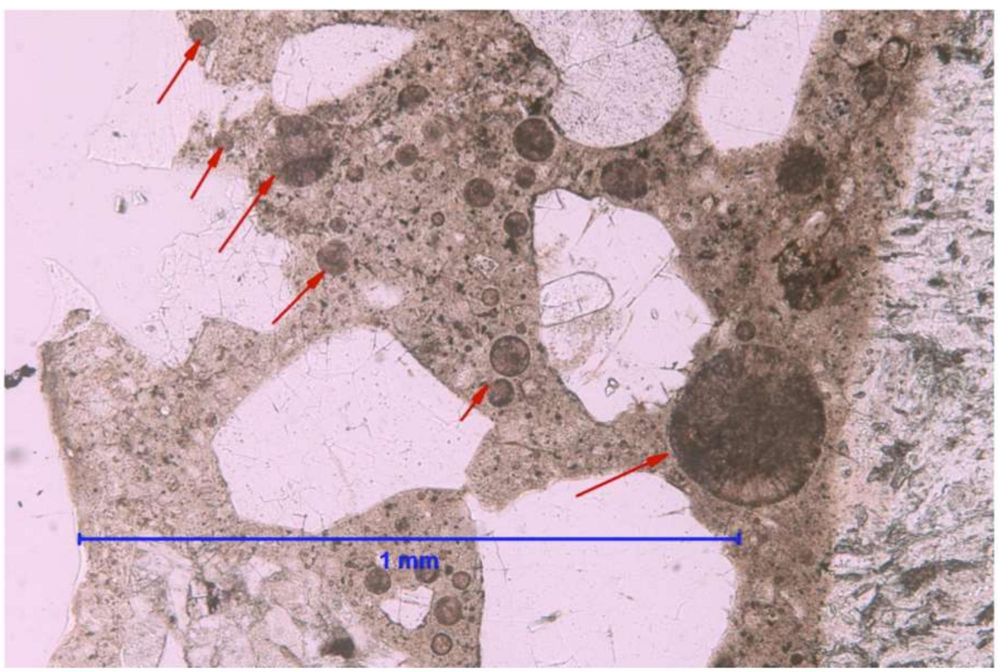
PROJECT: W/CM Study
Phase 2

PHOTO:
138



SAMPLE ID: 8480-27, 8 **DESCRIPTION:** Ettringite-filled air voidspaces within 5mm of the distressed joint face (left); at100mm depth in the core.
MAG: 30x

PHOTO:
139



SAMPLE ID: 8480-27, 8 **DESCRIPTION:** Stained, ettringite-filled, entrained sized air void spaces within 1mm of the distressed joint face (left); in thin section under plane polarized light.
MAG: 40x

Field Notes and Petrographic Reports for Project 0280-049a, Core C-4

Table A.14. Field notes for SP Number 0280-049, I-35.

Core	Location from Joint	RP	Station	Direction	Lane	Offset	Thickness
C-4							
C-5							
C-6			*No Data*				
C-7							
C-8							
C-9							

24-LAB-001 Petrographic Examination of Hardened Concrete
ASTM C856

Project No.	24-00776	Date:	June 26, 2014
Sample ID:	0280-049, C-04	Performed by:	C. Braaten

I. General Observations

1. Sample Dimensions: Our analysis was performed on both lapped sides of a 242 mm (9-1/2") x 112 mm (4-7/16") x 34 mm (1-5/16") thick section (in two pieces) and a 76 mm (3") x 52 mm (2") wide thin section that were sawcut and prepared from the original 120 mm (4-3/4") diameter x 242 mm (9-1/2") long core taken directly through a distressed sawcut joint. The thin section was located at between 80 mm and 160 mm depth in the core from the top surface; directly adjacent to the distressed joint surface.

2. Surface Conditions:
Top: Fairly smooth, traffic worn surface; exposing many traffic worn, fine aggregate surfaces.
Bottom: Rough, irregular; fractured surface.

3. Reinforcement: None observed.

4. General Physical Conditions: The core was taken through a sealed pavement joint. The dark gray silicone joint sealant was mostly de-bonded from both sides of the sawcut joint. Below the silicone joint sealant was a 12 mm (1/2") foam backer rod. The joint was characterized by an approx. 5 mm wide sawcut proceeding 68 mm (2-11/16") depth from the top surface and an approx. 10 mm wide reservoir cut to 37 mm (1-7/16") depth. Vertical scaling/spalling distress in the paste-only starts at as shallow as 50 mm depth in the sawcut joint surface and incorporates between a few mm and 24 mm of total concrete paste between the two sides of the joint crack. The joint plane is characterized by numerous relatively "clean" and un-distressed coarse aggregate protruding from the concrete. The widest loss of concrete (to 24 mm) occurs below 115 mm depth in the concrete from the top surface. The core does exhibit some residual interlock between the two halves. Several sub-vertical microcracks (incipient spalling) were observed generally within the paste-only and within 5 mm of the distressed joint surface. A few sub-horizontal microcracks were observed splaying from the distressed joint. The coarse aggregate appeared sound. No evidence of ASR associated with the coarse aggregate was observed. No reaction rims were obvious. Internal, randomly oriented, empty micro-fractures appear to have been produced by the crushing procedure. Numerous alkali-silica reacted shale fine aggregate were present in the core.

The rough screeded top surface of the core exhibits moderate mortar erosion/traffic wear; exposing several fine aggregate surfaces. The concrete was fairly well consolidated, with only a few entrapped voidspaces observed in excess of 22 mm in diameter in the mid-section of the core. The concrete was purposefully air entrained and originally contained a well-distributed air void system considered freeze-thaw resistant under severe exposure conditions. Original air void parameters include an 8.4% entrained-sized void volume and a 0.003" spacing factor. Secondary ettringite, with some portlandite, fills many of the smaller entrained sized voidspaces within approx. 10 mm of the distressed joint surface and approximately 5 mm from the bottom surface of the core. Void fillings decrease with depth from the joint plane. Actual measured air void parameters, which excludes the ettringite void fillings, in a band between approx. 0mm and at least 12mm (0-0.5") depth from the distressed joint surface (below 105mm depth in the core), are 2.8% entrained volume and a 0.011" spacing factor.

II. Aggregate

1. Coarse: 38 mm (1-1/2") nominal sized blended coarse aggregate consisting of crushed granite and gravel (rhyolite, basalt, carbonate, quartz, chert, sandstone, and granite). The coarse aggregate appeared well graded and exhibited good overall distribution.

2. Fine: Natural quartz, feldspar, and lithic sand (granite, chert, carbonates, basalt, rhyolite, siltstone and shale.) The grains were mostly sub-rounded with many smaller sub-angular particles. The fine aggregate appeared fairly graded and exhibited good overall uniform distribution.

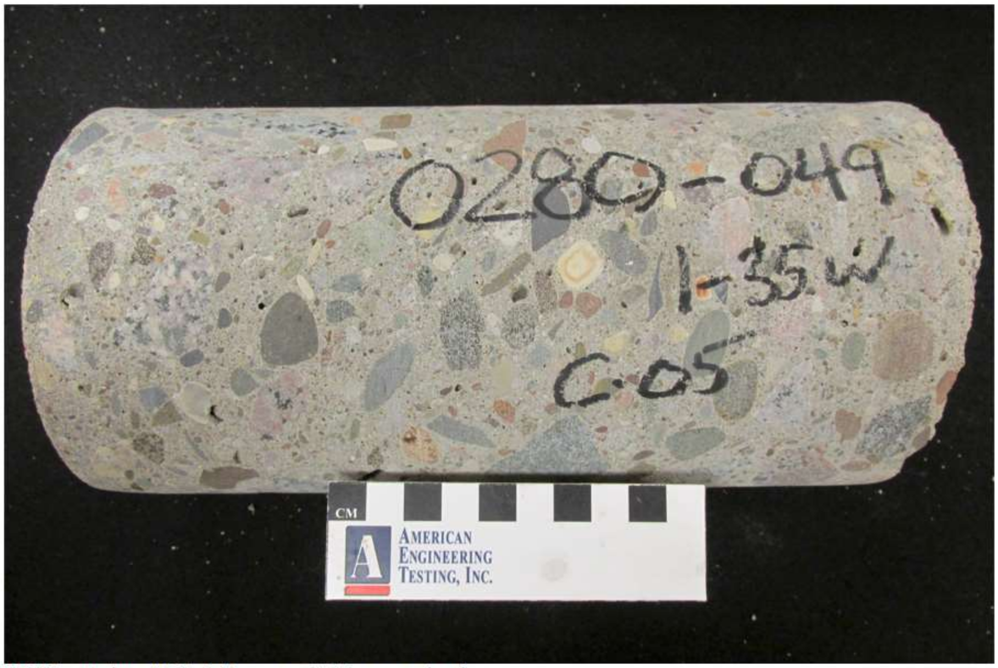
III. Cementitious Properties

1.	Air Content:	9.7% total original air void.
2.	Depth of carbonation:	Ranged from negligible up to 3 mm depth from the top surface of the core; "spiking" up to approximately 14 mm depth following a sub-vertical microcrack. Carbonation proceeding from the joint crack ranged from negligible up to 5 mm.
3.	Pozzolan presence:	Flyash was observed.
4.	Paste/aggregate bond:	
5.	Paste color:	Similar to light olive gray (Munsell® 5Y 6/1), similar to yellowish gray (Munsell® 5Y 8/1) in the carbonated zones.
6.	Paste hardness:	Moderate (Mohs 3).
7.	Microcracking:	Several sub-vertical microcracks (incipient spalling) were observed generally within the paste-only and within 5 mm of the distressed joint surface. A few sub-horizontal microcracks were observed splaying from the distressed joint.
8.	Secondary deposits:	Secondary ettringite, with some portlandite, fills many of the smaller entrained sized voidspaces within approx. 10 mm of the distressed joint surface and approximately 5 mm from the bottom surface of the core. Void fillings decrease with depth from the joint plane.
9.	w/cm:	Estimated at between 0. and 0. with approximately to % residual portland cement clinker particles and an amount of flyash visually consistent with a to % replacement of portland cement.
10.	Cement hydration:	Alites: . Belites:

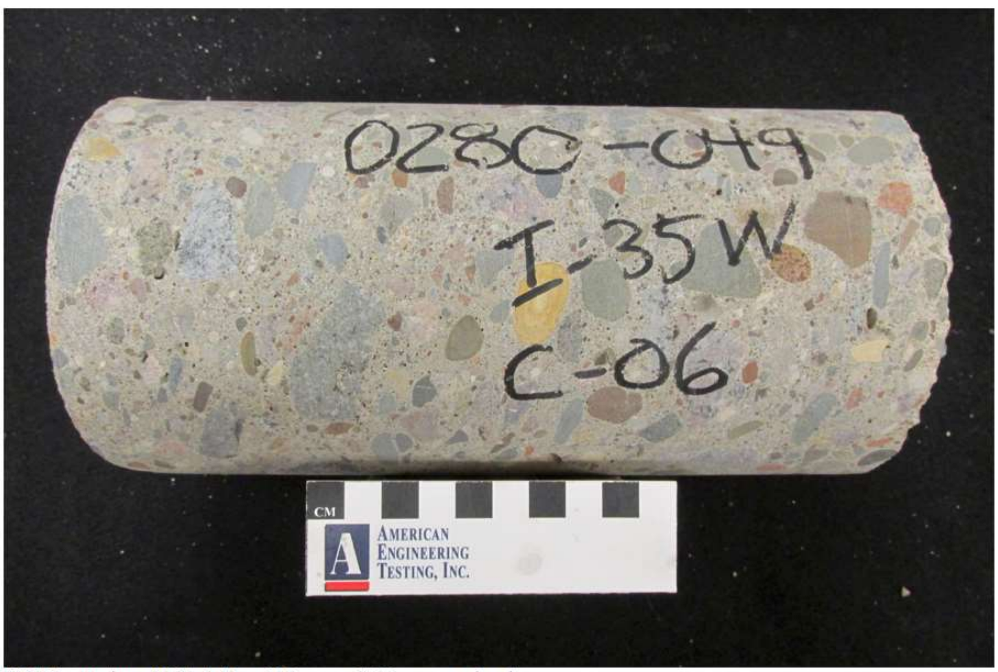
.

DESCRIPTION – Project 0280-049a, core C-04, as-received

DESCRIPTION – Project 0280-049a, core C-04 as-received

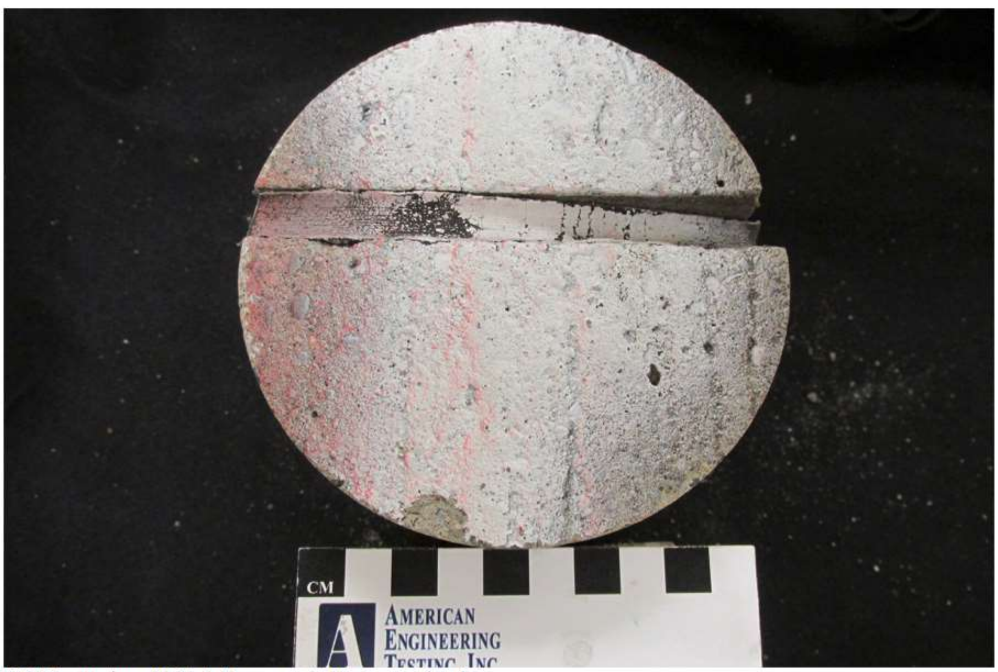


DESCRIPTION – Project 0280-049a, core C-05, as-received

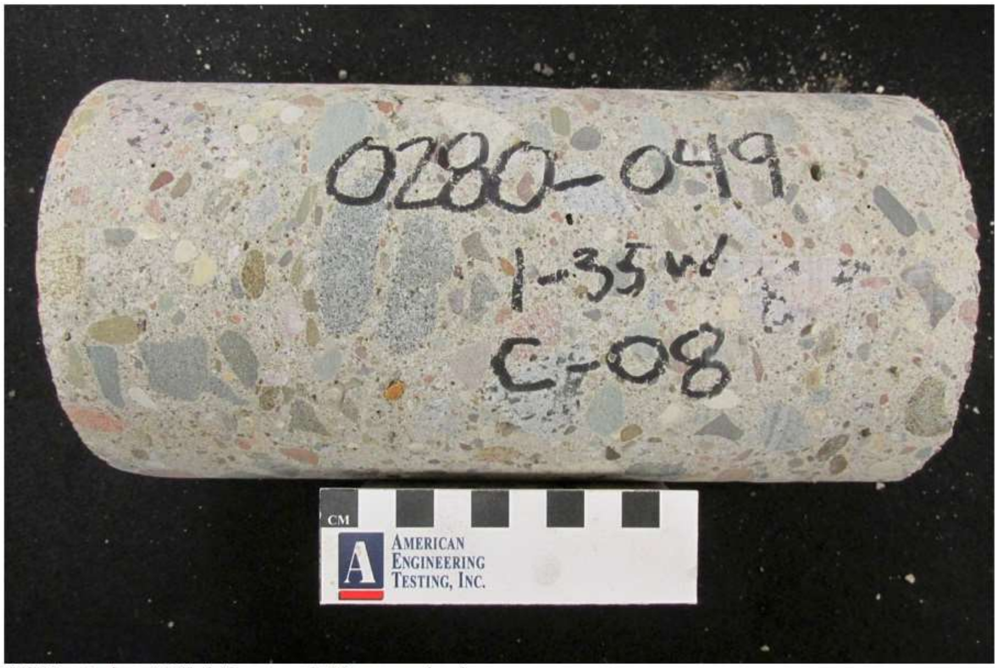


DESCRIPTION – Project 0280-049a -116, core C-06, as-received

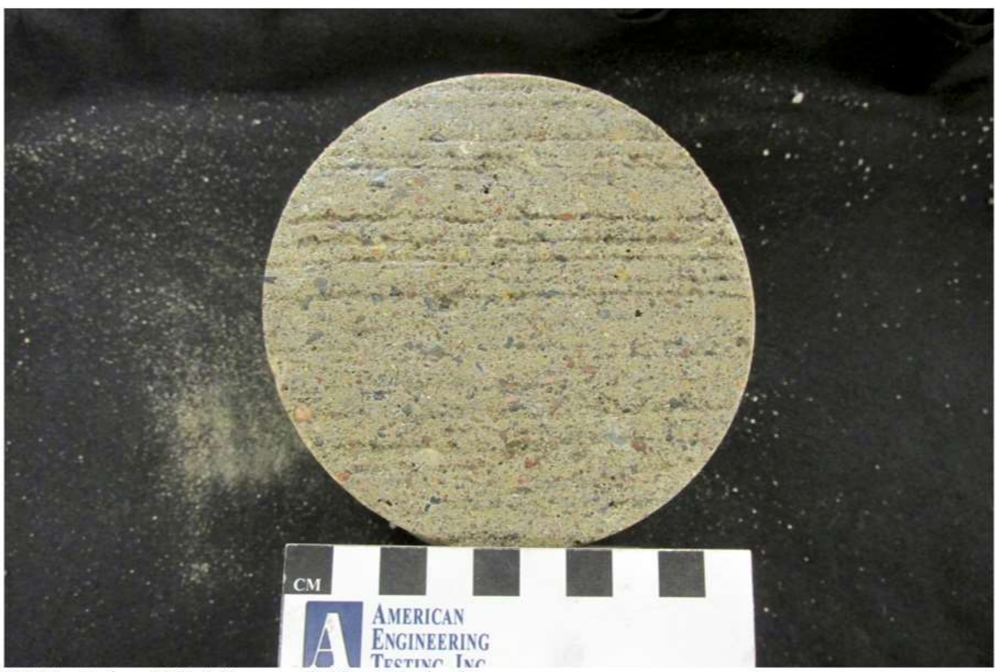
DESCRIPTION – Project 0280-049a, core C-07, as-received



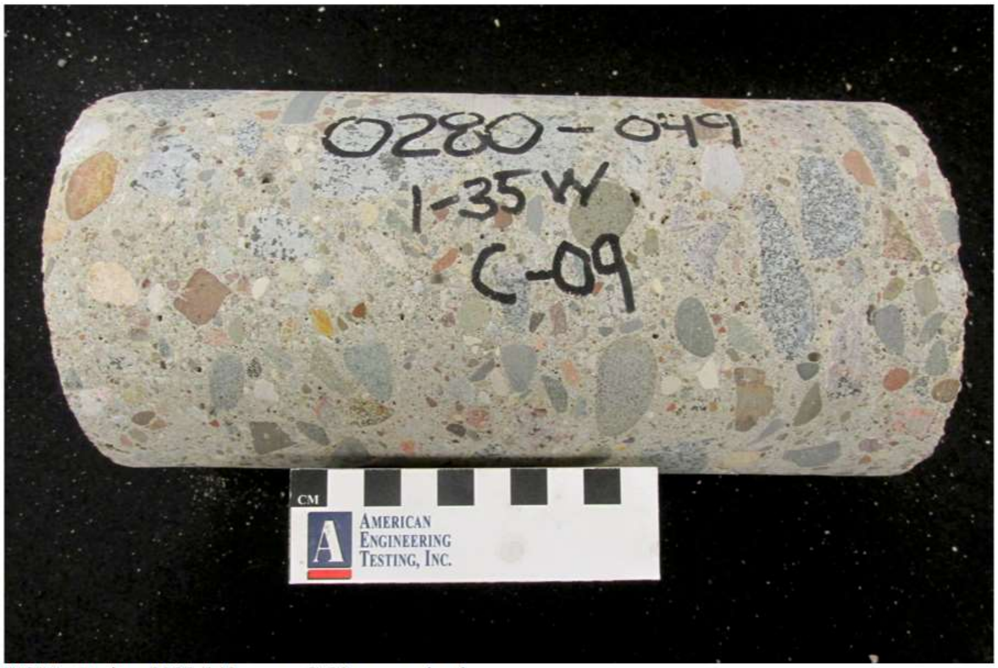
DESCRIPTION – Project 0280-049a, core C-07, as-received



DESCRIPTION – Project 0280-049a, core C-08, as-received



DESCRIPTION – Project 0280-049a, core C-09, as-received



DESCRIPTION – Project 0280-049a, core C-09, as-received

Field Notes and Petrographic Reports for Project 1907-53, Core C04

Table A.15. Field notes for SP Number 1907-53, US-55/TH-52.

Core	Location from Joint	RP	Station	Direction	Lane	Offset	Thickness
C1	ON		316+20	SB	PA	1.5’	13.000”
C2	2.0'		316+42	SB	PA	1.5’	13.000”
C3	2.0'		316+64	SB	PA	1.5’	13.000”
C4	ON		323+80	NB	DR	1.5’	13.000”
C5	2.0'		323+58	NB	DR	1.5’	13.000”
C6	2.0'		323+38	NB	DR	1.5’	13.000”
C7	ON		291+80	NB	DR	1.5’	13.000”
C8	2.0'		291+58	NB	DR	1.5’	13.000”
C9	2.0'		291+38	NB	DR	1.5’	13.000”

24-LAB-001 Petrographic Examination of Hardened Concrete
ASTM C856

Project No.	24-00776	Date:	June 30, 4014
Sample ID:	1907-53, C-04	Performed by:	D. Hunt

I. General Observations

1. Sample Dimensions: Our analysis was performed on both lapped sides of a 330mm (13") x 111mm (4-3/8") x 38mm (1-1/2") thick section (in two pieces) and a 76mm (3") x 52mm (2") wide thin section that were sawcut and prepared from the original 111mm (4-3/8") diameter x 330mm (13") long core taken directly through a distressed sawcut joint. The thin section was located at between 25 mm and 105 mm depth in the core from the top surface; directly adjacent to the severely distressed joint surface.

2. Surface Conditions:
   Top: Fairly rough, mortar eroded surface; exposing many fine aggregate surfaces.
   Bottom: Rough, irregular, formed surface; placed on grade.

3. Reinforcement: None observed.

4. General Physical Conditions: The core was taken directly through a severely distressed pavement joint. A very thin layer of silicone joint sealant, placed on a foam backer rod (?), was observed fairly well bonded to both sides of the sawcut joint, only, between 1mm and 9mm depth from the top surface. The thickness of the silicone joint sealant ranged from 1mm to 2mm at the bottom of the meniscus; above the foam backer rod. The joint was characterized by an approx. 4mm wide pilot sawcut, partially vertically scaled/spalled away, measurable to 72mm depth from the top surface, and an approx. 10mm wide reservoir cut to 33mm depth. The sawcut surfaces of the pilot cut and reservoir cut were coated with a layer of olive gray colored debris. The resulting joint crack proceeded the depth of the core and passes around most coarse aggregate particles it encounters. Vertical scaling/spalling along the joint begins as shallow as approx. 60mm depth; with a signifcant loss of paste beginning at approx. 70mm depth from the top surface. Residual interlock between the core halves was sporadic with interlock occurring between only a few coarse aggregate particles and their corresponding sockets. Paste loss along the joint crack consistently measured 10mm to 20 along the entire length of the crack. In general, paste loss was observed along the entire length of the joint crack with the widest loss of paste, up to 25mm, between 70mm and 110mm depth from the top surface. The joint faces were characterized by several relatively "clean" and un-distressed coarse aggregates protruding up to 25mm from relatively dirty concrete joint faces. A sub-vertical macrocrack, observed on the top surface of one core halve, proceeded across the top surface sub-perpendicular to the sawcut joint and was observed terminating on the vertically cored edge at approx. 50mm depth from the top surface of the core. Several sub-vertical microcracks (incipient spalling) were observed generally within the paste-only and within 5mm of the distressed joint surface below 76mm depth from the top surface of the core. A few sub-vertical drying shrinkage microcracks proceeded up to 7mm depth from the top surface. The coarse aggregate appeared sound. No evidence of ASR associated with the coarse aggregate was observed. A few alkali-silica "reacted" (ASR) shale fine aggregate particles were present in the core. The "reacted" shale particles exhibit internal cracking that propagates into the paste. ASR gel was observed partially filling a few air void spaces.

   The fairly rough top surface of the core exhibits mortar erosion; exposing many fine aggregate surfaces. The concrete was fairly well consolidated, with a few consolidation voidspaces observed up to 32mm in diameter in the core. The concrete was purposefully air entrained and contains a well-distributed air void system considered freeze-thaw resistant under severe exposure conditions. Original air void parameters include a 5.3% entrained-sized void volume and a 0.005" spacing factor. Secondary ettringite fills numerous entrained sized voidspaces within 10mm of the distressed joint faces; below 90mm depth in the core. Void fillings decrease with distance from the joint faces.

II. Aggregate

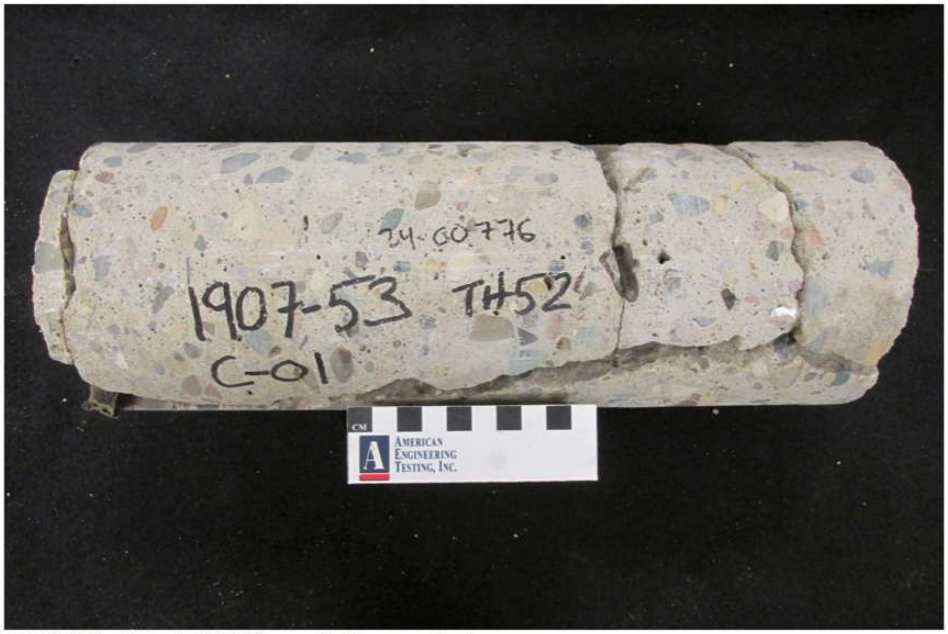
1. Coarse: 19mm (3/4") nominal sized recycled concrete and naturally occurring glacial gravel composed chiefly of granite, basalt, rhyolite, greywacke, carbonates and chert. The coarse aggregate appeared well graded and exhibited good overall distribution.

2. Fine: Natural quartz, feldspar, and lithic sand (granite, chert, carbonates, basalt, rhyolite, greywacke and shale.) The grains were mostly sub-rounded with many smaller sub-angular particles. The fine aggregate appeared fairly graded and exhibited good overall uniform distribution.

III. Cementitious Properties

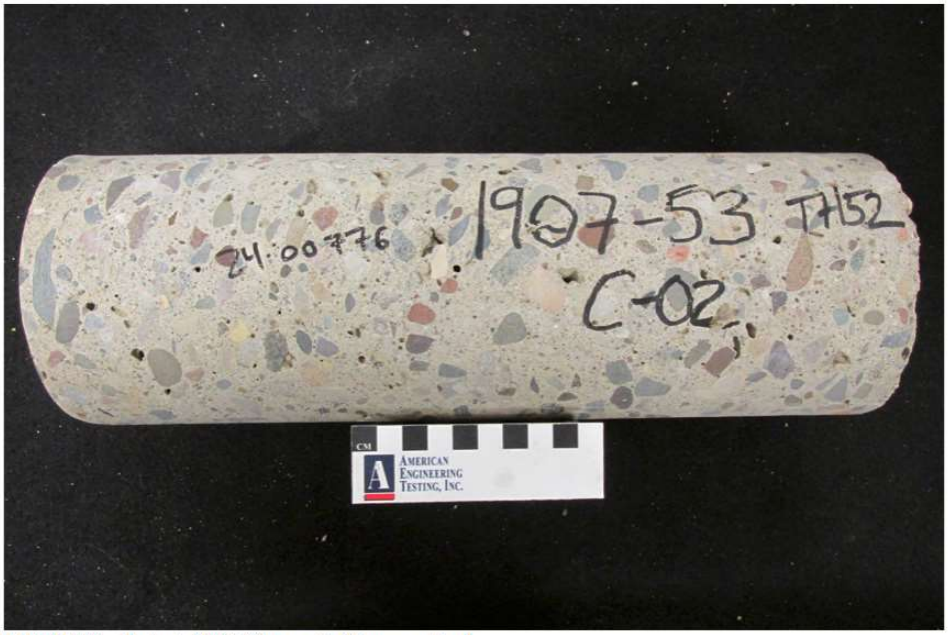
1. Air Content: 7.3% total original air void.

2.	Depth of carbonation:	Ranged from 1mm up to 4mm depth from the top surface of the core; "spiking" up to 7mm depth along a sub-vertical microcrack. Carbonation proceeded up to 16mm depth from the top surface along the reservoir cut. Carbonation depth proceeding from the joint crack ranged from 1mm up to 10mm.
3.	Pozzolan presence:	Flyash and ground granulated blast furnace slag was observed.
4.	Paste/aggregate bond:	
5.	Paste color:	Similar to pale yellowish brown (Munsell® 10YR 6/2) to approx. 120mm depth from the top surface becoming mottled pale yellowish brown to medium bluish gray (Munsell® 5B 5/1) between 120mm and 170mm depth becoming bluish gray below 170mm depth.
6.	Paste hardness:	Hard (Moh's 3.5-4).
7.	Microcracking:	A sub-vertical macrocrack, observed on the top surface of one core halve, proceeded across the top surface sub-perpendicular to the sawcut joint and was observed terminating on the vertically cored edge at approx. 50mm depth from the top surface of the core. Several sub-vertical microcracks (incipient spalling) were observed generally within the paste-only and within 5mm of the distressed joint surface below 76mm depth from the top surface of the core. A few sub-vertical drying shrinkage microcracks proceeded up to 7mm depth from the top surface.
8.	Secondary deposits:	Secondary ettringite fills numerous entrained sized voidspaces within 10mm of the distressed joint faces; below 90mm depth in the core. Void fillings decrease with distance from the joint faces. ASR gel was observed partially filling a few air void spaces.
9.	w/cm:	Estimated at between 0. and 0. with approximately to % residual portland cement clinker particles, approximately to % residual slag particles and an amount of flyash visually consistent with a to % replacement of portland cement.
10.	Cement hydration:	Alites: Belites:

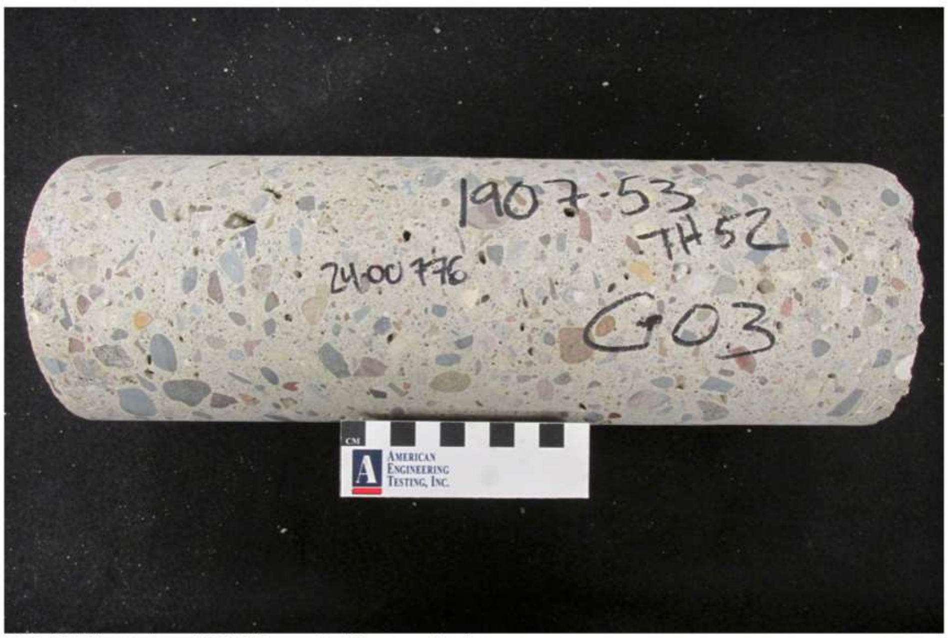


DESCRIPTION – Project 1907-53 core C-01 as-received.

DESCRIPTION – Project 1907-53 core C-01 as-received.



DESCRIPTION – Project 1907-53 core C-02 as-received.



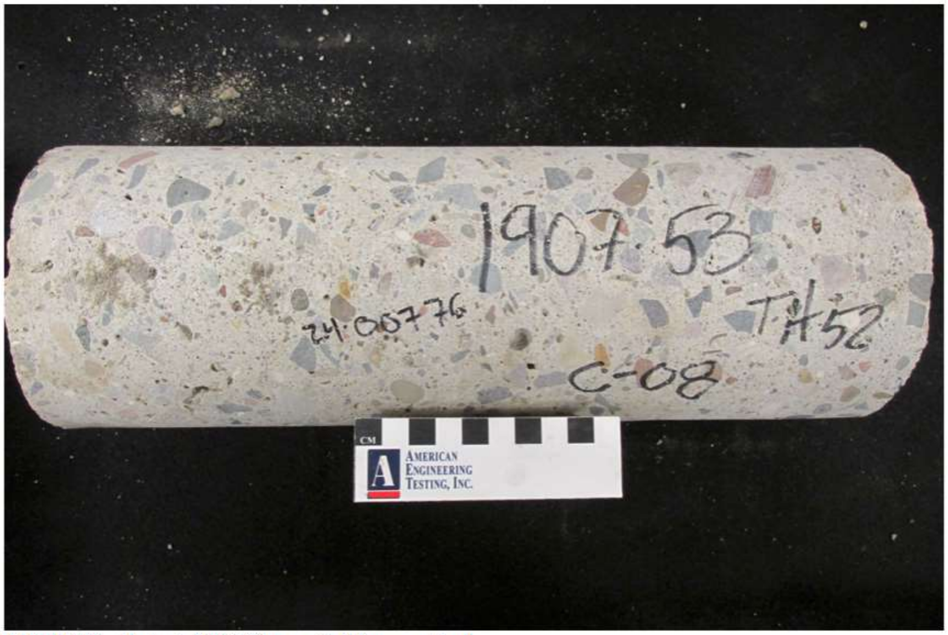
DESCRIPTION – Project 1907-53 core C-03 as-received.

DESCRIPTION – Project 1907-53 core C-04 as-received.

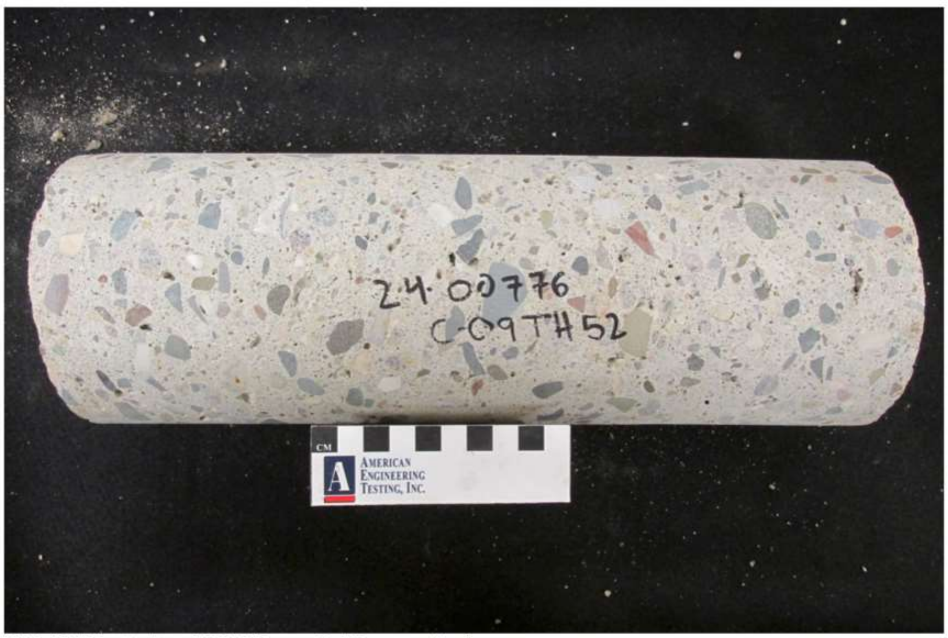
DESCRIPTION – Project 1907-53 core C-04 as-received.

DESCRIPTION – Project 1907-53 core C-05 as-received.

DESCRIPTION – Project 1907-53 core C-07 as-received.



DESCRIPTION – Project 1907-53 core C-08 as-received.



DESCRIPTION – Project 1907-53 core C-09 as-received.

Field Notes and Petrographic Reports for Project 1907-54, Cores C-1A, C-4, C-7

Table A.16. Field notes for SP Number 1907-54, US-55.

Core	Location from Joint	RP	Station	Direction	Lane	Offset	Thickness
C-1A	ON		353+30	EB	DR		12.500"
C-1	ON		353+30	EB	DR		6.000"
C-2	2.0'		353+60	EB	DR		12.250"
C-3	2.0'		353+85	EB	DR		12.250"
C-4	ON		372+30	WB	DR		12.000"
C-5	2.0'		372+20	WB	DR		12.250"
C-6	2.0'		371+80	WB	DR		12.250"
C-7	2.0'		411+80	NB	DR		8.000"
C-8	ON		412+00	NB	DR		9.000"
C-9	OFF		412+15	NB	DR		9.000"

00 LAB 001 Petrographic Examination of Hardened Concrete
ASTM: C-856

Project No.	28-00337	Date:	October 23, 2012
Sample ID:	1907-54, C-1A	Performed by:	D. Hunt, G. Moulzolf

I. General Observations

1. Sample Dimensions: Our analysis was performed on both lapped sides of a 318mm (12 1/2") x 114mm (4 1/2") x 42mm (1 5/8") thick section (in two pieces), a 318mm (12 1/2") x 102mm (4") x 31mm (1 1/4") thick section (in two pieces), and two 76mm (3") x 52mm (2") wide thin sections that were sawcut and prepared from the original 114mm (4 1/2") diameter x 318mm (12 1/2") long core taken directly through a distressed sawcut joint. The thin sections were located at between 51mm and 127mm depth and 242mm and 318mm depth in the core from the top surface; directly adjacent to the distressed joint surface.

2. Surface Conditions:
   Top: Fairly rough, textured, tined, mortar eroded/traffic worn surface; exposing many fine aggregate surfaces.
   Bottom: Rough, irregular, formed surface; placed on a natural aggregate sub-base.

3. Reinforcement: None observed.

4. General Physical Conditions: The core was taken directly through a distressed pavement joint. A silicone joint sealer was only partly attached to both sides of the sawcut joint between 3mm and 20mm depth from the top surface. The joint sealer was placed upon a 12mm diameter foam backer rod. The sealant appeared only originally well adhered at the tooled "meniscus" in the sealant between 3mm and up to 12mm depth into the joint. The joint was characterized by an approx. 5mm wide pilot sawcut proceeding to 80mm depth from the top surface and an approx. 10mm wide reservoir cut to 35mm depth; with the resulting joint crack proceeding the depth of the core. The joint crack proceeds around several coarse aggregate particles. In general, the greatest loss of concrete (up to 18mm wide), along the joint crack, occurs between approx. 100mm and 190 mm depth from the top surface of the core. Numerous, concentrated sub-vertical microcracks (incipient scaling) occur in soft and friable, distressed paste within 10mm of one side of the joint crack between 100 and 190mm depth from the top surface of the core. The joint crack is characterized by a "dirty" appearance with several un-distressed coarse aggregates protruding into the concrete joint. The joint plane is lined with a thin layer of grayish black debris lining the sawcut joint and the joint crack to a depth of 185mm. Below 185mm depth the joint crack is lined intermittently with a thin layer of grayish brown debris through the remaining depth of the core. Residual interlock between the two halves of core occurs mainly with the protruding coarse aggregate particles interlocking with their corresponding sockets between the base of the sawcut and approx. 115mm and between approx. 220mm and 295mm depth. A "dirty" pre-existing sub-horizontal fracture was present between 186mm and 200mm depth from the top surface on both sides of the joint crack. Further, several sub-horizontal microcracks, of unclear origin, were located between 140mm depth from the top surface and the bottom surface of the core. The coarse aggregate was composed of recycled, generally air entrained concrete containing natural glacial gravel. No evidence of ASR associated with the coarse aggregate was observed. Abundant alkali-silica "reacted" (ASR) shale fine aggregate particles were present in the core. The "reacted" shale particles exhibit internal cracking that propagates into the paste. ASR gel was observed partially lining a few air voids proximate to the reactive shale particles.

   The fairly rough textured and tined top surface of the core exhibits moderate traffic wear with exposing many fine aggregate surfaces. The concrete was well consolidated, with a few irregular shaped voidspaces observed up to10mm in size. The concrete was purposefully air entrained and originally contained a well-distributed air void system considered freeze-thaw resistant under severe exposure conditions. Original air void parameters include a 5.8% entrained-sized void volume and a 0.004" spacing factor. Secondary ettringite, with some portlandite, fills many of the smaller entrained sized voidspaces throughout the depth of the core below approx. 35mm depth from the top surface. Void fillings decrease with depth from the vertical distressed joint surfaces. Void fillings occur within the recycled concrete coarse aggregate also.

II. Aggregate

1. Coarse: 19mm (3/4") nominal sized recycled concrete and gravel consisting predominately of carbonates, chert, basalt, rhyolite, and granite. The coarse aggregate appeared well graded and exhibited good overall distribution.
2. Fine: Natural quartz, feldspar, and lithic sand (granite, chert, carbonates, basalt, siltstone and shale.) The grains were mostly sub-rounded with many smaller sub-angular particles. The fine aggregate appeared fairly graded and exhibited good overall uniform distribution.

III. Cementitious Properties

1. Air Content:	7.8% total original air void.
2. Depth of carbonation:	Ranged from negligible up to 7mm depth from the top surface of the core and ranged from negligible along the sawcut joint up to 12mm along the joint crack.
3. Pozzolan presence:	Flyash was observed.
4. Paste/aggregate bond:	Good.
5. Paste color:	Similar to Medium Light Gray (Munsell® N6)
6. Paste hardness:	Moderately hard (Moh's >3)
7. Microcracking:	Concentrated sub-vertical microcracks (incipient spalling) were observed generally within the paste-only and within 10mm of the distressed joint surface between 100mm and 190mm depth from the top surface of the core. A few fine, sub-vertical drying shrinkage microcracks proceed up to 4mm depth from the top surface.
8. Secondary deposits:	White, generally acicular grown ettringite along with some clear platelets of portlandite fills many of the finer entrained sized air voids scattered throughout the paste below approx. 35mm from the top surface. Voids within approx. 5mm of the distressed joint faces are mostly filled with secondary ettringite. Void fillings become less abundant with distance greater than 5mm from the distressed joint surface. ASR gel was observed filling to partially lining to filling a few air voids proximate to reactive shale fine aggregate particles.
9. w/cm:	Estimated at between 0.40 and 0.45 with approximately 5 to 7% residual portland cement clinker particles and an amount of flyash visually consistent with a 10 to 20% replacement of portland cement.
10. Cement hydration:	Alites: Mostly fully. Belites: Well to fully.

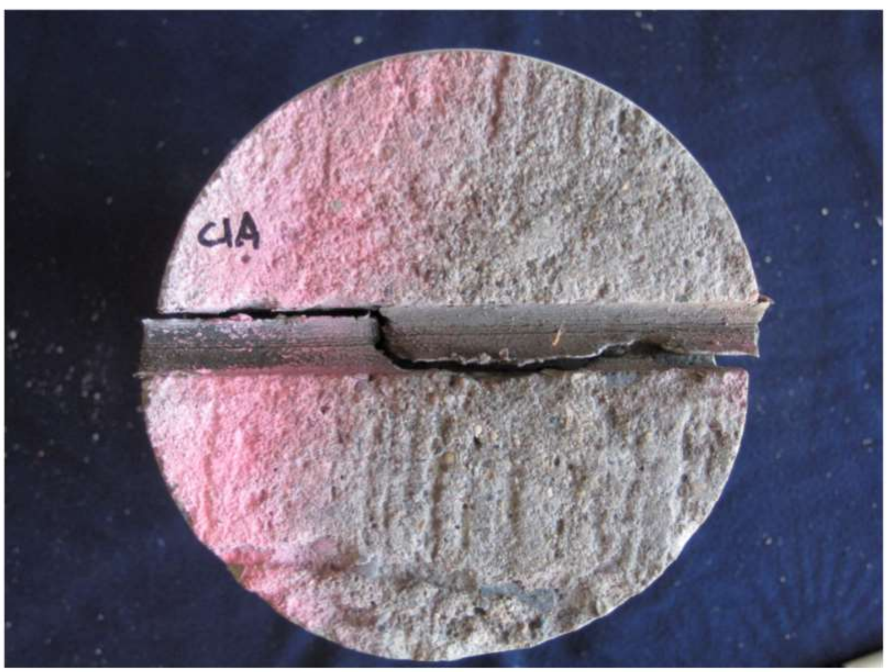
AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 2

PHOTO: 11

SAMPLE ID: 1907-54, C-1A **DESCRIPTION:** Jointed core sample utilized for petrographic analysis. The sealed top surface is right.

PHOTO: 12



SAMPLE ID: 1907-54, C-1A **DESCRIPTION:** Rough screeded and tined top surface of the core with mortar erosion and compromised sealant.

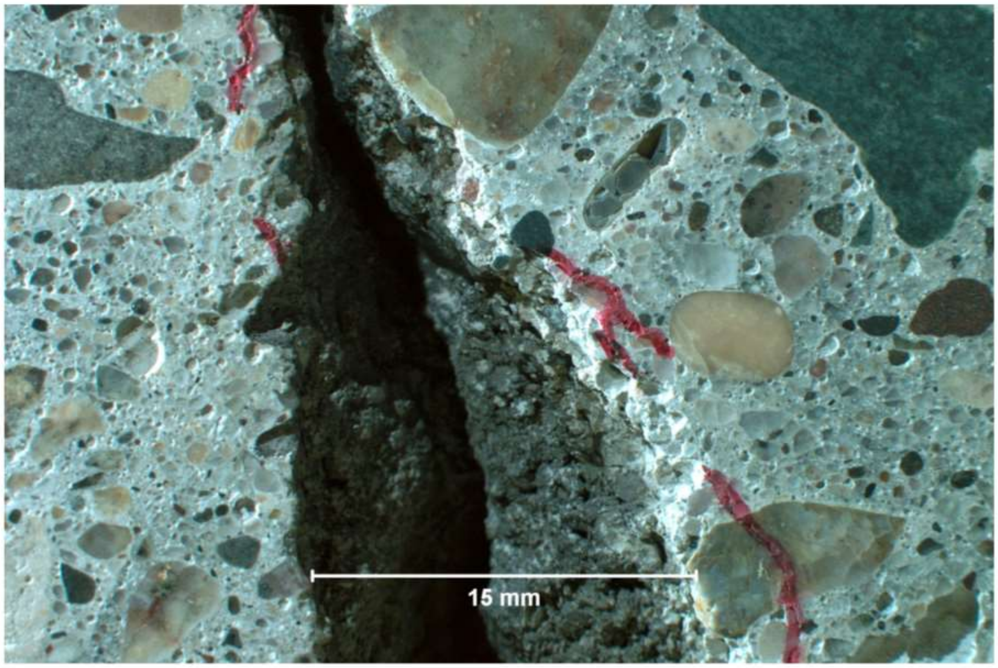
AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 2

PHOTO:
60

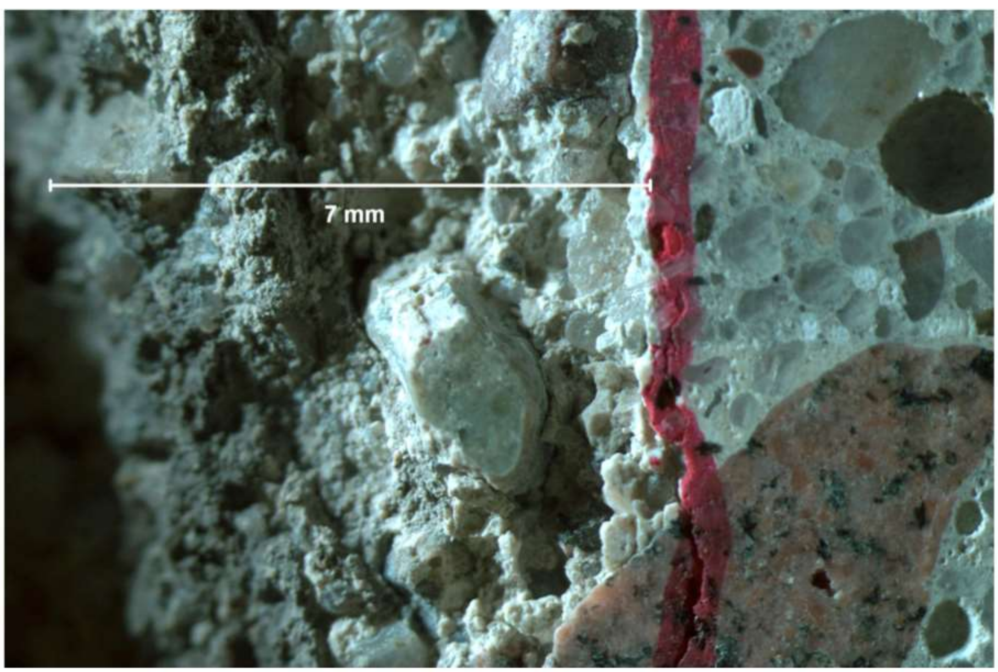
SAMPLE ID: 1907-54, C-1A **DESCRIPTION:** Sawcut and lapped cross section of core. The joint crack exhibited distress with the greatest concrete mass lost between approx. 100mm and 190mm depth from the top surface. Microcracking is mapped in red ink.

PHOTO: 88



SAMPLE ID: 1907-54, C-1A **DESCRIPTION:** The greatest mass loss along the joint occurs at greater than 100mm depth in the joint. Incipient spalling is mapped in red ink.
MAG: 5x

PHOTO: 89

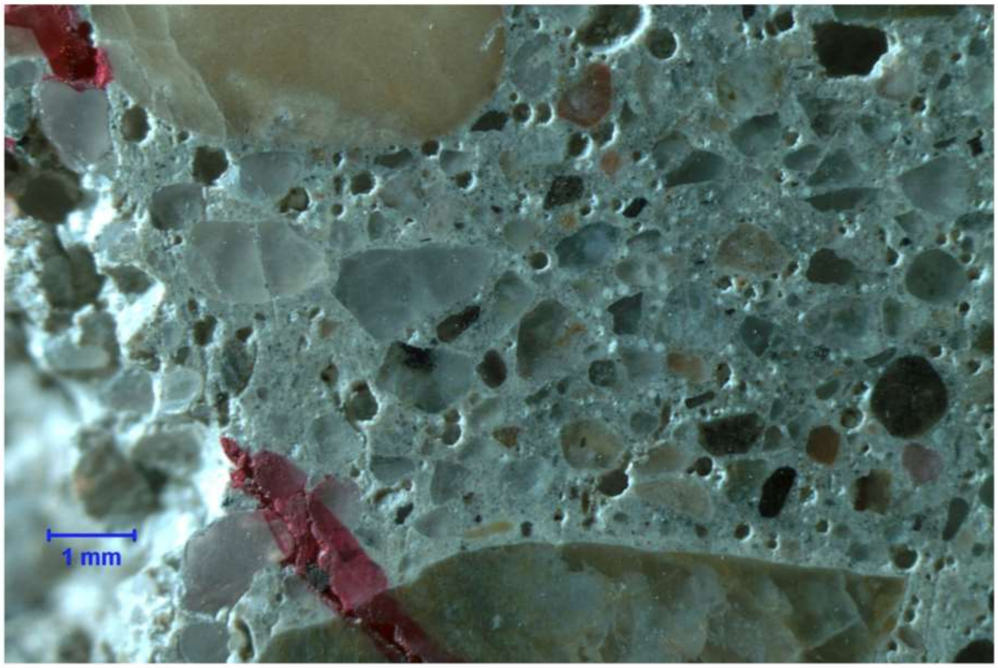


SAMPLE ID: 1907-54, C-1A **DESCRIPTION:** Severely distressed concrete paste at greater than 160mm depth in the joint. Note lack of (empty) entrained air voids to the right of the microcrack mapped in red ink.
MAG: 15x

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

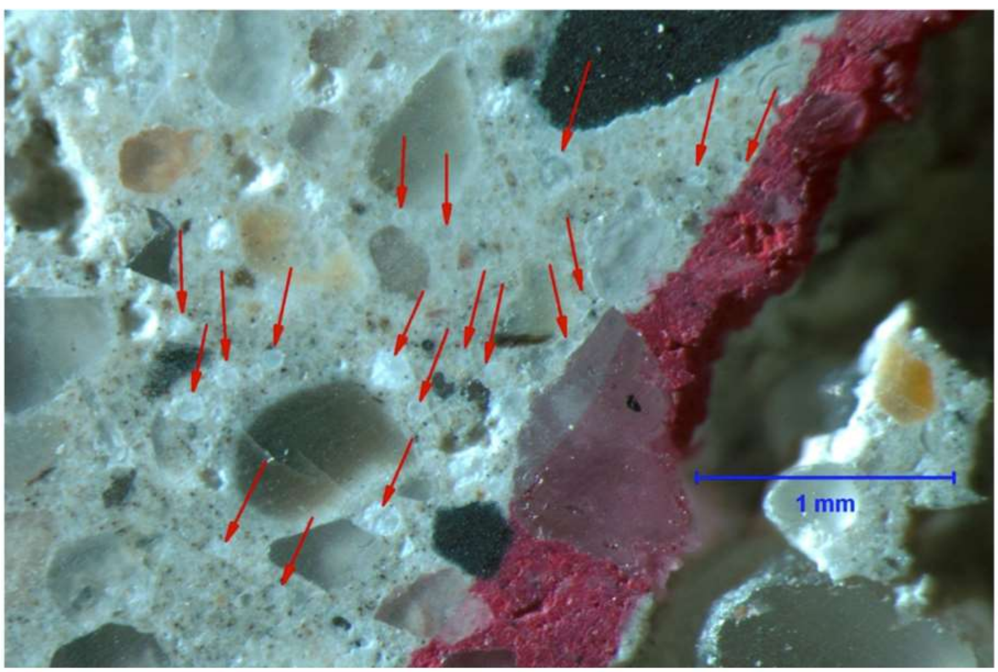
PROJECT: W/CM Study
Phase 2

PHOTO: 90



SAMPLE ID: 1907-54, C-1A **DESCRIPTION:** Compromised air void system due to secondary ettringite fillings at the distressed joint (L) at 105mm depth in the joint.
MAG: 15x

PHOTO: 91

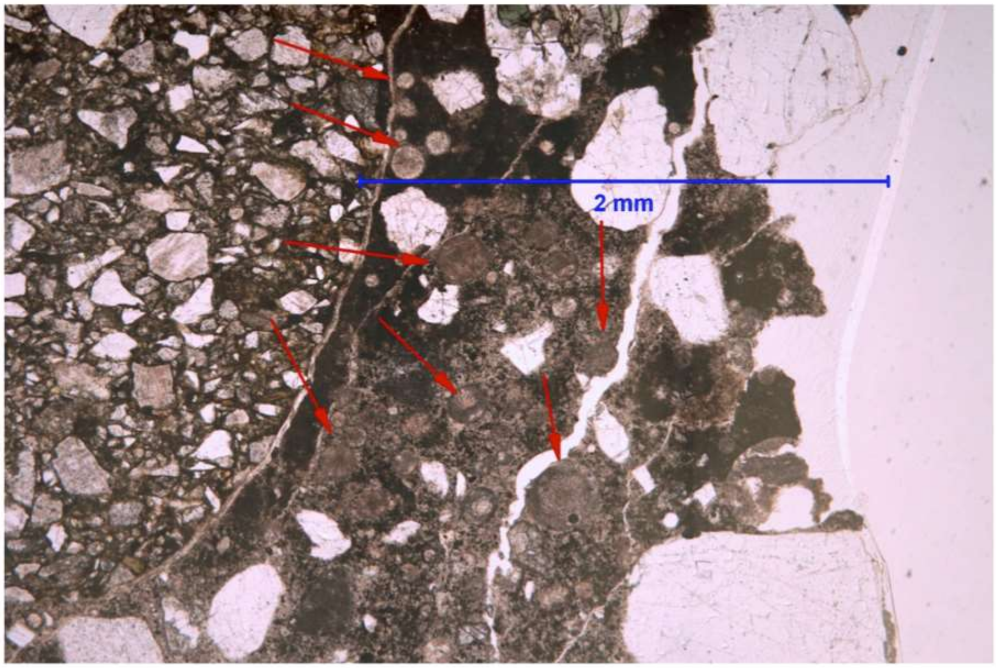


SAMPLE ID: 1907-54, C-1A **DESCRIPTION:** Clear to white secondary ettringite fills fine entrained air voidspaces along the distressed joint at 175mm depth in the core.
MAG: 50x

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

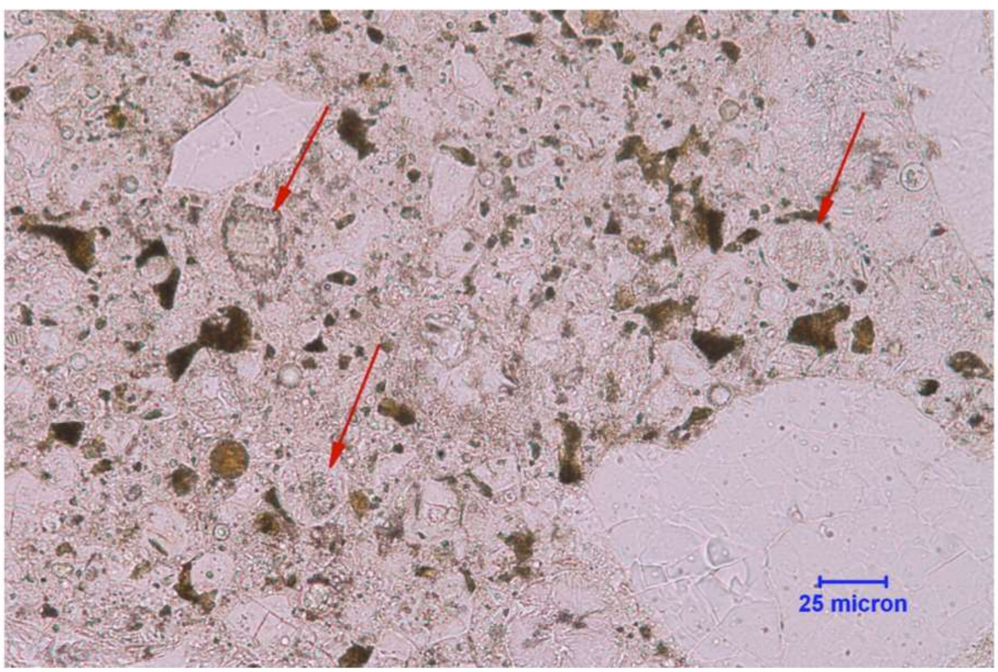
PROJECT: W/CM Study
Phase 2

PHOTO: 92



SAMPLE ID: 1907-54, C-1A **DESCRIPTION:** Secondary-ettringite filled air voidspaces in the paste directly adjacent to the distressed joint face; in thin section at mid-depth in the core, under plane polarized light.
MAG: 40x

PHOTO: 93



SAMPLE ID: 1907-54, C-1A **DESCRIPTION:** Well to fully hydrated belite portland cement clinker particles in thin section of concrete paste under plane polarized light. Note abundant spherical flyash pozzolan particles.
MAG: 400x

00 LAB 001 Petrographic Examination of Hardened Concrete
ASTM: C-856

Project No.	28-00337	Date:	August 21, 2012
Sample ID:	1907-54, C4	Performed by:	D. Hunt, G. Moulzolf

I. General Observations

1. Sample Dimensions: Our analysis was performed on both lapped sides of a 297mm (12 3/4") x 112mm (4 1/2") x 36mm (1 3/8") thick section (in two pieces), a 297mm (12 3/4") x 108mm (4 1/4") x 33mm (1 1/4") thick section (in two pieces), and two 76mm (3") x 52mm (2") wide thin sections that were sawcut and prepared from the original 114mm (4 1/2") diameter x 297mm (12 3/4") long core taken directly through a distressed sawcut joint. The thin sections were located at between 94mm and 119mm depth and 177mm and 258mm depth in the core from the top surface; directly adjacent to the distressed joint surface.

2. Surface Conditions:
Top: Fairly smooth, traffic worn surface; exposing many fine aggregate and a few coarse aggregate surfaces.
Bottom: Rough, irregular, formed surface; apparently placed on a natural granular sub-base.

3. Reinforcement: None observed.

4. General Physical Conditions: The core was taken directly through a pavement joint. A silicone joint sealant was observed well bonded to one side of the sawcut joint throughout most of it thickness between 6mm and 17mm depth from the top surface. The sealant was only intermittently bonded to the other side of the joint. The joint sealant was placed on a 12mm diameter foam backer rod. The joint was characterized by an approx. 7mm wide pilot sawcut proceeding 76mm (3") depth from the top surface and an approx. 10mm wide reservoir cut to 32mm depth with the resulting joint crack proceeding the entire depth of the core. A loss of cement paste (mortar erosion) occurs along the vertical side of the initial sawcut joint resulting in higher relief of fine aggregate and sawcut coarse aggregate particles relative to the surrounding cement paste. Paste loss of up to 10mm and residual interlock between the two halves of the core was observed between the base of the sawcut and approx. 140mm depth. Below approx. 140mm depth the mass loss is up to 30mm between 160mm to 225mm depth. The joint surfaces are vertically scaled/spalled away, leaving a "tunneled" appearance. Sub-vertical microcracks (incipient scaling/spalling) were observed within the paste and carbonate aggregate within 12mm of the distressed joint surface between approx. 90mm depth and the bottom surface of the core. Sub-horizontal to low angled apparently pre-existing cracks (fractures after coring) were observed between 155mm to 165mm depth, 206mm to 265mm depth, and 203mm to 215mm depth from the top surface. Abundant ASR gel was observed lining a few air voids proximate to reactive shale fine aggregate particles.

   The fairly smooth top surface of the core exhibits significant traffic wear; topographic highs have been worn smooth with exposed fine and coarse aggregate particles exhibiting worn surfaces. The concrete was well consolidated, with no voidspaces observed in excess of 8mm in diameter in the core. The concrete was purposefully air entrained and contains a well-distributed air void system. However, the concrete does not appear to have contained an air void system considered freeze-thaw resistant under severe exposure conditions. Original air void parameters include a 3.9% entrained-sized void volume and a 0.010" spacing factor. Secondary ettringite, with some portlandite, fills many of the smaller entrained sized voidspaces throughout the depth of the core further compromising the concretes durability.

II. Aggregate

1. Coarse: 37mm (1 1/2") nominal sized crushed dolostone. The coarse aggregate appeared well graded and exhibited good overall distribution.

2. Intermediate: 12mm (1/2") nominal sized natural gravel consisting predominately of granites, basalts, rhyolites, greywacke, gabbro, carbonates, and chert.

2. Fine: Natural quartz, feldspar, and lithic sand (granite, chert, carbonates, basalt, siltstone and shale.) The grains were mostly sub-rounded with many smaller sub-angular particles. The fine aggregate appeared fairly graded and exhibited good overall uniform distribution.

III. Cementitious Properties

1.	Air Content:	5.8% total original air void.
2.	Depth of carbonation:	Ranged from negligible up to 3mm depth from the top surface of the core; along sub-vertical drying shrinkage microcracking.
3.	Pozzolan presence:	Flyash was observed.
4.	Paste/aggregate bond:	Fair to good.
5.	Paste color:	Similar to Medium Gray (Munsell® N5) within approximately the top approx. 25mm becoming mottled Light Gray (Munsell® N4) to Medium Light Gray (Munsell® N6) below 25mm depth.
6.	Paste hardness:	Moderately hard (Moh's >3)
7.	Microcracking:	Several sub-vertical microcracks (incipient spalling) were observed generally within the paste and carbonate coarse aggregates within 12mm of the distressed joint surface between approx. 90mm and bottom surface of the core. Sub-horizontal to moderately angled microcracking occurs throughout the paste and several coarse aggregates below 72mm depth in the concrete. A few fine, sub-vertical drying shrinkage microcracks proceed up to 3mm depth from the top surface.
8.	Secondary deposits:	White, generally acicular grown ettringite along with some clear platelets of portlandite fills many of the finer entrained sized air voids scattered throughout the paste and the width of the core. Alkali silica reaction gel partially lines a few air voids proximate to reactive shale fine aggregate particles.
9.	w/cm:	Estimated at between 0.40 and 0.45 with approximately 5 to 7% residual portland cement clinker particles and an amount of flyash visually consistent with a 10 to 20% replacement of portland cement.
10.	Cement hydration:	Alites: Mostly fully. Belites: Well to fully.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 2

PHOTO: 13

SAMPLE ID: 1907-54, C-4 **DESCRIPTION:** Jointed core sample utilized for petrographic analysis. The sealed top surface is right. Note mass lost along joint crack.

PHOTO: 14

SAMPLE ID: 1907-54, C-4 **DESCRIPTION:** Fairly smooth traffic-worn top surface of the core with compromised joint sealant.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 2

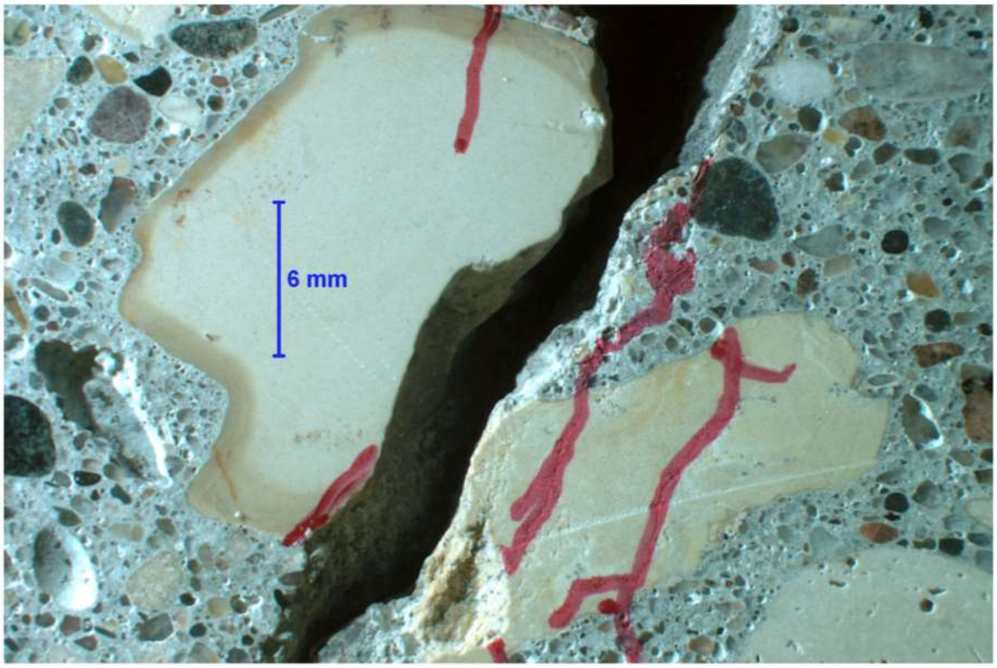
PHOTO:
61

SAMPLE ID: 1907-54, C-4 **DESCRIPTION:** Sawcut and lapped cross section of core. The joint crack exhibited distress with the greatest concrete mass lost between approx. 160mm and 225mm depth from the top surface. Microcracking is mapped in red ink.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

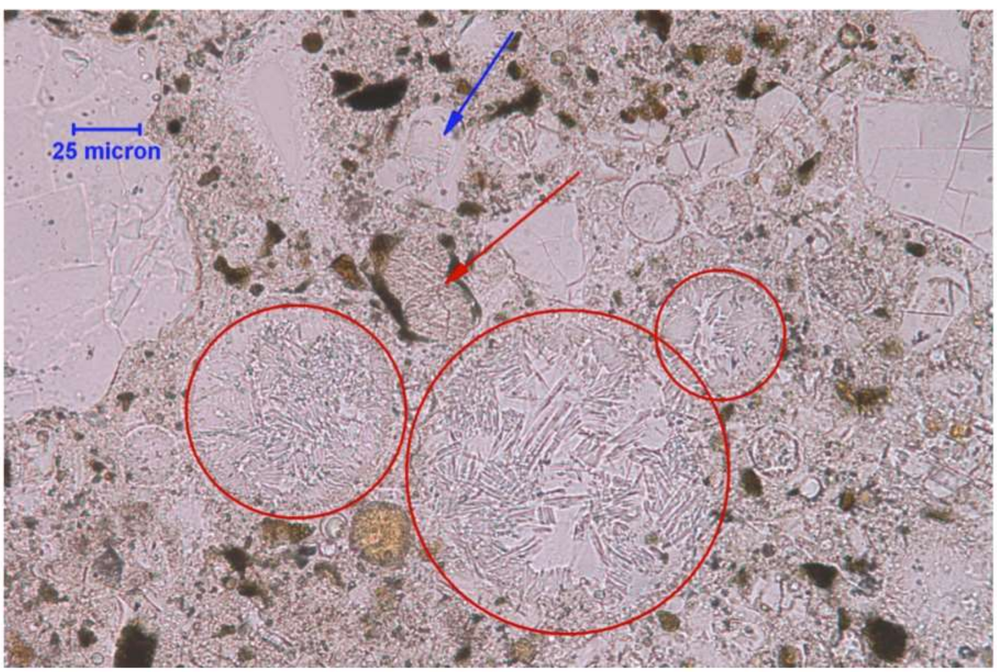
PROJECT: W/CM Study
Phase 2

PHOTO: 94



SAMPLE ID: 1907-54, C-4 **DESCRIPTION:** Coarse carbonate aggregates at below 95mm depth in the core are participating in the incipient distress along the length of the distressed joint plane
MAG: 5x

PHOTO: 95



SAMPLE ID: 1907-54, C-4 **DESCRIPTION:** Fully hydrated alite (blue arrow) and belite (red) portland cement clinker particle in thin section of concrete paste under plane polarized light. Secondary ettringite (mostly) filled air void spaces are outlined in red. Note abundant spherical flyash pozzolan particles.
MAG: 400x

00 LAB 001 Petrographic Examination of Hardened Concrete
ASTM: C-856

Project No.	28-00337	Date:	August 21, 2012
Sample ID:	1907-54, C7	Performed by:	D. Hunt, G. Moulzolf

I. General Observations

1. Sample Dimensions: Our analysis was performed on both lapped sides of a 205mm (8") x 114mm (4 1/2") x 31mm (1 1/4") thick section (in two pieces), a 205mm (8") x 108mm (4 1/4") x 37mm (1 3/8") thick section (in two pieces), and two 76mm (3") x 52mm (2") wide thin sections that were sawcut and prepared from the original 114mm (4 1/2") diameter x 205mm (8") long core taken directly through a distressed sawcut joint. The thin sections were located at between 55mm and 125mm depth and 135mm and 205mm depth in the core from the top surface; directly adjacent to the distressed joint surface.

2. Surface Conditions:
   Top: Fairly rough, traffic worn surface; exposing many fine aggregate and a few coarse aggregate surfaces.
   Bottom: Rough, irregular spalled surface; in a conical shape centered on the joint crack.

3. Reinforcement: None observed.

4. General Physical Conditions: The core was taken directly through a distressed pavement joint. A silicone joint sealant was mostly well bonded to one side of the sawcut joint between 1mm and 12mm depth from the top surface; apart from a 30mm long by 8mm thick sliver spall. The sealant was poorly and intermittently bonded to the other side. The joint sealant was placed on a 12mm diameter foam backer rod. One side of the core exhibits evidence of the first pilot sawcut to 52mm depth before severe vertical scaling/ spalling exposes larger coarse gravel aggregate particles fairly clean of paste below. A second, 11mm wide, "reservoir" sawcut is evident to 32mm depth in this surface. The adjacent sawcut surfaces are missing and completely spalled away below approx. 12mm depth. Dark brown staining and apparent fine concrete debris line the joint plane. The joint surfaces are vertically scaled/spalled away, leaving an up to approx. 17mm to 35mm wide void in the joint between 17mm depth and 170mm depth from the top surface. With some intermittent residual interlock between the two halves of the core between approx. 110mm and 150mm depth from the top surface. The void becomes wider with depth below approx. 170mm depth; proceeding at a moderate angle away from the original joint plane until encompassing the entire width of the core before reaching the sub-base. Concentrated sub-vertical microcracks (incipient spalling) were observed within the concrete paste, recycled concrete aggregates, and carbonate aggregates; within 11mm of the distressed joint surface between the top and bottom surfaces of the core.

   The fairly rough top surface of the core exhibits significant traffic wear; topographic highs have been worn smooth with exposed fine and coarse aggregate particles exhibiting worn surfaces. The concrete was well consolidated, with no voidspaces observed in excess of 10mm in diameter in the core. The concrete was purposefully air entrained and originally contained a well-distributed air void system considered freeze-thaw resistant under severe exposure conditions. Original air void parameters include a 6.9% entrained-sized void volume and a 0.005" spacing factor. Secondary ettringite, with some portlandite, fills many of the smaller entrained sized voidspaces throughout the depth of the core below approx. 12mm depth from the top surface. Void fillings are heavy at the distressed joint faces and decrease with depth from the vertical distressed joint surfaces.

II. Aggregate

1. Coarse: 19mm (3/4") nominal sized recycled concrete and gravel consisting predominately of carbonates, chert, basalt, rhyolite, and granite. The coarse aggregate appeared well graded and exhibited good overall distribution.

2. Fine: Natural quartz, feldspar, and lithic sand (granite, chert, carbonates, basalt, siltstone and shale.) The grains were mostly sub-rounded with many smaller sub-angular particles. The fine aggregate appeared fairly graded and exhibited good overall uniform distribution.

III. Cementitious Properties

1. Air Content: 6.9% total original air void.
2. Depth of carbonation: Ranged from 2mm up to 4mm depth from the top surface of the core. Apparent carbonation proceeds to several millimeters depth from the distressed joint surfaces.
3. Pozzolan presence: Flyash was observed.
4. Paste/aggregate bond: Good.
5. Paste color: Similar to Medium Light Gray (Munsell® N6)
6. Paste hardness: Moderately hard (Moh's >3)
7. Microcracking: Concentrated sub-vertical microcracks (incipient spalling) were observed within the concrete paste, recycled concrete aggregates, and carbonate aggregates within 11mm of the distressed joint surface between the top and bottom surfaces of the core. A few fine, sub-vertical drying shrinkage microcracks proceed up to 3mm depth from the top surface.
8. Secondary deposits: White, generally acicular grown ettringite along with some clear platelets of portlandite fills most of the finer entrained sized air voids scattered throughout the paste below approx. 12mm from the top surface. Void fillings become less abundant with distance greater than approx. 25mm from the distressed joint surface. A few rare "mats" of white ettringite partly fill incipient spalls on the joint plane.
9. w/cm: Estimated at between 0.39 and 0.44 with approximately 6 to 8% residual portland cement clinker particles and an amount of flyash visually consistent with a 10 to 20% replacement of portland cement.
10. Cement hydration: Alites: Fully.
    Belites: Mostly fully.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 2

PHOTO: 15

SAMPLE ID: 1907-54, C-7 **DESCRIPTION:** Jointed core sample utilized for petrographic analysis. The sealed top surface is right. Note mass lost along joint crack at base of core.

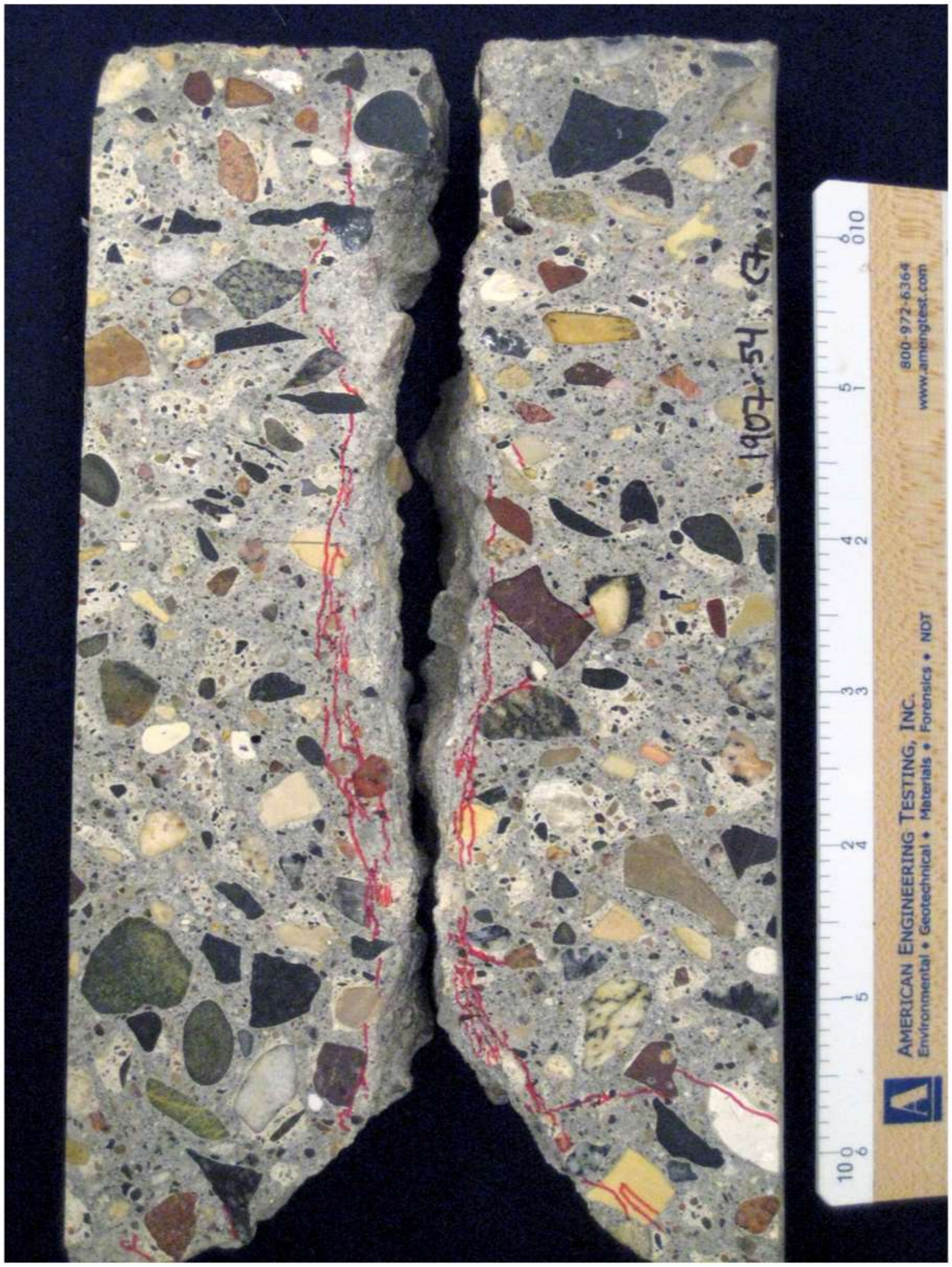
PHOTO: 16

SAMPLE ID: 1907-54, C-7 **DESCRIPTION:** Rough screeded and tined top surface of the core with traffic wear and compromised sealant.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 2

PHOTO:
62

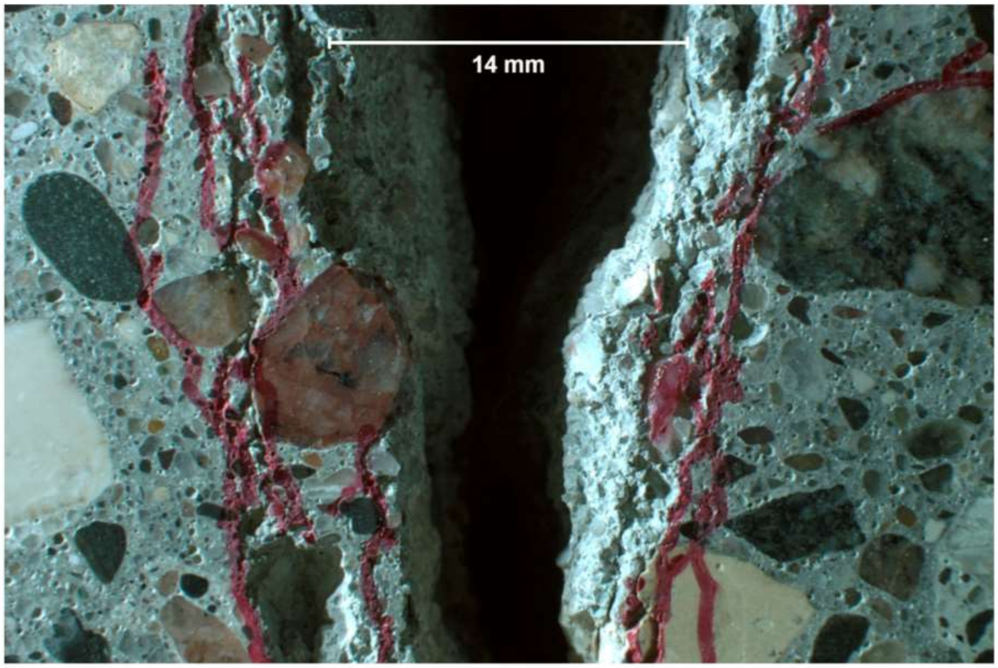


SAMPLE ID: 1907-54, C-7 **DESCRIPTION:** Sawcut and lapped cross section of core. The joint crack exhibited significant incipient distress. Microcracking is mapped in red ink.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

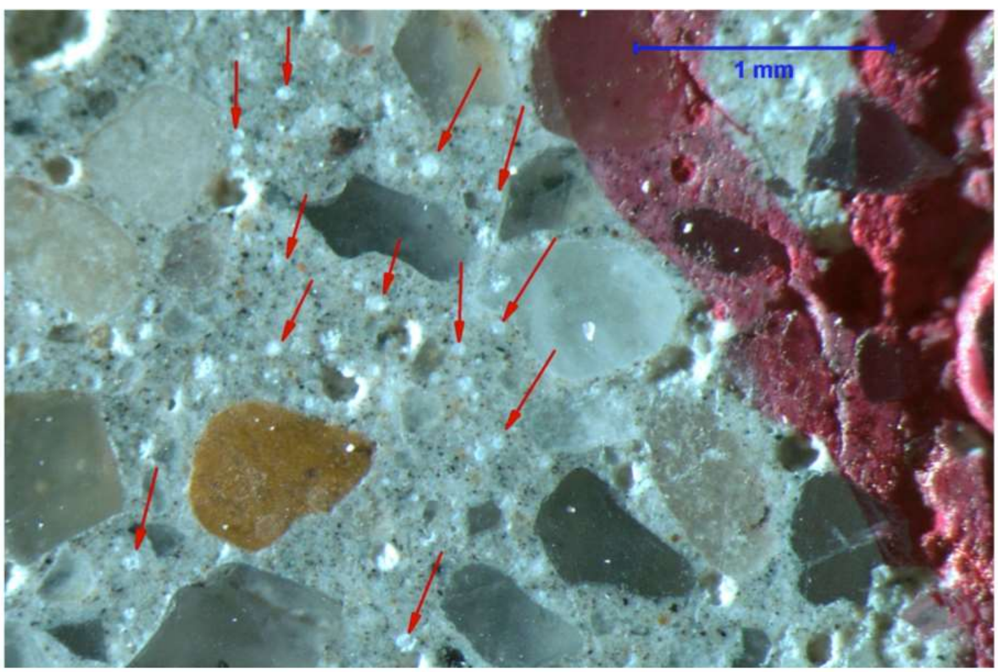
PROJECT: W/CM Study
Phase 2

PHOTO: 96



SAMPLE ID: 1907-54, C-7 **DESCRIPTION:** Concentrated incipient distress along the length of the distressed joint plane at below 110mm depth in the core.
MAG: 5x

PHOTO: 97



SAMPLE ID: 1907-54, C-7 **DESCRIPTION:** Secondary ettringite filled air voidspaces at below 125mm depth in the core and 8mm depth from the joint.
MAG: 50x

Field Notes and Petrographic Reports for Project 2782-268, Core C4

Table A.17. Field notes for SP Number 2782-268, I-35.

Core	Location from Joint	RP	Station	Direction	Lane	Offset	Thickness
C-1							
C-2							
C-3							
C-4			*No Data*				
C-5							
C-6							
C-7							
C-8							

24-LAB-001 Petrographic Examination of Hardened Concrete
ASTM C856

Project No.	24-00776	Date:	June 27, 4014
Sample ID:	2782-268, C-4	Performed by:	D. Hunt

I. General Observations

1. Sample Dimensions: Our analysis was performed on both lapped sides of a 332mm (13-1/8") x 115mm (4-1/2") x 38mm (1-1/2") thick section (in two pieces) and a 76mm (3") x 52mm (2") wide thin section that were sawcut and prepared from the original 115mm (4-1/2") diameter x 332mm (13-1/8") long core taken directly through a distressed sawcut joint. The thin section was located at between 45 mm and 125 mm depth in the core from the top surface; directly adjacent to the distressed joint surface.

2. Surface Conditions:
Top: Fairly smooth, traffic worn surface; exposing several, traffic worn, fine aggregate surfaces.
Bottom: Rough, irregular, formed surface; placed on grade.

3. Reinforcement: None observed.

4. General Physical Conditions: The core was taken directly through a distressed pavement joint. A silicone joint sealant was observed poorly bonded to both sides of the sawcut joint with a little residual tooled meniscus remaining adhered to the sawcut surface. The sealant was placed upon a 12mm diameter foam backer rod. The joint was characterized by an approx. 4mm wide pilot sawcut, partially vertically scaled/spalled away, measurable to 84mm depth from the top surface, and an approx. 10mm wide reservoir cut to 35mm depth. The sawcut surface of the pilot cut was heavily coated with a thick layer of brown debris. The resulting joint crack proceeded the depth of the core and was intermittently coated with a thin layer of light brown debris; passing around most of the coarse aggregate particles it encounters. Vertical scaling/spalling along the joint begins as shallow as approx. 35mm depth; with a significant loss of paste along one side of the pilot sawcut cut between 35mm and 85mm and significant paste loss beginning on the other side of the pilot sawcut at approx. 60mm depth. Significant paste loss occurs along the entire length of the joint crack with the greatest loss, up to 20mm, between 60mm and 115mm depth from the top surface. Interlock between the core halves appears to be between the protruding coarse aggregate particles and their corresponding sockets only. In general, the widest loss of paste occurred along within the lower portion of the pilot cut and area just below the pilot cut. This zone is characterized by several relatively "clean" and un-distressed coarse aggregates protruding from relatively dirty concrete joint faces. Soft, lighter colored paste was observed within approx. 5mm of the pilot sawcut and the resulting joint crack below approx. 35mm depth from the top surface. Numerous sub-vertical microcracks (incipient spalling) were observed generally within the paste-only and within 6mm of the distressed joint surface, beginning at approx. 41mm depth from the top surface proximate to the more severely distressed pilot sawcut joint. Several sub-vertical microcracks (incipient spalling) were observed intermittently within 3mm along the remaining depth of the joint crack. The coarse and fine aggregate appeared sound. No evidence of ASR associated with either the coarse or fine aggregate was observed.

   The fairly smooth top surface of the core exhibits significant traffic wear; topographic highs have been worn smooth with exposed fine aggregate particles exhibiting worn surfaces. The concrete was fairly well consolidated, with a several consolidation voidspaces observed up to 15mm in diameter in the core. The concrete was purposefully air entrained and contains a fairly well-distributed air void system considered freeze-thaw resistant under severe exposure conditions. Coalescence of air voids was observed around the perimeter of several coarse aggregate particles. Original air void parameters include a 10.4% entrained-sized void volume and a 0.002" spacing factor. Secondary ettringite fills numerous entrained sized voidspaces within 5mm of the distressed joint faces; below 60mm depth in the core. Void fillings decrease with distance from the joint faces.

II. Aggregate

1. Coarse: 38mm (1-1/2") nominal sized natural glacial gravel composed chiefly of granite, basalt, rhyolite, greywacke, sandstone and carbonates. The coarse aggregate appeared well graded and exhibited good overall distribution.

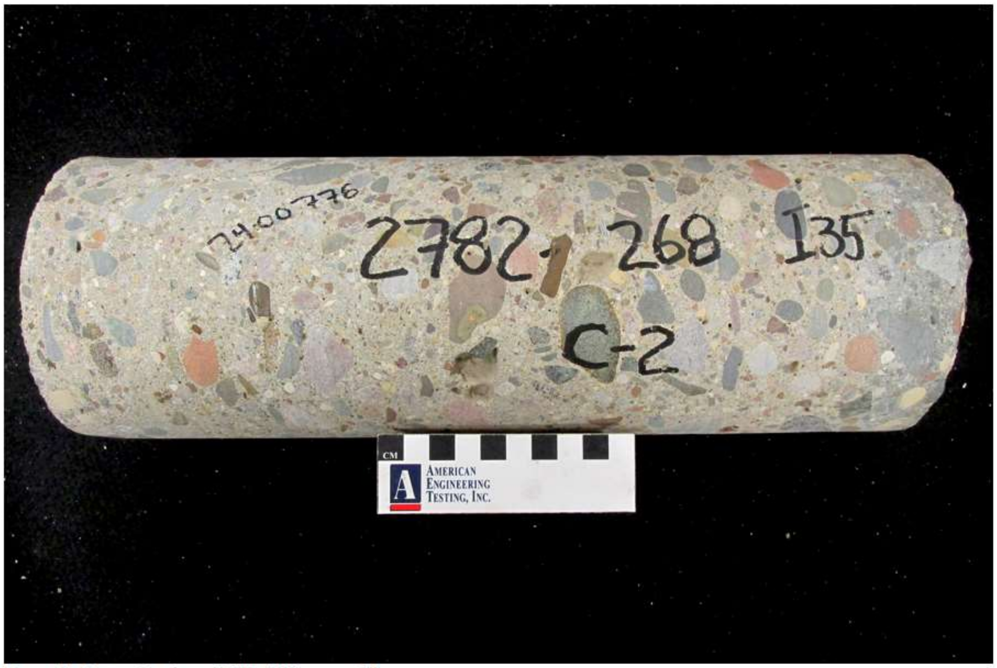
2. Fine: Natural quartz, feldspar, and lithic sand (granite, chert, carbonates, basalt, rhyolite, sandstone, greywacke and shale.) The grains were mostly sub-rounded with many smaller sub-angular particles. The fine aggregate appeared fairly graded and exhibited good overall uniform distribution.

III. Cementitious Properties

1. Air Content:	13.1% total original air void.
2. Depth of carbonation:	Ranged from <1mm up to 2mm depth from the top surface of the core; "spiking" up to 10mm depth along a paste/aggregate boundary and a cluster of air void spaces. Carbonation depth proceeding from the sawcut joint and resulting joint crack ranged from negligible up to 10mm.
3. Pozzolan presence:	Flyash was observed.
4. Paste/aggregate bond:	
5. Paste color:	Similar to medium light gray (Munsell® N6). Very light gray (Munsell® N8) up to 5mm depth along the joint crack.
6. Paste hardness:	Moderately hard (Moh's 3-3.5) becoming soft (Moh's <2) within lighter colored areas of paste up to 5mm from the joint crack below approx. 35mm depth from the top surface of the core.
7. Microcracking:	Numerous sub-vertical microcracks (incipient spalling) were observed generally within the paste-only and within 6mm of the distressed joint surface, beginning at approx. 41mm depth from the top surface proximate to the more severely distressed pilot sawcut joint. Several sub-vertical microcracks (incipient spalling) were observed intermittently within 3mm along the remaining depth of the joint crack.
8. Secondary deposits:	Secondary ettringite fills numerous entrained sized voidspaces within 5mm of the distressed joint faces; below 60mm depth in the core. Void fillings decrease with distance from the joint faces.
9. w/cm:	Estimated at between 0. and 0. with approximately to % residual portland cement clinker particles and an amount of flyash visually consistent with a to % replacement of portland cement.
10. Cement hydration:	Alites: . Belites: .

Description – Project 2782-268, core C1

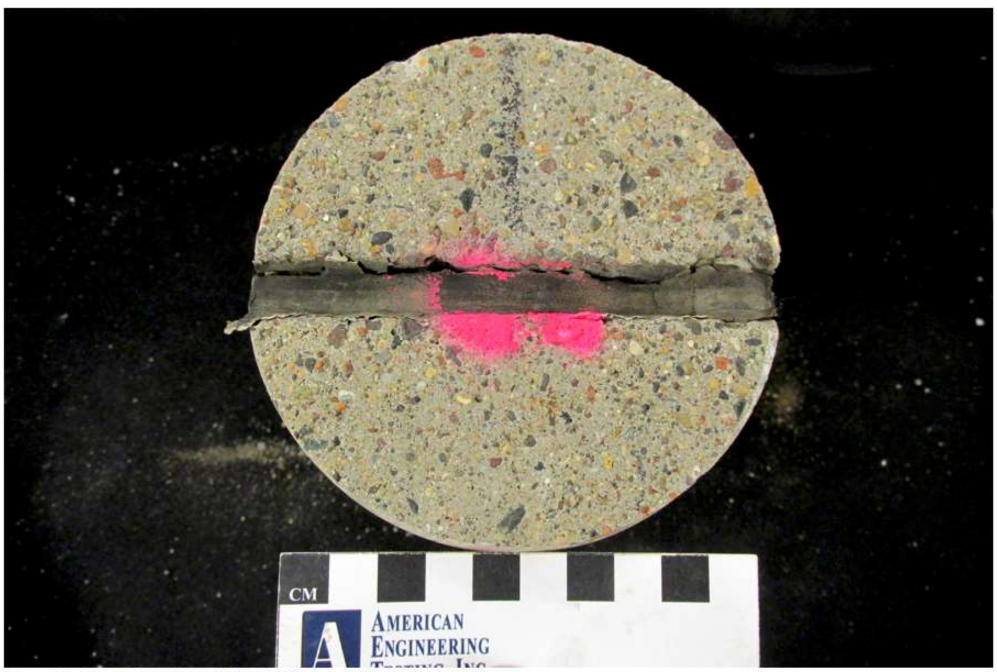
Description – Project 2782-268, core C1



Description – Project 2782-268, core C2

Description – Project 2782-268, core C3

Description – Project 2782-268, core C4



Description – Project 2782-268, core C4

Description – Project 2782-268, core C5

Description – Project 2782-268, core C6

Description – Project 2782-268, core C7

Description – Project 2782-268, core C7

Description – Project 2782-268, core C8

Description – Project 2782-268, core C9

Field Notes and Petrographic Reports for Project 2786-115, Core 3J

Table A.18. Field notes for SP Number 2786-115, I-94.

Core	Field Notes
3	20’ west of light pole A9X18 on EB 694, west of Zane Avenue, right lane
4	55’ west of light pole A9X17 on EB 694, west of Zane Avenue, right lane

24-LAB-001 Petrographic Examination of Hardened Concrete
ASTM C856

Project No.	24-00776	Date:	June 17, 4014
Sample ID:	2786-115, 3J	Performed by:	D. Hunt

I. General Observations

1. Sample Dimensions: Our analysis was performed on both lapped sides of a 176mm (6-15/16") x 143mm (5-5/8") x 40mm (1-9/16") thick section (in two pieces and a 76mm (3") x 52mm (2") wide thin section that were sawcut and prepared from the original 143mm (5-5/8") diameter x 176mm (6-15/16") long core taken directly through a distressed sawcut joint. The thin section was located at between 55 mm and 135 mm depth in the core from the top surface; directly adjacent to the distressed joint surface.

2. Surface Conditions:
Top: Fairly smooth, traffic worn surface; exposing many traffic worn, fine aggregate surfaces.
Bottom: Rough, irregular, fractured surface with a steel dowel impression.

3. Reinforcement: A steel dowel impression, at least 25mm (1") in diameter, was observed on the fractured bottom surface of the core.

4. General Physical Conditions: The core was taken directly through a distressed pavement joint. A neoprene pavement seal was observed in the joint. A small amount of an apparent adhesive was observed on the bottom portion of the neoprene seal and on the vertical face of the saw-cut reservoir joint between 12mm and 18mm depth from the top surface of the core. The joint was characterized by an approx. 4mm wide pilot sawcut, partially vertically scaled/spalled away, measurable to 75mm depth from the top surface, and an approx. 10mm wide reservoir cut to 35mm depth. The resulting joint crack proceeded the depth of the core and passes around all coarse aggregate particles it encounters. Vertical scaling/spalling along the joint begins as shallow as approx. 66mm depth; with a slight loss of paste along a portion of the pilot cut. Up to approximately 14mm of paste loss occurs along the joint between 60mm and 95mm depth from the top surface. Thin paste loss with some residual interlock between the core halves occurs between 95mm and 170mm from the top surface. In general, the widest loss of paste occurred between 60mm and 90mm depth from the top surface. This zone is characterized by several relatively "clean" and un-distressed coarse aggregates protruding from relatively "dirty" concrete joint faces. Several sub-vertical microcracks (incipient spalling) were observed generally within the paste-only and within 3mm of the distressed joint surface between 55mm and 165mm depth from the top surface of the core. The coarse aggregate appeared sound. No evidence of ASR associated with the coarse aggregate was observed. A few alkali-silica "reacted" (ASR) shale fine aggregate particles were present in the core. The "reacted" shale particles exhibit internal cracking that propagates into the paste. ASR gel was observed partially filling a few air voids proximate to the reactive shale particles

   The fairly smooth top surface of the core exhibits significant traffic wear; topographic highs have been worn smooth with exposed fine aggregate particles exhibiting worn surfaces. The concrete was well consolidated, with a few consolidation voidspaces observed up to 16mm in diameter in the core. The concrete was purposefully air entrained and contains a well-distributed air void system considered freeze-thaw resistant under severe exposure conditions. Original air void parameters include a 6.6% entrained-sized void volume and a 0.004" spacing factor. Secondary ettringite fills numerous entrained sized voidspaces within 5mm of the distressed joint faces; below 35mm depth in the core. Void fillings decrease with distance from the joint faces.

II. Aggregate

1. Coarse: 38mm (1-1/2") nominal sized crushed granite. The coarse aggregate appeared well graded and exhibited good overall distribution.

2. Fine: Natural quartz, feldspar, and lithic sand (granite, chert, carbonates, basalt, rhyolite, siltstone and shale.) The grains were mostly sub-rounded with many smaller sub-angular particles. The fine aggregate appeared fairly graded and exhibited good overall uniform distribution.

III. Cementitious Properties

1.	Air Content:	7.0% total original air void.
2.	Depth of carbonation:	Ranged from negligible up to 2mm depth from the top surface of the core; "spiking" up to 6mm along a paste/coarse aggregate boundary exposed on the top surface. Carbonation proceeding from the joint crack ranged from negligible up to 1mm.
3.	Pozzolan presence:	Flyash was observed.
4.	Paste/aggregate bond:	
5.	Paste color:	Similar to Medium Gray (Munsell® N5).
6.	Paste hardness:	Moderately hard (Moh's 3-3.5).
7.	Microcracking:	Some sub-vertical microcracks (incipient spalling) were observed generally within the paste-only and within 3mm of the distressed joint surface between 55mm 165mm depth from the top surface of the core.
8.	Secondary deposits:	Secondary ettringite fills numerous entrained sized voidspaces within 5mm of the cracked joint; below 35mm depth from the top surface. Void fillings decrease with depth from the joint faces. Alkali silica reaction gel partially fills air void spaces proximate to abundant reactive shale fine aggregate particles.
9.	w/cm:	Estimated at between 0. and 0. with approximately to % residual portland cement clinker particles and an amount of flyash visually consistent with a to % replacement of portland cement.
10.	Cement hydration:	Alites: . Belites: .

DESCRIPTION – Project 2786-115, core 3J, as-received

DESCRIPTION – Project 2786-115, core 3J, as-received

DESCRIPTION – Project 2786-115, core 4J, as-received

DESCRIPTION – Project 2786-115, core 4J, as-received

Field Notes and Petrographic Reports for Project 2786-116, Cores 1J, 2J

Table A.19. Field notes for SP Number 2786-116, I-94.

Core	Field Notes
1	5’ west of light pole A9T10 on EB 694, west of Zane Avenue, right lane
2	100’ west of light pole A9T9 on EB 694, west of Zane Avenue, right lane

24-LAB-001 Petrographic Examination of Hardened Concrete
ASTM C856

Project No.	24-00776	Date:	July 1, 2014
Sample ID:	2786-116, 1J	Performed by:	D. Hunt

I. General Observations

1. Sample Dimensions: Our analysis was performed on both lapped sides of a 342mm (13-1/2") x 143mm (5-5/8") x 44mm (1-3/4") thick section (in two pieces) and a 76mm (3") x 52mm (2") wide thin section that were sawcut and prepared from the original 143mm (5-5/8") diameter x 342mm (13-1/2") long core taken directly through a formed and sawcut joint. The thin section was located at between 82 mm and 162 mm depth in the core from the top surface; directly adjacent to the formed joint surface.

2. Surface Conditions:
   Top: Fairly smooth, traffic worn surface; exposing many traffic worn, fine aggregate surfaces.
   Bottom: Rough, fairly irregular, formed surface; placed on grade.

3. Reinforcement: None observed.

4. General Physical Conditions: The core was taken directly through a formed pavement joint. A bitumen pavement seal was observed in the joint. The bitumen joint sealer appeared to be well bonded to only one side of the sawcut joint with remnants of bitumen adhered to the sawcut joint to approx. 8mm depth from the top surface. The joint was characterized by an approx. 10mm wide reservoir sawcut to 30mm depth above the contact between two formed surfaces. The concrete, on one side of the formed joint, was well consolidated and appeared to have been placed against formwork with a few "bug" holes and a few consolidation voidspaces observed up to 15mm in diameter on the formed surface. The formed surface of the other side of the joint, placed against the previous concrete placement was poorly consolidated and exhibited numerous consolidation void spaces in the form of a nearly continuous plane of void spaces along the length of the formed surface below 70mm depth from the top surface. Consolidation voids were observed up to 50mm from the formed surface between 210mm and 245mm depth from the top surface. The formed surfaces were thinly coated with brown debris. Several sub-vertical microcracks (incipient spalling) were observed generally within the paste-only and within 3mm of the unconsolidated formed joint surface below 30mm depth from the top surface of the core. No evidence of ASR associated with the coarse aggregate was observed. ASR gel was observed partially filling an air void proximate to a reactive fine chert particle.

   The fairly smooth top surface of the core exhibits traffic wear; topographic highs have been worn smooth with exposed fine aggregate particles exhibiting worn surfaces. The concrete was purposefully air entrained and contains a well-distributed air void system considered freeze-thaw resistant under severe exposure conditions. Original air void parameters include a 6.8% entrained-sized void volume and a 0.002" spacing factor. Secondary ettringite partially fills to fills numerous smaller entrained sized voidspaces within 10mm of the formed joint faces; below 30mm depth in the core. Void fillings decrease with distance from the joint faces.

II. Aggregate

1. Coarse: 25mm (1") nominal sized natural glacial gravel composed chiefly of basalt, gabbro, granite rhyolite, greywacke, sandstone, carbonates, chert and granite. The coarse aggregate appeared well graded and exhibited good overall distribution.

2. Fine: Natural quartz, feldspar, and lithic sand (basalt, rhyolite, greywacke. sandstone, carbonates, chert and granite.) The grains were mostly sub-rounded with many smaller sub-angular particles. The fine aggregate appeared fairly graded and exhibited good overall uniform distribution.

III. Cementitious Properties

1. Air Content: 9.0% total original air void.
2. Depth of carbonation: Ranged from negligible up to 3mm depth from the top surface of the core; "spiking" up to 8mm along a paste/coarse aggregate boundary near the top surface. Carbonation ranged from negligible up to 7mm depth from the formed joint surface.
3. Pozzolan presence: Flyash was observed.
4. Paste/aggregate bond:
5. Paste color: Similar to Brownish Gray (Munsell® 5YR 4/1) with some mottled areas of light gray paste (Munsell® N7) predominately proximate to the formed joint surfaces.
6. Paste hardness: Hard (Moh's 3.5-4).
7. Microcracking: None observed.

8.	Secondary deposits:	Secondary ettringite partially fills to fills numerous smaller entrained sized voidspaces within 10mm of the formed joint faces; below 30mm depth in the core. Void fillings decrease with distance from the joint faces.
9.	w/cm:	Estimated at between 0. and 0. with approximately to % residual portland cement clinker particles and an amount of flyash visually consistent with a to % replacement of portland cement.
10.	Cement hydration:	Alites: . Belites: .

DESCRIPTION – Project 2786-116, core 1J, as-received

DESCRIPTION – Project 2786-116, core 1J, as-received

24-LAB-001 Petrographic Examination of Hardened Concrete
ASTM C856

Project No.	24-00776	Date:	June 23, 2014
Sample ID:	2786-116, 2J	Performed by:	D. Hunt

I. General Observations

1. Sample Dimensions: Our analysis was performed on both lapped sides of a 335mm (13-1/4") x 143mm (5-5/8") x 40mm (1-9/16") thick section (in two pieces) and a 76mm (3") x 52mm (2") wide thin section that were sawcut and prepared from the original 143mm (5-5/8") diameter x 340mm (13-3/8") long core taken directly through a distressed sawcut joint. The thin section was located at between 45 mm and 125 mm depth in the core from the top surface; directly adjacent to the distressed joint surface.

2. Surface Conditions:
   Top: Fairly smooth, traffic worn surface; exposing many traffic worn, fine aggregate surfaces.
   Bottom: Rough, fairly irregular, formed surface; placed on grade.

3. Reinforcement: None observed.

4. General Physical Conditions: The core was taken directly through a distressed pavement joint. A neoprene pavement seal was observed in the joint. A small amount of an apparent adhesive was observed on the vertical face of the saw-cut reservoir joint between 20mm and 25mm depth from the top surface of the core. The joint was characterized by an approx. 4mm wide pilot sawcut, partially vertically scaled/spalled away, measurable to 75mm depth from the top surface, and an approx. 10mm wide reservoir cut to 32mm depth. The resulting joint crack proceeded the depth of the core and passes around all coarse aggregate particles it encounters. Vertical scaling/spalling along the joint begins as shallow as approx. 58mm depth; with a slight loss of paste along a portion of the pilot cut. Up to approximately 17mm of paste loss occurs along the joint between 75mm and 130mm depth from the top surface. Thin paste loss with good residual interlock between the core halves occurs between 140mm and 335mm from the top surface. In general, the widest loss of paste occurred between 75mm and 130mm depth from the top surface. This zone is characterized by several relatively "clean" and un-distressed coarse aggregates protruding from relatively clean concrete joint faces. Several sub-vertical microcracks (incipient spalling) were observed generally within the paste-only and within 6mm of the distressed joint surface between 62mm and 325mm depth from the top surface of the core. The coarse and fine aggregate appeared sound. No evidence of ASR associated with either the coarse or fine aggregate was observed.

   The fairly smooth top surface of the core exhibits significant traffic wear; topographic highs have been worn smooth with exposed fine aggregate particles exhibiting worn surfaces. The concrete was well consolidated, with a few consolidation voidspaces observed up to 14mm in diameter in the core. The concrete was purposefully air entrained and contains a well-distributed air void system considered freeze-thaw resistant under severe exposure conditions. Original air void parameters include a 6.8% entrained-sized void volume and a 0.003" spacing factor. Secondary ettringite fills numerous entrained sized voidspaces within 15mm of the distressed joint faces; below 50mm depth in the core. Void fillings decrease with distance from the joint faces.

II. Aggregate

1. Coarse: 25mm (1") nominal sized natural glacial gravel composed chiefly of basalt, rhyolite, siltstone, sandstone, carbonates, chert and granite. The coarse aggregate appeared well graded and exhibited good overall distribution.

2. Fine: Natural quartz, feldspar, and lithic sand (basalt, rhyolite, siltstone. sandstone, carbonates, chert and granite.) The grains were mostly sub-rounded with many smaller sub-angular particles. The fine aggregate appeared fairly graded and exhibited good overall uniform distribution.

III. Cementitious Properties

1. Air Content:	8.2% total original air void.
2. Depth of carbonation:	Ranged from negligible up to 3mm depth from the top surface of the core; "spiking" up to 4mm along a paste/coarse aggregate boundary. Carbonation proceeding from the joint crack ranged from negligible up to 3mm.
3. Pozzolan presence:	Flyash was observed.
4. Paste/aggregate bond:	
5. Paste color:	Similar to Medium Dark Gray (Munsell® N4) becoming lighter colored, similar to Medium Gray (Munsell® N6), within the top 25mm of the core.
6. Paste hardness:	Hard (Moh's 3.5-4).

7. Microcracking: Many sub-vertical microcracks (incipient spalling) were observed generally within the paste-only and within 6mm of the distressed joint surface between 62mm 325mm depth from the top surface of the core.
8. Secondary deposits: Secondary ettringite fills numerous entrained sized voidspaces within 15mm of the cracked joint; below 50mm depth from the top surface. Void fillings decrease with distance from the joint faces.
9. w/cm: Estimated at between 0. and 0. with approximately to % residual portland cement clinker particles and an amount of flyash visually consistent with a to % replacement of portland cement.
10. Cement hydration: Alites: .
    Belites: .

Field Notes and Petrographic Reports for Project 2786-117, Core 6J

Table A.20. Field notes for SP Number 2786-117, I-94.

Core	Field Notes
5	220’ west of overhead sign for Hemlock Lane on WB 694. Core was on EB 694, left lane
6	100’ east of overhead sign for Hemlock Lane on WB 694. Core was on EB 694, left lane

24-LAB-001 Petrographic Examination of Hardened Concrete
ASTM C856

Project No. 24-00776 | Date: June 24, 2014
Sample ID: 2786-117, 6J | Performed by: C. Braaten

I. General Observations

1. Sample Dimensions: Our analysis was performed on both lapped sides of a 325 mm (12-13/16") x 86 mm (3-3/8") x 37 mm (1-7/16") thick section (in two pieces) and a 76 mm (3") x 52 mm (2") wide thin section that were sawcut and prepared from the original 95 mm (3-3/4") diameter x 338 mm (13-3/8") long core taken directly through a distressed sawcut joint. The thin section was located at between 20 mm and 100 mm depth in the core from the top surface; directly adjacent to the distressed joint surface.

2. Surface Conditions:
Top: Fairly smooth, traffic worn surface; exposing many traffic worn, fine aggregate surfaces. Approximately 90% of the top surface was coated with a yellowed epoxy.
Bottom: Rough, irregular, fractured surface with a steel dowel impression.

3. Reinforcement: None observed.

4. General Physical Conditions: The core was taken directly through a distressed pavement joint. A neoprene pavement seal was observed in the joint. A small amount of an apparent adhesive was observed on a portion of the neoprene seal and on the vertical face of the saw-cut reservoir joint between 10 mm and 31 mm depth from the top surface of the core. The joint was characterized by an approx. 10 mm wide reservoir cut to 35 mm depth. The resulting joint crack proceeded the depth of the core and passes around granite coarse aggregate particles and through a few gravel coarse aggregate particles it encounters. Vertical scaling/spalling distress in the paste-only starts at as shallow as 35 mm depth in the sawcut joint surface and incorporates between a few mm and 14 mm of total concrete paste between the two sides of the joint crack. The joint plane is characterized by numerous relatively "clean" and un-distressed coarse aggregate protruding from the concrete. The widest loss of concrete (to 14 mm) occurs below 180 mm depth in the concrete from the top surface. The core does exhibit some residual interlock between the two halves. Several sub-vertical microcracks (incipient spalling) were observed generally within the paste-only and within 5 mm of the distressed joint surface. One sub-horizontal macrocrack occurs at approx. 165 mm (6-1/2") depth from the top surface, proceeds from the joint surface, sub-perpendicularly, to the cored edge, and proceeds around coarse aggregate particles. A second sub-horizontal macrocrack occurs at approx. 231 mm (9-1/8") depth from the top surface, proceeds from the joint surface (opposite side of the joint surface from the previous macrocrack), sub-perpendicularly, to the cored edge, and proceeds around coarse aggregate particles. The coarse aggregate appeared sound. No evidence of ASR associated with the coarse aggregate was observed. A few alkali-silica "reacted" (ASR) shale fine aggregate particles were present in the core. The "reacted" shale particles exhibit internal cracking that propagates into the paste.

Approximately 90% of the fairly smooth top surface of the core was coated with a yellowed epoxy layer, up to approximately 7 mm thick, which appears moderately desiccated and exhibits some traffic wear; a few topographic highs have been worn fairly smooth with exposed fine aggregate particles exhibiting worn surfaces. The concrete was well consolidated, with a few consolidation voidspaces observed up to 14 mm in diameter in the core. Numerous irregular shaped, entrained to entrapped sized bleedwater voids were observed between the top surface and 105 mm depth from the tops surface of the core. The concrete was purposefully air entrained and contains a well-distributed air void system considered freeze-thaw resistant under severe exposure conditions. Original air void parameters include a 8.6% entrained-sized void volume and a 0.002" spacing factor. Secondary ettringite, with some portlandite, fills many of the smaller entrained sized voidspaces within approx. 16 mm of the distressed joint surface and approximately 8 mm from the bottom surface of the core. Void fillings decrease with depth from the joint plane.

II. Aggregate

1. Coarse: 38 mm (1-1/2") nominal sized gravel consisting of rhyolite, basalt, carbonate, quartz, chert, sandstone, and granite. The coarse aggregate appeared poorly graded and exhibited fair overall distribution.

2. Intermediate: 19 mm (3/4") nominal sized crushed granite. The intermediate aggregate appeared well graded and exhibited good overall distribution.

3. Fine: Natural quartz, feldspar, and lithic sand (granite, chert, carbonates, basalt, rhyolite, siltstone and shale.) The grains were mostly sub-rounded with many smaller sub-angular particles. The fine aggregate appeared fairly graded and exhibited good overall uniform distribution.

III. Cementitious Properties

1.	Air Content:	10% total original air void.
2.	Depth of carbonation:	Ranged from negligible up to 4 mm depth from the top surface of the core. Carbonation proceeding from the joint crack ranged from negligible up to 4 mm.
3.	Pozzolan presence:	Flyash was observed.
4.	Paste/aggregate bond:	
5.	Paste color:	Similar to olive gray (Munsell® 5Y 4/1), similar to yellowish gray (Munsell® 5Y 8/1) in the carbonated zones.
6.	Paste hardness:	Moderate (Mohs 3).
7.	Macro/Microcracking:	Several sub-vertical microcracks (incipient spalling) were observed generally within the paste-only and within 5 mm of the distressed joint surface. One sub-horizontal macrocrack occurs at approx. 165 mm (6-1/2") depth from the top surface, proceeds from the joint surface, sub-perpendicularly, to the cored edge, and proceeds around coarse aggregate particles. A second sub-horizontal macrocrack occurs at approx. 231 mm (9-1/8") depth from the top surface, proceeds from the joint surface (opposite side of the joint surface from the previous macrocrack), sub-perpendicularly, to the cored edge, and proceeds around coarse aggregate particles.
8.	Secondary deposits:	Secondary ettringite, with some portlandite, fills many of the smaller entrained sized voidspaces within approx. 16 mm of the distressed joint surface and approximately 8 mm from the bottom surface of the core. Void fillings decrease with depth from the joint plane.
9.	w/cm:	Estimated at between 0. and 0. with approximately to % residual portland cement clinker particles and an amount of flyash visually consistent with a to % replacement of portland cement.
10.	Cement hydration:	Alites: . Belites: .

DESCRIPTION – Project 2786-117, core 6J, as-received

DESCRIPTION – Project 2786-117, core 6J, as-received

Field Notes and Petrographic Reports for Project 2313-13, Cores M001, M002

Table A.21. Field notes for SP Number 2313-13, US-63.

Core	Location from Joint	RP	Station	Direction	Lane	Offset	Thickness
M001	ON	1.600		SB	DR	7.0'	8.500"
M002	OFF	2.000		SB	DR	7.0'	9.000"
M004	OFF	4.500		SB	DR	7.0'	9.250"
M005	OFF	10.000		SB	DR	7.0'	8.750"
M006	OFF	11.000		SB	DR	7.0'	9.000"
M008	OFF	12.400		SB	DR	7.0'	9.250"
M009	OFF	12.600		SB	DR	7.0'	9.000"

00 LAB 001 Petrographic Examination of Hardened Concrete
ASTM: C-856

Project No.	28-00337	Date:	December 30, 2011
Sample ID:	M001, SP2313-13	Performed by:	G. Moulzolf

I. General Observations

1. Sample Dimensions: The core was taken directly through a distressed pavement joint. Our analysis was performed on both lapped sides of a cross section (two pieces) of core sawcut "normal" to a distressed joint measuring 224mm (8 ¾") x 100mm (4") x 31mm (1 ¼") thick, a 222mm (8 ¾") x 95mm (3 ¾") x 34mm (1 ¼") thick section (in two pieces), and two 76mm (3") x 52mm (2") wide thin sections that were sawcut and prepared from the original 100mm (4") diameter x 224mm (8 ¾") long core. The thin sections were located between 0mm and 60mm depth from the top surface and 62mm and 126mm depth in the core; in cross section and along the sawcut and distressed portions of the joint.

2. Surface Conditions:
Top: Rough screeded surface with moderate mortar erosion exposing a few coarse aggregate surfaces.
Bottom: Rough, irregular, formed surface.

3. Reinforcement: None observed.

4. General Physical Conditions: The core exhibits poor overall condition. The core was taken through a moderately distressed pavement joint. The joint was characterized by an obvious reservoir sawcut proceeding to 34mm (1 ¼") and a pilot cut to at least 52mm depth from the top surface with remnants of a brown, apparent neoprene sealant adhesive(?) at below 20mm depth in the joint. The joint seal was not included with the core sample. Vertical scaling/spalling starts at as shallow as 24mm depth in the joint and incorporates between 2mm and 21mm of total concrete paste and dolostone aggregate between the two sides of the joint crack; losing the bottom extent of the pilot sawcut. The widest loss of concrete (18-21mm) occurs between 30 and 65mm depth in the concrete; with the thinnest paste loss and residual interlock between the two halves of core below approx. 160mm depth. Concentrated sub-vertical microcracks (incipient spalling) were observed generally within the paste and aggregates within 3mm of the distressed joint surface between the sawcut and bottom surface of the core. A high angled microcrack located at 8mm from the sawcut on the top surface proceeds to 19mm depth and intersects the sawcut joint. Sub-horizontal micro/macrocracking occurs at approx. 38mm, 122mm, 145mm, 192mm, and 205mm depth from the top surface on one side of the joint and at approx. 105mm and 195mm depth on the other side of the joint.

   The rough screeded top surface of the core exhibits moderate mortar erosion; exposing a few coarse aggregate surfaces. The concrete was fairly well consolidated, with a single entrapped voidspace observed in excess of 12mm in diameter in the core. The concrete was purposefully air entrained and originally contained a well-distributed air void system considered freeze-thaw resistant under severe exposure conditions. Original air void parameters include a 4.4% entrained-sized void volume and a 0.005" spacing factor. Secondary ettringite, with some portlandite, fills many of the smaller entrained sized voidspaces throughout the depth of the core apart from the top approx. 19mm. Void fillings increase with depth from the top 19mm and voids are similarly filled throughout the diameter of the core. Actual measured air void parameters, excluding the ettringite void fillings, in a band between approx. 0mm and 25mm (0-1") depth from the distressed joint surface (below 41mm depth in the core), are 2.9% entrained volume and a 0.010" spacing factor.

II. Aggregate

1. Coarse: 25mm (1") nominal sized crushed carbonate composed of fine grained, variably brown-colored dolostone. The coarse aggregate appeared well graded and exhibited good overall distribution.

2. Fine: Natural quartz, feldspar, and lithic sand. The grains were mostly sub-rounded with many smaller sub-angular particles. The fine aggregate appeared fairly graded and exhibited good overall uniform distribution.

III. Cementitious Properties

1. Air Content: 5.4% total original air content. 4.5% total "actual" un-filled air between 0mm and 25mm depth from the distressed joint (below the sawcut).
2. Depth of carbonation: Ranges from negligible up to 10mm depth, intermittently, from the top surface of the core; along sub-vertical drying shrinkage microcracks.
3. Pozzolan presence: Flyash was observed.
4. Paste/aggregate bond: Fair to good.
5. Paste color: Similar to Light Brownish Gray (Munsell® 5YR 6/1).
6. Paste hardness: Moderately hard (Moh's 3)
7. Microcracking: Some concentrated sub-vertical microcracks (incipient spalling) were observed generally within the paste-only and within 3mm of the distressed joint surface between the sawcut joint and bottom surfaces of the core. A few fine, sub-vertical drying shrinkage microcracks proceed up to 5mm depth from the top surface. A high angled microcrack located at 8mm from the sawcut on the top surface proceeds to 19mm depth and intersects the sawcut joint. Sub-horizontal micro/macrocracking occurs at approx. 38mm, 122mm, 145mm, 192mm, and 205mm depth from the top surface on one side of the joint and at approx. 105mm and 195mm depth on the other side of the joint; proceeding mostly through the paste-only.
8. Secondary deposits: White, generally acicular grown ettringite along with some clear platelets of portlandite fills most of the finer entrained sized air voids scattered throughout the paste from the top 19mm of paste through the depth of the core. Void fillings become more abundant with distance from the top approx. 19mm of the core. Voids within thin zones of "carbonated" paste on the perimeter of some coarse aggregate particles, at scattered at depth in the core, are free of secondary deposits.
9. w/cm: Estimated at between 0.42 and 0.47 with approximately 5 to 7% residual portland cement clinker particles and an amount of flyash visually consistent with a 15 to 25% replacement of portland cement.
10. Cement hydration: Alites: Well to mostly fully.
    Belites: Well.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 1

PHOTO:
19

SAMPLE ID: 2313-13, M001 **DESCRIPTION:** Overall view of the core sample. The top surface was left.

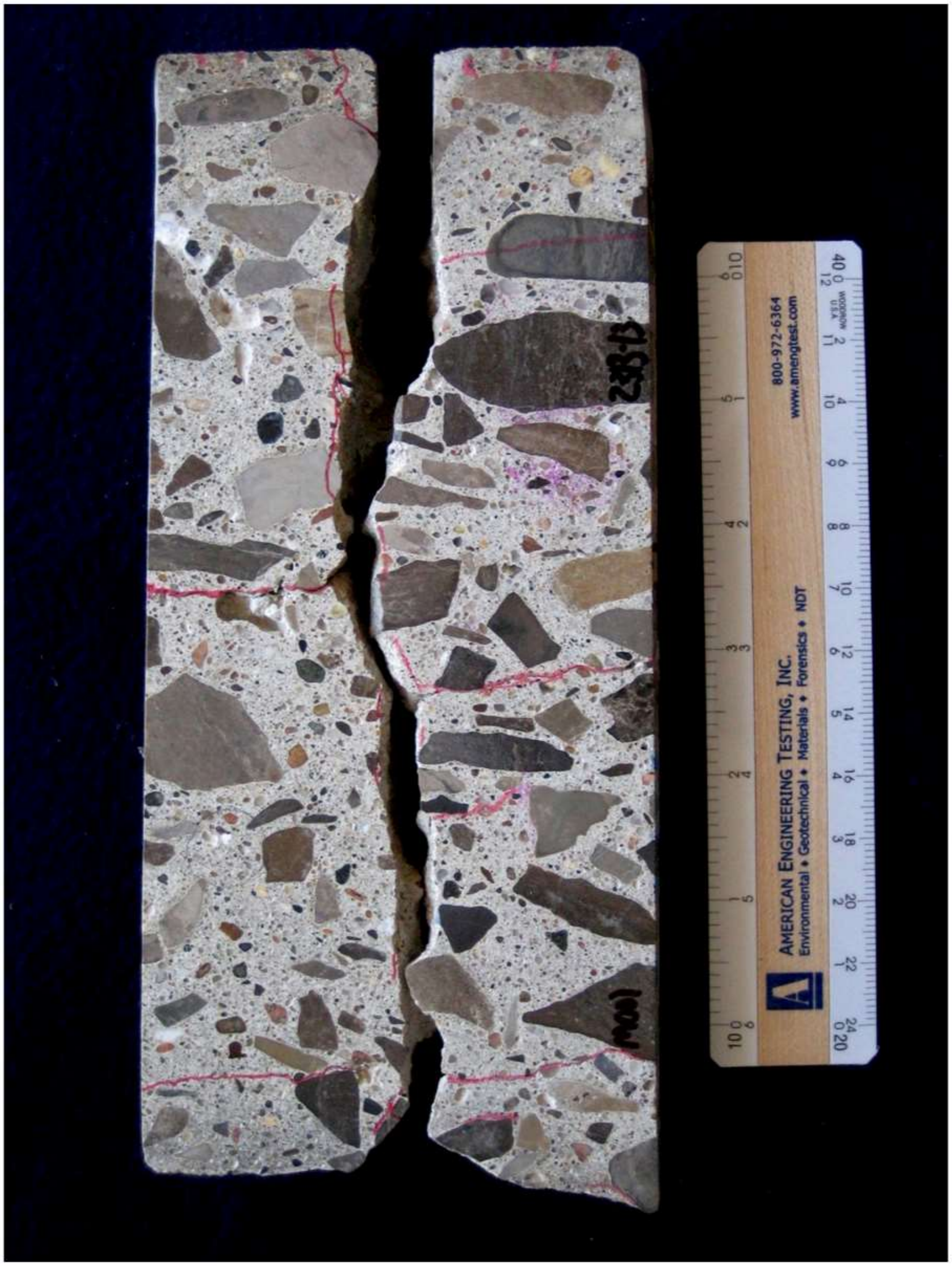
PHOTO:
20

SAMPLE ID: 2313-13, M001 **DESCRIPTION:** Rough mortar-eroded top surface of the core; with sawcut control joint.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 1

PHOTO:
84

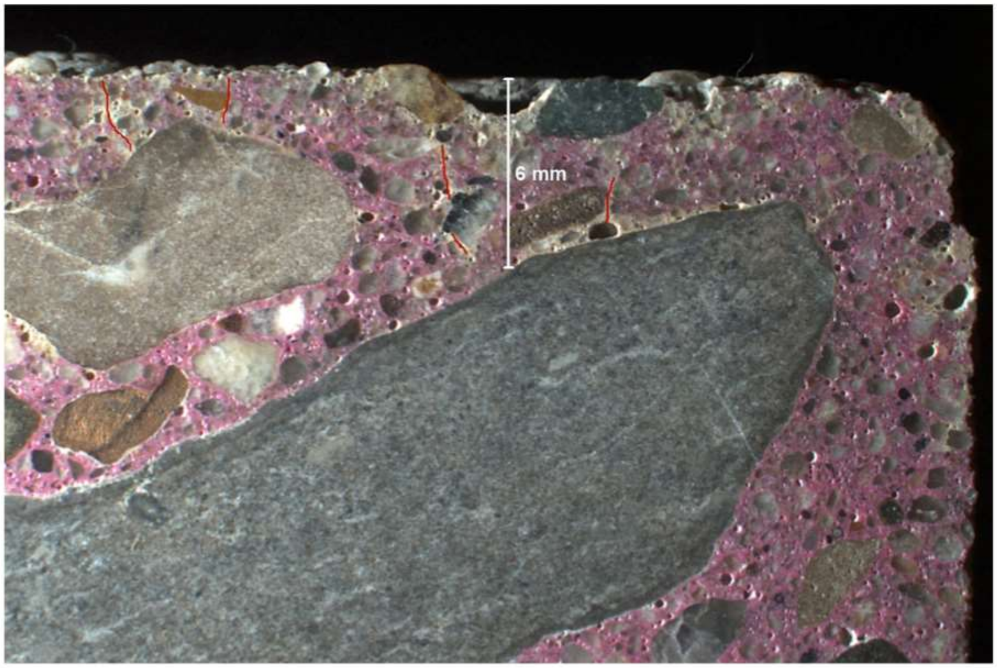


SAMPLE ID: 2313-13, M001 **DESCRIPTION:** Sawcut and lapped cross section of core exhibits mass loss along the joint plane; especially at the base of the sawcut. Joint was originally neoprene(?) sealed. Incipient spalling and sub-horizontal fractures (epoxied) are mapped -in red ink.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

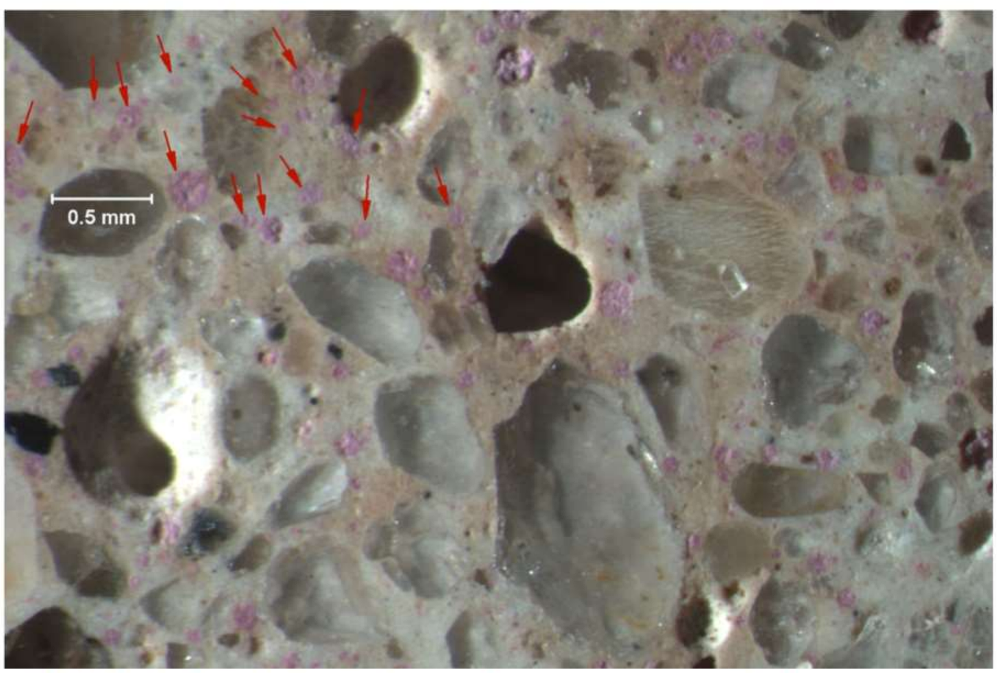
PROJECT: W/CM Study
Phase 1

PHOTO: 106



SAMPLE ID: 2313-13, M001 **DESCRIPTION:** Carbonation (unstained paste) ranged from negligible up to 6mm depth, intermittently, and in this image, from the top surface. Freshly sawcut and lapped cross section exposed to phenolphthalein pH indicator
MAG: 5x.

PHOTO: 107

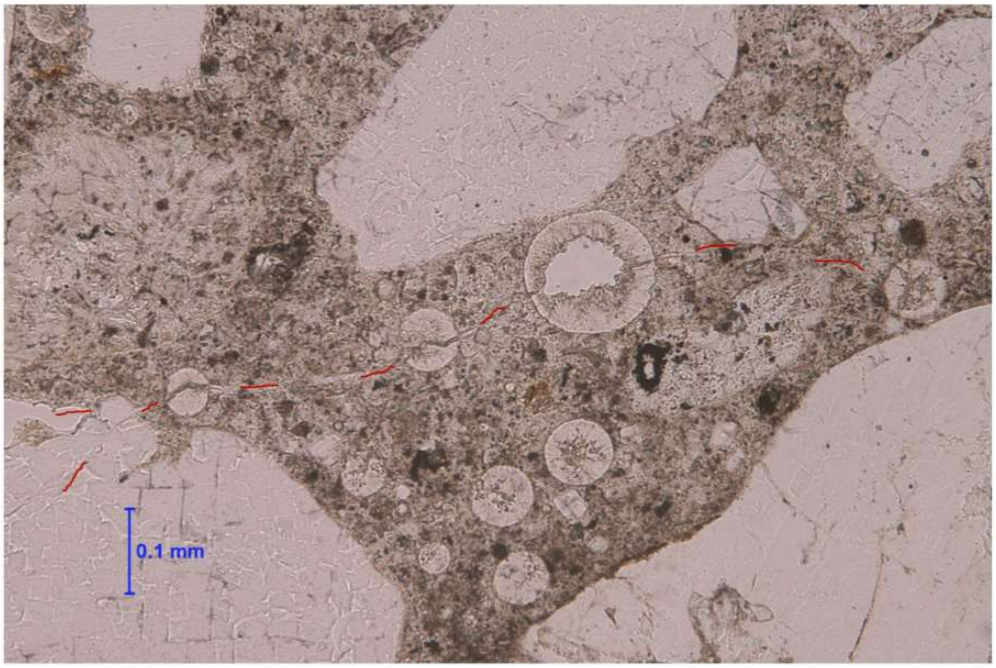


SAMPLE ID: 2312-13, M001 **DESCRIPTION:** Ettringite-filled air void spaces (stained) at 146mm depth from the top surface and 8mm depth from the distressed joint plane. Nearly all finer entrained air voidspaces are filled with secondary ettr.
MAG: 30x

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

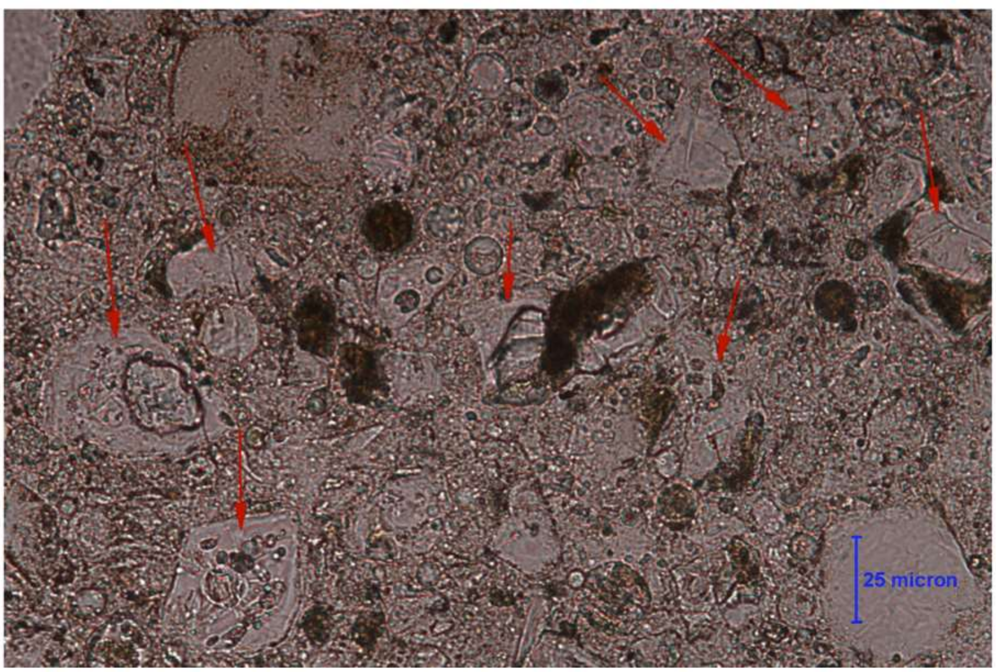
PROJECT: W/CM Study
Phase 1

PHOTO:
108



SAMPLE ID: 2313-13, M001 **DESCRIPTION:** Ettringite filled and partly filled air voidspaces in thin section of concrete paste at approx. 70mm depth from the top surface and 12mm depth from the distressed joint plane. Note microcracking bisects fillings. Plane polarized light.
MAG: 100x

PHOTO:
109



SAMPLE ID: 2312-13, M001 **DESCRIPTION:** Well to fully hydrated alite portland cement clinker particles (arrows) and abundant spherical flyash pozzolan particles in thin section of concrete paste under plane polarized light.
MAG: 400x

00 LAB 001 Petrographic Examination of Hardened Concrete
ASTM: C-856

Project No.	28-00337	Date:	December 30, 2011
Sample ID:	M002, SP2313-13	Performed by:	G. Moulzolf

I. General Observations

1. Sample Dimensions: Our analysis was performed on both lapped sides of a 229mm (9") x 100mm (4") x 32mm (1 ¼") thick section, a 229mm (9") x 93mm (3 5/8") x 32mm (1 ¼") thick section, and a 76mm (3") x 52mm (2") wide thin section that were sawcut and prepared from the original 100mm (4") diameter x 229mm (9") long core.

2. Surface Conditions:
   Top: Rough screeded and tined surface.
   Bottom: Rough, irregular, formed surface; placed on crushed limestone sub-base.

3. Reinforcement: None observed.

4. General Physical Conditions: The core exhibits good overall condition. The rough screeded and tined top surface of the core exhibits minor mortar erosion; exposing many fine aggregate surfaces. The concrete was fairly well consolidated, with a few voidspaces in excess of 12mm in diameter scattered in the top half of the core. The concrete was purposefully air entrained and contains a well-distributed air void system considered freeze-thaw resistant under severe exposure conditions.

II. Aggregate

1. Coarse: 25mm (1") nominal sized crushed carbonate composed of fine grained, variably brown-colored dolostone. The coarse aggregate appeared well graded and exhibited good overall distribution.

2. Fine: Natural quartz, feldspar, and lithic sand. The grains were mostly sub-rounded with many smaller sub-angular particles. The fine aggregate appeared fairly graded and exhibited good overall uniform distribution.

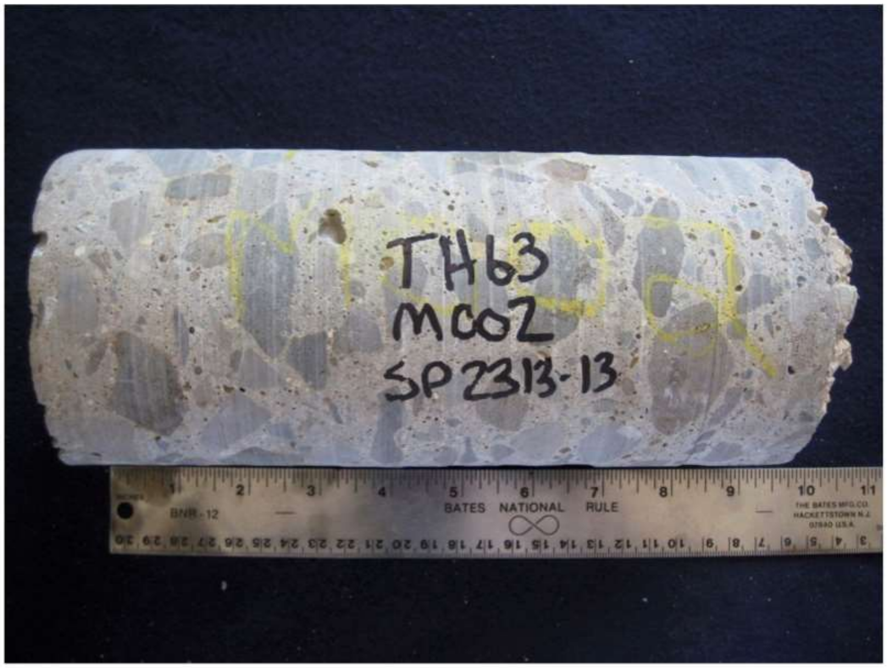
III. Cementitious Properties

1. Air Content: 5.3% total
2. Depth of carbonation: Ranges from negligible up to 12mm depth, intermittently, from the top surface of the core; along sub-vertical drying shrinkage microcracks.
3. Pozzolan presence: Flyash was observed.
4. Paste/aggregate bond: Fair to good.
5. Paste color: Similar to Light Brownish Gray (Munsell® 5YR 6/1).
6. Paste hardness: Moderately hard (Moh's 3)
7. Microcracking: Several, fine, sub-vertical drying shrinkage microcracks proceed up to 6mm depth from the top surface; one proceeds to 35mm depth. No other microcracking was evident in the core.
8. Secondary deposits: White ettringite partly fills most of the finest entrained sized air voids scattered throughout the sample and occurs as scattered acicular clumps in most other voids; Ettringite fills most of the entrained sized voids in the bottom approx. 20mm of the core.
9. w/cm: Estimated at between 0.42 and 0.47 with approximately 5 to 7% residual portland cement clinker particles and an amount of flyash visually consistent with a 15 to 25% replacement of portland cement.
10. Cement hydration: Alites: Well to fully.
    Belites: Well.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 1

PHOTO:
21



SAMPLE ID: 2313-13, M002 **DESCRIPTION:** Overall view of the mid-panel core sample subjected to petrographic analysis. The top surface was left.

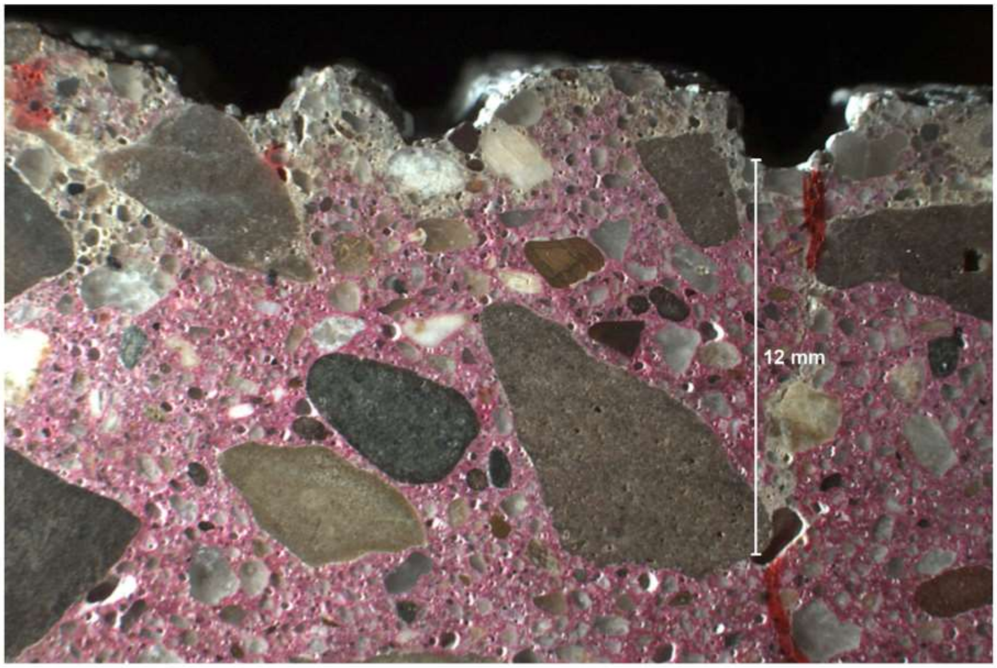
PHOTO:
22

SAMPLE ID: 2313-13, M002 **DESCRIPTION:** Rough screeded and tined surface with minor mortar erosion..

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

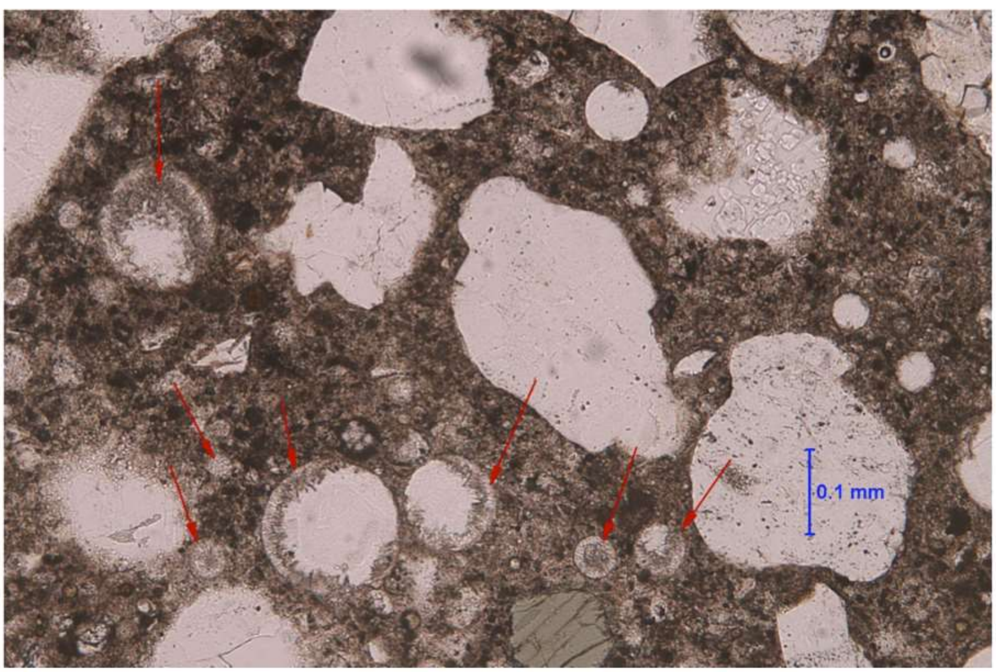
PROJECT: W/CM Study
Phase 1

PHOTO:
110



SAMPLE ID: 2313-13, M002 **DESCRIPTION:** Carbonation (unstained paste) ranged from negligible up to 12mm depth from the top surface, intermittently along sub-vertical microcracking partly mapped in red ink.
MAG: 5x

PHOTO:
111



SAMPLE ID: 2312-13, M002 **DESCRIPTION:** Very fine void fillings and large void linings by secondary ettringite in thin section of concrete under plane polarized light; at 170mm + depth in the mid-panel core.
MAG: 100x

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 1

PHOTO:
23

SAMPLE ID: 2313-13, M004 **DESCRIPTION:** Overall view of the mid-panel core sample subjected to rapid chloride permeability testing. The top surface is left.

PHOTO:
24

SAMPLE ID: 2313-13, M004 **DESCRIPTION:** Rough screeded and tined surface with minor mortar erosion.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 1

PHOTO:
25

SAMPLE ID: 2313-13, M005 **DESCRIPTION:** Overall view of the mid-panel core sample subjected to rapid chloride permeability testing. The top surface is left.

PHOTO:
26

SAMPLE ID: 2313-13, M005 **DESCRIPTION:** Rough screeded and tined surface with minor mortar erosion.

Field Notes and Petrographic Reports for Project 2480-88, Core M001

Table A.22. Field notes for SP Number 2480-088, I-35.

Core	Location from Joint	RP	Station	Direction	Lane	Offset	Thickness
M001	ON	13.800		NB	RT	7.0'	10.500"
M002	OFF	14.200		NB	RT	7.0'	11.250"
M003	OFF	15.000		NB	RT	7.0'	10.250"
M004	OFF	16.000		NB	RT	7.0'	13.250"
M006	OFF	17.000		NB	RT	7.0'	12.000"
M007	OFF	18.000		NB	RT	7.0'	11.000"
M008	OFF	19.000		NB	RT	7.0'	12.000"

00 LAB 001 Petrographic Examination of Hardened Concrete
ASTM: C-856

Project No.	28-00337	Date:	January 30, 2012
Sample ID:	M001, SP2480-88	Performed by:	G. Moulzolf

I. General Observations

1. Sample Dimensions: The core was taken directly through a pavement joint. Our analysis was performed on both lapped sides of a cross section (two pieces) of core sawcut "normal" to a sealed sawcut joint measuring 270mm (10 ½") x 100mm (4") x 27mm (1") thick, a 270mm (10 ½") x 97mm (3 ¾") x 40mm (1 5/8") thick section (in two pieces), and two 76mm (3") x 52mm (2") wide thin sections that were sawcut and prepared from the original 100mm (4") diameter x 270mm (10 ½") long core. The thin sections were located between approx. 12mm and 95mm depth and 160mm and 230mm depth in the core; in cross section and along the sawcut and distressed portions of the joint.

2. Surface Conditions:
   Top: Rough screeded and tined surface with minor mortar erosion exposing fine aggregate surfaces.
   Bottom: Rough, irregular, formed surface.

3. Reinforcement: None observed.

4. General Physical Conditions: The core exhibits fair overall condition. The core was taken through a pavement joint exhibiting some vertical distress and mass loss. The joint was characterized by an approx. 8mm wide sawcut proceeding to 90mm (3 ½") depth from the top surface with remnants of a black bitumen (hot pour) sealant. The sealant was not adhered to both sides of the sawcut. Vertical scaling/spalling appears to start at as shallow as 45mm depth in the sawcut and incorporates between 0mm and 15mm of total concrete paste and dolostone aggregate between the two sides of the joint crack. The widest loss of concrete (15mm) occurs between the base of the sawcut (90mm) and 111mm depth in the concrete. The concrete retains some residual interlock between the two halves of core below approx. 150mm depth. Concentrated sub-vertical microcracks (incipient spalling) were observed within the paste and coarse aggregates generally within 6mm of the distressed joint surface between 73mm depth and the bottom surface of the core.

   The rough screeded and tined top surface of the core exhibits minor mortar erosion; exposing fine aggregate surfaces. The concrete was fairly well consolidated, with a few entrapped voidspaces observed in excess of 12mm in diameter at mid-depth in the core. The concrete was purposefully air entrained and originally contained an only fairly-distributed air void system considered freeze-thaw resistant under severe exposure conditions. Some unevenness in volume of the air voids was noted with depth. Original air void parameters include a 4.1% entrained-sized void volume and a 0.007" spacing factor. Secondary ettringite fills many of the smaller entrained sized voidspaces within 3mm depth of the distressed joint surfaces. Void fillings greatly decrease with further depth from the spalled joint surface.

II. Aggregate

1. Coarse: 37mm (1 ½") nominal sized crushed carbonate composed of fine grained, variably brown-colored dolostone. The coarse aggregate appeared well graded and exhibited good overall distribution.

2. Fine: Natural quartz, feldspar, and lithic sand. The grains were mostly sub-rounded with many smaller sub-angular particles. The fine aggregate appeared fairly graded and exhibited good overall uniform distribution.

III. Cementitious Properties

1. Air Content: 5.5% total original air content.
2. Depth of carbonation: Ranges from negligible up to 10mm depth, intermittently, from the top surface of the core; along sub-vertical drying shrinkage microcracks.
3. Pozzolan presence: Flyash was observed.
4. Paste/aggregate bond: Fair to good.
5. Paste color: Similar to Light Brownish Gray (Munsell® 5YR 6/1).
6. Paste hardness: Moderately hard (Moh's 3)
7. Microcracking: Concentrated sub-vertical microcracks (incipient spalling) were observed within the paste and dolostone coarse aggregate within 6mm of the distressed joint surface between 73mm depth in the joint and the bottom surface of the core. A single sub-vertical drying shrinkage microcrack proceeds up to 13mm depth from the top surface.
8. Secondary deposits: White to clear ettringite fills most of the finer entrained sized air voids in the paste generally within 3mm of the distressed (spalled) joint surfaces. Some, scattered, fine entrained voids are filled or lined with ettringite outside this zone.
9. w/cm: Estimated at between 0.42 and 0.47 with approximately 5 to 7% residual portland cement clinker particles and an amount of flyash visually consistent with a 15 to 25% replacement of portland cement.
10. Cement hydration: Alites: Well to mostly fully.
    Belites: Well.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 1

PHOTO:
27

SAMPLE ID: 2480-88, M001 **DESCRIPTION:** Overall view of the jointed core utilized for petrographic analysis. The top surface is left.

PHOTO:
28

SAMPLE ID: 2480-88, M001 **DESCRIPTION:** Rough screeded top surface with minor mortar erosion.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 1

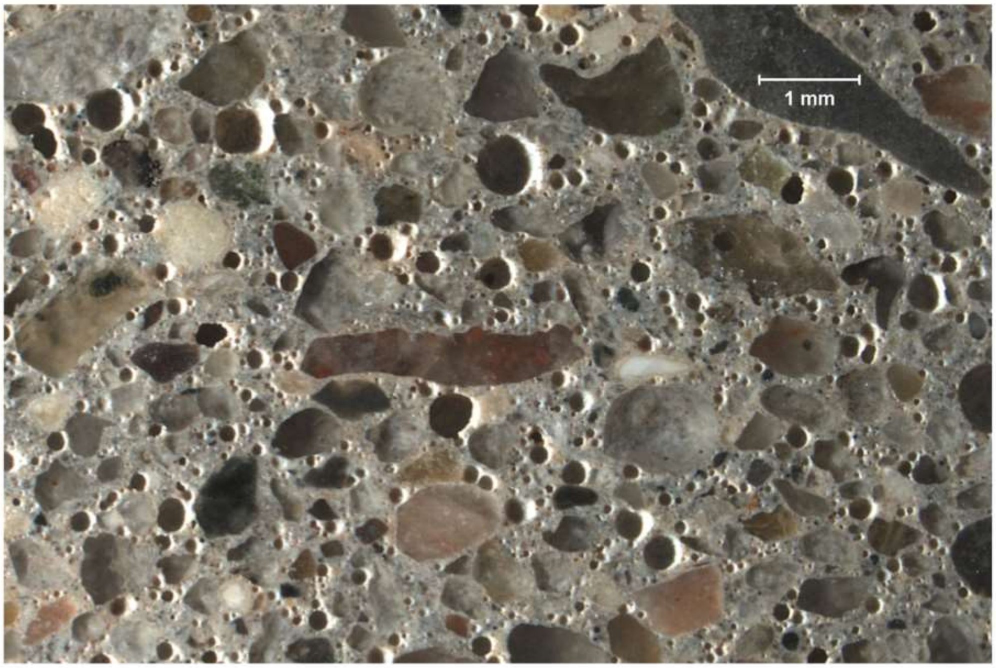
PHOTO:
85

SAMPLE ID: 2480-88, M001 **DESCRIPTION:** Sawcut and lapped cross section of core. The single sawcut control joint was originally sealed with "hot pour". Note distress in the form of sub-vertical incipient spalls mapped in red ink.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

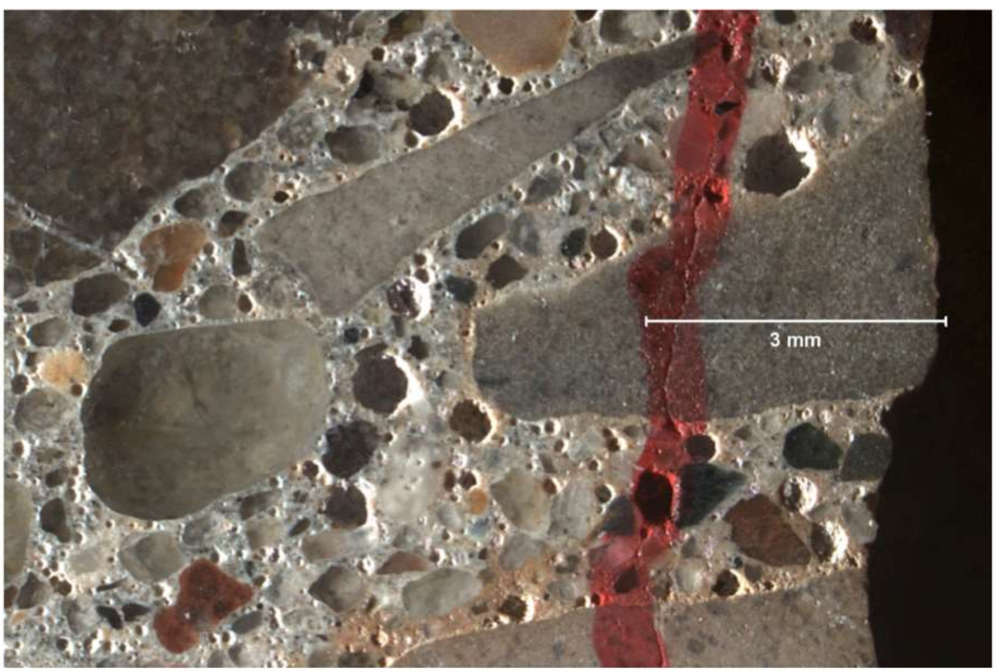
PROJECT: W/CM Study
Phase 1

PHOTO:
112



SAMPLE ID: 2480-88, M001 **DESCRIPTION:** Overall hardened air content is relatively unfilled with secondary ettringite at 210mm from the top surface and 40mm depth from the distressed joint plane.
MAG: 15x

PHOTO:
113

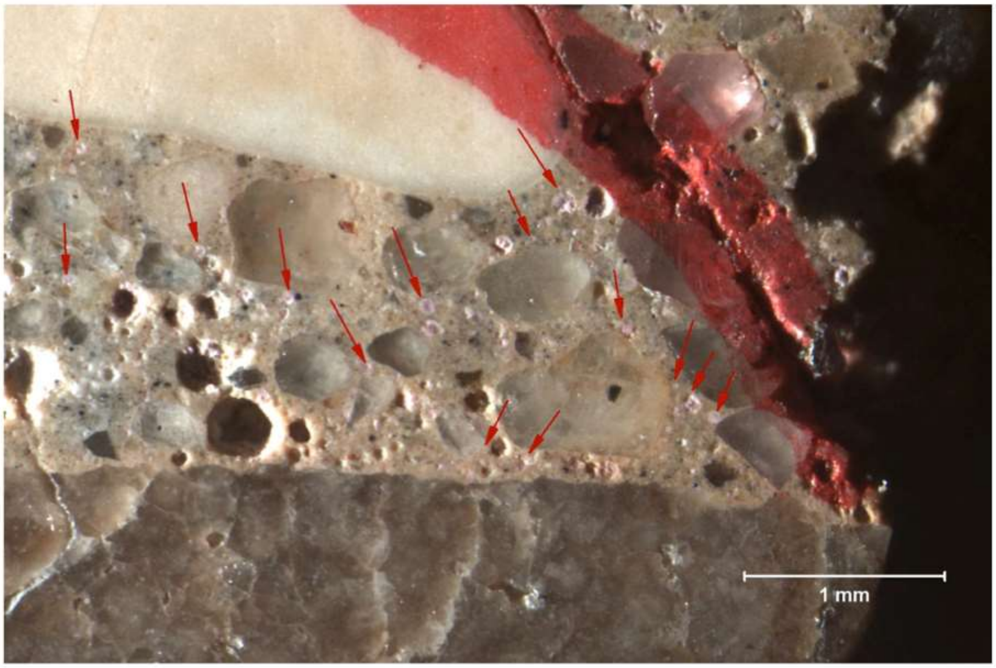


SAMPLE ID: 2480-88, M001 **DESCRIPTION:** Most of the fine air voids within 3mm of the distressed joint plane and 225mm depth from the top surface are filled by secondary ettringite. Freeze-thaw microcracking is mapped in red ink.
MAG: 15x

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

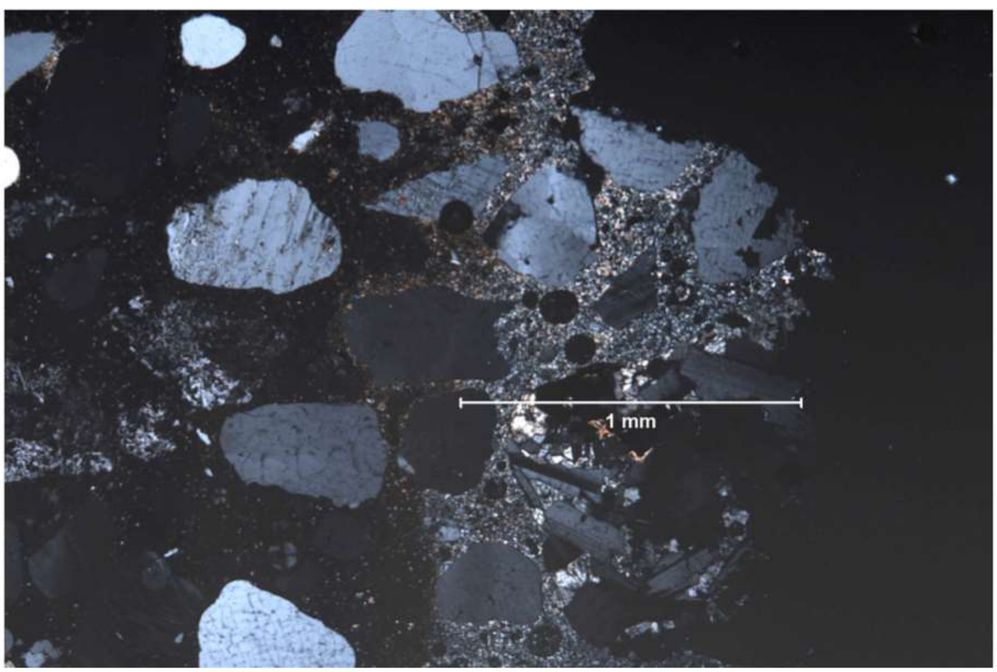
PROJECT: W/CM Study
Phase 1

PHOTO:
114



SAMPLE ID: 2480-88, M001 **DESCRIPTION:** Fine ettringite filled voids are marked with arrows at the distressed joint plane (right).
MAG: 30x

PHOTO:
115



SAMPLE ID: 2480-88, M001 **DESCRIPTION:** Brightly colored carbonated paste at the outer 1mm of the distressed joint plane (right); in thin section of concrete under cross polarized light.
MAG: 40x

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 1

PHOTO:
29

SAMPLE ID: 2480-88, M006 **DESCRIPTION:** Overall view of the mid-panel core utilized for rapid chloride permeability testing. The top surface is left.

PHOTO:
30

SAMPLE ID: 2480-88, M006 **DESCRIPTION:** Rough screeded and tined top surface with minor mortar erosion.

Field Notes and Petrographic Reports for Project 2480-91, Core M018

Table A.23. Field notes for SP Number 2480-91, I-35.

Core	Location from Joint	RP	Station	Direction	Lane	Offset	Thickness
M010	OFF	21.000		NB	RT	7.0'	11.000"
M011	OFF	21.600		NB	RT	7.0'	9.250"
M013	OFF	23.100		NB	RT	7.0'	13.000"
M015	OFF	25.000		NB	RT	7.0'	10.250"
M016	OFF	26.000		NB	RT	7.0'	10.000"
M017	OFF	26.500		NB	RT	7.0'	12.250"
M018	ON	27.000		NB	RT	7.0'	9.750"

00 LAB 001 Petrographic Examination of Hardened Concrete
ASTM: C-856

Project No.	28-00337	Date:	January 31, 2012
Sample ID:	MO18, SP2480-91	Performed by:	D. Hunt, G. Moulzolf

I. General Observations

1. Sample Dimensions: The core was taken directly through a sealed, sawcut and cracked pavement joint. Our analysis was performed on both lapped sides of a cross section (two pieces) of core sawcut "normal" to a sawcut and cracked joint measuring 250mm (9 7/8") x 100mm (3 5/8") x 25mm (1") thick, a 250mm (9 7/8") x 90mm (3 1/2") x up to 28mm (1 1/8") thick section (in two pieces), and two 76mm (3") x 52mm (2") wide thin sections that were sawcut and prepared from the original 100mm (4") diameter x 240mm (9 1/2") long core. The thin sections were located between 0mm and 76mm depth from the top surface and 75mm and 250mm depth in the core; in cross section and along the sawcut and cracked portions of the joint.

2. Surface Conditions:
   Top: Fairly smooth, screeded surface; with minor traffic wear exposing fine aggregate surfaces.
   Bottom: Rough, irregular, formed surface; placed on grade.

3. Reinforcement: None observed.

4. General Physical Conditions: The core was taken through a sealed pavement joint. A black neoprene insert was placed into the sawcut joint. The joint was characterized by an approx. 5mm wide sawcut proceeding 55mm (2 1/4") depth from the top surface and an approx. 10mm wide reservoir cut to 32mm (1 1/4") depth. Several sub-vertical microcracks (incipient scaling/spalling), observed in the paste-only, were present between approx. 125mm and 240mm depth in the joint crack surface and within 10mm of the joint plane. A roughly inverted "V" shaped section of concrete was missing on the bottom surface measuring approximately 50mm wide on the bottom surface and intersecting the joint crack at approximately 210mm depth from the top surface. The joint plane is characterized by a few relatively "clean" and un-distressed carbonate coarse aggregates protruding from the concrete joint. The widest loss of concrete (2mm to 6mm) occurs between 138mm and 210mm depth in the concrete from the top surface. The core exhibits relatively tight, residual interlock between the two halves of core; with a few coarse aggregate bisected by the joint at depth in the core. The coarse carbonate aggregate appeared sound. No evidence of ASR associated with the coarse aggregate was observed. A few alkali-silica "reacted" shale fine aggregate were present in the core.

   The apparent originally screeded top surface of the core exhibits a smooth, traffic worn surface; exposing many fine aggregate surfaces. The concrete was fairly well consolidated, with only a few entrapped voidspace observed up to 20mm in diameter in the mid-section of the core. The concrete was purposefully air entrained and originally contained a well-distributed air void system considered freeze-thaw resistant under severe exposure conditions. Original air void parameters include a 5.7% entrained-sized void volume and a 0.005" spacing factor. Secondary ettringite, with some portlandite, fills most of the smaller entrained sized voidspaces within approx. 4mm of the joint plane/surface. Void fillings decrease with depth from the joint plane.

II. Aggregate

1. Coarse: 19mm (¾") nominal sized crushed carbonate. The coarse aggregate appeared well graded and exhibited good overall distribution.

2. Fine: Natural quartz, feldspar, and lithic sand with a few shale particles. The grains were mostly sub-rounded with many smaller sub-angular particles. The fine aggregate appeared fairly graded and exhibited good overall uniform distribution.

III. Cementitious Properties

1. Air Content: 5.7% original entrained air content. 1.0% entrapped air content.
2. Depth of carbonation: Up to 6mm depth from the top surface of the core. Mostly negligible along the sawcut joint. Ranged from mostly negligible up to 4mm depth from the distressed joint surface with lateral ingress of carbonation along paste/aggregate boundaries up to 17 mm.
3. Pozzolan presence: Flyash was observed.
4. Paste/aggregate bond: Good.
5. Paste color: Mottled Medium Light Gray (Munsell® N6) to tan.
6. Paste hardness: Moderately hard (Moh's 3)
7. Microcracking: Few sub-vertical microcracks (incipient spalling) were observed along the joint (cracked) surface between 125mm and 240mm depth from the top surface of the core. A few fine, sub-vertical drying shrinkage microcracks proceed up to 8mm depth from the top surface.
8. Secondary deposits: White, generally acicular grown ettringite along with some clear platelets of portlandite fills most of the finer entrained sized air voids between the joint surface and approx. 4mm depth into the core. Void fillings become less abundant with distance from this zone. Alkali silica reaction (ASR) gel lightly lines a few air voids proximate to reactive shale fine aggregate particles.
9. w/cm: Estimated at between 0.39 and 0.44 with approximately 6 to 8% residual portland cement clinker particles and an amount of flyash visually consistent with a 20 to 30% replacement of portland cement.
10. Cement hydration: Alites: Well to fully.
    Belites: Well.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 1

PHOTO:
33

SAMPLE ID: 2480-91, M018 **DESCRIPTION:** Overall view of the jointed core utilized for petrographic analysis. The top surface is left.

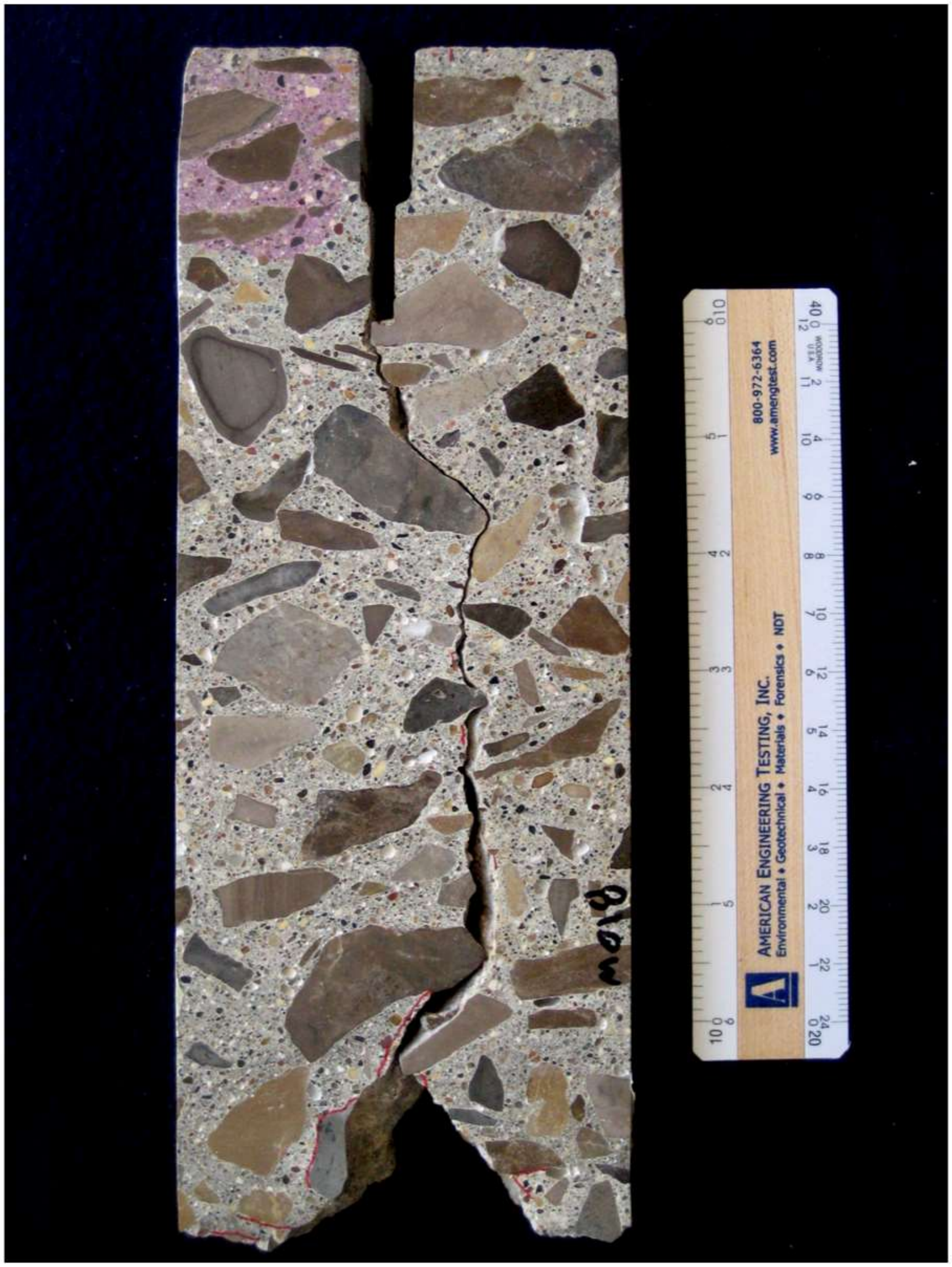
PHOTO:
34

SAMPLE ID: 2480-91, M018 **DESCRIPTION:** Rough screeded top surface of the core with neoprene-sealed control joint.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

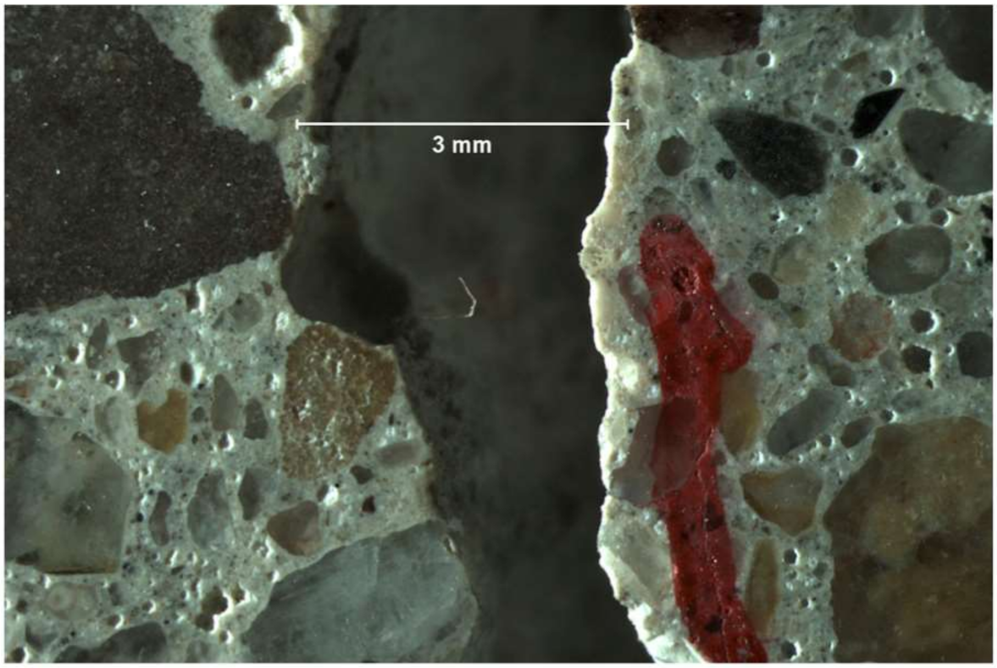
PROJECT: W/CM Study
Phase 1

PHOTO:
86



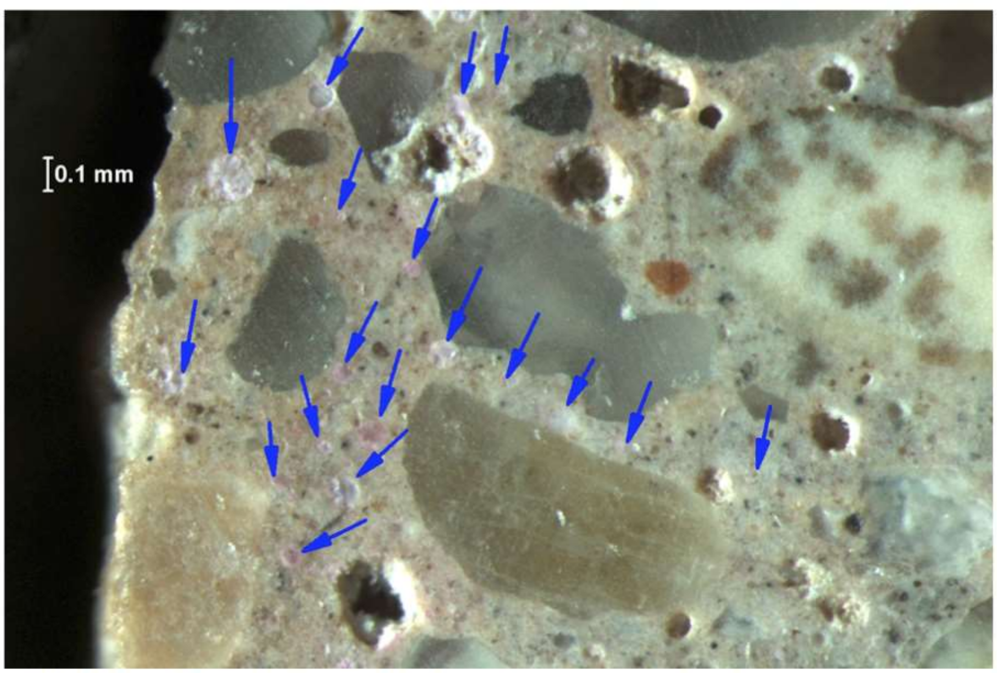
SAMPLE ID: 2480-91, M018 **DESCRIPTION:** Sawcut and lapped cross section of core. The core exhibits tight interlock of the joint crack with some apparent moderate-angled spalling at the base of the joint.

PHOTO:
116



SAMPLE ID: 2480-91, M018 **DESCRIPTION:** Note loss of air entrainment due to ettringite fillings adjacent to the distressed joint plane (center).
MAG: 15x

PHOTO:
117



SAMPLE ID: 2480-91, M018 **DESCRIPTION:** Nearly all of the finest entrained sized air voidspaces proximate to the distressed joint plane are filled with secondary ettringite. Image from 155mm depth from the top surface.
MAG: 50x

AET PROJECT NO:	28-00337	**DATE:** December 31, 2012
PROJECT:	W/CM Study Phase 1	

PHOTO:
31

SAMPLE ID: 2480-91, M013 **DESCRIPTION:** Overall view of the mid-panel core utilized for rapid chloride permeability testing. The top surface is left.

PHOTO:
32

SAMPLE ID: 2480-91, M013 **DESCRIPTION:** Rough screeded top surface with minor mortar erosion.

Field Notes and Petrographic Reports for Project 5507-47, Cores M004, M005

Table A.24. Field notes for SP Number 5507-47, US-52.

Core	Location from Joint	RP	Station	Direction	Lane	Offset	Thickness
M002	OFF	50.900		NB	RT	7.0'	8.250"
M003	2.0'	50.300		SB	LT	7.0'	8.500"
M004	ON	49.000		SB	RT	7.0'	8.125"
M005	OFF	48.000		SB	RT	7.0'	8.000"
M006	OFF	47.000		SB	RT	7.0'	8.125"
M008	OFF	48.000		NB	RT	7.0'	8.500"
M009	OFF	49.000		NB	RT	7.0'	8.250"

00 LAB 001 Petrographic Examination of Hardened Concrete
ASTM: C-856

Project No.	28-00337	Date:	December 30, 2011
Sample ID:	M004, SP5507-47	Performed by:	G. Moulzolf

I. General Observations

1. Sample Dimensions: The core was taken directly though a distressed pavement joint. Our analysis was performed on both lapped sides of a cross section (two pieces) of core sawcut "normal" to a the distressed joint measuring (in total) 209mm (8 ¼") x 100mm (4") x 32mm (1 ¼") thick, a 209mm (8 ¼") x 95mm (3 ¾") x 25mm (1") thick section, and two 76mm (3") x 52mm (2") wide thin sections that were sawcut and prepared from the original 100mm (4") diameter x 209mm (8 ¼") long core. The thin sections were located between 27mm and 90mm depth and 130mm and 200mm depth in the core, in cross section and along the sawcut and distressed portions of the joint.

2. Surface Conditions:
Top: Rough screeded surface with mortar erosion exposing many fine aggregate surfaces; partly covered by a thin coat of white marking paint.
Bottom: Rough, irregular, fractured surface.

3. Reinforcement: None observed.

4. General Physical Conditions: The core exhibits poor overall condition. The core was taken through a moderately to severely distressed pavement joint. The joint was characterized by an approx. 11mm wide sawcut proceeding at least 38mm (1 ½") depth from the top surface. Evidence of a pilot cut was missing due to loss of concrete. An unattached 6mm thick light gray silicon joint sealant and light gray backer rod were included with the core. Incipient vertical scaling/spalling starts at as shallow as 24mm depth in the sawcut joint and incorporates between 8mm and 27mm of total concrete paste and dolostone aggregate between the two sides of the joint crack. The widest loss of concrete (15mm-27mm) occurs between approx. 40 and 120mm depth in the concrete; with the thinnest paste loss (8mm) generally below approx. 140mm depth in the core. Concentrated sub-vertical microcracks (incipient spalling) were observed generally within the paste and dolostone aggregates within 10mm of the distressed joint surface between the sawcut and bottom surface of the core. "Fresh" sub-horizontal fractures, most likely produced during coring, occur at approx. 75mm and 98mm depth from the top surface on one side of the joint and at approx. 117mm depth on the other side of the joint. Other sub-horizontally oriented microcracks were present at 43mm, 61mm, 97mm, 107mm, 137mm, 162mm, and 192mm in the core. This cracking and several other randomly oriented microcracks located below approx. 120mm depth, proceeds through most dolostone coarse aggregates it encounters.

   The rough screeded top surface of the core exhibits minor mortar erosion; exposing many fine aggregate surfaces. The concrete was fairly well consolidated, with only two voidspaces observed in excess of 12mm in diameter at mid-depth in the core. The concrete was purposefully air entrained and contains a well-distributed air void system considered freeze-thaw resistant under severe exposure conditions. Original air-void parameters include a 5.4% entrained air void volume and a 0.005" spacing factor. Secondary ettringite, with some portlandite, fills many of the smaller entrained sized voidspaces throughout the depth of the core apart from the top approx. 5mm. The finest void fillings generally increase with depth from the top surface and decrease with distance from the joint, with the greatest degree of void filling within 6mm of the distressed joint plane. Actual measured air void parameters, excluding the ettringite void fillings, in a band between approx. 0mm and 12mm (0"-0.5") depth from the distressed joint surface (at below 120mm depth in the core), are 3.7% entrained volume (a loss of 1.7% volume) with a 0.007" spacing factor.

II. Aggregate

1. Coarse: 25mm (1") nominal sized crushed carbonate composed of fine grained, variably buff to pale yellowish brown-colored dolostone. The coarse aggregate appeared well graded and exhibited good overall distribution.

2. Fine: Natural quartz, feldspar, and lithic sand. The grains were mostly sub-rounded with many smaller sub-angular particles. The fine aggregate appeared fairly graded and exhibited good overall uniform distribution.

III. Cementitious Properties

1. Air Content: 6.3% total original air.
2. Depth of carbonation: Ranges from negligible up to 5mm depth from the top surface of the core and up to 4mm depth from the sawcut joint surface. Carbonation appears to proceed up to 5mm depth from the distressed joint plane.
3. Pozzolan presence: Flyash was observed.
4. Paste/aggregate bond: Fair to good.
5. Paste color: Light tannish gray.
6. Paste hardness: Moderately hard (Moh's 3)
7. Microcracking: A few, fine, sub-vertical drying shrinkage microcracks proceed up to 5mm depth from the top surface. A single 8mm long sub-horizontally oriented microcrack occurs along the paste – aggregate boundary of a coarse aggregate between 2mm and 4mm depth of the core. sub-horizontally oriented microcracks were present at 43mm, 61mm, 97mm, 107mm, 137mm, 162mm, and 192mm in the core. This cracking and several other randomly oriented microcracks located below approx. 120mm depth, proceeds through most dolostone coarse aggregates it encounters.
8. Secondary deposits: White ettringite and a small amount of portlandite fills many of the smaller entrained sized voidspaces throughout the depth of the core apart from the mostly carbonated top approx. 5mm. The finest void fillings generally increase with depth from the top surface and decrease with distance from the joint, with the greatest degree of void filling within 6mm of the distressed joint plane. Clear to white ASR gel product lines or fills rare voidspaces adjacent to scattered reactive fine aggregate particles.
9. w/cm: Estimated at between 0.42 and 0.47 with approximately 5 to 7% residual portland cement clinker particles and an amount of flyash visually consistent with a 15 to 25% replacement of portland cement.
10. Cement hydration: Alites: Well to fully.
    Belites: Well.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 1

PHOTO:
49

SAMPLE ID: 5507-47, M004 **DESCRIPTION:** Overall view of the jointed core utilized for petrographic analysis. The top surface is left. Note "tunneling" distress.

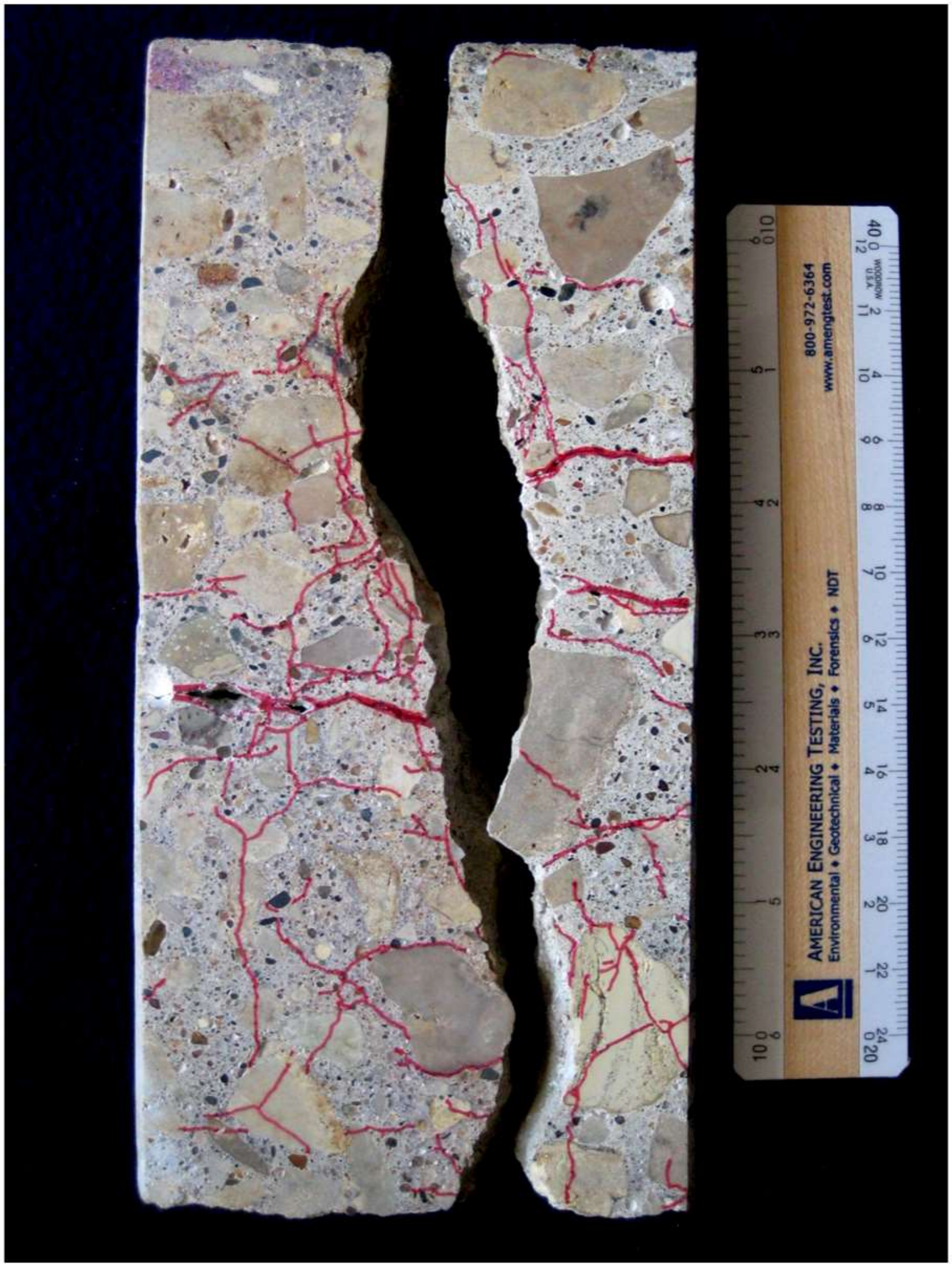
PHOTO:
50

SAMPLE ID: 5507-47, M004 **DESCRIPTION:** Rough screeded and jointed top surface of the core with minor mortar erosion. Note silicone joint sealant.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 1

PHOTO:
91

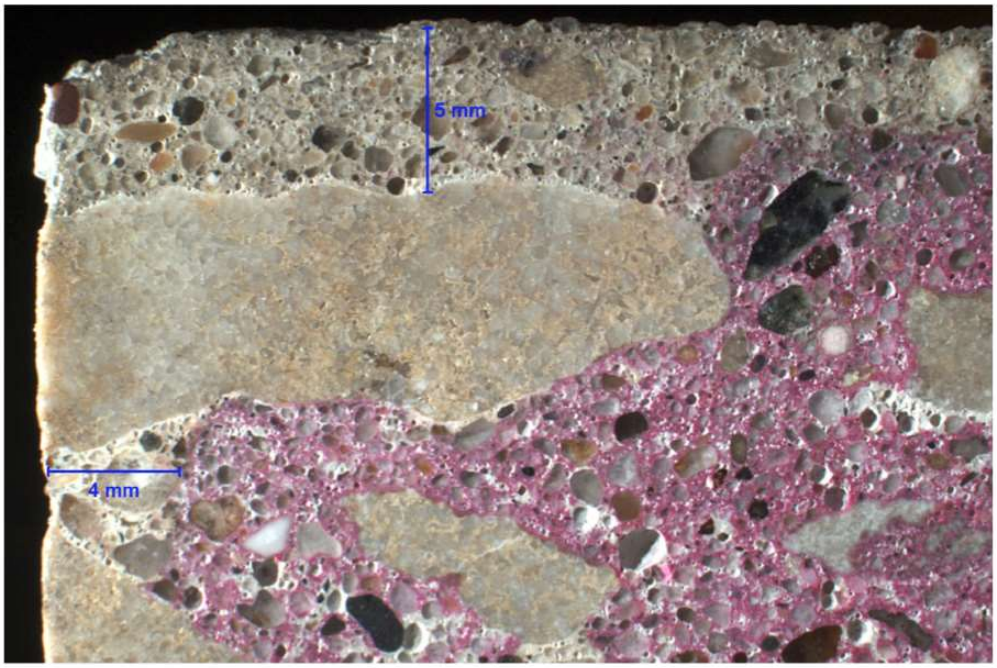


SAMPLE ID: 5507-47, M004 **DESCRIPTION:** Sawcut and lapped cross section of core. The silicone sealant was completely de-bonded from both sides of the sawcut. Microcracking is mapped in red ink. The coarse aggregates exhibit apparent "d-cracking". Note the widest loss of paste between approx..40mm and 120 mm depth.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

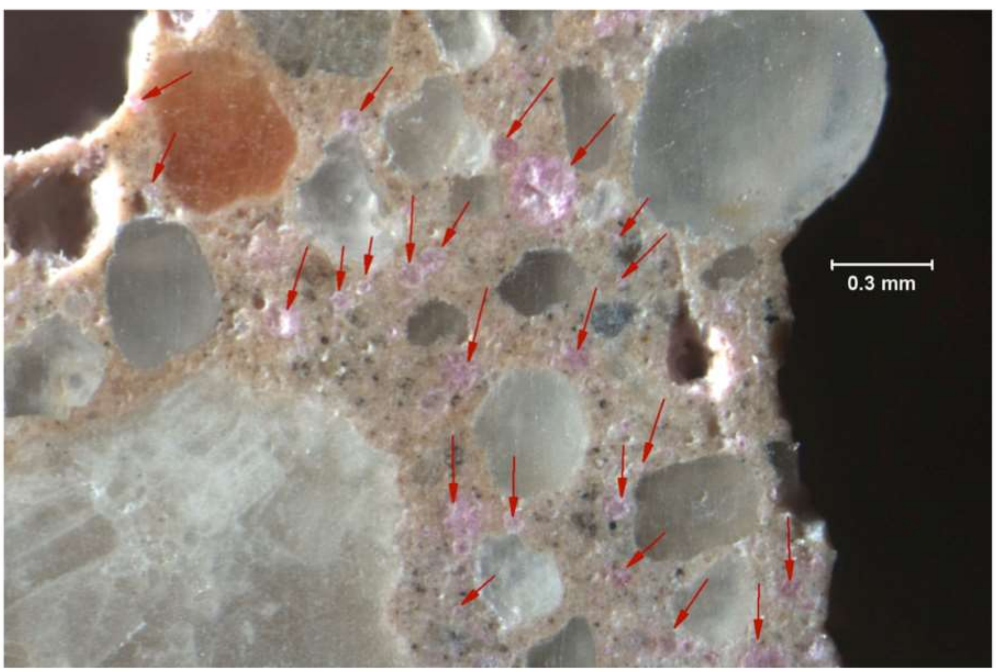
PROJECT: W/CM Study
Phase 1

PHOTO:
134



SAMPLE ID: 5507-47, M004 **DESCRIPTION:** Carbonation (unstained paste) proceeded up to 5mm depth from the top surface (in this image).
MAG: 5x

PHOTO:
135



SAMPLE ID: 5507-47, M004 **DESCRIPTION:** Ettringite filled entrained sized voidspaces (stained purple) in the concrete directly adjacent to the distressed joint plane.
MAG: 50x

00 LAB 001 Petrographic Examination of Hardened Concrete
ASTM: C-856

Project No.	28-00337	Date:	December 30, 2011
Sample ID:	M005, SP5507-47	Performed by:	G. Moulzolf

I. General Observations

1. Sample Dimensions: Our analysis was performed on the 204mm thick concrete portion of both lapped sides of a 240mm (9 3/8") x 100mm (4") x 32mm (1 ¼") thick section, a 238mm (9 3/8") x 95mm (3 ¾") x 32mm (1 ¼") thick section, and a 76mm (3") x 52mm (2") wide thin section that were sawcut and prepared from the original 100mm (4") diameter x 240mm (9 3/8") long core.

2. Surface Conditions:
   Top: Rough screeded and tined surface with mortar erosion exposing many fine aggregate surfaces; mostly covered by a thin coat of white marking paint.
   Bottom: Rough, irregular, formed surface; placed on at least 35mm of asphaltic base.

3. Reinforcement: None observed.

4. General Physical Conditions: The rough screeded and tined top surface of the core exhibits minor mortar erosion; exposing many fine aggregate surfaces. Tining proceeds up to 4mm depth. The concrete was fairly well consolidated, with only two voidspaces observed in excess of 12mm in diameter at mid-depth in the core. The concrete was purposefully air entrained and contains a well-distributed air void system considered freeze-thaw resistant under severe exposure conditions. Original air-void parameters include a 4.2% entrained air void volume and a 0.006" spacing factor. Secondary ettringite, fills many of the finest air voidspaces below approx. 15mm depth in the core or 0.4% of the overall entrained air void volume. Further, the spacing factor is now 0.007". Discontinuous, sub-horizontally oriented bleedwater voids, or possibly frost crystal impressions, were pervasive along paste – fine aggregate boundaries in much of the top up to 4mm of the core. The concrete was placed upon on a porous bitumen and crushed carbonate base. Darker colored, denser paste in the bottom approx. 10mm of the core was produced by moisture loss to the sub-base shortly after placement.

II. Aggregate

1. Coarse: 25mm (1") nominal sized crushed carbonate composed of fine grained, variably buff to pale yellowish brown-colored dolostone. The coarse aggregate appeared well graded and exhibited good overall distribution.

2. Fine: Natural quartz, feldspar, and lithic sand. The grains were mostly sub-rounded with many smaller sub-angular particles. The fine aggregate appeared fairly graded and exhibited good overall uniform distribution.

III. Cementitious Properties

1. Air Content: 5.1% total
2. Depth of carbonation: Ranges from negligible up to 10mm depth, intermittently, from the top surface of the core; along sub-vertical drying shrinkage microcracks and porous carbonate coarse aggregates.
3. Pozzolan presence: Flyash was observed.
4. Paste/aggregate bond: Fair to good.
5. Paste color: Light tannish gray becoming similar to Medium Gray (Munsell® N5) in the bottom approx. 10mm.
6. Paste hardness: Moderately hard (Moh's 3)
7. Microcracking: A few, fine, sub-vertical drying shrinkage microcracks proceed up to 7mm depth from the top surface. Discontinuous sub-horizontally oriented bleedwater voids or frost crystal impressions were pervasive along paste – fine aggregate boundaries in much of the top up to 4mm of the core.

8. Secondary deposits: White ettringite lines most voidspaces below approx. 15mm depth in the cores and fills many of the finest entrained sized air voids. Portlandite lines the discontinuous voids in the paste in the top 4mm of the core. Clear to white ASR gel product lines or fills rare voidspaces adjacent to scattered reactive fine aggregate particles.

9. w/cm: Estimated at between 0.42 and 0.47 with approximately 5 to 7% residual portland cement clinker particles and an amount of flyash visually consistent with a 15 to 25% replacement of portland cement.

10. Cement hydration: Alites: Well to fully.
Belites: Well.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 1

PHOTO:
51

SAMPLE ID: 5507-47, M005 **DESCRIPTION:** Overall view of the mid-panel core utilized for petrographic analysis. The top surface is left.

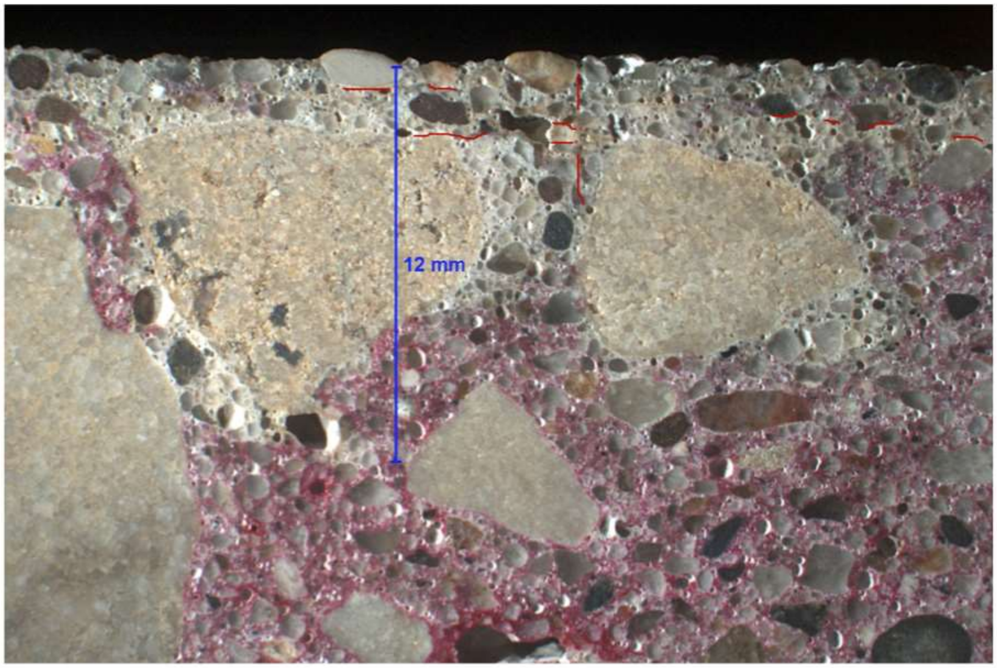
PHOTO:
52

SAMPLE ID: 5507-47, M005 **DESCRIPTION:** Rough screeded and tined top surface of the core with minor mortar erosion.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

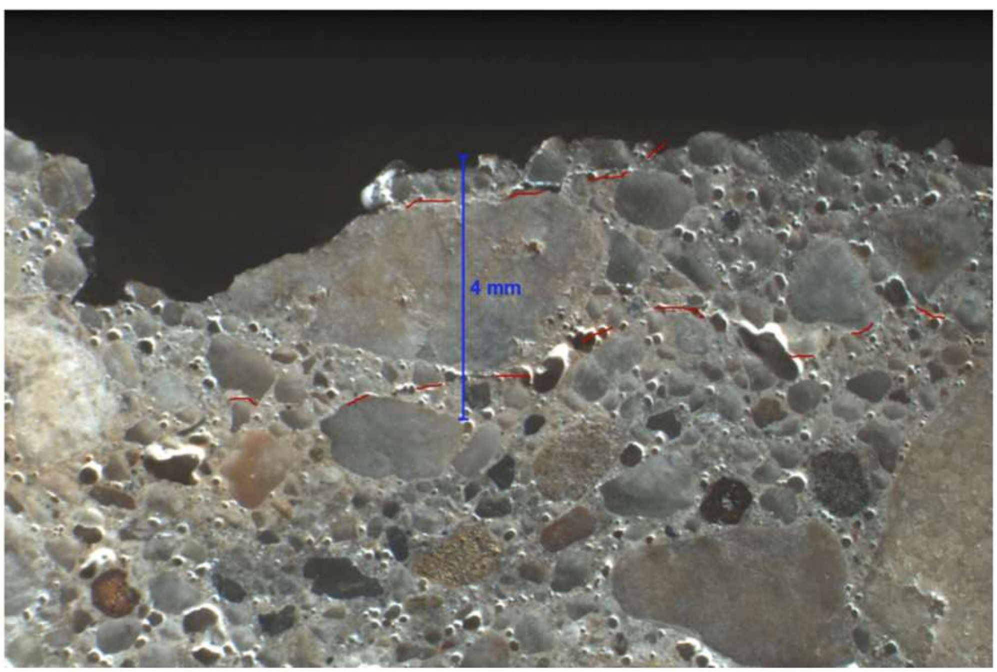
PROJECT: W/CM Study
Phase 1

PHOTO:
136



SAMPLE ID: 5507-47, M005 **DESCRIPTION:** Carbonation (unstained paste) proceeded up to 12mm depth from the top surface; along porous dolostone aggregate particles.
MAG: 5x

PHOTO:
137

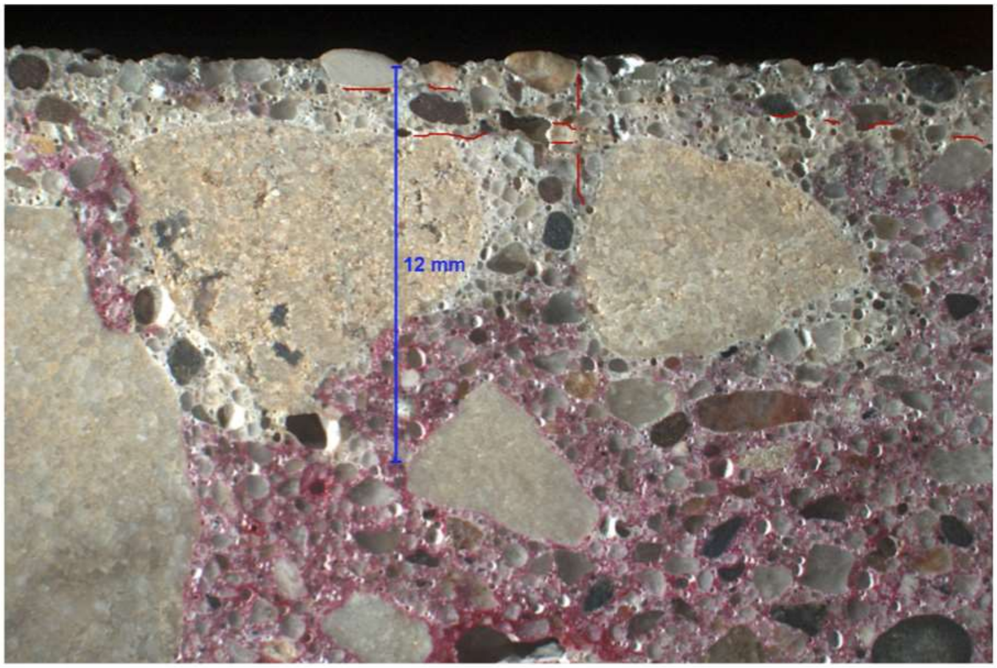


SAMPLE ID: 5507-47, M005 **DESCRIPTION:** Sub-horizontal microcracking within 4mm of the top surface is mapped in red dashed line.
MAG: 10x

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

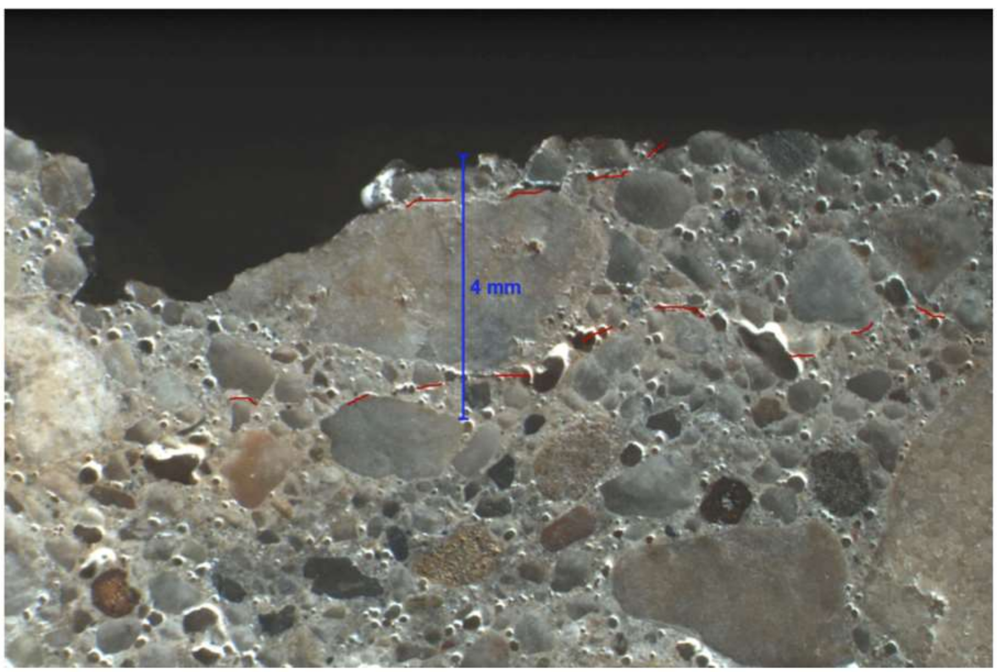
PROJECT: W/CM Study
Phase 1

PHOTO:
136



SAMPLE ID: 5507-47, M005 **DESCRIPTION:** Carbonation (unstained paste) proceeded up to 12mm depth from the top surface; along porous dolostone aggregate particles.
MAG: 5x

PHOTO:
137

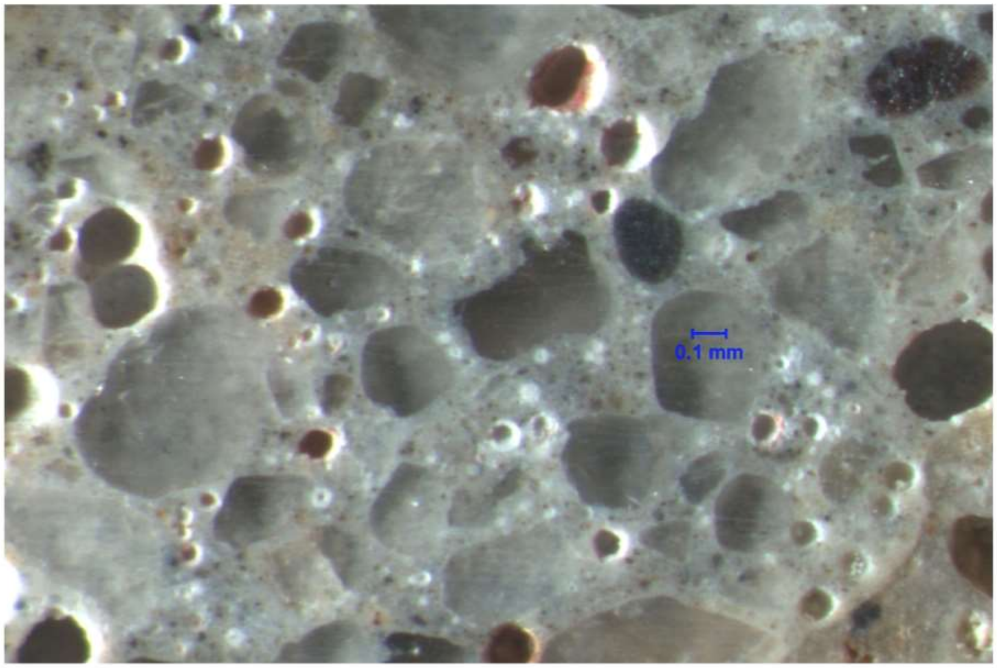


SAMPLE ID: 5507-47, M005 **DESCRIPTION:** Sub-horizontal microcracking within 4mm of the top surface is mapped in red dashed line.
MAG: 10x

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

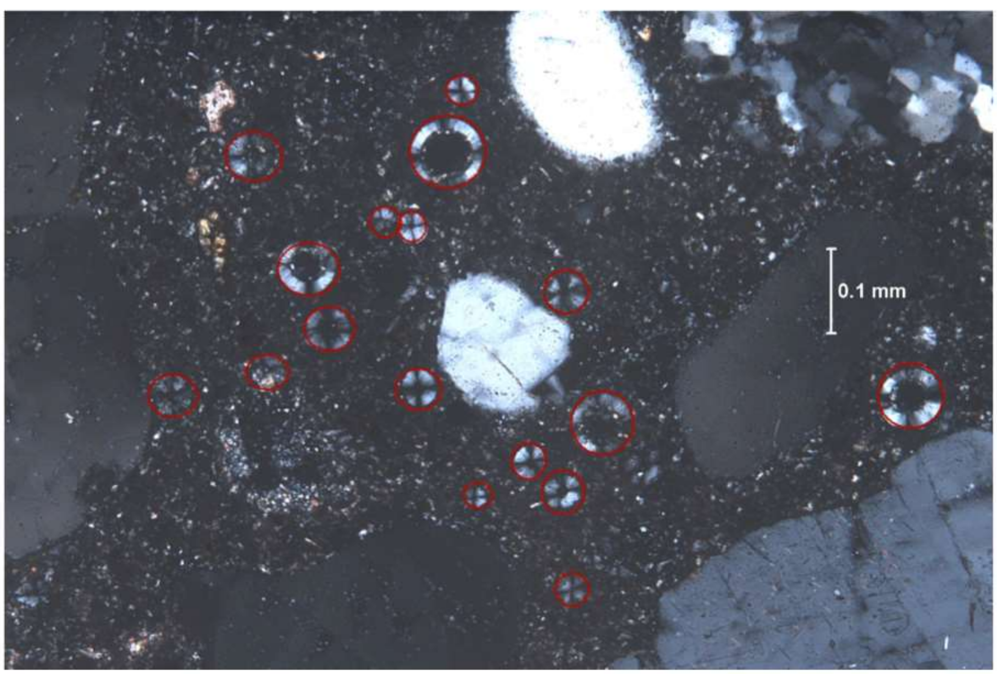
PROJECT: W/CM Study
Phase 1

PHOTO:
138



SAMPLE ID: 5507-47, M005 **DESCRIPTION:** White ettringite fills many of the finest entrained air voidspaces at 125mm depth in the core in this image.
MAG: 50x

PHOTO:
139



SAMPLE ID: 5507-47, M005 **DESCRIPTION:** Ettringite lined or filled entrained air voidspaces are outline in red; in thin section of concrete at 150mm depth in the core.
MAG: 100x

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 1

PHOTO:
53

SAMPLE ID: 5507-47, M006 **DESCRIPTION:** Overall view of the mid-panel core utilized for rapid chloride permeability. The top surface is left.

PHOTO:
54

SAMPLE ID: 5507-47, M006 **DESCRIPTION:** Rough screeded and tined top surface of the core with minor mortar erosion.

Field Notes and Petrographic Reports for Project 0702-98, Core 5

Table A.25. Field notes for SP Number 0702-98, US-14.

Core	Field Notes	GPS Coordinates
1	Hwy 14 West of 22, cores from westbound lane.	N44º 09’ 22.2”, W93º 50’ 22.1”
2		N44º 09’ 22.5”, W93º 50’ 23.4”
3		N44º 09’ 22.6”, W93º 50’ 24.1”
4		N44º 09’ 22.2”, W93º 50’ 22.3”
5		N44º 09’ 22.4”, W93º 50’ 23.7”
6		N44º 09’ 22.6”, W93º 50’ 24.3”

24-LAB-001 Petrographic Examination of Hardened Concrete
ASTM C856

Project No.	24-00776	Date:	June 16, 2014
Sample ID:	0702-98, #5	Performed by:	C. Braaten

I. General Observations

1. Sample Dimensions: The core was taken directly through a sealed, sawcut and cracked pavement joint with paste loss at depth in the joint. Our analysis was performed on both lapped sides of a cross section (two pieces) of core sawcut "normal" to a sawcut and cracked joint measuring 227 mm (8-15/16") x 138 mm (5-7/16") x 24 mm (15/16") thick and one 76 mm (3") x 52 mm (2") wide thin section that was sawcut and prepared from the original 145 mm (5-11/16") diameter x 230 mm (9-1/16") long core. The thin section was located between 12 mm and 92 mm depth from the top surface; in cross section and along the sawcut and cracked and distressed portions of the joint.

2. Surface Conditions:
   Top: Rough mortar eroded surface; with several exposed coarse aggregate surfaces.
   Bottom: Rough, irregular; formed surface. Placed on grade.

3. Reinforcement: A 31 mm (1-1/4") diameter epoxy coated dowel was observed at approximately 102 mm (4") depth from the top surface. No corrosion was observed.

4. General Physical Conditions: The core was taken through a sealed pavement joint. The dark gray silicone joint sealant was mostly de-bonded from both sides of the sawcut joint. Below the silicone joint sealant was a 12 mm (1/2") foam backer rod. The joint was characterized by an approx. 5 mm wide sawcut proceeding 55 mm (2-1/8") depth from the top surface and an approx. 12 mm wide reservoir cut to 27 mm (1-1/16") depth. Vertical scaling/spalling distress in the paste-only starts at as shallow as 27 mm depth in the sawcut joint surface and incorporates between a few mm and 20 mm of total concrete paste between the two sides of the joint crack. The joint plane is characterized by numerous relatively "clean" and un-distressed quartzite coarse aggregate protruding from the concrete. The widest loss of concrete (to 20 mm) occurs below 40 mm depth in the concrete from the top surface. The core does exhibit some residual interlock between the two halves. Sub-vertical microcracks (incipient spalling) were relatively rare in the intact paste. One sub-horizontal macrocrack occurs at approx. 110 mm (4-5/16") depth from the top surface, proceeds from the joint surface, sub-perpendicularly, to the cored edge, and proceeds around and through coarse aggregate particles. The coarse quartzite aggregate appeared sound. No evidence of ASR associated with the coarse aggregate was observed. No reaction rims were obvious. Internal, randomly oriented, empty micro-fractures appear to have been produced by the crushing procedure. Numerous alkali-silica reacted shale fine aggregate were present in the core.

   The rough screeded top surface of the core exhibits moderate mortar erosion/traffic wear; exposing several coarse aggregate surfaces. The concrete was fairly well consolidated, with only a few entrapped voidspaces observed in excess of 12 mm in diameter in the mid-section of the core. The concrete was purposefully air entrained and originally contained a well-distributed air void system considered freeze-thaw resistant under severe exposure conditions. Original air void parameters include a 5.8% entrained-sized void volume and a 0.003" spacing factor. Secondary ettringite, with some portlandite, fills many of the smaller entrained sized voidspaces within approx. 15 mm of the distressed joint surface and approximately 30 mm from the bottom surface of the core. Void fillings decrease with depth from the joint plane. Actual measured air void parameters, which excludes the ettringite void fillings, in a band between approx. 0mm and at least 12mm (0-0.5") depth from the distressed joint surface (below 105mm depth in the core), are 2.8% entrained volume and a 0.011" spacing factor.

II. Aggregate

1. Coarse: 37 mm (1-1/2") nominal sized crushed quartzite. The coarse aggregate appeared well graded and exhibited good overall distribution.

2. Fine: Natural quartz, feldspar, and lithic sand. The grains were mostly sub-rounded with many smaller sub-angular particles. The fine aggregate appeared fairly graded and exhibited good overall uniform distribution.

III. Cementitious Properties

1. Air Content:	8.0% total original air content. 4.0% total "actual" un-filled air between 0mm and 12mm depth from the distressed joint (below 105mm depth).
2. Depth of carbonation:	Ranged from negligible up to 9 mm depth from the top surface of the core; along sub-vertical distressed joint. Ranged from negligible up to 2 mm depth from the distressed joint surface.
3. Paste/aggregate bond:	Fair.
4. Paste color:	Mottled light olive gray to Medium Gray (Munsell® 5Y 6/1 to N6).
6. Paste hardness:	Moderately soft (Mohs ≈ 2.5 - 3).
7. Microcracking:	Sub-vertical microcracks (incipient spalling) were relatively rare in the intact paste. One sub-horizontal macrocrack occurs at approx. 110 mm (4-5/16") depth from the top surface, proceeds from the joint surface, sub-perpendicularly, to the cored edge, and proceeds around and through coarse aggregate particles.
8. Secondary deposits:	White, generally acicular grown ettringite along with some clear platelets of portlandite fills many of the smaller entrained sized void spaces within approx. 15 mm of the distressed joint surface and approximately 30 mm from the bottom surface of the core. Void fillings become less abundant with distance from the joint.
9. w/cm:	Estimated at between 0.43 and 0.48 with approximately 3 to 5% residual portland cement clinker particles and an amount of flyash visually consistent with a 20 to 30% replacement of portland cement.
10. Cement hydration:	Alites: Mostly fully Belites: Well

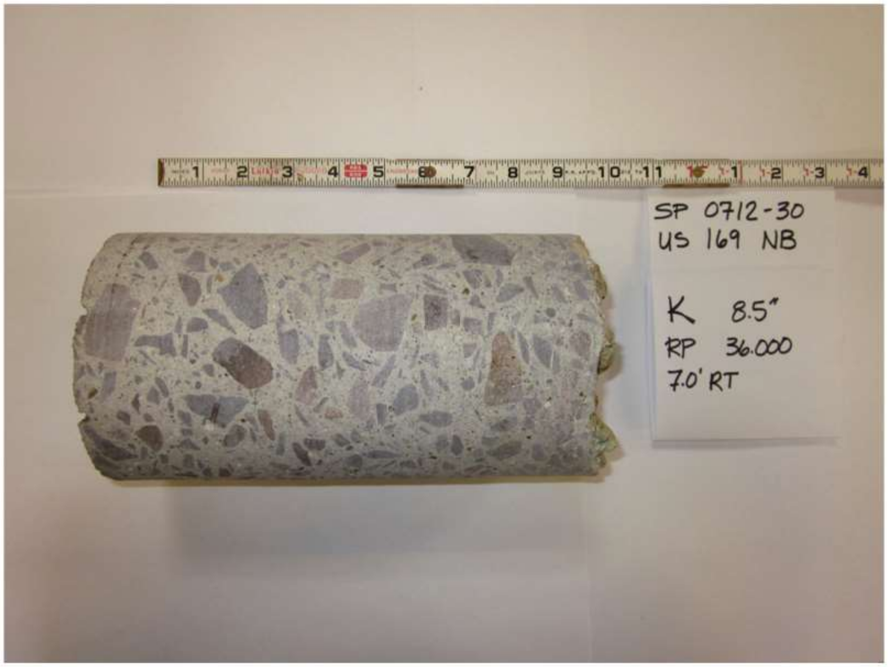
Description – Project 0702-98, Core 5

Description – Project 0702-98, Core 5

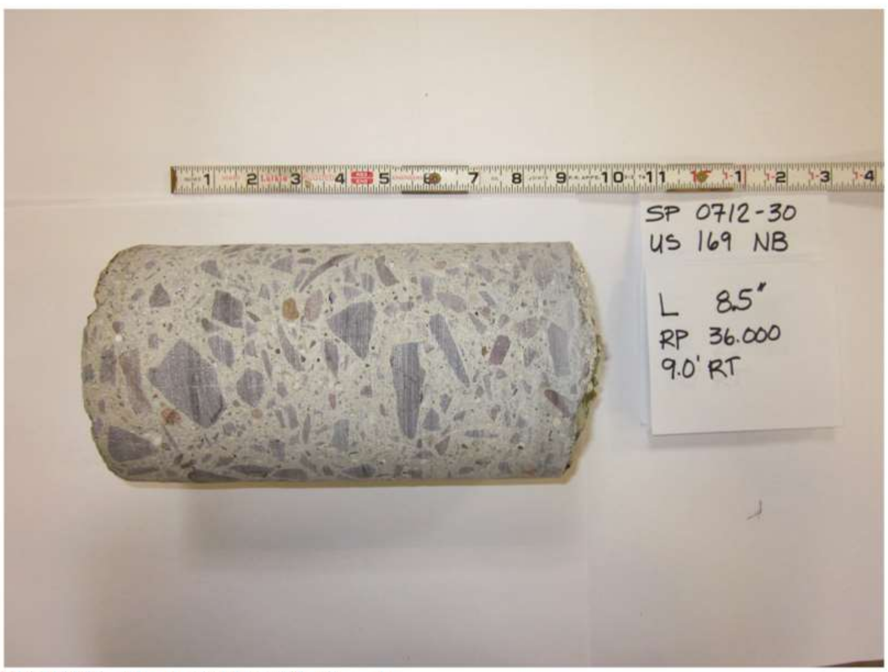
Field Notes and Petrographic Reports for Project 0712-30, Cores K, L, M

Table A.26. Field notes for SP Number 0712-30, US-169.

Core	Location from Joint	RP	Station	Direction	Lane	Offset	Thickness
K	OFF	36.000		NB		7.0'	8.500"
L	OFF	36.000		NB		9.0'	8.500"
M	OFF	36.000		NB		6.0'	8.500"

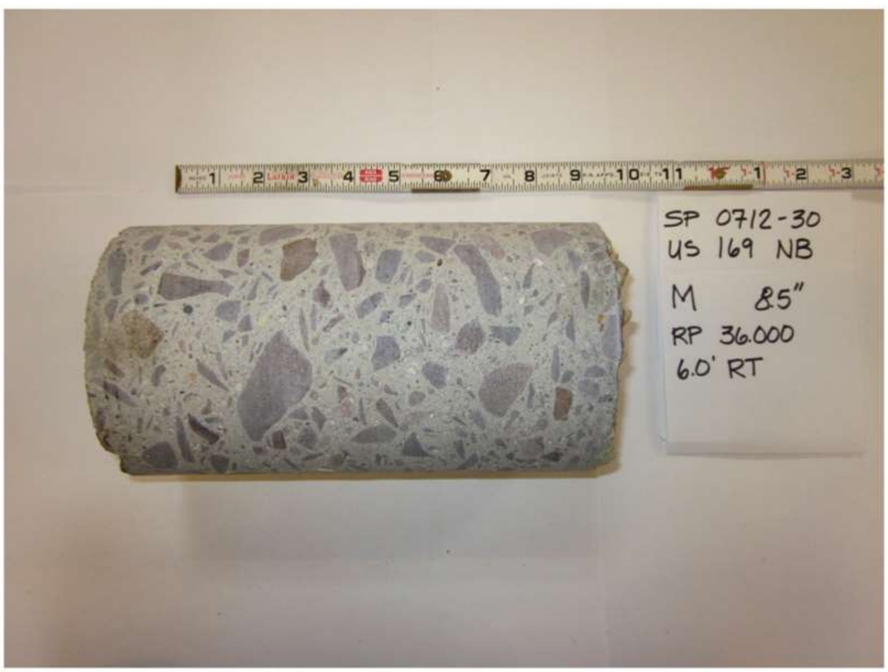


DESCRIPTION – Project 0712-30, Core K



DESCRIPTION – Project 0712-30, Core L

DESCRIPTION – Project 0712-30, Core L



DESCRIPTION – Project 0712-30, Core M

DESCRIPTION – Project 0712-30, Core M

Field Notes and Petrographic Reports for Project 0712-32, Core 1

Table A.27. Field notes for SP Number 0712-32, US 169.

Core	Field Notes	GPS Coordinates
1	US 169 WB South lane North of Garden City	N44º 6’ 20.3”, W94º 8’ 1.8”
2		N44º 6’ 19.4”, W94º 8’ 1.9”
3		N44º 6’ 18.9”, W94º 8’ 2”
4		N44º 6’ 20.2”, W94º 8’ 1.8”
5		N44º 6’ 19.7”, W94º 8’ 1.8”
6		N44º 6’ 18.8”, W94º 8’ 2”

24-LAB-001 Petrographic Examination of Hardened Concrete
ASTM C856

Project No.	24-00776	Date:	June 25, 2014
Sample ID:	0712-32, 1	Performed by:	C. Braaten

I. General Observations

1. Sample Dimensions: The core was taken directly through a sealed, sawcut and cracked pavement joint with paste loss at depth in the joint. Our analysis was performed on both lapped sides of a cross section (two pieces) of core sawcut "normal" to a sawcut and cracked joint measuring 210 mm (8-1/4") x 130 mm (5-1/8") x 49 mm (1-15/16") thick and one 76 mm (3") x 52 mm (2") wide thin section that was sawcut and prepared from the original 145 mm (5-11/16") diameter x 210 mm (8-1/4") long core. The thin section was located between the top surface and 80 mm depth from the top surface; in cross section and along the sawcut and cracked and distressed portions of the joint.

2. Surface Conditions:
   Top: Rough, tined surface with mortar erosion; with many exposed fine aggregate surfaces.
   Bottom: Rough, irregular; formed surface. Placed on grade.

3. Reinforcement: A 31 mm (1-1/4") diameter epoxy coated dowel was observed at approximately 102 mm (4") depth from the top surface. No corrosion was observed.

4. General Physical Conditions: The core was taken through a sealed pavement joint. The dark gray silicone joint sealant was mostly de-bonded from both sides of the sawcut joint. Below the silicone joint sealant was a 12 mm (1/2") foam backer rod. The joint was characterized by an approx. 10 mm wide reservoir cut with depth measured to 15 mm from the top surface. Any evidence of the exact depth of the reservoir cut or the presence of a pilot cut appeared to be lost due to vertical scaling/spalling distress. Vertical scaling/spalling distress in the paste-only starts at as shallow as 15 mm depth in the sawcut joint surface, directly below the silicone joint sealant, and incorporates between a few mm and 26 mm of total concrete paste between the two sides of the joint crack. The joint plane is characterized by several relatively "clean" and un-distressed quartzite coarse aggregate protruding from the concrete. The widest loss of concrete (to 26 mm) occurs below 41 mm depth in the concrete from the top surface. The core does exhibit some residual interlock between the two halves. Several sub-vertical microcracks (incipient spalling) were observed generally within the paste-only and within 10 mm of the distressed joint surface. The coarse quartzite aggregate appeared sound. No evidence of ASR associated with the coarse aggregate was observed. No reaction rims were obvious. Internal, randomly oriented, empty micro-fractures appear to have been produced by the crushing procedure. Numerous alkali-silica reacted shale fine aggregate were present in the core.

   The rough tined top surface of the core exhibits mortar erosion/traffic wear; with the tines being significantly worn, rounded, smoothed, and exposing many fine aggregate surfaces. Several areas within the core were observed to have a lighter paste color and reduced air voids. The largest of these areas was approximately 18 mm x 14 mm in maximum dimensions. The concrete was fairly well consolidated, with only a few entrapped voidspaces observed in excess of 14 mm in diameter near the top and mid-section of the core. The concrete was purposefully air entrained and originally contained a well-distributed air void system considered freeze-thaw resistant under severe exposure conditions. Original air void parameters include a 3.9% entrained-sized void volume and a 0.005" spacing factor. Secondary ettringite, with some portlandite, fills many of the smaller entrained sized voidspaces within approx. 10 mm of the distressed joint surface and approximately 5 mm from the bottom surface of the core. Void fillings decrease with depth from the joint plane. Actual measured air void parameters, which excludes the ettringite void fillings, in a band between approx. 0mm and at least 12mm (0-0.5") depth from the distressed joint surface (below 105mm depth in the core), are 2.8% entrained volume and a 0.011" spacing factor.

II. Aggregate

1. Coarse: 37 mm (1-1/2") nominal sized crushed quartzite. The coarse aggregate appeared well graded and exhibited good overall distribution.

2. Fine: Natural quartz, feldspar, and lithic sand. The grains were mostly sub-rounded with many smaller sub-angular particles. The fine aggregate appeared fairly graded and exhibited good overall uniform distribution.

III. Cementitious Properties

1. Air Content:	7.3% total original air content. 4.0% total "actual" un-filled air between 0mm and 12mm depth from the distressed joint (below 105mm depth).
2. Depth of carbonation:	Ranged from negligible up to 1 mm depth from the top surface of the core; "spiking" up to 9 mm depth along sub-vertical microcrack. Ranged from negligible up to 9 mm depth from the distressed joint surface.
3. Paste/aggregate bond:	
4. Paste color:	Similar to medium light gray (Munsell® N6), with several areas that were very light gray (Munsell® N8).
6. Paste hardness:	Moderate to moderately hard (Mohs ≈ 3 – 3.5).
7. Microcracking:	Several sub-vertical microcracks (incipient spalling) were observed generally within the paste-only and within 10 mm of the distressed joint surface.
8. Secondary deposits:	Secondary ettringite, with some portlandite, fills many of the smaller entrained sized voidspaces within approx. 10 mm of the distressed joint surface and approximately 5 mm from the bottom surface of the core. Void fillings decrease with depth from the joint plane.
9. w/cm:	Estimated at between 0.43 and 0.48 with approximately 3 to 5% residual portland cement clinker particles and an amount of flyash visually consistent with a 20 to 30% replacement of portland cement.
10. Cement hydration:	Alites: Mostly fully Belites: Well

DESCRIPTION – Project 0712-32, Core 1

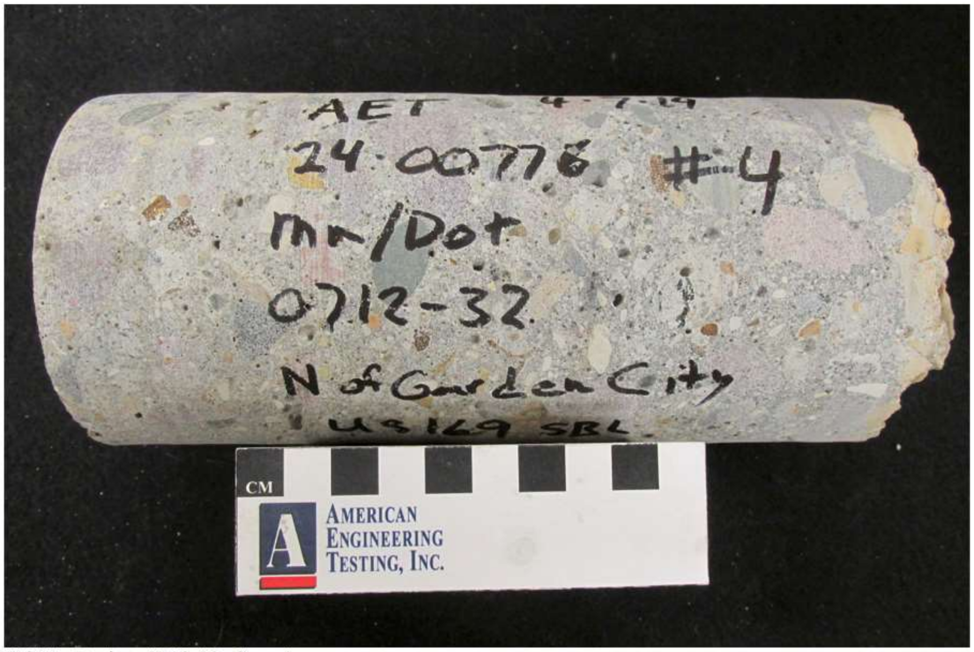
DESCRIPTION – Project 0712-32, Core 1

DESCRIPTION – Project 0712-32, Core 2

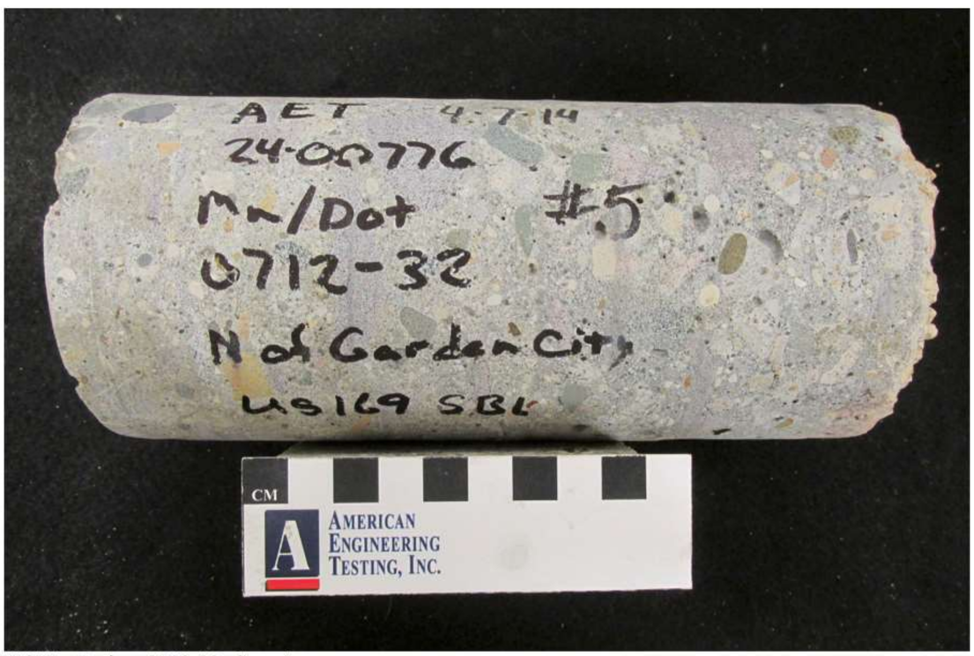
DESCRIPTION – Project 0712-32, Core 2

DESCRIPTION – Project 0712-32, Core 3

DESCRIPTION – Project 0712-32, Core 3



DESCRIPTION – Project 0712-32, Core 4



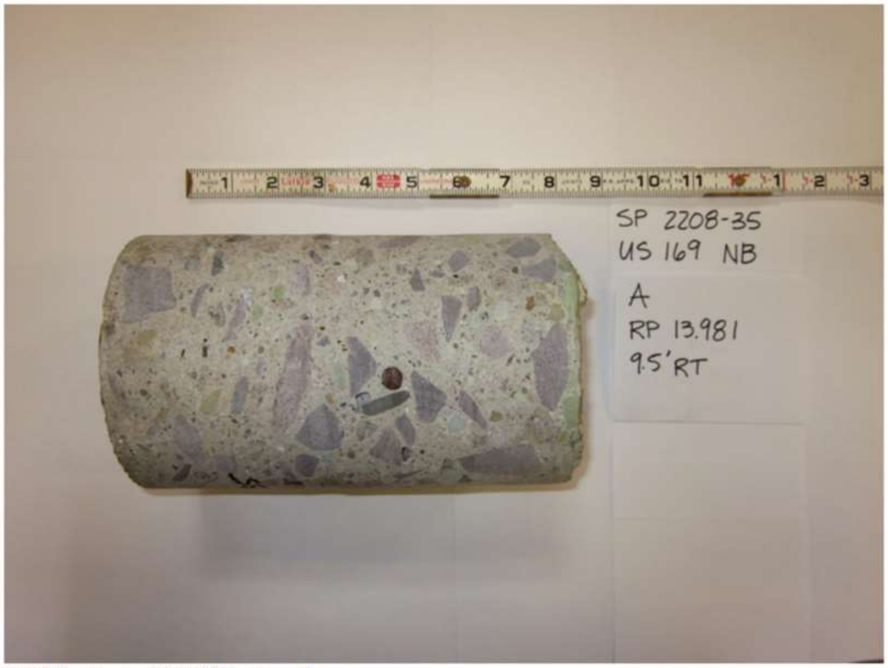
DESCRIPTION – Project 0712-32, Core 5

DESCRIPTION – Project 0712-32, Core 6

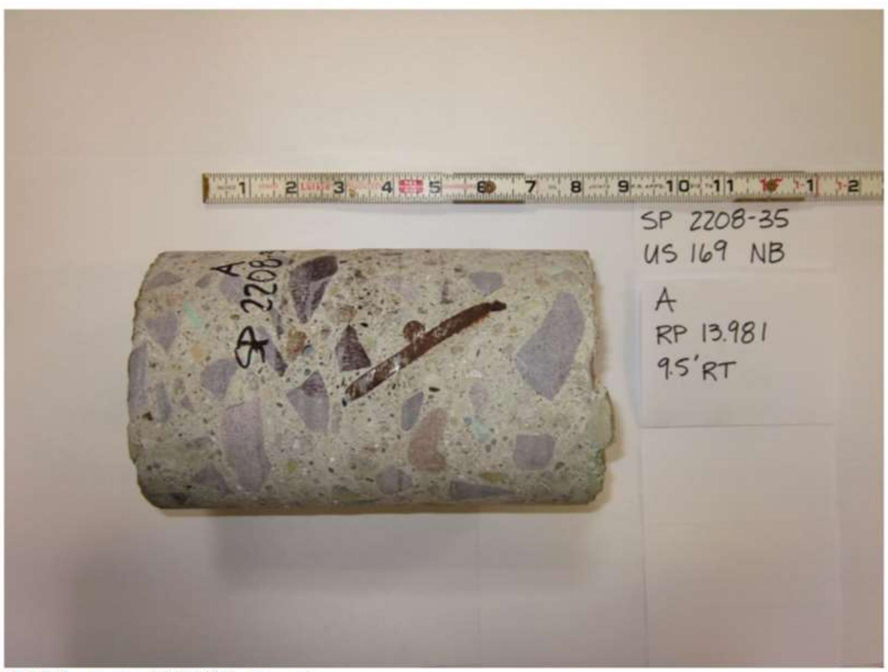
Field Notes and Petrographic Reports for Project 2208-35, Cores A, B, C

Table A.28. Field notes for SP Number 2208-35, US-169.

Core	Location from Joint	RP	Station	Direction	Lane	Offset	Thickness
A	OFF	13.891		NB		9.5'	7.500"
C	OFF	13.981		NB		8.5'	7.500"



DESCRIPTION – Project 2208-35, Core A



DESCRIPTION – Project 2208-35, Core A

DESCRIPTION – Project 2208-35, Core B

DESCRIPTION – Project 2208-35, Core B

DESCRIPTION – Project 2208-35, Core B

DESCRIPTION – Project 2208-35, Core C

Field Notes and Petrographic Reports for Project 2208-36, Cores D, E, F, G, H

Table A.29. Field notes for SP Number 2208-36, US-169.

Core	Location from Joint	RP	Station	Direction	Lane	Offset	Thickness
D	OFF	21.923		NB		7.5'	8.000"
E	OFF	21.923		NB		7.0'	8.250"
F	OFF	23.955		NB		4.0'	8.000"
G	OFF	23.955		NB		5.0'	8.000"
H	OFF	25.873		NB		5.0'	7.500"
I	OFF	25.907		NB		7.0'	7.750"
J	OFF	25.990		NB		6.0'	8.250"

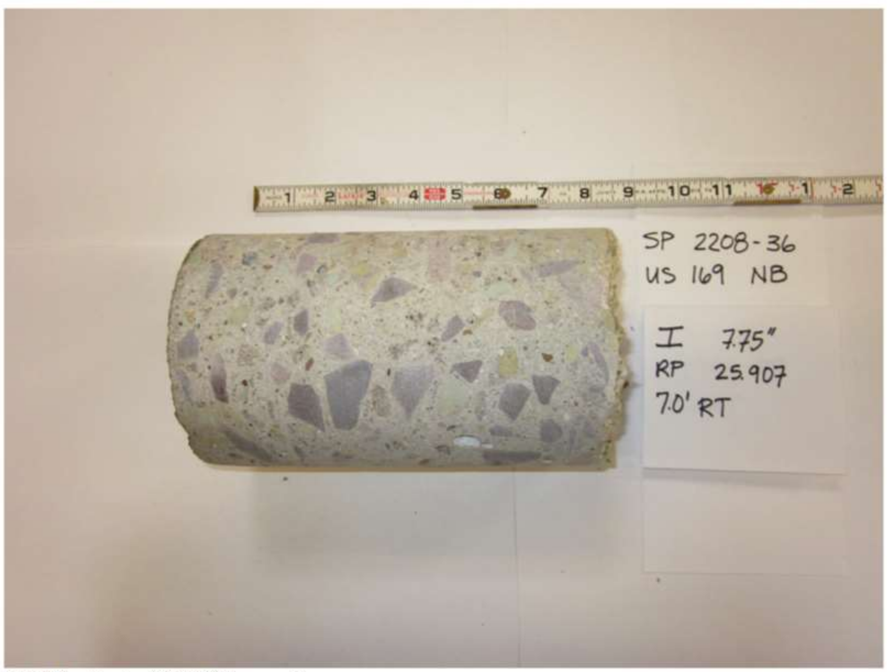
DESCRIPTION – Project 2208-36, core D

DESCRIPTION – Project 2208-36, core E

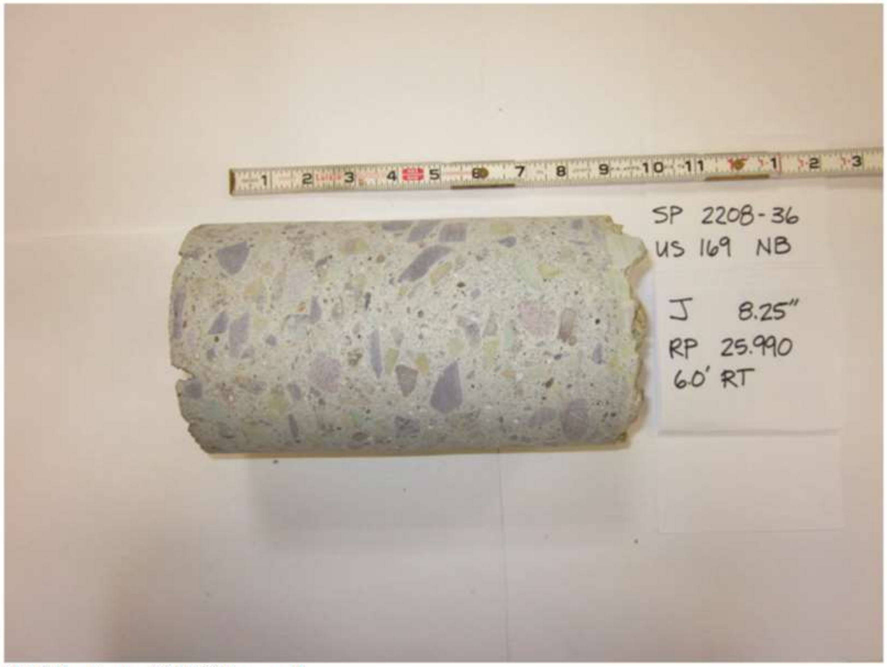
DESCRIPTION – Project 2208-36, core F

DESCRIPTION – Project 2208-36, core G

DESCRIPTION – Project 2208-36, core H



DESCRIPTION – Project 2208-36, core I



DESCRIPTION – Project 2208-36, core J

DESCRIPTION – Project 2208-36, assorted cores

Field Notes and Petrographic Reports for Project 3204-59, Core 3

Table A.30. Field notes for SP Number 3204-59, MN-60.

Core	Field Notes	GPS Coordinates
1	MN 60 WB South lane Huron Lake & Wilder	N43º 48’ 48.9”, W95º 16’ 15.6”
2		N43º 48’ 48.8”, W95º 16’ 16.2”
3		N43º 48’ 48.7”, W95º 16’ 16.6”
4		N43º 48’ 48.9”, W95º 16’ 16.7”
5		N43º 48’ 48.8”, W95º 16’ 16.3”
6		N43º 48’ 48.7”, W95º 16’ 16.7”

24-LAB-001 Petrographic Examination of Hardened Concrete
ASTM C856

Project No.	24-00776	Date:	June 17, 2014
Sample ID:	3204-59, #3	Performed by:	C. Braaten

I. General Observations

1. Sample Dimensions: The core was taken directly through a sealed, sawcut and cracked pavement joint with paste loss at depth in the joint. Our analysis was performed on both lapped sides of a cross section (two pieces) of core sawcut "normal" to a sawcut and cracked joint measuring 229 mm (9") x 142 mm (5-9/16") x 32 mm (1-1/4") thick and one 76 mm (3") x 52 mm (2") wide thin section that was sawcut and prepared from the original 145 mm (5-11/16") diameter x 230 mm (9-1/16") long core. The thin section was located between 40 mm and 120 mm depth from the top surface; in cross section and along the sawcut and cracked and distressed portions of the joint.

2. Surface Conditions:
   Top: Rough, mortar eroded surface; with several exposed coarse aggregate surfaces. Approximately 20% of the top surface was coated with a desiccated, pale yellowish orange (Munsell® 10YR 8/6) paint.
   Bottom: Rough, irregular; spalled surface.

3. Reinforcement: A 7 mm (1-1/4") diameter epoxy coated rebar was observed at approximately 200 mm (7-7/8") depth from the top surface. No corrosion was observed.

4. General Physical Conditions: The core was taken through a sealed pavement joint. The light gray silicone joint sealant was mostly de-bonded from both sides of the sawcut joint. Below the silicone joint sealant was a 12 mm (1/2") foam backer rod. The joint was characterized by an approx. 4 mm wide sawcut proceeding 58 mm (2-1/4") depth from the top surface and an approx. 11 mm wide reservoir cut to 30 mm (1-3/16") depth. Vertical scaling/spalling distress in the paste-only starts at as shallow as 30 mm depth in the sawcut joint surface and incorporates between a few mm and 15 mm of total concrete paste between the two sides of the joint crack. The joint plane is characterized by numerous relatively "clean" and un-distressed quartzite coarse aggregate protruding from the concrete. The widest loss of concrete (to 15 mm) occurs below 20 mm depth in the concrete from the top surface. The core does exhibit some residual interlock between the two halves. Sub-vertical microcracks (incipient spalling) were relatively rare in the intact paste. The coarse quartzite aggregate appeared sound. No evidence of ASR associated with the coarse aggregate was observed. No reaction rims were obvious. Internal, randomly oriented, empty micro-fractures appear to have been produced by the crushing procedure. Numerous alkali-silica reacted shale fine aggregate were present in the core.

   The rough screeded top surface of the core exhibits moderate mortar erosion/traffic wear; exposing several coarse aggregate surfaces. The concrete was fairly well consolidated, with only a few entrapped voidspaces observed in excess of 12 mm in diameter in the mid-section of the core. The concrete was purposefully air entrained and originally contained a well-distributed air void system considered freeze-thaw resistant under severe exposure conditions. Original air void parameters include a 4.7% entrained-sized void volume and a 0.004" spacing factor. Secondary ettringite, with some portlandite, fills many of the smaller entrained sized voidspaces within approx. 21 mm of the distressed joint surface and approximately 15 mm from the bottom surface of the core. Void fillings decrease with depth from the joint plane. Actual measured air void parameters, which excludes the ettringite void fillings, in a band between approx. 0mm and at least 12mm (0-0.5") depth from the distressed joint surface (below 105mm depth in the core), are 2.8% entrained volume and a 0.011" spacing factor.

II. Aggregate

1. Coarse: 37 mm (1-1/2") nominal sized crushed quartzite. The coarse aggregate appeared well graded and exhibited good overall distribution.

2. Fine: Natural quartz, feldspar, and lithic sand. The grains were mostly sub-rounded with many smaller sub-angular particles. The fine aggregate appeared fairly graded and exhibited good overall uniform distribution.

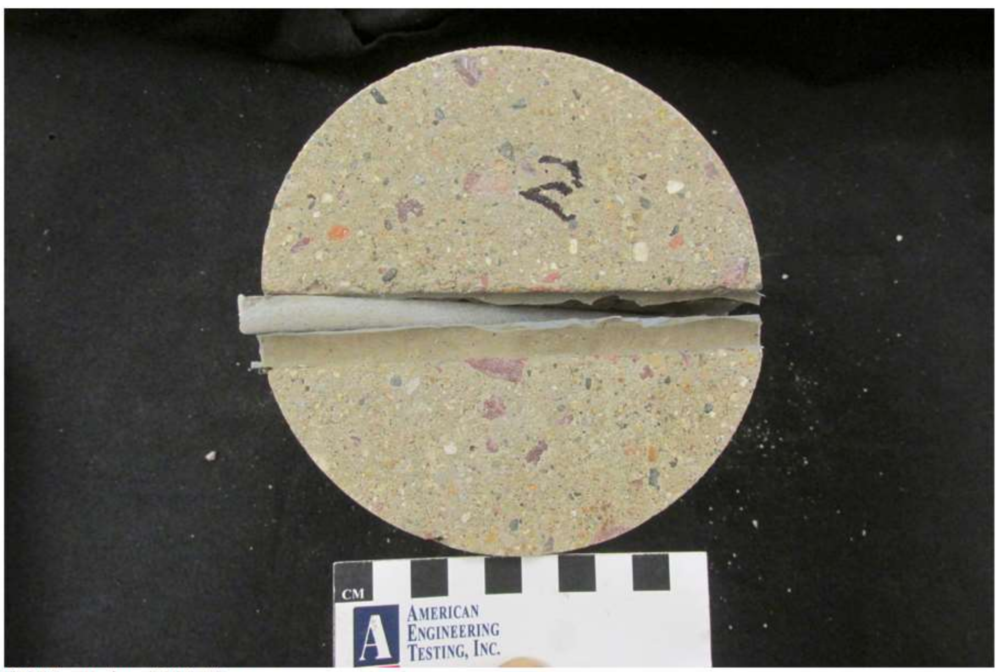
III. Cementitious Properties

1. Air Content: 5.5% total original air content. 4.0% total "actual" un-filled air between 0mm and 12mm depth from the distressed joint (below 105mm depth).
2. Depth of carbonation: Ranged from negligible up to 2 mm depth from the top surface of the core. Ranged from negligible up to 4 mm depth from the distressed joint surface.
3. Paste/aggregate bond: Fair.
4. Paste color: Mottled light olive gray to Medium Gray (Munsell® 5Y 6/1 to N6).
6. Paste hardness: Moderately soft (Mohs ≈ 2.5 - 3).
7. Microcracking: Sub-vertical microcracks (incipient spalling) were relatively rare in the intact paste.
8. Secondary deposits: White, generally acicular grown ettringite along with some clear platelets of portlandite fills many of the smaller entrained sized void spaces within approx. 21 mm of the distressed joint surface and approximately 15 mm from the bottom surface of the core. Void fillings become less abundant with distance from the joint.
9. w/cm: Estimated at between 0.43 and 0.48 with approximately 3 to 5% residual portland cement clinker particles and an amount of flyash visually consistent with a 20 to 30% replacement of portland cement.
10. Cement hydration: Alites: Mostly fully
    Belites: Well

DESCRIPTION – Project 3204-59, core

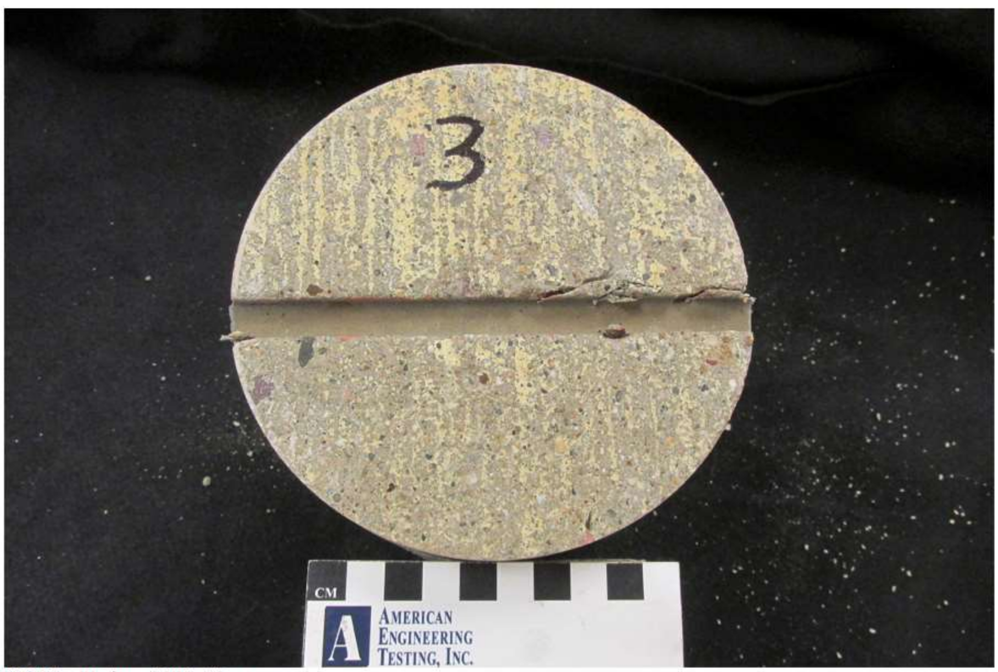
DESCRIPTION – Project 3204-59, core

DESCRIPTION – Project 3204-59, core



DESCRIPTION – Project 3204-59, core

DESCRIPTION – Project 3204-59, core



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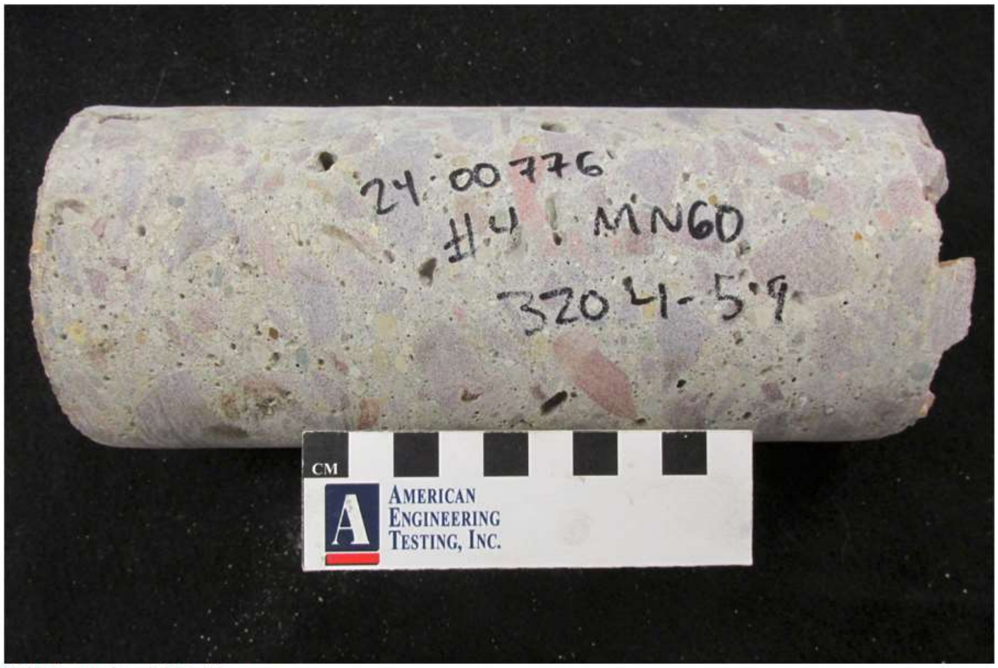
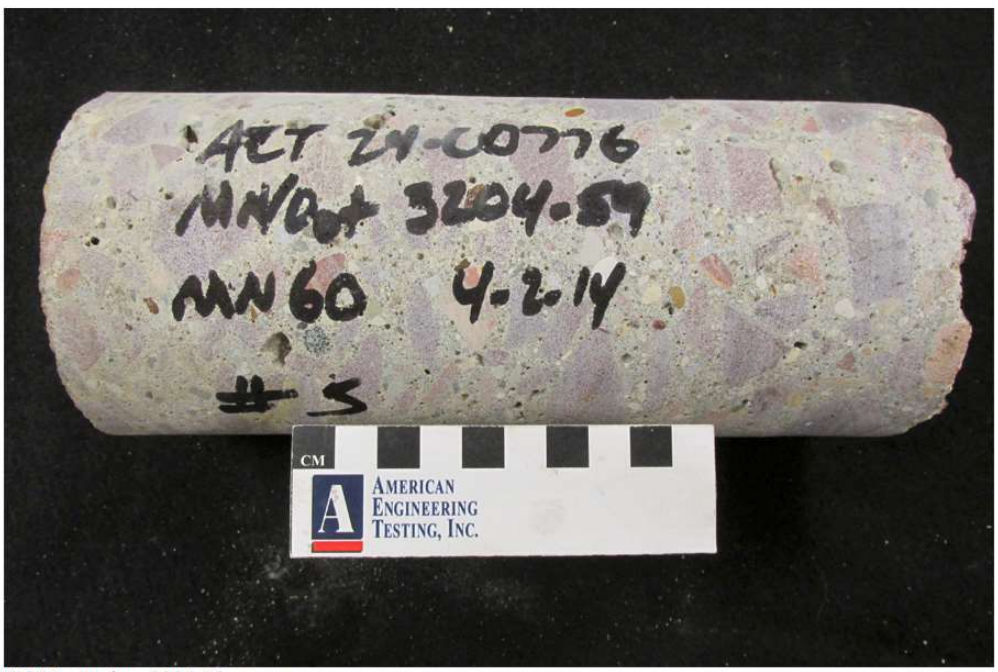
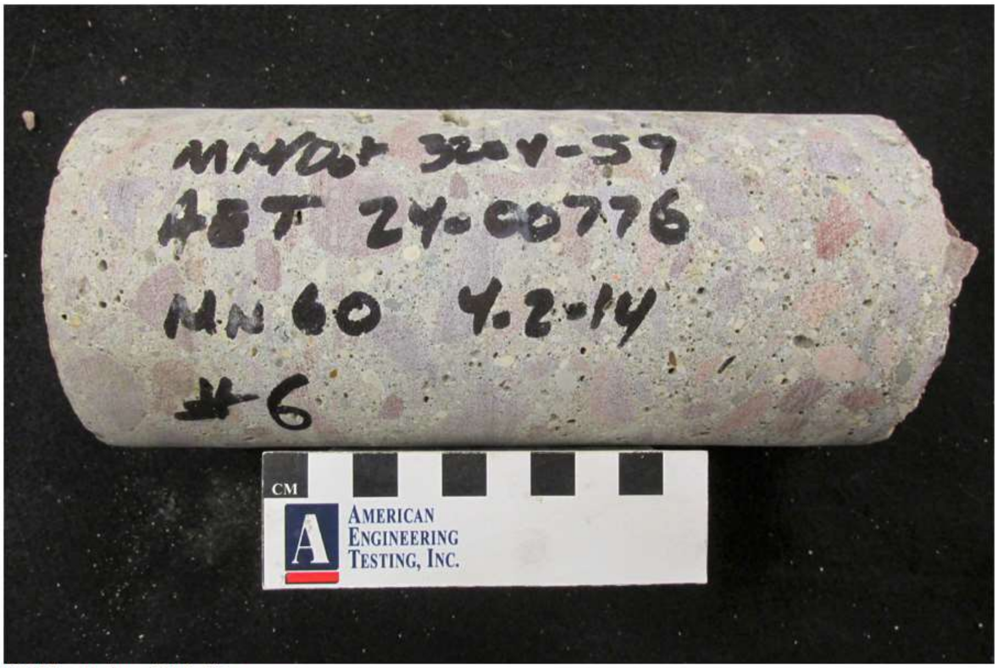


DESCRIPTION – Project 3204-59, core



DESCRIPTION – Project 3204-59, core



DESCRIPTION – Project 3204-59, core

Field Notes and Petrographic Reports for Project 3204-62, Core 1

Table A.31. Field notes for SP Number 3204-62, MN 60.

Core	Field Notes	GPS Coordinates
1	MN 60 WB South lane Brewster & Huron Lake	N43º 43’ 27.3”, W95º 25’ 56.4”
2		N43º 43’ 27.1”, W95º 25’ 56.1”
3		N43º 43’ 26.9”, W95º 25’ 57.1”
4		N43º 43’ 26.9”, W95º 25’ 57.3”
5		N43º 43’ 27.1”, W95º 25’ 56.7”
6		N43º 43’ 27.3”, W95º 25’ 56.6”

24-LAB-001 Petrographic Examination of Hardened Concrete
ASTM C856

Project No.	24-00776	Date:	June 24, 4014
Sample ID:	3204-62, #1	Performed by:	D. Hunt

I. General Observations

1. Sample Dimensions: Our analysis was performed on both lapped sides of a 230mm (9-1/16") x 143mm (5-5/8") x 35mm (1-3/8") thick section (in two pieces) and a 76mm (3") x 52mm (2") wide thin section that were sawcut and prepared from the original 143mm (5-5/8") diameter x 230mm (9-1/16") long core taken directly through a distressed sawcut joint. The thin section was located at between 35 mm and 115 mm depth in the core from the top surface; directly adjacent to the distressed joint surface.

2. Surface Conditions:
   Top: Fairly smooth, traffic worn and slightly "gouged" surface; exposing several, traffic worn, fine aggregate surfaces.
   Bottom: Rough, irregular, formed surface; placed on grade.

3. Reinforcement: None observed.

4. General Physical Conditions: The core was taken directly through a distressed pavement joint. A silicone joint sealant was observed well bonded to one side of the sawcut joint, only, between 1mm and 16mm depth from the top surface. The sealant was originally poorly bonded to the other side of the joint; with a little residual tooled meniscus remaining adhered to the sawcut surface. The joint was characterized by an approx. 4mm wide pilot sawcut, partially vertically scaled/spalled away, measurable to 68mm depth from the top surface, and an approx. 10mm wide reservoir cut to 27mm depth. The sawcut surface of the pilot cut was coated with a layer of pale brown debris. The resulting joint crack proceeded the depth of the core and passes around most coarse aggregate particles it encounters. Vertical scaling/spalling along the joint begins as shallow as approx. 55mm depth; with a signifcant loss of paste along a portion of the pilot cut between 55mm and 75mm. Up to approximately 15mm of paste loss occurs along the joint between 60mm and 110mm depth from the top surface. Thin paste loss with good residual interlock between the core halves occurs between 140mm and 230mm from the top surface. Areas of soft, friable paste were observed at between approximately 160mm and 195mm depth from the top surface; up to 1mm depth from the joint crack. In general, the widest loss of paste occurred between 60mm and 110mm depth from the top surface. This zone is characterized by several relatively "clean" and un-distressed coarse aggregates protruding from relatively clean concrete joint faces. Several sub-vertical microcracks (incipient spalling) were observed generally within the paste-only and within 3mm of the distressed joint surface between 77mm and 210mm depth from the top surface of the core. A few sub-vertical drying shrinkage microcracks proceeded up to 3mm depth from the top surface. A small, sub-vertically fractured section of concrete measuring approx. 19mm by 12mm was observed on the top surface of the core, adjacent to the joint and adhered to the silicone joint sealant. The fracture intersected the silicone joint sealant at approx. 6mm depth from the top surface. The coarse aggregate appeared sound. No evidence of ASR associated with the coarse aggregate was observed. A few alkali-silica "reacted" (ASR) shale fine aggregate particles were present in the core. The "reacted" shale particles exhibit internal cracking that propagates into the paste. ASR gel was observed partially filling an air void space.

   The fairly smooth top surface of the core exhibits significant traffic wear; topographic highs have been worn smooth with exposed fine aggregate particles exhibiting worn surfaces. The concrete was well consolidated, with a few consolidation voidspaces observed up to 10mm in diameter in the core. The concrete was purposefully air entrained and contains a well-distributed air void system considered freeze-thaw resistant under severe exposure conditions. Original air void parameters include a 4.6% entrained-sized void volume and a 0.005" spacing factor. Secondary ettringite fills numerous entrained sized voidspaces within 3mm of the distressed joint faces; below 65mm depth in the core. Void fillings decrease with distance from the joint faces.

II. Aggregate

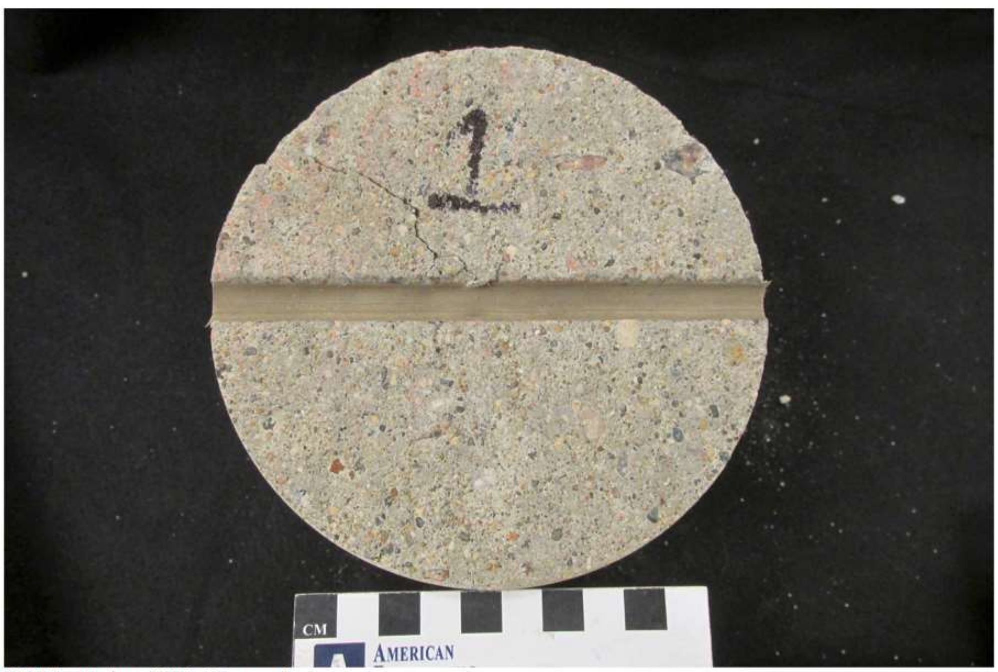
1. Coarse: 38mm (1-1/2") nominal sized crushed granite. The coarse aggregate appeared well graded and exhibited good overall distribution.

2. Fine: Natural quartz, feldspar, and lithic sand (granite, chert, carbonates, basalt, rhyolite, siltstone and shale.) The grains were mostly sub-rounded with many smaller sub-angular particles. The fine aggregate appeared fairly graded and exhibited good overall uniform distribution.

III. Cementitious Properties

1. Air Content:	5.5% total original air void.
2. Depth of carbonation:	Ranged from negligible up to 3mm depth from the top surface of the core; "spiking" up to 8mm depth along a paste/aggregate boundary and a cluster of air void spaces. Carbonation depth proceeding from the joint crack ranged from negligible up to 3mm.
3. Pozzolan presence:	Flyash and ground granulated blast furnace slag was observed.
4. Paste/aggregate bond:	
5. Paste color:	Similar to pale yellowish brown (Munsell® 10YR 6/2) to approx. 25mm depth from the top surface becoming mottled yellowish brown to medium bluish gray (Munsell® 5B 5/1) between 25mm and 140mm depth becoming bluish gray below 140mm depth.
6. Paste hardness:	Hard (Moh's 3.5-4) with a few soft areas of paste (Moh's <2) within 1mm of the joint crack between 160mm and 190mm depth from the top surface of the core.
7. Microcracking:	Several sub-vertical microcracks (incipient spalling) were observed generally within the paste-only and within 3mm of the distressed joint surface between 77mm and 210mm depth from the top surface of the core. A few sub-vertical drying shrinkage microcracks proceeded up to 3mm depth from the top surface. A small, sub-vertically fractured section of concrete measuring approx. 19mm by 12mm was observed on the top surface of the core, adhered to the silicone joint sealant. The fracture intersected the silicone joint sealant at approx. 6mm depth from the top surface.
8. Secondary deposits:	Secondary ettringite fills numerous entrained sized voidspaces within 3mm of the cracked joint; below 35mm depth from the top surface. Void fillings decrease with depth from the joint faces. Alkali silica reaction gel was observed partially filling an air void space.
9. w/cm:	Estimated at between 0. and 0. with approximately to % residual portland cement clinker particles, approximately to % residual slag particles and an amount of flyash visually consistent with a to % replacement of portland cement.
10. Cement hydration:	Alites: . Belites: .

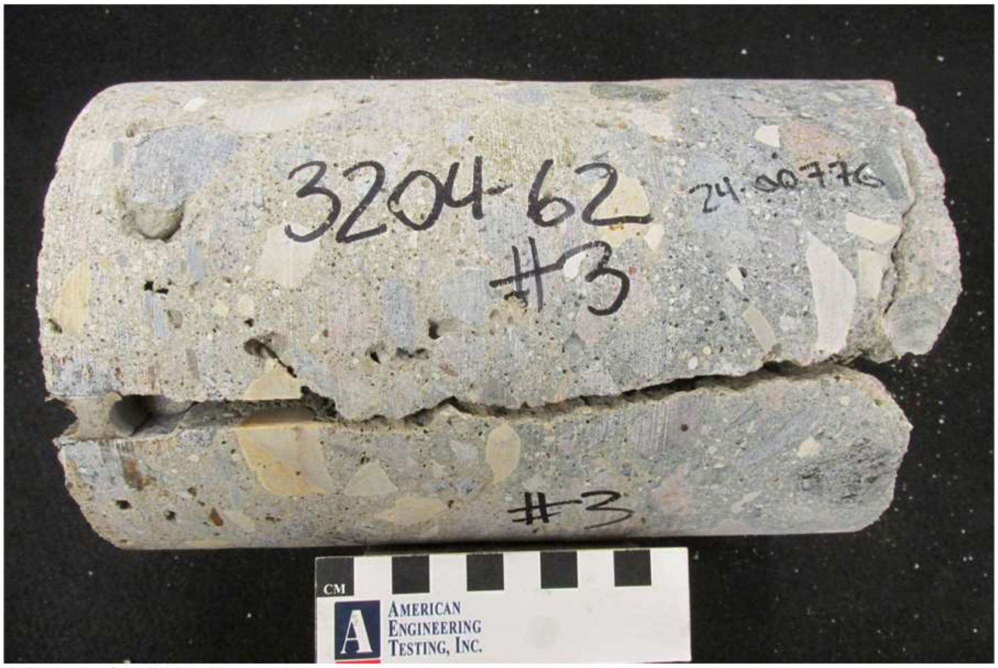
DESCRIPTION – Project 3204-62, core 1



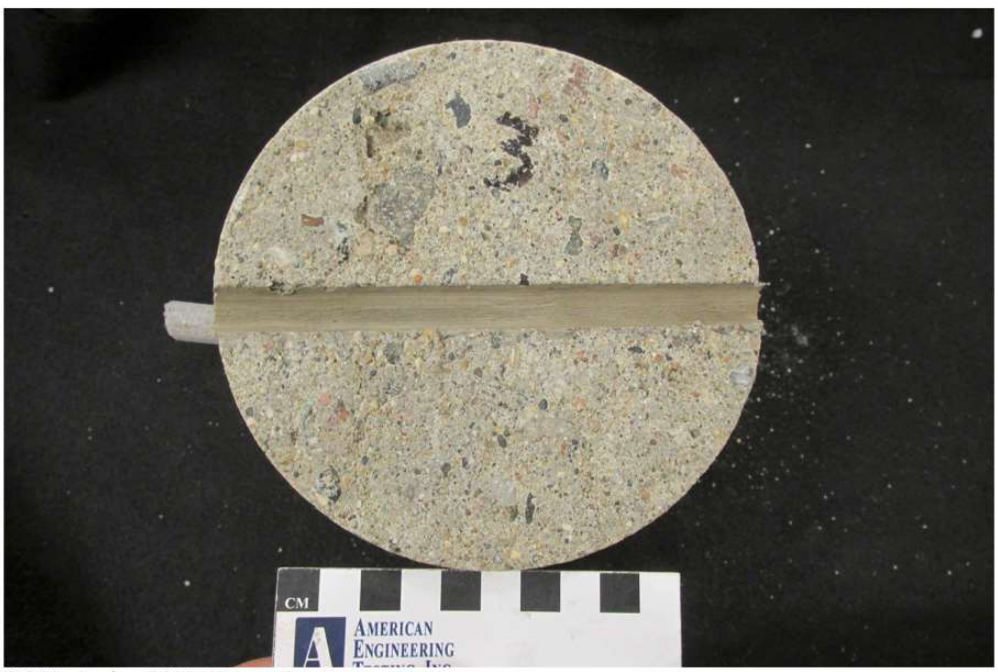
DESCRIPTION – Project 3204-62, core 1

DESCRIPTION – Project 3204-62, core 2

DESCRIPTION – Project 3204-62, core 2



DESCRIPTION – Project 3204-62, core 3



DESCRIPTION – Project 3204-62, core 3

Field Notes and Petrographic Reports for Project 4013-41, Core 1

Table A.32. Field notes for SP Number 4013-41, US-169.

Core	Field Notes	GPS Coordinates
C-1	US 169 WB South lane Worthington & Brewster	N44º 28’ 44.9”, W93º 54’ 53.7”
C-2		N44º 28’ 44.9”, W93º 54’ 53.1”
C-3		N44º 28’ 45.1”, W93º 54’ 53.4”
C-4		N44º 28’ 45.0”, W93º 54’ 52.6”
C-5		N44º 28’ 45.0”, W93º 54’ 53.0”
C-6		N44º 28 44.9”, W93º 54’ 53.6”

24-LAB-001 Petrographic Examination of Hardened Concrete
ASTM C856

Project No.	24-00776	Date:	June 23, 2014
Sample ID:	4013-41, 1	Performed by:	C. Braaten

I. General Observations

1. Sample Dimensions: Our analysis was performed on both lapped sides of a 289 mm (11-3/8") x 139 mm (5-1/2") x 39 mm (1-9/16") thick section (in two pieces) and a 76mm (3") x 52mm (2") wide thin section that were sawcut and prepared from the original 145 mm (5-11/16") diameter x 290 mm (11-7/16") long core taken directly through a distressed sawcut joint. The thin section was located at between 47 mm and 127 mm depth in the core from the top surface; directly adjacent to the distressed joint surface.

2. Surface Conditions:
   Top: Fairly rough, tined surface with traffic wear; exposing many traffic worn, fine and coarse aggregate surfaces.
   Bottom: Rough, irregular; spalled surface.

3. Reinforcement: None observed.

4. General Physical Conditions: The core was taken directly through a distressed pavement joint. A neoprene pavement seal was observed in the joint. The joint was characterized by an approx. 5 mm wide sawcut proceeding 60 mm (2-3/8") depth from the top surface and an approx. 10 mm wide reservoir cut to 34 mm (1-5/16") depth. Vertical scaling/spalling distress in the paste-only starts at as shallow as 34 mm depth in the sawcut joint surface and incorporates between a few mm and 15 mm of total concrete paste between the two sides of the joint crack. The joint plane is characterized by numerous relatively “clean” and un-distressed granite coarse aggregate protruding from the concrete. The widest loss of concrete (to 15 mm) occurs below 130 mm depth in the concrete from the top surface. The core does exhibit some residual interlock between the two halves. Sub-vertical microcracks (incipient spalling) were relatively rare in the intact paste. The coarse granite aggregate appeared sound. No evidence of ASR associated with the coarse aggregate was observed. No reaction rims were obvious. Internal, randomly oriented, empty micro-fractures appear to have been produced by the crushing procedure. Numerous alkali-silica reacted shale fine aggregate were present in the core.

   The fairly rough top surface of the core exhibits significant traffic wear; topographic highs have been worn down with exposed fine aggregate particles exhibiting worn surfaces. The concrete was well consolidated, with several consolidation voidspaces observed up to 20 mm in diameter in the core. The concrete was purposefully air entrained and contains a well-distributed air void system considered freeze-thaw resistant under severe exposure conditions. Original air void parameters include a 7.0% entrained-sized void volume and a 0.002" spacing factor. Secondary ettringite fills numerous entrained sized voidspaces within 5mm of the distressed joint faces; below 5 mm depth in the core. Void fillings decrease with depth from the joint faces.

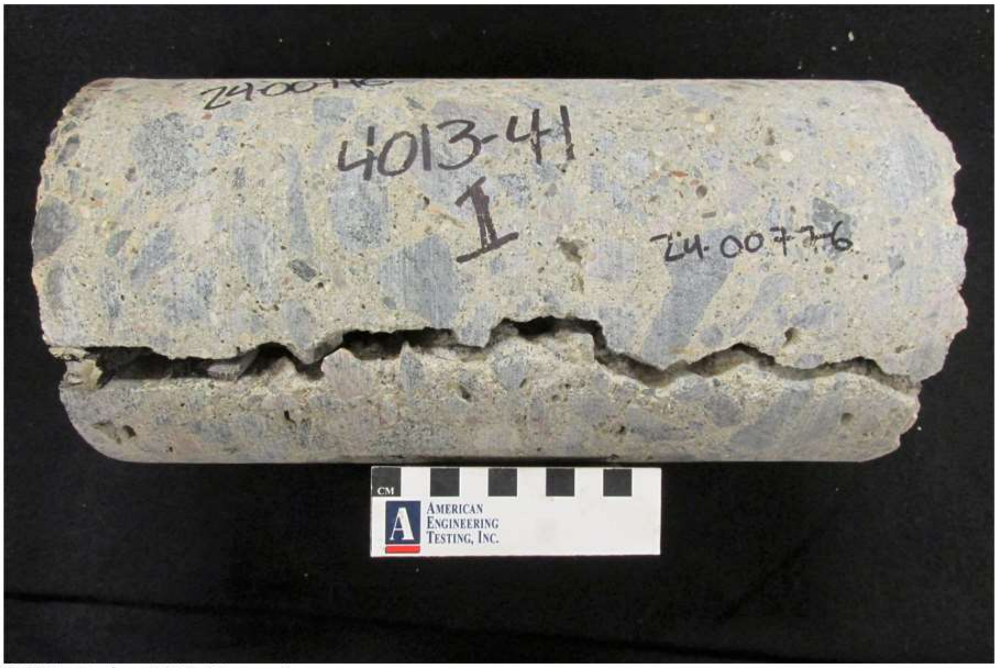
II. Aggregate

1. Coarse: 38 mm (1-1/2") nominal sized crushed granite. The coarse aggregate appeared well graded and exhibited good overall distribution.

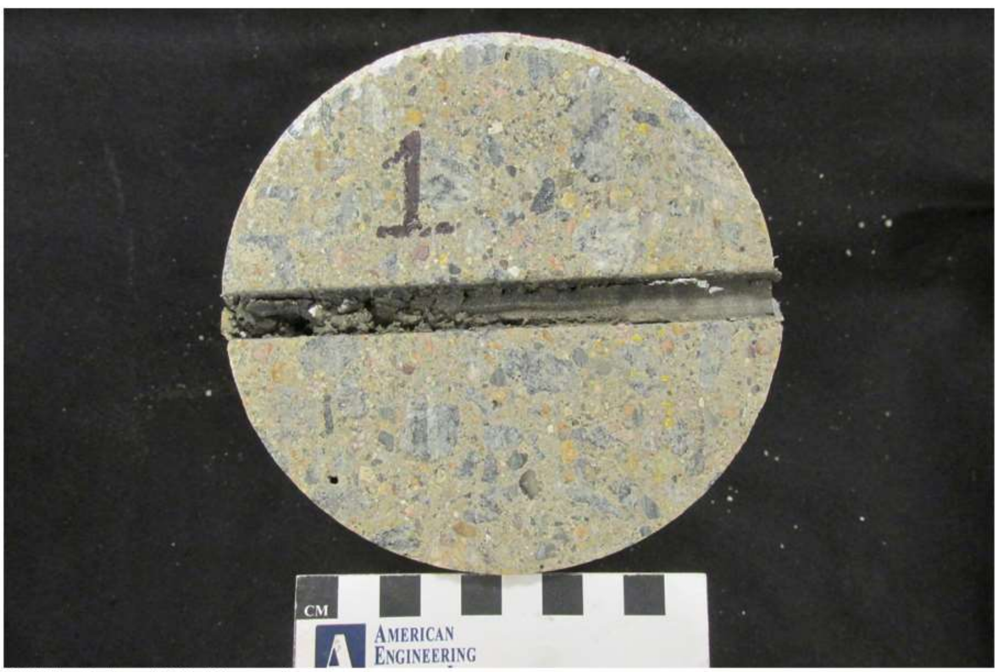
2. Fine: Natural quartz, feldspar, and lithic sand (granite, chert, carbonates, basalt, rhyolite, siltstone and shale.) The grains were mostly sub-rounded with many smaller sub-angular particles. The fine aggregate appeared fairly graded and exhibited good overall uniform distribution.

III. Cementitious Properties

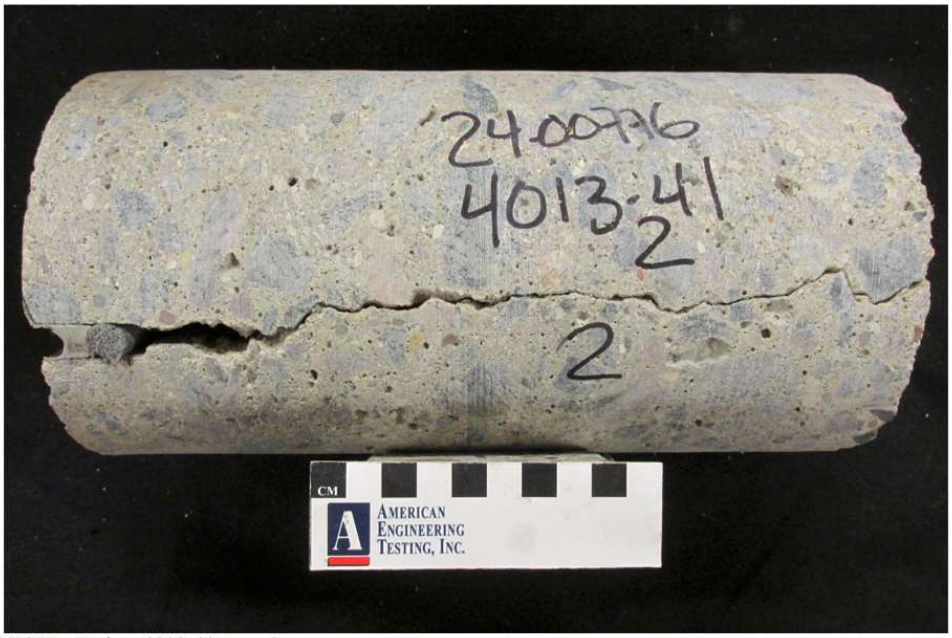
1. Air Content:	9.6% total original air void.
2. Depth of carbonation:	Ranged from negligible up to 2 mm depth from the top surface of the core; "spiking" up to 5 mm along the distressed pavement joint. Carbonation proceeding from the joint crack ranged from negligible up to 5mm.
3. Pozzolan presence:	Flyash was observed.
4. Paste/aggregate bond:	
5. Paste color:	Similar to light olive gray (Munsell® 5Y 6/1) with several areas that are similar to very pale orange (Munsell® 10YR 8/2).
6. Paste hardness:	Moderately soft (Mohs 2.5 - 3).
7. Microcracking:	Sub-vertical microcracks (incipient spalling) were relatively rare in the intact paste.
8. Secondary deposits:	Secondary ettringite fills numerous entrained sized voidspaces within 5mm of the distressed joint faces; below 5 mm depth in the core. Void fillings decrease with depth from the joint faces.
9. w/cm:	Estimated at between 0. and 0. with approximately to % residual portland cement clinker particles and an amount of flyash visually consistent with a to % replacement of portland cement.
10. Cement hydration:	Alites: . Belites: .



DESCRIPTION – Project 4013-41, core 1



DESCRIPTION – Project 4013-41, core 1



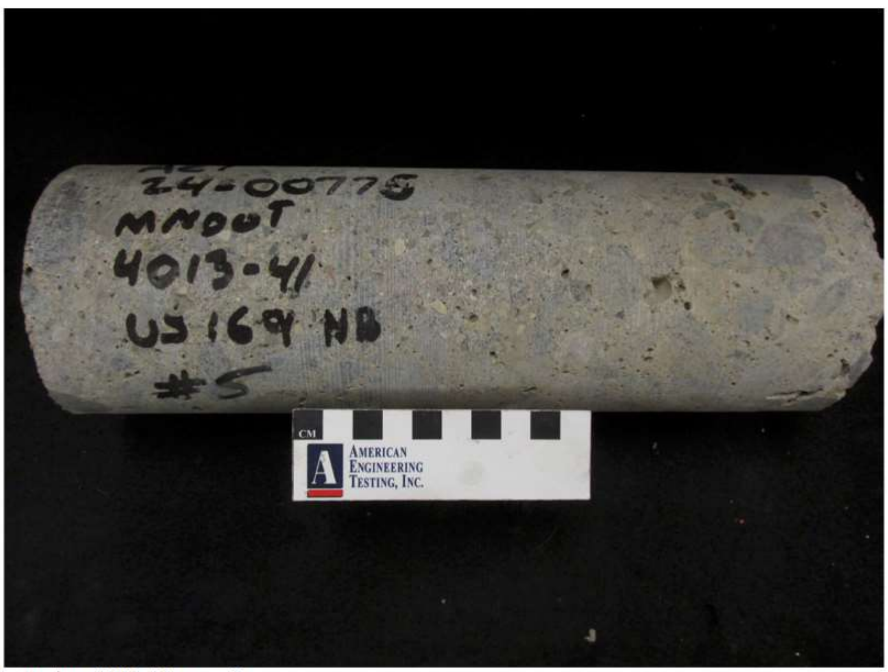
DESCRIPTION – Project 4013-41, core 2

DESCRIPTION – Project 4013-41, core 2

DESCRIPTION – Project 4013-41, core 3

DESCRIPTION – Project 4013-41, core 3

DESCRIPTION – Project 4013-41, core 4



DESCRIPTION – Project 4013-41, core 5

DESCRIPTION – Project 4013-41, core 6

Field Notes and Petrographic Reports for Project 5306-37, Core 3

Table A.33. Field notes for SP Number 5306-37, MN 60.

Core	Field Notes	GPS Coordinates
1	MN 60 WB South lane Worthington & Brewster	N43º 39’ 55.2”, W95º 31’ 23.2”
2		N43º 39’ 55”, W95º 31’ 23.5”
3		N43º 39’ 54.8”, W95º 31’ 23.8”
4		N43º 39’ 54.9”, W95º 31’ 23.6”
5		N43º 39’ 55”, W95º 31’ 23.6”
6		N43º 39’ 55.1”, W95º 31’ 23.3”

24-LAB-001 Petrographic Examination of Hardened Concrete
ASTM C856

Project No.	24-00776	Date:	June 17, 2014
Sample ID:	5306-37, #3	Performed by:	C. Braaten

I. General Observations

1. Sample Dimensions: The core was taken directly through a sealed, sawcut and cracked pavement joint with paste loss at depth in the joint. Our analysis was performed on both lapped sides of a cross section (two pieces) of core sawcut "normal" to a sawcut and cracked joint measuring 225 mm (8-7/8") x 137 mm (5-3/8") x 34 mm (1-5/16") thick and one 76 mm (3") x 52 mm (2") wide thin section that was sawcut and prepared from the original 145 mm (5-11/16") diameter x 232 mm (9-1/8") long core. The thin section was located between 52 mm and 132 mm depth from the top surface; in cross section and along the sawcut and cracked and distressed portions of the joint.

2. Surface Conditions:
   Top: Rough mortar eroded surface; with several exposed coarse aggregate surfaces. Two indentations, approximately 70 mm long x 3 mm wide x 2 mm deep, parallel to one another and parallel to the joint were observed on the top surface.
   Bottom: Rough, irregular; spalled surface.

3. Reinforcement: None observed.

4. General Physical Conditions: The core was taken through a sealed pavement joint. The light gray silicone joint sealant was mostly de-bonded from both sides of the sawcut joint. Below the silicone joint sealant was a 12 mm (1/2") foam backer rod. The joint was characterized by an approx. 5 mm wide sawcut proceeding 48 mm (1-7/8") depth from the top surface and an approx. 10 mm wide reservoir cut to 29 mm (1-1/8") depth. Vertical scaling/spalling distress in the paste-only starts at as shallow as 29 mm depth in the sawcut joint surface and incorporates between a few mm and 21 mm of total concrete paste between the two sides of the joint crack. The joint plane is characterized by numerous relatively "clean" and un-distressed quartzite coarse aggregate protruding from the concrete. The widest loss of concrete (to 21 mm) occurs below 65 mm depth in the concrete from the top surface. The core does exhibit some residual interlock between the two halves. Sub-vertical microcracks (incipient spalling) were relatively rare in the intact paste. One sub-horizontal macrocrack occurs at approx. 115 mm (4-1/2") depth from the top surface, proceeds from the joint surface, sub-perpendicularly, to the cored edge, and proceeds around and through coarse aggregate particles. This macrocrack tapers to a microcrack on the opposite side of the distressed joint surface and proceeds approximately 75 mm from the joint surface into the paste. The coarse quartzite aggregate appeared sound. Evidence of minor ASR associated with the coarse aggregate was observed. No reaction rims were obvious. Internal, randomly oriented, empty micro-fractures appear to have been produced by the crushing procedure. Numerous alkali-silica reacted shale fine aggregate were present in the core.

   The rough screeded top surface of the core exhibits moderate mortar erosion/traffic wear; exposing several coarse aggregate surfaces. The concrete was fairly well consolidated, with only a few entrapped voidspaces observed in excess of 12 mm in diameter in the mid-section of the core. The concrete was purposefully air entrained and originally contained a well-distributed air void system considered freeze-thaw resistant under severe exposure conditions. Original air void parameters include a 4.7% entrained-sized void volume and a 0.003" spacing factor. Secondary ettringite, with some portlandite, fills many of the smaller entrained sized voidspaces within approx. 15 mm of the distressed joint surface and approximately 25 mm from the bottom surface of the core. Void fillings decrease with depth from the joint plane. Actual measured air void parameters, which excludes the ettringite void fillings, in a band between approx. 0mm and at least 12mm (0-0.5") depth from the distressed joint surface (below 105mm depth in the core), are 2.8% entrained volume and a 0.011" spacing factor.

II. Aggregate

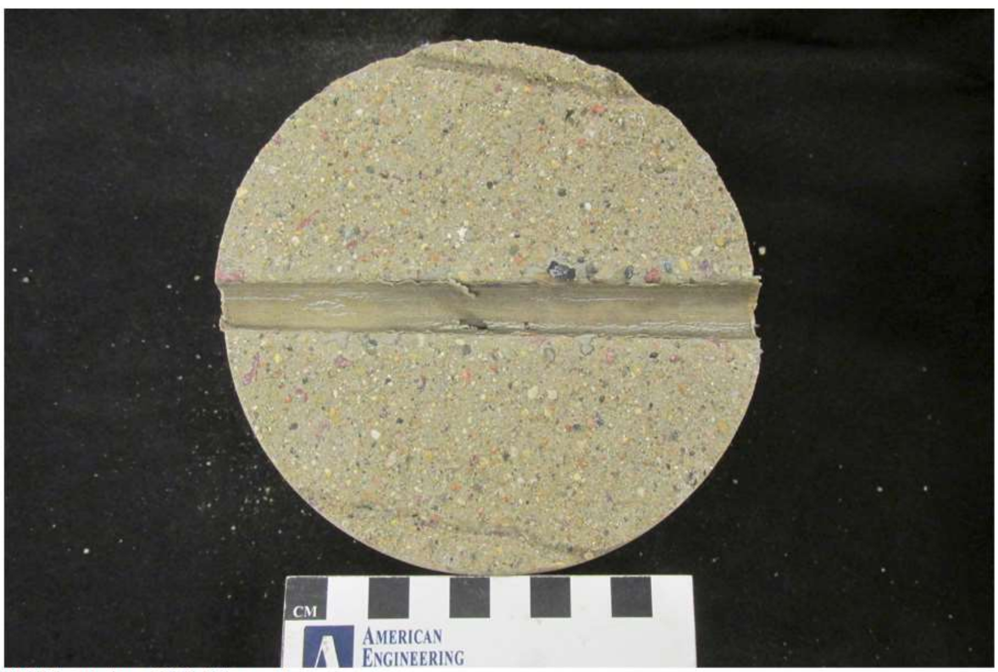
1. Coarse: 37 mm (1-1/2") nominal sized crushed quartzite. The coarse aggregate appeared well graded and exhibited good overall distribution.

2. Fine: Natural quartz, feldspar, and lithic sand. The grains were mostly sub-rounded with many smaller sub-angular particles. The fine aggregate appeared fairly graded and exhibited good overall uniform distribution.

III. Cementitious Properties

1. Air Content:	6.3% total original air content. 4.0% total "actual" un-filled air between 0mm and 12mm depth from the distressed joint (below 105mm depth).
2. Depth of carbonation:	Ranged from negligible up to 7 mm depth from the top surface of the core; along sub-vertical distressed joint. Ranged from negligible up to 2 mm depth from the distressed joint surface. Ranged from negligible up to 2 mm depth from the bottom surface of the core.
3. Paste/aggregate bond:	Fair.
4. Paste color:	Mottled light olive gray to Medium Gray (Munsell® 5Y 6/1 to N6).
6. Paste hardness:	Moderately soft (Mohs ≈ 2.5 - 3).
7. Microcracking:	One sub-horizontal macrocrack occurs at approx. 115 mm (4-1/2") depth from the top surface, proceeds from the joint surface, sub-perpendicularly, to the cored edge, and proceeds around and through coarse aggregate particles. This macrocrack tapers to a microcrack on the opposite side of the distressed joint surface and proceeds approximately 75 mm from the joint surface into the paste.
8. Secondary deposits:	Evidence of minor ASR associated with the coarse aggregate was observed. White, generally acicular grown ettringite along with some clear platelets of portlandite fills many of the smaller entrained sized void spaces within approx. 15 mm of the distressed joint surface and approximately 25 mm from the bottom surface of the core. Void fillings become less abundant with distance from the joint.
9. w/cm:	Estimated at between 0.43 and 0.48 with approximately 3 to 5% residual portland cement clinker particles and an amount of flyash visually consistent with a 20 to 30% replacement of portland cement.
10. Cement hydration:	Alites: Mostly fully Belites: Well

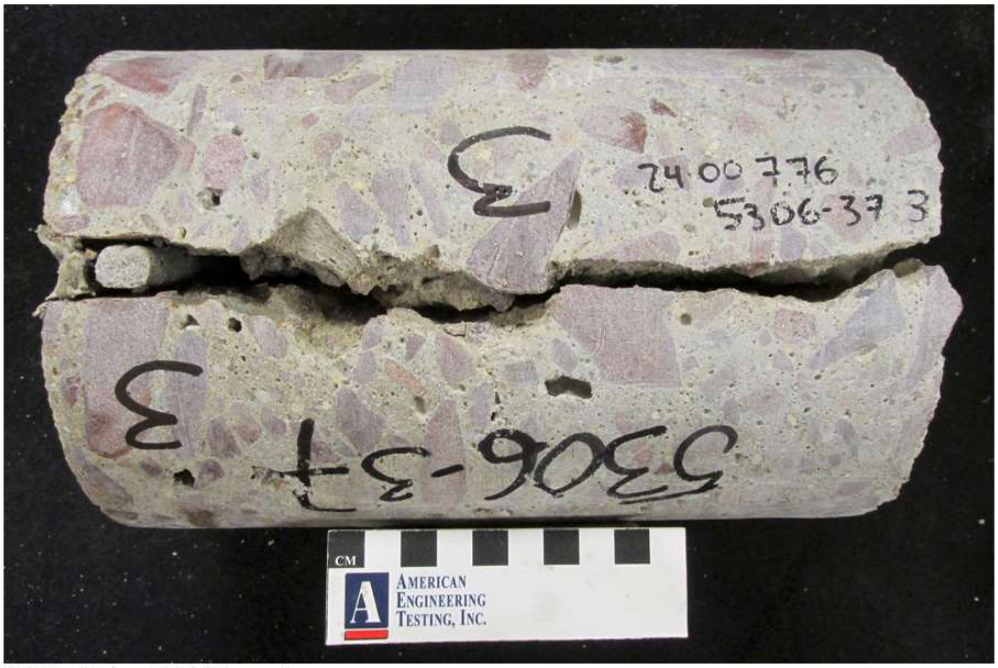
DESCRIPTION – Project 5306-37, core 1



DESCRIPTION – Project 5306-37, core 1

DESCRIPTION – Project 5306-37, core 2

DESCRIPTION – Project 5306-37, core 2



DESCRIPTION – Project 5306-37, core 3

DESCRIPTION – Project 5306-37, core 3

DESCRIPTION – Project 5306-37, core 4

DESCRIPTION – Project 5306-37, core 5

DESCRIPTION – Project 5306-37, core 6

Field Notes and Petrographic Reports for Project 6507-04, Core 22

Table A.34. Field notes for SP Number 6507-04, MN-19.

Core	Location from Joint	RP	Station	Direction	Lane	Offset	Thickness
20	1.0'	93.430	1130	EB		7.0'	8.000"
21	3.0'	93.430	1130	EB		7.0'	8.000"
22	ON	94.860	1205	EB		7.0'	8.000"
23	1.0'	94.860	1205	EB		7.0'	8.000"
24	3.0'	94.860	1205	EB		7.0'	8.000"
26	1.0'	69.5	1290	EB		7.0'	8.000"
27	3.0'	69.470	1290	EB		7.0'	8.000"

00 LAB 001 Petrographic Examination of Hardened Concrete
ASTM: C-856

Project No.	28-00337	Date:	February 29, 2012
Sample ID:	22, SP6507-04	Performed by:	D. Hunt, G. Moulzolf

I. General Observations

1. Sample Dimensions: Our analysis was performed on both lapped sides of a 196mm (7 ¾") x 92mm (3 ⅝") x 34mm (1 ⅜") thick section (in two pieces), a 197mm (7 ¾")" x 101mm (4") x 32mm (1 ¼") thick section (in two pieces), and two 76mm (3") x 52mm (2") wide thin sections that were sawcut and prepared from the original 101mm (4") diameter x 196mm (7 ¾") long core taken directly through a distressed sawcut joint. The thin sections were located at between 0mm and 75mm depth and 77mm and 152mm depth in the core from the top surface; directly adjacent to the distressed joint surface.

2. Surface Conditions:
   Top: Rough screeded, tined, and traffic worn surface; exposing many fine aggregate and a few coarse aggregate surfaces.
   Bottom: Rough, irregular, formed surface; placed on a natural aggregate sub-base.

3. Reinforcement: None observed.

4. General Physical Conditions: The core was taken directly through a severely distressed pavement joint. One side of the core exhibits evidence of the first pilot sawcut to 62mm depth. A second approx. 11mm wide "reservoir" cut is evident to 33mm depth. Vertical scaling/spalling and mortar erosion exposes coarse and fine aggregates along much of the sawcut. An apparently originally well bonded silicon joint sealant was present; placed upon a foam backer rod. The joint sealant was loosened along sliver spalling within the concrete joint edges intermittently along both sides of the joint. The resulting joint crack below the sawcuts appears to have splayed at a low angle into two crack planes. Apparent raveling of this thin section of concrete during coring has left an up to approx. 30mm (1 1/4") wide void in the core sample between approx. 65mm and 165mm depth from the top surface.

   The rough screeded top surface of the core exhibits moderate mortar erosion; exposing several coarse aggregate surfaces. The concrete was well consolidated, with no voidspaces observed in excess of 12mm in diameter in the core. The concrete was purposefully air entrained and contains a well-distributed air void system considered freeze-thaw resistant under severe exposure conditions. Original air void parameters include a 5.5% entrained-sized void volume and a 0.006" spacing factor. Secondary ettringite, with some portlandite, fills many of the smaller entrained sized voidspaces throughout the depth of the core apart from the partly carbonated top approx. 7mm. Void fillings decrease with depth from the vertical joint crack surfaces. Actual air void parameters, excluding the ettringite void fillings in a band between approx. 0mm and 20mm (¾") depth from the distressed joint surface are 4.2% entrained air volume and a 0.007" spacing factor. An anomalous, apparent recycled and non – air entrained concrete aggregate particle was observed at depth in the core.

II. Aggregate

1. Coarse: 25mm (1") nominal sized crushed granitic gneiss. The coarse aggregate appeared well graded and exhibited good overall distribution.

2. Fine: Natural quartz, feldspar, and lithic sand. The grains were mostly sub-rounded with many smaller sub-angular particles. The fine aggregate appeared fairly graded and exhibited good overall uniform distribution.

00 LAB 001 Petrographic Examination of Hardened Concrete
ASTM: C-856

Project No.	28-00337	Date:	February 29, 2012
Sample ID:	22, SP6507-04	Performed by:	D. Hunt, G. Moulzolf

I. General Observations

1. Sample Dimensions: Our analysis was performed on both lapped sides of a 196mm (7 ¾") x 92mm (3 ⅝") x 34mm (1 ⅜") thick section (in two pieces), a 197mm (7 ¾")" x 101mm (4") x 32mm (1 ¼") thick section (in two pieces), and two 76mm (3") x 52mm (2") wide thin sections that were sawcut and prepared from the original 101mm (4") diameter x 196mm (7 ¾") long core taken directly through a distressed sawcut joint. The thin sections were located at between 0mm and 75mm depth and 77mm and 152mm depth in the core from the top surface; directly adjacent to the distressed joint surface.

2. Surface Conditions:
   Top: Rough screeded, tined, and traffic worn surface; exposing many fine aggregate and a few coarse aggregate surfaces.
   Bottom: Rough, irregular, formed surface; placed on a natural aggregate sub-base.

3. Reinforcement: None observed.

4. General Physical Conditions: The core was taken directly through a severely distressed pavement joint. One side of the core exhibits evidence of the first pilot sawcut to 62mm depth. A second approx. 11mm wide "reservoir" cut is evident to 33mm depth. Vertical scaling/spalling and mortar erosion exposes coarse and fine aggregates along much of the sawcut. An apparently originally well bonded silicon joint sealant was present; placed upon a foam backer rod. The joint sealant was loosened along sliver spalling within the concrete joint edges intermittently along both sides of the joint. The resulting joint crack below the sawcuts appears to have splayed at a low angle into two crack planes. Apparent raveling of this thin section of concrete during coring has left an up to approx. 30mm (1 1/4") wide void in the core sample between approx. 65mm and 165mm depth from the top surface.

   The rough screeded top surface of the core exhibits moderate mortar erosion; exposing several coarse aggregate surfaces. The concrete was well consolidated, with no voidspaces observed in excess of 12mm in diameter in the core. The concrete was purposefully air entrained and contains a well-distributed air void system considered freeze-thaw resistant under severe exposure conditions. Original air void parameters include a 5.5% entrained-sized void volume and a 0.006" spacing factor. Secondary ettringite, with some portlandite, fills many of the smaller entrained sized voidspaces throughout the depth of the core apart from the partly carbonated top approx. 7mm. Void fillings decrease with depth from the vertical joint crack surfaces. Actual air void parameters, excluding the ettringite void fillings in a band between approx. 0mm and 20mm (¾") depth from the distressed joint surface are 4.2% entrained air volume and a 0.007" spacing factor. An anomalous, apparent recycled and non – air entrained concrete aggregate particle was observed at depth in the core.

II. Aggregate

1. Coarse: 25mm (1") nominal sized crushed granitic gneiss. The coarse aggregate appeared well graded and exhibited good overall distribution.

2. Fine: Natural quartz, feldspar, and lithic sand. The grains were mostly sub-rounded with many smaller sub-angular particles. The fine aggregate appeared fairly graded and exhibited good overall uniform distribution.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 1

PHOTO:
67

SAMPLE ID: 6507-04, 22 **DESCRIPTION:** Overall view of the jointed core utilized for petrographic analysis. The top surface is left. Note "tunneling" distress at base of sawcut.

PHOTO:
68

SAMPLE ID: 6507-04, 22 **DESCRIPTION:** Top surface of the core exhibits silicone-sealed sawcut control joint.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 1

PHOTO:
69

SAMPLE ID: 6507-04, 23 **DESCRIPTION:** Overall view of the mid-panel core utilized for petrographic analysis. The top surface is left.

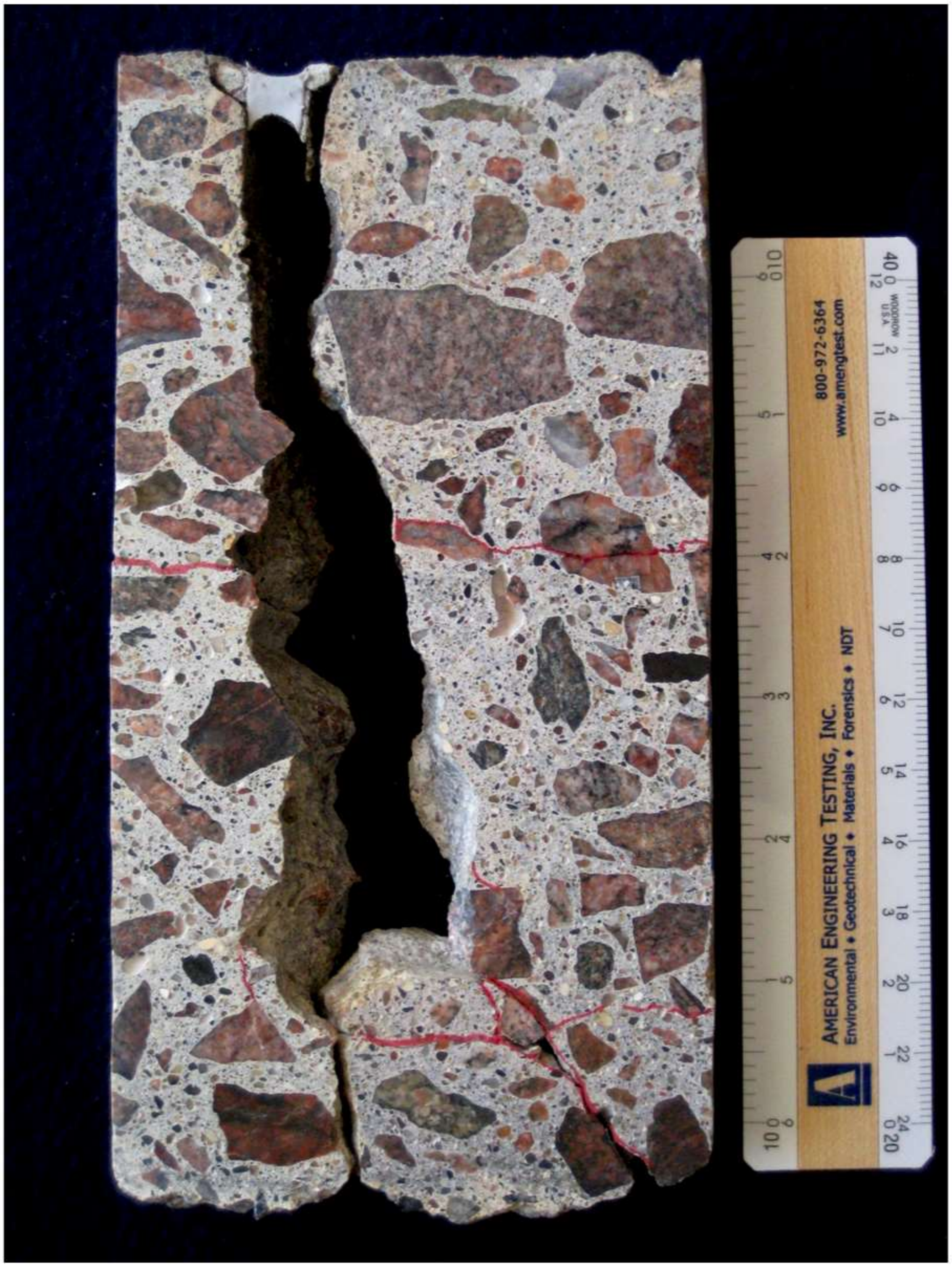
PHOTO:
70

SAMPLE ID: 6507-04, 24 **DESCRIPTION:** Overall view of the mid-panel core utilized for petrographic analysis. The top surface is left.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 1

PHOTO:
94



SAMPLE ID: 6507-04, 22 **DESCRIPTION:** Sawcut and lapped cross section of core. The silicone sealant was apparently well bonded to both sides of the now sliver-spalled joint. A sub-horizontal fracture and microcracks are mapped in red ink. Mass loss between the two sections appears to have been raveling of a splayed joint crack and not freeze-thaw.

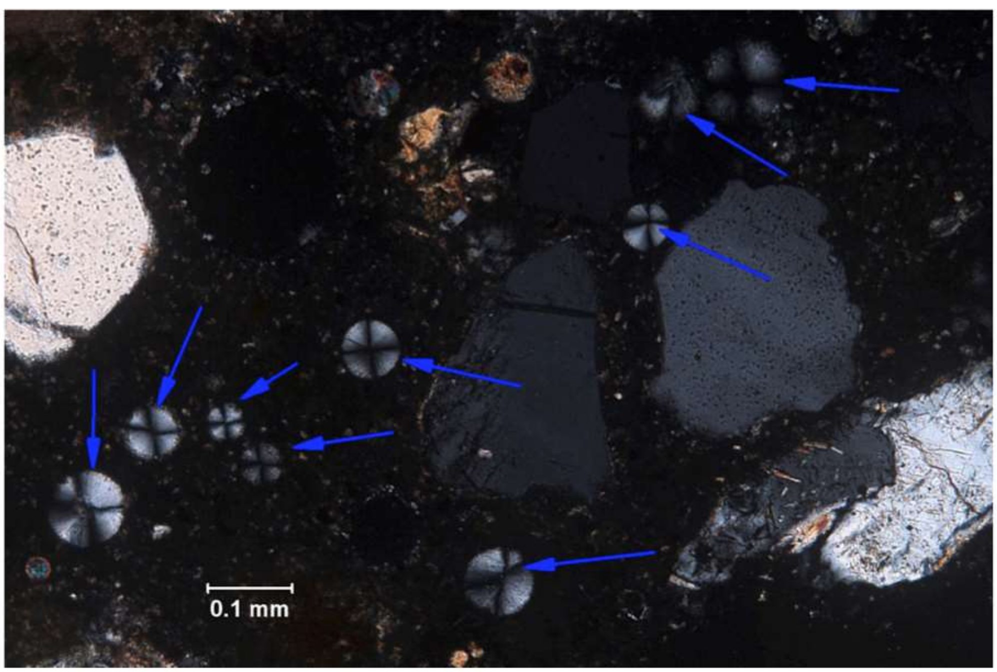
AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 1

PHOTO:
148

SAMPLE ID: 6507-04, 22 **DESCRIPTION:** The top surface of the core exhibits significant traffic wear and/or mortar erosion.
MAG: 5x

PHOTO:
149



SAMPLE ID: 6507-04, 22 **DESCRIPTION:** Fine entrained-sized air void spaces adjacent to the joint crack plane are filled with secondary ettringite (arrows); in thin section under cross polarized light.
MAG: 100x

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 1

PHOTO:
69

SAMPLE ID: 6507-04, 23 **DESCRIPTION:** Overall view of the mid-panel core utilized for petrographic analysis. The top surface is left.

PHOTO:
70

SAMPLE ID: 6507-04, 24 **DESCRIPTION:** Overall view of the mid-panel core utilized for petrographic analysis. The top surface is left.

Field Notes and Petrographic Reports for Project 7204-13, Core 28

Table A.35. Field notes for SP Number 7204-13, MN-19.

Core	Location from Joint	RP	Station	Direction	Lane	Offset	Thickness
28	ON	104.426	1710	EB		7.0'	7.500"
29	1.0'	104.426	1710	EB		7.0'	7.500"
30	3.0'	104.426	1710	EB		7.0'	7.500"
32	1.0'	106.139	1800	EB		7.0'	8.000"
33	3.0'	106.139	1800	EB		7.0'	8.000"
35	1.0'	108.035	1900	EB		7.0'	8.000"
36	3.0'	108.035	1900	EB		7.0'	8.000"

00 LAB 001 Petrographic Examination of Hardened Concrete
ASTM: C-856

Project No.	28-00337	Date:	January 31, 2012
Sample ID:	28, SP7204-13	Performed by:	G. Moulzolf

I. General Observations

1. Sample Dimensions: The core was taken directly through a sealed, sawcut and cracked pavement joint with paste loss at depth in the joint. Our analysis was performed on both lapped sides of a cross section (two pieces) of core sawcut "normal" to a sawcut and cracked joint measuring 190mm (7 ½") x 100mm (4") x 25mm (1") thick, a 185mm (7 ¼") x 96mm (3 ¾") x 42mm (1 ⅝") thick section (in two pieces), and two 76mm (3") x 52mm (2") wide thin sections that were sawcut and prepared from the original 100mm (4") diameter x 190mm (7 ½") long core. The thin sections were located between 23mm and 100mm depth from the top surface and 100mm and 173mm depth in the core; in cross section and along the sawcut and cracked and distressed portions of the joint.

2. Surface Conditions:
Top: Rough mortar eroded surface; with several exposed coarse aggregate surfaces.
Bottom: Rough, irregular, spalled surface.

3. Reinforcement: None observed.

4. General Physical Conditions: The core was taken through a sealed pavement joint. The light gray silicone joint sealant was mostly de-bonded from both sides of the sawcut joint. The joint was characterized by an approx. 4mm wide sawcut proceeding 63mm (2 ½") depth from the top surface and an approx. 8mm wide reservoir cut to 36mm (1 ⅜") depth. Vertical scaling/spalling distress in the paste-only starts at as shallow as 37mm depth in the sawcut joint surface and incorporates between a few mm and 19mm of total concrete paste between the two sides of the joint crack. The joint plane is characterized by numerous relatively "clean" and un-distressed quartzite coarse aggregate protruding from the concrete. The widest loss of concrete (to 19mm) occurs below 75mm depth in the concrete from the top surface. It is also apparent that there was loss of concrete paste and aggregates at the bottom surface. The core does exhibit some residual interlock between the two halves. Sub-vertical microcracks (incipient spalling) were relatively rare in the intact paste. Several relatively fine sub-horizontal microcracks occur at approx. 58mm, 91mm, 97mm, 130mm, and 150mm depth from the top surface on either side of the joint; proceeding through the paste only. The coarse quartzite aggregate appeared sound. No evidence of ASR associated with the coarse aggregate was observed. No reaction rims were obvious. Internal, randomly oriented, empty micro-fractures appear to have been produced by the crushing procedure. Numerous alkali-silica reacted shale fine aggregate were present in the core.

   The rough screeded top surface of the core exhibits moderate mortar erosion/traffic wear; exposing several coarse aggregate surfaces. The concrete was fairly well consolidated, with only a few entrapped voidspace observed in excess of 12mm in diameter in the mid-section of the core. The concrete was purposefully air entrained and originally contained a well-distributed air void system considered freeze-thaw resistant under severe exposure conditions. Original air void parameters include a 4.2% entrained-sized void volume and a 0.007" spacing factor. Secondary ettringite, with some portlandite, fills many of the smaller entrained sized voidspaces within approx. 12mm of the distressed joint surface and bottom surface of the core. Void fillings decrease with depth from the joint plane. Actual measured air void parameters, which excludes the ettringite void fillings, in a band between approx. 0mm and at least 12mm (0-0.5") depth from the distressed joint surface (below 105mm depth in the core), are 2.8% entrained volume and a 0.011" spacing factor.

II. Aggregate

1. Coarse: 37mm (1 ½") nominal sized crushed quartzite. The coarse aggregate appeared well graded and exhibited good overall distribution.

2. Fine: Natural quartz, feldspar, and lithic sand. The grains were mostly sub-rounded with many smaller sub-angular particles. The fine aggregate appeared fairly graded and exhibited good overall uniform distribution.

III. Cementitious Properties

1. Air Content:	5.3% total original air content. 4.0% total "actual" un-filled air between 0mm and 12mm depth from the distressed joint (below 105mm depth).
2. Depth of carbonation:	Ranged from 2mm up to 9mm depth from the top surface of the core; along sub-vertical drying shrinkage microcracking. Ranged from 1mm to 4mm depth from the distressed joint surface.
3. Pozzolan presence:	Flyash was observed.
4. Paste/aggregate bond:	Fair.
5. Paste color:	Mottled Medium Light Gray (Munsell® N6) to Medium Gray (N5).
6. Paste hardness:	Moderately hard (Moh's 3)
7. Microcracking:	A single sub-vertical microcrack (incipient spalling) was observed along a paste-crushed quartzite boundary and within 5mm of the distressed joint surface between 76mm and 86mm depth from the top surface of the core. A few fine, sub-vertical drying shrinkage microcracks proceed up to 10mm depth from the top surface. Fine sub-horizontal microcracking, mostly proceeding the width of the core half; occurs at approx. 58mm, 91mm, 97mm, 130mm, and 150mm from the top surface on either side of the joint. The microcracks proceed through the paste-only.
8. Secondary deposits:	White, generally acicular grown ettringite along with some clear platelets of portlandite fills most of the finer entrained sized air voids between the distressed joint surface and approx. 12mm depth into the core. Void fillings become less abundant with distance from the joint. Also, ettringite partly fills some of the sub-horizontal microcracking.
9. w/cm:	Estimated at between 0.43 and 0.48 with approximately 3 to 5% residual portland cement clinker particles and an amount of flyash visually consistent with a 20 to 30% replacement of portland cement.
10. Cement hydration:	Alites: Mostly fully. Belites: Well.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 1

PHOTO:
71

SAMPLE ID: 7204-13, 28 **DESCRIPTION:** Overall view of the jointed core utilized for petrographic analysis. The top surface is left. Note loss of some concrete mass along the length of the joint.

PHOTO:
72

SAMPLE ID: 7204-13, 28 **DESCRIPTION:** Mortar-eroded top surface of the core exhibits a sawcut and silicone sealed joint.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 1

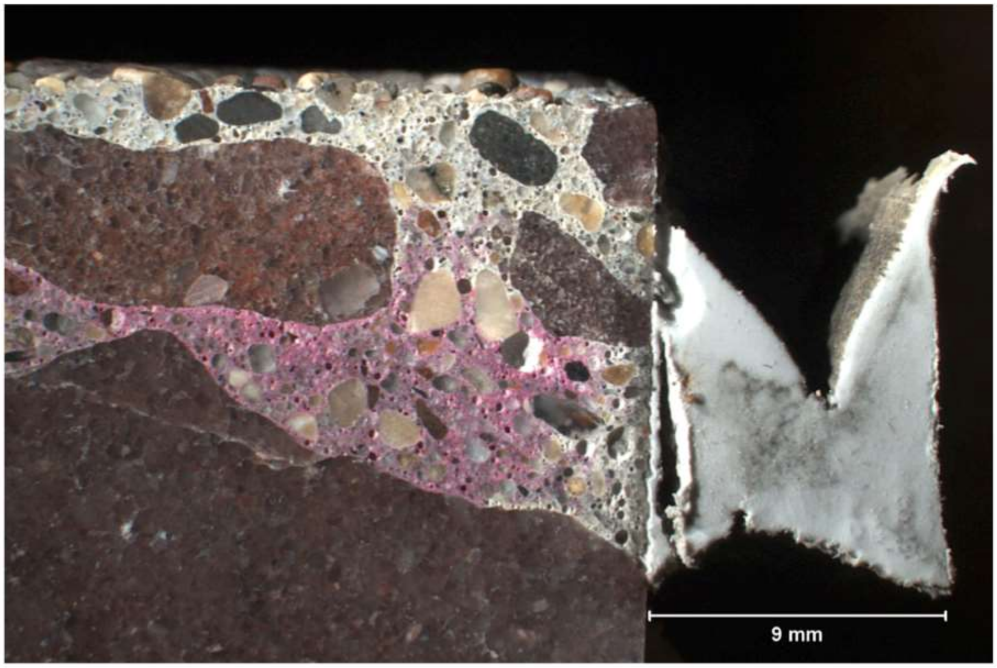
PHOTO:
95

SAMPLE ID: 7204-13, 28 **DESCRIPTION:** Sawcut and lapped cross section of core. The silicone sealant was mostly de-bonded from both sides of the joint. Sub-horizontal microcracks are mapped in red ink. Mass loss of up to 19mm of concrete paste occurs along the length of the joint crack.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

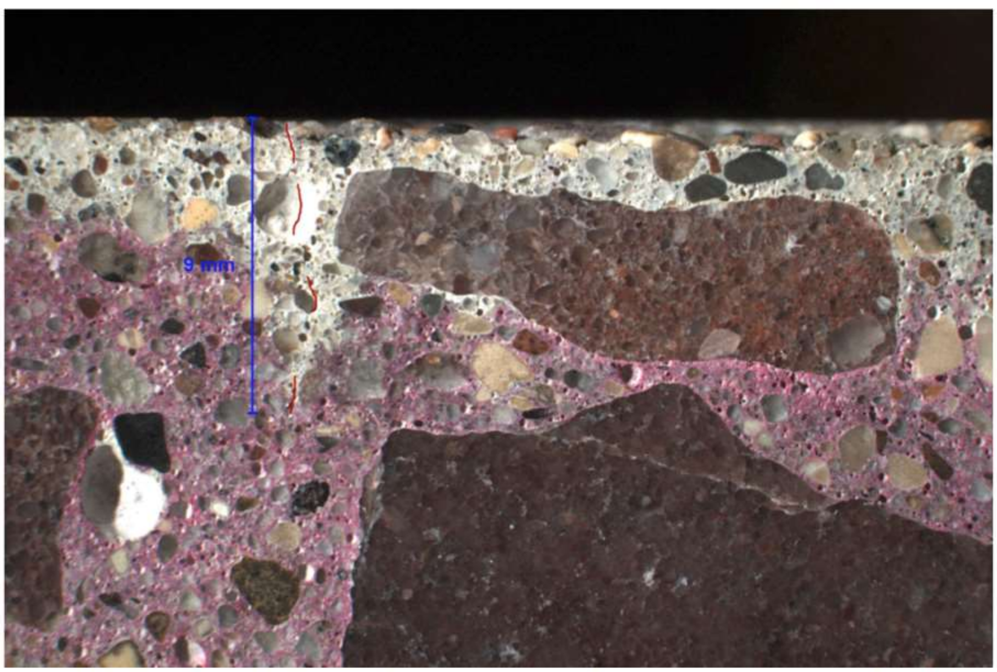
PROJECT: W/CM Study
Phase 1

PHOTO:
150



SAMPLE ID: 7204-13, 28 **DESCRIPTION:** Silicone joint sealant was mostly de-bonded from both sides of the joint.
MAG: 5x

PHOTO:
151

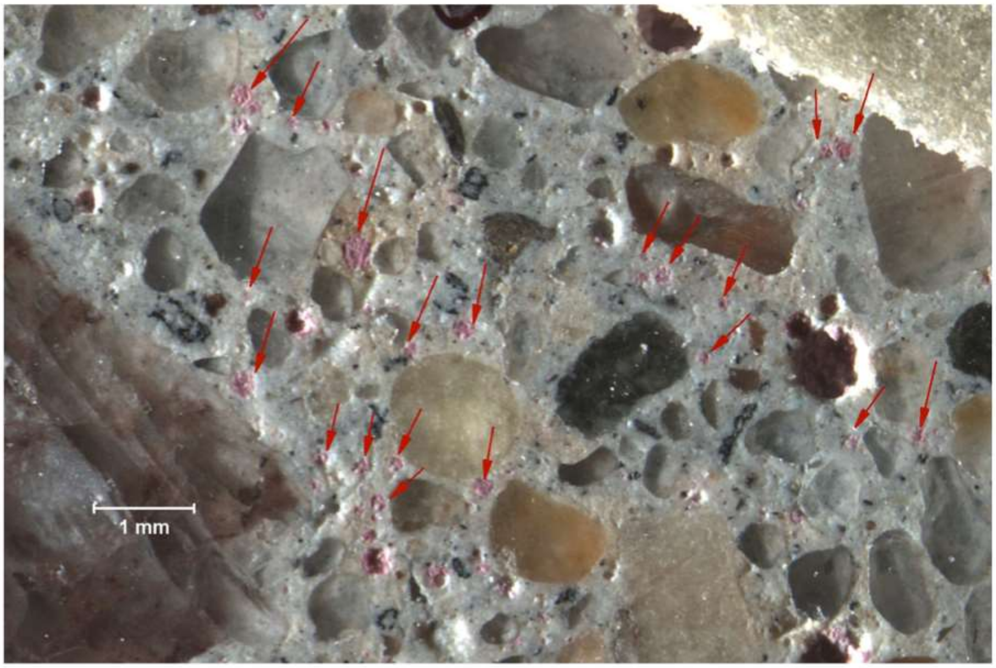


SAMPLE ID: 7204-13, 28 **DESCRIPTION:** Carbonation (unstained paste) proceeded up to 9mm depth from the top surface; along sub-vertical shrinkage microcracking mapped in red dashed line.
MAG: 100x

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

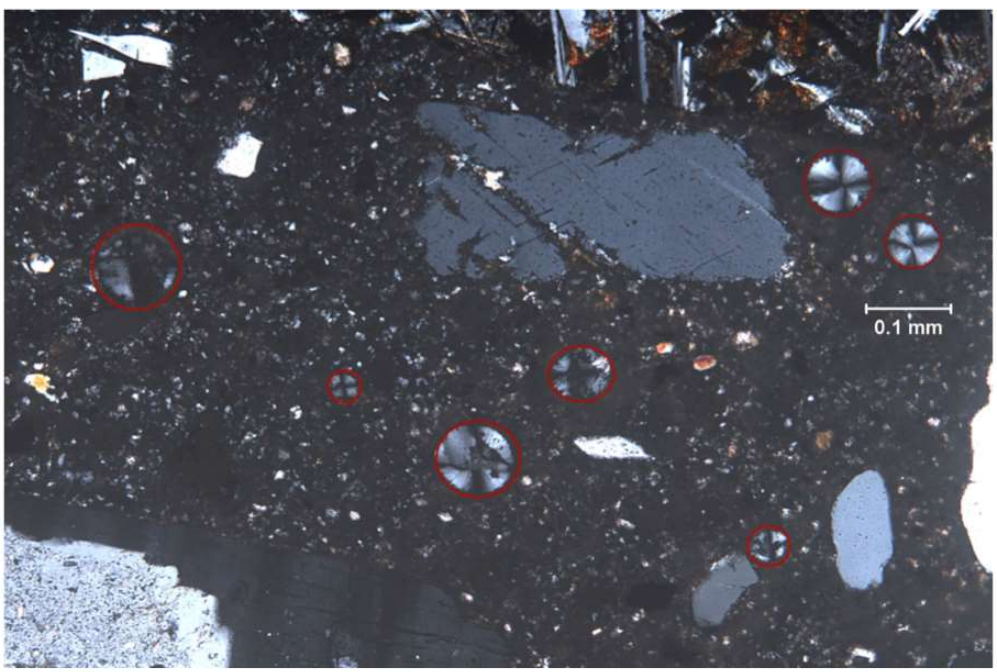
PROJECT: W/CM Study
Phase 1

PHOTO: 152



SAMPLE ID: 7204-13, 28 **DESCRIPTION:** Abundant ettringite filled voidspaces (stained purple) at 10mm depth from the distressed joint crack and 105mm depth from the top surface.
MAG: 15x

PHOTO: 153



SAMPLE ID: 7204-13, 28 **DESCRIPTION:** Fine entrained sized ettringite filled voidspaces within 3mm of the distressed joint plane; in thin section under cross polarized light.
MAG: 100x

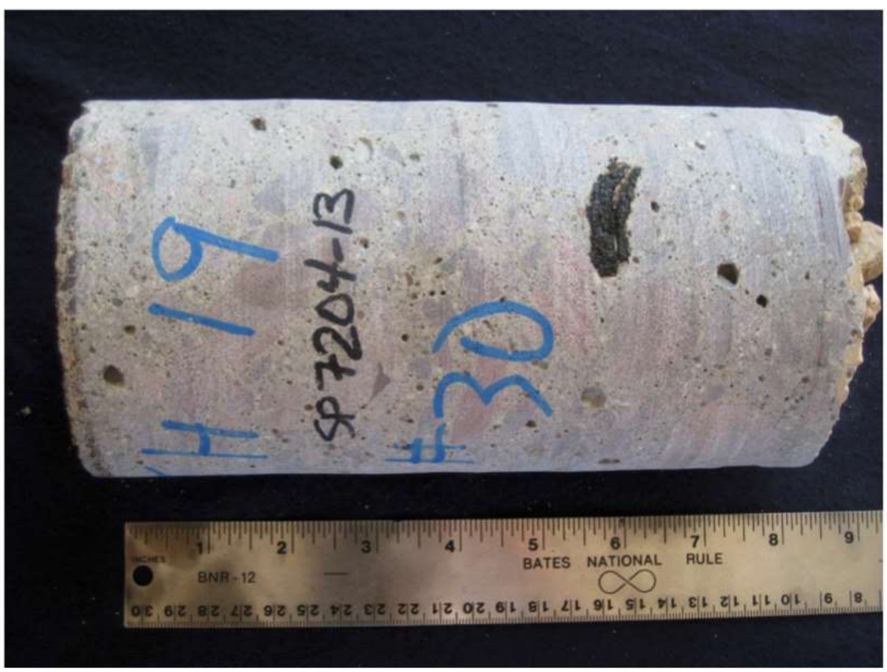
AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 1

PHOTO:
73

SAMPLE ID: 7204-13, 29 **DESCRIPTION:** Overall view of the mid-panel core utilized for rapid chloride permeability testing.

PHOTO:
74



SAMPLE ID: 7204-13, 30 **DESCRIPTION:** Overall view of the mid-panel core utilized for rapid chloride permeability testing.

Field Notes and Petrographic Reports for Project 4705-30, Cores 4, 7

Table A.36. Field notes for SP Number 4705-30, US-12.

Core	Location from Joint	RP	Station	Direction	Lane	Offset	Thickness
2	1.0'	108.223	405+00	EB		19.0'	8.500"
3	3.0'	108.223	405+00	EB		19.0'	8.500"
4	ON	112.990	181+800	EB		7.0'	10.000"
5	1.0'	112.990	181+800	EB		7.0'	10.000"
6	3.0'	112.990	181+800	EB		7.0'	9.750"
7	ON	116.716	00+800	EB		7.0'	9.250"
8	1.0'	116.716	00+800	EB		7.0'	8.750"
9	3.0'	116.716	00+800	EB		7.0'	9.000"

00 LAB 001 Petrographic Examination of Hardened Concrete
ASTM: C-856

Project No.	28-00337	Date:	January 31, 2012
Sample ID:	4, SP4705-30	Performed by:	G. Moulzolf

I. General Observations

1. Sample Dimensions: The core was taken directly through a sealed, sawcut and cracked pavement joint. Our analysis was performed on both lapped sides of a cross section (two pieces) of core sawcut "normal" to a sawcut and cracked joint measuring 245mm (9 ⅝") x 100mm (4") x 33mm (1 ¼") thick, a 240mm (9 ½") x 95mm (3 ¾") x up to 32mm (1 ¼") thick section (in two pieces), and two 76mm (3") x 52mm (2") wide thin sections that were sawcut and prepared from the original 100mm (4") diameter x 245mm (9 ⅝") long core. The thin sections were located between 5mm and 80mm depth and 150mm and 230mm depth in from the top surface of the core; in cross section and along the sawcut and cracked and distressed portions of the joint.

2. Surface Conditions:
   Top: Rough screeded surface with minor mortar erosion exposing fine aggregate surfaces.
   Bottom: Rough, irregular, formed surface; placed on recycled concrete base, some of which is incorporated into the bottom surface of the concrete.

3. Reinforcement: None observed.

4. General Physical Conditions: The core was taken through a sealed pavement joint. The light gray silicone joint sealant was mostly de-bonded from both sides of the sawcut joint. The joint was characterized by an intact approx. 3mm wide sawcut proceeding 64mm (2 ½") depth from the top surface and an approx. 10mm wide reservoir cut to 37mm (1 ½") depth; with the resulting joint crack proceeding the depth of the core. A foam backer rod was present. The core was fractured in sub-horizontal orientations at approx. 132mm and 230mm on one side of the joint and 113mm, 167mm, and 217mm on the other. A few fine sub-vertical microcracks (incipient scaling/spalling), proceeding through the paste-only, were observed in thin section only, between 150mm and 230mm depth from the top surface and within a few mm of the distressed joint surface. A loss of paste incorporates between negligible and 12mm of total concrete paste between the two sides of the joint crack. The cracked joint plane is characterized by numerous relatively "clean" and un-distressed granitic gneiss coarse aggregates protruding from the concrete joint. In general, the widest loss of concrete (at least 10mm) occurs between 95mm and 182mm depth. A wider degree of distress, in the form of a conical void, occurs below 210mm depth from the top surface. The core exhibits significant residual interlock between the two halves of core. The coarse granitic gneiss aggregate appeared sound. No evidence of ASR associated with the coarse aggregate was observed. Numerous alkali-silica "reacted" shale and chert fine aggregate were present in the core. Sub-horizontal microcracking, mostly in the paste and proceeding through of the reacted shale and chert fine aggregates, occur at approx. 95mm, 92mm, 122mm, and 137mm; with several microcracks concentrated below 215mm depth in the cross section of core.

   The rough screeded top surface of the core exhibits moderate mortar erosion/traffic wear; exposing many fine aggregate surfaces. The concrete was fairly well consolidated, with only a few entrapped voidspace observed up to 12mm in diameter in the mid-section of the core. The concrete was purposefully air entrained and originally contained a well-distributed air void system considered freeze-thaw resistant under severe exposure conditions. Original air void parameters include a 6.9% entrained-sized void volume and a 0.004" spacing factor. Secondary ettringite, with some portlandite, fills most of the smaller entrained sized voidspaces within approx. 10mm of the joint plane/crack surface. Void fillings decrease with depth from this zone. Actual measured air void parameters, which excludes the ettringite void fillings, in a band between approx. 0mm and at least 22mm (0-1.0") depth from the joint surface (below 70mm depth in the core), are a 4.8% entrained volume and a 0.007" spacing factor.

II. Aggregate

1. Coarse: 19mm (¾") nominal sized crushed granitic gneiss. The coarse aggregate appeared well graded and exhibited good overall distribution.

2. Fine: Natural quartz, feldspar, and lithic sand. The grains were mostly sub-rounded with many smaller sub-angular particles. The fine aggregate appeared fairly graded and exhibited good overall uniform distribution.

III. Cementitious Properties

1. Air Content: 6.9% original entrained air content. 4.8% "actual" un-filled entrained air between 0mm and at least 25mm depth from the distressed joint (below 70mm depth from the top surface).
2. Depth of carbonation: Ranged from 1mm up to 8mm depth from the top surface of the core; along sub-vertical drying shrinkage microcracking. Ranged from negligible up to 2mm depth from the sawcut joint surface and from 2mm up to approx. 10mm depth from the distressed joint surface.
3. Pozzolan presence: Flyash was observed.
4. Paste/aggregate bond: Fair.
5. Paste color: Mottled Light Gray (Munsell® N7) to tan.
6. Paste hardness: Moderate (<Moh's 3)
7. Microcracking: Several fine sub-vertical microcracks (incipient spalling) were observed in thin section (in the paste-only) along the joint (cracked) surface between 150mm and 230mm depth from the top surface of the core. A few fine, sub-vertical drying shrinkage microcracks proceed up to 7mm depth from the top surface. Sub-horizontal microcracking, mostly in the paste and proceeding through a few reactive shale and chert fine aggregates, occur at approx. 95mm, 92mm, 122mm, 137mm, and several concentrated below 215mm depth in the cross section of core.
8. Secondary deposits: White ettringite, along with some scattered clear platelets of portlandite, fills most of the entrained sized air voids between the distressed joint surface (and below 30mm depth from the top surface along the sawcut) and approx. 5 to 10mm depth into the core. Void fillings become less abundant with distance from this zone.
9. w/cm: Estimated at between 0.43 and 0.48 with approximately 4 to 6% residual portland cement clinker particles and an amount of flyash visually consistent with a 15 to 25% replacement of portland cement.
10. Cement hydration: Alites: Mostly fully.
    Belites: Well.

AET PROJECT NO:	28-00337	**DATE:** December 31, 2012
PROJECT:	W/CM Study Phase 1	

PHOTO:
43

SAMPLE ID: 4705-30, 4 **DESCRIPTION:** Overall view of the jointed core utilized for petrographic analysis. The top surface is left. Note mass lost along the joint.

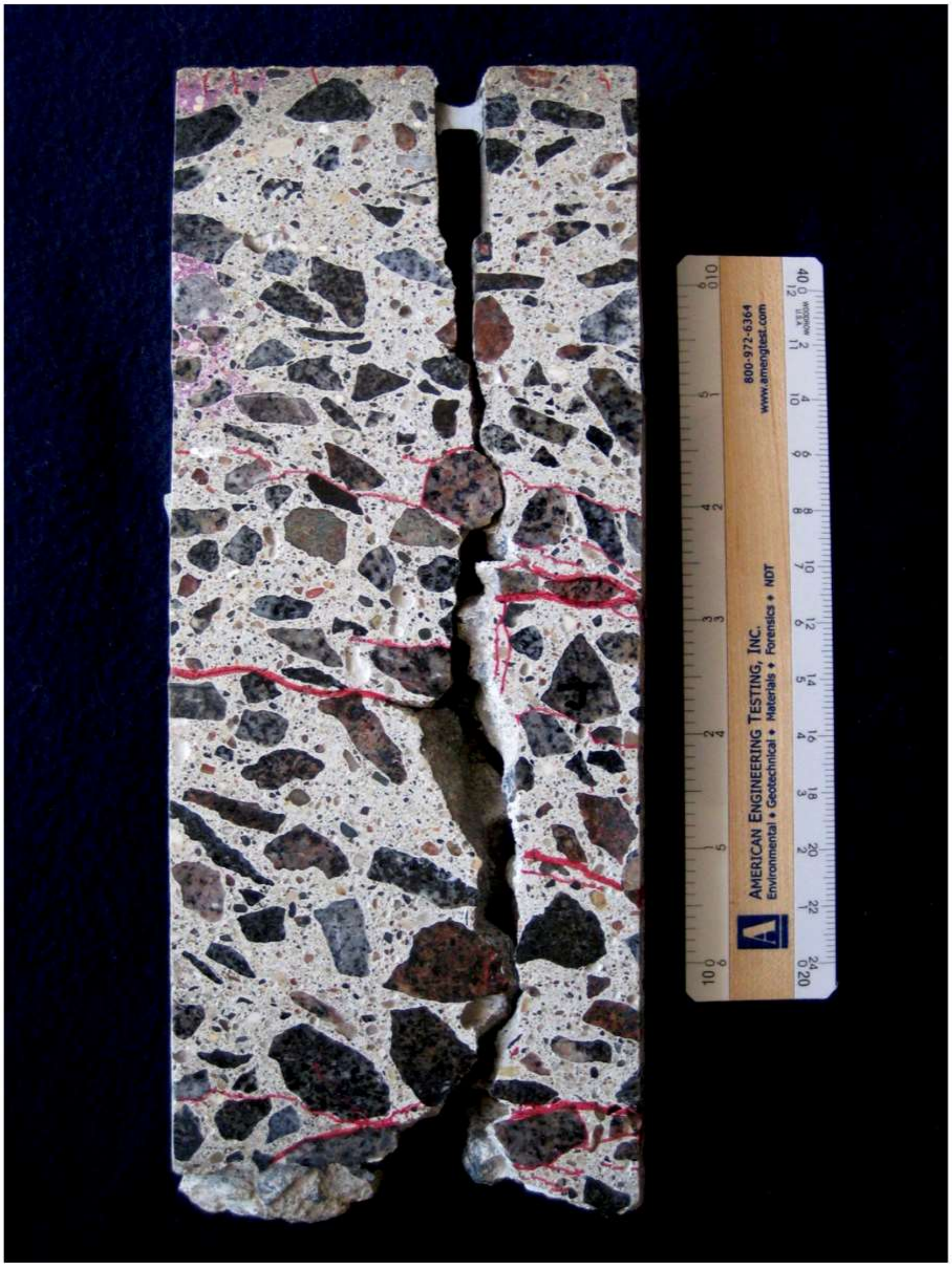
PHOTO:
44

SAMPLE ID: 4705-30, 4 **DESCRIPTION:** Rough screeded and jointed top surface of the core with minor mortar erosion. Note silicone sealant.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 1

PHOTO:
89

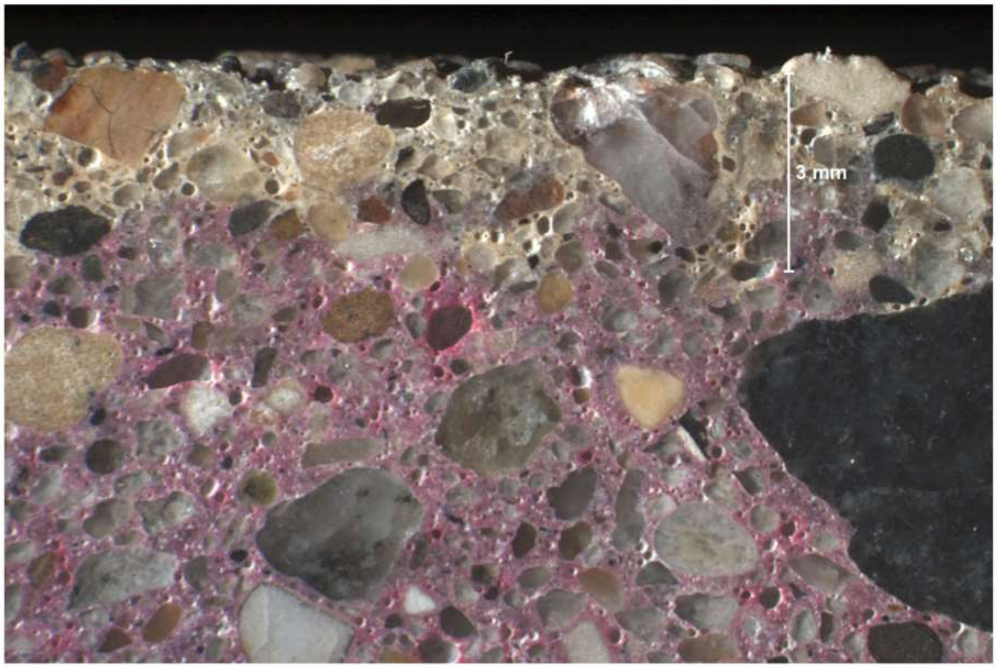


SAMPLE ID: 4705-30, 4 **DESCRIPTION:** Sawcut and lapped cross section of core. The core exhibits the most mass loss between 95mm and 182mm depth in the joint. Incipient vertical spalling was mapped in red ink. Sub-horizontal fracturing is also mapped in red ink. The silicone sealant is mostly de-bonded from both sides of the sawcut.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

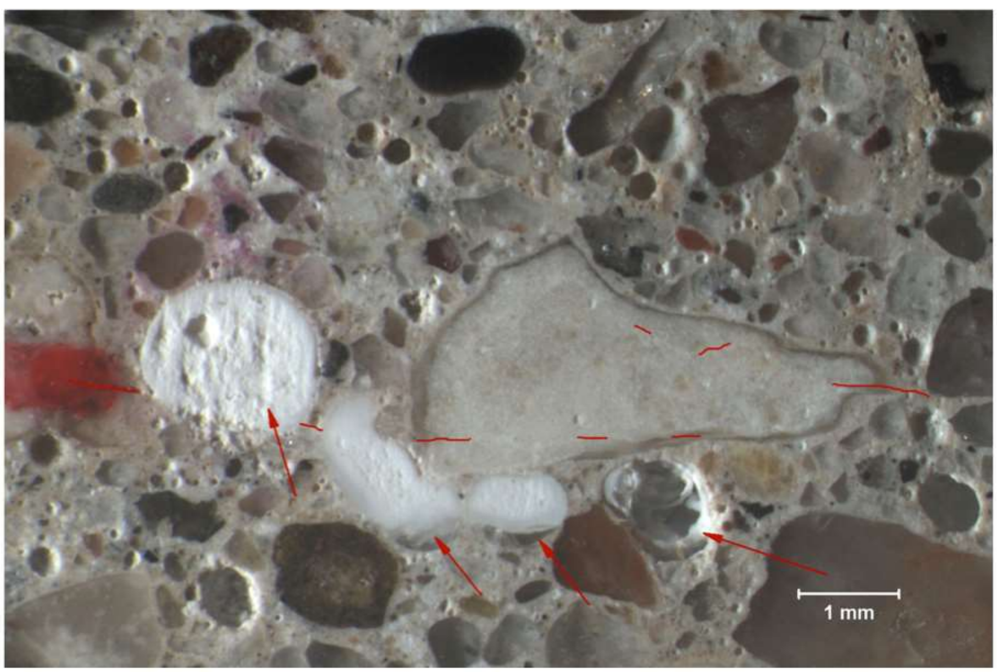
PROJECT: W/CM Study
Phase 1

PHOTO:
124



SAMPLE ID: 4705-30, 4 **DESCRIPTION:** Carbonation (unstained paste) proceeded up to 3mm depth (in this image) from the top surface of the core.
MAG: 10x

PHOTO:
125



SAMPLE ID: 4705-30, 4 **DESCRIPTION:** Isolated alkali-silica reaction (ASR) of a chert fine aggregate particles at mid-depth in the core. White to clear ASR fills or lines adjacent air voids (arrows).
MAG: 15x

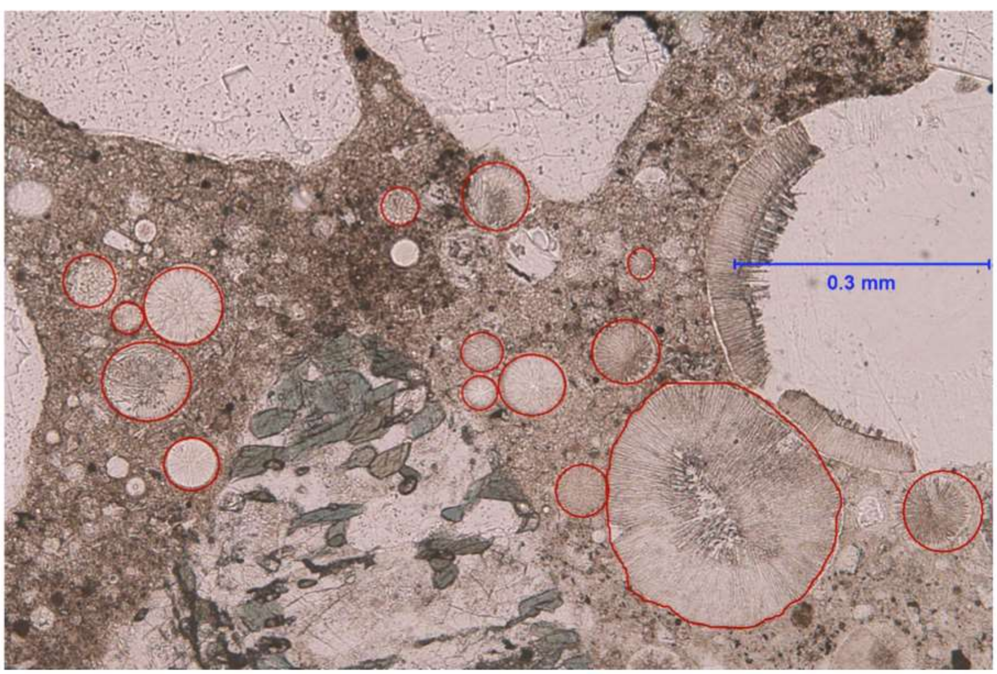
AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 1

PHOTO:
126

SAMPLE ID: 4705-30, 4 **DESCRIPTION:** Abundant ettringite-filled fine entrained voidspaces (stained purple) at 155mm depth in the core and 20mm depth from the distressed joint plane.
MAG: 30x

PHOTO:
127



SAMPLE ID: 4705-30, 4 **DESCRIPTION:** Nearly all of the finer entrained sized voidspaces are filled with secondary ettringite at 210mm depth in the core and within 5mm of the joint. Outlined in red and in thin section under plane polarized light
MAG 100x.

00 LAB 001 Petrographic Examination of Hardened Concrete
ASTM: C-856

Project No.	28-00337	Date:	January 31, 2012
Sample ID:	7, SP4705-30	Performed by:	G. Moulzolf

I. General Observations

1. Sample Dimensions: The core was taken directly through a sealed, sawcut and cracked pavement joint. Our analysis was performed on both lapped sides of a cross section (two pieces) of core sawcut "normal" to a sawcut and cracked joint measuring 237mm (9 ⅜") x 100mm (4") x 25mm (1") thick, a 240mm (9 ½") x 100mm (4") x up to 45mm (1 ¾") thick section (in two pieces), and two 76mm (3") x 52mm (2") wide thin sections that were sawcut and prepared from the original 100mm (4") diameter x 240mm (9 ½") long core. The thin sections were located between 23mm and 100mm depth from the top surface and 145mm and 225mm depth in the core; in cross section and along the sawcut and cracked portions of the joint.

2. Surface Conditions:
   Top: Rough screeded surface with minor mortar erosion exposing fine aggregate surfaces.
   Bottom: Rough, irregular, formed surface; placed on recycled concrete base, some of which is incorporated into the bottom surface of the concrete.

3. Reinforcement: None observed.

4. General Physical Conditions: The core was taken through a sealed pavement joint. The light gray silicone joint sealant was mostly de-bonded from both sides of the sawcut joint. The joint was characterized by an approx. 3mm wide sawcut proceeding 65mm (2 ½") depth from the top surface and an approx. 10mm wide reservoir cut to 32mm (1 ¼") depth; with foam backer rod. Several sub-vertical microcracks (incipient scaling/spalling), observed in the paste-only, were observed between 75mm and 215mm depth in the cracked joint surface and incorporates between a few mm and 8mm of total concrete paste between the two sides of the joint crack. The joint plane is characterized by numerous relatively "clean" and un-distressed granitic gneiss coarse aggregates protruding from the concrete joint. The widest loss of concrete (4mm to 7mm) occurs between 65mm and 75mm depth in the concrete from the top surface. The core exhibits relatively tight, residual interlock between the two halves of core; with a few coarse aggregate bisected by the joint at depth in the core. The coarse granitic gneiss aggregate appeared sound. No evidence of ASR associated with the coarse aggregate was observed. Numerous alkali-silica "reacted" shale fine aggregate were present in the core.

   The rough screeded top surface of the core exhibits moderate mortar erosion/traffic wear; exposing many fine aggregate surfaces. The concrete was fairly well consolidated, with only a few entrapped voidspace observed up to 12mm in diameter in the mid-section of the core. The concrete was purposefully air entrained and originally contained a well-distributed air void system considered freeze-thaw resistant under severe exposure conditions. Original air void parameters include a 4.3% entrained-sized void volume and a 0.007" spacing factor. Secondary ettringite, with some portlandite, fills most of the smaller entrained sized voidspaces within approx. 20mm of the joint plane/surface. Void fillings decrease with depth from the joint plane. Actual measured air void parameters, which excludes the ettringite void fillings, in a band between approx. 0mm and at least 20mm (0-0.75") depth from the joint surface (below 57mm depth in the core), are 2.5% entrained volume and a 0.013" spacing factor.

II. Aggregate

1. Coarse: 19mm (¾") nominal sized crushed granitic gneiss. The coarse aggregate appeared well graded and exhibited good overall distribution.

2. Fine: Natural quartz, feldspar, and lithic sand. The grains were mostly sub-rounded with many smaller sub-angular particles. The fine aggregate appeared fairly graded and exhibited good overall uniform distribution.

III. Cementitious Properties

1.	Air Content:	4.3% original entrained air content. 2.5% "actual" un-filled entrained air between 0mm and at least 20mm depth from the distressed joint (below 57mm depth).
2.	Depth of carbonation:	Up to 6mm depth from the top surface of the core. Mostly negligible along the sawcut joint. Ranged from mostly negligible up to 4mm depth from the distressed joint surface.
3.	Pozzolan presence:	Flyash was observed.
4.	Paste/aggregate bond:	Fair.
5.	Paste color:	Mottled Medium Light Gray (Munsell® N6) to tan.
6.	Paste hardness:	Moderately hard (Moh's 3)
7.	Microcracking:	Several sub-vertical microcracks (incipient spalling) were observed along the joint (cracked) surface between 75mm and 215mm depth from the top surface of the core. A few fine, sub-vertical drying shrinkage microcracks proceed up to 5mm depth from the top surface.
8.	Secondary deposits:	White, generally acicular grown ettringite along with some clear platelets of portlandite fills most of the finer entrained sized air voids between the joint surface and approx. 20mm depth into the core. Void fillings become less abundant with distance from this zone.
9.	w/cm:	Estimated at between 0.40 and 0.45 with approximately 6 to 8% residual portland cement clinker particles and an amount of flyash visually consistent with a 15 to 25% replacement of portland cement.
10.	Cement hydration:	Alites: Well to fully. Belites: Well.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 1

PHOTO:
47

SAMPLE ID: 4705-30, 7 **DESCRIPTION:** Overall view of the jointed core utilized for petrographic analysis. The top surface is left.

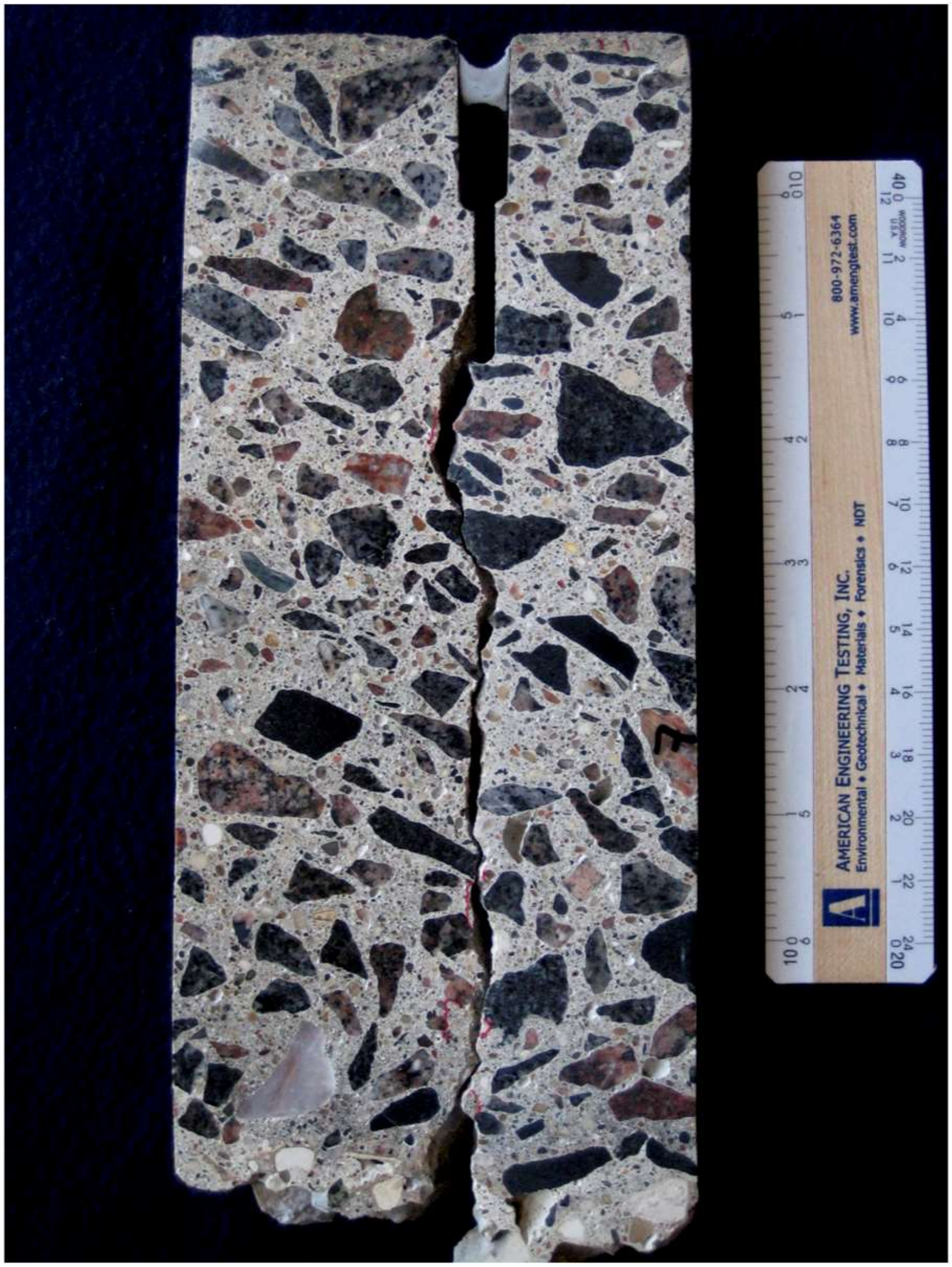
PHOTO:
48

SAMPLE ID: 4705-30, 7 **DESCRIPTION:** Rough screeded and jointed top surface of the core with minor mortar erosion. Note silicone joint sealant.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 1

PHOTO:
90

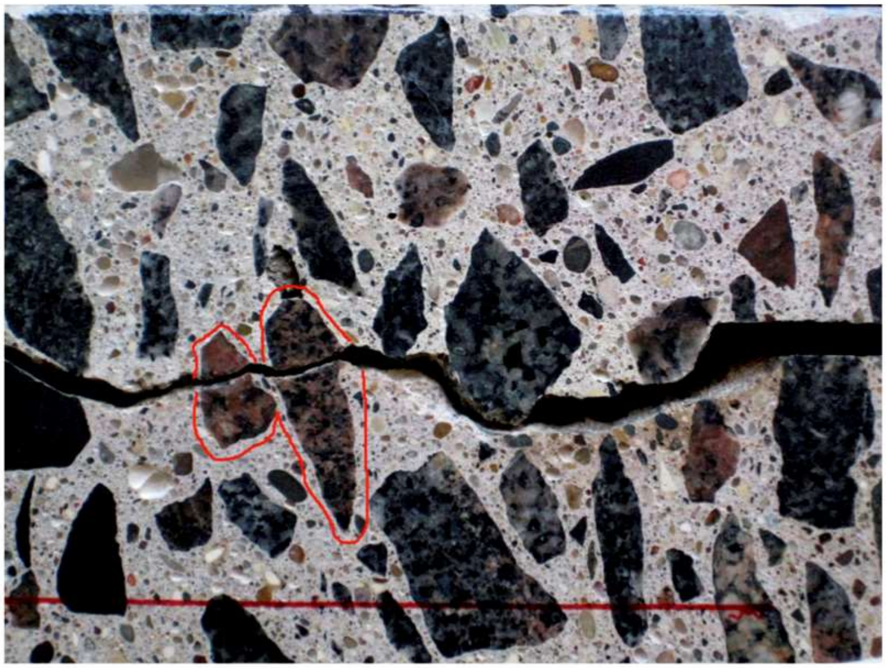


SAMPLE ID: 4705-30, 7 **DESCRIPTION:** Sawcut and lapped cross section of core. The silicone sealant was mostly de-bonded from both sides of the sawcut. The joint exhibits residual interlock and the crack bisects a few coarse aggregates. The widest loss of paste of 4mm to 7mm occurs between 65mm and 75mm depth in the core.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

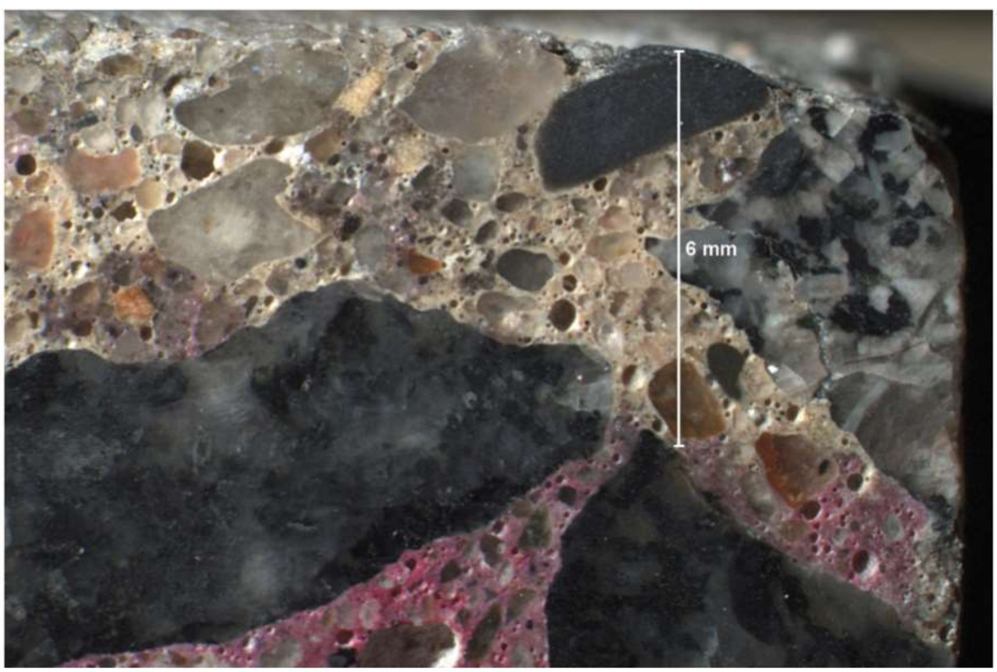
PROJECT: W/CM Study
Phase 1

PHOTO:
128



SAMPLE ID: 4705-30, 7 **DESCRIPTION:** Coarse aggregates are bisected by the activated joint crack (outlined in red). Sawcut control is right.
MAG: NA

PHOTO:
129

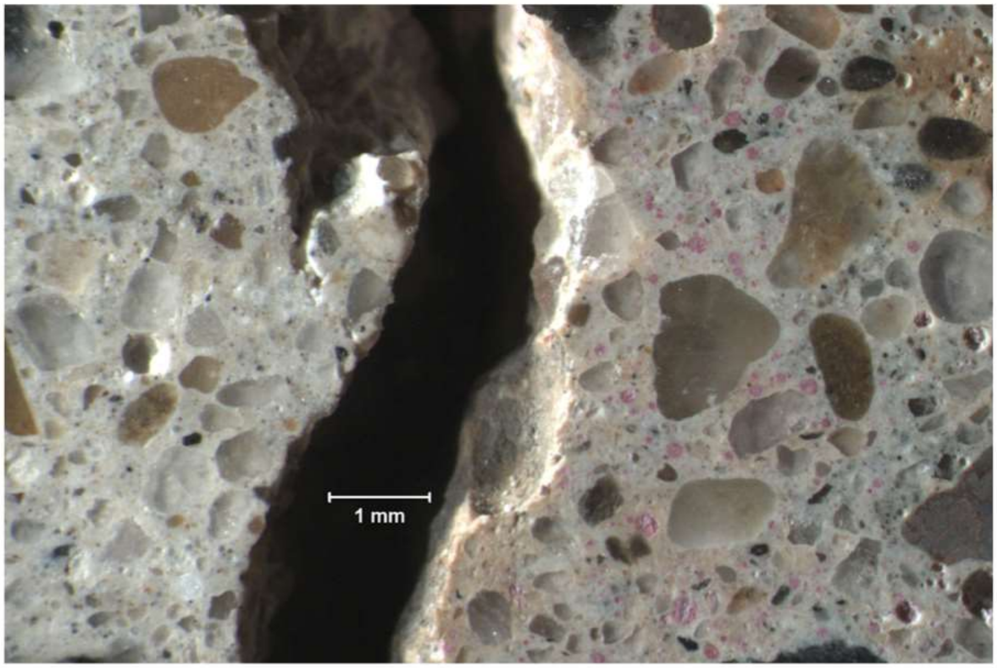


SAMPLE ID: 4705-30, 7 **DESCRIPTION:** Carbonation (unstained paste) proceeded up to 6mm depth from the top surface of the concrete.
MAG: 10x

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

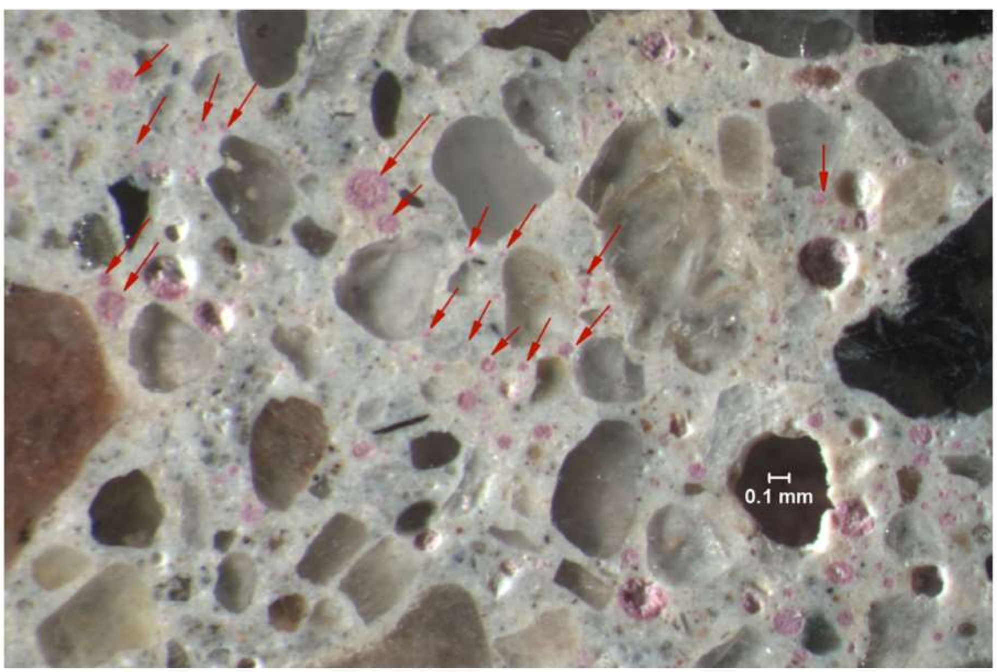
PROJECT: W/CM Study
Phase 1

PHOTO:
130



SAMPLE ID: 4705-30, 7 **DESCRIPTION:** The concrete, adjacent to the joint crack at 130mm depth from the top surface, appears nearly devoid of entrained air voids due to fillings with secondary ettringite.
MAG: 15x

PHOTO:
131

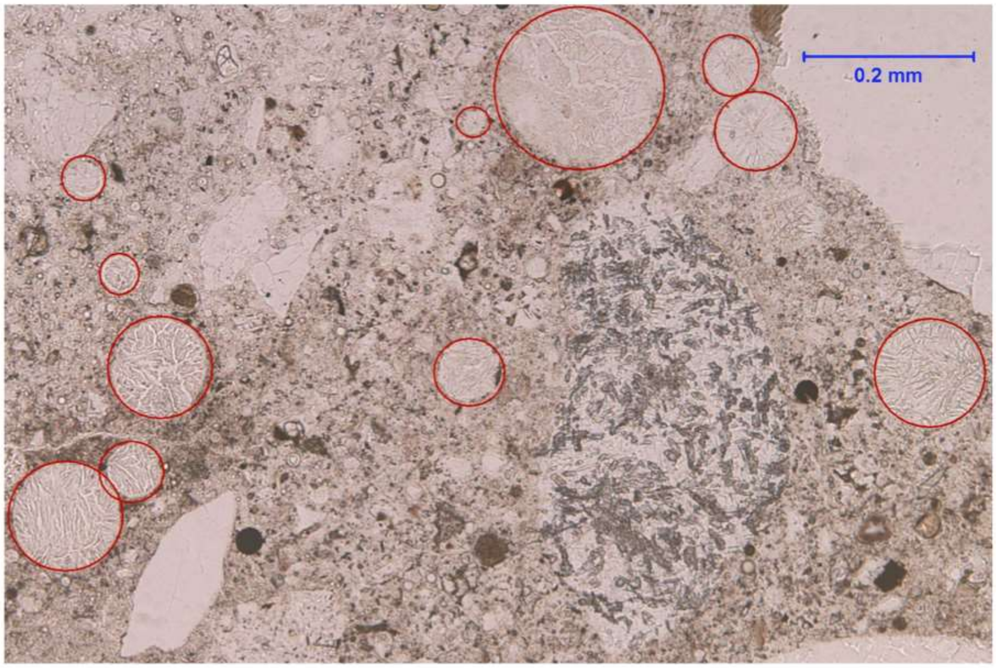


SAMPLE ID: 4705-30, 7 **DESCRIPTION:** Ettringite-filled voids (stained purple) within 8mm of the joint plane at 120mm depth in the core.
MAG: 30x

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

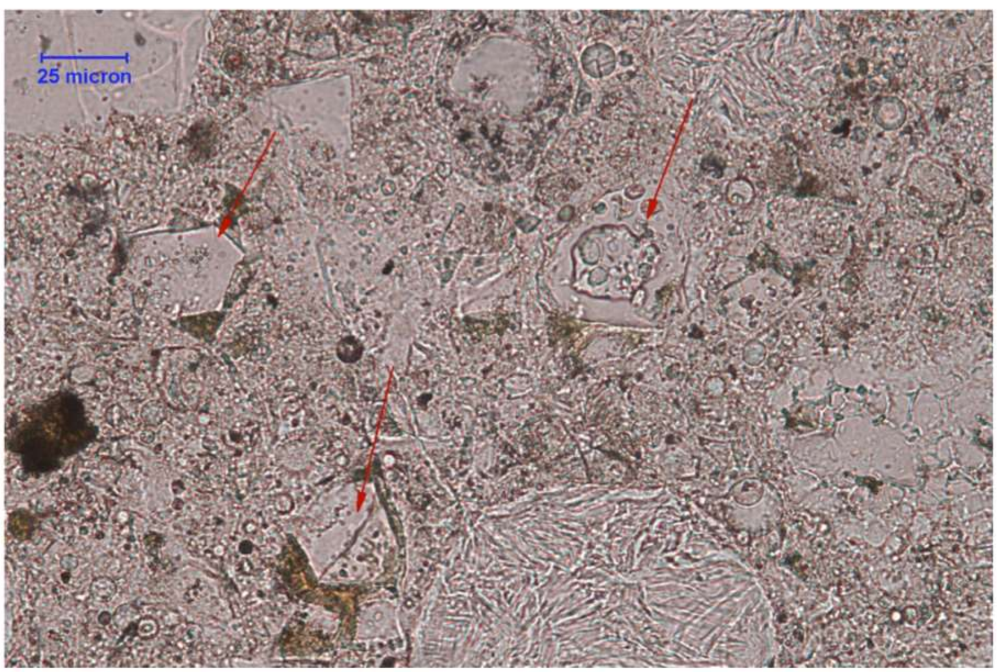
PROJECT: W/CM Study
Phase 1

PHOTO:
132



SAMPLE ID: 4705-30, 7 **DESCRIPTION:** The entrained sized voids, adjacent to the joint crack at mid-depth in the core, are filled with secondary ettringite. In thin section under plane polarized light.
MAG: 100x

PHOTO:
133



SAMPLE ID: 4705-30, 7 **DESCRIPTION:** Well to fully hydrated alite portland cement clinker particles in thin section of concrete paste under plane polarized light.
MAG: 400x

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 1

PHOTO:
41

SAMPLE ID: 4705-30, 3 **DESCRIPTION:** Overall view of the jointed core utilized for rapid chloride permeability. The top surface is left.

PHOTO:
42

SAMPLE ID: 4705-30, 3 **DESCRIPTION:** Rough screeded and tined top surface of the core with minor mortar erosion.

AET PROJECT NO: 28-00337 **DATE:** December 31, 2012

PROJECT: W/CM Study
Phase 1

PHOTO:
45

SAMPLE ID: 4705-30, 6 **DESCRIPTION:** Overall view of the mid-panel core utilized for rapid chloride permeability. The top surface is left.

PHOTO:
46

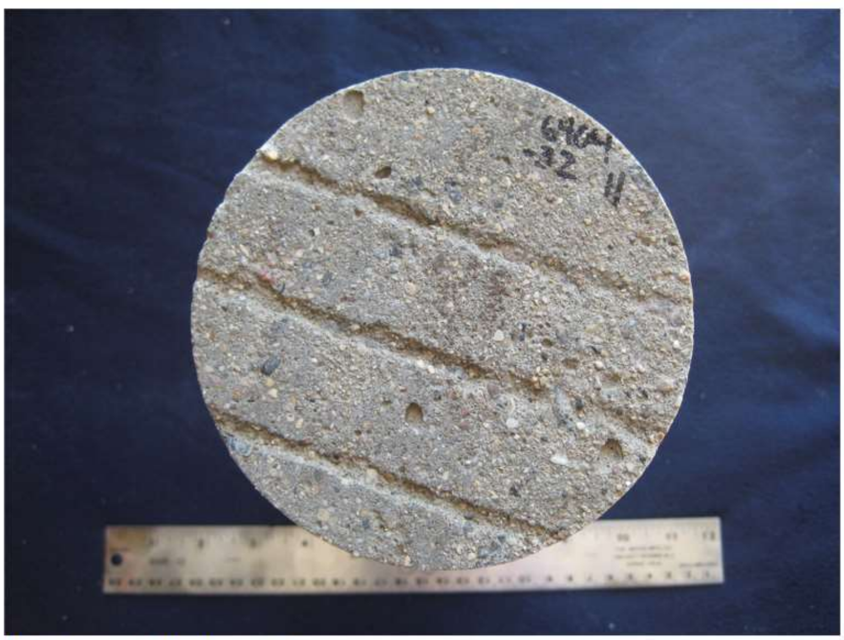
SAMPLE ID: 4705-30, 6 **DESCRIPTION:** Rough screeded and tined top surface of the core with minor mortar erosion.

Field Notes and Petrographic Reports for Project 6404-32, Cores 11, 12

Table A.37. Field notes for SP Number 6404-32, MN-19.

Core	Location from Joint	RP	Station	Direction	Lane	Offset	Thickness
11	1.0'	74.237	110+00	EB		7.0'	9.000"
12	3.0'	74.237	110+00	EB		7.0'	9.000"
14	1.0'	76.128	210+00	WB		-19.0'	9.000"
15	3.0'	76.128	210+00	WB		-19.0'	9.000"
17	1.0'	78.011	310+00	EB		7.0'	8.500"
18	3.0'	78.011	310+00	EB		7.0'	8.500"

DESCRIPTION – Project 6404-32, core 11



DESCRIPTION – Project 6404-32, core 11

DESCRIPTION – Project 6404-32, core 12

DESCRIPTION – Project 6404-32, core 12

APPENDIX B – PAVEMENT MANAGEMENT DATA

Appendix B - Pavement Management System Data

Introduction

Included in this Appendix are the pavement management system data provided by MnDOT. The data are organized by district. The terms BEGIN_RFP and DIR refer to field codes in the MnDOT database.

District 1 – 0980-127

Table B.1. Measured IRI for selected sections of project 0980-127, constructed in 1992. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

Year	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)						
	218 +0.494 I	219 +0.000 I	220 +0.000 I	221 +0.000 I	222 +0.000 I	223 +0.000 I	224 +0.000 I
1992	151	139	163	125	123	130	139
1994	93	90	103	77	72	93	97
1996	92	102	89	94	65	91	111
1998	53	63	65	56	46	52	61
2000	54	64	68	54	46	51	61
2001	47	60	72	65	40	48	58
2002	54	65	77	73	45	53	72
2003	74	85	85	77	64	72	72
2004	79	85	85	70	60	67	72
2005	78	81	81	65	60	63	67
2006	79	79	80	63	55	61	61
2007	92	85	83	67	56	62	67
2008	98	88	86	68	60	65	66
2009	77	87	108	86	73	79	67
2010	73	86	84	68	70	75	65
2011	80	85	84	66	58	67	72
2012	87	86	86	67	59	67	69
2013	90	90	89	72	63	72	73
2014	89	89	90	73	64	73	72
2015	91	92	92	75	62	74	78

Table B.2. Measured PQI for selected sections of project 0980-127, constructed in 1992. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)						
	218 +0.494	219 +0.000	220 +0.000	221 +0.000	222 +0.000	223 +0.000	224 +0.000
Year	I	I	I	I	I	I	I
1992	3.1	3.3	1.9	2.0	2.3	2.2	2.8
1994	3.8	3.9	3.8	4.0	4.0	3.8	3.8
1996	3.9	3.8	3.9	3.8	4.1	3.9	3.7
1998	4.0	3.9	3.9	4.0	4.1	4.0	3.9
2000	4.0	3.9	3.8	4.0	4.1	4.0	3.9
2001	4.1	3.9	3.8	3.9	4.2	4.1	4.0
2002	4.0	3.9	3.8	3.9	4.1	4.0	3.8
2003	3.8	3.7	3.7	3.7	3.9	3.8	3.8
2004	3.7	3.7	3.7	3.8	3.9	3.9	3.8
2005	3.7	3.7	3.7	3.9	3.9	3.9	3.9
2006	3.6	3.7	3.7	3.8	4.0	3.9	3.9
2007	3.4	3.5	3.6	3.7	4.0	3.9	3.8
2008	3.1	3.3	3.4	3.4	3.3	3.7	3.9
2009	3.4	3.3	3.2	3.2	3.1	3.5	3.8
2010	2.9	3.2	3.2	3.1	3.1	3.4	3.6
2011	3.7	3.7	3.7	3.8	4.0	3.8	3.8
2012	3.7	3.7	3.6	3.6	4.0	3.7	3.8
2013	3.5	3.6	3.5	3.5	3.7	3.6	3.7
2014	3.5	3.6	3.5	3.5	3.7	3.5	3.6
2015	3.3	3.6	3.4	3.4	3.6	3.5	3.5

Table B.3. Measured RQI for selected sections of project 0980-127, constructed in 1992. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)						
	218 +0.494	219 +0.000	220 +0.000	221 +0.000	222 +0.000	223 +0.000	224 +0.000
Year	I	I	I	I	I	I	I
1992	2.9	3.0	2.7	3.2	3.2	3.1	3.0
1994	3.7	3.8	3.6	4.0	4.1	3.7	3.7
1996	3.8	3.6	3.8	3.7	4.3	3.8	3.4
1998	4.1	3.8	3.8	4.0	4.2	4.1	3.9
2000	4.0	3.8	3.7	4.0	4.2	4.1	3.9
2001	4.3	3.9	3.7	3.9	4.5	4.2	4.0
2002	4.1	3.8	3.6	3.8	4.3	4.1	3.7
2003	3.7	3.4	3.4	3.5	3.9	3.7	3.7
2004	3.5	3.4	3.4	3.7	3.9	3.8	3.7
2005	3.4	3.4	3.4	3.8	3.9	3.9	3.8
2006	3.3	3.6	3.5	3.9	4.0	3.9	3.9
2007	2.9	3.3	3.3	3.7	4.0	3.9	3.7
2008	2.8	3.2	3.2	3.7	3.8	3.7	3.8
2009	3.5	3.2	2.8	3.2	3.4	3.4	3.7
2010	3.6	3.4	3.3	3.7	3.5	3.4	3.7
2011	3.5	3.4	3.5	3.8	4.0	3.7	3.7
2012	3.4	3.4	3.4	3.8	4.0	3.7	3.7
2013	3.3	3.3	3.3	3.7	3.9	3.7	3.6
2014	3.3	3.3	3.3	3.7	3.9	3.6	3.6
2015	3.3	3.3	3.2	3.6	3.8	3.6	3.5

Table B.4. Measured SR for selected sections of project 0980-127, constructed in 1992. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)						
	218 +0.494	219 +0.000	220 +0.000	221 +0.000	222 +0.000	223 +0.000	224 +0.000
Year	I	I	I	I	I	I	I
1992	3.4	3.6	1.4	1.3	1.6	1.5	2.7
1994	4.0	4.0	4.0	4.0	4.0	4.0	4.0
1996	4.0	4.0	4.0	4.0	4.0	4.0	4.0
1998	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2000	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2001							
2002	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2003							
2004	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2005							
2006	4.0	3.8	3.9	3.8	4.0	3.9	4.0
2007							
2008	3.4	3.4	3.7	3.2	2.9	3.7	4.0
2009							
2010	2.4	3.1	3.1	2.6	2.7	3.5	3.5
2011	4.0	4.0	4.0	3.9	4.0	4.0	4.0
2012	4.0	4.0	3.9	3.5	4.0	3.7	3.9
2013	3.8	4.0	3.8	3.4	3.5	3.5	3.8
2014	3.7	3.9	3.7	3.3	3.5	3.4	3.6
2015	3.3	4.0	3.7	3.2	3.5	3.4	3.5

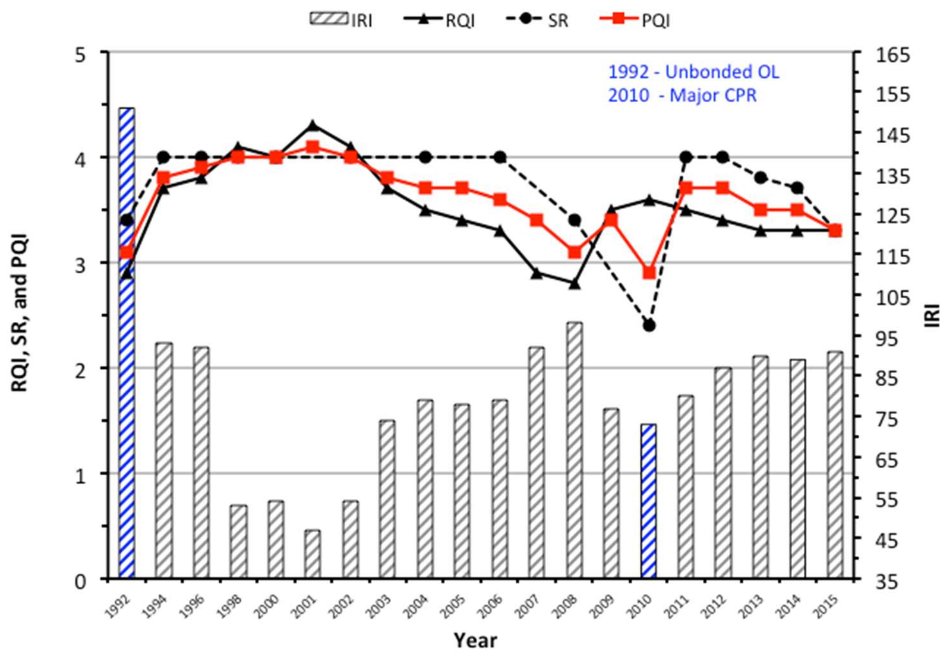


Figure B.1. Pavement management system data for section 218+0.494, direction I, of project 0980–127 constructed in 1992. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

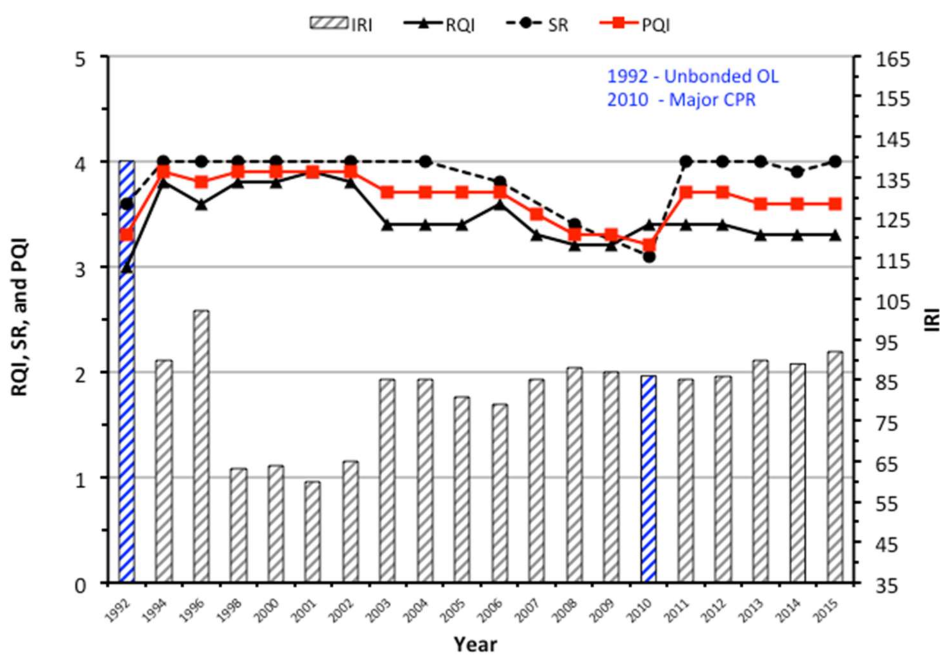


Figure B.2. Pavement management system data for section 219+0.000, direction I, of project 0980–127 constructed in 1992. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

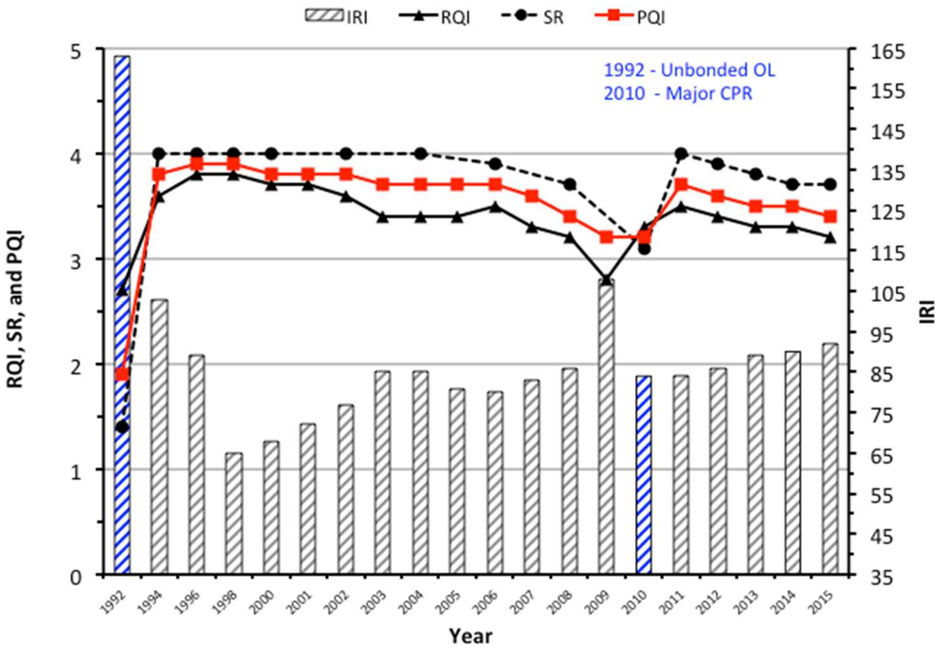


Figure B.3. Pavement management system data for section 220+0.000, direction I, of project 0980–127 constructed in 1992. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

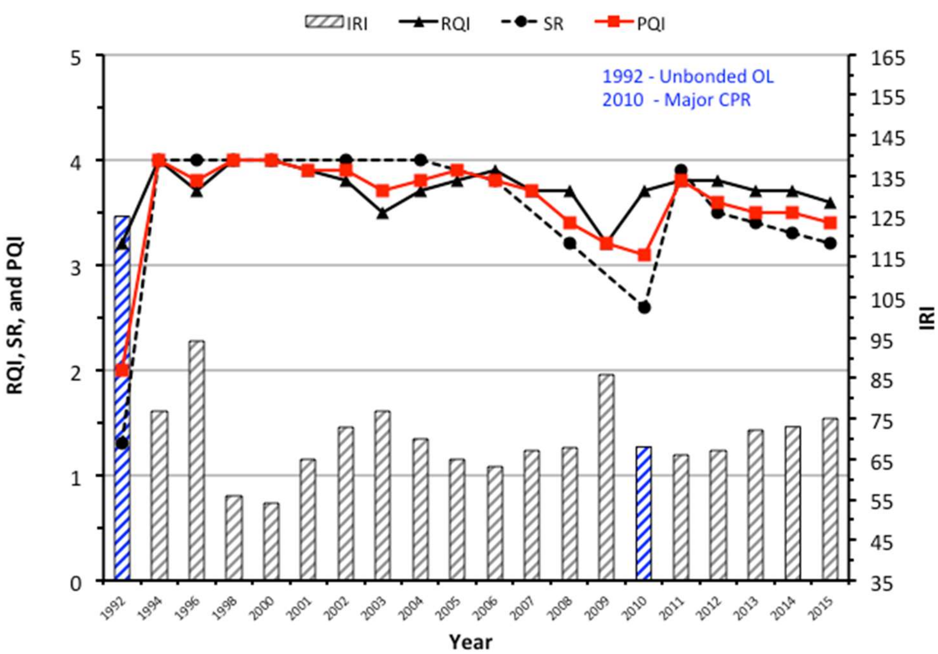


Figure B.4. Pavement management system data for section 221+0.000, direction I, of project 0980–127 constructed in 1992. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

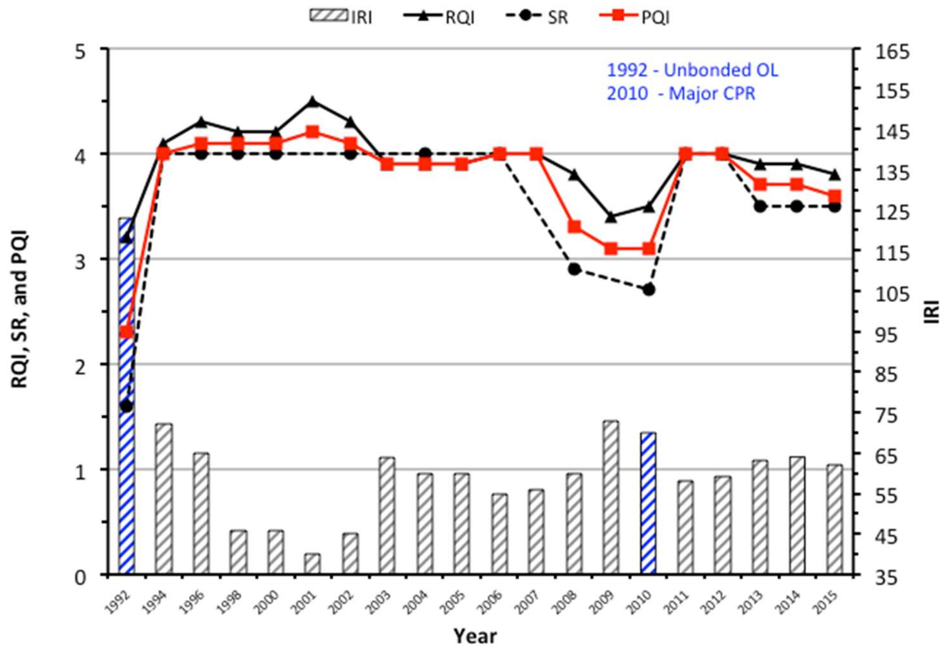


Figure B.5. Pavement management system data for section 222+0.000, direction I, of project 0980–127 constructed in 1992. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

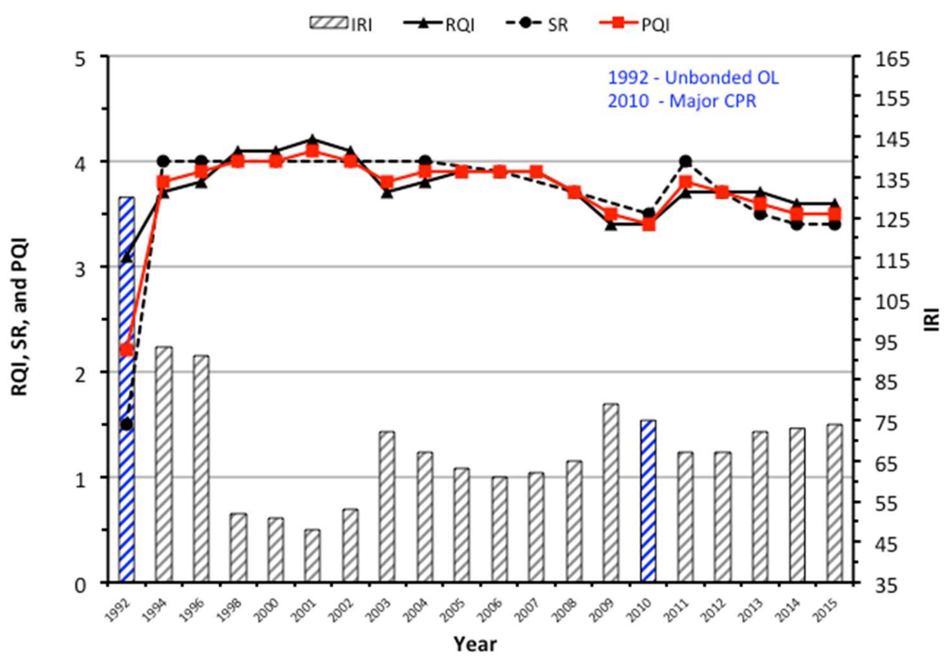


Figure B.6. Pavement management system data for section 223+0.000, direction I, of project 0980–127 constructed in 1992. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

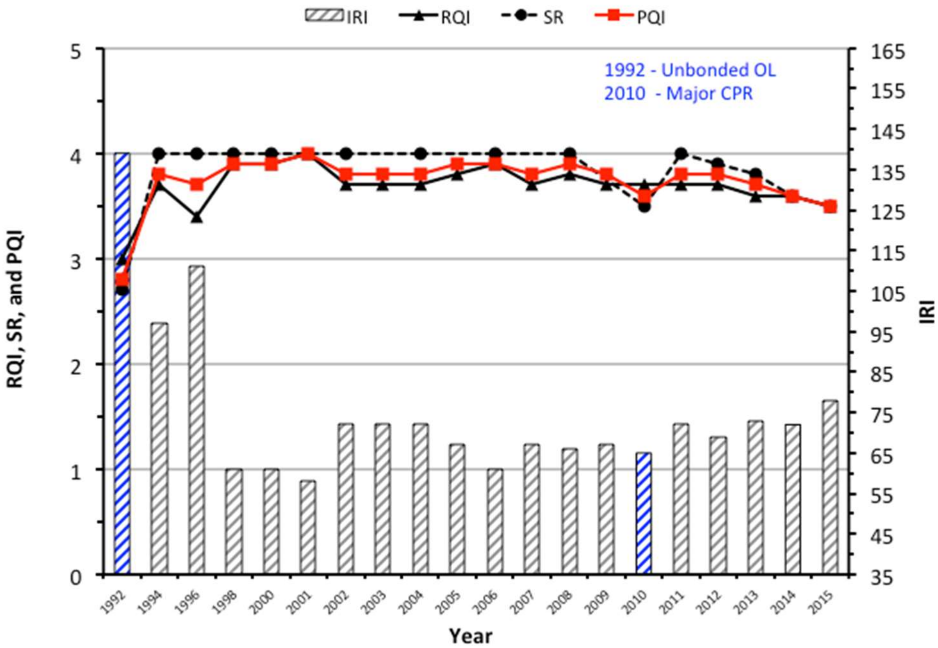


Figure B.7. Pavement management system data for section 224+0.000, direction I, of project 0980–127 constructed in 1992. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

District 1 – 3805-67

Table B.5. Measured IRI for selected sections of project 3805-67, constructed in 1996. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)						
Year	37 +0.430 D	38 +0.000 D	37 +0.430 I	38 +0.000 I	34 +0.657 U	36 +0.000 U	37 +0.000
1996							
1999	72	65	73	87	75	82	75
2001	80	83	86	98	82	89	96
2002	78	83	90	99	87	92	97
2003	97	95	105	111	91	100	106
2004	93	92	103	104	84	93	105
2005	92	83	105	99	84	96	106
2006	92	82	101	95	82	91	103
2007	82	88	93	98	83	90	108
2008	86	94	95	100	87	90	113
2009	91	99	105	116	98	107	127
2010	83	91	94	97	87	93	113
2011	92	101	111	120	102	109	131
2012	87	90	106	105	90	96	117
2013	93	97	96	105	91	93	114
2014	88	93	99	108	95	99	125
2015	93	101	103	115	102	105	129

Table B.6. Measured PQI for selected sections of project 3805-67, constructed in 1996. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)						
Year	37 +0.430 D	38 +0.000 D	37 +0.430 I	38 +0.000 I	34 +0.657 U	36 +0.000 U	37 +0.000
1996							
1999	3.8	3.9	3.8	3.6	3.8	3.7	3.8
2001	3.7	3.7	3.7	3.6	3.7	3.6	3.6
2002	3.8	3.7	3.7	3.6	3.7	3.6	3.6
2003	3.6	3.6	3.6	3.5	3.7	3.6	3.5
2004	3.6	3.7	3.6	3.6	3.7	3.6	3.5
2005	3.6	3.7	3.6	3.6	3.7	3.6	3.5
2006	3.6	3.7	3.6	3.6	3.7	3.7	3.5
2007	3.7	3.7	3.7	3.6	3.7	3.7	3.5
2008	3.7	3.7	3.6	3.4	3.6	3.6	3.4
2009	3.6	3.6	3.5	3.1	3.5	3.4	3.2
2010	3.7	3.7	3.6	3.3	3.6	3.6	3.4
2011	3.6	3.5	3.5	3.1	3.5	3.5	3.2
2012	3.6	3.5	3.6	3.2	3.6	3.6	3.3
2013	3.6	3.6	3.6	3.5	3.5	3.6	3.4
2014	3.6	3.6	3.6	3.5	3.4	3.5	3.3
2015	3.6	3.5	3.5	3.4	3.4	3.5	3.3

Table B.7. Measured RQI for selected sections of project 3805-67, constructed in 1996. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)						
Year	37 +0.430 D	38 +0.000 D	37 +0.430 I	38 +0.000 I	34 +0.657 U	36 +0.000 U	37 +0.000
1996							
1999	3.6	3.8	3.6	3.3	3.6	3.4	3.6
2001	3.5	3.5	3.4	3.2	3.4	3.3	3.2
2002	3.6	3.5	3.5	3.2	3.4	3.3	3.3
2003	3.3	3.3	3.2	3.1	3.4	3.2	3.1
2004	3.3	3.4	3.3	3.2	3.4	3.3	3.1
2005	3.3	3.5	3.2	3.2	3.4	3.2	3.1
2006	3.3	3.5	3.3	3.3	3.5	3.4	3.1
2007	3.4	3.4	3.4	3.2	3.5	3.4	3.0
2008	3.4	3.4	3.2	3.1	3.3	3.3	2.9
2009	3.2	3.2	3.0	2.8	3.0	2.9	2.7
2010	3.4	3.4	3.3	3.2	3.3	3.2	3.0
2011	3.3	3.3	3.0	2.8	3.1	3.0	2.7
2012	3.4	3.3	3.2	3.1	3.3	3.2	2.9
2013	3.3	3.2	3.2	3.1	3.3	3.3	2.9
2014	3.3	3.2	3.2	3.0	3.1	3.1	2.7
2015	3.3	3.0	3.1	2.9	3.0	3.0	2.7

Table B.8. Measured SR for selected sections of project 3805-67, constructed in 1996. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)						
	37 +0.430	38 +0.000	37 +0.430	38 +0.000	34 +0.657	36 +0.000	37 +0.000
Year	D	D	I	I	U	U	U
1996							
1999	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2001	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2002							
2003	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2004							
2005			4.0	4.0	4.0	4.0	4.0
2006	4.0	4.0					
2007			4.0	4.0	4.0	4.0	4.0
2008	4.0	4.0	4.0	3.8	4.0	4.0	4.0
2009	4.0	4.0	4.0	3.5	4.0	4.0	3.9
2010							
2011	3.9	3.8	4.0	3.4	4.0	4.0	3.7
2012							
2013	4.0	4.0	4.0	4.0	3.8	4.0	4.0
2014							
2015	4.0	4.0	4.0	4.0	3.8	4.0	4.0

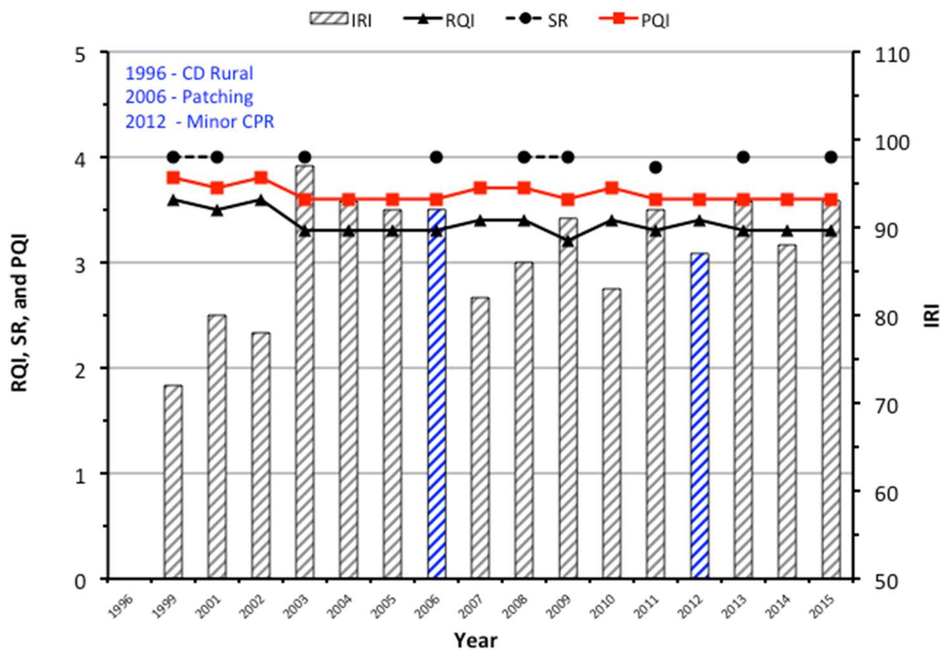


Figure B.8. Pavement management system data for section 37+0.043, direction D, of project 3805–67 constructed in 1996. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

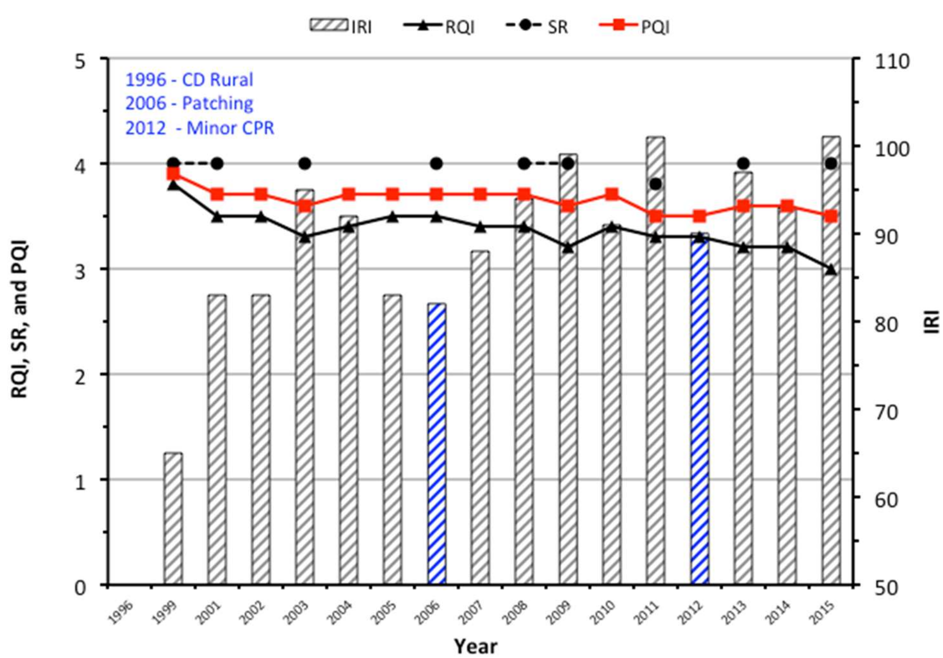


Figure B.9. Pavement management system data for section 38+0.000, direction D, of project 3805–67 constructed in 1996. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

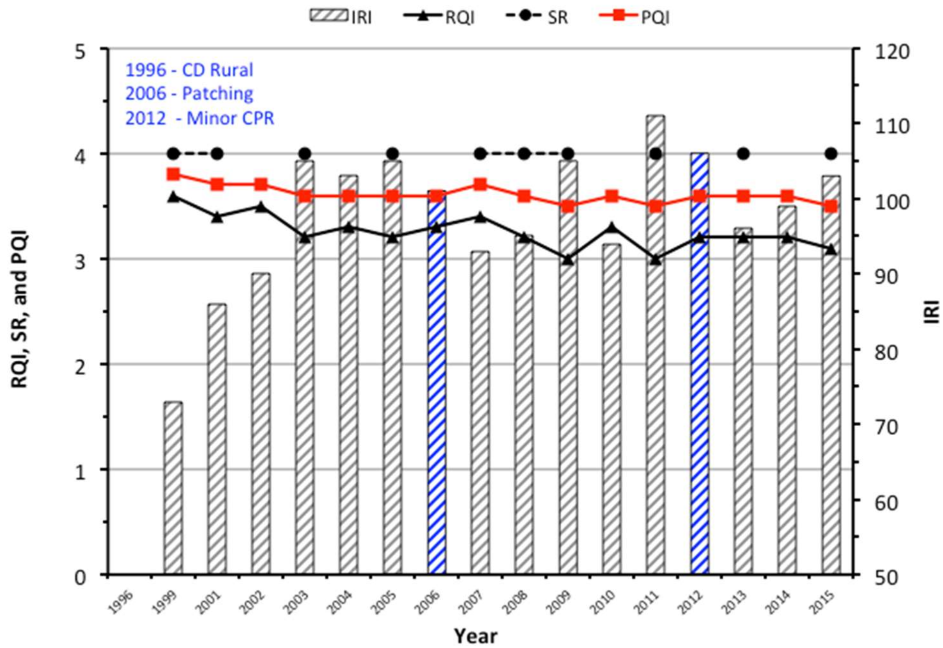


Figure B.10. Pavement management system data for section 37+0.043, direction I, of project 3805–67 constructed in 1996. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

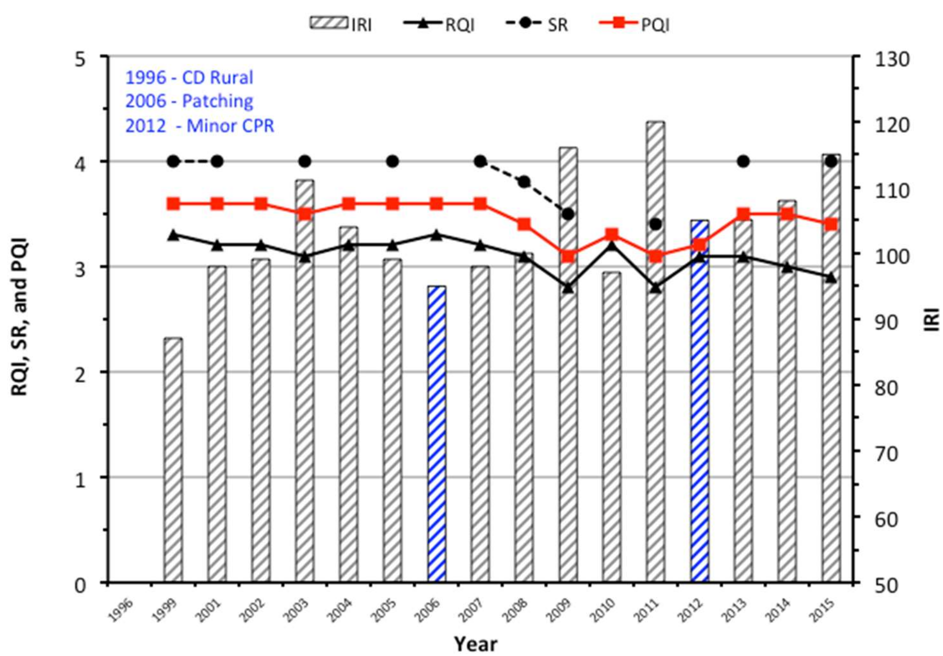


Figure B.11. Pavement management system data for section 38+0.000, direction I, of project 3805–67 constructed in 1996. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

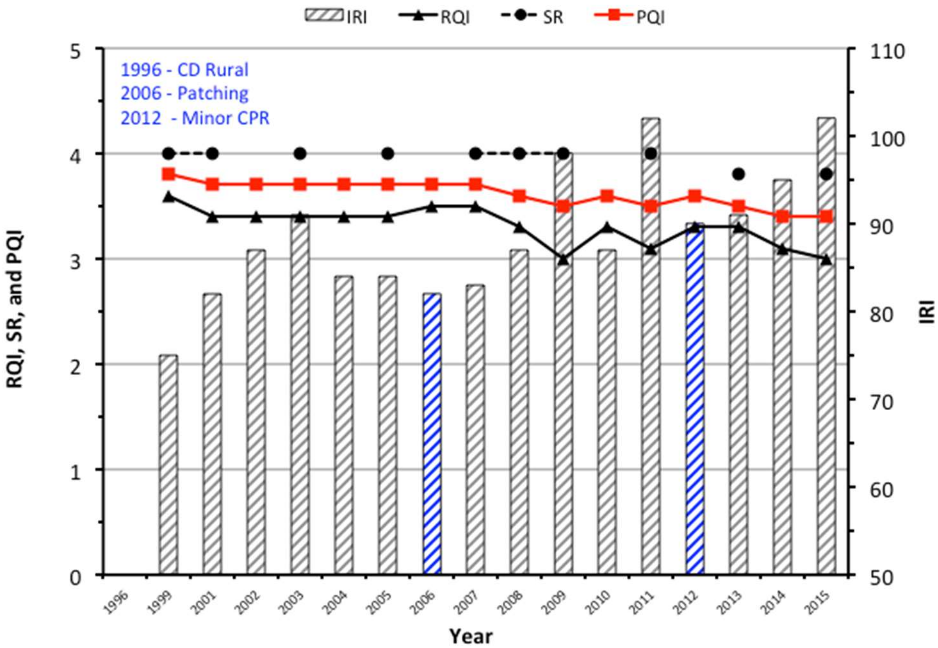


Figure B.12. Pavement management system data for section 34+0.657, direction U, of project 3805–67 constructed in 1996. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

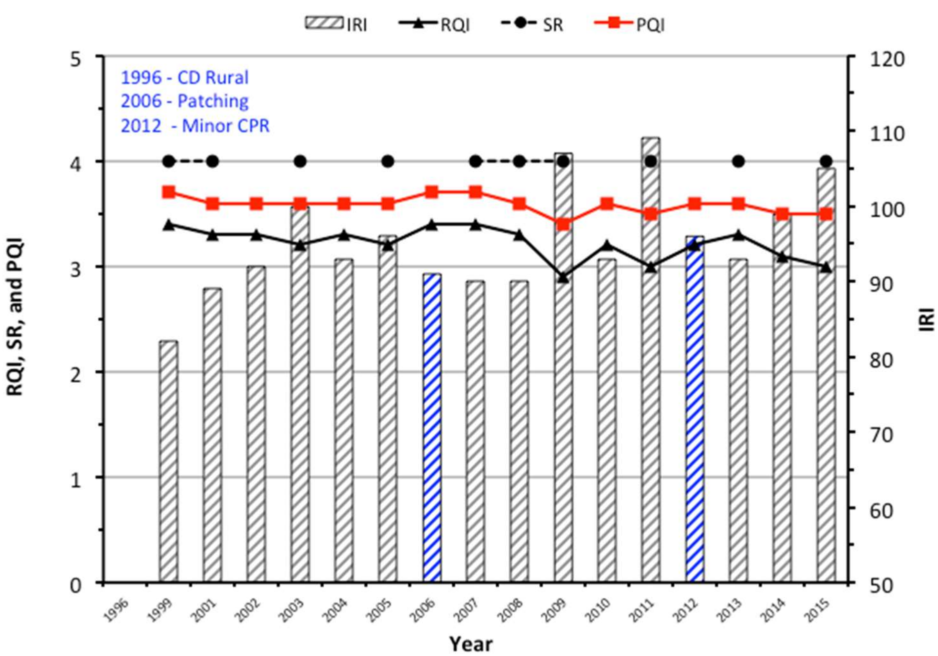


Figure B.13. Pavement management system data for section 36+0.000, direction U, of project 3805–67 constructed in 1996. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

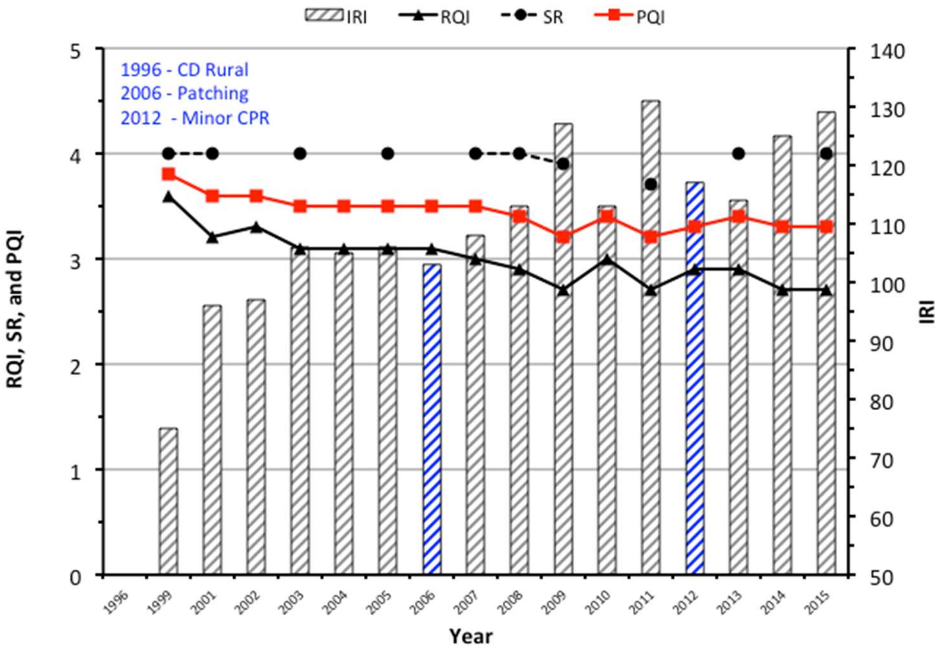


Figure B.14. Pavement management system data for section 37+0.000, direction U, of project 3805–67 constructed in 1996. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

District 2 – 6019-22

Table B.9. Measured IRI for selected sections of project 6019-22, constructed in 2000. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)			
	0 +0.958	2 +0.000	3 +0.000	4 +0.000
Year	I	I	I	I
2000	163	136	98	98
2001	45	50	54	54
2002	69	47	58	58
2003	65	64	71	67
2004	60	62	64	64
2005	78	61	67	69
2006	59	61	74	63
2007	68	69	73	70
2008	66	63	67	67
2009	90	74	72	79
2010	66	62	65	68
2011	95	81	78	89
2012	84	69	70	76
2013	82	71	73	78
2014	73	66	67	71
2015	75	70	74	74

Table B.10. Measured PQI for selected sections of project 6019-22, constructed in 2000. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)			
	0 +0.958	2 +0.000	3 +0.000	4 +0.000
Year	I	I	I	I
2000	1.8	2.1	2.8	2.8
2001	2.5	2.7	3.2	3.2
2002	3.9	4.1	4.0	4.0
2003	4.0	3.9	3.8	3.8
2004	4.0	3.9	3.9	3.2
2005	3.8	3.9	3.9	3.2
2006	4.0	3.9	3.8	3.9
2007	3.9	3.8	3.8	3.8
2008	3.9	3.9	3.9	3.9
2009	3.6	3.8	3.8	3.7
2010	3.9	3.9	3.9	3.9
2011	3.6	3.7	3.7	3.7
2012	3.7	3.8	3.8	3.8
2013	3.7	3.8	3.8	3.8
2014	3.8	3.9	3.9	3.8
2015	3.8	3.8	3.8	3.8

Table B.11. Measured RQI for selected sections of project 6019-22, constructed in 2000. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)			
	0 +0.958	2 +0.000	3 +0.000	4 +0.000
Year	I	I	I	I
2000	2.1	2.5	3.1	3.1
2001	4.3	4.2	4.0	4.0
2002	3.8	4.3	4.0	4.0
2003	4.0	3.9	3.7	3.6
2004	4.0	3.9	3.9	3.6
2005	3.6	3.9	3.9	3.6
2006	4.0	3.9	3.7	3.9
2007	3.8	3.7	3.7	3.7
2008	3.8	3.9	3.8	3.8
2009	3.2	3.6	3.6	3.5
2010	3.8	3.9	3.9	3.8
2011	3.2	3.5	3.5	3.4
2012	3.4	3.7	3.7	3.6
2013	3.5	3.7	3.7	3.6
2014	3.7	3.8	3.8	3.7
2015	3.6	3.7	3.7	3.7

Table B.12. Measured SR for selected sections of project 6019-22, constructed in 2000. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)			
	0 +0.958	2 +0.000	3 +0.000	4 +0.000
Year	I	I	I	I
2000	1.5	1.8	2.5	2.5
2001				
2002	4.0	4.0	4.0	4.0
2003				
2004	4.0	4.0	4.0	2.8
2005				
2006	4.0	4.0	4.0	4.0
2007				
2008	4.0	4.0	4.0	4.0
2009				
2010	4.0	4.0	4.0	4.0
2011				
2012	4.0	4.0	4.0	4.0
2013				
2014	4.0	4.0	4.0	4.0
2015	4.0	4.0	4.0	4.0

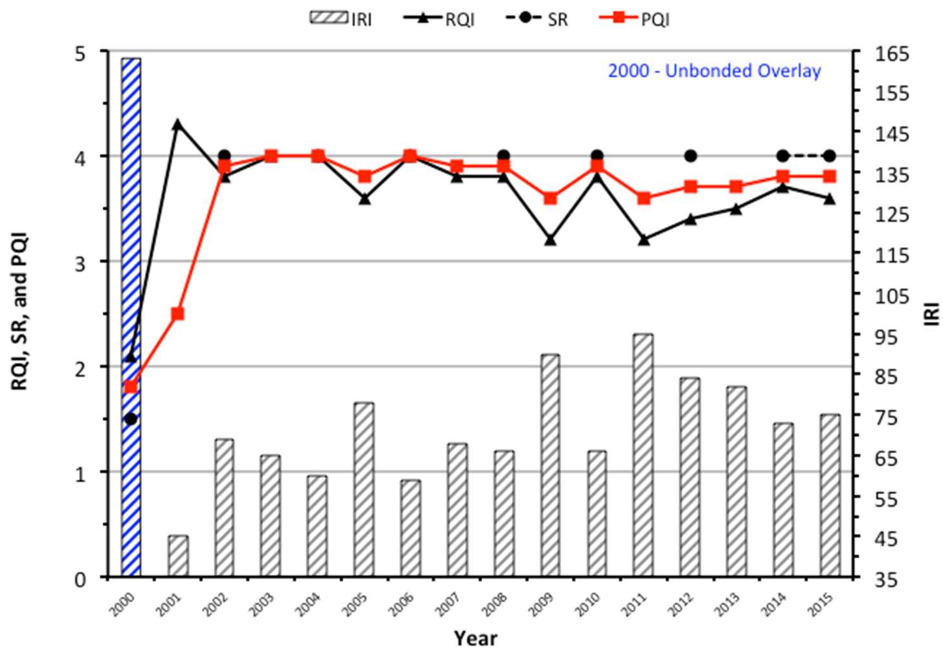


Figure B.15. Pavement management system data for section 0+0.958, direction I, of project 6019–22 constructed in 2000. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

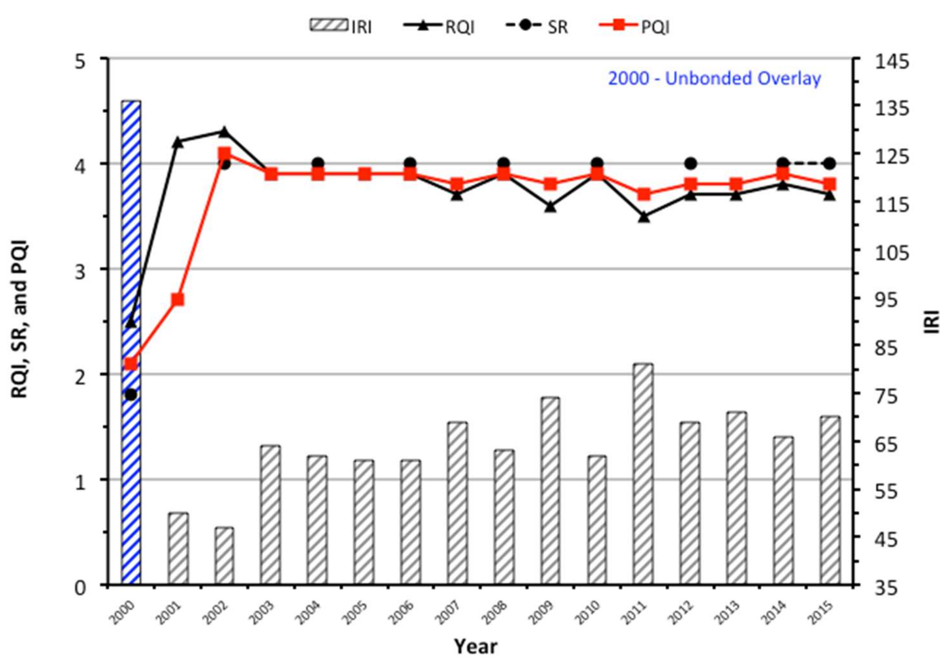


Figure B.16. Pavement management system data for section 2+0.000, direction I, of project 6019–22 constructed in 2000. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

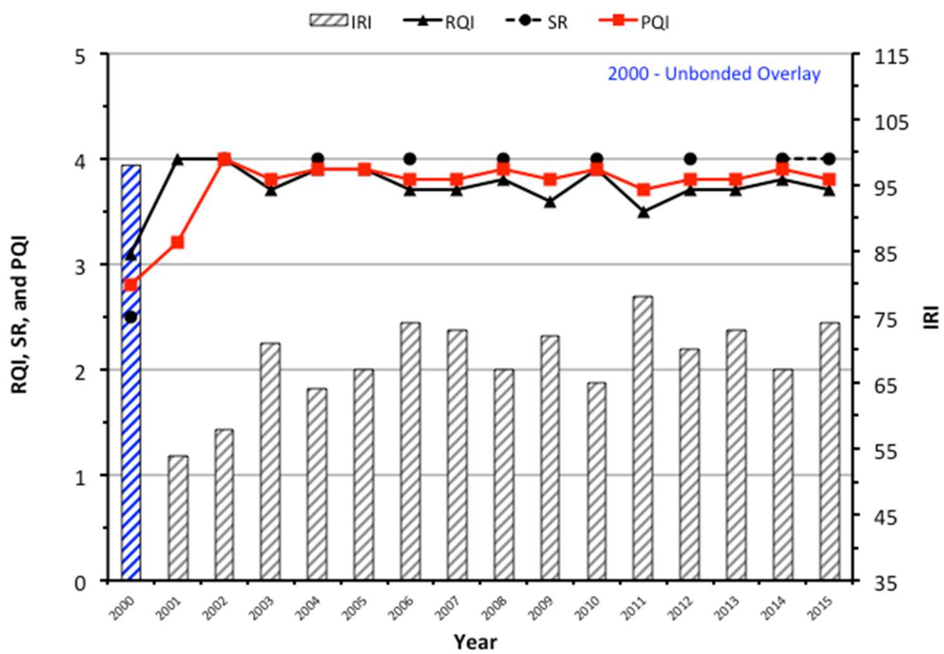


Figure B.17. Pavement management system data for section 3+0.000, direction I, of project 6019–22 constructed in 2000. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

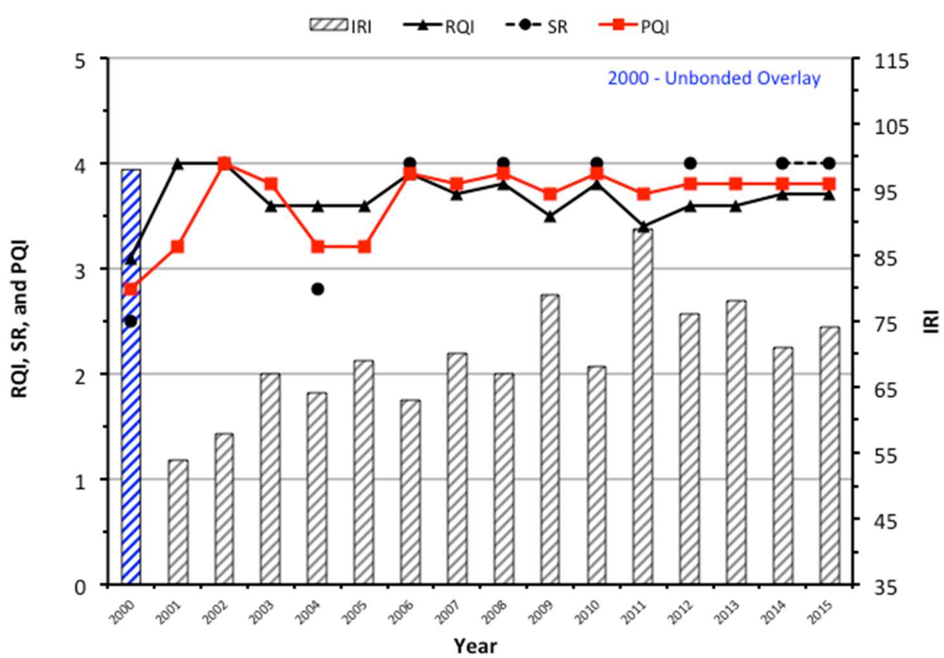


Figure B.18. Pavement management system data for section 4+0.000, direction I, of project 6019–22 constructed in 2000. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

District 3 – 7380-199

Table B.13. Measured IRI for selected sections of project 7380-199, constructed in 1998. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)												
	115 +0.283	116 +0.000	117 +0.000	118 +0.000	119 +0.000	120 +0.000	121 +0.000	122 +0.000	123 +0.000	124 +0.000	125 +0.000	126 +0.000	127 +0.000
Year	I	I	I	I	I	I	I	I	I	I	I	I	I
1998	147	143	150	163	149	122	110	163	154	143	151	132	146
2000	64	56	59	56	60	61	56	61	59	61	68	60	59
2001	70	48	60	51	63	60	51	55	48	66	74	60	51
2002	74	52	72	61	73	89	63	78	69	67	86	76	81
2003	79	67	79	70	79	80	72	78	80	75	81	75	81
2004	74	67	75	71	77	81	69	74	74	75	76	77	84
2005	69	60	66	63	66	68	59	65	62	66	65	67	72
2006	76	66	69	67	71	72	70	70	68	70	68	64	70
2007	74	65	68	66	71	73	64	70	67	68	67	68	73
2008	75	69	71	69	77	73	78	79	68	70	69	69	77
2009	73	64	67	64	68	69	63	68	65	67	67	65	75
2010	68	62	66	63	66	67	60	65	63	68	67	66	74
2011	73	64	70	67	71	72	64	70	67	73	71	71	85
2012	74	64	69	66	73	69	65	68	71	73	71	70	79
2013	72	63	67	66	68	69	62	68	66	69	69	67	78
2014	71	64	70	67	74	73	65	69	67	71	70	69	80
2015	78	67	72	68	72	71	67	71	69	71	70	68	77

Table B.14. Measured PQI for selected sections of project 7380-199, constructed in 1998. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)												
	115 +0.283	116 +0.000	117 +0.000	118 +0.000	119 +0.000	120 +0.000	121 +0.000	122 +0.000	123 +0.000	124 +0.000	125 +0.000	126 +0.000	127 +0.000
Year	I	I	I	I	I	I	I	I	I	I	I	I	I
1998	2.1	2.0	1.7	1.8	1.9	1.9	2.5	1.5	1.6	1.7	1.7	1.8	1.8
2000	3.9	4.0	3.9	4.0	3.9	3.9	4.0	3.9	3.9	3.9	3.8	3.9	3.9
2001	3.9	4.2	4.0	4.1	3.9	4.0	4.0	4.0	4.1	3.9	3.8	3.9	4.1
2002	3.7	4.0	3.8	3.9	3.8	3.7	3.9	3.8	3.8	3.8	3.7	3.8	3.7
2003	3.7	3.9	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.7	3.8	3.8
2004	3.8	3.9	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.7	3.8	3.7
2005	3.9	4.0	3.9	3.9	3.9	3.9	4.0	3.9	4.0	3.9	3.9	3.9	3.8
2006	3.8	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.8
2007	3.8	3.9	3.9	3.9	3.8	3.9	3.9	3.9	3.9	3.8	3.8	3.9	3.8
2008	3.8	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.8
2009	3.8	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.8
2010	3.9	3.9	3.9	3.9	3.9	3.9	4.0	3.9	3.9	3.8	3.8	3.8	3.8
2011	3.8	3.9	3.8	3.8	3.9	3.8	3.9	3.9	3.9	3.8	3.8	3.8	3.7
2012	3.8	3.9	3.9	3.9	3.9	3.9	4.0	3.9	3.9	3.8	3.8	3.9	3.7
2013	3.8	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.8	3.8	3.9	3.7
2014	3.8	3.9	3.8	3.9	3.9	3.9	3.9	3.9	3.9	3.8	3.8	3.8	3.6
2015	3.8	3.9	3.8	3.8	3.8	3.8	3.9	3.8	3.9	3.8	3.8	3.8	3.7

Table B.15. Measured RQI for selected sections of project 7380-199, constructed in 1998. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)												
	115 +0.283	116 +0.000	117 +0.000	118 +0.000	119 +0.000	120 +0.000	121 +0.000	122 +0.000	123 +0.000	124 +0.000	125 +0.000	126 +0.000	127 +0.000
Year	I	I	I	I	I	I	I	I	I	I	I	I	I
1998	2.3	2.4	2.3	2.1	2.3	2.7	2.9	2.1	2.2	2.4	2.3	2.6	2.4
2000	3.8	4.0	3.9	4.0	3.9	3.9	4.0	3.9	3.9	3.9	3.7	3.9	3.9
2001	3.8	4.4	4.0	4.2	3.9	4.0	4.1	4.1	4.2	3.9	3.6	3.9	4.2
2002	3.5	4.1	3.7	3.8	3.7	3.4	3.9	3.6	3.7	3.7	3.4	3.6	3.4
2003	3.5	3.8	3.6	3.7	3.6	3.6	3.7	3.6	3.6	3.6	3.4	3.6	3.6
2004	3.6	3.8	3.6	3.6	3.6	3.6	3.7	3.6	3.7	3.6	3.5	3.6	3.4
2005	3.8	4.0	3.8	3.8	3.9	3.8	4.0	3.9	4.0	3.8	3.8	3.8	3.7
2006	3.6	3.8	3.8	3.8	3.8	3.8	3.9	3.8	3.8	3.8	3.8	3.8	3.7
2007	3.6	3.8	3.8	3.8	3.7	3.8	3.9	3.8	3.8	3.7	3.7	3.8	3.7
2008	3.6	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.7
2009	3.7	3.9	3.8	3.8	3.8	3.8	3.9	3.8	3.9	3.8	3.8	3.8	3.7
2010	3.8	3.9	3.8	3.8	3.8	3.8	4.0	3.8	3.9	3.7	3.7	3.7	3.6
2011	3.7	3.9	3.7	3.7	3.8	3.7	3.9	3.8	3.9	3.7	3.7	3.7	3.5
2012	3.6	3.9	3.8	3.8	3.8	3.8	4.0	3.8	3.9	3.7	3.7	3.8	3.6
2013	3.7	3.9	3.8	3.8	3.8	3.8	3.9	3.8	3.9	3.7	3.7	3.8	3.5
2014	3.7	3.8	3.7	3.8	3.8	3.8	3.9	3.8	3.9	3.7	3.7	3.7	3.5
2015	3.6	3.8	3.7	3.7	3.7	3.7	3.8	3.8	3.8	3.7	3.7	3.7	3.6

Table B.16. Measured SR for selected sections of project 7380-199, constructed in 1998. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)												
	115 +0.283	116 +0.000	117 +0.000	118 +0.000	119 +0.000	120 +0.000	121 +0.000	122 +0.000	123 +0.000	124 +0.000	125 +0.000	126 +0.000	127 +0.000
Year	I	I	I	I	I	I	I	I	I	I	I	I	I
1998	1.9	1.6	1.3	1.5	1.6	1.3	2.2	1.1	1.2	1.2	1.3	1.2	1.3
2000	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2001													
2002	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2003	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2004	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2005													
2006	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2007													
2008	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2009	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2010	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2011	3.9	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2012	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.9
2013	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.9
2014	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.8
2015	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.9	4.0	4.0	4.0	4.0	3.9

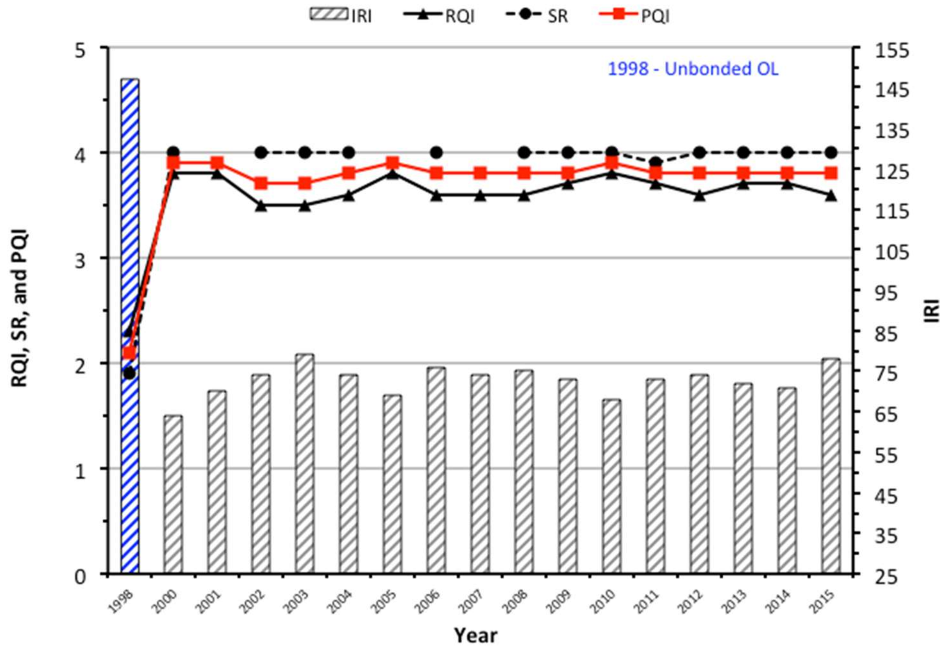


Figure B.19. Pavement management system data for section 115+0.283, direction I, of project 7380–199 constructed in 1998. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

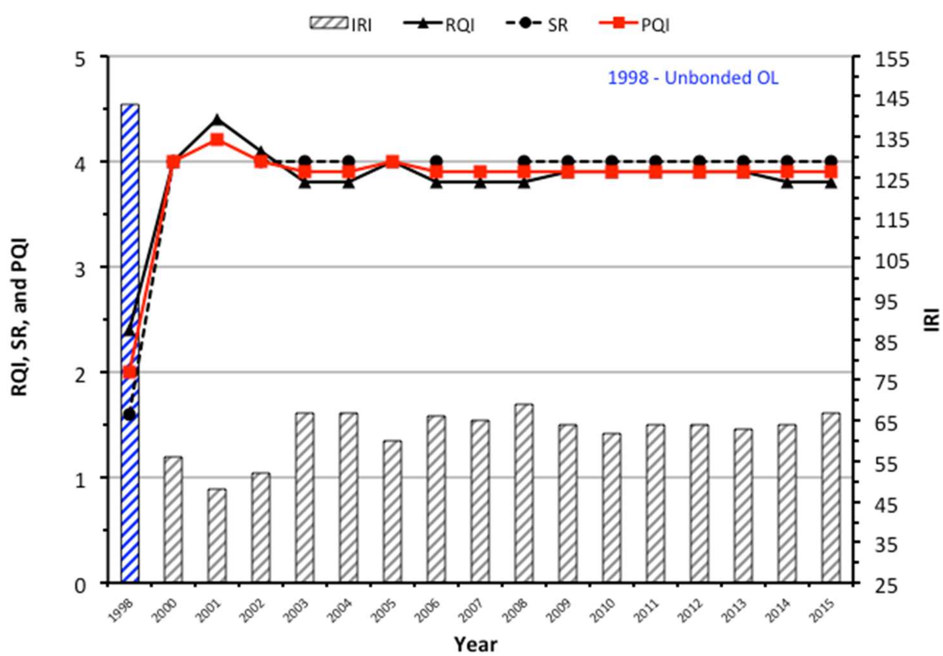


Figure B.20. Pavement management system data for section 116+0.000, direction I, of project 7380–199 constructed in 1998. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

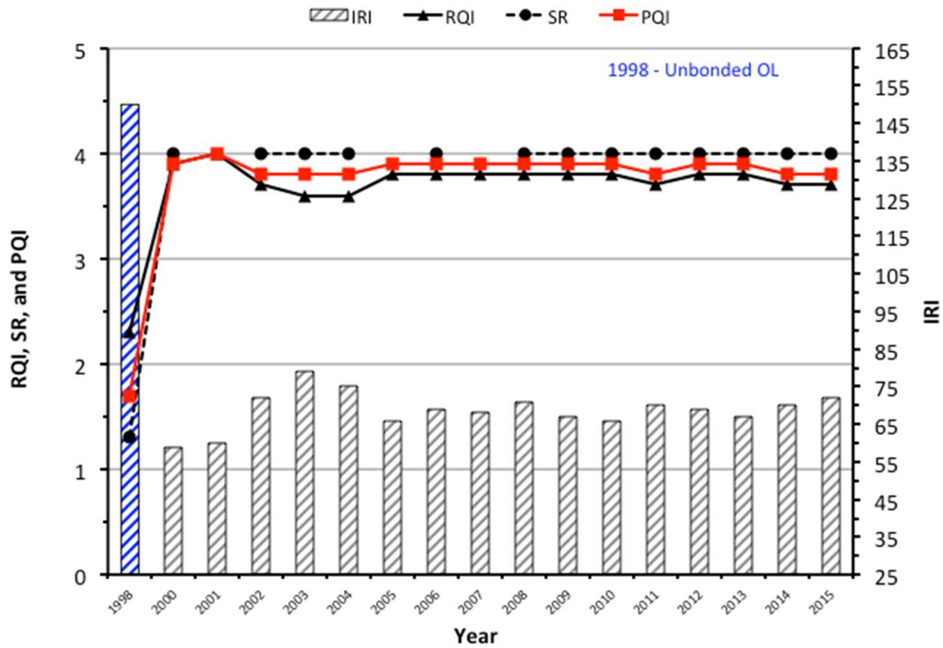


Figure B.21. Pavement management system data for section 117+0.000, direction I, of project 7380–199 constructed in 1998. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

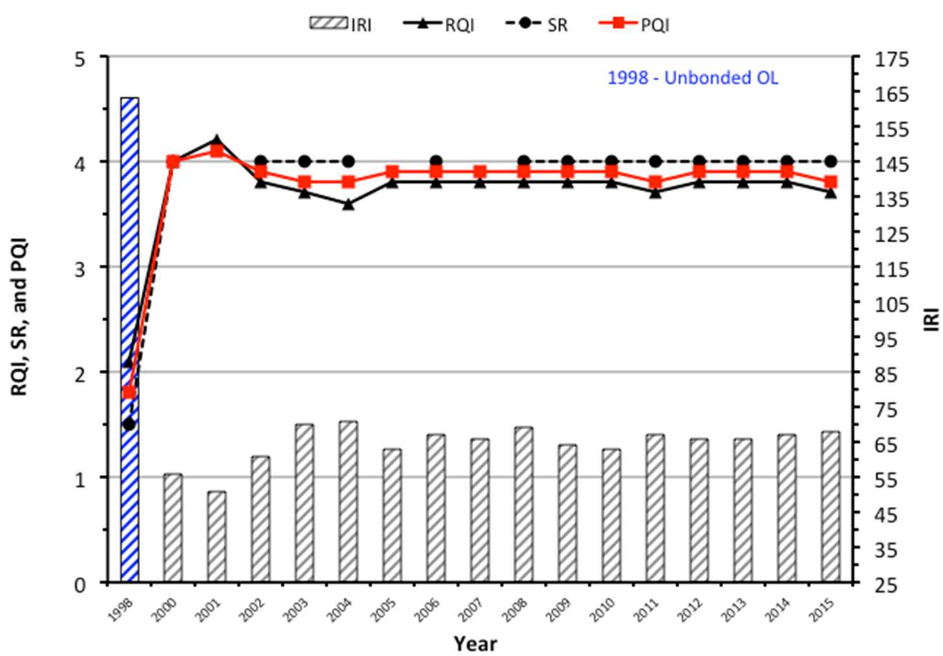


Figure B.22. Pavement management system data for section 118+0.000, direction I, of project 7380–199 constructed in 1998. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

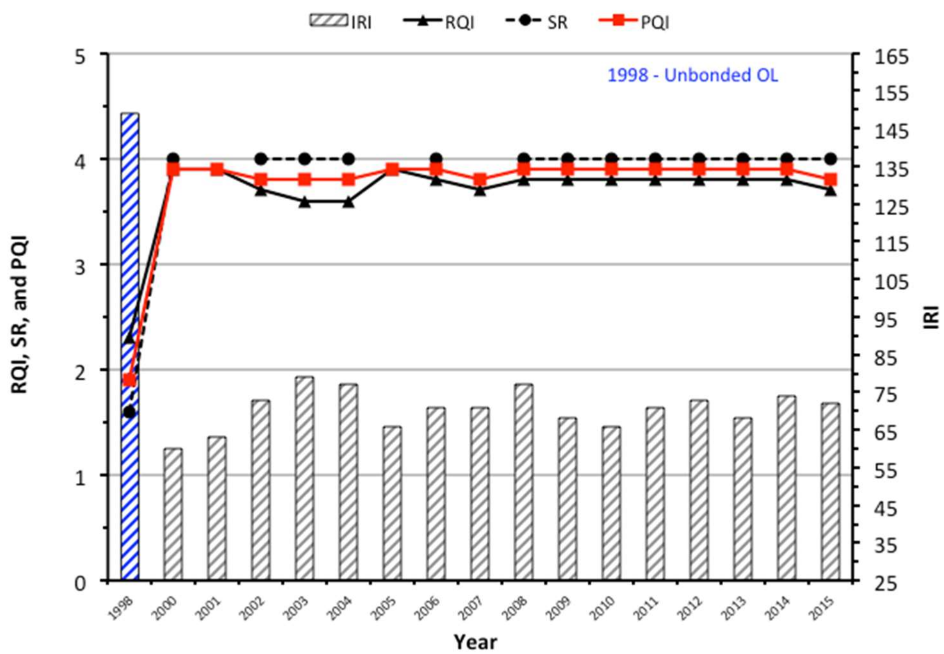


Figure B.23. Pavement management system data for section 119+0.000, direction I, of project 7380–199 constructed in 1998. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

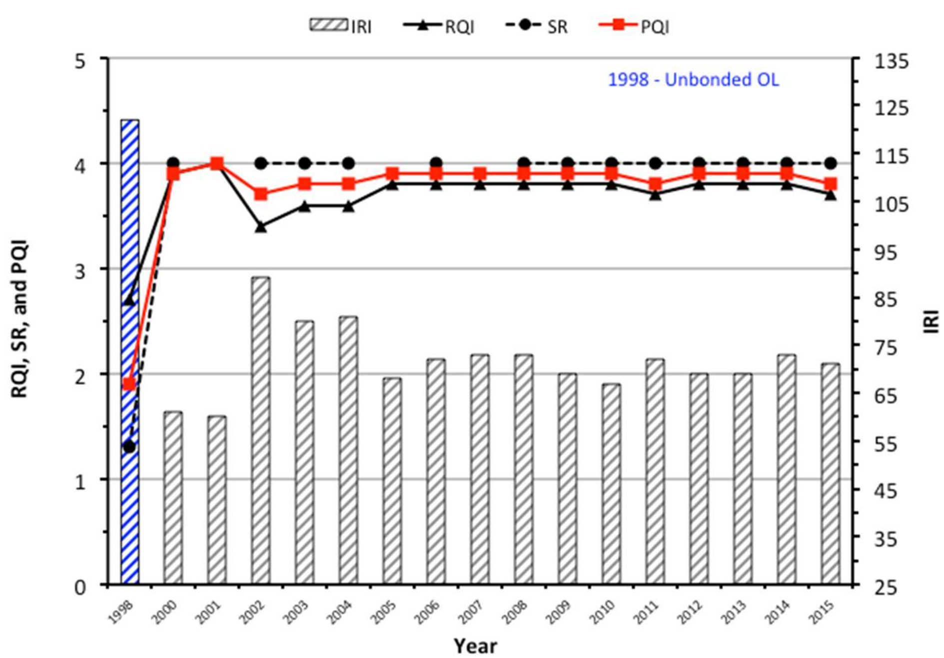


Figure B.24. Pavement management system data for section 120+0.000, direction I, of project 7380–199 constructed in 1998. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

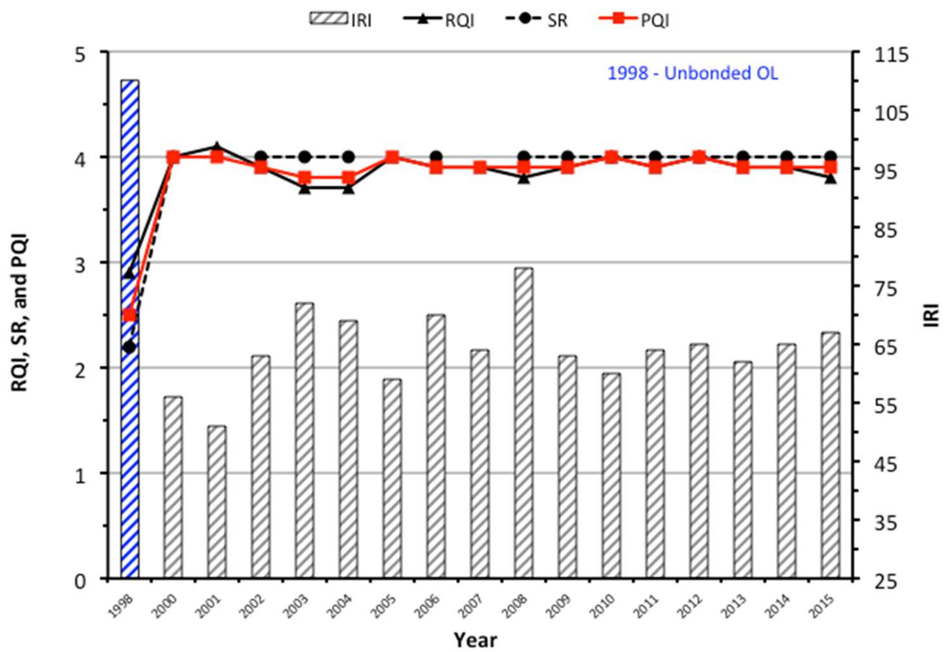


Figure B.25. Pavement management system data for section 121+0.000, direction I, of project 7380–199 constructed in 1998. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

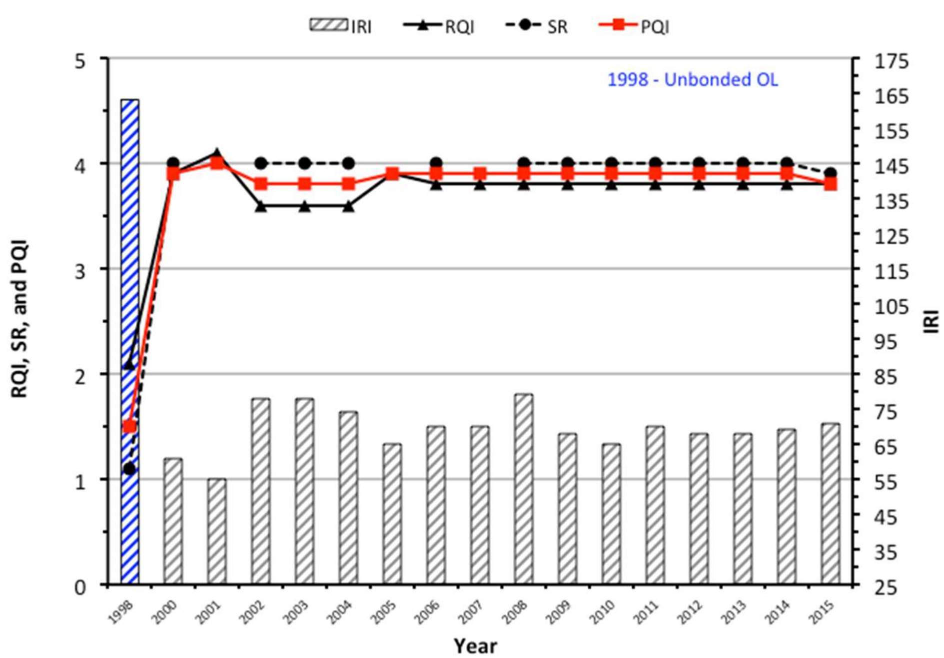


Figure B.26. Pavement management system data for section 122+0.000, direction I, of project 7380–199 constructed in 1998. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

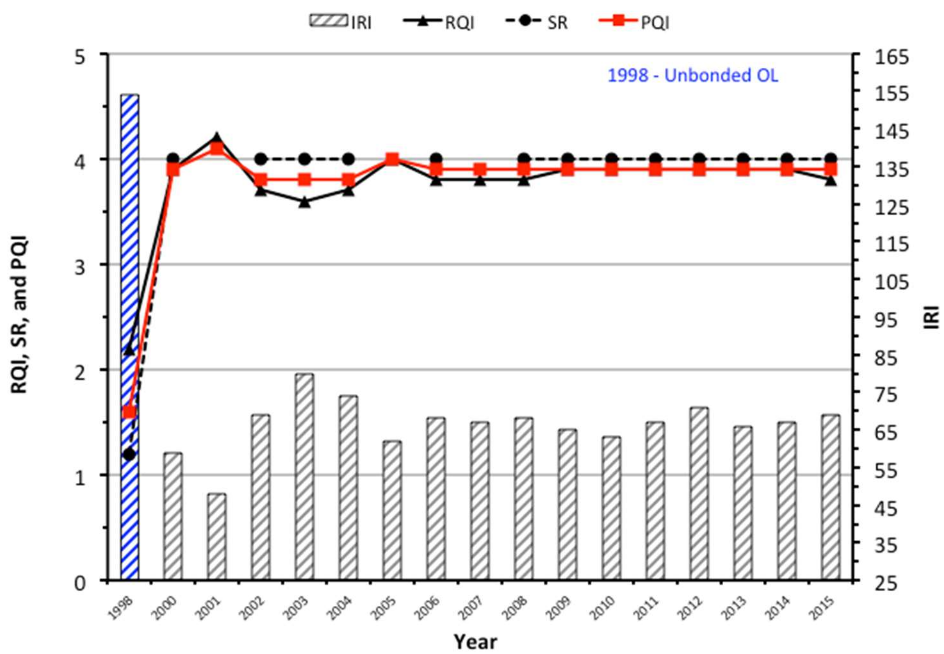


Figure B.27. Pavement management system data for section 123+0.000, direction I, of project 7380–199 constructed in 1998. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

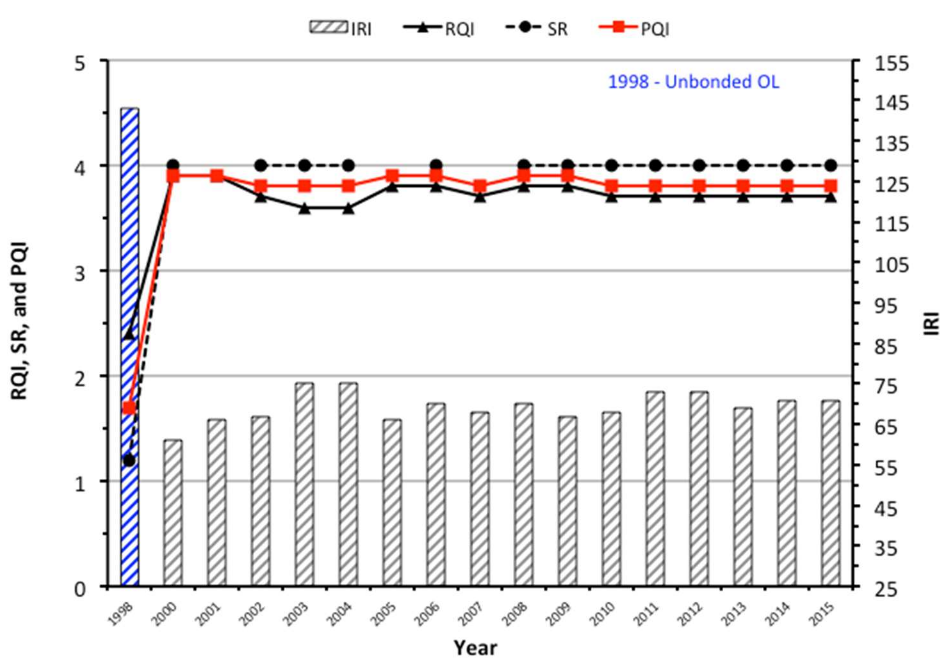


Figure B.28. Pavement management system data for section 124+0.000, direction I, of project 7380–199 constructed in 1998. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

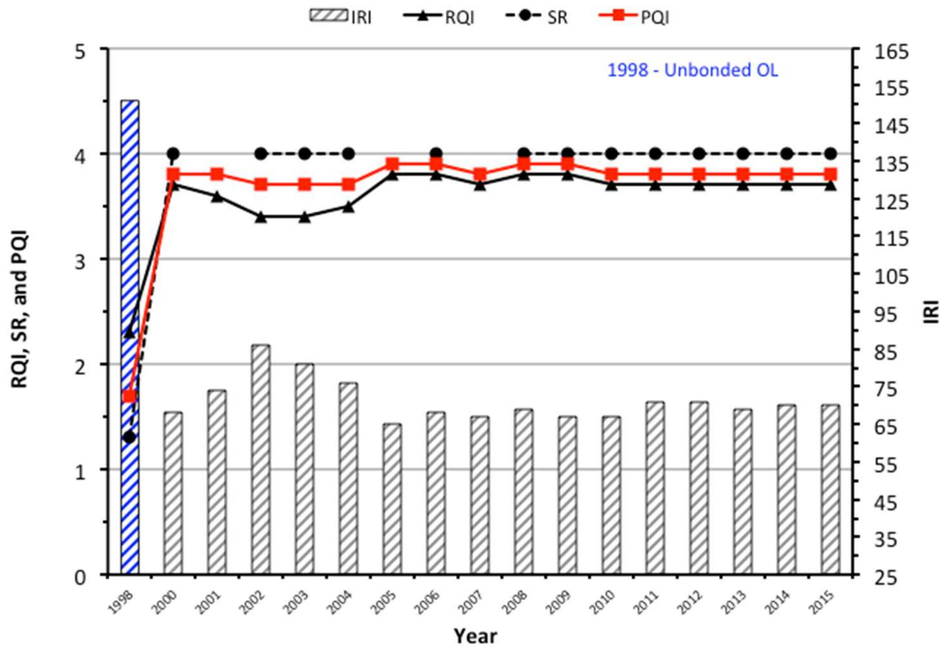


Figure B.29. Pavement management system data for section 125+0.000, direction I, of project 7380–199 constructed in 1998. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

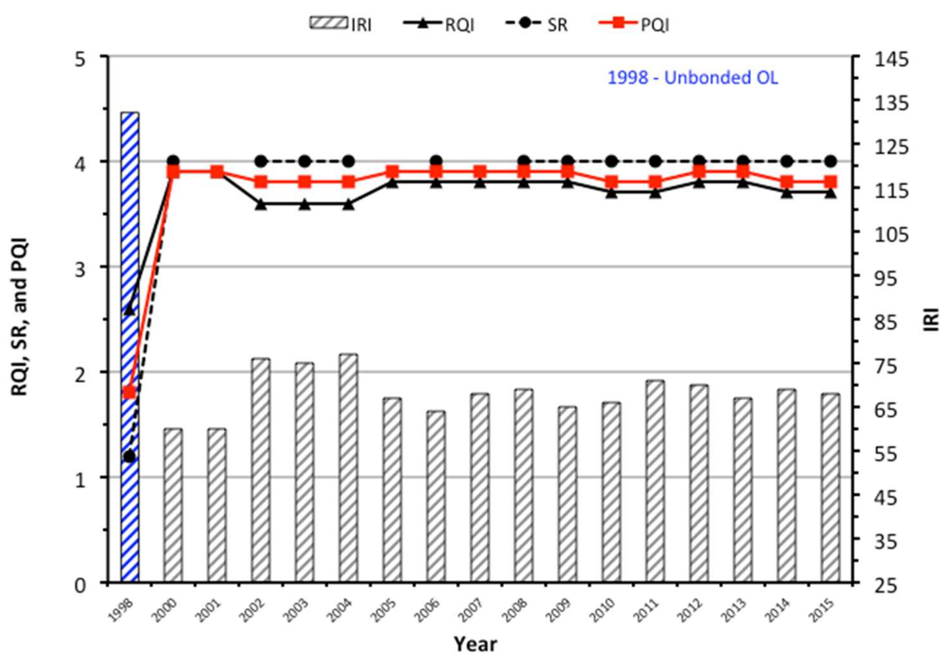


Figure B.30. Pavement management system data for section 126+0.000, direction I, of project 7380–199 constructed in 1998. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

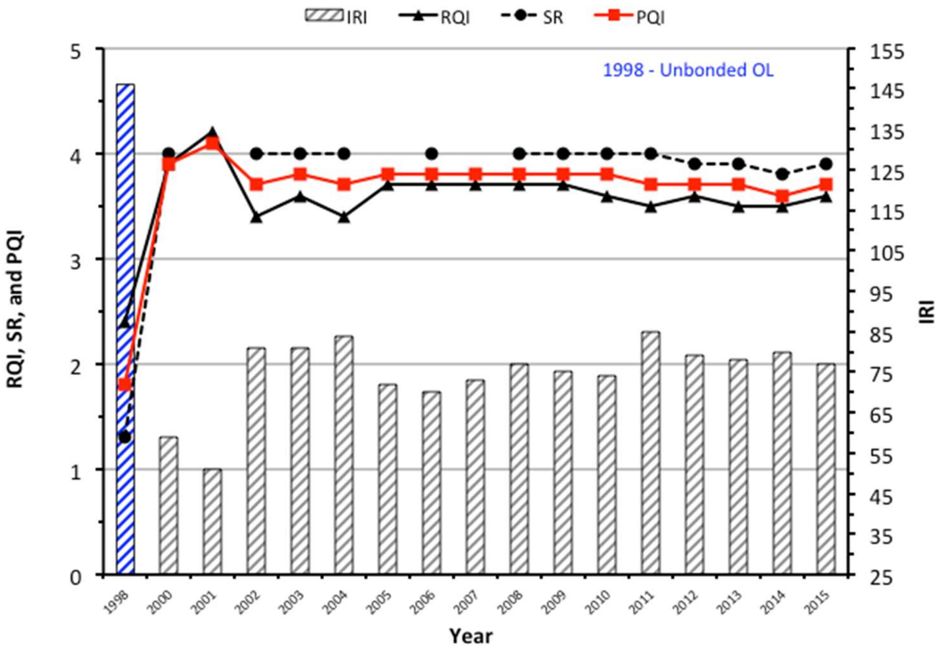


Figure B.31. Pavement management system data for section 127+0.000, direction I, of project 7380–199 constructed in 1998. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

District 3 – 7380-200

Table B.17. Measured IRI for selected sections of project 7380-200, constructed in 1999. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)												
	115 +0.283	116 +0.000	117 +0.000	118 +0.000	119 +0.000	120 +0.000	121 +0.000	122 +0.000	123 +0.000	124 +0.000	125 +0.000	126 +0.000	127 +0.000
Year	D	D	D	D	D	D	D	D	D	D	D	D	D
1999	127	132	139	139	129	117	99	142	127	135	153	151	125
2001	73	50	53	56	63	60	51	55	48	66	74	60	51
2002	83	55	61	67	75	67	62	64	52	72	92	76	54
2003	75	71	78	77	76	78	65	68	67	67	78	68	88
2004	78	70	80	77	80	83	70	77	73	74	84	74	87
2005	71	66	74	72	72	75	62	68	65	63	68	64	82
2006	67	65	70	67	68	68	60	65	64	61	68	56	72
2007	72	68	73	72	73	74	62	68	68	63	70	62	80
2008	80	72	83	84	78	79	67	73	73	71	76	70	86
2009	73	69	74	73	74	75	63	68	67	63	70	66	78
2010	74	74	80	75	80	79	67	73	73	68	72	67	84
2011	79	75	83	79	83	83	67	76	74	70	76	71	86
2012	79	75	80	86	86	79	69	72	71	69	78	72	90
2013	82	78	84	79	83	84	70	77	75	70	78	73	90
2014	83	79	86	83	83	80	67	74	74	69	75	72	86
2015	80	77	83	80	82	77	65	73	74	67	76	68	81

Table B.18. Measured PQI for selected sections of project 7380-200, constructed in 1999. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)												
	115 +0.283	116 +0.000	117 +0.000	118 +0.000	119 +0.000	120 +0.000	121 +0.000	122 +0.000	123 +0.000	124 +0.000	125 +0.000	126 +0.000	127 +0.000
Year	D	D	D	D	D	D	D	D	D	D	D	D	D
1999	2.1	2.2	2.1	2.2	2.0	2.2	2.8	2.3	2.0	2.1	1.7	1.8	2.7
2001	2.5	4.1	4.0	4.0	3.9	4.0	4.0	4.0	4.1	3.9	3.8	3.9	4.1
2002	2.3	4.0	3.9	3.9	3.7	3.8	3.8	3.9	4.0	3.7	3.6	3.7	4.0
2003	3.7	3.8	3.7	3.8	3.7	3.7	3.8	3.9	3.9	3.8	3.7	3.9	3.7
2004	3.7	3.8	3.7	3.8	3.7	3.7	3.8	3.8	3.8	3.8	3.7	3.8	3.6
2005	3.8	3.9	3.8	3.8	3.8	3.8	3.9	3.8	3.9	3.9	3.8	3.9	3.7
2006	3.9	3.9	3.8	3.9	3.8	3.8	3.9	3.9	3.9	3.9	3.8	4.0	3.8
2007	3.8	3.8	3.8	3.8	3.8	3.8	3.9	3.8	3.8	3.9	3.8	3.9	3.7
2008	3.7	3.8	3.8	3.8	3.7	3.7	3.8	3.8	3.8	3.8	3.8	3.8	3.7
2009	3.8	3.8	3.8	3.8	3.8	3.8	3.9	3.8	3.9	3.9	3.8	3.9	3.8
2010	3.8	3.8	3.7	3.8	3.7	3.7	3.8	3.8	3.8	3.8	3.8	3.8	3.7
2011	3.7	3.8	3.7	3.8	3.7	3.7	3.8	3.8	3.8	3.8	3.7	3.8	3.6
2012	3.7	3.8	3.8	3.8	3.7	3.7	3.8	3.8	3.8	3.8	3.8	3.8	3.7
2013	3.6	3.7	3.7	3.8	3.7	3.7	3.8	3.8	3.8	3.8	3.7	3.8	3.6
2014	3.6	3.7	3.7	3.7	3.7	3.7	3.8	3.8	3.7	3.8	3.8	3.8	3.7
2015	3.6	3.7	3.7	3.7	3.7	3.8	3.8	3.8	3.7	3.7	3.7	3.9	3.7

Table B.19. Measured RQI for selected sections of project 7380-200, constructed in 1999. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)												
	115 +0.283	116 +0.000	117 +0.000	118 +0.000	119 +0.000	120 +0.000	121 +0.000	122 +0.000	123 +0.000	124 +0.000	125 +0.000	126 +0.000	127 +0.000
Year	D	D	D	D	D	D	D	D	D	D	D	D	D
1999	2.7	2.6	2.5	2.5	2.6	2.8	3.1	2.4	2.7	2.5	2.3	2.3	2.7
2001	3.8	4.2	4.1	4.1	3.9	4.0	4.1	4.1	4.2	3.9	3.6	3.9	4.2
2002	3.4	4.0	3.9	3.8	3.5	3.7	3.7	3.8	4.0	3.5	3.3	3.5	4.0
2003	3.5	3.6	3.5	3.7	3.5	3.5	3.7	3.8	3.8	3.7	3.5	3.8	3.4
2004	3.5	3.7	3.5	3.6	3.4	3.4	3.6	3.6	3.6	3.6	3.4	3.6	3.3
2005	3.7	3.8	3.7	3.7	3.6	3.6	3.8	3.7	3.8	3.8	3.7	3.9	3.5
2006	3.8	3.8	3.7	3.8	3.7	3.7	3.8	3.8	3.8	3.9	3.7	4.0	3.7
2007	3.7	3.7	3.6	3.7	3.6	3.6	3.8	3.7	3.7	3.8	3.7	3.9	3.5
2008	3.5	3.7	3.6	3.7	3.5	3.5	3.7	3.7	3.7	3.7	3.6	3.7	3.4
2009	3.6	3.7	3.6	3.7	3.6	3.6	3.8	3.7	3.8	3.8	3.7	3.9	3.6
2010	3.6	3.6	3.5	3.6	3.5	3.5	3.7	3.7	3.6	3.7	3.6	3.7	3.4
2011	3.5	3.6	3.5	3.6	3.4	3.4	3.7	3.6	3.6	3.7	3.5	3.7	3.3
2012	3.6	3.7	3.6	3.6	3.5	3.5	3.7	3.6	3.7	3.7	3.6	3.8	3.4
2013	3.4	3.5	3.5	3.6	3.4	3.4	3.6	3.6	3.6	3.7	3.5	3.7	3.3
2014	3.4	3.5	3.4	3.5	3.4	3.5	3.7	3.6	3.6	3.7	3.6	3.7	3.4
2015	3.5	3.6	3.4	3.5	3.4	3.6	3.7	3.7	3.6	3.7	3.5	3.8	3.5

Table B.20. Measured SR for selected sections of project 7380-200, constructed in 1999. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)												
	115 +0.283	116 +0.000	117 +0.000	118 +0.000	119 +0.000	120 +0.000	121 +0.000	122 +0.000	123 +0.000	124 +0.000	125 +0.000	126 +0.000	127 +0.000
Year	D	D	D	D	D	D	D	D	D	D	D	D	D
1999	1.6	1.8	1.7	1.9	1.6	1.8	2.5	2.2	1.5	1.7	1.3	1.4	2.7
2001		4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2002													
2003	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2004													
2005	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2006													4.0
2007													
2008	3.9	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2009	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2010	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2011	3.9	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.9	4.0	4.0	4.0
2012	3.9	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.9	4.0
2013	3.9	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2014	3.9	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.9	3.9	4.0	3.9	4.0
2015	3.8	3.8	4.0	4.0	4.0	4.0	4.0	4.0	3.9	3.8	4.0	4.0	4.0

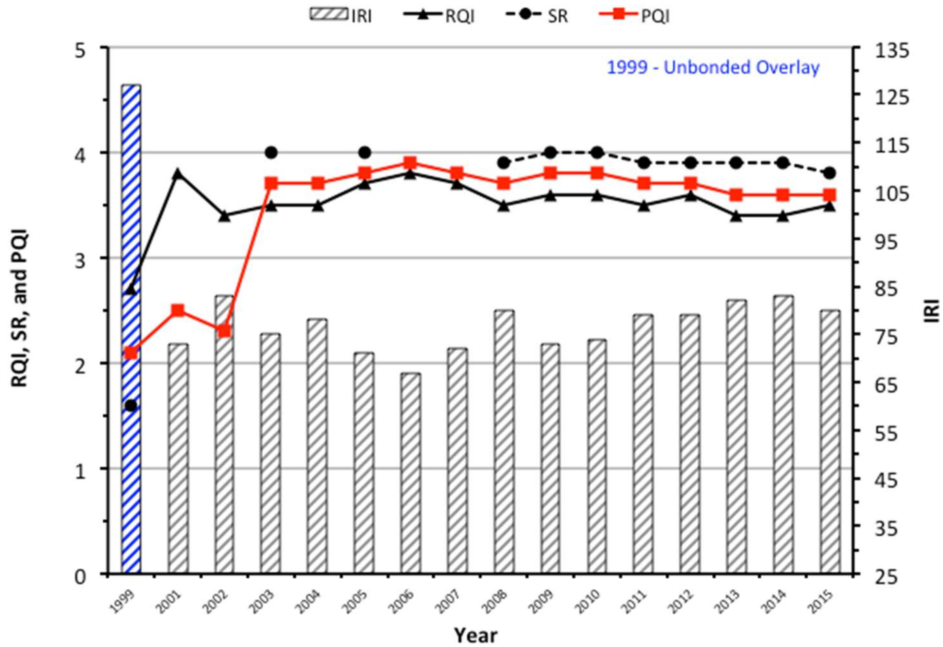


Figure B.32. Pavement management system data for section 115+0.283, direction D, of project 7380–200 constructed in 1999. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

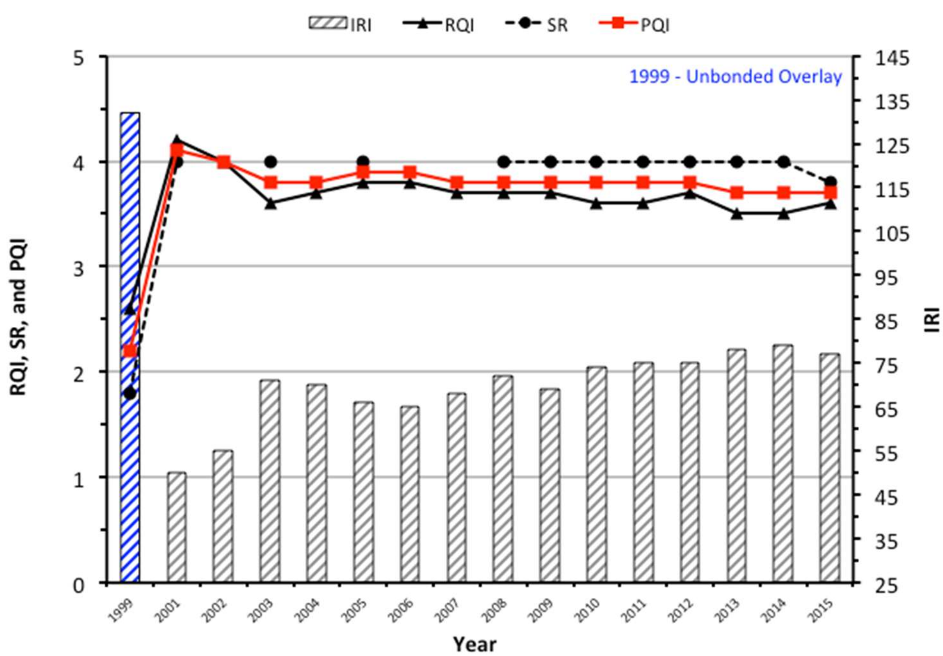


Figure B.33. Pavement management system data for section 116+0.000, direction D, of project 7380–200 constructed in 1999. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

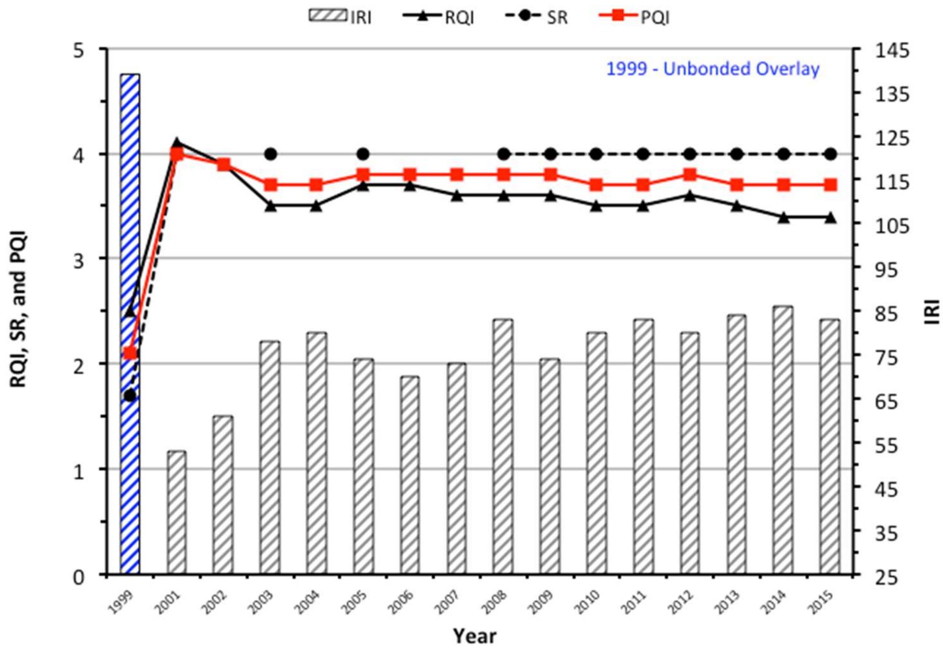


Figure B.34. Pavement management system data for section 117+0.000, direction D, of project 7380–200 constructed in 1999. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

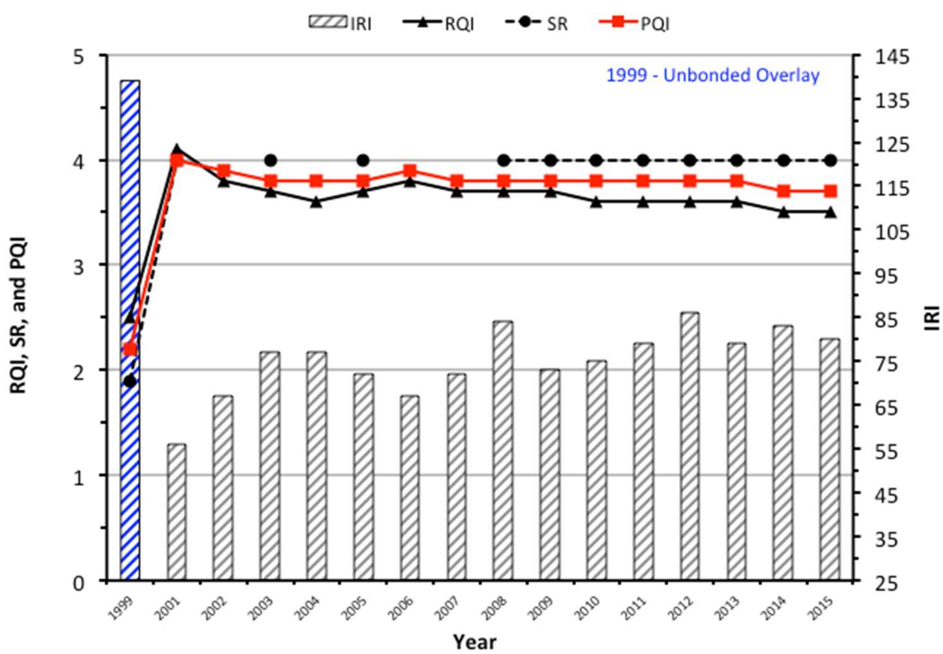


Figure B.35. Pavement management system data for section 118+0.000, direction D, of project 7380–200 constructed in 1999. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

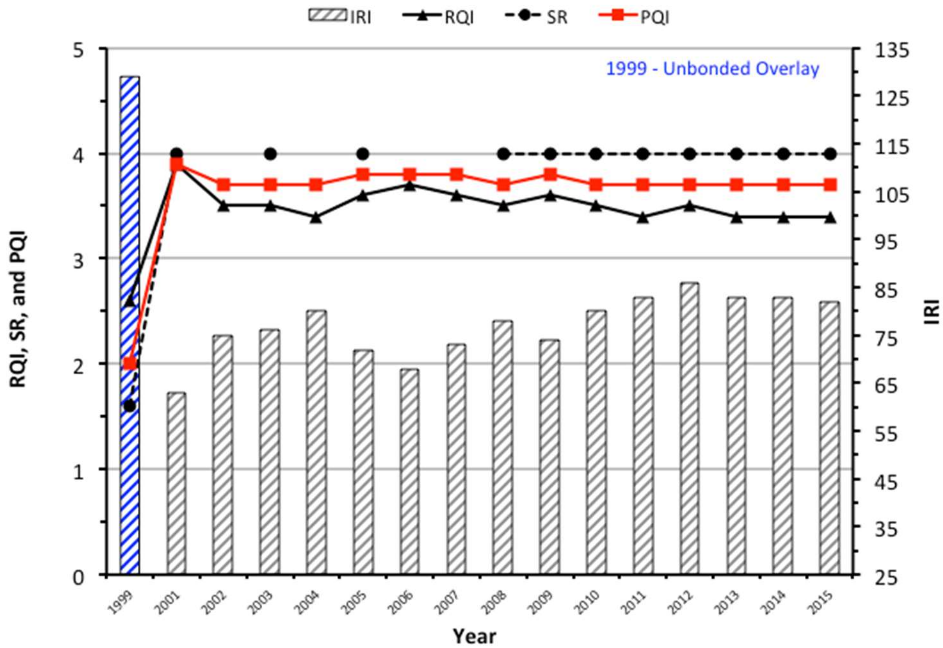


Figure B.36. Pavement management system data for section 119+0.000, direction D, of project 7380–200 constructed in 1999. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

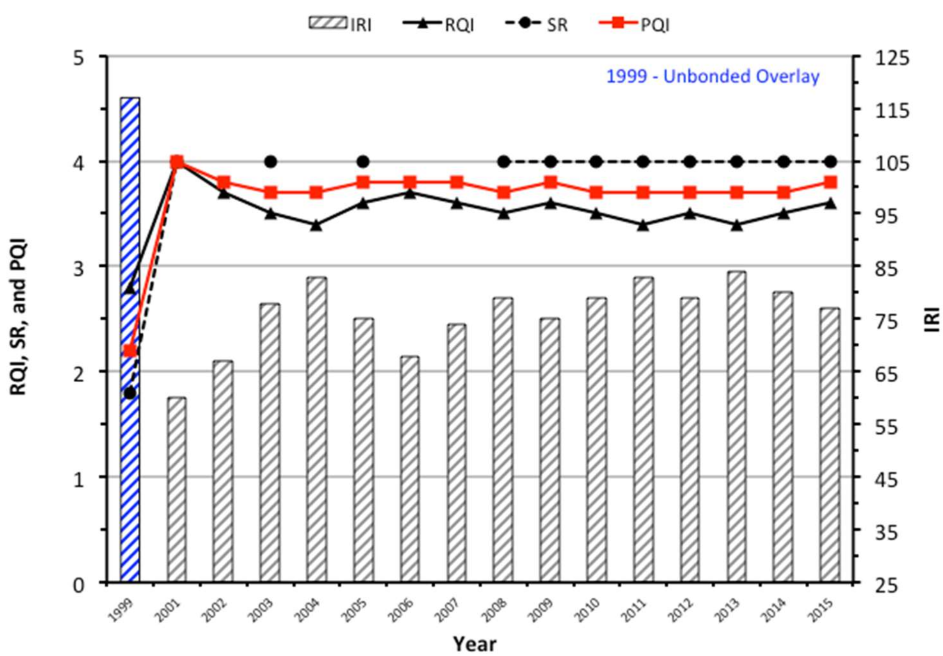


Figure B.37. Pavement management system data for section 120+0.000, direction D, of project 7380–200 constructed in 1999. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

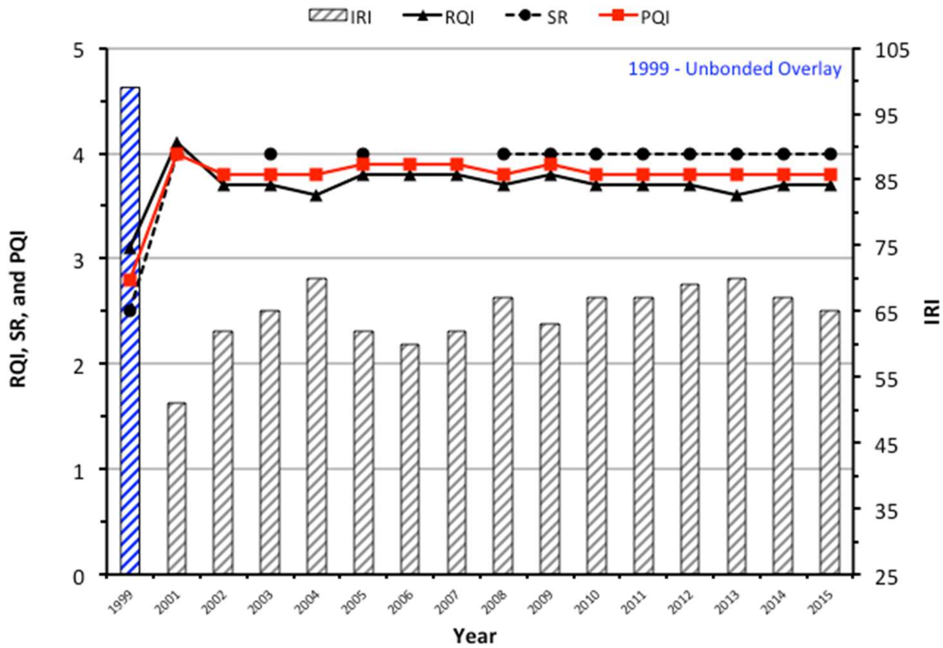


Figure B.38. Pavement management system data for section 121+0.000, direction D, of project 7380–200 constructed in 1999. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

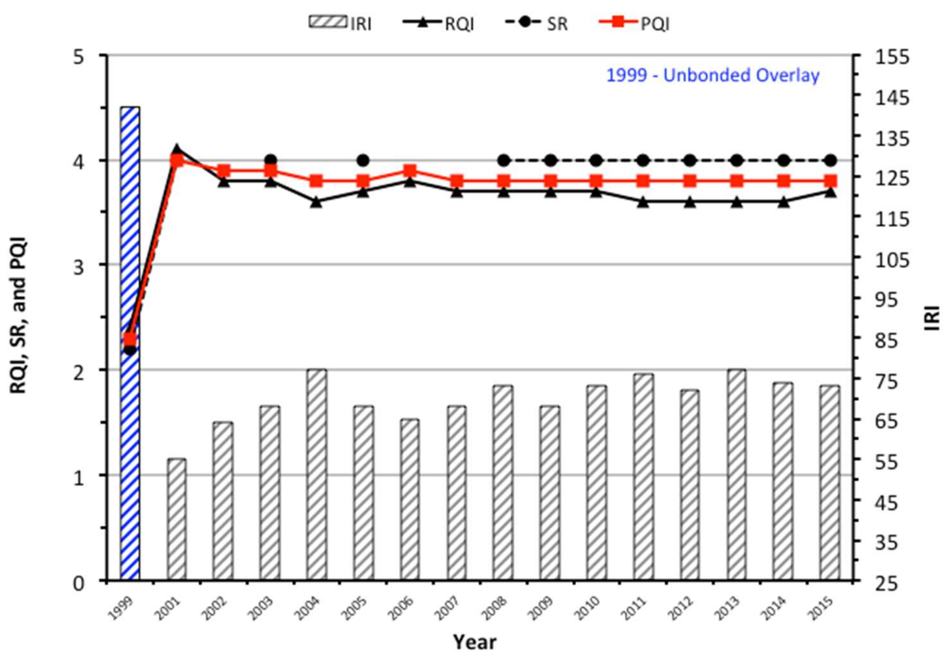


Figure B.39. Pavement management system data for section 122+0.000, direction D, of project 7380–200 constructed in 1999. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

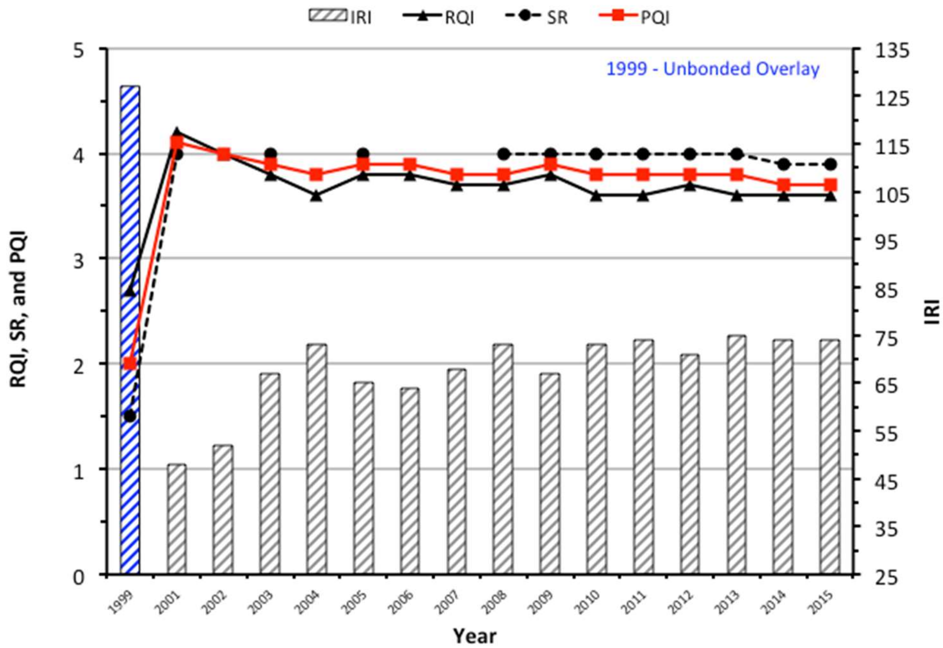


Figure B.40. Pavement management system data for section 123+0.000, direction D, of project 7380–200 constructed in 1999. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

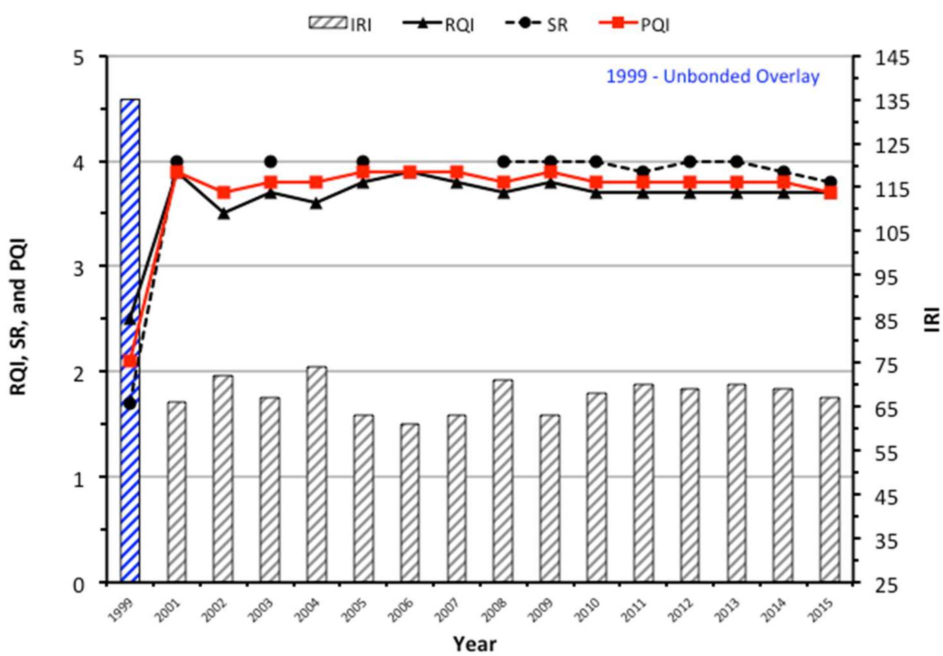


Figure B.41. Pavement management system data for section 124+0.000, direction D, of project 7380–200 constructed in 1999. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

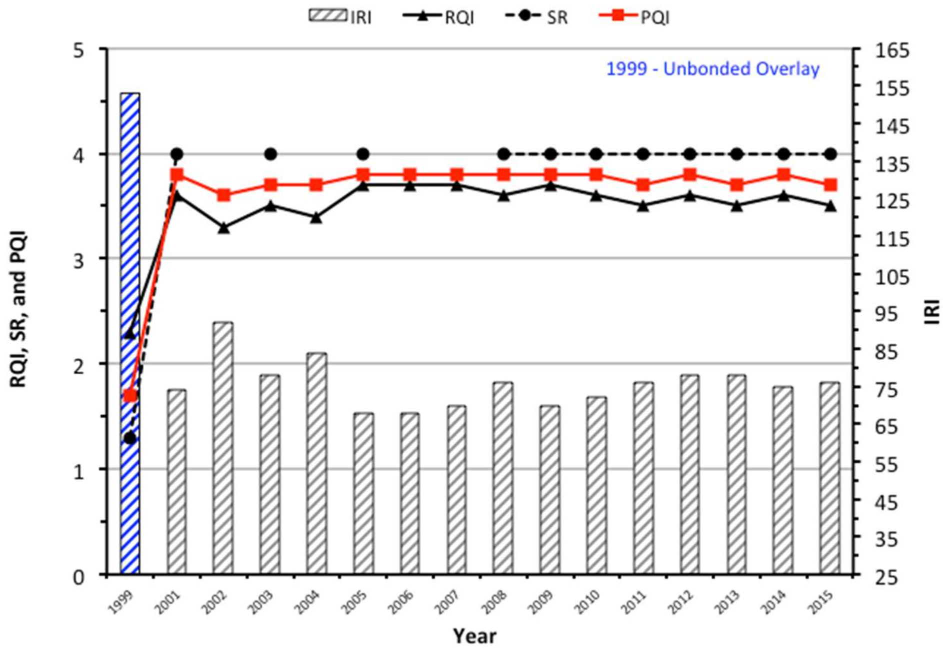


Figure B.42. Pavement management system data for section 125+0.000, direction D, of project 7380–200 constructed in 1999. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

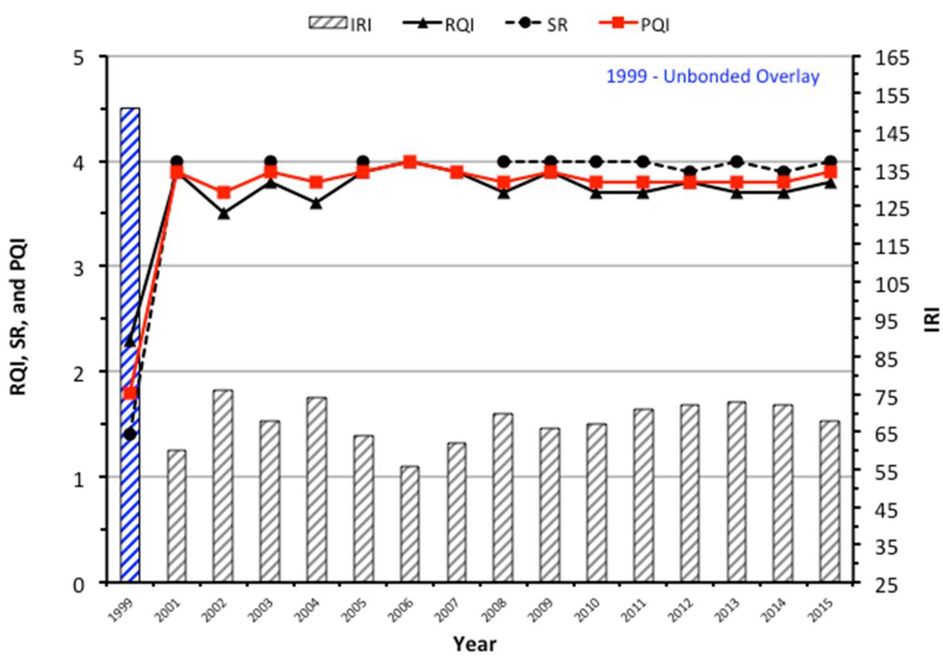


Figure B.43. Pavement management system data for section 126+0.000, direction D, of project 7380–200 constructed in 1999. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

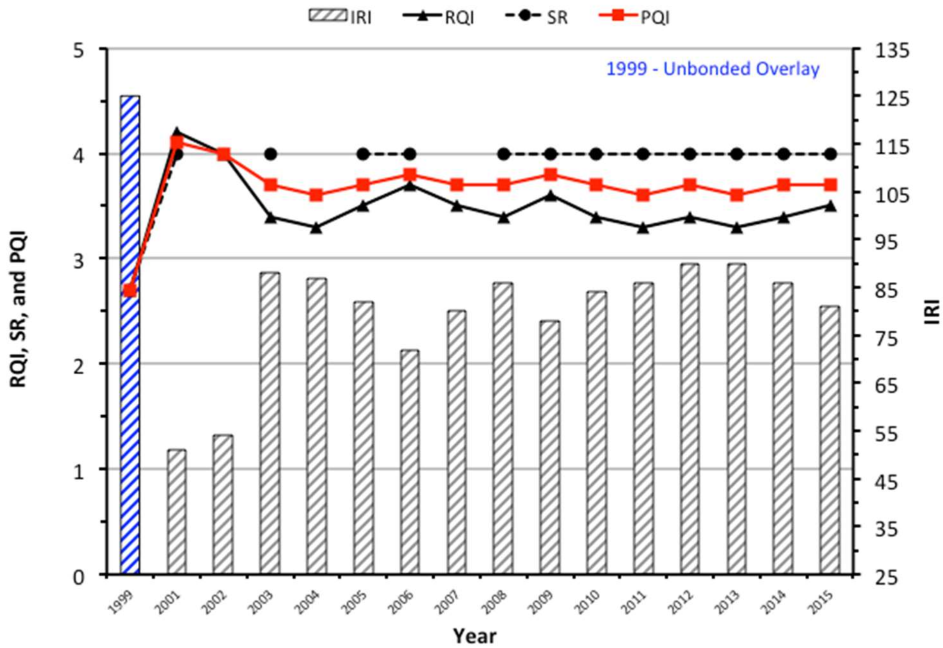


Figure B.44. Pavement management system data for section 127+0.000, direction D, of project 7380–200 constructed in 1999. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

District 4 – 1480-131

Table B.21. Measured IRI for selected sections of project 1480-131, constructed in 1998. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)												
	24 +0.040	25 +0.000	26 +0.000	27 +0.000	28 +0.000	29 +0.000	30 +0.000	25 +0.000	26 +0.000	27 +0.000	28 +0.000	29 +0.000	30 +0.000
Year	D	D	D	D	D	D	D	I	I	I	I	I	I
1998	101	77	73	74	110	125	158	84	86	80	94	108	122
1999	49	41	42	40	45	45	48	87	91	80	106	115	139
2000	48	44	44	42	46	46	49	104	101	91	108	120	148
2001	52	36	44	36	54	48	63	43	47	32	45	41	54
2002	50	52	44	33	59	43	57	37	38	26	45	41	57
2003	71	61	74	71	83	70	71	61	61	60	63	65	68
2004	72	59	67	61	79	67	70	54	58	54	55	56	63
2005	60	48	48	49	56	55	60	50	52	50	50	55	61
2006	55	49	48	47	55	52	59	49	50	50	50	52	60
2007	76	54	51	51	59	61	67	61	59	59	56	60	67
2008	64	54	54	52	62	62	68	56	57	55	52	57	63
2009	79	57	58	54	64	63	70	68	66	65	59	61	75
2010	68	52	48	50	57	56	62	56	54	54	53	60	66
2011	75	67	64	62	71	76	81	64	63	62	60	61	72
2012	73	67	63	64	67	77	81	63	62	61	56	60	71
2013	74	62	61	59	66	72	77	62	62	60	55	60	73
2014	65	59	50	50	57	61	66	68	65	66	60	61	71
2015	74	61	56	54	64	66	71	75	72	72	63	67	77

Table B.22. Measured PQI for selected sections of project 1480-131, constructed in 1998. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)												
	24 +0.040	25 +0.000	26 +0.000	27 +0.000	28 +0.000	29 +0.000	30 +0.000	25 +0.000	26 +0.000	27 +0.000	28 +0.000	29 +0.000	30 +0.000
Year	D	D	D	D	D	D	D	I	I	I	I	I	I
1998	3.0	3.3	3.6	3.5	2.7	2.6	2.1	3.4	3.4	3.3	3.3	2.9	2.8
1999	4.1	4.2	4.1	4.2	4.1	4.1	4.1	3.1	3.3	3.3	3.1	3.0	3.1
2000	4.1	4.1	4.1	4.1	4.1	4.1	4.1	2.7	3.0	3.1	3.0	2.7	2.5
2001	4.1	4.3	4.2	4.3	4.1	4.1	4.0	4.2	4.2	4.3	4.1	4.2	4.0
2002	4.1	4.1	4.2	4.3	4.0	4.2	4.0	4.2	4.2	4.4	4.1	4.2	3.9
2003	3.9	4.0	3.8	3.9	3.7	3.9	3.9	3.9	3.9	3.9	3.9	3.8	3.8
2004	3.8	4.0	3.9	3.9	3.8	3.9	3.8	4.0	4.0	4.0	4.0	3.9	3.8
2005	4.0	4.1	4.1	4.1	4.0	4.0	4.0	4.0	4.0	4.0	4.1	4.0	3.9
2006	4.0	4.1	4.1	4.1	4.1	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.9
2007	3.8	4.0	4.1	4.1	4.0	3.9	3.9	3.9	3.9	3.9	4.0	3.9	3.8
2008	3.9	4.0	4.1	4.1	4.0	3.9	3.9	3.9	4.0	4.0	4.0	4.0	3.8
2009	3.7	4.0	4.0	3.9	3.9	3.9	3.8	3.8	3.8	3.9	3.9	3.9	3.7
2010	3.9	4.0	4.1	4.1	4.0	4.0	3.9	3.9	4.0	4.0	4.0	4.0	3.9
2011	3.8	3.9	3.9	3.8	3.9	3.7	3.7	3.9	3.9	3.9	3.9	3.9	3.7
2012	3.8	3.9	3.9	3.8	3.9	3.7	3.7	3.9	3.9	3.9	4.0	3.9	3.7
2013	3.8	3.9	3.9	3.9	3.9	3.7	3.7	3.7	3.8	3.9	4.0	3.9	3.6
2014	3.8	3.9	4.1	3.9	3.9	3.7	3.8	3.8	3.8	3.8	3.9	3.9	3.7
2015	3.8	3.9	4.0	3.9	4.0	3.8	3.8	3.7	3.7	3.8	3.9	3.9	3.6

Table B.23. Measured RQI for selected sections of project 1480-131, constructed in 1998. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)												
	24 +0.040	25 +0.000	26 +0.000	27 +0.000	28 +0.000	29 +0.000	30 +0.000	25 +0.000	26 +0.000	27 +0.000	28 +0.000	29 +0.000	30 +0.000
Year	D	D	D	D	D	D	D	I	I	I	I	I	I
1998	3.1	3.5	3.6	3.6	2.9	2.7	2.2	3.4	3.4	3.5	3.2	3.0	2.7
1999	4.2	4.4	4.3	4.4	4.3	4.3	4.2	3.3	3.3	3.5	3.0	2.8	2.5
2000	4.2	4.3	4.3	4.3	4.2	4.2	4.2	3.0	3.1	3.3	3.0	2.8	2.3
2001	4.3	4.7	4.5	4.7	4.3	4.4	4.1	4.5	4.4	4.7	4.3	4.4	4.1
2002	4.2	4.2	4.4	4.7	4.1	4.4	4.1	4.5	4.5	4.9	4.3	4.4	4.0
2003	3.8	4.0	3.7	3.8	3.4	3.9	3.8	3.9	3.9	3.9	3.8	3.7	3.7
2004	3.7	4.0	3.8	3.9	3.6	3.8	3.7	4.0	4.0	4.0	4.0	3.9	3.8
2005	4.0	4.3	4.3	4.3	4.1	4.2	4.0	4.1	4.1	4.1	4.2	4.1	3.9
2006	4.1	4.2	4.3	4.3	4.2	4.2	4.0	4.1	4.1	4.1	4.1	4.1	3.9
2007	3.6	4.1	4.2	4.2	4.0	3.9	3.8	3.8	3.9	3.9	4.0	3.9	3.7
2008	3.9	4.1	4.2	4.2	4.0	4.0	3.8	3.9	4.0	4.0	4.1	4.0	3.8
2009	3.5	4.0	4.1	4.1	3.9	3.9	3.7	3.6	3.7	3.8	3.9	3.8	3.6
2010	3.8	4.1	4.2	4.2	4.1	4.1	3.9	3.9	4.0	4.0	4.1	4.0	3.9
2011	3.7	3.8	3.9	3.9	3.8	3.7	3.6	3.8	3.8	3.8	3.9	3.9	3.6
2012	3.7	3.8	3.9	3.8	3.8	3.6	3.6	3.8	3.9	3.8	4.0	3.9	3.6
2013	3.7	3.9	4.0	4.0	3.9	3.7	3.6	3.8	3.8	3.9	4.0	3.9	3.5
2014	3.8	3.9	4.2	4.1	4.0	3.8	3.8	3.6	3.8	3.7	3.9	3.9	3.7
2015	3.7	3.9	4.1	4.1	4.0	3.9	3.8	3.5	3.6	3.7	3.8	3.8	3.6

Table B.24. Measured SR for selected sections of project 1480-131, constructed in 1998. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)												
	24 +0.040	25 +0.000	26 +0.000	27 +0.000	28 +0.000	29 +0.000	30 +0.000	25 +0.000	26 +0.000	27 +0.000	28 +0.000	29 +0.000	30 +0.000
Year	D	D	D	D	D	D	D	I	I	I	I	I	I
1998	2.9	3.2	3.7	3.4	2.5	2.5	2.1	3.5	3.4	3.1	3.4	2.8	3.0
1999	4.0	4.0	4.0	4.0	4.0	4.0	4.0	2.9	3.4	3.2	3.3	3.2	3.8
2000	4.0	4.0	4.0	4.0	4.0	4.0	4.0	2.5	3.0	2.9	3.0	2.7	2.8
2001	4.0	4.0	4.0	4.0	4.0	3.9	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2002	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.9
2003	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.9
2004	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.9
2005	4.0	4.0	4.0	4.0	4.0	3.9	4.0	4.0	4.0	4.0	4.0	4.0	3.9
2006													
2007	4.0	4.0	4.0	4.0	4.0	3.9	4.0	4.0	4.0	4.0	4.0	4.0	3.9
2008													
2009	4.0	4.0	4.0	3.8	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.9
2010	4.0	4.0	4.0	4.0	4.0	3.9	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2011	4.0	4.0	4.0	3.8	4.0	3.8	3.9	4.0	4.0	4.0	4.0	4.0	3.9
2012	4.0	4.0	4.0	3.8	4.0	3.8	3.9	4.0	4.0	4.0	4.0	4.0	3.9
2013	4.0	4.0	3.9	3.8	4.0	3.7	3.8	3.7	3.9	4.0	4.0	4.0	3.7
2014	3.9	4.0	4.0	3.8	3.9	3.6	3.8	4.0	3.9	3.9	4.0	4.0	3.7
2015	4.0	4.0	3.9	3.8	4.0	3.7	3.8	4.0	3.9	3.9	4.0	4.0	3.7

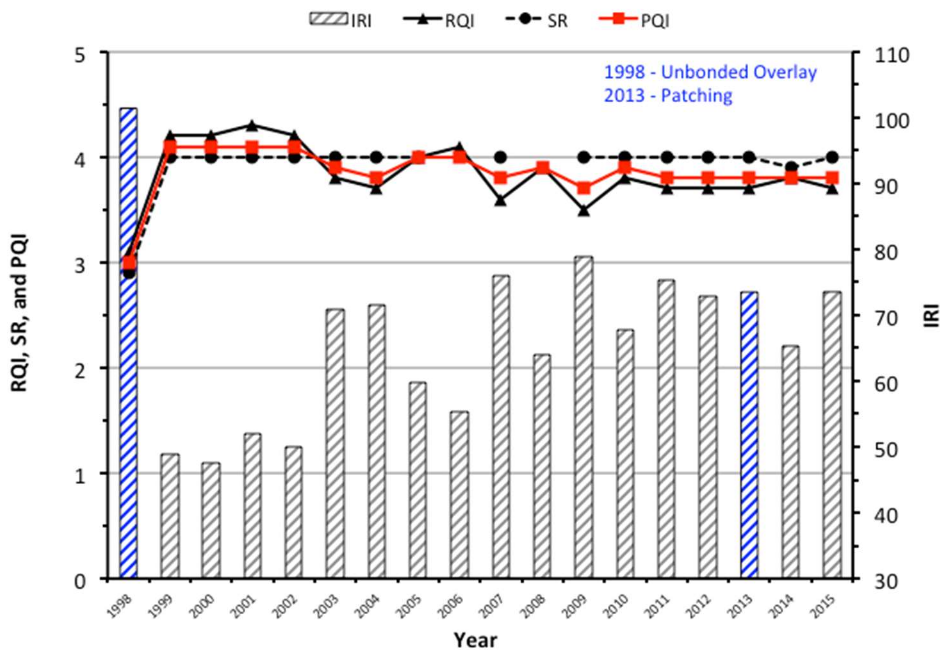


Figure B.45. Pavement management system data for section 24+0.040, direction DD, of project 1480–131 constructed in 1998. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

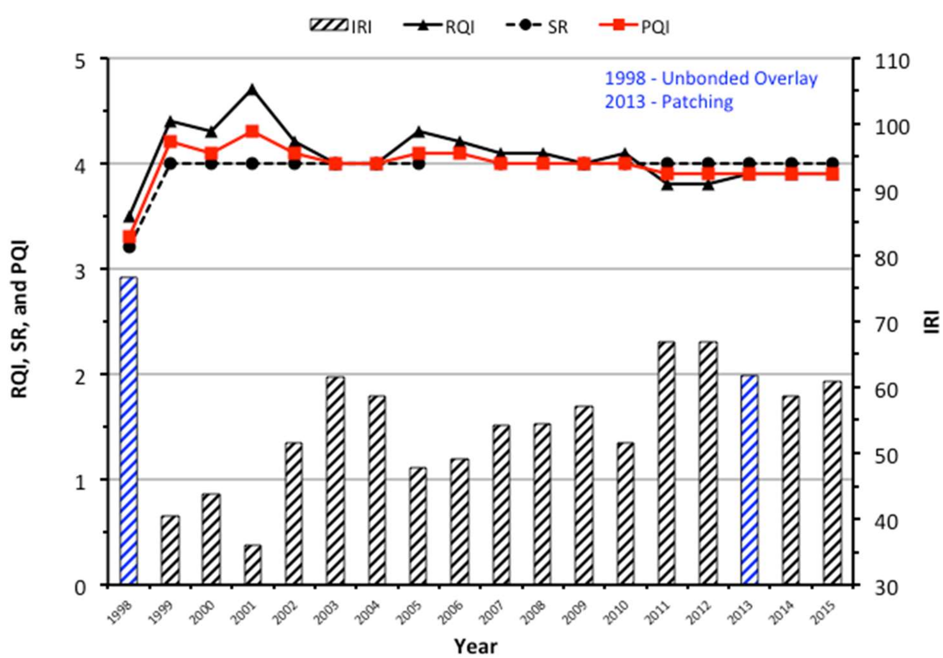


Figure B.46. Pavement management system data for section 25+0.000, direction D, of project 1480–131 constructed in 1998. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

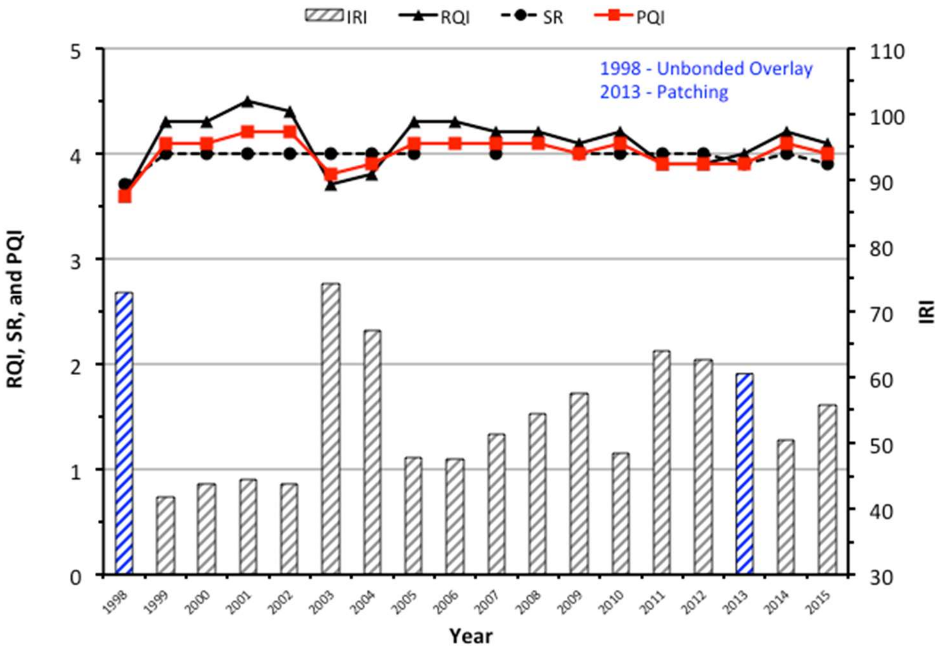


Figure B.47. Pavement management system data for section 26+0.000, direction D, of project 1480–131 constructed in 1998. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

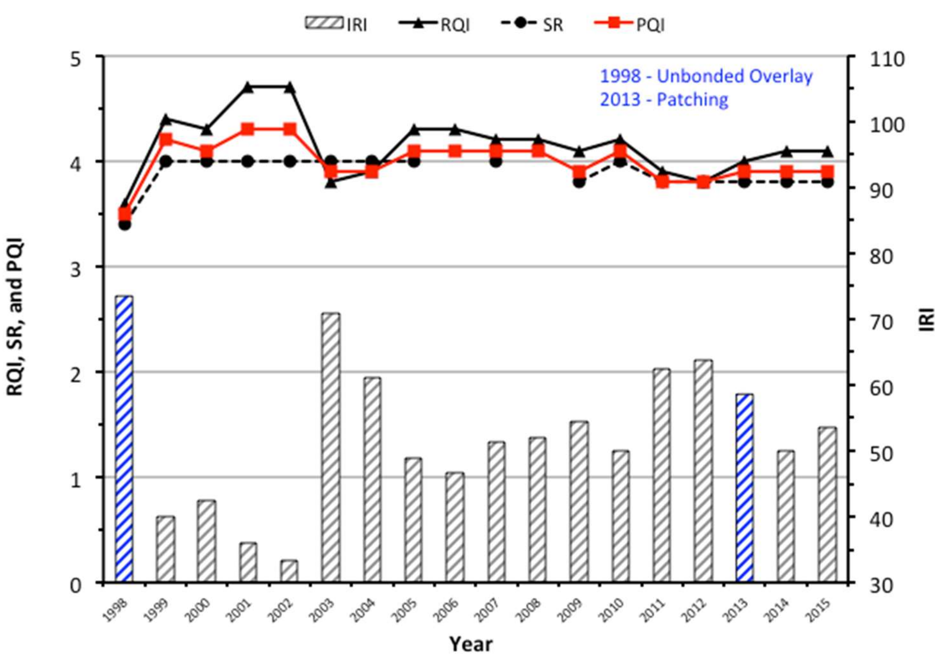


Figure B.48. Pavement management system data for section 27+0.000, direction D, of project 1480–131 constructed in 1998. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

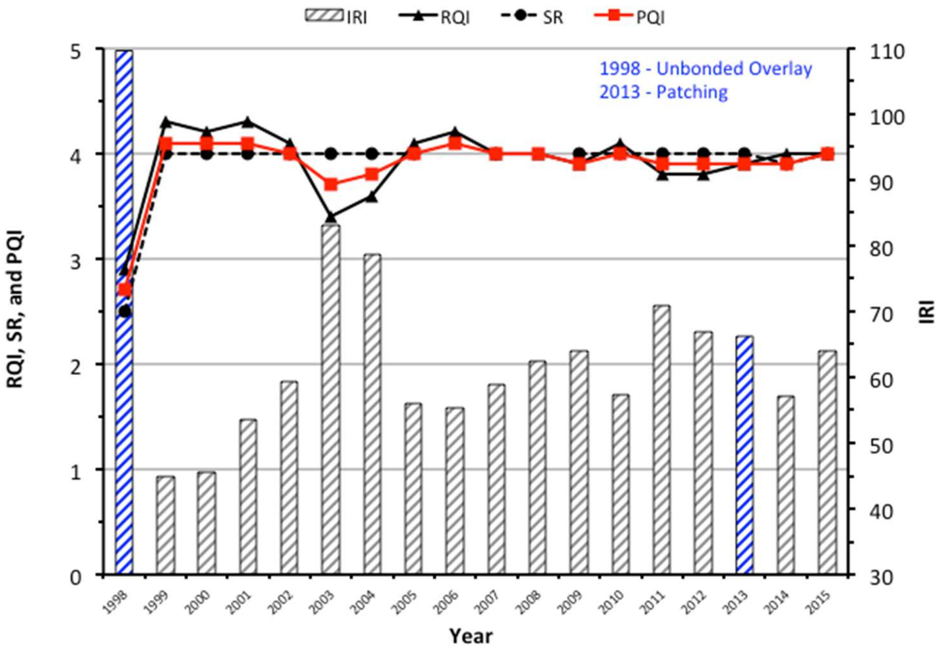


Figure B.49. Pavement management system data for section 28+0.000, direction D, of project 1480–131 constructed in 1998. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

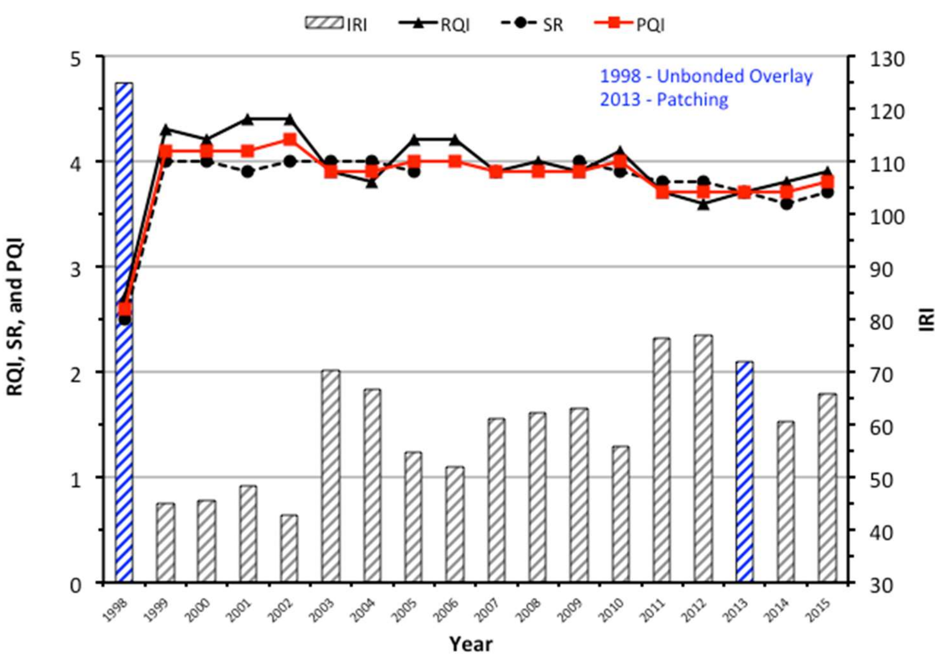


Figure B.50. Pavement management system data for section 29+0.000, direction D, of project 1480–131 constructed in 1998. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

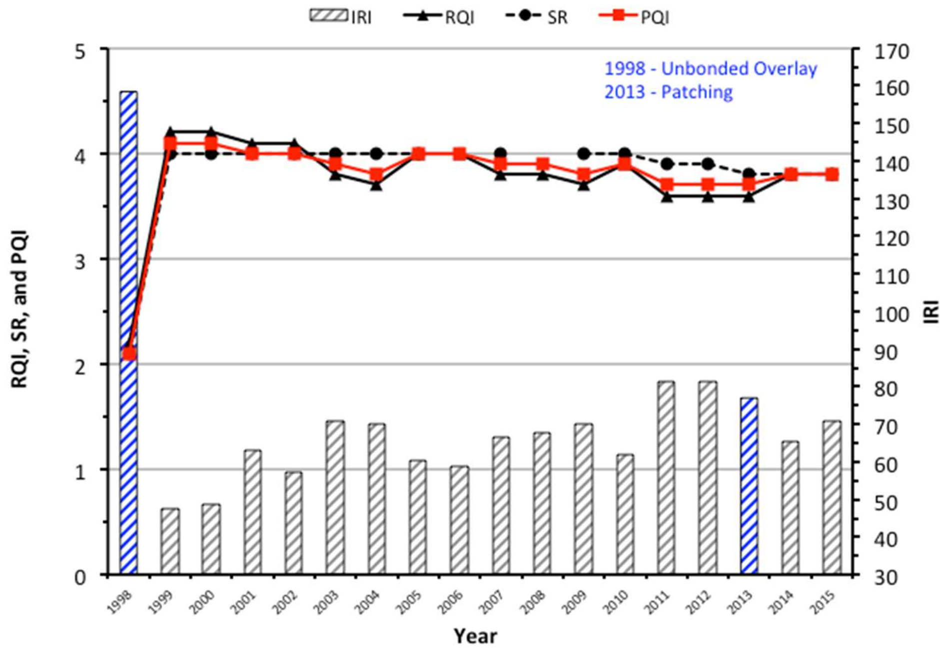


Figure B.51. Pavement management system data for section 30+0.000, direction D, of project 1480–131 constructed in 1998. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

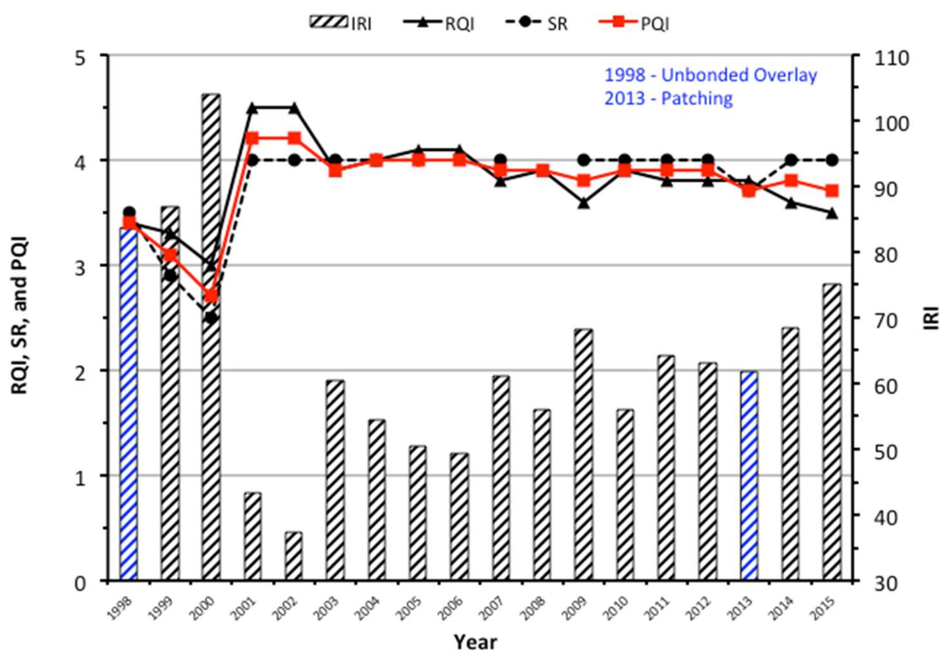


Figure B.52. Pavement management system data for section 25+0.000, direction I, of project 1480–131 constructed in 1998. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

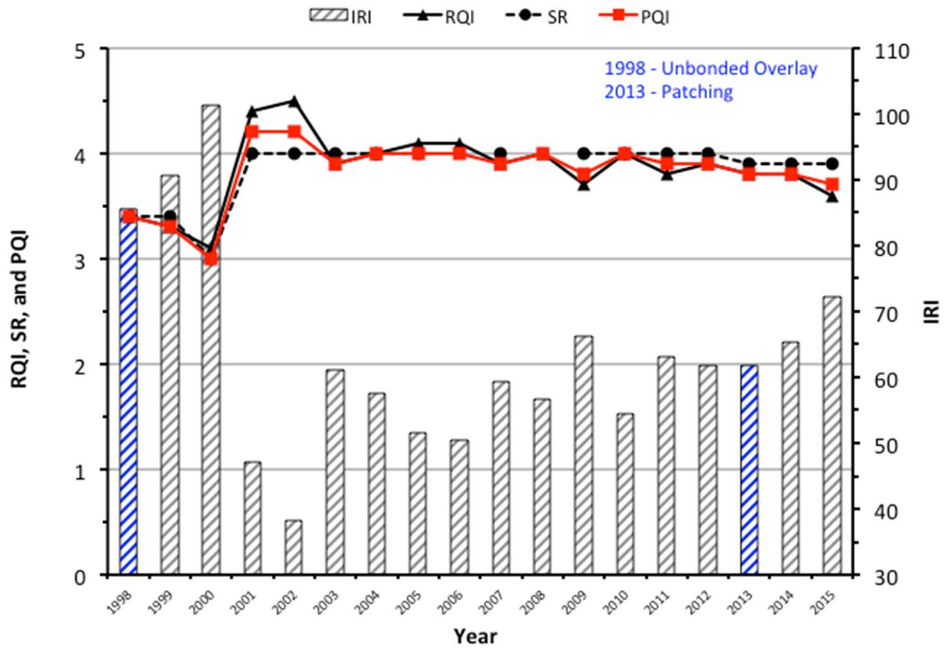


Figure B.53. Pavement management system data for section 26+0.000, direction I, of project 1480–131 constructed in 1998. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

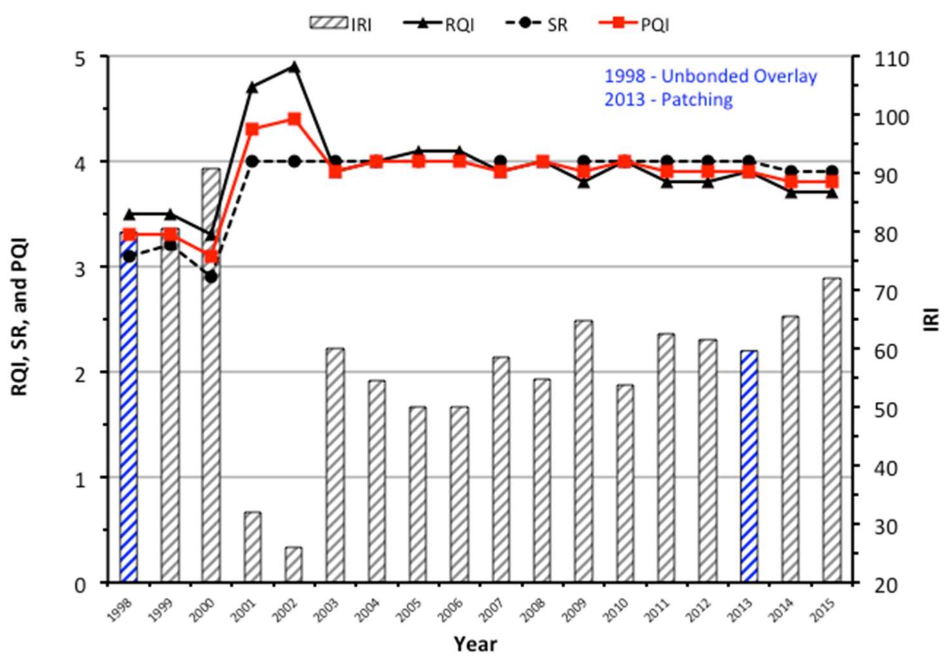


Figure B.54. Pavement management system data for section 27+0.000, direction I, of project 1480–131 constructed in 1998. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

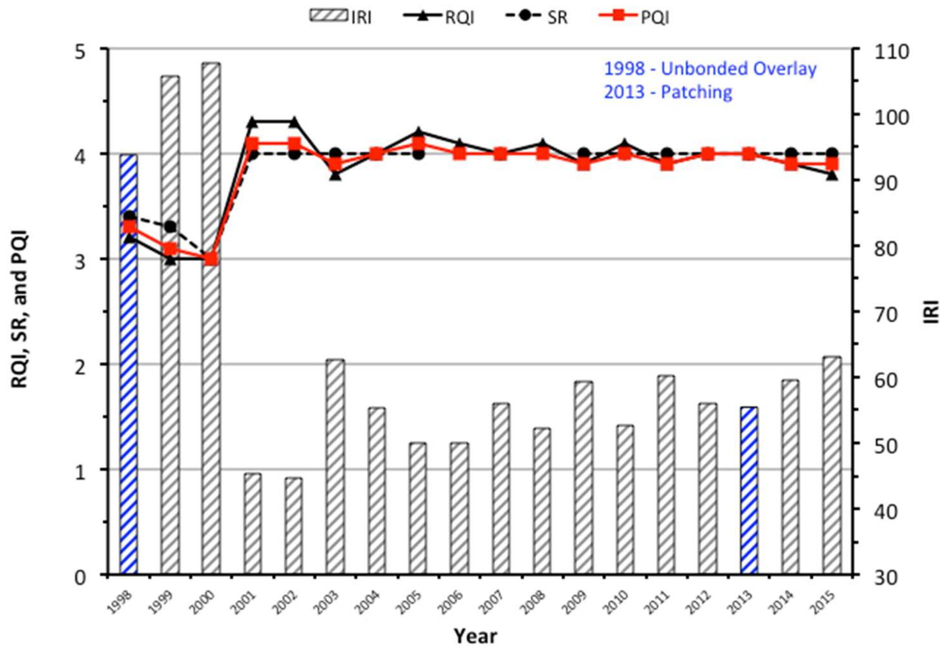


Figure B.55. Pavement management system data for section 28+0.000, direction I, of project 1480–131 constructed in 1998. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

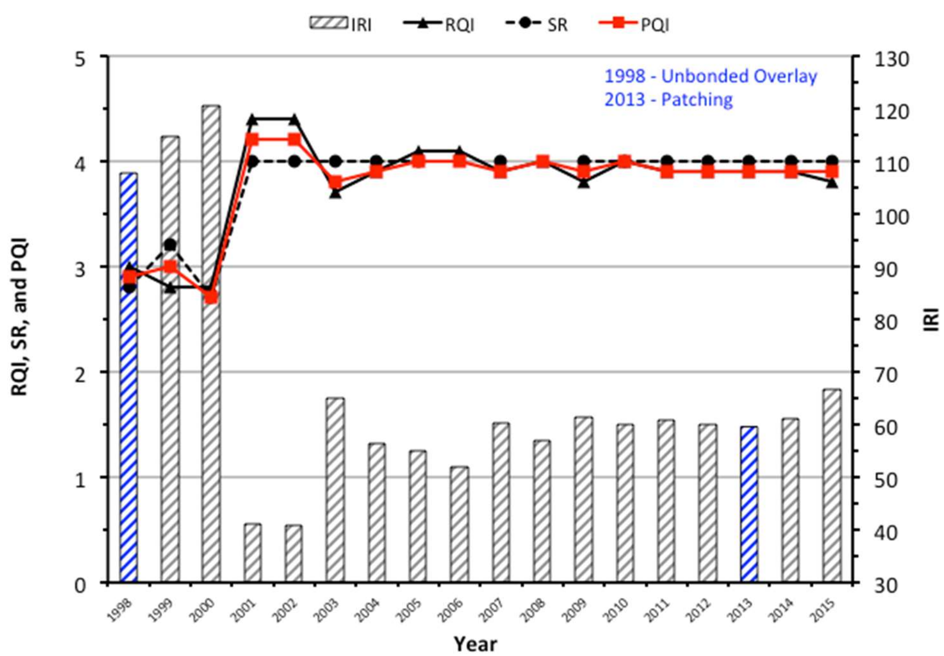


Figure B.56. Pavement management system data for section 29+0.000, direction I, of project 1480–131 constructed in 1998. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

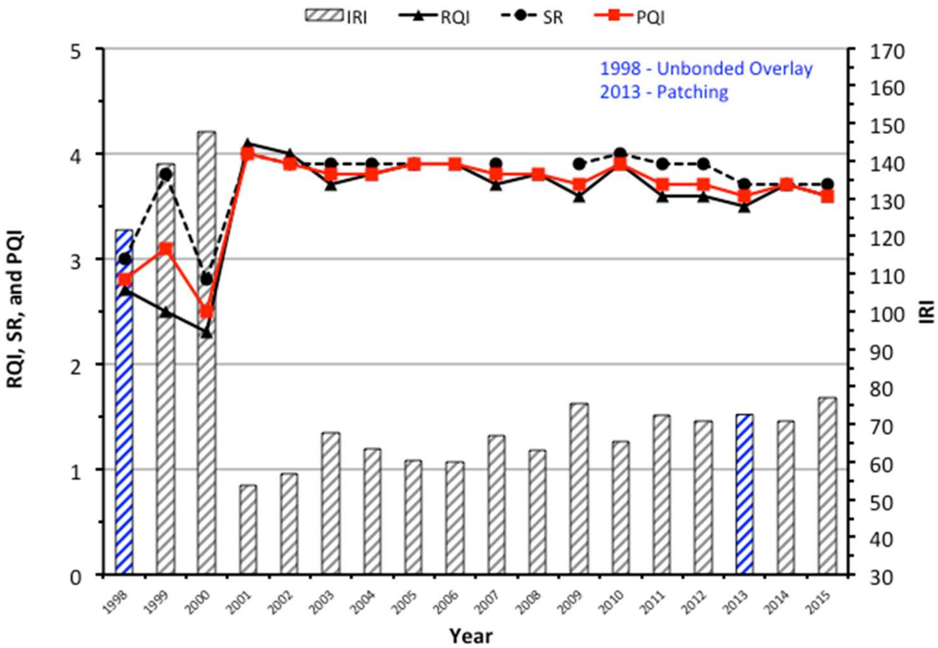


Figure B.57. Pavement management system data for section 30+0.000, direction I, of project 1480–131 constructed in 1998. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

District 4 – 2180-78

Table B.25. Measured IRI for selected sections of project 2180-78, constructed in 1995. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)				
	110 +0.024	111 +0.000	112 +0.000	113 +0.000	114 +0.000
Year	I	I	I	I	I
1995					
1997	44	39	42	37	49
1998	49	45	49	44	54
1999	47	42	47	42	52
2000	56	49	54	51	60
2001	46	39	45	33	52
2002	46	37	42	33	52
2003	68	55	69	59	73
2004	60	53	61	56	69
2005	53	45	59	49	66
2006					
2007	67	48	59	54	69
2008	59	50	61	55	69
2009	66	58	69	62	81
2010	60	51	61	56	67
2011	60	50	62	58	71
2012	59	49	61	56	71
2013	58	48	61	56	70
2014	60	49	62	58	73
2015	62	50	64	59	74

Table B.26. Measured PQI for selected sections of project 2180-78, constructed in 1995. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)				
	110 +0.024	111 +0.000	112 +0.000	113 +0.000	114 +0.000
Year	I	I	I	I	I
1995					
1997	4.1	4.2	4.1	4.2	4.0
1998	4.1	4.1	4.1	4.1	4.0
1999	4.1	4.1	4.1	4.1	4.0
2000	4.0	4.0	4.0	4.0	3.9
2001	4.1	4.2	4.1	4.3	4.1
2002	4.1	4.2	4.1	4.3	4.1
2003	3.8	4.0	3.9	3.9	3.8
2004	3.9	4.0	3.9	3.9	3.8
2005	4.0	4.1	4.0	4.1	3.9
2006					
2007	3.9	4.1	3.9	4.0	3.8
2008	4.0	4.1	3.9	4.0	3.8
2009	3.7	3.9	3.8	3.9	3.7
2010	3.8	4.1	3.9	4.0	3.8
2011	3.8	4.0	3.9	4.0	3.8
2012	3.8	4.0	3.9	4.0	3.8
2013	3.5	4.0	3.9	3.9	3.8
2014	3.6	4.0	3.9	3.9	3.7
2015	3.5	4.0	3.9	3.9	3.8

Table B.27. Measured RQI for selected sections of project 2180-78, constructed in 1995. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)				
	110 +0.024	111 +0.000	112 +0.000	113 +0.000	114 +0.000
Year	I	I	I	I	I
1995					
1997	4.3	4.4	4.3	4.5	4.1
1998	4.2	4.3	4.2	4.3	4.0
1999	4.2	4.3	4.2	4.3	4.1
2000	4.0	4.1	4.0	4.1	3.9
2001	4.3	4.5	4.3	4.6	4.2
2002	4.2	4.5	4.3	4.7	4.2
2003	3.7	4.1	3.8	3.9	3.6
2004	3.8	4.0	3.9	3.9	3.7
2005	4.1	4.3	4.0	4.2	3.8
2006					
2007	3.9	4.2	3.9	4.0	3.7
2008	4.0	4.2	3.9	4.0	3.7
2009	3.8	3.9	3.7	3.8	3.4
2010	3.9	4.2	3.9	4.0	3.7
2011	3.9	4.2	3.9	4.0	3.7
2012	3.9	4.2	3.9	4.0	3.7
2013	3.9	4.2	3.9	4.0	3.7
2014	3.9	4.2	3.9	3.9	3.6
2015	3.9	4.2	3.8	3.9	3.7

Table B.28. Measured SR for selected sections of project 2180-78, constructed in 1995. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)				
	110 +0.024	111 +0.000	112 +0.000	113 +0.000	114 +0.000
Year	I	I	I	I	I
1995					
1997	4.0	4.0	4.0	4.0	4.0
1998	4.0	4.0	4.0	4.0	4.0
1999	4.0	4.0	4.0	4.0	4.0
2000	4.0	4.0	4.0	4.0	4.0
2001	4.0	4.0	4.0	4.0	4.0
2002	4.0	4.0	4.0	4.0	4.0
2003	4.0	4.0	4.0	4.0	4.0
2004	4.0	4.0	4.0	4.0	4.0
2005	4.0	4.0	4.0	4.0	4.0
2006					
2007	4.0	4.0	4.0	4.0	4.0
2008					
2009	3.7	4.0	4.0	4.0	4.0
2010	3.8	4.0	4.0	4.0	4.0
2011	3.7	3.9	4.0	4.0	4.0
2012	3.7	3.9	4.0	4.0	4.0
2013	3.1	3.9	4.0	3.8	3.9
2014	3.3	3.8	4.0	3.9	3.9
2015	3.1	3.9	4.0	4.0	4.0

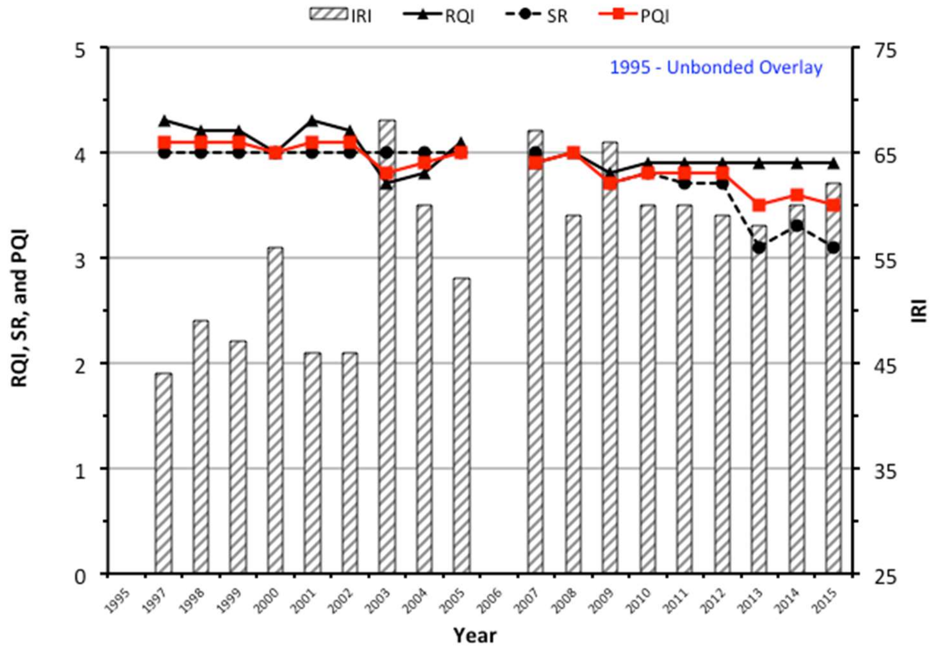


Figure B.58. Pavement management system data for section 110+0.024, direction I, of project 2180–78 constructed in 1995. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

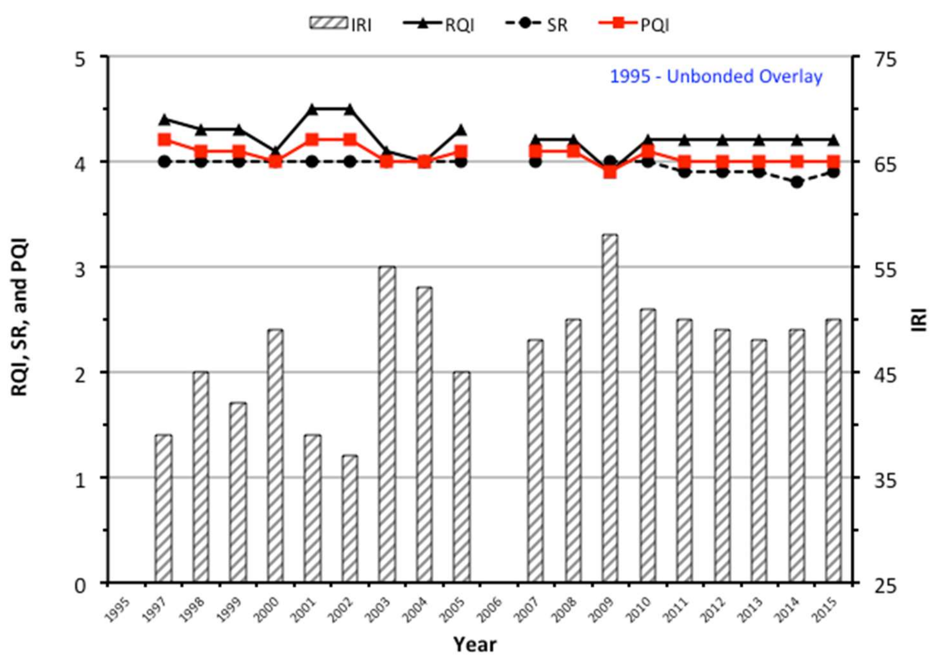


Figure B.59. Pavement management system data for section 111+0.000, direction I, of project 2180–78 constructed in 1995. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

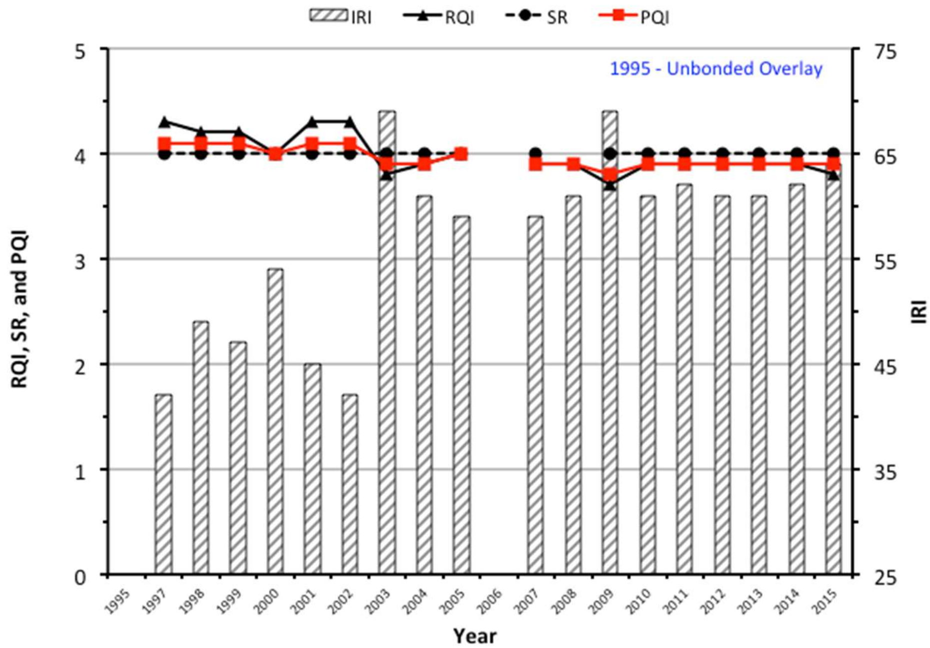


Figure B.60. Pavement management system data for section 112+0.000, direction I, of project 2180–78 constructed in 1995. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

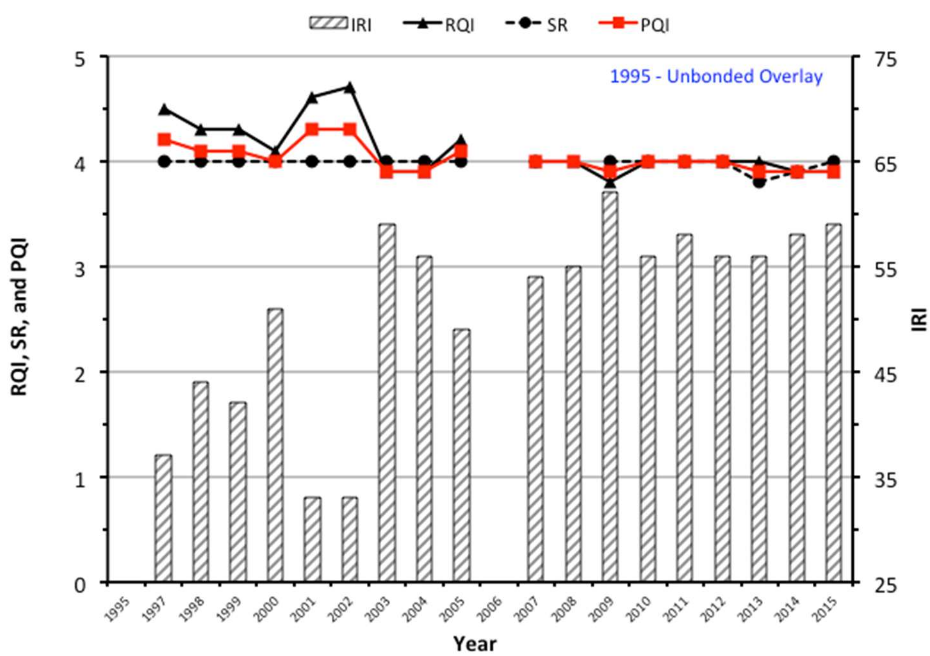


Figure B.61. Pavement management system data for section 113+0.000, direction I, of project 2180–78 constructed in 1995. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

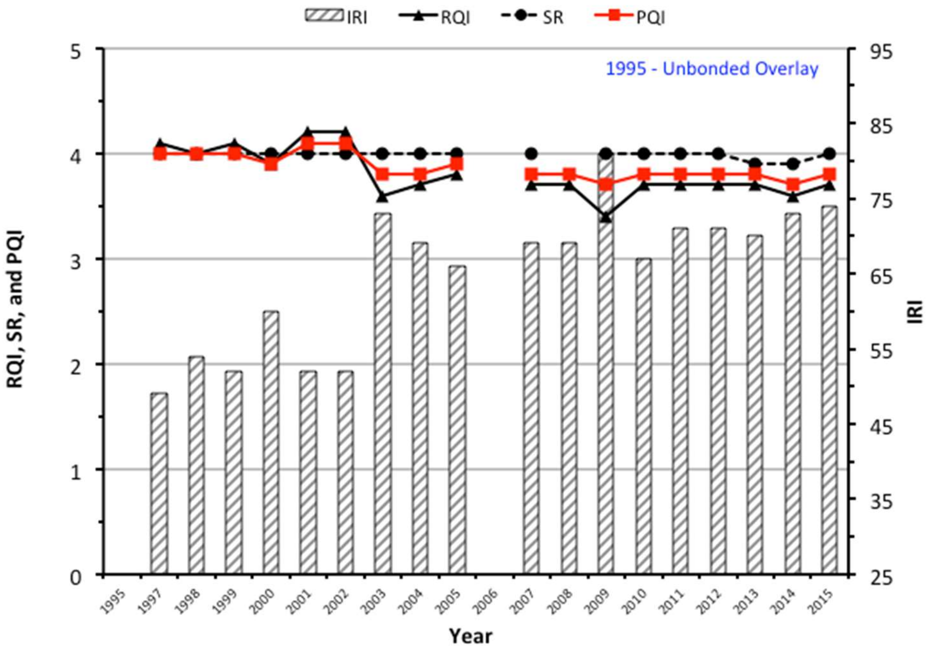


Figure B.62. Pavement management system data for section 114+0.000, direction I, of project 2180–78 constructed in 1995. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

District 4 – 5680-111

Table B.29. Measured IRI for selected sections of project 5680-111, constructed in 1997. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)													
	37 +0.230	38 +0.000	39 +0.000	40 +0.000	41 +0.000	42 +0.000	43 +0.000	44 +0.000	45 +0.000	46 +0.000	47 +0.000	48 +0.000	49 +0.000	50 +0.000
Year	D	D	D	D	D	D	D	D	D	D	D	D	D	D
1997														
1998	49	56	49	54	59	68	56	52	68	65	59	52	56	73
1999	49	51	48	54	56	66	58	53	65	61	54	53	58	75
2000	51	52	51	56	60	71	59	56	70	63	56	59	59	82
2001	71	59	77	68	87	84	77	69	93	87	78	79	79	116
2002	66	52	68	63	80	80	70	60	83	80	67	69	73	101
2003	72	72	65	75	76	92	77	75	92	87	73	83	78	103
2004	70	70	66	72	74	93	76	73	91	86	74	75	75	98
2005	67	64	59	67	70	84	69	70	80	83	69	71	69	94
2006	69	69	62	68	73	87	74	76	89	91	76	78	77	99
2007	75	75	66	73	80	95	78	81	95	97	85	82	82	107
2008	81	77	70	80	89	100	85	86	98	101	86	86	86	109
2009	79	76	67	74	84	98	82	81	97	98	86	85	85	109
2010	74	72	64	72	79	94	79	77	94	96	84	83	81	104
2011	91	87	80	89	96	106	95	93	108	112	97	96	93	122
2012	87	85	77	86	95	105	93	92	106	109	96	94	91	120
2013	78	76	67	73	82	94	80	80	96	98	83	81	80	106
2014	95	93	80	91	101	108	95	93	102	118	101	97	95	123
2015	84	81	70	78	91	100	85	90	80	91	87	85	84	115

Table B.30. Measured PQI for selected sections of project 5680-111, constructed in 1997. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)													
	37 +0.230	38 +0.000	39 +0.000	40 +0.000	41 +0.000	42 +0.000	43 +0.000	44 +0.000	45 +0.000	46 +0.000	47 +0.000	48 +0.000	49 +0.000	50 +0.000
Year	D	D	D	D	D	D	D	D	D	D	D	D	D	D
1997														
1998	4.0	4.0	4.0	4.0	3.9	3.8	4.0	4.0	3.8	3.9	3.9	4.0	4.0	3.8
1999	4.0	4.0	4.1	4.0	4.0	3.9	4.0	4.0	3.9	3.9	3.9	4.0	4.0	3.8
2000	4.0	4.0	4.0	4.0	3.9	3.8	3.9	4.0	3.8	3.9	4.0	3.9	3.9	3.7
2001	3.9	4.0	3.9	3.9	3.7	3.7	3.8	4.0	3.7	3.7	3.8	3.8	3.8	3.5
2002	4.0	4.0	3.9	3.9	3.8	3.7	3.9	4.0	3.7	3.8	3.8	3.8	3.9	3.5
2003	3.9	3.8	3.9	3.8	3.8	3.6	3.8	3.8	3.6	3.7	3.8	3.7	3.8	3.5
2004	3.9	3.8	3.9	3.8	3.8	3.6	3.8	3.8	3.6	3.7	3.7	3.8	3.8	3.6
2005	3.9	3.9	4.0	3.9	3.9	3.7	3.9	3.9	3.7	3.7	3.8	3.8	3.9	3.6
2006	3.9	3.9	3.9	3.9	3.8	3.6	3.8	3.8	3.7	3.6	3.7	3.7	3.8	3.5
2007	3.8	3.8	3.9	3.8	3.7	3.6	3.8	3.7	3.6	3.6	3.6	3.7	3.7	3.4
2008	3.7	3.8	3.8	3.8	3.7	3.6	3.7	3.7	3.6	3.5	3.6	3.7	3.7	3.4
2009	3.8	3.7	3.8	3.8	3.7	3.6	3.7	3.7	3.5	3.5	3.6	3.7	3.7	3.4
2010	3.8	3.8	3.9	3.8	3.8	3.6	3.8	3.8	3.6	3.6	3.7	3.7	3.7	3.5
2011	3.7	3.7	3.8	3.7	3.6	3.5	3.6	3.6	3.5	3.4	3.5	3.6	3.6	3.3
2012	3.7	3.7	3.8	3.7	3.6	3.5	3.6	3.7	3.5	3.5	3.5	3.6	3.7	3.3
2013	3.8	3.7	3.9	3.8	3.7	3.6	3.8	3.8	3.6	3.6	3.6	3.7	3.8	3.5
2014	3.6	3.6	3.7	3.6	3.5	3.5	3.6	3.6	3.5	3.3	3.4	3.6	3.5	3.3
2015	3.7	3.7	3.8	3.8	3.7	3.6	3.7	3.6	3.7	3.6	3.6	3.7	3.7	3.3

Table B.31. Measured RQI for selected sections of project 5680-111, constructed in 1997. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)													
	37 +0.230	38 +0.000	39 +0.000	40 +0.000	41 +0.000	42 +0.000	43 +0.000	44 +0.000	45 +0.000	46 +0.000	47 +0.000	48 +0.000	49 +0.000	50 +0.000
Year	D	D	D	D	D	D	D	D	D	D	D	D	D	D
1997														
1998	4.1	4.0	4.1	4.0	3.9	3.7	4.0	4.1	3.7	3.8	3.9	4.1	4.0	3.6
1999	4.1	4.1	4.2	4.0	4.0	3.8	4.0	4.1	3.8	3.9	4.0	4.1	4.0	3.6
2000	4.1	4.1	4.1	4.0	3.9	3.7	3.9	4.0	3.7	3.8	4.0	3.9	3.9	3.4
2001	3.8	4.0	3.8	3.9	3.5	3.5	3.7	4.0	3.4	3.5	3.7	3.7	3.7	3.0
2002	4.0	4.1	3.9	3.9	3.6	3.5	3.8	4.0	3.5	3.6	3.8	3.7	3.8	3.1
2003	3.8	3.7	3.9	3.7	3.6	3.2	3.6	3.7	3.3	3.4	3.7	3.5	3.6	3.1
2004	3.8	3.7	3.8	3.7	3.7	3.3	3.6	3.7	3.3	3.4	3.6	3.6	3.6	3.2
2005	3.9	3.9	4.0	3.8	3.8	3.5	3.8	3.8	3.5	3.5	3.8	3.7	3.8	3.3
2006	3.8	3.8	3.9	3.8	3.7	3.3	3.6	3.6	3.4	3.3	3.6	3.5	3.6	3.1
2007	3.6	3.6	3.8	3.7	3.5	3.3	3.6	3.5	3.2	3.2	3.4	3.4	3.5	3.0
2008	3.5	3.6	3.7	3.6	3.4	3.2	3.4	3.5	3.2	3.1	3.4	3.4	3.4	3.0
2009	3.6	3.5	3.7	3.6	3.5	3.2	3.5	3.5	3.1	3.1	3.3	3.4	3.4	2.9
2010	3.7	3.7	3.9	3.7	3.6	3.3	3.6	3.7	3.2	3.2	3.5	3.5	3.5	3.1
2011	3.4	3.4	3.6	3.4	3.3	3.1	3.3	3.3	3.0	2.9	3.2	3.2	3.3	2.7
2012	3.4	3.4	3.6	3.5	3.3	3.1	3.3	3.4	3.0	3.0	3.2	3.3	3.4	2.8
2013	3.6	3.6	3.8	3.7	3.5	3.3	3.6	3.6	3.2	3.2	3.4	3.5	3.6	3.0
2014	3.2	3.2	3.5	3.3	3.1	3.0	3.2	3.3	3.0	2.8	3.0	3.2	3.3	2.7
2015	3.5	3.5	3.7	3.6	3.4	3.2	3.5	3.3	3.5	3.3	3.4	3.4	3.5	2.8

Table B.32. Measured SR for selected sections of project 5680-111, constructed in 1997. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)													
	37 +0.230	38 +0.000	39 +0.000	40 +0.000	41 +0.000	42 +0.000	43 +0.000	44 +0.000	45 +0.000	46 +0.000	47 +0.000	48 +0.000	49 +0.000	50 +0.000
Year	D	D	D	D	D	D	D	D	D	D	D	D	D	D
1997														
1998	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
1999	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.9	4.0	4.0	4.0
2000	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2001	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.9	4.0	4.0	4.0
2002	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.9	4.0	4.0	4.0
2003	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.9	4.0	4.0	4.0
2004	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.9	4.0	4.0	4.0
2005	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.9	4.0	4.0	4.0
2006														
2007	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.9	4.0	4.0	3.9
2008														
2009	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.9	4.0	4.0	4.0
2010	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.9	4.0	4.0	4.0
2011	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.9	4.0	4.0	4.0
2012	4.0	4.0	4.0	4.0	3.9	4.0	4.0	4.0	4.0	4.0	3.9	4.0	4.0	4.0
2013	4.0	3.9	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.9	4.0	4.0	4.0
2014	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.9	4.0	3.8	4.0
2015	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0		4.0	3.9	4.0	4.0	4.0

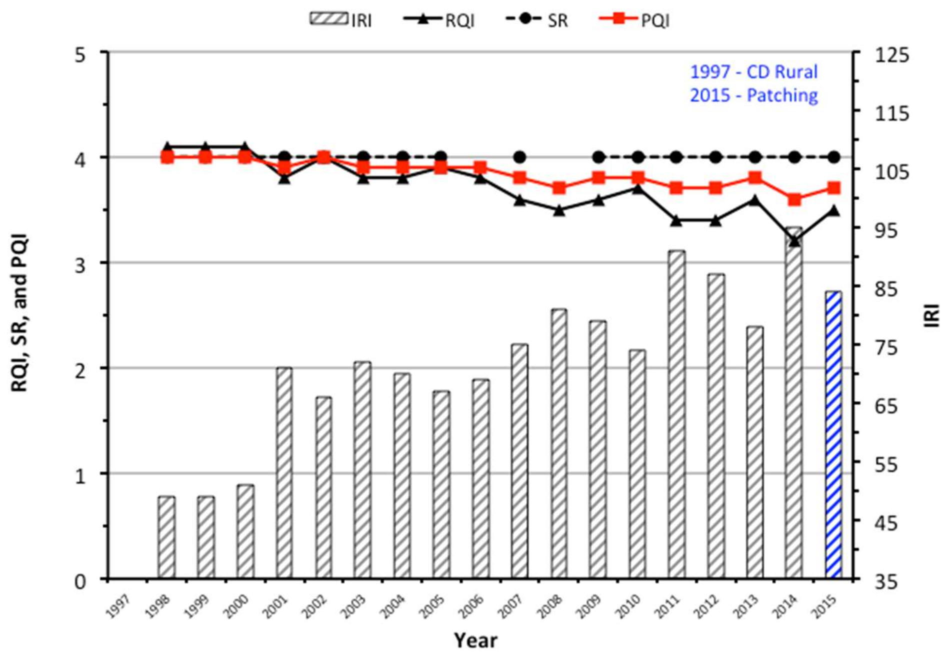


Figure B.63. Pavement management system data for section 37+0.230, direction D, of project 5680–111 constructed in 1997. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

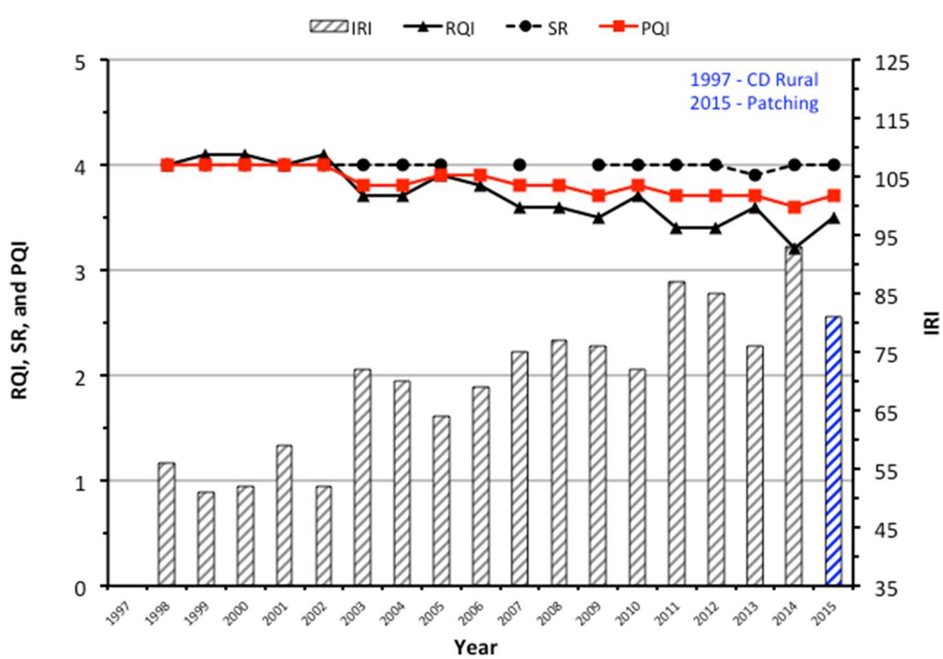


Figure B.64. Pavement management system data for section 38+0.000, direction D, of project 5680–111 constructed in 1997. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

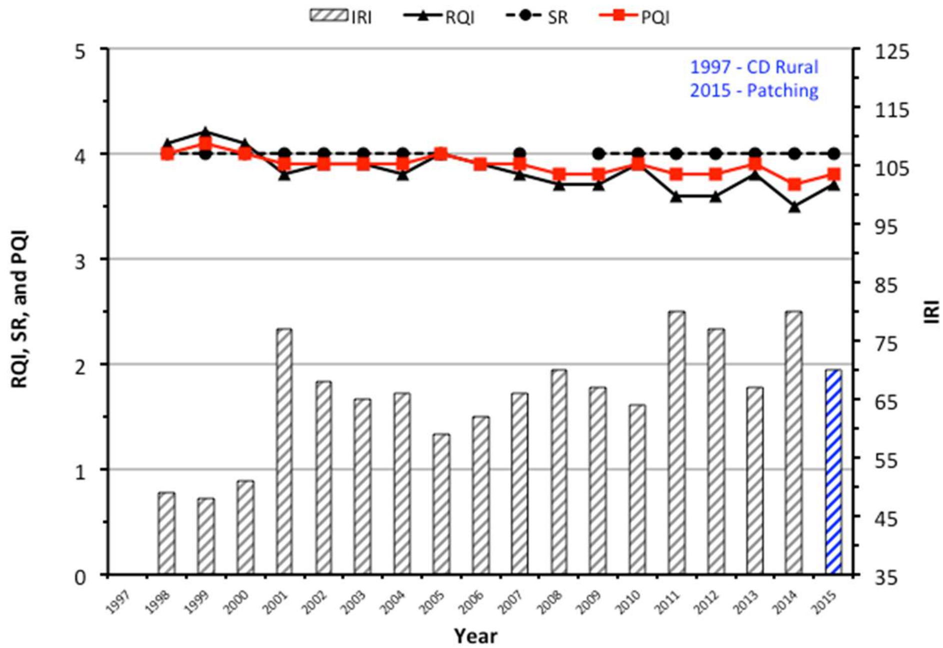


Figure B.65. Pavement management system data for section 39+0.000, direction D, of project 5680–111 constructed in 1997. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

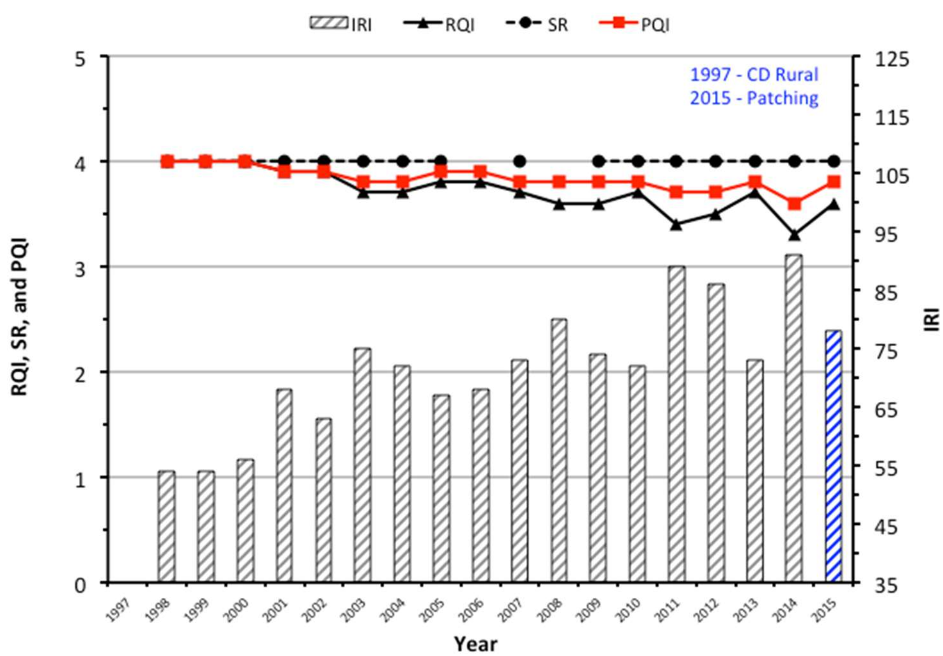


Figure B.66. Pavement management system data for section 40+0.000, direction D, of project 5680–111 constructed in 1997. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

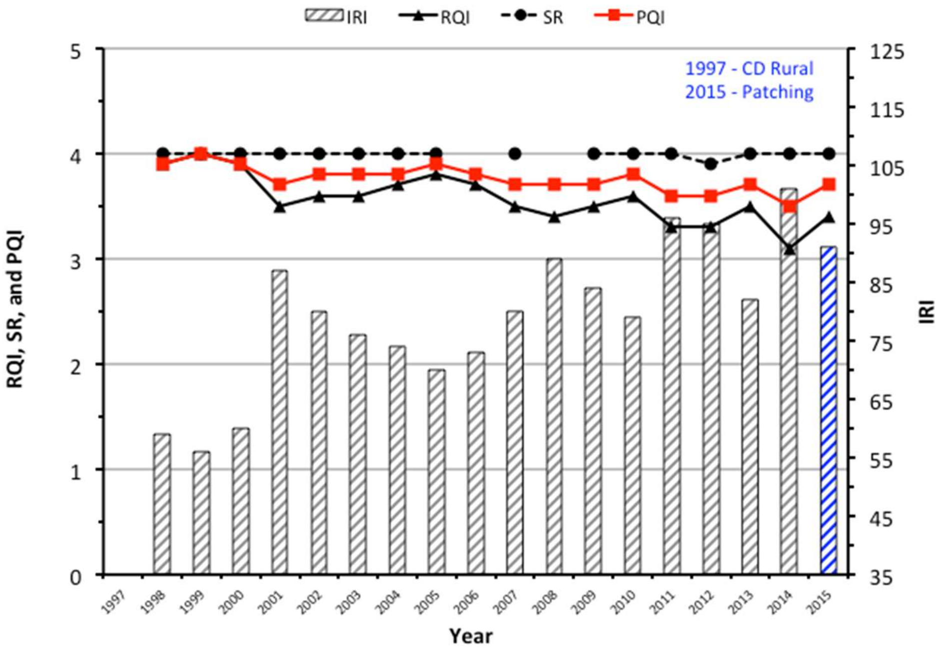


Figure B.67. Pavement management system data for section 41+0.000, direction D, of project 5680–111 constructed in 1997. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

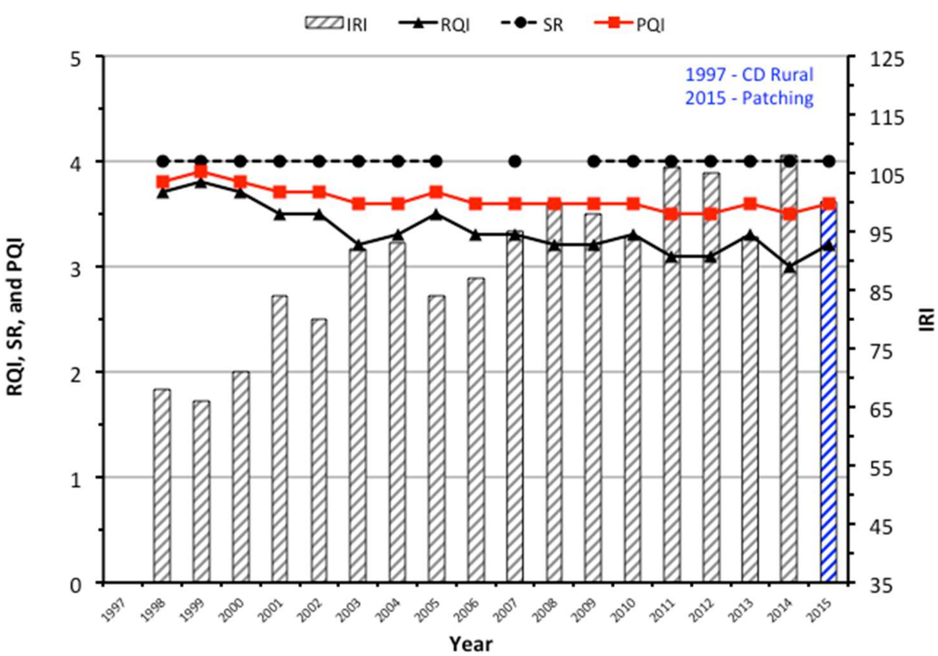


Figure B.68. Pavement management system data for section 42+0.000, direction D, of project 5680–111 constructed in 1997. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

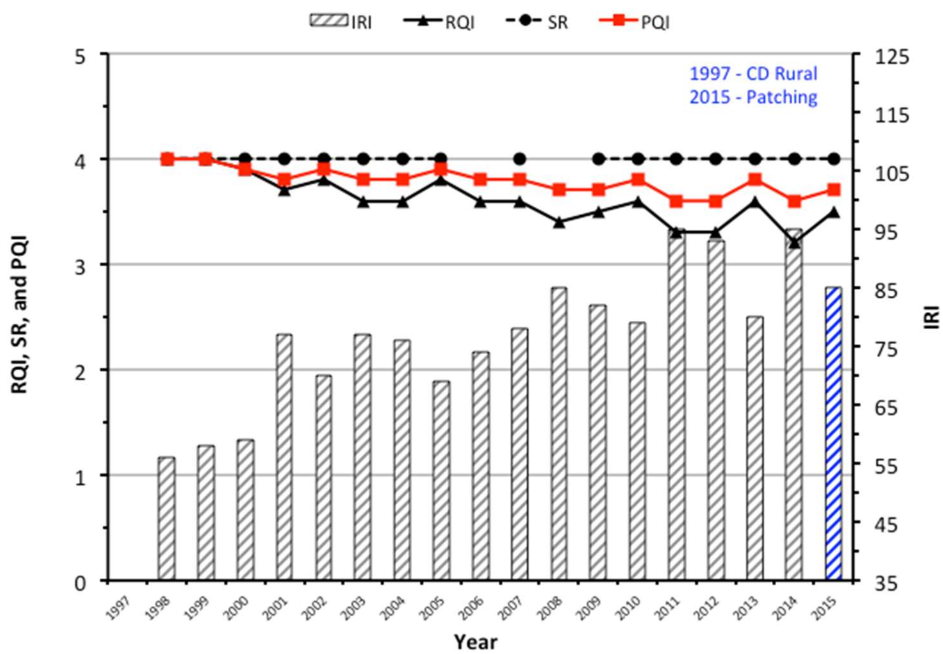


Figure B.69. Pavement management system data for section 43+0.000, direction D, of project 5680–111 constructed in 1997. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

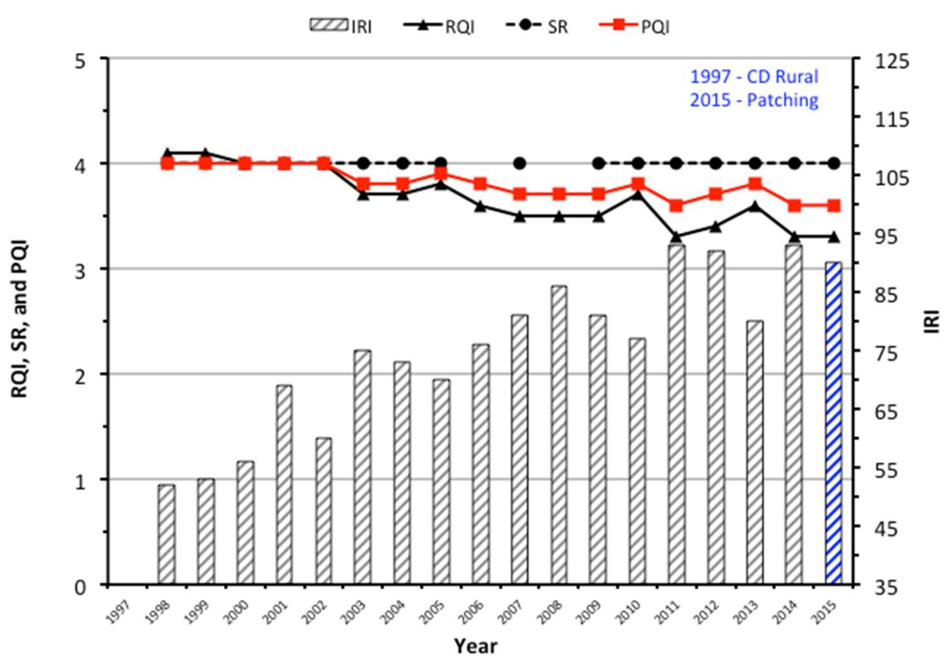


Figure B.70. Pavement management system data for section 44+0.000, direction D, of project 5680–111 constructed in 1997. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

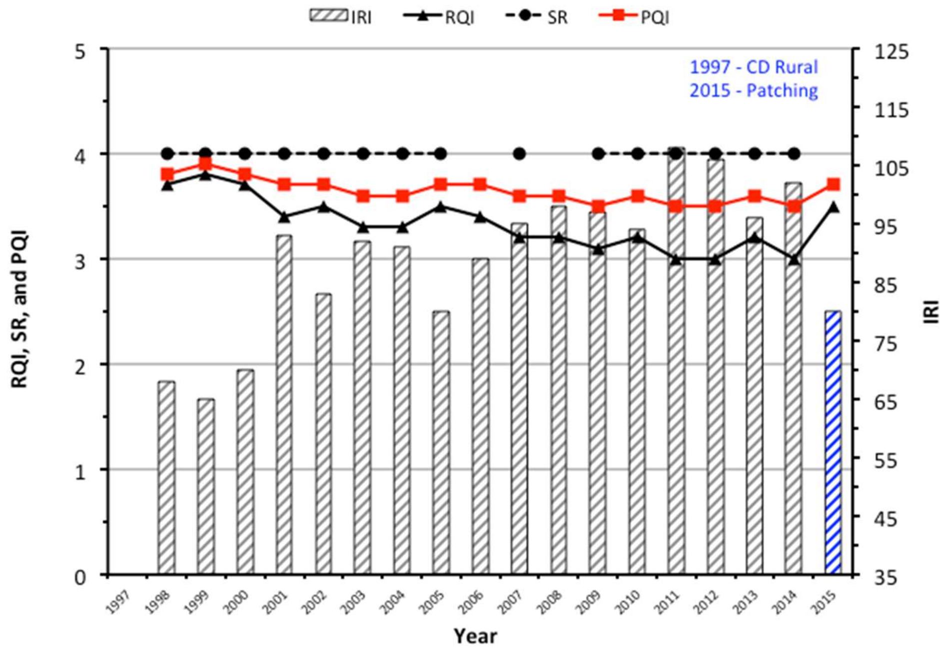


Figure B.71. Pavement management system data for section 45+0.000, direction D, of project 5680–111 constructed in 1997. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

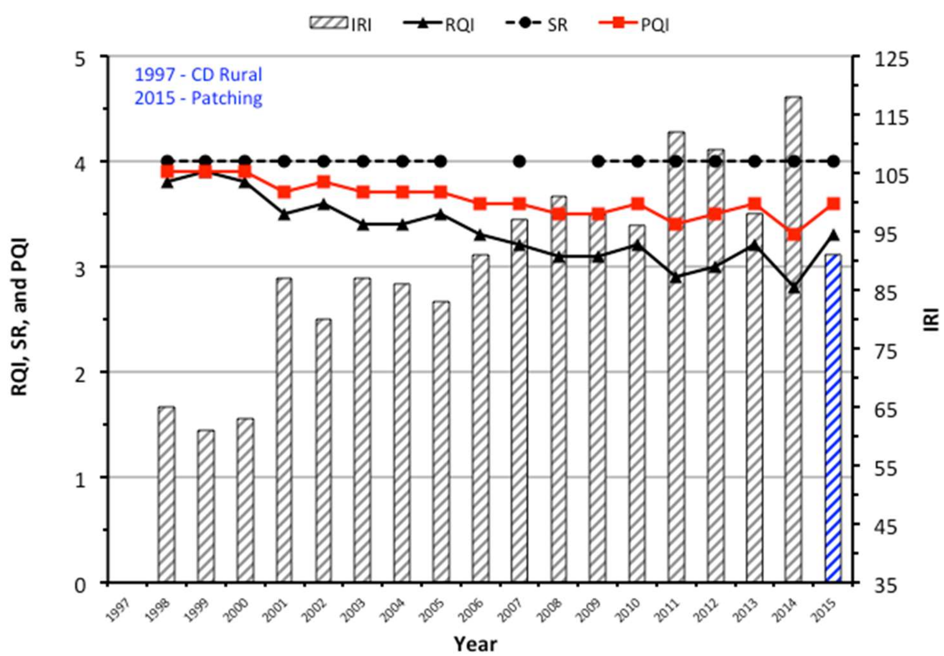


Figure B.72. Pavement management system data for section 46+0.000, direction D, of project 5680–111 constructed in 1997. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

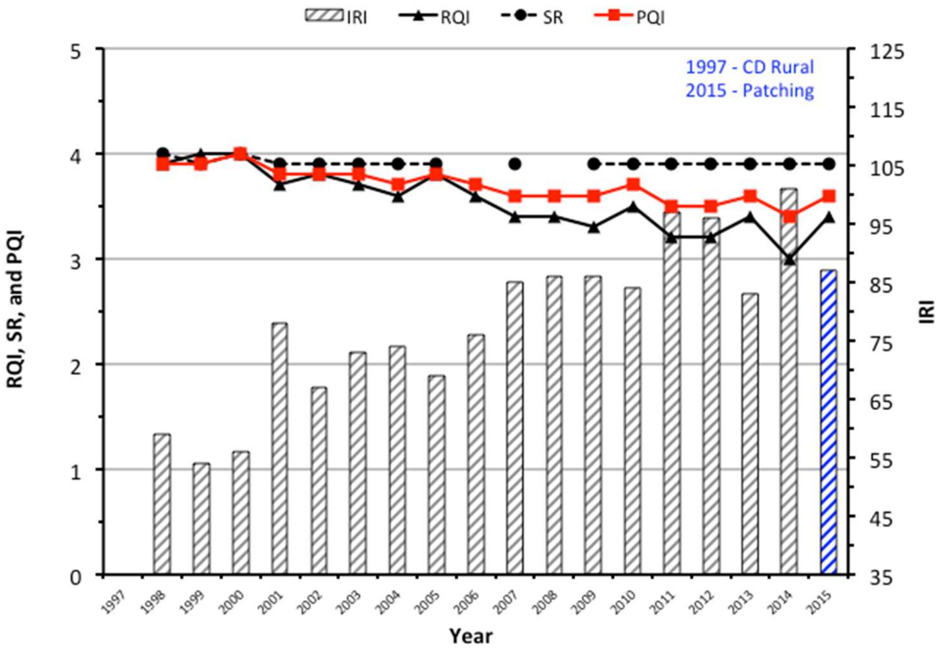


Figure B.73. Pavement management system data for section 47+0.000, direction D, of project 5680–111 constructed in 1997. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

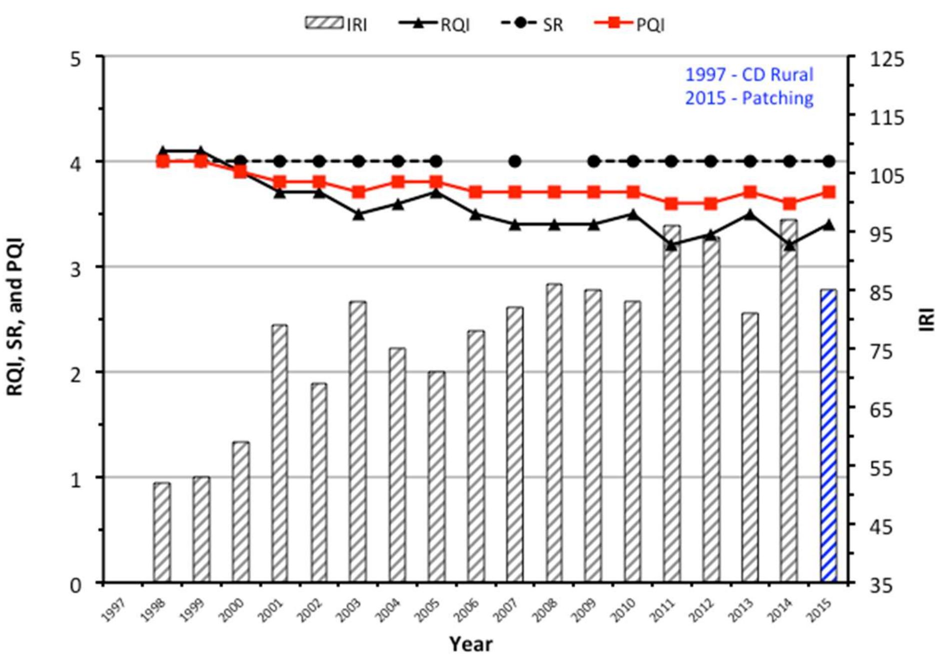


Figure B.74. Pavement management system data for section 48+0.000, direction D, of project 5680–111 constructed in 1997. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

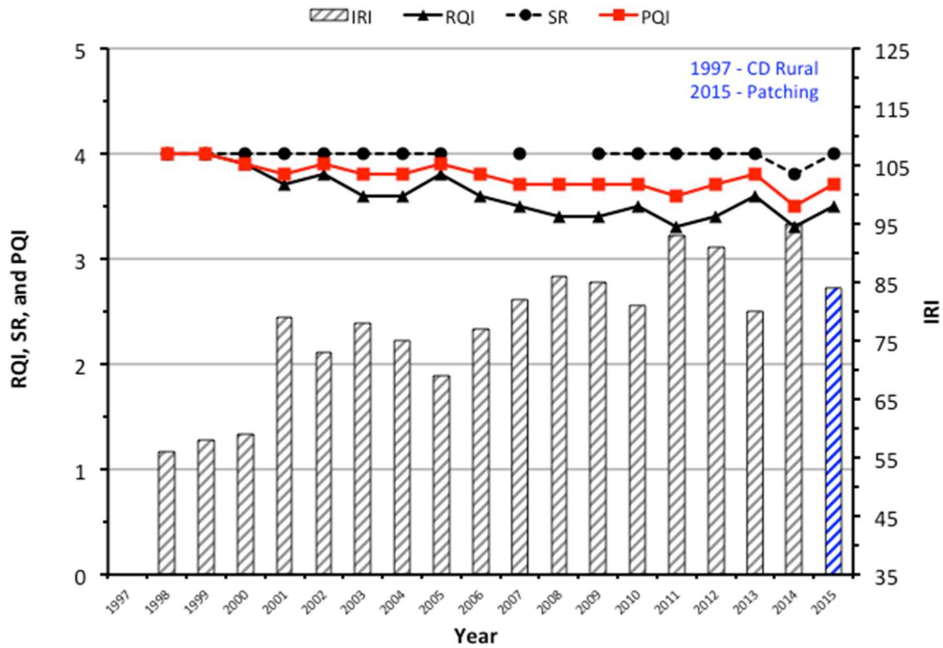


Figure B.75. Pavement management system data for section 49+0.000, direction D, of project 5680–111 constructed in 1997. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

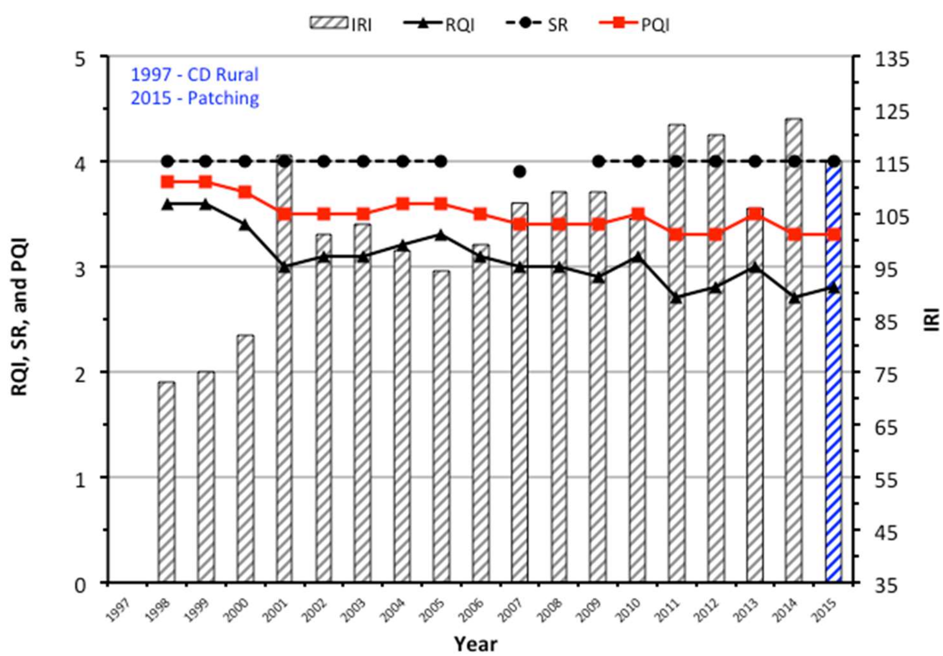


Figure B.76. Pavement management system data for section 50+0.000, direction D, of project 5680–111 constructed in 1997. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

District 4 – 8480-26

Table B.33. Measured IRI for selected sections of project 8480-26, constructed in 1993. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)				
	31 +0.834	33 +0.000	34 +0.000	35 +0.000	36 +0.000
Year	I	I	I	I	I
1993					
1994	116	108	105	105	117
1996	106	108	90	103	96
1997	67	63	63	63	63
1998	63	58	53	58	54
1999	65	61	54	60	56
2000	75	68	64	72	67
2001	69	76	68	93	86
2002	64	65	63	83	75
2003	90	83	83	86	87
2004	86	79	80	81	77
2005	87	79	78	80	77
2006	86	77	78	77	74
2007	88	80	78	79	74
2008	93	85	82	84	78
2009	97	88	86	86	81
2010	97	86	84	86	82
2011	98	86	84	86	81
2012	99	86	87	89	81
2013	105	87	86	89	84
2014	105	89	82	86	76
2015	101	86	82	87	80

Table B.34. Measured PQI for selected sections of project 8480-26, constructed in 1993. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)				
	31 +0.834	33 +0.000	34 +0.000	35 +0.000	36 +0.000
Year	I	I	I	I	I
1993					
1994	3.7	3.7	3.7	3.7	3.7
1996	3.7	3.7	3.9	3.8	3.8
1997	3.8	3.8	3.9	3.9	3.9
1998	3.9	3.9	4.0	4.0	4.0
1999	3.9	3.8	4.0	3.9	3.9
2000	3.7	3.7	3.9	3.8	3.9
2001	3.8	3.6	3.9	3.7	3.7
2002	3.8	3.7	3.9	3.7	3.7
2003	3.6	3.5	3.7	3.7	3.7
2004	3.6	3.6	3.7	3.7	3.7
2005	3.6	3.6	3.8	3.7	3.7
2006	3.6	3.6	3.8	3.7	3.7
2007	3.5	3.6	3.8	3.7	3.8
2008	3.5	3.5	3.7	3.7	3.7
2009	3.4	3.4	3.7	3.6	3.7
2010	3.4	3.5	3.7	3.6	3.7
2011	3.3	3.4	3.7	3.5	3.7
2012	3.2	3.4	3.5	3.5	3.6
2013	3.1	3.3	3.5	3.4	3.6
2014	3.1	3.3	3.6	3.4	3.7
2015	3.1	3.2	3.6	3.4	3.7

Table B.35. Measured RQI for selected sections of project 8480-26, constructed in 1993. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)				
	31 +0.834	33 +0.000	34 +0.000	35 +0.000	36 +0.000
Year	I	I	I	I	I
1993					
1994	3.4	3.5	3.5	3.5	3.4
1996	3.5	3.5	3.8	3.6	3.7
1997	3.8	3.8	3.8	3.8	3.8
1998	3.8	4.0	4.1	4.0	4.0
1999	3.8	3.9	4.0	3.9	4.0
2000	3.6	3.7	3.8	3.6	3.8
2001	3.8	3.6	3.9	3.4	3.5
2002	3.9	3.8	3.9	3.5	3.6
2003	3.3	3.4	3.5	3.5	3.5
2004	3.4	3.5	3.5	3.5	3.6
2005	3.4	3.5	3.6	3.5	3.6
2006	3.4	3.5	3.6	3.6	3.6
2007	3.3	3.5	3.6	3.5	3.7
2008	3.2	3.4	3.5	3.5	3.6
2009	3.1	3.3	3.4	3.4	3.5
2010	3.2	3.4	3.4	3.4	3.5
2011	3.1	3.4	3.4	3.4	3.5
2012	3.1	3.3	3.4	3.4	3.5
2013	3.0	3.3	3.4	3.3	3.5
2014	3.0	3.3	3.5	3.5	3.6
2015	3.1	3.3	3.5	3.4	3.6

Table B.36. Measured SR for selected sections of project 8480-26, constructed in 1993. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)				
	31 +0.834	33 +0.000	34 +0.000	35 +0.000	36 +0.000
Year	I	I	I	I	I
1993					
1994	4.0	4.0	4.0	4.0	4.0
1996	4.0	3.9	4.0	4.0	4.0
1997	3.9	3.8	4.0	4.0	4.0
1998	4.0	3.8	4.0	4.0	4.0
1999	4.0	3.8	4.0	4.0	3.9
2000	3.9	3.8	4.0	4.0	4.0
2001	3.9	3.7	4.0	4.0	4.0
2002	3.7	3.7	4.0	4.0	3.9
2003	3.9	3.7	4.0	4.0	3.9
2004	3.9	3.7	4.0	4.0	3.9
2005	3.9	3.8	4.0	3.9	3.9
2006					
2007	3.8	3.7	4.0	4.0	3.9
2008					
2009	3.8	3.6	4.0	3.8	3.9
2010	3.7	3.6	4.0	3.8	3.9
2011	3.6	3.5	4.0	3.7	3.9
2012	3.4	3.5	3.7	3.6	3.8
2013	3.3	3.4	3.6	3.6	3.8
2014	3.2	3.4	3.8	3.3	3.8
2015	3.2	3.1	3.7	3.5	3.8

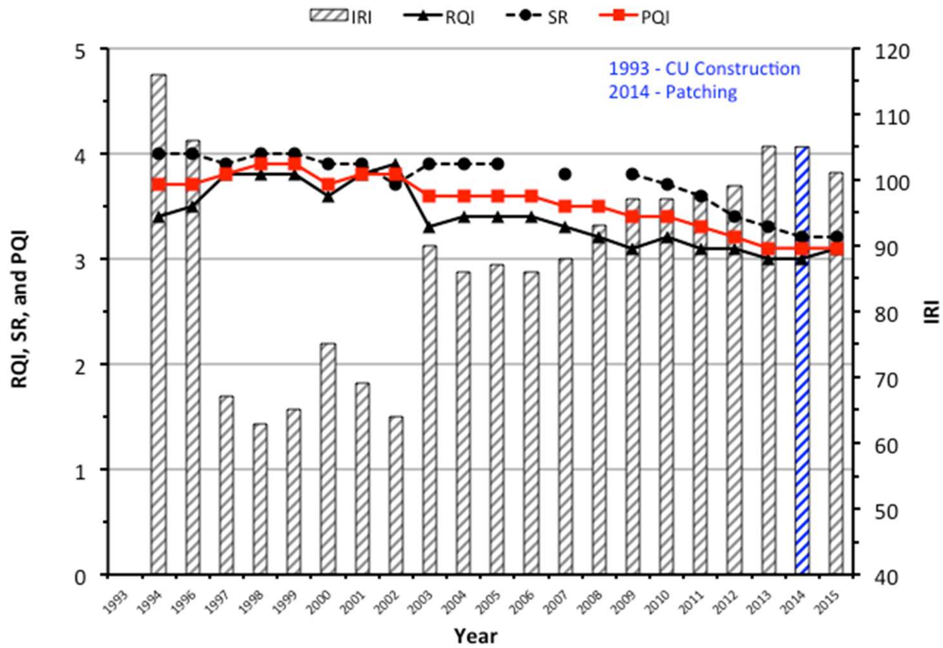


Figure B.77. Pavement management system data for section 31+0.834, direction I, of project 8480–26 constructed in 1993. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

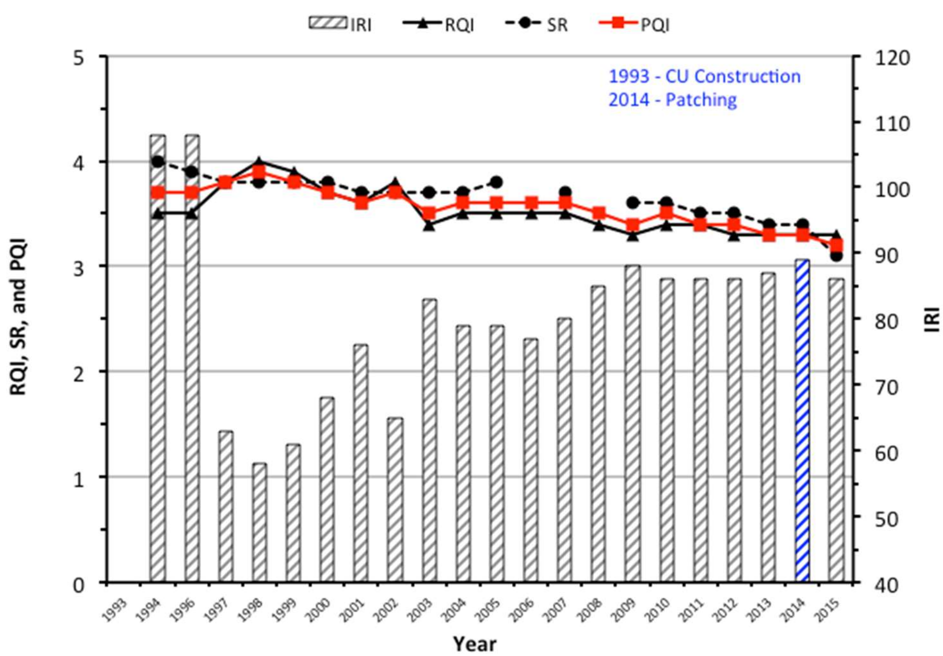


Figure B.78. Pavement management system data for section 33+0.000, direction I, of project 8480–26 constructed in 1993. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

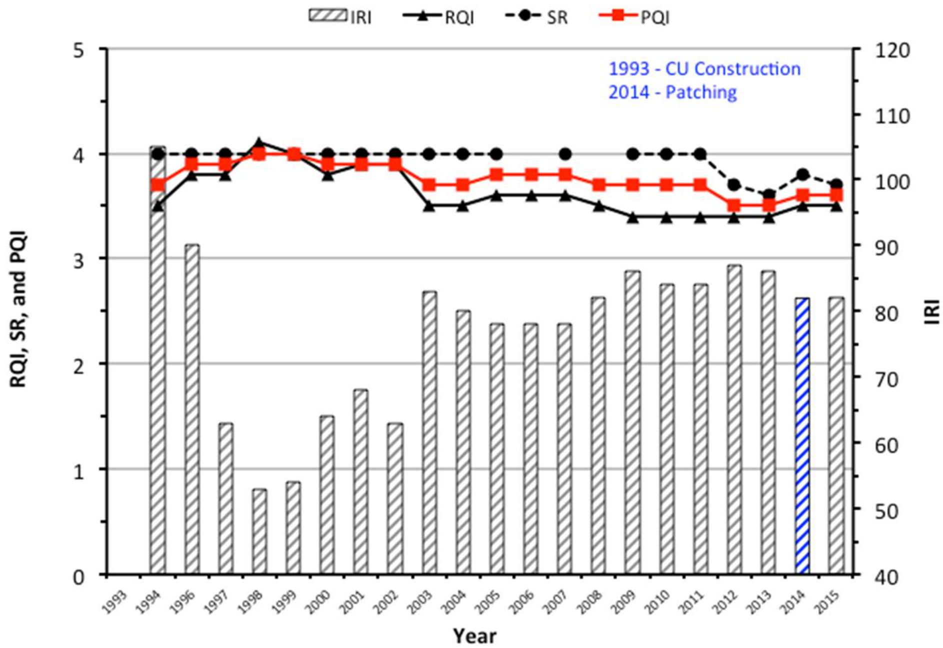


Figure B.79. Pavement management system data for section 34+0.000, direction I, of project 8480–26 constructed in 1993. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

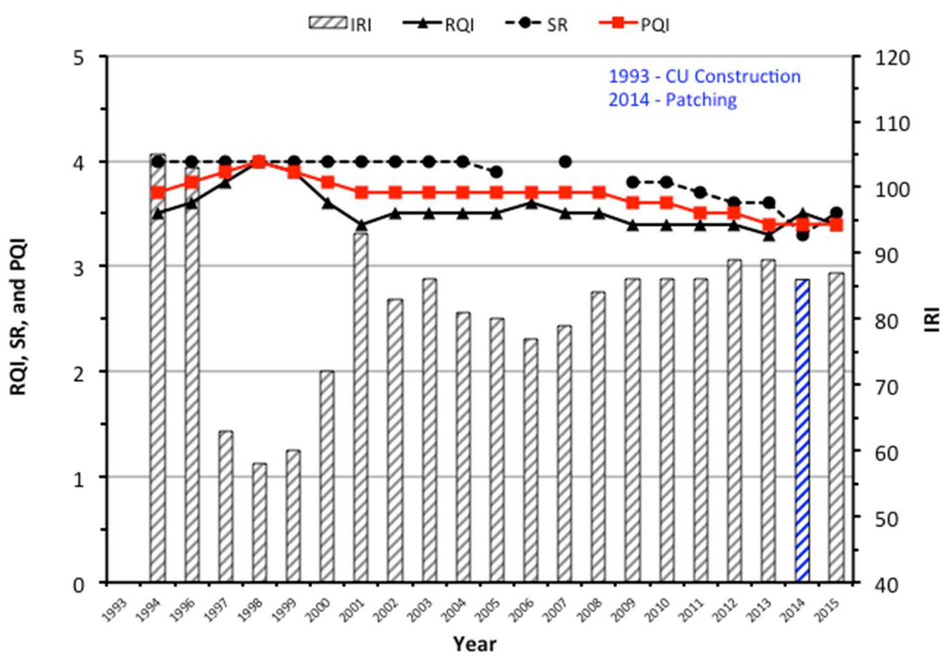


Figure B.80. Pavement management system data for section 35+0.000, direction I, of project 8480–26 constructed in 1993. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

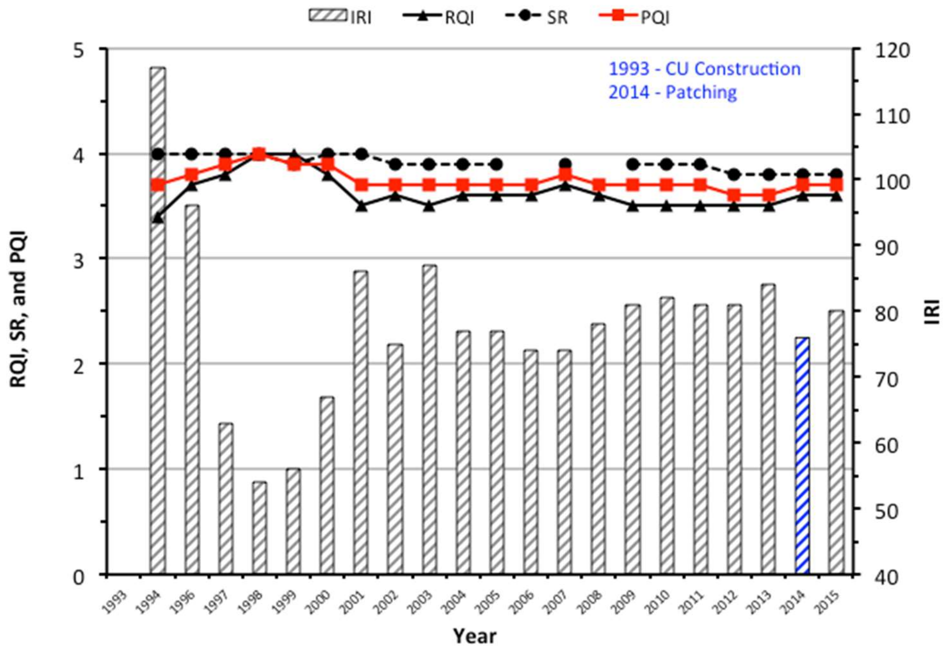


Figure B.81. Pavement management system data for section 36+0.000, direction DIU, of project 8480–26 constructed in 1993. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

District 4 – 8480-27

Table B.37. Measured IRI for selected sections of project 8480-27, constructed in 1995. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)					
	31 +0.000	32 +0.000	33 +0.000	34 +0.000	35 +0.000	36 +0.000
Year	D	D	D	D	D	D
1995						
1996	116	121	102	118	108	116
1997	46	51	45	47	51	48
1998	47	51	46	47	53	49
1999	47	52	46	49	51	49
2000	47	52	46	49	53	51
2001	48	54	59	62	63	71
2002	47	52	59	59	62	64
2003	68	77	67	72	73	67
2004	65	73	66	67	73	63
2005	60	66	56	61	63	57
2006	56	65	55	58	59	56
2007	65	73	64	67	67	65
2008	66	73	64	68	68	67
2009	69	77	67	70	73	69
2010	64	70	60	63	65	65
2011	84	91	82	82	82	85
2012	81	88	77	81	80	81
2013	80	75	67	70	72	69
2014	69	78	64	72	80	83
2015	75	80	67	73	76	73

Table B.38. Measured PQI for selected sections of project 8480-27, constructed in 1995. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)					
	31 +0.000	32 +0.000	33 +0.000	34 +0.000	35 +0.000	36 +0.000
Year	D	D	D	D	D	D
1995						
1996	3.7	3.6	3.8	3.6	3.7	3.7
1997	4.1	4.0	4.1	4.1	4.0	4.1
1998	4.1	4.0	4.1	4.1	4.0	4.1
1999	4.1	4.0	4.1	4.1	4.0	4.0
2000	4.1	4.0	4.1	4.1	4.0	4.0
2001	4.2	4.1	4.1	4.0	3.9	3.9
2002	4.1	4.1	4.0	4.0	3.8	3.9
2003	3.9	3.8	4.0	3.9	3.7	3.8
2004	3.9	3.8	3.9	3.9	3.7	3.9
2005	4.0	3.9	4.0	4.0	3.8	4.0
2006	4.0	3.9	4.0	4.0	3.8	4.0
2007	3.9	3.8	3.9	3.9	3.7	3.9
2008	3.9	3.8	3.9	3.9	3.7	3.9
2009	3.8	3.8	3.8	3.8	3.6	3.8
2010	3.8	3.8	3.9	3.9	3.6	3.9
2011	3.6	3.6	3.6	3.7	3.4	3.5
2012	3.5	3.4	3.6	3.8	3.4	3.4
2013	3.5	3.5	3.7	3.9	3.5	3.4
2014	3.8	3.5	3.7	3.8	3.3	3.4
2015	3.6	3.7	3.7	3.8	3.5	3.5

Table B.39. Measured RQI for selected sections of project 8480-27, constructed in 1995. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)					
	31 +0.000	32 +0.000	33 +0.000	34 +0.000	35 +0.000	36 +0.000
Year	D	D	D	D	D	D
1995						
1996	3.4	3.3	3.6	3.3	3.5	3.4
1997	4.2	4.1	4.3	4.2	4.1	4.2
1998	4.2	4.1	4.2	4.2	4.1	4.2
1999	4.2	4.1	4.2	4.2	4.1	4.1
2000	4.2	4.1	4.2	4.2	4.1	4.1
2001	4.4	4.2	4.2	4.1	4.0	3.8
2002	4.3	4.2	4.1	4.1	3.9	3.9
2003	3.9	3.6	4.0	3.8	3.7	3.7
2004	3.9	3.7	3.9	3.8	3.7	3.8
2005	4.1	3.9	4.1	4.0	3.9	4.0
2006	4.1	3.8	4.1	4.0	3.9	4.0
2007	3.8	3.7	3.9	3.8	3.7	3.8
2008	3.9	3.7	3.9	3.8	3.7	3.8
2009	3.8	3.6	3.8	3.7	3.6	3.7
2010	3.8	3.7	4.0	3.9	3.8	3.8
2011	3.5	3.4	3.5	3.5	3.4	3.4
2012	3.5	3.4	3.6	3.6	3.5	3.5
2013	3.5	3.6	3.8	3.8	3.6	3.7
2014	3.7	3.5	3.8	3.6	3.3	3.4
2015	3.7	3.6	3.8	3.7	3.5	3.6

Table B.40. Measured SR for selected sections of project 8480-27, constructed in 1995. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)					
	31 +0.000	32 +0.000	33 +0.000	34 +0.000	35 +0.000	36 +0.000
Year	D	D	D	D	D	D
1995						
1996	4.0	4.0	4.0	4.0	4.0	4.0
1997	4.0	4.0	4.0	4.0	4.0	4.0
1998	4.0	4.0	4.0	4.0	4.0	4.0
1999	4.0	4.0	4.0	4.0	3.9	4.0
2000	4.0	4.0	4.0	4.0	3.9	4.0
2001	4.0	4.0	4.0	4.0	3.8	4.0
2002	4.0	4.0	4.0	4.0	3.8	4.0
2003	4.0	4.0	4.0	4.0	3.8	4.0
2004	4.0	4.0	4.0	4.0	3.8	4.0
2005	4.0	4.0	4.0	4.0	3.8	4.0
2006						
2007	4.0	4.0	4.0	4.0	3.8	4.0
2008						
2009	3.9	4.0	3.9	4.0	3.7	4.0
2010	3.9	3.9	3.9	4.0	3.5	4.0
2011	3.8	3.8	3.7	4.0	3.4	3.7
2012	3.6	3.5	3.6	4.0	3.3	3.4
2013	3.5	3.4	3.7	4.0	3.4	3.1
2014	3.9	3.6	3.7	4.0	3.3	3.4
2015	3.6	3.8	3.7	4.0	3.5	3.4

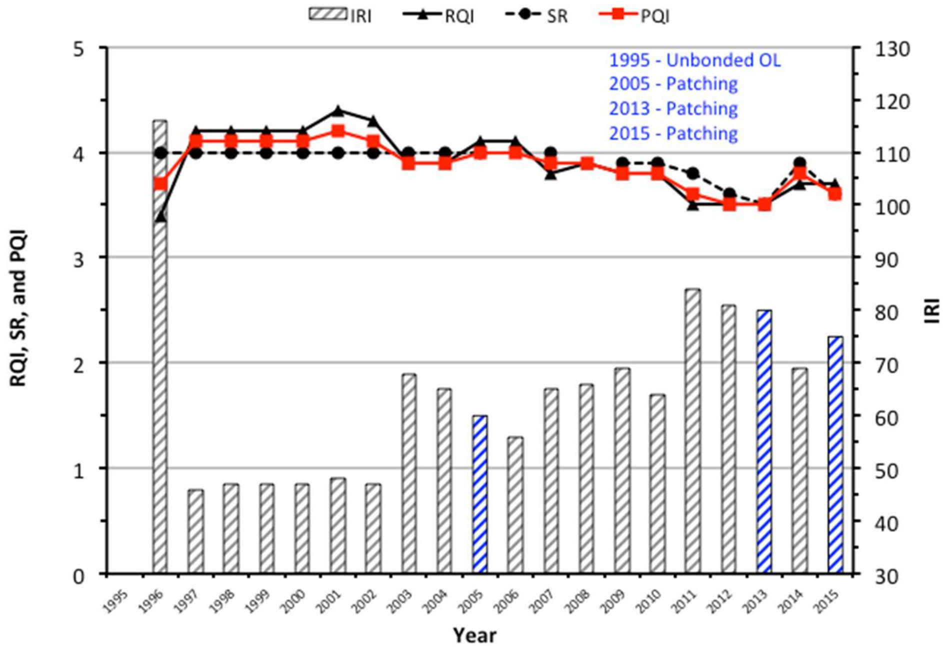


Figure B.82. Pavement management system data for section 31+0.000, direction D, of project 8480–27 constructed in 1995. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

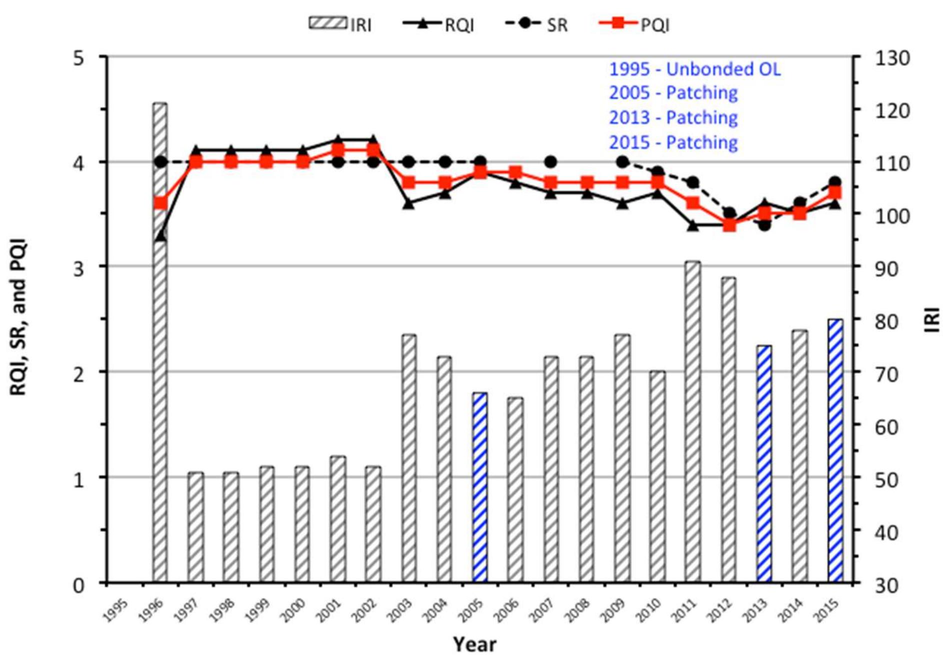


Figure B.83. Pavement management system data for section 32+0.000, direction D, of project 8480–27 constructed in 1995. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

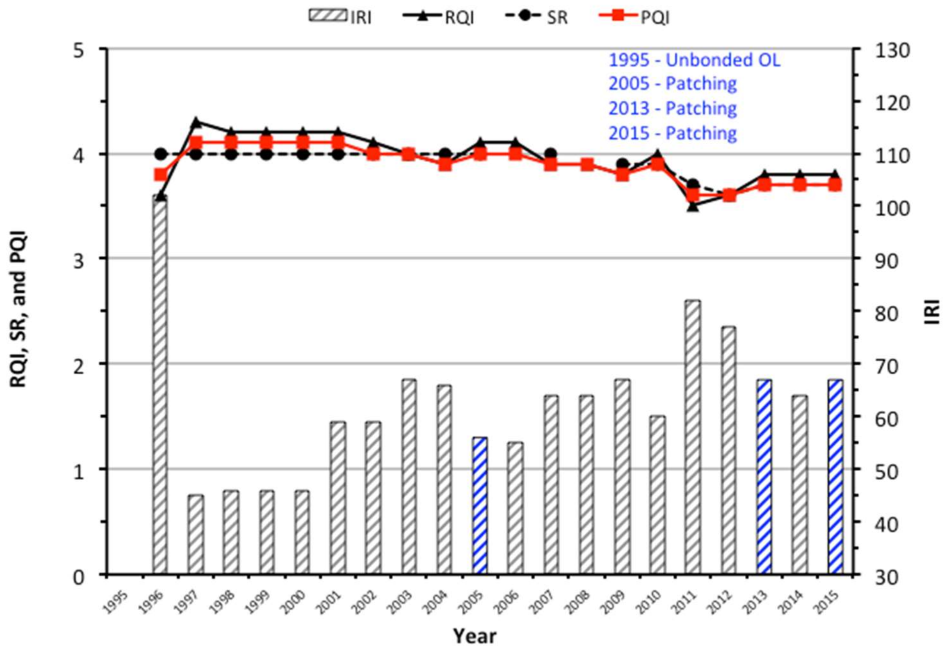


Figure B.84. Pavement management system data for section 33+0.000, direction D, of project 8480–27 constructed in 1995. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

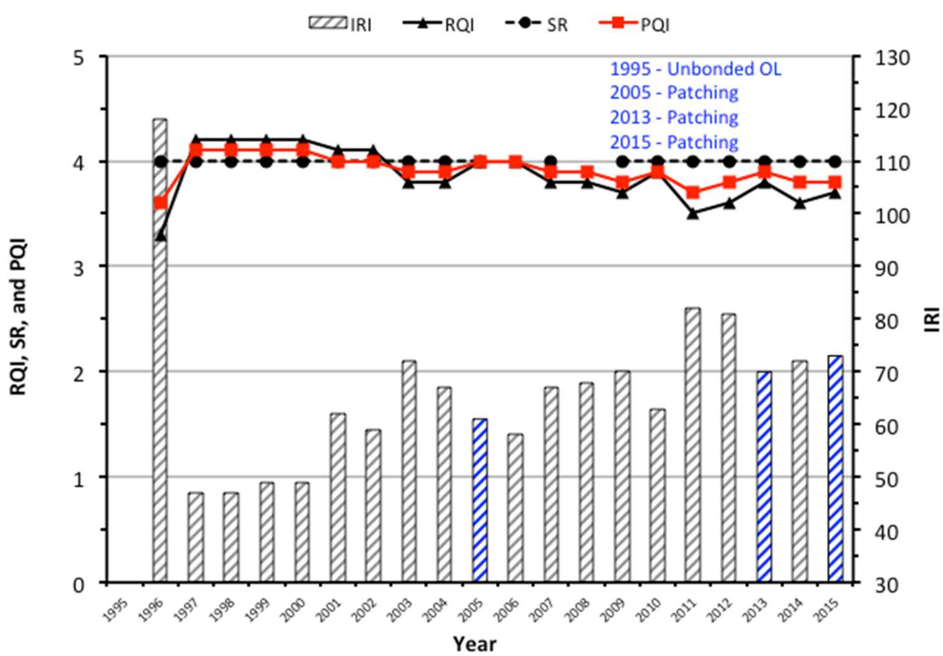


Figure B.85. Pavement management system data for section 34+0.000, direction D, of project 8480–27 constructed in 1995. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

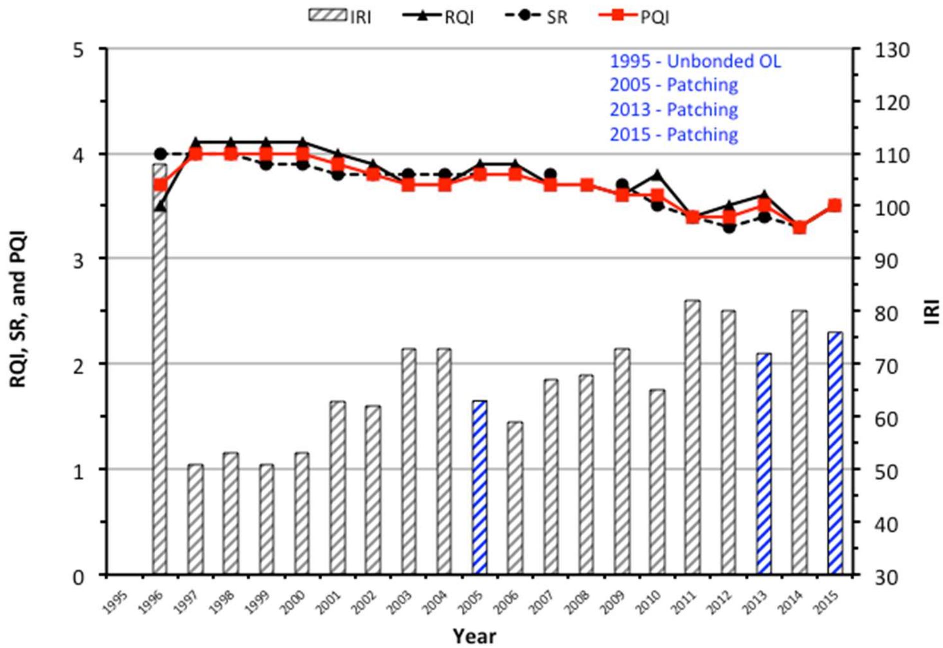


Figure B.86. Pavement management system data for section 35+0.000, direction D, of project 8480–27 constructed in 1995. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

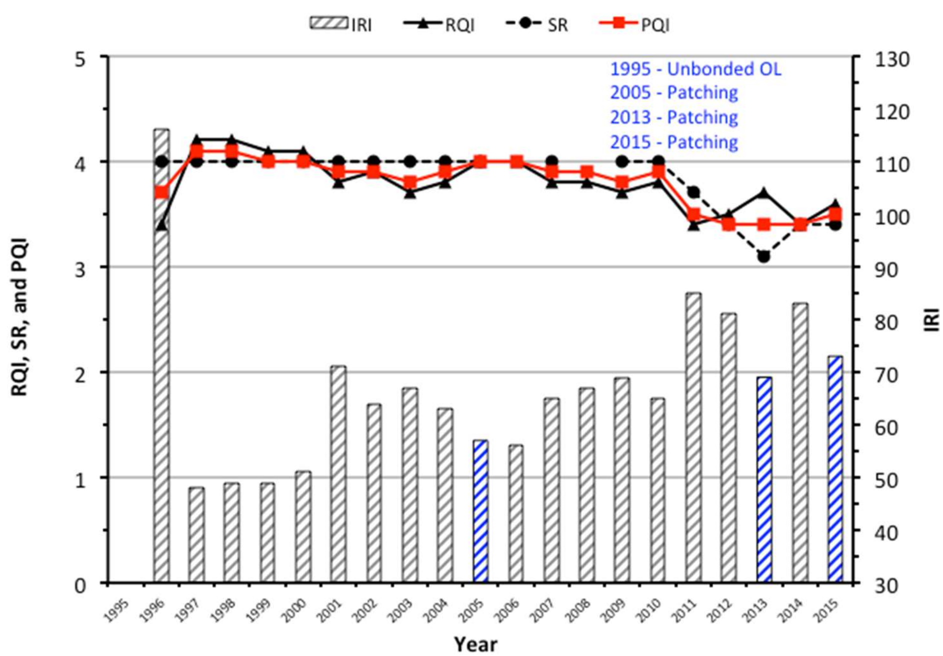


Figure B.87. Pavement management system data for section 36+0.000, direction D, of project 8480–27 constructed in 1995. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

District 4 – 2180-71

Table B.41. Measured IRI for selected sections of project 2180-71, constructed in 1993. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)						
	96 +0.327	97 +0.000	98 +0.000	99 +0.000	100 +0.000	101 +0.000	102 +0.000
Year	D	D	D	D	D	D	D
1993	105	113	94	92	102	124	102
1994	98	117	98	96	111	99	96
1997	65	78	58	61	72	58	61
1998	68	77	58	61	72	61	61
1999	68	80	64	61	78	61	67
2000	71	75	59	60	77	63	61
2001	95	112	69		93	75	83
2002	89	104	62	63	86	68	75
2003	95	111	80	77	104	97	90
2004	89	101	75	73	96	90	85
2005	81	96	68	62	87	82	74
2006	80	94	69	64	86	80	76
2007	86	103	75	71	93	87	83
2008	88	104	80	73	94	96	90
2009	93	110	77	71	98	91	88
2010	87	102	69	71	92	84	77
2011	95	106	78	69	95	92	78
2012	91	110	83	73	95	101	92
2013	92	114	76	73	94	97	90
2014	93	110	76	71	94	94	87
2015	102	118	86	79	98	106	93

Table B.42. Measured PQI for selected sections of project 2180-71, constructed in 1993. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)						
	96 +0.327	97 +0.000	98 +0.000	99 +0.000	100 +0.000	101 +0.000	102 +0.000
Year	D	D	D	D	D	D	D
1993	3.0	2.9	3.2	3.3	2.7	3.0	3.2
1994	3.8	3.7	3.8	3.8	3.7	3.8	3.8
1997	3.9	3.7	4.0	3.9	3.8	4.0	3.9
1998	3.8	3.7	4.0	3.9	3.8	3.9	3.9
1999	3.8	3.7	3.9	3.9	3.7	3.9	3.9
2000	3.8	3.8	3.9	3.9	3.7	3.9	3.9
2001	3.7	3.5	3.8		3.7	3.8	3.7
2002	3.7	3.6	3.9	3.9	3.7	3.9	3.7
2003	3.6	3.5	3.7	3.8	3.6	3.6	3.6
2004	3.7	3.5	3.7	3.8	3.6	3.6	3.6
2005	3.8	3.6	3.8	3.9	3.7	3.7	3.8
2006	3.8	3.6	3.8	3.9	3.6	3.7	3.7
2007	3.7	3.5	3.7	3.8	3.6	3.7	3.7
2008	3.7	3.5	3.7	3.8	3.6	3.6	3.6
2009	3.5	3.5	3.7	3.8	3.5	3.6	3.5
2010	3.4	3.5	3.8	3.8	3.6	3.6	3.7
2011	3.2	3.5	3.6	3.8	3.6	3.6	3.5
2012	3.3	3.4	3.5	3.7	3.6	3.4	3.4
2013	3.0	3.3	3.6	3.8	3.6	3.4	3.4
2014	3.0	3.2	3.6	3.8	3.6	3.4	3.4
2015	3.1	3.2	3.6	3.7	3.6	3.3	3.4

Table B.43. Measured RQI for selected sections of project 2180-71, constructed in 1993. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)						
	96 +0.327	97 +0.000	98 +0.000	99 +0.000	100 +0.000	101 +0.000	102 +0.000
Year	D	D	D	D	D	D	D
1993	3.5	3.4	3.7	3.7	3.6	3.2	3.6
1994	3.7	3.4	3.6	3.7	3.4	3.6	3.7
1997	3.8	3.5	4.0	3.9	3.6	4.0	3.9
1998	3.7	3.5	4.0	3.9	3.6	3.9	3.9
1999	3.7	3.5	3.8	3.9	3.5	3.9	3.8
2000	3.7	3.6	3.9	3.9	3.5	3.8	3.9
2001	3.5	3.1	3.7		3.4	3.7	3.4
2002	3.5	3.2	3.8	3.8	3.4	3.8	3.5
2003	3.3	3.0	3.5	3.6	3.2	3.2	3.2
2004	3.5	3.1	3.5	3.6	3.2	3.3	3.3
2005	3.6	3.2	3.7	3.8	3.4	3.5	3.6
2006	3.6	3.2	3.6	3.8	3.3	3.5	3.5
2007	3.5	3.0	3.5	3.6	3.2	3.4	3.4
2008	3.5	3.1	3.5	3.6	3.2	3.2	3.2
2009	3.4	3.0	3.5	3.6	3.1	3.3	3.3
2010	3.4	3.1	3.7	3.6	3.3	3.4	3.5
2011	3.3	3.1	3.5	3.7	3.3	3.3	3.4
2012	3.4	2.9	3.4	3.5	3.2	3.0	3.2
2013	3.4	2.8	3.5	3.6	3.2	3.2	3.3
2014	3.2	2.9	3.5	3.6	3.2	3.2	3.2
2015	3.2	2.8	3.3	3.5	3.2	3.0	3.2

Table B.44. Measured SR for selected sections of project 2180-71, constructed in 1993. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)						
	96 +0.327	97 +0.000	98 +0.000	99 +0.000	100 +0.000	101 +0.000	102 +0.000
Year	D	D	D	D	D	D	D
1993	2.5	2.5	2.8	3.0	2.1	2.8	2.8
1994	4.0	4.0	4.0	4.0	4.0	4.0	4.0
1997	4.0	4.0	4.0	4.0	4.0	4.0	4.0
1998	4.0	4.0	4.0	4.0	4.0	4.0	4.0
1999	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2000	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2001	4.0	4.0	4.0		4.0	4.0	4.0
2002	3.9	4.0	4.0	4.0	4.0	4.0	3.9
2003	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2004	4.0	4.0	3.9	4.0	4.0	4.0	4.0
2005	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2006							
2007	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2008							
2009	3.6	4.0	3.9	4.0	4.0	4.0	3.8
2010	3.5	4.0	3.9	4.0	4.0	3.9	3.9
2011	3.2	3.9	3.7	4.0	4.0	3.9	3.7
2012							
2013	2.6	3.8	3.7	4.0	4.0	3.6	3.6
2014	2.8	3.6	3.7	4.0	4.0	3.7	3.7
2015	3.1	3.6	3.9	4.0	4.0	3.7	3.7

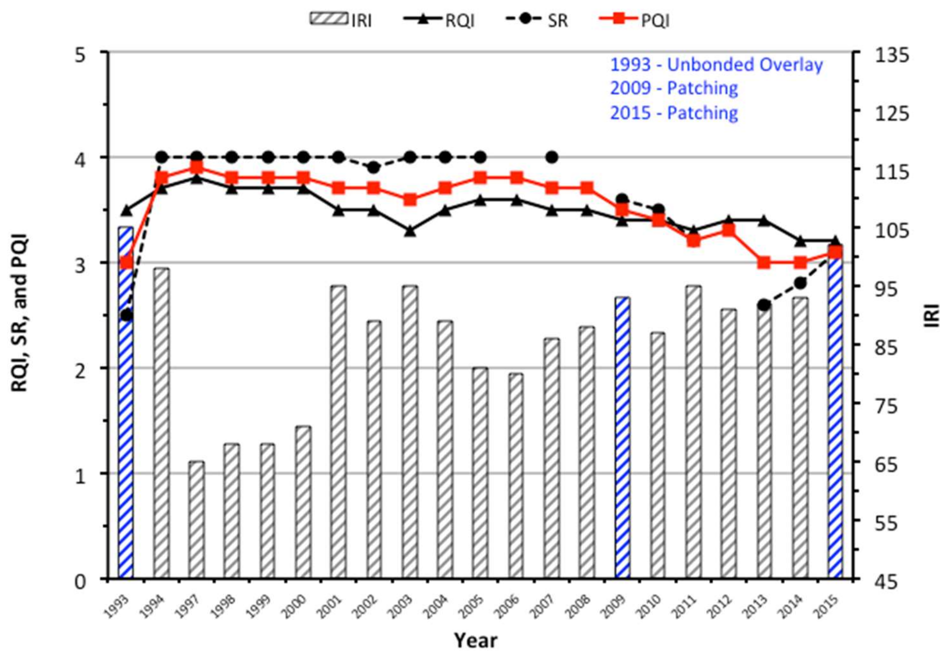


Figure B.88. Pavement management system data for section 96+0.327, direction D, of project 2180–71 constructed in 1993. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

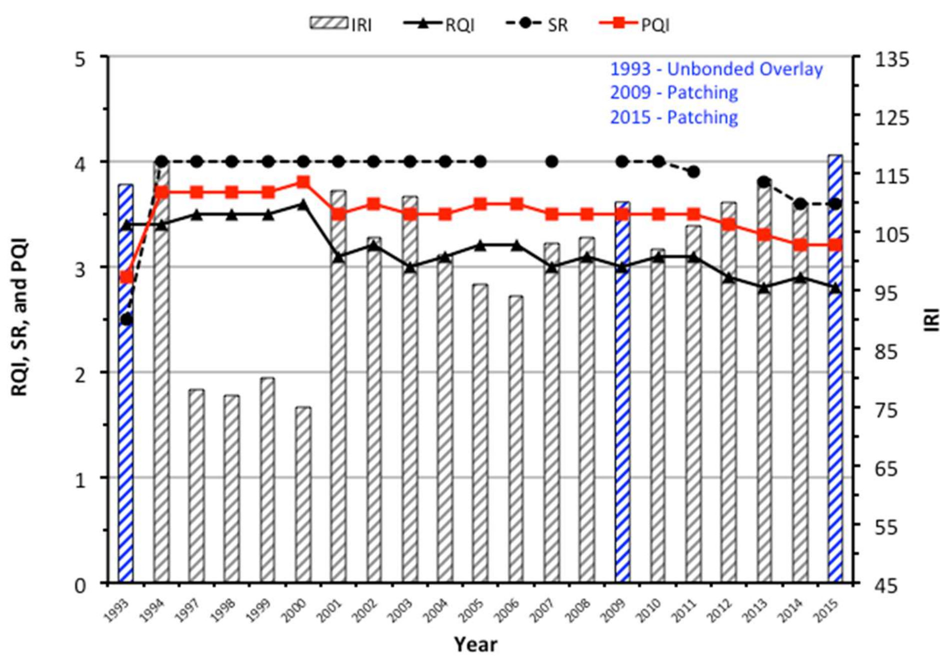


Figure B.89. Pavement management system data for section 97+0.000, direction D, of project 2180–71 constructed in 1993. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

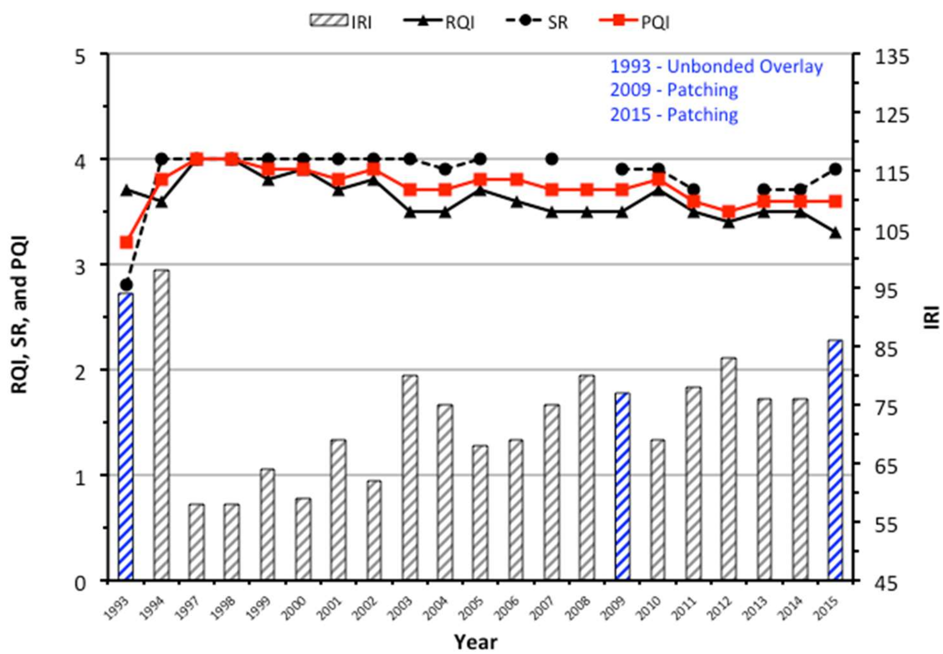


Figure B.90. Pavement management system data for section 98+0.000, direction D, of project 2180–71 constructed in 1993. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

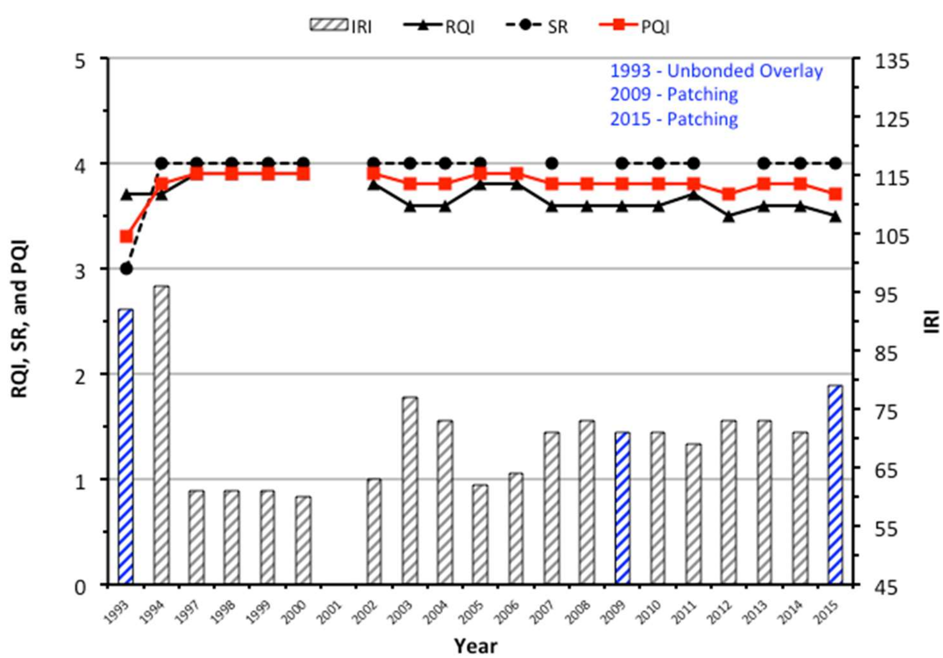


Figure B.91. Pavement management system data for section 99+0.000, direction D, of project 2180–71 constructed in 1993. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

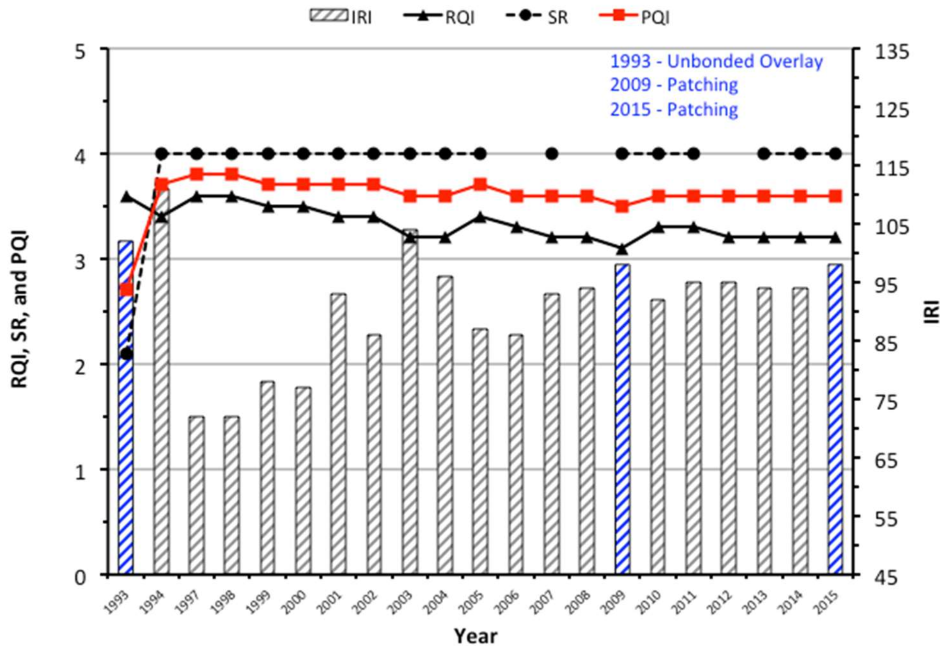


Figure B.92. Pavement management system data for section 100+0.000, direction D, of project 2180–71 constructed in 1993. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

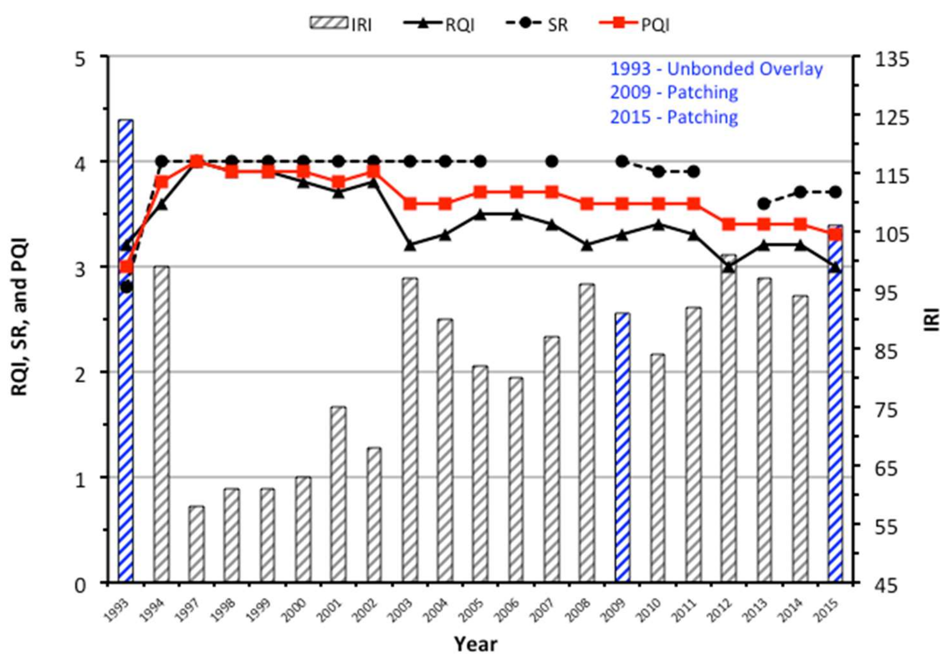


Figure B.93. Pavement management system data for section 101+0.000, direction D, of project 2180–71 constructed in 1993. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

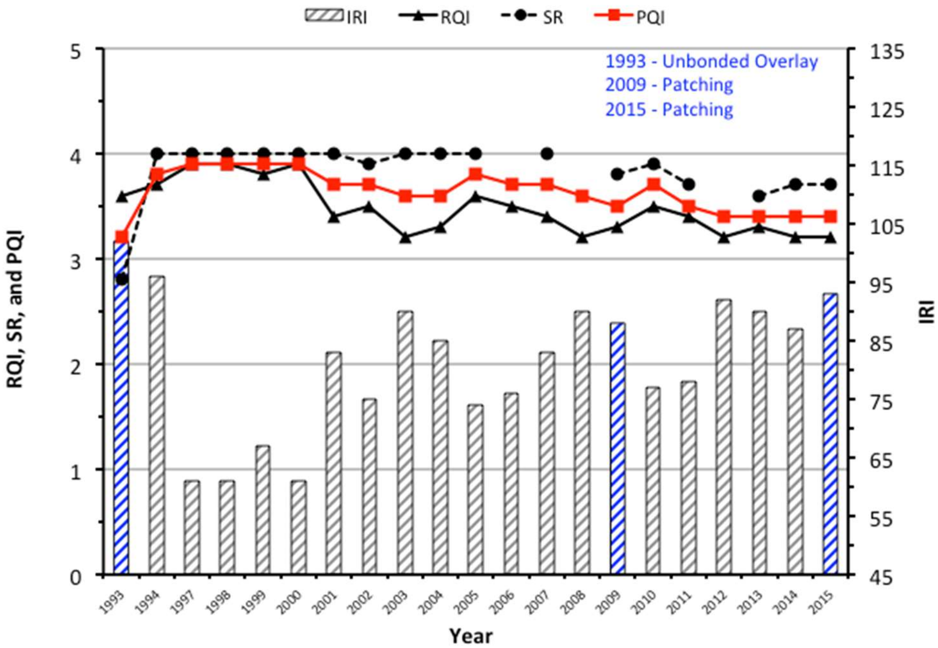


Figure B.94. Pavement management system data for section 102+0.000, direction D, of project 2180–71 constructed in 1993. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

District 4 – 2180-80

Table B.45. Measured IRI for selected sections of project 2180-80, constructed in 1998. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)						
	102 +0.795	104 +0.000	105 +0.000	106 +0.000	107 +0.000	108 +0.000	109 +0.000
Year	I	I	I	I	I	I	I
1998							
1999	58	61	49	42	47	44	45
2000	56	68	56	52	52	52	52
2001	46	69	51	41	45	43	42
2002	46	70	50	42	47	42	42
2003	69	78	72	63	63	60	61
2004	63	74	64	54	58	58	54
2005	54	66	55	47	47	48	45
2006							
2007	62	77	64	55	57	57	51
2008	63	77	64	58	59	57	52
2009	56	66	58	47	48	51	48
2010	56	66	58	47	48	51	48
2011	60	76	64	54	55	56	51
2012	61	76	63	54	56	56	53
2013	62	77	66	55	56	58	52
2014	67	80	66	58	59	59	55
2015	75	85	72	61	62	62	58

Table B.46. Measured PQI for selected sections of project 2180-80, constructed in 1998. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)						
	102 +0.795	104 +0.000	105 +0.000	106 +0.000	107 +0.000	108 +0.000	109 +0.000
Year	I	I	I	I	I	I	I
1998							
1999	4.0	3.9	4.1	4.1	4.1	4.1	4.1
2000	3.9	3.8	4.0	4.0	4.0	4.0	4.0
2001	4.1	3.9	4.1	4.2	4.1	4.2	4.2
2002	4.1	3.8	4.1	4.0	4.1	4.2	4.2
2003	3.8	3.7	3.8	3.9	3.9	3.9	3.9
2004	3.9	3.7	3.9	4.0	3.9	3.9	4.0
2005	4.0	3.9	4.0	4.1	4.1	4.1	4.1
2006							
2007	3.9	3.7	3.9	4.0	3.9	4.0	4.0
2008	3.9	3.7	3.9	4.0	3.9	4.0	4.0
2009	4.0	3.8	4.0	4.1	4.1	4.0	4.1
2010	4.0	3.8	4.0	4.1	4.1	4.0	4.1
2011	3.9	3.7	3.8	4.0	3.9	3.9	4.0
2012	3.9	3.7	3.8	3.9	3.9	3.9	4.0
2013	3.7	3.7	3.7	3.9	3.8	3.8	3.9
2014	3.7	3.6	3.8	3.9	3.8	3.9	3.8
2015	3.8	3.7	3.6	3.9	3.8	3.9	3.9

Table B.47. Measured RQI for selected sections of project 2180-80, constructed in 1998. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)						
	102 +0.795	104 +0.000	105 +0.000	106 +0.000	107 +0.000	108 +0.000	109 +0.000
Year	I	I	I	I	I	I	I
1998							
1999	4.0	3.9	4.2	4.3	4.2	4.3	4.3
2000	4.0	3.7	4.0	4.1	4.1	4.1	4.1
2001	4.3	3.8	4.2	4.4	4.3	4.4	4.4
2002	4.3	3.7	4.2	4.5	4.3	4.4	4.4
2003	3.7	3.5	3.6	3.8	3.8	3.9	3.9
2004	3.8	3.5	3.8	4.0	3.9	3.9	4.0
2005	4.0	3.8	4.0	4.2	4.2	4.2	4.3
2006							
2007	3.8	3.5	3.8	4.0	3.9	4.0	4.1
2008	3.8	3.5	3.8	4.0	3.9	4.0	4.1
2009	4.0	3.7	4.0	4.2	4.2	4.1	4.2
2010	4.0	3.7	4.0	4.2	4.2	4.1	4.2
2011	3.9	3.5	3.8	4.1	3.9	4.0	4.1
2012	3.9	3.5	3.8	4.0	3.9	4.0	4.1
2013	3.8	3.5	3.7	4.0	3.9	4.0	4.1
2014	3.6	3.4	3.8	3.9	3.8	3.9	4.0
2015	3.6	3.4	3.6	3.9	3.8	3.9	4.0

Table B.48. Measured SR for selected sections of project 2180-80, constructed in 1998. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)						
	102 +0.795	104 +0.000	105 +0.000	106 +0.000	107 +0.000	108 +0.000	109 +0.000
Year	I	I	I	I	I	I	I
1998							
1999	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2000	3.9	4.0	4.0	4.0	4.0	4.0	4.0
2001	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2002	4.0	4.0	4.0	3.6	4.0	4.0	4.0
2003	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2004	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2005	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2006							
2007	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2008							
2009	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2010	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2011	4.0	4.0	3.9	3.9	4.0	3.9	4.0
2012	3.9	4.0	3.8	3.9	4.0	3.9	3.9
2013	3.7	3.9	3.7	3.9	3.7	3.7	3.8
2014	3.9	3.9	3.9	4.0	3.9	3.9	3.7
2015	4.0	4.0	3.7	4.0	3.9	3.9	3.9

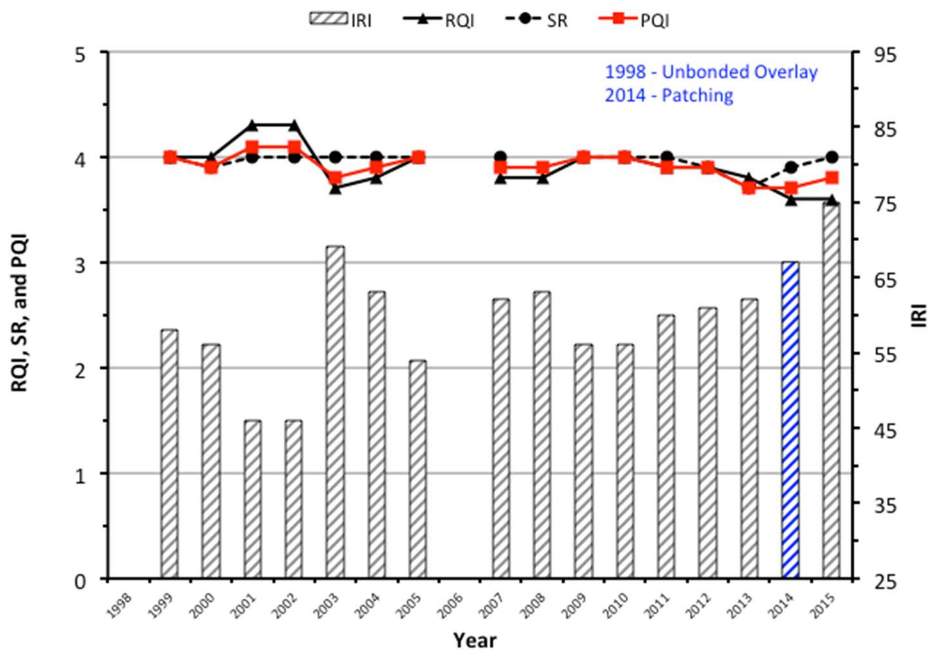


Figure B.95. Pavement management system data for section 102+0.795, direction I, of project 2180–80 constructed in 1998. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

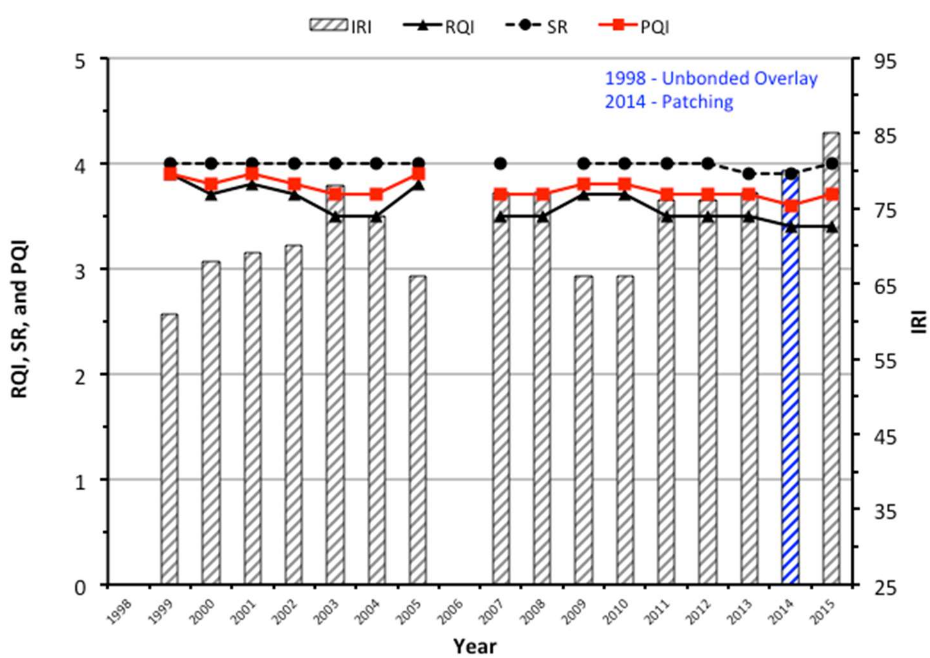


Figure B.96. Pavement management system data for section 104+0.000, direction I, of project 2180–80 constructed in 1998. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

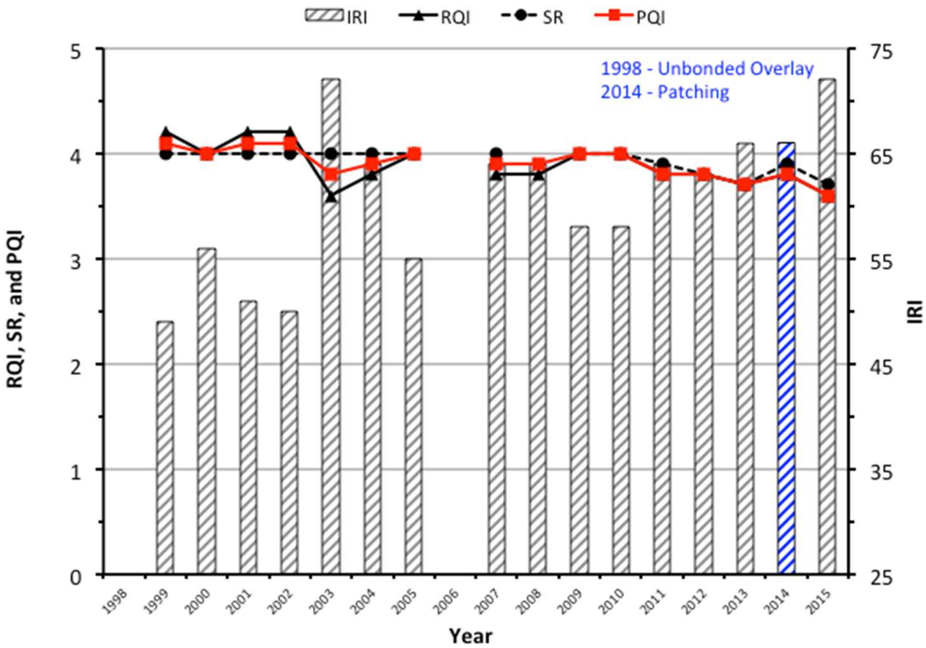


Figure B.97. Pavement management system data for section 105+0.000, direction I, of project 2180–80 constructed in 1998. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

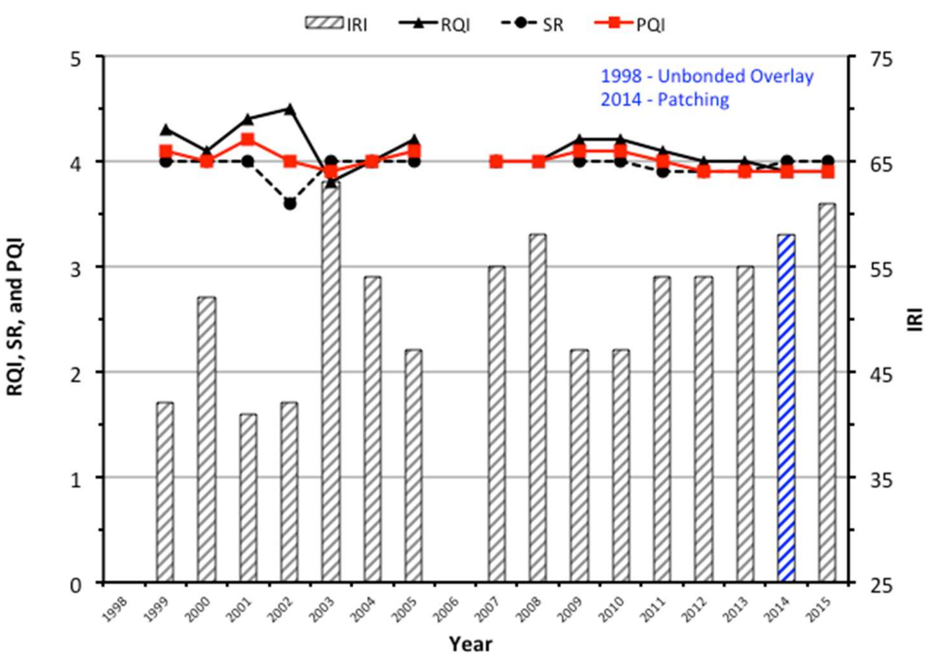


Figure B.98. Pavement management system data for section 106+0.000, direction I, of project 2180–80 constructed in 1998. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

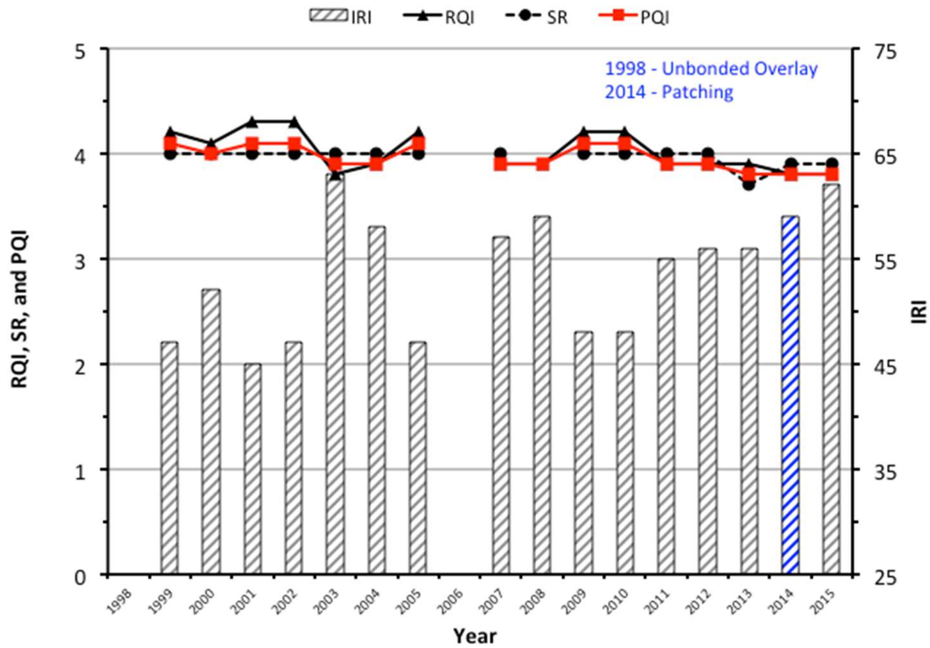


Figure B.99. Pavement management system data for section 107+0.000, direction I, of project 2180–80 constructed in 1998. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

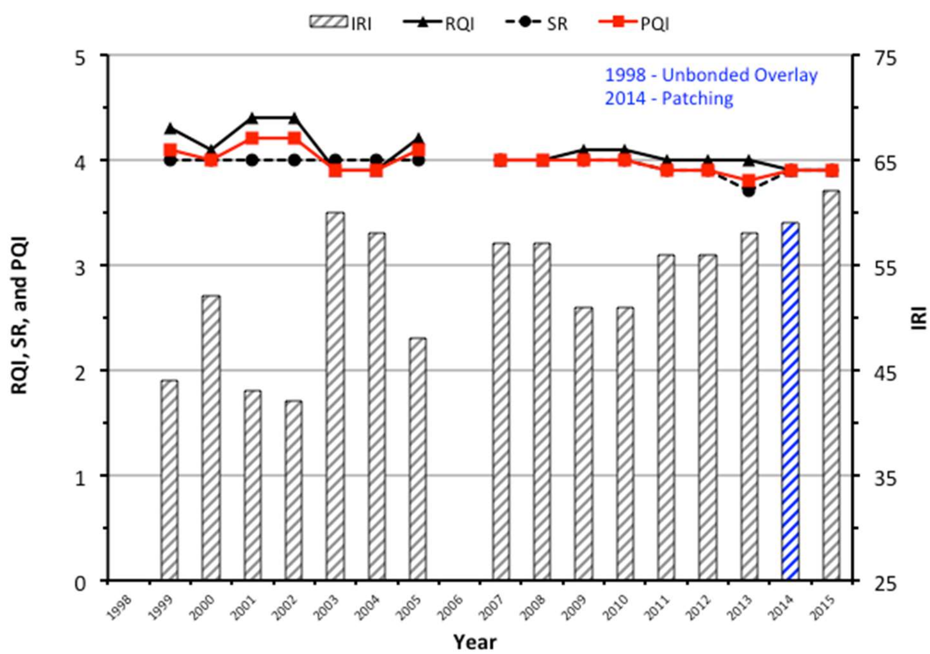


Figure B.100. Pavement management system data for section 108+0.000, direction I, of project 2180–80 constructed in 1998. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

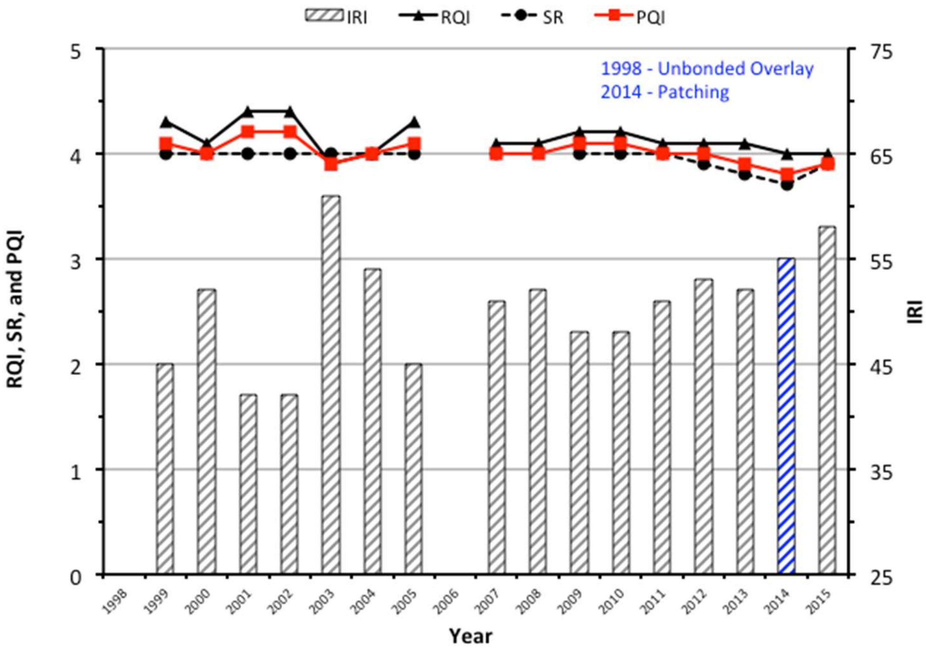


Figure B.101. Pavement management system data for section 109+0.000, direction I, of project 2180–80 constructed in 1998. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

District Metro – 1907-53

Table B.49. Measured IRI for selected sections of project 1907-53, constructed in 1994. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)					
	204 +0.050	205 +0.000	206 +0.000	204 +0.050	205 +0.000	206 +0.000
Year	D	D	D	I	I	I
1994						
1997	66	67	91	82	71	66
1999	60	65	92	82	71	68
2001	69	78	99	103	86	81
2002	88	88	114	112	93	96
2003	78	85	115	105	92	88
2004	79	92	133	108	90	83
2005	89	100	144	118	92	82
2006	80	93	133	105	92	80
2007	80	97	127	108	97	83
2008	73	93	135	109	94	82
2009	74	93	129	106	95	80
2010	74	100	135	110	99	87
2011	80	99	136	111	96	86
2012	78	102	143	113	99	82
2013	77	100	142	116	98	86
2014	78	101	136	113	102	85
2015	80	102	127	115	106	88

Table B.50. Measured PQI for selected sections of project 1907-53, constructed in 1994. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)					
	204 +0.050	205 +0.000	206 +0.000	204 +0.050	205 +0.000	206 +0.000
Year	D	D	D	I	I	I
1994						
1997	3.9	3.9	3.6	3.7	3.8	3.9
1999	3.9	3.9	3.6	3.7	3.8	3.8
2001	3.8	3.8	3.6	3.5	3.7	3.7
2002	3.7	3.7	3.4	3.5	3.6	3.5
2003	3.8	3.7	3.4	3.5	3.6	3.6
2004	3.7	3.6	3.2	3.5	3.6	3.7
2005	3.6	3.6	3.2	3.4	3.6	3.7
2006	3.7	3.6	3.2	3.5	3.6	3.7
2007	3.7	3.6	3.2	3.5	3.6	3.7
2008	3.8	3.6	3.1	3.5	3.6	3.7
2009	3.7	3.6	3.1	3.5	3.5	3.7
2010	3.7	3.6	3.1	3.4	3.5	3.7
2011	3.7	3.6	3.1	3.5	3.5	3.7
2012	3.7	3.5	3.0	3.4	3.5	3.7
2013	3.8	3.6	3.0	3.4	3.5	3.7
2014	3.7	3.6	3.0	3.4	3.5	3.7
2015	3.7	3.6	3.3	3.5	3.4	3.7

Table B.51. Measured RQI for selected sections of project 1907-53, constructed in 1994. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)					
	204 +0.050	205 +0.000	206 +0.000	204 +0.050	205 +0.000	206 +0.000
Year	D	D	D	I	I	I
1994						
1997	3.8	3.8	3.3	3.4	3.7	3.8
1999	3.9	3.8	3.2	3.4	3.7	3.7
2001	3.7	3.7	3.2	3.1	3.4	3.5
2002	3.4	3.4	2.9	3.0	3.3	3.1
2003	3.6	3.5	2.9	3.1	3.3	3.3
2004	3.5	3.3	2.6	3.1	3.2	3.4
2005	3.3	3.2	2.5	2.9	3.3	3.4
2006	3.5	3.3	2.6	3.1	3.3	3.5
2007	3.5	3.3	2.7	3.0	3.2	3.5
2008	3.6	3.3	2.6	3.0	3.2	3.5
2009	3.6	3.3	2.6	3.1	3.2	3.5
2010	3.6	3.2	2.6	3.0	3.2	3.4
2011	3.5	3.2	2.5	3.0	3.2	3.4
2012	3.5	3.1	2.4	2.9	3.2	3.5
2013	3.6	3.2	2.4	2.9	3.1	3.4
2014	3.5	3.2	2.5	3.0	3.1	3.4
2015	3.5	3.2	2.7	3.0	3.0	3.4

Table B.52. Measured SR for selected sections of project 1907-53, constructed in 1994. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)					
	204 +0.050	205 +0.000	206 +0.000	204 +0.050	205 +0.000	206 +0.000
Year	D	D	D	I	I	I
1994						
1997	4.0	4.0	4.0	4.0	4.0	4.0
1999	4.0	4.0	4.0	4.0	4.0	4.0
2001	4.0	4.0	4.0	4.0	4.0	4.0
2002						
2003	4.0	4.0	3.9	4.0	4.0	4.0
2004						
2005	4.0	4.0	4.0	4.0	4.0	4.0
2006						
2007	4.0	4.0	3.8	4.0	4.0	4.0
2008						
2009	3.9	4.0	3.8	3.9	3.9	4.0
2010						
2011	4.0	4.0	3.8	4.0	3.8	4.0
2012						
2013	4.0	4.0	3.7	3.9	3.9	4.0
2014						
2015	4.0	4.0	4.0	4.0	3.9	4.0

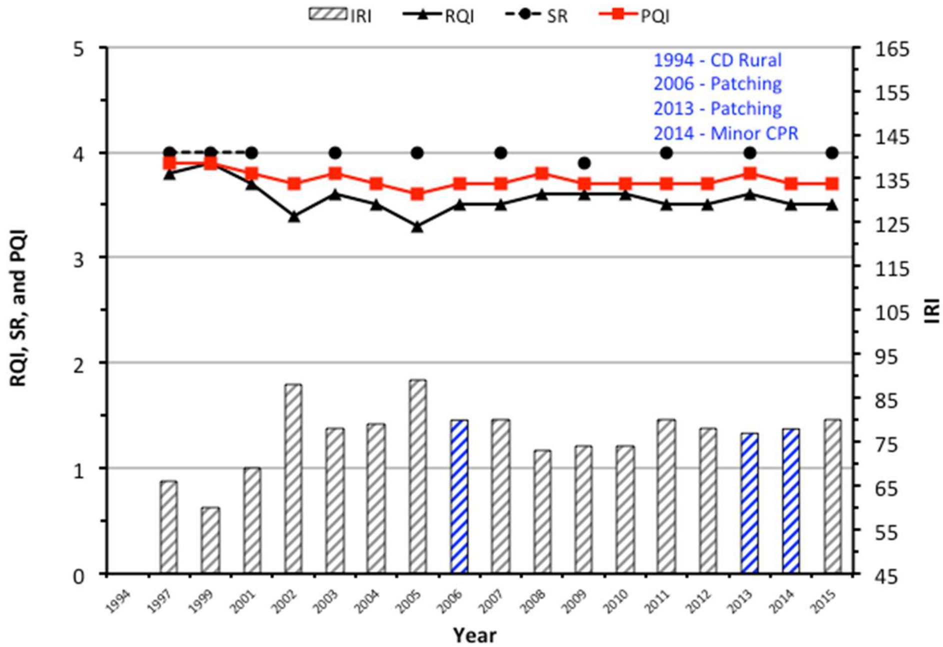


Figure B.102. Pavement management system data for section 204+0.050, direction D, of project 1907–53 constructed in 1994. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

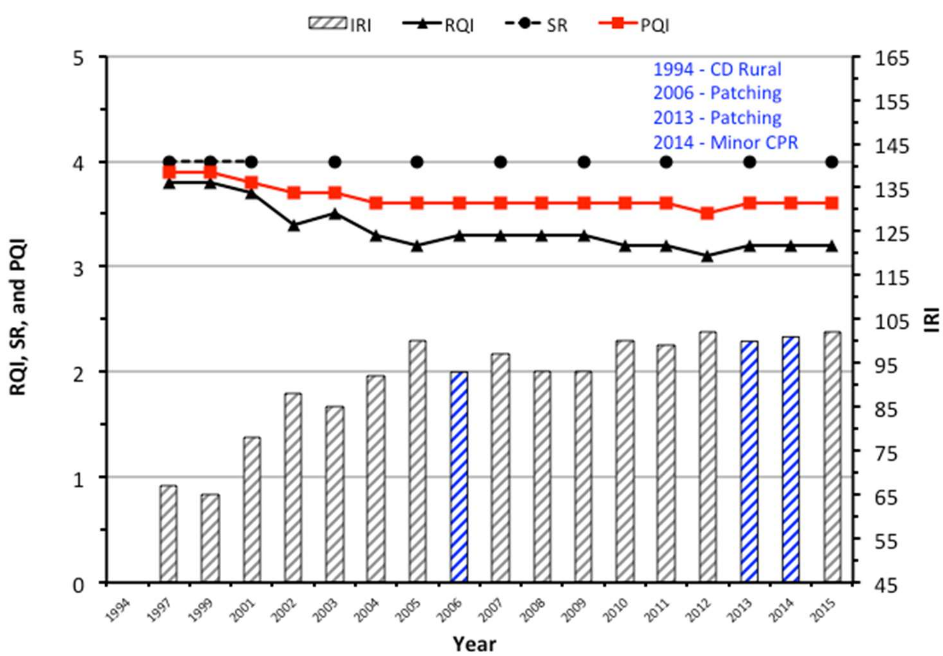


Figure B.103. Pavement management system data for section 205+0.000, direction D, of project 1907–53 constructed in 1994. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

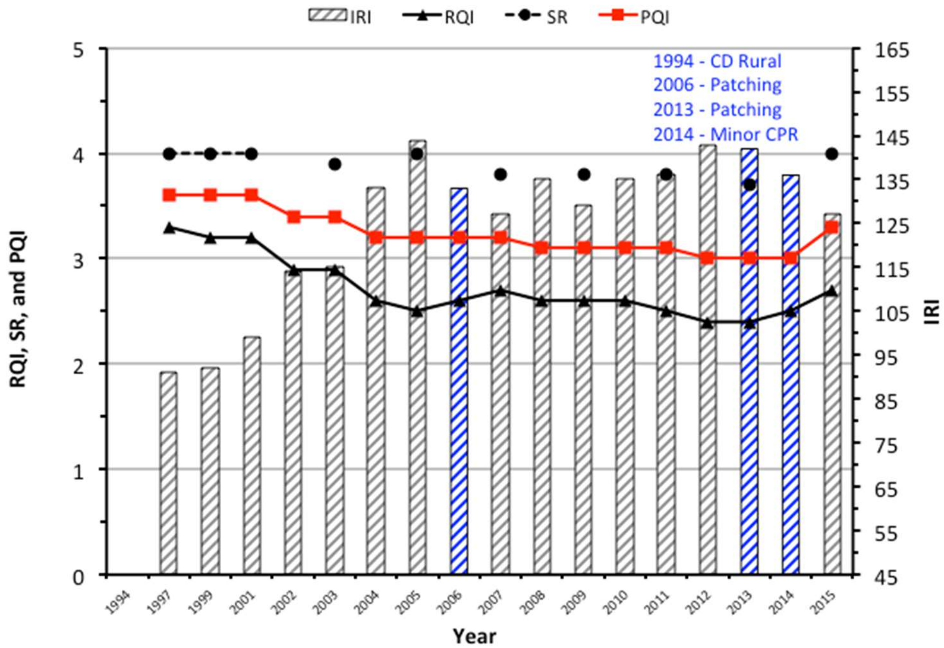


Figure B.104. Pavement management system data for section 206+0.000, direction D, of project 1907–53 constructed in 1994. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

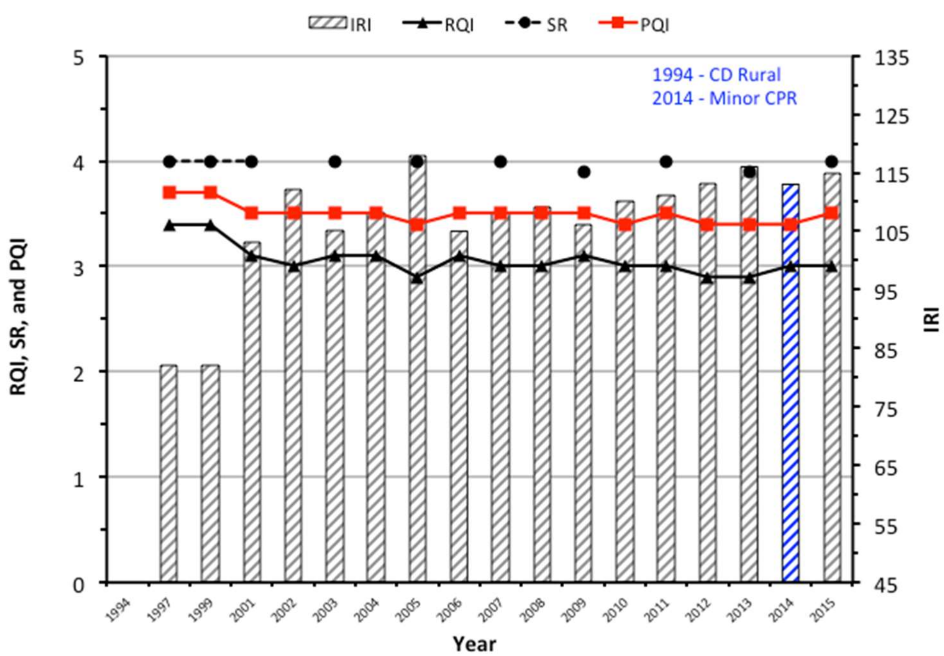


Figure B.105. Pavement management system data for section 204+0.050, direction I, of project 1907–53 constructed in 1994. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

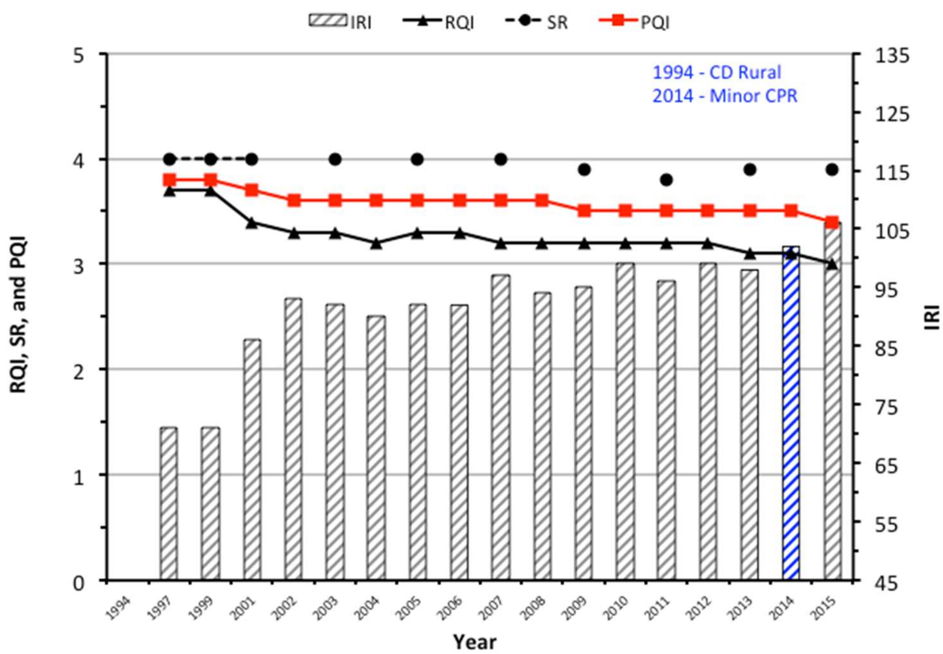


Figure B.106. Pavement management system data for section 205+0.000, direction I, of project 1907–53 constructed in 1994. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

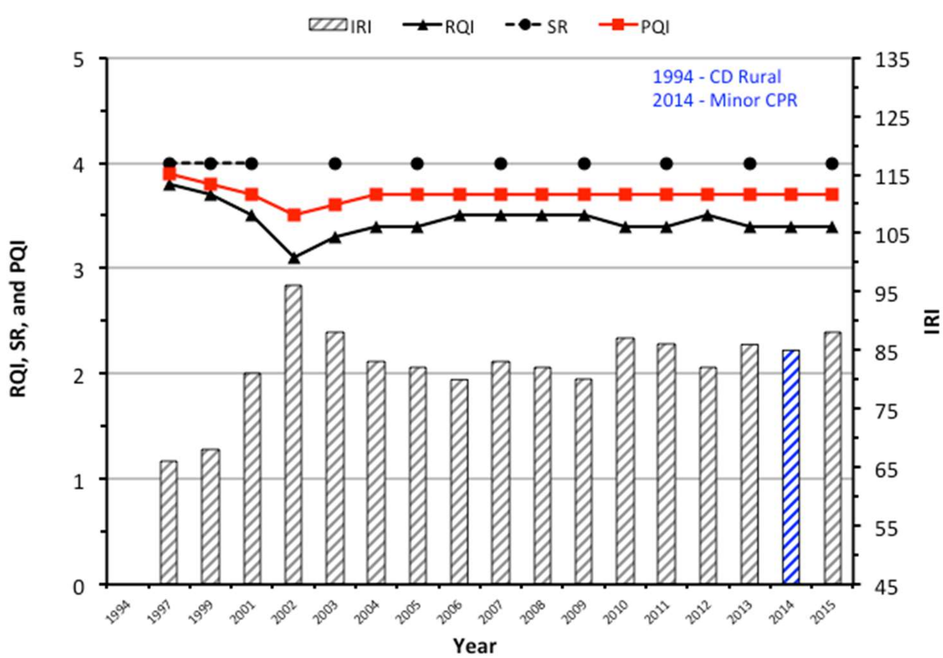


Figure B.107. Pavement management system data for section 206+0.000, direction I, of project 1907–53 constructed in 1994. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

District Metro – 2782-268

Table B.53. Measured IRI for selected sections of project 2782-268, constructed in 1999. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)	
	9+ 0.113	9+ 0.113
Year	D	I
1999		
2001	85	105
2002	70	118
2003	83	112
2004	81	128
2005	78	123
2006	73	118
2007	81	120
2008	86	135
2009	87	122
2010	83	123
2011	91	114
2012	86	113
2013	95	115
2014	90	114
2015	90	115

Table B.54. Measured PQI for selected sections of project 2782-268, constructed in 1999. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)	
	9+ 0.113	9+ 0.113
Year	D	I
1999		
2001	3.4	3.2
2002	3.8	3.5
2003	3.7	3.5
2004	3.8	3.4
2005	3.8	3.5
2006	3.8	3.5
2007	3.7	3.3
2008	3.7	3.3
2009	3.7	3.3
2010	3.7	3.3
2011	3.7	3.4
2012	3.7	3.4
2013	3.6	3.4
2014	3.7	3.3
2015	3.7	3.2

Table B.55. Measured RQI for selected sections of project 2782-268, constructed in 1999. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)	
	9+ 0.113	9+ 0.113
Year	D	I
1999		
2001	3.3	3.0
2002	3.7	3.0
2003	3.5	3.0
2004	3.6	2.9
2005	3.6	3.0
2006	3.7	3.0
2007	3.5	2.8
2008	3.5	2.7
2009	3.5	2.8
2010	3.5	2.7
2011	3.5	2.9
2012	3.5	2.9
2013	3.3	2.9
2014	3.4	2.9
2015	3.4	2.8

Table B.56. Measured SR for selected sections of project 2782-268, constructed in 1999. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)	
	9+ 0.113	9+ 0.113
Year	D	I
1999		
2001		
2002	4.0	4.0
2003		
2004	4.0	4.0
2005		
2006	4.0	4.0
2007		
2008	4.0	
2009		4.0
2010	4.0	4.0
2011	4.0	4.0
2012	4.0	4.0
2013	4.0	4.0
2014	4.0	3.8
2015	4.0	3.7

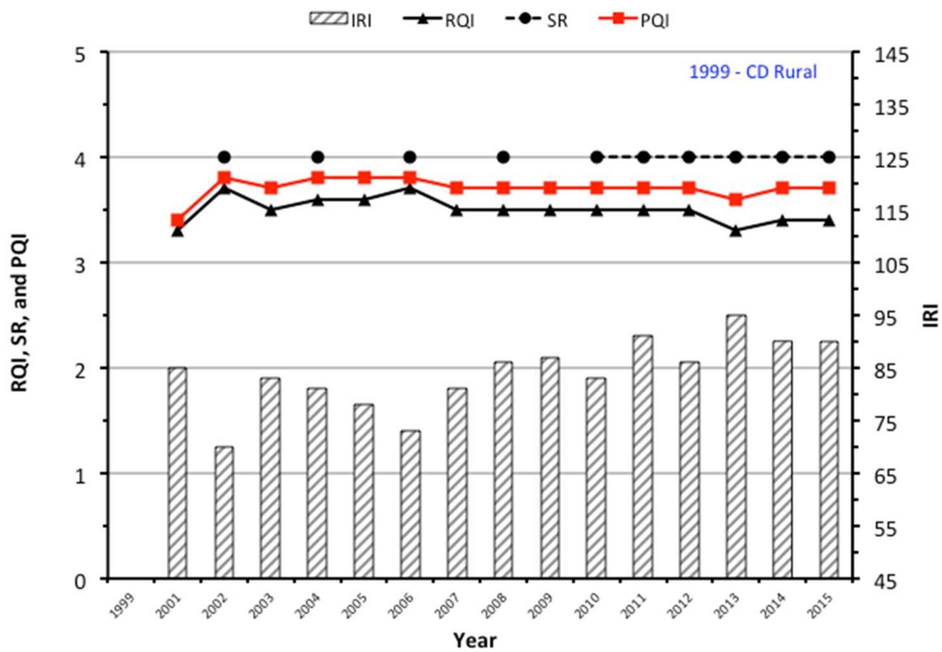


Figure B.108. Pavement management system data for section 9+0.113, direction D, of project 2782–268 constructed in 1999. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

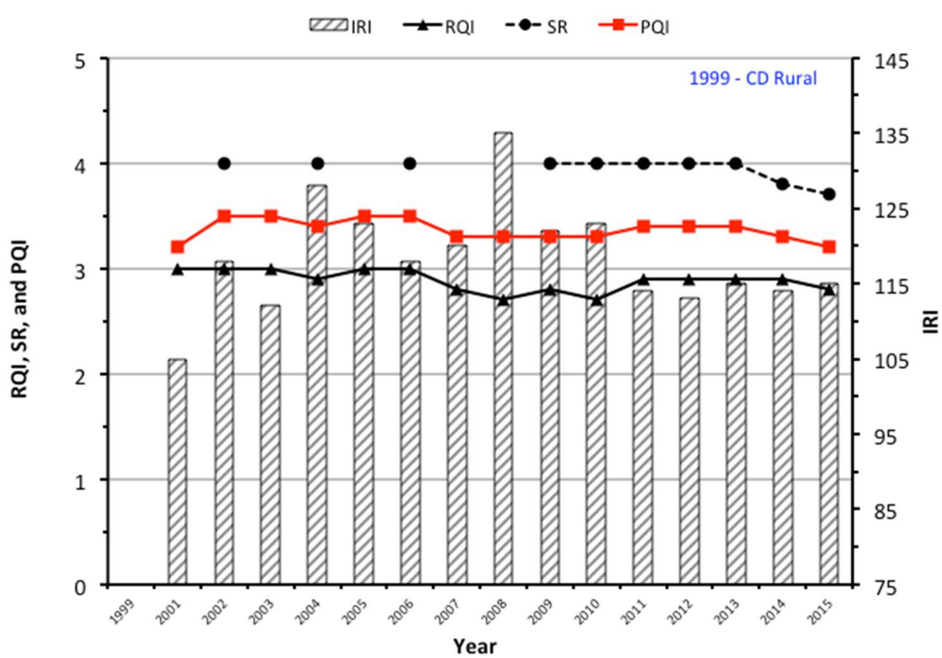


Figure B.109. Pavement management system data for section 9+0.113, direction I, of project 2782–268 constructed in 1999. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

District Metro – 0280-49a

Table B.57. Measured IRI for selected sections of project 0280-49a, constructed in 2000. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_REFP) and Direction (DIR)					
	34 +0.850	36 +0.000	37 +0.000	38 +0.000	39 +0.000	40 +0.000
Year	D	D	D	D	D	D
2000	85	78	49	45	51	45
2001	63	48	33	47	52	56
2002	79	58	42	56	65	60
2003	86	64	47	58	69	60
2004	78	78	78	86	87	80
2005	76	71	64	75	84	78
2006	68	68	60	67	72	72
2007	68	67	58	68	77	75
2008	66	66	59	67	77	77
2009	67	71	59	67	78	73
2010	66	72	61	68	81	82
2011	71	73	61	70	81	76
2012	71	71	62	67	83	79
2013	73	75	62	71	83	78
2014	68	73	62	70	80	81
2015	69	74	62	67	75	76

Table B.58. Measured PQI for selected sections of project 0280-49a, constructed in 2000. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_REFP) and Direction (DIR)					
	34 +0.850	36 +0.000	37 +0.000	38 +0.000	39 +0.000	40 +0.000
Year	D	D	D	D	D	D
2000	3.0	1.6	3.7	3.5	3.7	3.4
2001	3.2	1.8	3.9	3.5	3.8	3.4
2002	3.8	3.9	4.2	4.0	3.9	4.0
2003	3.8	3.9	4.1	4.0	3.9	3.9
2004	3.8	3.8	3.7	3.6	3.7	3.7
2005	3.9	3.9	3.9	3.8	3.7	3.8
2006	3.9	3.9	4.0	3.9	3.9	3.9
2007	4.0	3.9	4.0	3.9	3.9	3.8
2008	3.9	3.9	4.0	3.9	3.9	3.8
2009	3.9	3.9	4.0	3.9	3.8	3.8
2010	3.9	3.9	4.0	3.9	3.8	3.7
2011	3.8	3.9	4.0	3.9	3.8	3.8
2012	3.7	3.9	4.0	3.9	3.8	3.8
2013	3.8	3.8	3.9	3.9	3.8	3.6
2014	3.7	3.8	3.9	3.9	3.8	3.6
2015	3.7	3.8	3.9	3.9	3.8	3.7

Table B.59. Measured RQI for selected sections of project 0280-49a, constructed in 2000. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_REFP) and Direction (DIR)					
	34 +0.850	36 +0.000	37 +0.000	38 +0.000	39 +0.000	40 +0.000
Year	D	D	D	D	D	D
2000	3.3	3.4	3.8	3.9	3.8	3.9
2001	3.7	4.0	4.3	4.0	4.0	3.9
2002	3.7	3.9	4.4	4.0	3.9	4.0
2003	3.6	3.8	4.2	4.0	3.9	3.9
2004	3.6	3.6	3.5	3.3	3.5	3.5
2005	3.8	3.8	3.9	3.7	3.5	3.6
2006	3.8	3.8	4.0	3.9	3.8	3.8
2007	4.0	3.9	4.1	3.9	3.8	3.7
2008	3.9	3.8	4.1	3.9	3.8	3.6
2009	3.9	3.8	4.1	3.9	3.7	3.6
2010	3.9	3.8	4.0	3.8	3.6	3.5
2011	3.8	3.8	4.0	3.8	3.7	3.7
2012	3.8	3.8	4.0	3.8	3.6	3.6
2013	3.8	3.8	3.9	3.8	3.7	3.6
2014	3.8	3.7	3.9	3.8	3.6	3.5
2015	3.8	3.7	3.9	3.8	3.7	3.6

Table B.60. Measured SR for selected sections of project 0280-49a, constructed in 2000. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_REFP) and Direction (DIR)					
	34 +0.850	36 +0.000	37 +0.000	38 +0.000	39 +0.000	40 +0.000
Year	D	D	D	D	D	D
2000	2.8	0.8	3.6	3.1	3.6	2.9
2001						
2002	4.0	4.0	4.0	4.0	4.0	4.0
2003						
2004	4.0	4.0	4.0	4.0	4.0	4.0
2005						
2006	4.0	4.0	4.0	4.0	4.0	4.0
2007						
2008	3.9	4.0	4.0	4.0	4.0	4.0
2009						
2010	3.9	4.0	4.0	4.0	4.0	3.9
2011	3.8	4.0	4.0	4.0	4.0	4.0
2012	3.7	4.0	4.0	4.0	4.0	4.0
2013	3.8	3.9	4.0	4.0	4.0	3.7
2014	3.6	4.0	4.0	4.0	4.0	3.8
2015	3.7	4.0	4.0	4.0	4.0	3.9

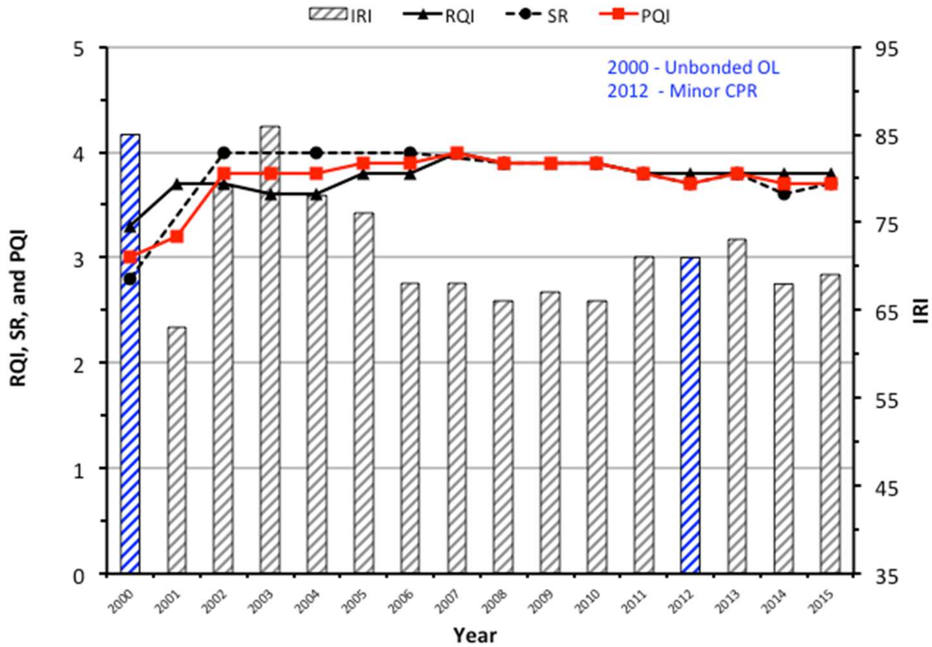


Figure B.110. Pavement management system data for section 34+0.850, direction D, of project 0280–49a constructed in 2000. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

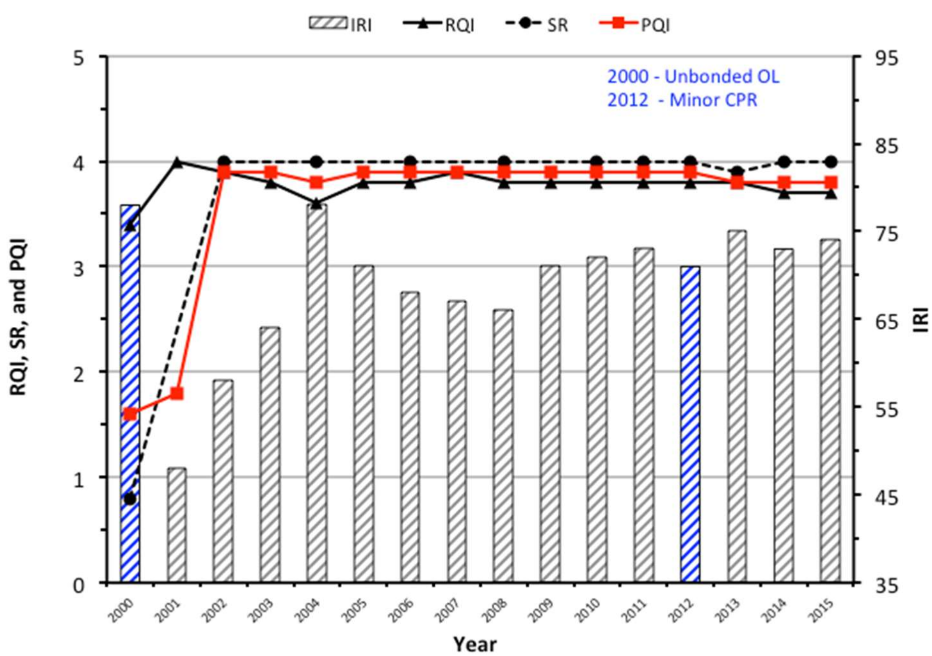


Figure B.111. Pavement management system data for section 36+0.000, direction D, of project 0280–49a constructed in 2000. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

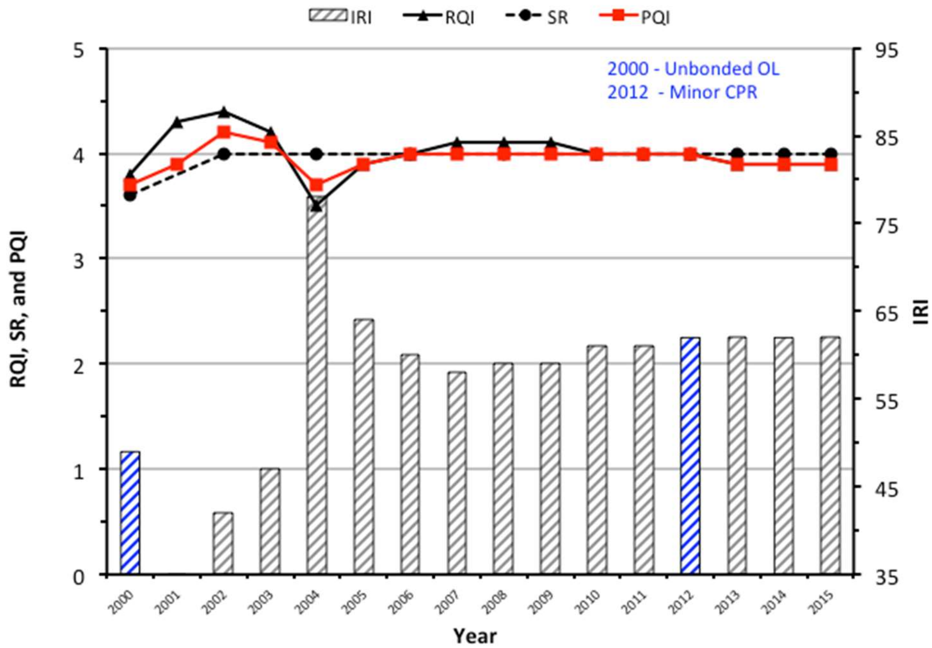


Figure B.112. Pavement management system data for section 37+0.000, direction D, of project 0280–49a constructed in 2000. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

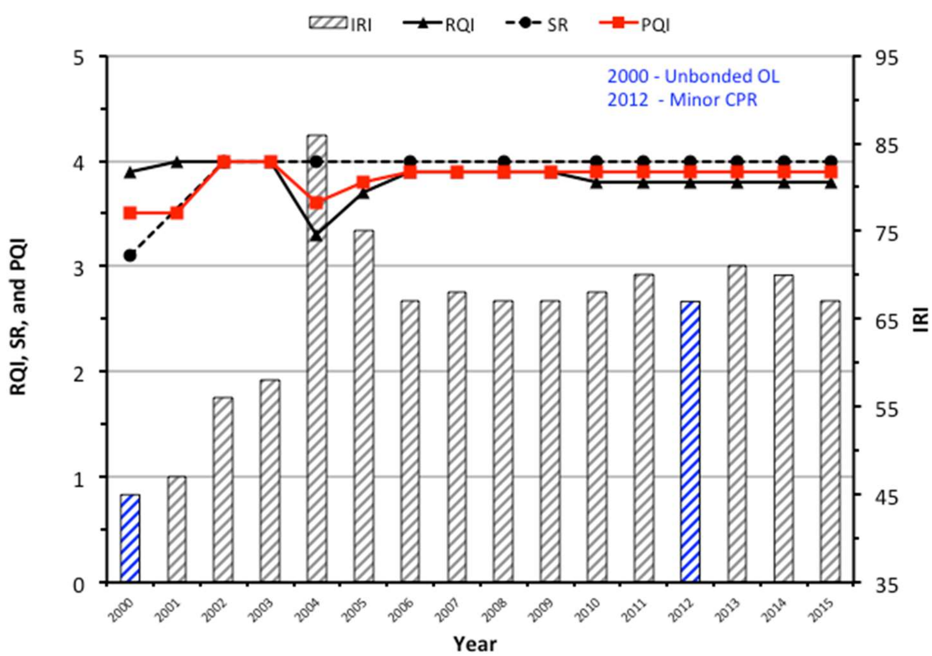


Figure B.113. Pavement management system data for section 38+0.000, direction D, of project 0280–49a constructed in 2000. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

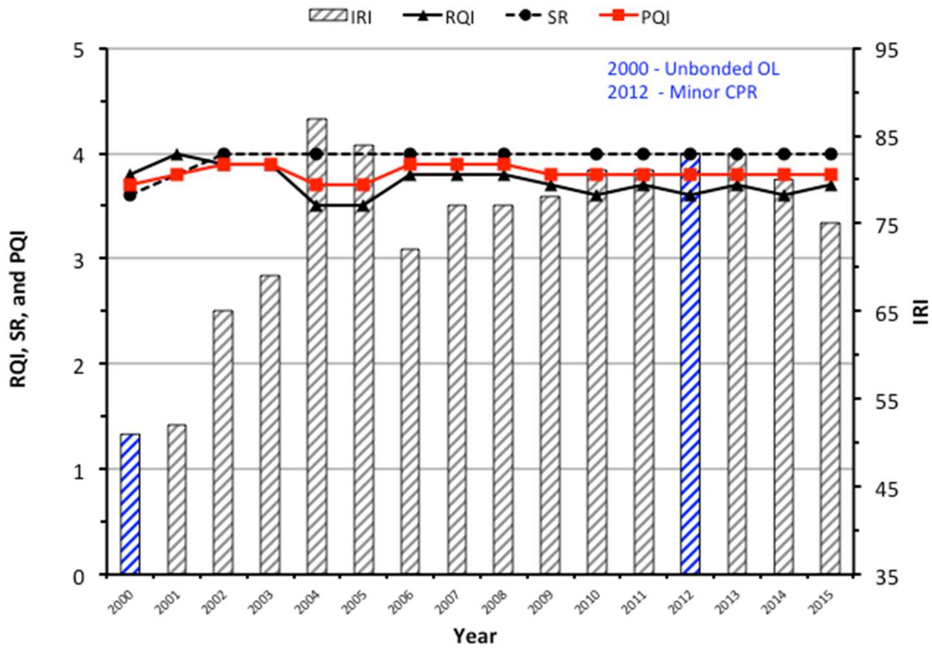


Figure B.114. Pavement management system data for section 39+0.000, direction D, of project 0280–49a constructed in 2000. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

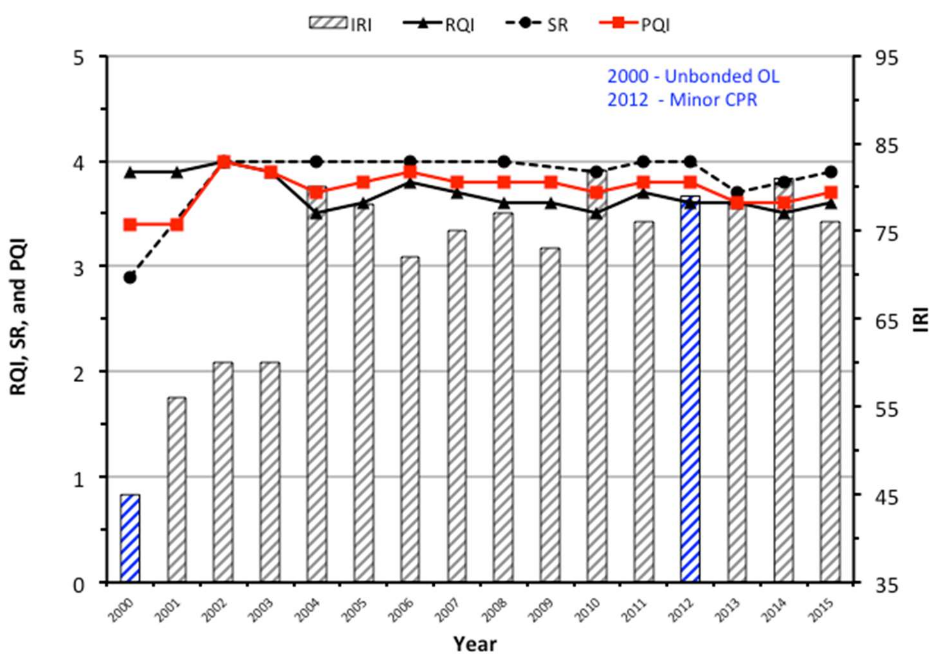


Figure B.115. Pavement management system data for section 40+0.000, direction D, of project 0280–49a constructed in 2000. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

District 6 – 2313-13

Table B.61. Measured IRI for selected sections of project 2313-13, constructed in 1996. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)												
	0 +0.000	1 +0.000	2 +0.000	3 +0.000	4 +0.000	5 +0.000	6 +0.000	7 +0.000	8 +0.000	9 +0.000	10 +0.000	11 +0.000	12 +0.000
Year	U	U	U	U	U	U	U	U	U	U	U	U	U
1996													
1997	48	47	44	45	48	42	42	49	47	59	44	47	53
1999	56	54	56	54	71	60	56	60	63	73	59	61	65
2000													
2001	67	63	41	50	82	50	44	72	73	91	72	56	51
2002	79	75	47	56	92	56	48	80	82	100	45	65	57
2003	59	67	67	66	89	68	61	63	63	87	58	66	72
2004	73	86	80	74	107	83	71	75	75	93	69	77	82
2005	71	78	71	67	102	76	65	72	70	94	66	71	80
2006	73	91	82	74	112	86	71	77	75	95	74	80	82
2007	76	91	81	74	112	88	73	79	78	99	76	83	86
2008	67	80	75	71	101	75	62	67	66	91	64	72	83
2009	69	88	82	74	113	86	67	74	74	98	71	77	85
2010	65	80	73	67	102	77	63	66	67	91	65	71	91
2011	65	89	79	74	112	85	69	74	75	98	72	77	92
2012	93	111	98	89	135	108	89	92	93	112	92	96	100
2013	74	93	82	77	122	95	75	78	82	102	79	83	97
2014	64	90	83	79	115	85	70	69	73	99	71	76	89
2015	86	114	99	90	171	108	86	88	86	134	90	94	320

Table B.62. Measured PQI for selected sections of project 2313-13, constructed in 1996. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)												
	0 +0.000	1 +0.000	2 +0.000	3 +0.000	4 +0.000	5 +0.000	6 +0.000	7 +0.000	8 +0.000	9 +0.000	10 +0.000	11 +0.000	12 +0.000
Year	U	U	U	U	U	U	U	U	U	U	U	U	U
1996													
1997	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	3.9	4.1	4.1	4.0
1999	4.0	4.0	4.0	4.0	3.8	3.9	4.0	3.9	3.9	3.8	3.9	3.9	3.9
2000													
2001	3.9	3.9	4.2	4.1	3.7	4.1	4.1	3.8	3.8	3.7	3.8	4.0	4.0
2002	3.8	3.8	4.1	4.0	3.6	4.0	4.1	3.8	3.7	3.6	4.2	3.9	4.0
2003	4.0	3.9	3.9	3.9	3.7	3.9	3.9	3.9	4.0	3.7	4.0	3.9	3.8
2004	3.8	3.7	3.8	3.8	3.5	3.8	3.9	3.8	3.8	3.7	3.9	3.8	3.7
2005	3.9	3.8	3.8	3.9	3.6	3.8	3.9	3.8	3.9	3.7	3.9	3.9	3.7
2006	3.8	3.7	3.7	3.8	3.5	3.7	3.8	3.8	3.8	3.6	3.8	3.8	3.7
2007	3.8	3.6	3.7	3.8	3.4	3.7	3.8	3.8	3.8	3.6	3.8	3.7	3.6
2008	3.9	3.7	3.8	3.9	3.6	3.8	3.9	3.9	3.9	3.7	3.9	3.9	3.7
2009	3.8	3.6	3.7	3.8	3.4	3.7	3.9	3.8	3.8	3.6	3.8	3.8	3.7
2010	3.9	3.7	3.8	3.9	3.5	3.8	3.9	3.9	3.9	3.7	3.9	3.8	3.6
2011	3.9	3.6	3.8	3.8	3.5	3.7	3.8	3.8	3.8	3.6	3.8	3.8	3.6
2012	3.6	3.4	3.6	3.7	3.2	3.4	3.6	3.6	3.6	3.5	3.6	3.6	3.5
2013	3.8	3.6	3.7	3.8	3.4	3.6	3.8	3.7	3.7	3.6	3.8	3.7	3.6
2014	3.9	3.6	3.7	3.7	3.4	3.6	3.8	3.8	3.8	3.6	3.8	3.8	3.6
2015	3.7	3.3	3.5	3.6	2.8	3.4	3.6	3.6	3.7	3.2	3.6	3.6	1.1

Table B.63. Measured RQI for selected sections of project 2313-13, constructed in 1996. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)												
	0 +0.000	1 +0.000	2 +0.000	3 +0.000	4 +0.000	5 +0.000	6 +0.000	7 +0.000	8 +0.000	9 +0.000	10 +0.000	11 +0.000	12 +0.000
Year	U	U	U	U	U	U	U	U	U	U	U	U	U
1996													
1997	4.2	4.2	4.3	4.3	4.2	4.3	4.3	4.2	4.2	3.9	4.3	4.2	4.1
1999	4.0	4.0	4.0	4.0	3.7	3.9	4.0	3.9	3.8	3.6	3.9	3.9	3.8
2000													
2001	3.8	3.9	4.4	4.2	3.5	4.2	4.3	3.7	3.7	3.4	3.7	4.1	4.1
2002	3.6	3.6	4.3	4.0	3.3	4.1	4.2	3.6	3.5	3.2	4.4	3.8	4.0
2003	4.0	3.8	3.8	3.8	3.4	3.8	3.9	3.9	4.0	3.5	4.1	3.9	3.7
2004	3.7	3.5	3.6	3.7	3.1	3.6	3.8	3.7	3.7	3.4	3.8	3.6	3.5
2005	3.8	3.6	3.7	3.8	3.2	3.7	3.9	3.7	3.8	3.4	3.9	3.8	3.5
2006	3.7	3.4	3.5	3.7	3.0	3.5	3.7	3.6	3.7	3.3	3.7	3.6	3.5
2007	3.6	3.3	3.5	3.6	2.9	3.4	3.7	3.6	3.6	3.2	3.7	3.5	3.3
2008	3.8	3.5	3.6	3.8	3.2	3.7	3.9	3.8	3.9	3.4	3.9	3.8	3.5
2009	3.7	3.3	3.5	3.6	2.9	3.4	3.8	3.7	3.7	3.2	3.7	3.6	3.4
2010	3.9	3.5	3.6	3.8	3.1	3.6	3.9	3.8	3.8	3.4	3.9	3.7	3.3
2011	3.8	3.3	3.6	3.7	3.0	3.5	3.8	3.7	3.7	3.2	3.7	3.6	3.3
2012	3.3	2.9	3.2	3.4	2.6	3.0	3.4	3.3	3.3	3.0	3.3	3.3	3.1
2013	3.7	3.3	3.5	3.6	2.9	3.3	3.7	3.6	3.5	3.2	3.6	3.5	3.2
2014	3.9	3.3	3.5	3.5	2.9	3.5	3.7	3.7	3.7	3.2	3.7	3.6	3.3
2015	3.4	2.8	3.1	3.3	2.0	3.0	3.4	3.3	3.4	2.6	3.3	3.2	0.3

Table B.64. Measured SR for selected sections of project 2313-13, constructed in 1996. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)												
	0 +0.000	1 +0.000	2 +0.000	3 +0.000	4 +0.000	5 +0.000	6 +0.000	7 +0.000	8 +0.000	9 +0.000	10 +0.000	11 +0.000	12 +0.000
Year	U	U	U	U	U	U	U	U	U	U	U	U	U
1996													
1997	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
1999	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2000													
2001	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0		4.0	4.0
2002													
2003	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2004													
2005	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2006													
2007	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2008													
2009	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2010													
2011	4.0	4.0	4.0	4.0	4.0	3.9	3.9	3.9	4.0	4.0	4.0	4.0	4.0
2012													
2013													
2014	4.0	4.0	4.0	3.9	4.0	3.8	3.9	3.9	4.0	4.0	4.0	4.0	4.0
2015													

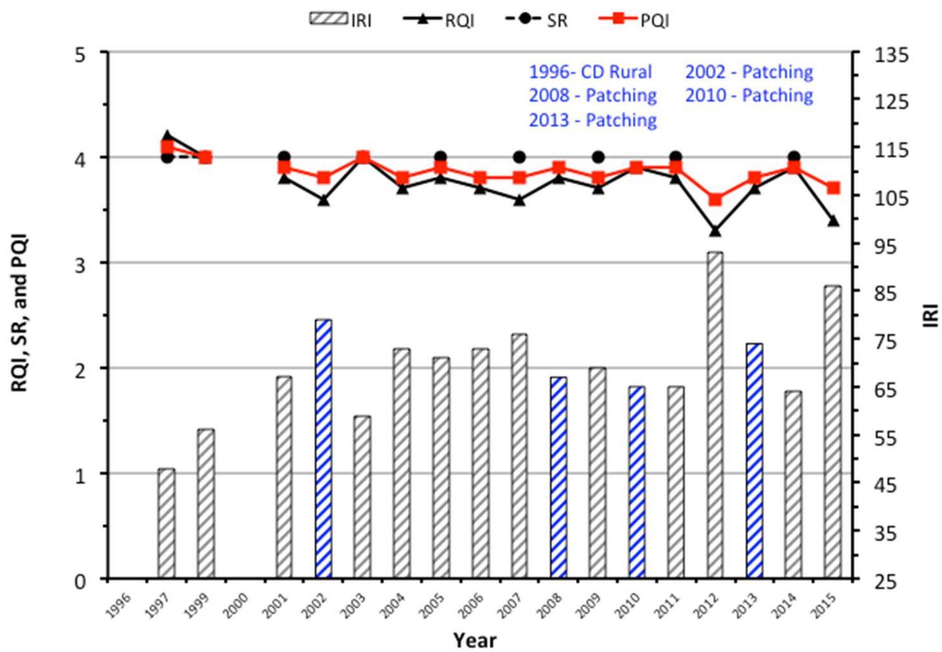


Figure B.116. Pavement management system data for section 0+0.000, direction U, of project 2313–13 constructed in 1996. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

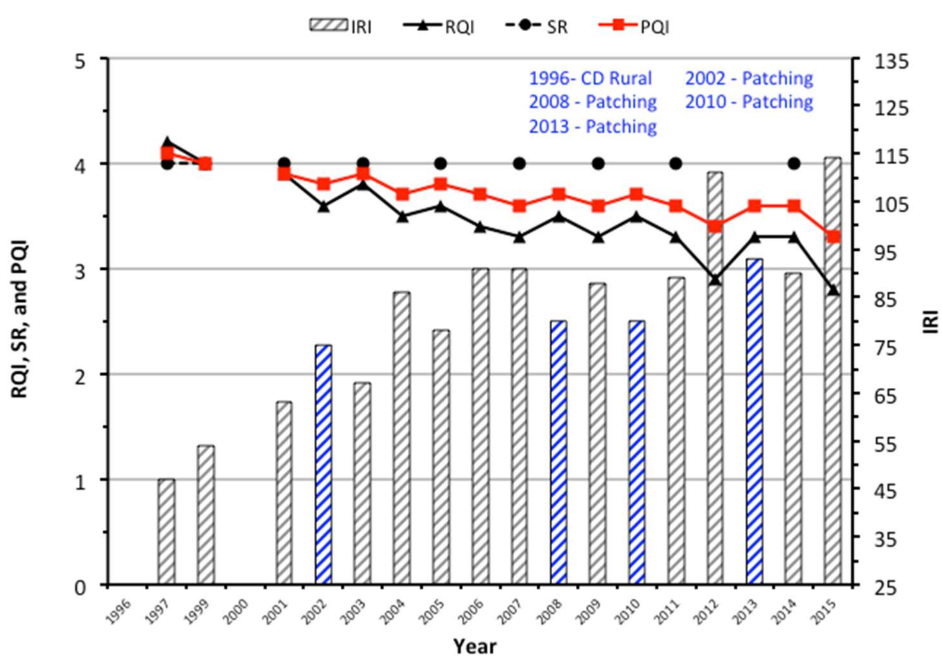


Figure B.117. Pavement management system data for section 1+0.000, direction U, of project 2313–13 constructed in 1999. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

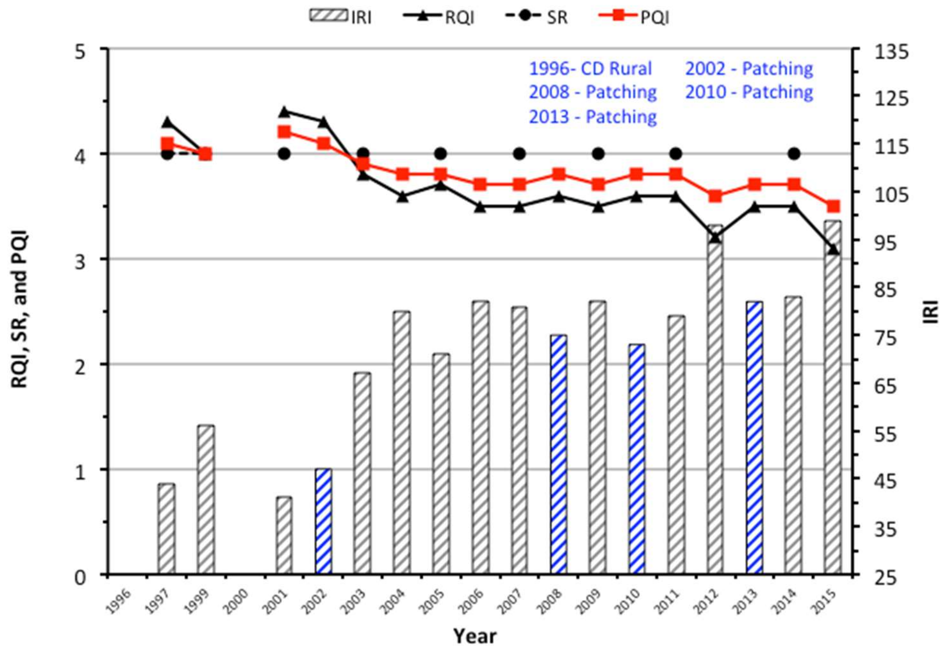


Figure B.118. Pavement management system data for section 2+0.000, direction U, of project 2313–13 constructed in 1999. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

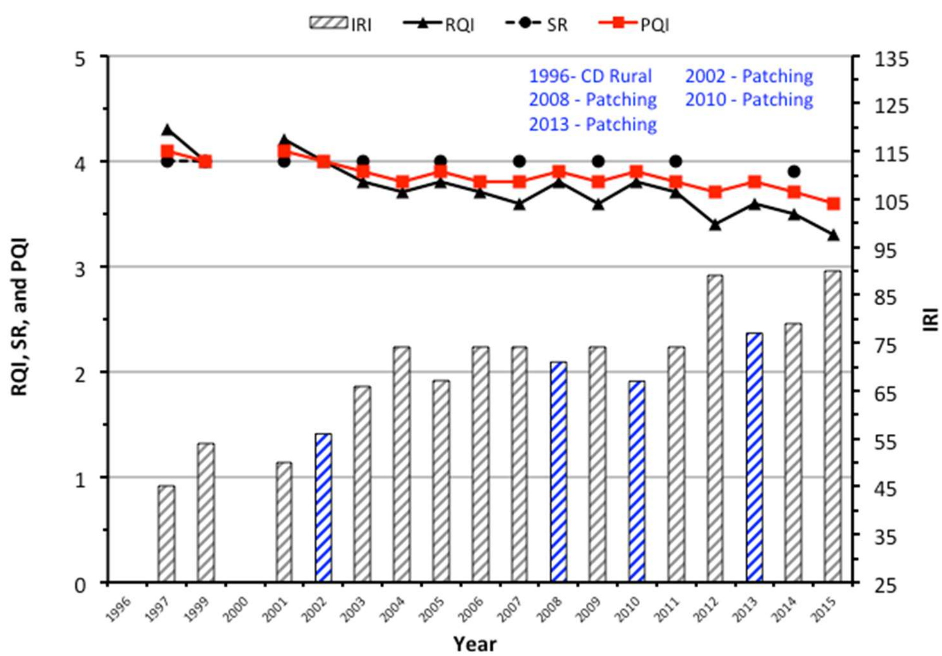


Figure B.119. Pavement management system data for section 3+0.000, direction U, of project 2313–13 constructed in 1999. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

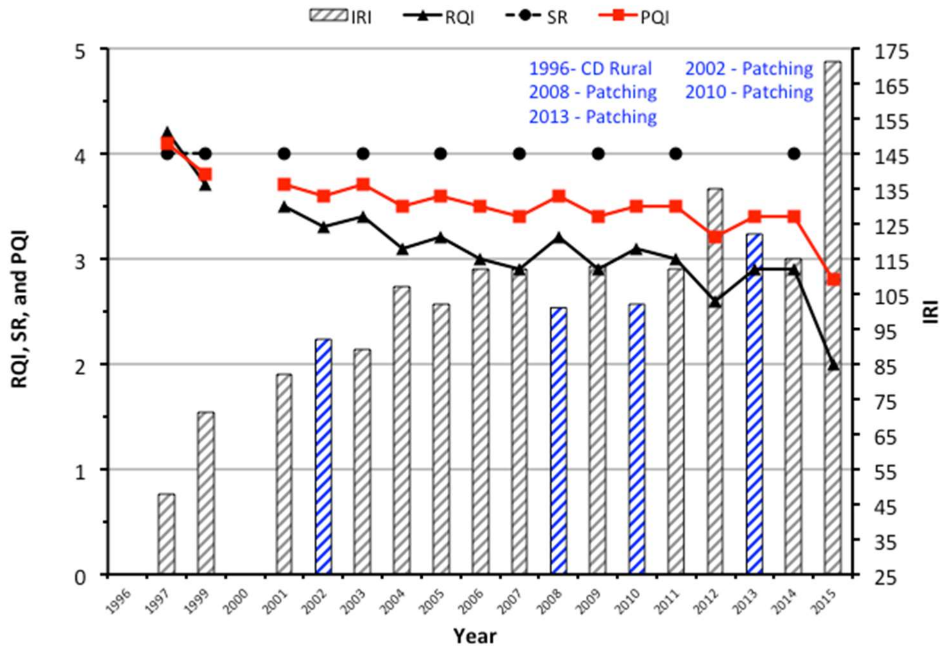


Figure B.120. Pavement management system data for section 4+0.000, direction U, of project 2313–13 constructed in 1999. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

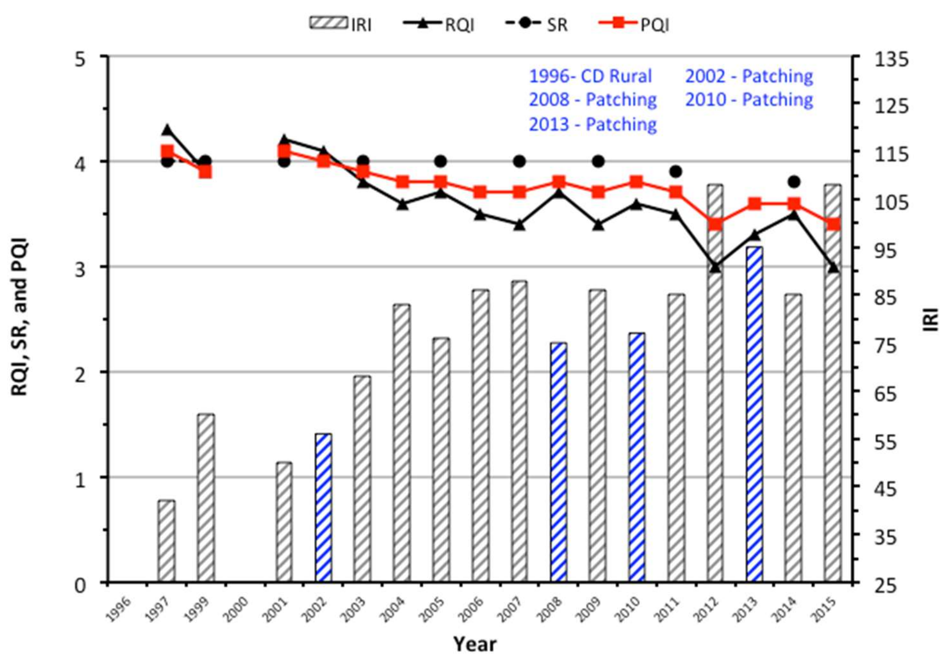


Figure B.121. Pavement management system data for section 5+0.000, direction U, of project 2313–13 constructed in 1999. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

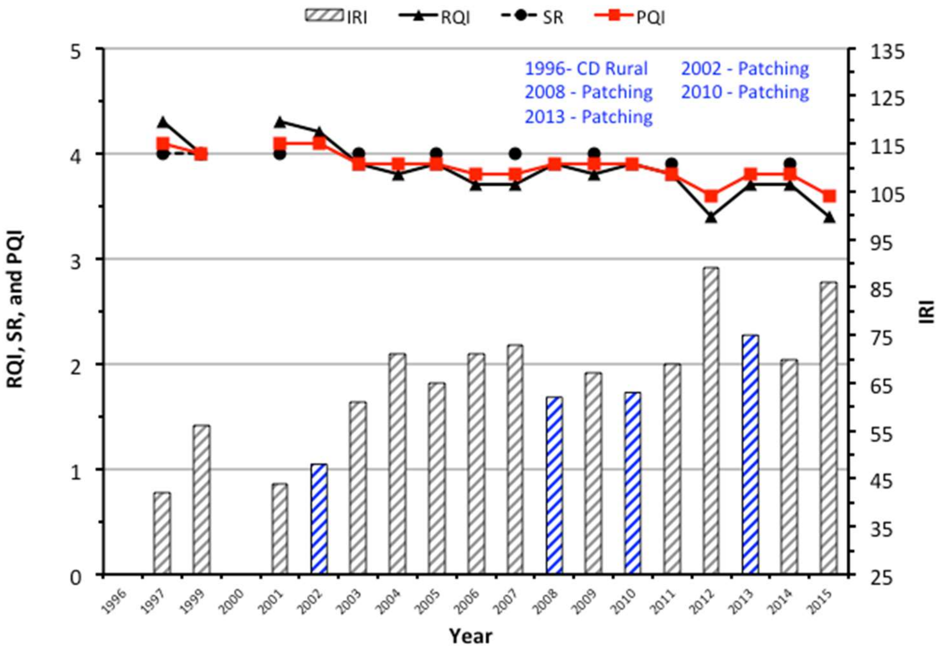


Figure B.122. Pavement management system data for section 6+0.000, direction U, of project 2313–13 constructed in 1999. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

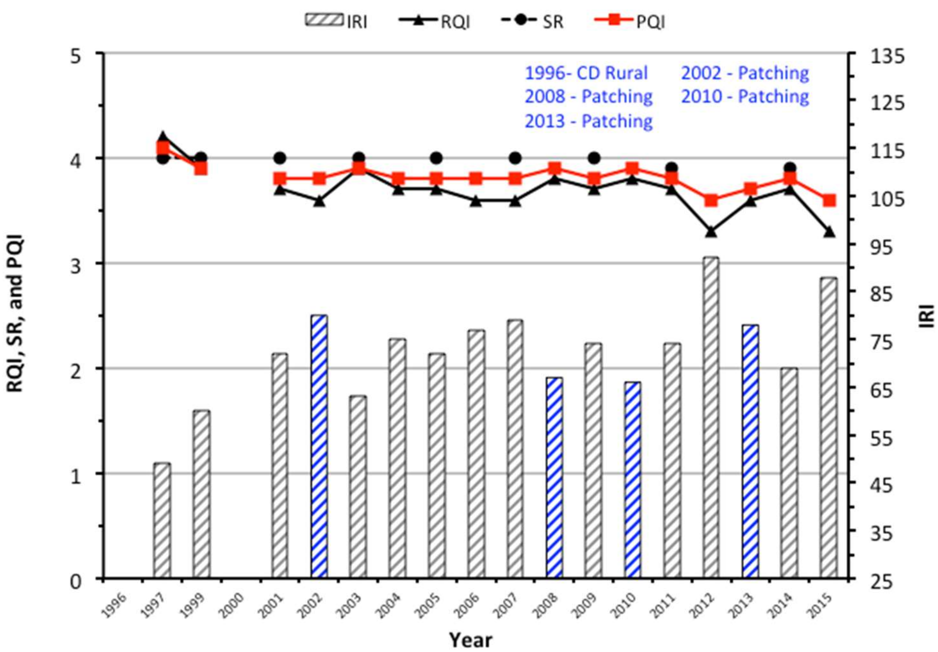


Figure B.123. Pavement management system data for section 7+0.000, direction U, of project 2313–13 constructed in 1999. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

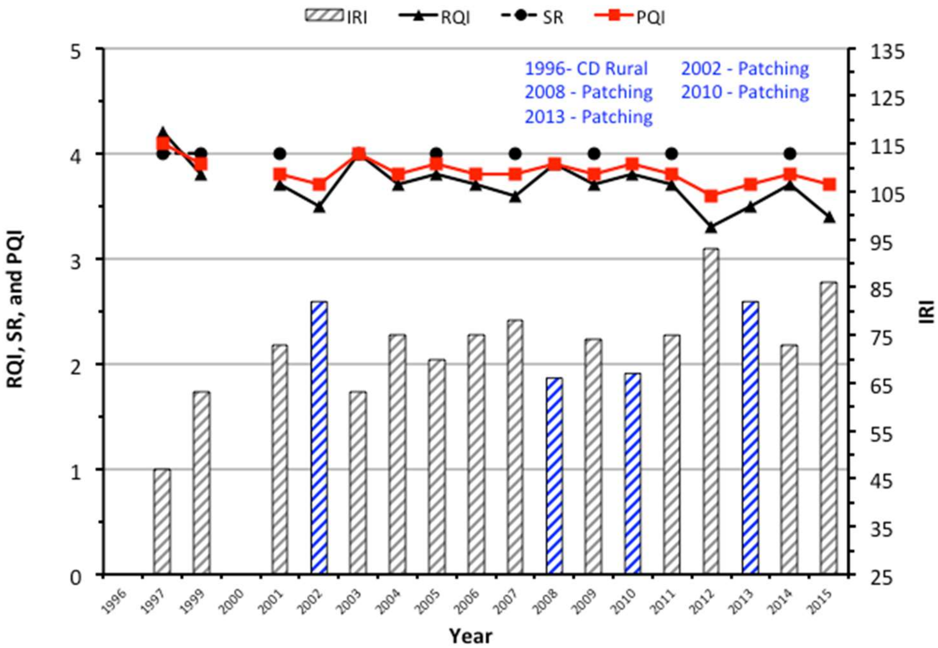


Figure B.124. Pavement management system data for section 8+0.000, direction U, of project 2313–13 constructed in 1999. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

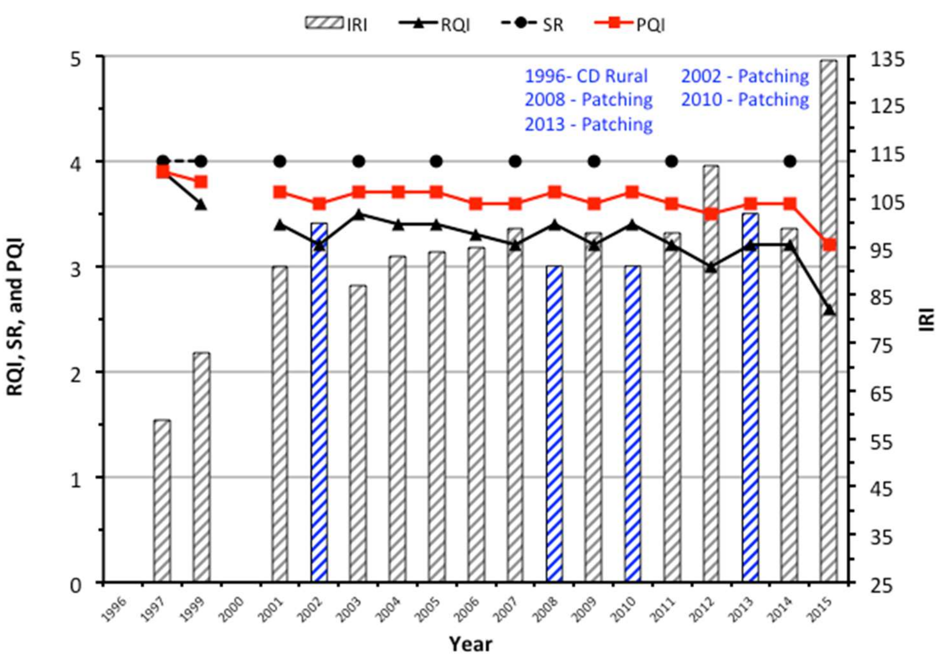


Figure B.125. Pavement management system data for section 9+0.000, direction U, of project 2313–13 constructed in 1999. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

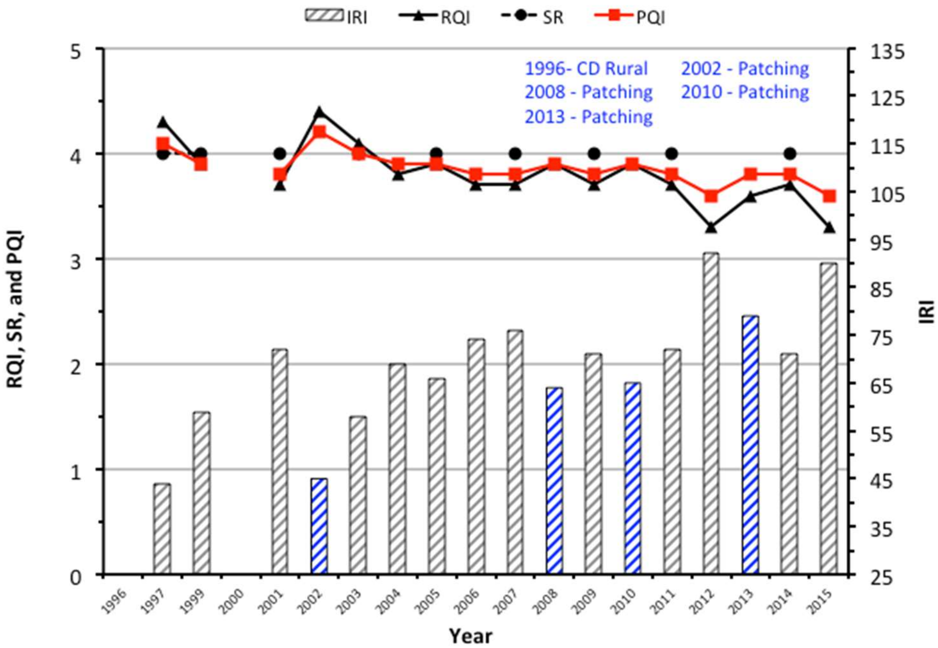


Figure B.126. Pavement management system data for section 10+0.000, direction U, of project 2313–13 constructed in 1999. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

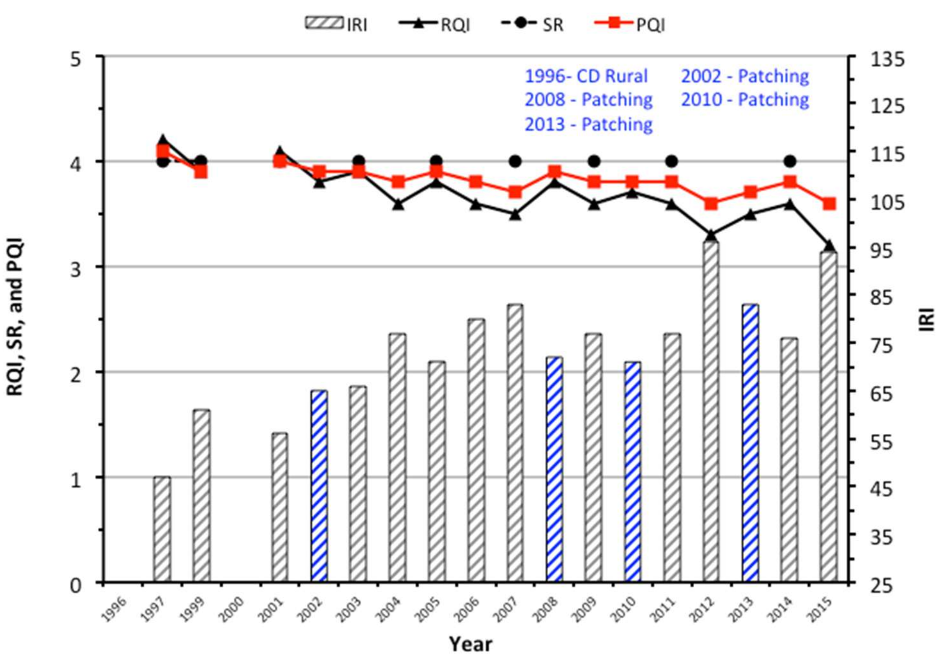


Figure B.127. Pavement management system data for section 11+0.000, direction U, of project 2313–13 constructed in 1999. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

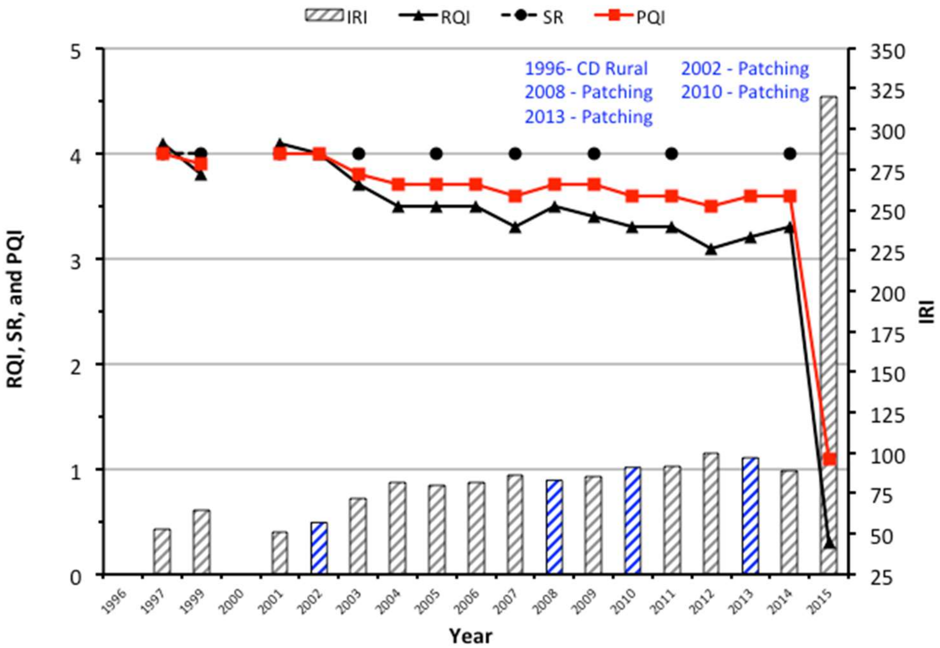


Figure B.128. Pavement management system data for section 12+0.000, direction U, of project 2313–13 constructed in 1999. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

District 6 – 5507-47

Table B.65. Measured IRI for selected sections of project 5507-47, constructed in 1992. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)													
	46 +0.285	46 +0.683	47 +0.000	48 +0.000	49 +0.000	50 +0.000	51 +0.000	46 +0.285	46 +0.683	47 +0.000	48 +0.000	49 +0.000	50 +0.000	51 +0.000
Year	D	D	D	D	D	D	D	I	I	I	I	I	I	I
1992														
1994		67	59	60	73	84	96	75	64	61	58	70	83	113
1995	91	72	69	68	82	82	99	80	78	100	82	80	101	100
1996	94	71	61	65	81	91	105	72	67	62	58	80	86	105
1997	73	64	54	51	61	73	84	61	61	61	54	70	75	94
1998	79	61	53	49	63	70	84	59	61	59	54	64	75	96
1999	77	64	52	49	59	112	79	61	56	56	52	67	106	94
2000	82	67	58	56	67	75	85	59	56	51	49	61	75	90
2001	80	75	62	52	83	86	95	74	63	64	64	82	107	112
2002	82	78	67	59	88	93	103	54	69	64	65	80	109	112
2003	93	75	64	61	81	92	100	76	68	67	68	80	99	115
2004	89	75	61	59	78	90	103	75	71	63	66	73	92	131
2005	98	83	70	66	82	92	108	80	65	62	64	76	94	117
2006	92	71	58	55	73	81	95	72	61	56	59	66	85	107
2007	97	80	67	61	80	88	105	73	60	54	58	66	86	105
2008	103	80	70	60	80	91	108	81	76	63	64	73	91	78
2009	98	74	63	62	79	94	108	82	66	60	64	70	92	116
2010	96	71	58	59	74	88	107	74	61	55	57	65	86	110
2011	111	77	62	65	80	83	126	84	74	70	68	79	102	143
2012	133	92	72	64	88	84	133	86	70	62	64	72	89	118
2013	126	80	64	67	81	84	129	84	68	59	61	70	85	123
2014	124	81	63	69	81	86	132	88	76	63	64	72	88	124
2015	106	83	71	73	84	90	123	94	86	69	69	79	94	130

Table B.66. Measured PQI for selected sections of project 5507-47, constructed in 1992. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)													
	46 +0.285	46 +0.683	47 +0.000	48 +0.000	49 +0.000	50 +0.000	51 +0.000	46 +0.285	46 +0.683	47 +0.000	48 +0.000	49 +0.000	50 +0.000	51 +0.000
Year	D	D	D	D	D	D	D	I	I	I	I	I	I	I
1992														
1994		4.1	4.2	4.2	4.0	3.9	3.8	4.0	4.1	4.1	4.2	4.1	3.9	3.7
1995	3.9	4.0	4.1	4.1	3.9	3.9	3.8	4.0	4.0	3.8	3.9	4.0	3.8	3.8
1996	3.8	4.0	4.1	4.1	3.9	3.9	3.7	4.0	4.1	4.1	4.2	4.0	3.9	3.7
1997	3.8	3.9	4.0	4.0	3.9	3.8	3.7	3.9	3.9	3.9	4.0	3.8	3.8	3.6
1998	3.7	3.9	4.0	4.1	3.9	3.8	3.7	3.9	3.9	3.9	4.0	3.9	3.8	3.6
1999	3.7	3.9	4.0	4.0	3.9	3.4	3.7	3.9	4.0	4.0	4.0	3.9	3.5	3.6
2000	3.7	3.9	4.0	4.0	3.9	3.8	3.7	3.9	4.0	4.0	4.0	3.9	3.8	3.6
2001	3.7	3.8	3.9	4.0	3.8	3.7	3.6	3.8	3.9	3.9	3.9	3.8	3.5	3.5
2002	3.7	3.8	3.9	3.9	3.6	3.6	3.5	4.1	3.8	3.9	3.9	3.7	3.5	3.4
2003	3.6	3.8	3.9	3.9	3.8	3.6	3.6	3.8	3.8	3.8	3.8	3.7	3.5	3.4
2004	3.6	3.8	3.9	3.9	3.7	3.6	3.5	3.8	3.8	3.9	3.9	3.8	3.6	3.3
2005	3.6	3.7	3.8	3.9	3.7	3.6	3.5	3.8	3.9	3.9	3.9	3.7	3.6	3.4
2006	3.6	3.8	4.0	4.0	3.8	3.7	3.6	3.8	3.9	4.0	3.9	3.9	3.7	3.5
2007	3.6	3.7	3.9	3.9	3.7	3.6	3.5	3.8	3.9	4.0	4.0	3.9	3.7	3.5
2008	3.5	3.8	3.9	4.0	3.7	3.6	3.1	3.8	3.8	3.9	3.9	3.8	3.6	3.7
2009	3.5	3.8	3.9	3.9	3.7	3.6	3.1	3.7	3.8	3.9	3.9	3.8	3.6	3.3
2010	3.6	3.8	4.0	3.9	3.8	3.6	2.8	3.7	3.9	4.0	4.0	3.8	3.7	3.4
2011	3.4	3.8	3.9	3.8	3.7	3.7	2.7	3.6	3.8	3.8	3.8	3.7	3.5	3.1
2012	3.0	3.4	3.7	3.7	3.5	3.5	2.5	3.1	3.6	3.8	3.7	3.6	3.7	3.3
2013	3.0	3.5	3.8	3.7	3.6	3.5	2.5	3.2	3.6	3.9	3.8	3.7	3.7	3.3
2014	2.8	3.3	3.8	3.6	3.5	3.2	2.2	3.0	3.3	3.7	3.8	3.6	3.6	3.2
2015	3.1	3.3	3.7	3.6	3.4	3.2	2.3	2.9	3.2	3.7	3.8	3.5	3.6	3.1

Table B.67. Measured RQI for selected sections of project 5507-47, constructed in 1992. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)													
	46 +0.285	46 +0.683	47 +0.000	48 +0.000	49 +0.000	50 +0.000	51 +0.000	46 +0.285	46 +0.683	47 +0.000	48 +0.000	49 +0.000	50 +0.000	51 +0.000
Year	D	D	D	D	D	D	D	I	I	I	I	I	I	I
1992														
1994		4.2	4.4	4.4	4.1	3.9	3.7	4.1	4.3	4.3	4.4	4.2	3.9	3.4
1995	3.8	4.1	4.2	4.2	3.9	3.9	3.6	4.0	4.0	3.6	3.9	4.0	3.6	3.6
1996	3.7	4.1	4.3	4.3	3.9	3.8	3.5	4.1	4.2	4.3	4.4	4.0	3.9	3.5
1997	3.6	3.8	4.0	4.1	3.9	3.6	3.4	3.9	3.9	3.9	4.0	3.7	3.6	3.2
1998	3.5	3.9	4.1	4.2	3.8	3.7	3.4	3.9	3.9	3.9	4.0	3.8	3.6	3.2
1999	3.5	3.8	4.1	4.1	3.9	2.9	3.5	3.9	4.0	4.0	4.1	3.8	3.0	3.2
2000	3.4	3.8	4.0	4.0	3.8	3.6	3.4	3.9	4.0	4.1	4.1	3.9	3.6	3.3
2001	3.5	3.7	3.9	4.1	3.6	3.4	3.3	3.7	3.8	3.9	3.9	3.6	3.1	3.0
2002	3.5	3.6	3.8	3.9	3.4	3.3	3.1	4.2	3.7	3.8	3.8	3.5	3.0	2.9
2003	3.3	3.7	3.9	3.9	3.6	3.3	3.2	3.7	3.7	3.7	3.7	3.5	3.1	2.9
2004	3.3	3.7	3.9	3.9	3.6	3.3	3.1	3.7	3.7	3.8	3.8	3.6	3.2	2.7
2005	3.2	3.5	3.7	3.8	3.5	3.3	3.0	3.6	3.8	3.8	3.8	3.5	3.2	2.9
2006	3.3	3.7	4.0	4.0	3.7	3.5	3.2	3.7	3.8	4.0	3.9	3.8	3.4	3.0
2007	3.2	3.5	3.8	3.9	3.5	3.3	3.0	3.7	3.8	4.0	4.0	3.8	3.4	3.0
2008	3.1	3.6	3.8	4.0	3.6	3.3	2.9	3.6	3.7	3.9	3.8	3.6	3.3	3.5
2009	3.1	3.6	3.8	3.8	3.5	3.2	2.9	3.5	3.7	3.8	3.8	3.7	3.2	2.8
2010	3.2	3.7	4.0	3.9	3.7	3.3	2.9	3.7	3.8	4.0	4.0	3.8	3.4	3.0
2011	2.9	3.7	3.9	3.8	3.6	3.5	2.7	3.4	3.6	3.7	3.7	3.5	3.1	2.5
2012	2.5	3.4	3.7	3.8	3.3	3.4	2.5	3.4	3.7	3.8	3.8	3.6	3.4	2.8
2013	2.5	3.6	3.9	3.7	3.5	3.4	2.6	3.5	3.7	3.9	3.9	3.7	3.4	2.8
2014	2.6	3.5	3.9	3.7	3.5	3.3	2.5	3.4	3.5	3.8	3.8	3.7	3.3	2.7
2015	3.1	3.5	3.7	3.7	3.4	3.2	2.7	3.2	3.4	3.7	3.7	3.5	3.2	2.6

Table B.68. Measured SR for selected sections of project 5507-47, constructed in 1992. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)													
	46 +0.285	46 +0.683	47 +0.000	48 +0.000	49 +0.000	50 +0.000	51 +0.000	46 +0.285	46 +0.683	47 +0.000	48 +0.000	49 +0.000	50 +0.000	51 +0.000
Year	D	D	D	D	D	D	D	I	I	I	I	I	I	I
1992														
1994		4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
1995	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
1996	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
1997	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
1998	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
1999	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2000	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2001	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2002	4.0	4.0	4.0	3.9	3.8	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2003	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2004	4.0	4.0	4.0	4.0	3.9	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2005														
2006	4.0	4.0	4.0	4.0	4.0	4.0	4.0		4.0	4.0	4.0	4.0	4.0	4.0
2007								4.0						
2008	4.0	4.0	4.0	4.0	3.9	4.0	3.3	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2009														
2010	4.0	4.0	4.0	3.9	3.9	4.0	2.7	3.8	4.0	4.0	4.0	3.9	4.0	3.9
2011														
2012	3.5	3.4	3.8	3.7	3.7	3.6	2.5	2.9	3.5	3.9	3.7	3.7	4.0	4.0
2013														
2014	3.1	3.2	3.7	3.6	3.5	3.2	1.9	2.7	3.1	3.7	3.9	3.6	4.0	3.7
2015														

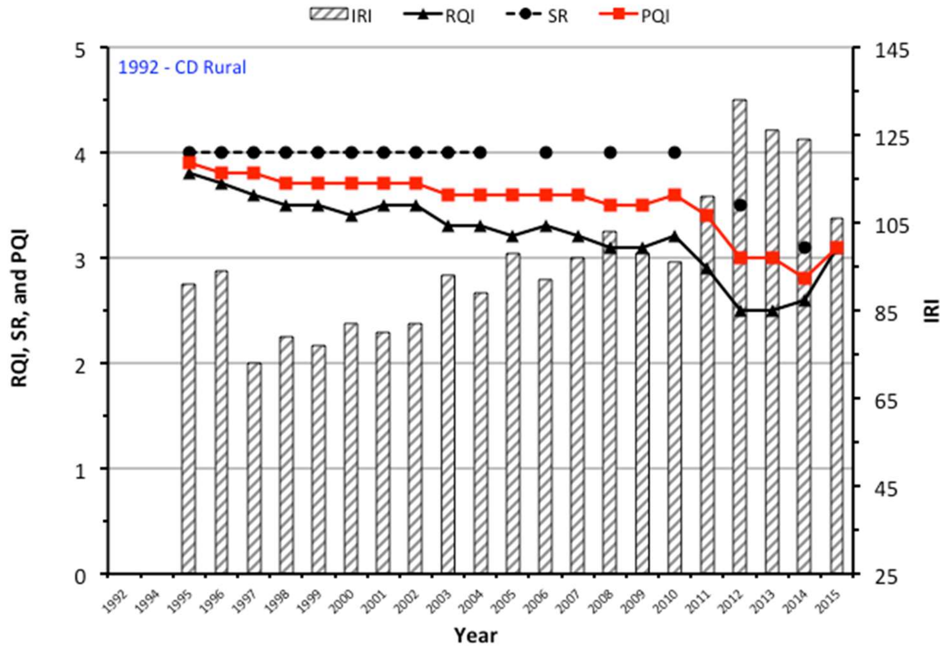


Figure B.129. Pavement management system data for section 46+0.285, direction D, of project 5507–47 constructed in 1992. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

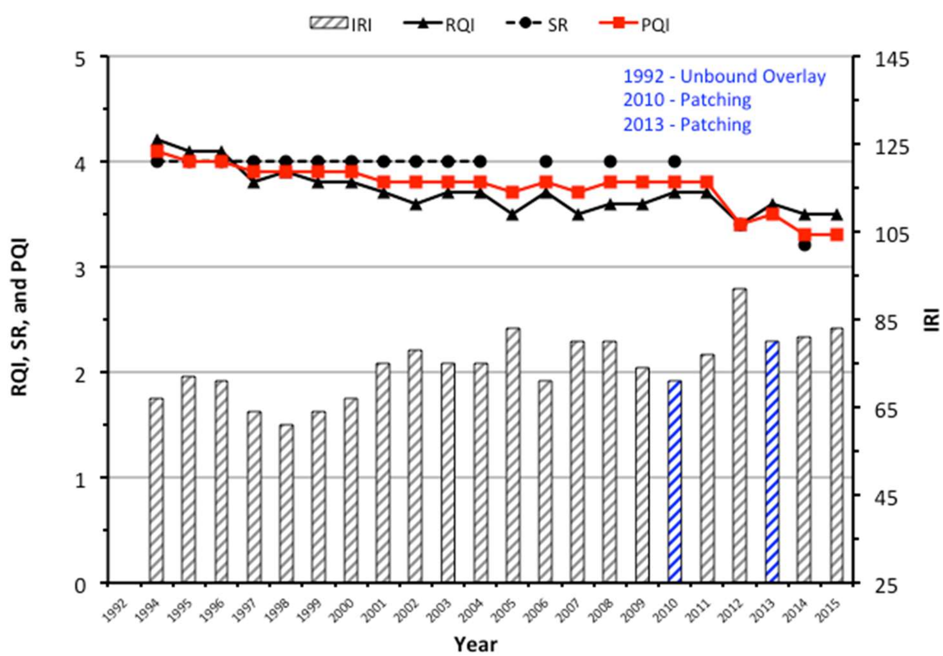


Figure B.130. Pavement management system data for section 46+0.683, direction D, of project 5507–47 constructed in 1992. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

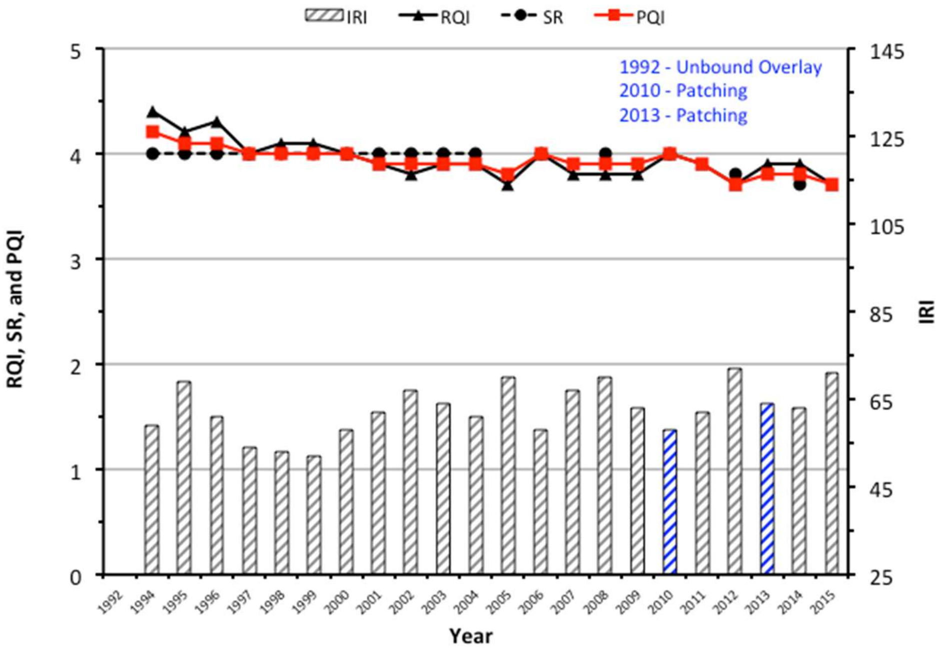


Figure B.131. Pavement management system data for section 47+0.000, direction D, of project 5507–47 constructed in 1992. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

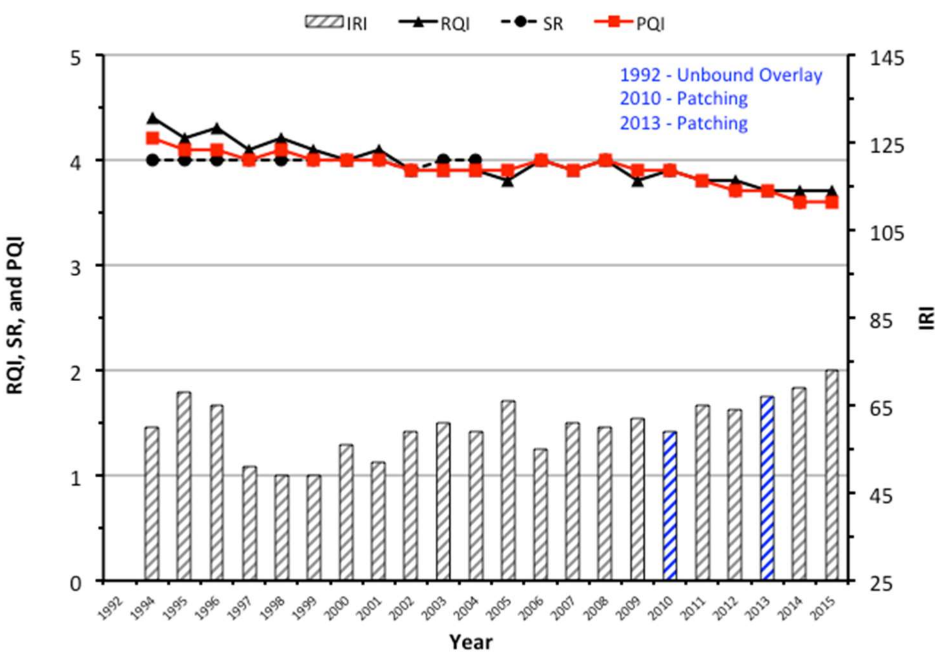


Figure B.132. Pavement management system data for section 48+0.000, direction D, of project 5507–47 constructed in 1992. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

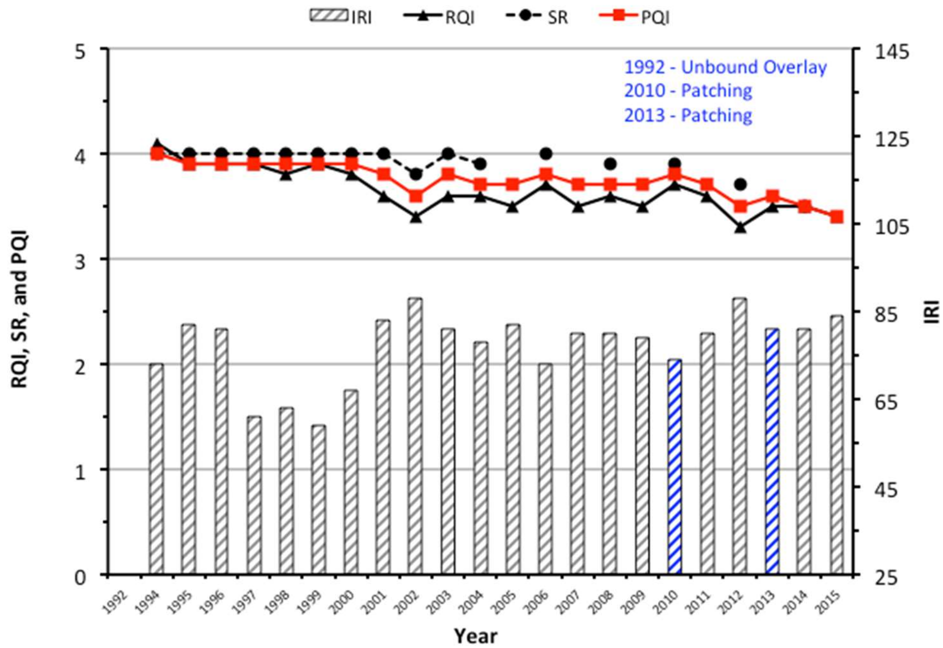


Figure B.133. Pavement management system data for section 49+0.000, direction D, of project 5507–47 constructed in 1992. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

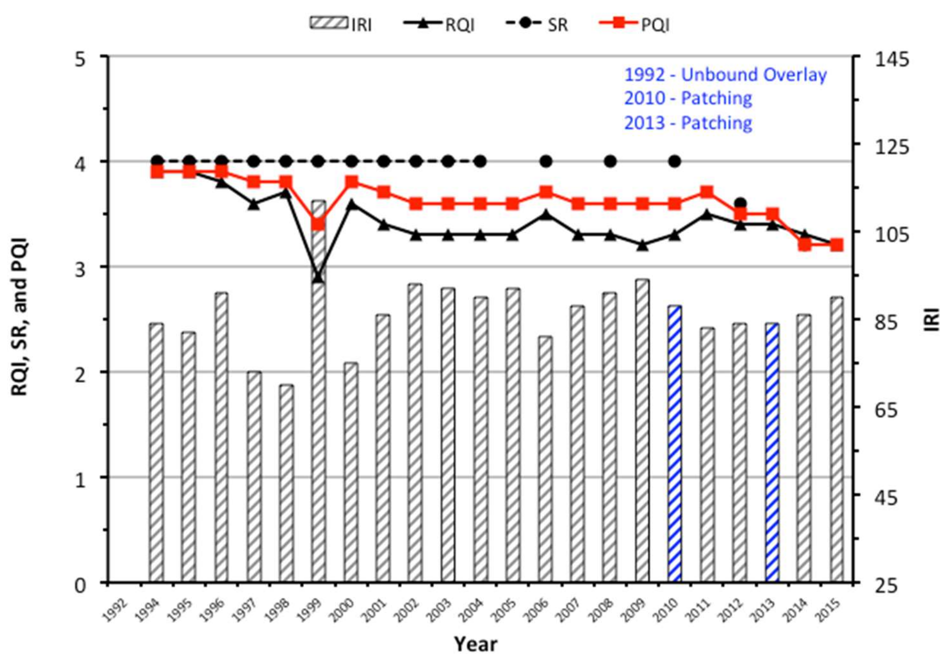


Figure B.134. Pavement management system data for section 50+0.000, direction D, of project 5507–47 constructed in 1992. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

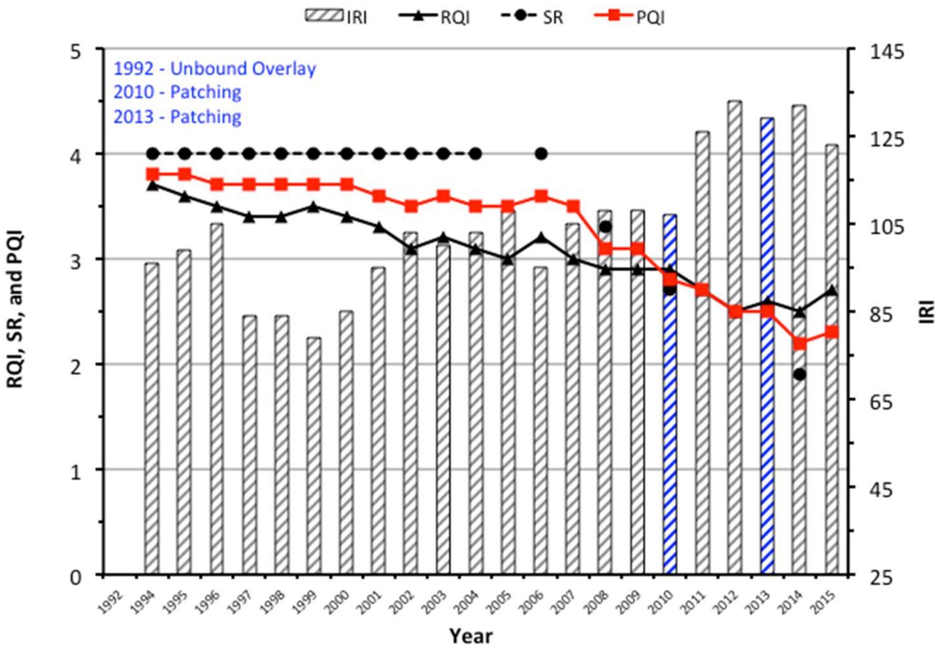


Figure B.135. Pavement management system data for section 51+0.000, direction D, of project 5507–47 constructed in 1992. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

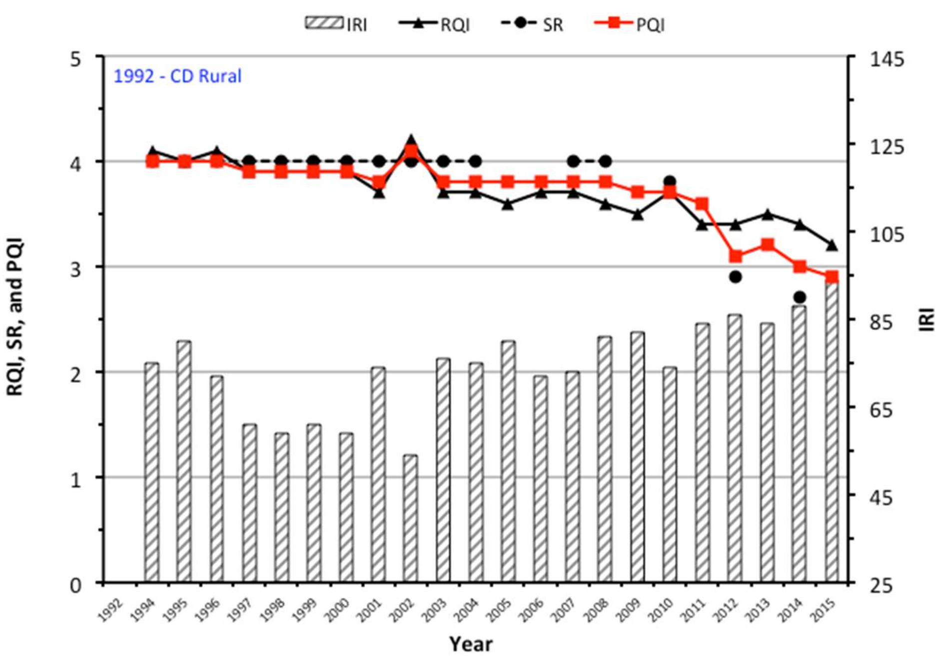


Figure B.136. Pavement management system data for section 46+0.285, direction I, of project 5507–47 constructed in 1992. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

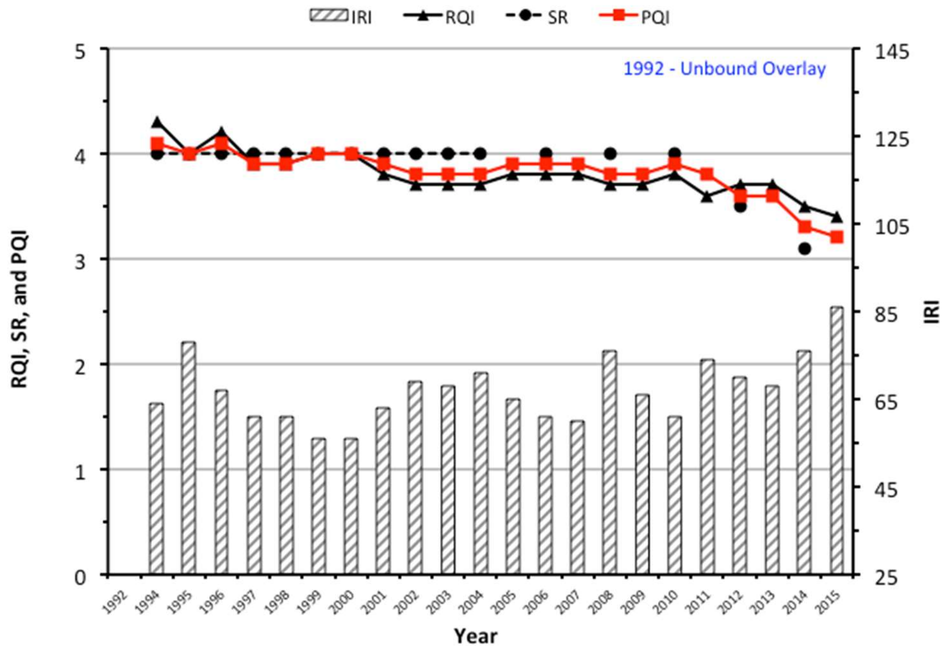


Figure B.137. Pavement management system data for section 46+0.683, direction I, of project 5507–47 constructed in 1992. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

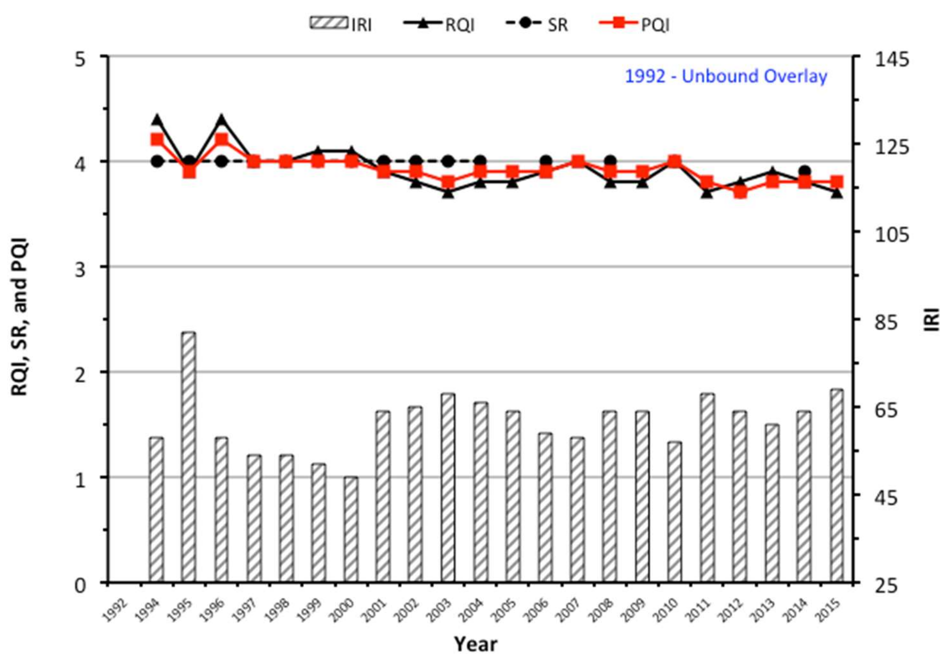


Figure B.138. Pavement management system data for section 47+0.000, direction I, of project 5507–47 constructed in 1992. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

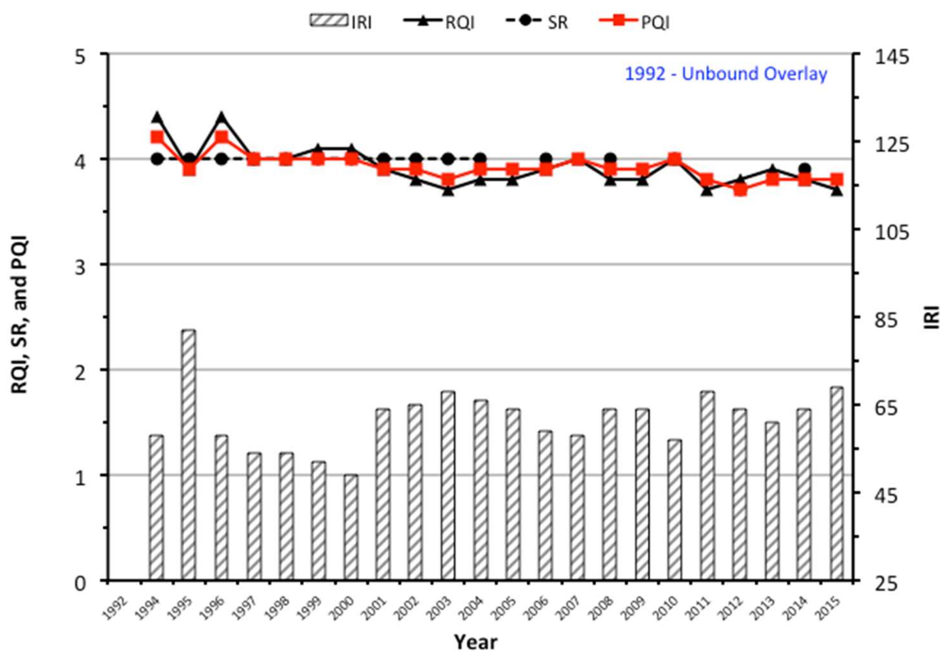


Figure B.139. Pavement management system data for section 48+0.000, direction I, of project 5507–47 constructed in 1992. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

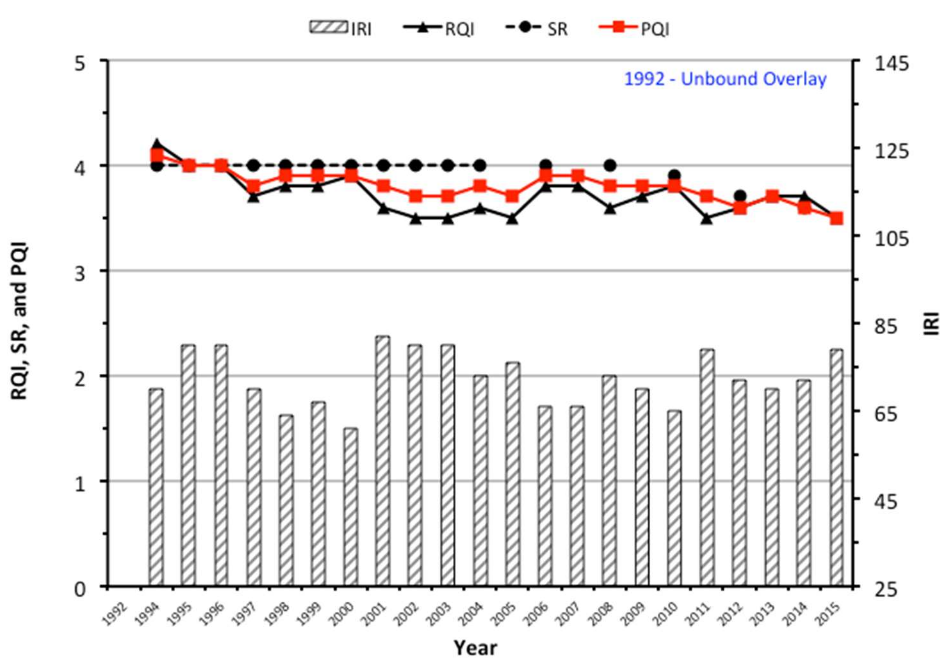


Figure B.140. Pavement management system data for section 49+0.000, direction I, of project 5507–47 constructed in 1992. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

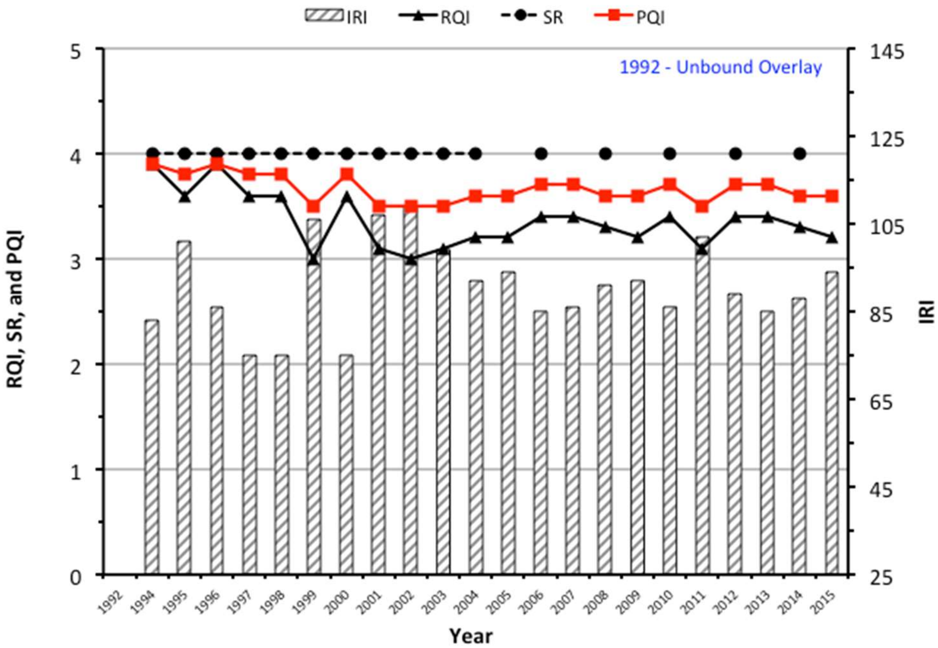


Figure B.141. Pavement management system data for section 50+0.000, direction I, of project 5507–47 constructed in 1992. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

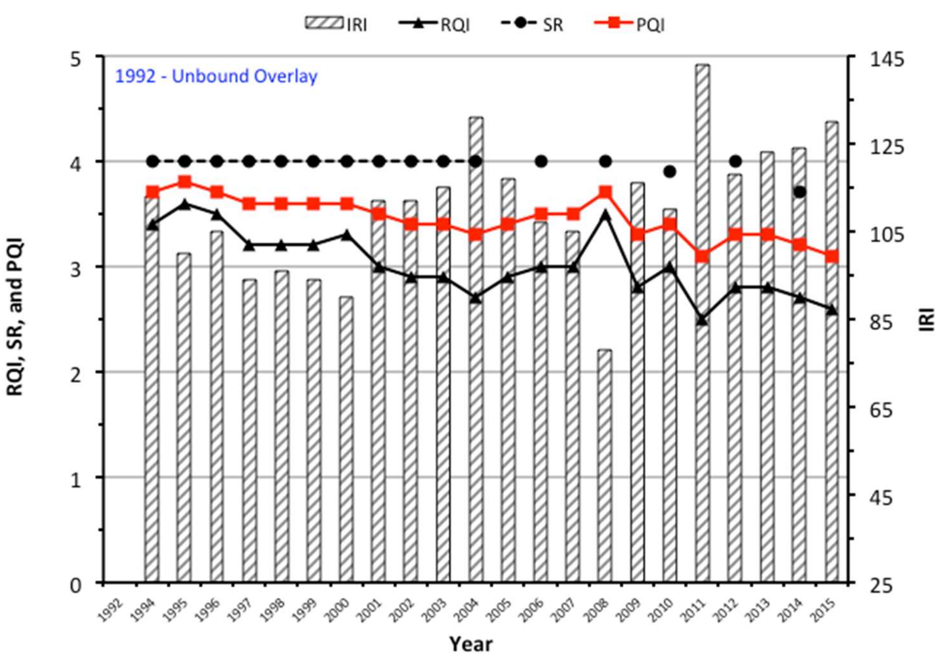


Figure B.142. Pavement management system data for section 51+0.000, direction I, of project 5507–47 constructed in 1992. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

District 6 – 2480-88

Table B.69. Measured IRI for selected sections of project 2480-88, constructed in 1998. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)						
	13 +0.473	14 +0.000	15 +0.000	16 +0.000	17 +0.000	18 +0.000	19 +0.000
Year	I	I	I	I	I	I	I
1998	110	124	112	113	143	137	141
1999	56	39	41	49	48	51	53
2000	59	40	42	47	46	52	49
2001	56	36	35	42	38	63	54
2002	58	37	38	59	52	88	82
2003	64	54	57	65	64	66	65
2004	73	48	52	58	60	64	58
2005	70	50	57	62	67	68	68
2006	62	42	46	51	55	56	50
2007	74	54	54	58	57	63	56
2008	65	47	48	54	54	59	51
2009	80	61	54	58	61	64	55
2010	66	46	48	51	55	58	51
2011	73	51	51	56	58	63	53
2012	76	50	50	57	59	63	54
2013	89	63	59	67	64	70	61
2014	74	48	51	57	61	64	54
2015	70	50	51	57	60	63	55

Table B.70. Measured PQI for selected sections of project 2480-88, constructed in 1998. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)						
	13 +0.473	14 +0.000	15 +0.000	16 +0.000	17 +0.000	18 +0.000	19 +0.000
Year	I	I	I	I	I	I	I
1998	3.2	3.0	3.2	3.1	2.5	3.0	2.7
1999	4.0	4.2	4.2	4.1	4.1	4.0	4.0
2000	3.9	4.2	4.1	4.1	4.1	4.0	4.0
2001	4.0	4.3	4.2	4.1	4.2	3.9	4.0
2002	3.9	4.2	4.1	3.9	4.0	3.7	3.7
2003	3.9	4.0	3.9	3.8	3.9	3.9	3.9
2004	3.8	4.1	4.0	3.9	3.9	3.9	4.0
2005	3.8	4.0	3.9	3.9	3.8	3.8	3.8
2006	3.9	4.1	4.1	4.0	3.9	4.0	4.0
2007	3.7	4.0	4.0	3.9	3.9	3.9	4.0
2008	3.9	4.1	4.1	4.0	4.0	4.0	4.1
2009	3.7	3.9	3.9	3.9	3.9	3.8	3.9
2010	3.8	4.1	4.1	4.0	3.9	3.9	4.0
2011	3.8	4.0	4.0	3.9	3.9	3.9	4.0
2012	3.7	4.0	4.0	3.9	3.9	3.9	4.0
2013	3.6	3.9	3.9	3.8	3.9	3.8	3.9
2014	3.7	4.1	4.0	3.9	3.9	3.8	4.0
2015	3.8	4.0	4.0	3.9	3.9	3.9	4.0

Table B.71. Measured RQI for selected sections of project 2480-88, constructed in 1998. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)						
	13 +0.473	14 +0.000	15 +0.000	16 +0.000	17 +0.000	18 +0.000	19 +0.000
Year	I	I	I	I	I	I	I
1998	2.9	2.7	2.9	2.9	2.4	2.5	2.4
1999	4.0	4.4	4.4	4.2	4.2	4.1	4.1
2000	3.9	4.4	4.3	4.2	4.2	4.1	4.1
2001	4.1	4.6	4.5	4.3	4.5	3.9	4.1
2002	3.8	4.4	4.3	3.8	4.0	3.4	3.5
2003	3.8	4.0	3.9	3.7	3.8	3.8	3.8
2004	3.6	4.2	4.1	3.8	3.9	3.8	4.0
2005	3.6	4.1	3.9	3.8	3.7	3.7	3.7
2006	3.8	4.3	4.2	4.1	3.9	4.0	4.1
2007	3.5	4.1	4.0	3.9	3.9	3.8	4.0
2008	3.8	4.2	4.2	4.0	4.1	4.0	4.2
2009	3.4	3.9	3.9	3.8	3.8	3.7	3.9
2010	3.7	4.3	4.2	4.0	3.9	3.9	4.1
2011	3.6	4.1	4.1	3.9	3.9	3.8	4.1
2012	3.5	4.1	4.1	3.9	3.8	3.8	4.1
2013	3.2	3.8	3.9	3.7	3.8	3.7	3.8
2014	3.5	4.2	4.1	3.9	3.8	3.7	4.0
2015	3.6	4.1	4.1	3.9	3.9	3.8	4.0

Table B.72. Measured SR for selected sections of project 2480-88, constructed in 1998. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)						
	13 +0.473	14 +0.000	15 +0.000	16 +0.000	17 +0.000	18 +0.000	19 +0.000
Year	I	I	I	I	I	I	I
1998	3.6	3.4	3.6	3.4	2.7	3.7	3.0
1999	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2000	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2001	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2002	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2003	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2004	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2005	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2006	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2007	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2008	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2009	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2010	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2011	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2012	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2013	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2014	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2015	4.0	4.0	4.0	4.0	4.0	4.0	4.0

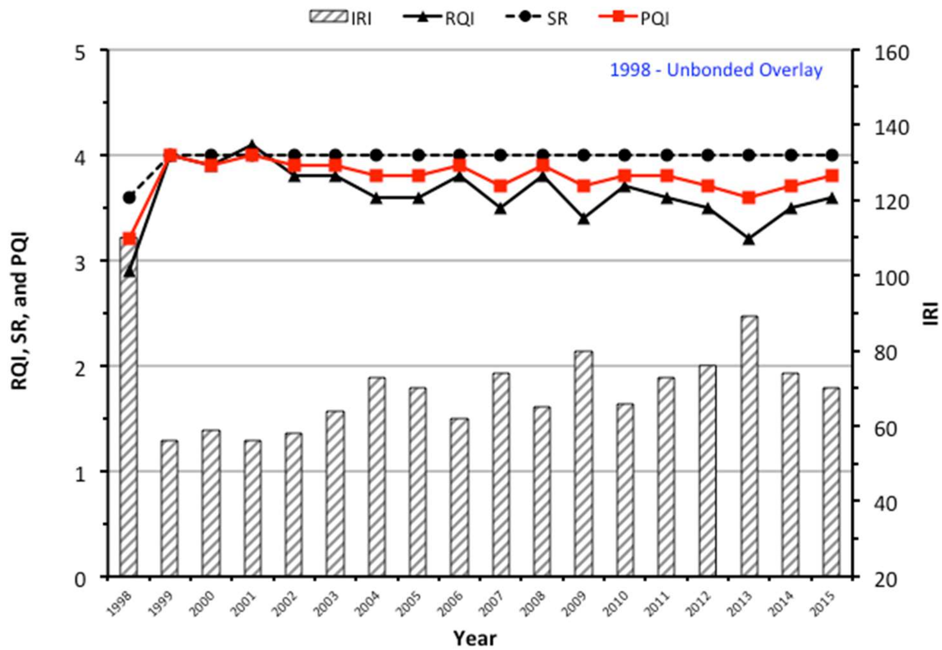


Figure B.143. Pavement management system data for section 13+0.473, direction I, of project 2480–88 constructed in 1998. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

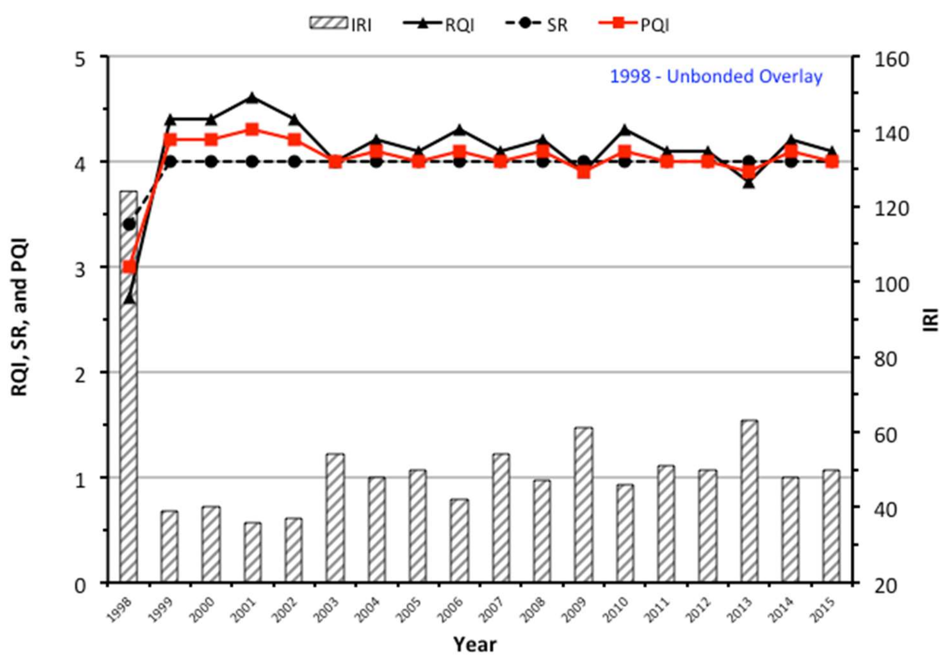


Figure B.144. Pavement management system data for section 14+0.000, direction I, of project 2480–88 constructed in 1998. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

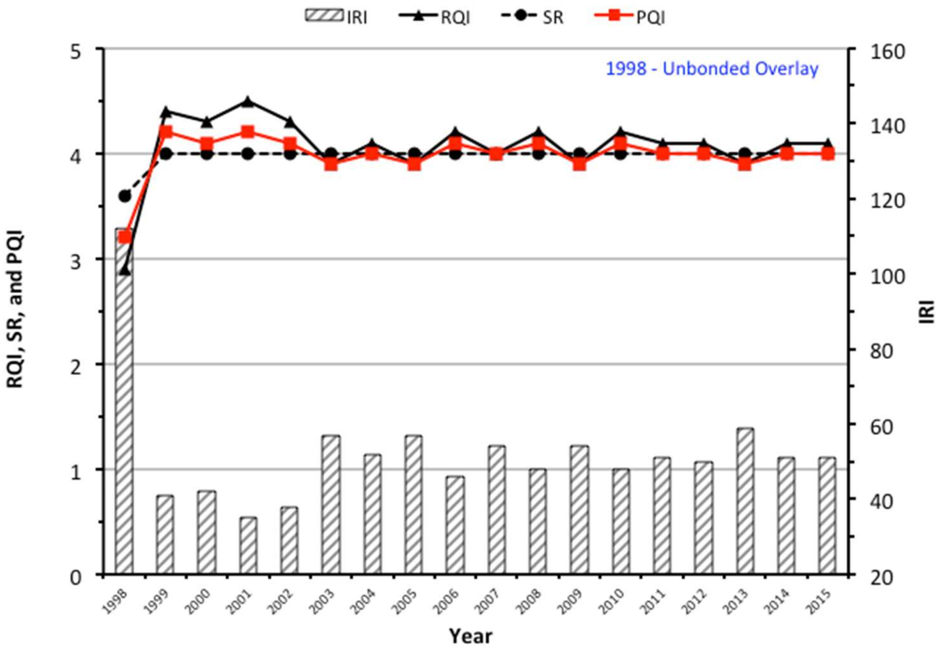


Figure B.145. Pavement management system data for section 15+0.000, direction I, of project 2480–88 constructed in 1998. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

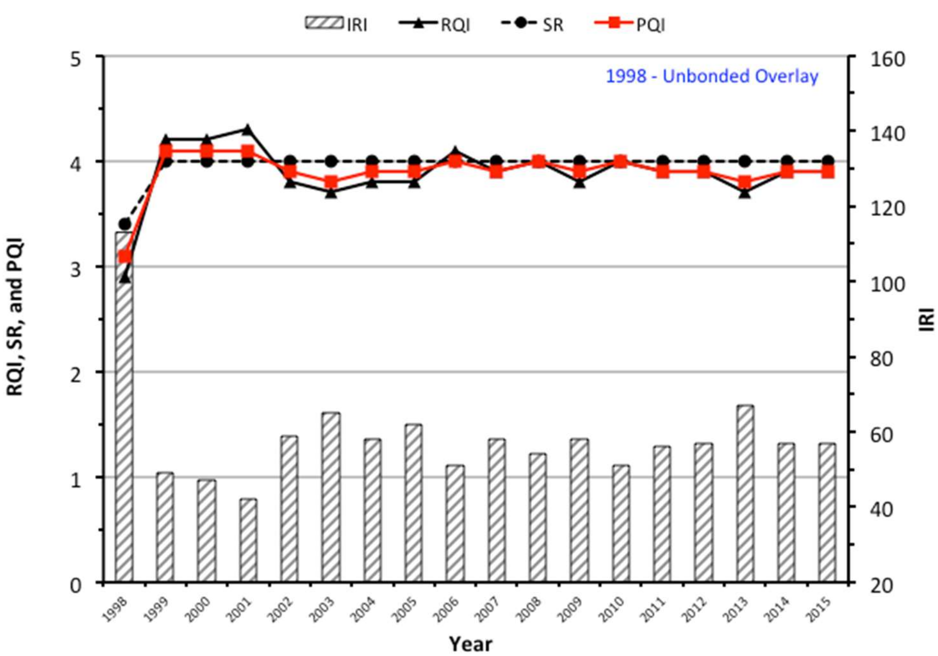


Figure B.146. Pavement management system data for section 16+0.000, direction I, of project 2480–88 constructed in 1998. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

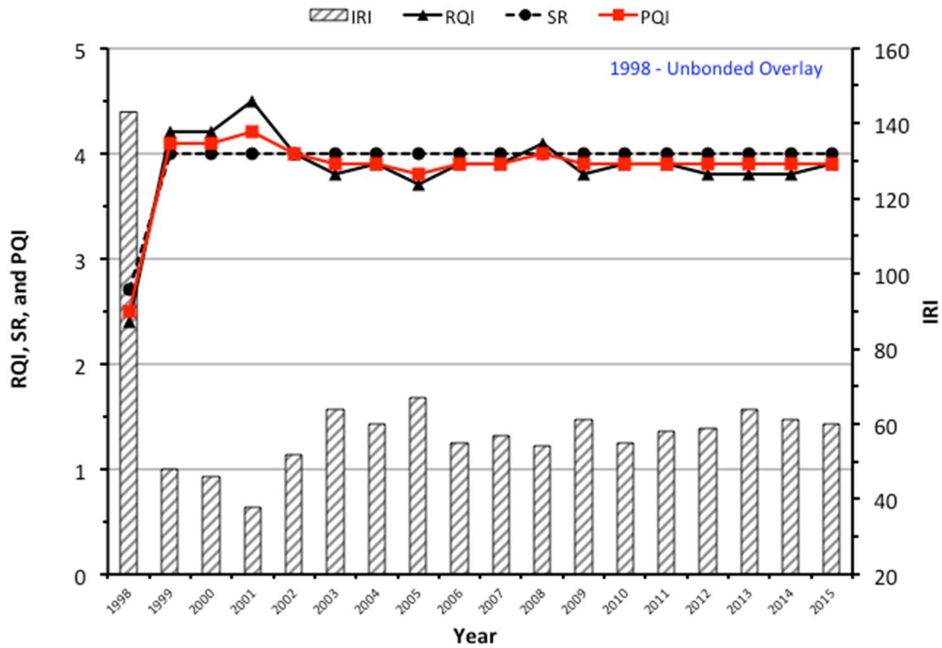


Figure B.147. Pavement management system data for section 17+0.000, direction I, of project 2480–88 constructed in 1998. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

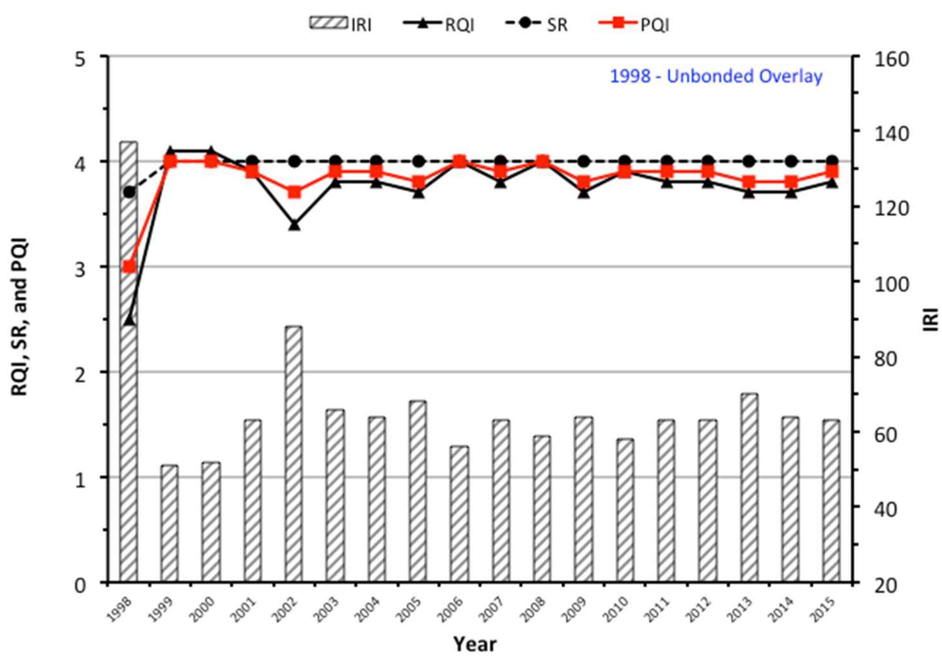


Figure B.148. Pavement management system data for section 18+0.000, direction I, of project 2480–88 constructed in 1998. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

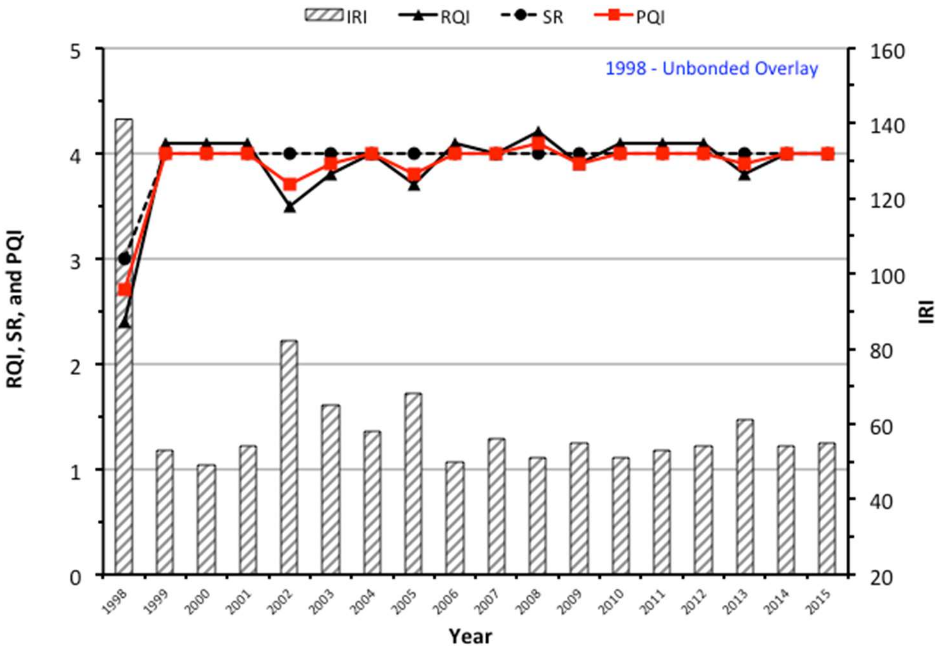


Figure B.149. Pavement management system data for section 19+0.000, direction I, of project 2480–88 constructed in 1998. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

District 6 – 2480-91

Table B.73. Measured IRI for selected sections of project 2480-91, constructed in 2000. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)						
	20 +0.113	21 +0.000	22 +0.000	23 +0.000	24 +0.000	25 +0.000	26 +0.000
Year	I	I	I	I	I	I	I
2000	184	179	144	172	163	139	113
2001	65	85	81	79	67	72	73
2002	95	102	91	106	80	81	80
2003	83		78	84	73	80	80
2004	80	85	76	83	74	78	77
2005	80	92	84	92	82	89	81
2006	67	72	70	73	61	70	72
2007	68	70	66	65	56	64	66
2008	72	80	73	80	66	77	74
2009	75	83	74	80	66	79	75
2010	65	71	67	71	59	67	71
2011	66	73	69	73	59	68	71
2012	68	74	67	73	58	67	68
2013	71	74	69	72	62	67	69
2014	67	74	72	72	61	69	72
2015	68	73	70	74	59	71	72

Table B.74. Measured PQI for selected sections of project 2480-91, constructed in 2000. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)						
	20 +0.113	21 +0.000	22 +0.000	23 +0.000	24 +0.000	25 +0.000	26 +0.000
Year	I	I	I	I	I	I	I
2000	2.0	1.9	2.0	2.2	2.1	2.1	2.3
2001	3.9	3.8	3.8	3.8	4.0	3.9	3.9
2002	3.7	3.5	3.6	3.5	3.8	3.7	3.7
2003	3.7		3.8	3.7	3.8	3.7	3.7
2004	3.8	3.7	3.7	3.7	3.8	3.7	3.8
2005	3.7	3.6	3.7	3.6	3.7	3.6	3.7
2006	3.9	3.8	3.8	3.8	4.0	3.8	3.8
2007	3.9	3.8	3.8	3.9	4.0	3.9	3.9
2008	3.9	3.7	3.8	3.7	3.9	3.7	3.8
2009	3.8	3.7	3.8	3.7	3.9	3.7	3.8
2010	3.9	3.8	3.9	3.8	4.0	3.9	3.8
2011	3.9	3.7	3.8	3.8	4.0	3.8	3.8
2012	3.9	3.8	3.9	3.8	4.0	3.9	3.8
2013	3.8	3.7	3.8	3.8	3.9	3.8	3.8
2014	3.9	3.8	3.8	3.8	3.9	3.9	3.8
2015	3.9	3.7	3.8	3.7	4.0	3.8	3.8

Table B.75. Measured RQI for selected sections of project 2480-91, constructed in 2000. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)						
	20 +0.113	21 +0.000	22 +0.000	23 +0.000	24 +0.000	25 +0.000	26 +0.000
Year	I	I	I	I	I	I	I
2000	1.8	1.9	2.4	2.0	2.1	2.5	2.9
2001	3.9	3.6	3.7	3.6	4.0	3.9	3.9
2002	3.4	3.0	3.3	3.1	3.6	3.4	3.5
2003	3.5		3.6	3.4	3.7	3.5	3.5
2004	3.6	3.4	3.5	3.5	3.7	3.5	3.7
2005	3.5	3.2	3.4	3.2	3.5	3.2	3.5
2006	3.8	3.7	3.7	3.7	4.0	3.7	3.7
2007	3.9	3.7	3.7	3.8	4.0	3.8	3.8
2008	3.8	3.5	3.6	3.5	3.8	3.5	3.6
2009	3.6	3.4	3.6	3.5	3.8	3.4	3.6
2010	3.8	3.7	3.8	3.7	4.1	3.8	3.7
2011	3.8	3.6	3.7	3.7	4.0	3.7	3.7
2012	3.8	3.6	3.8	3.7	4.0	3.8	3.7
2013	3.7	3.6	3.7	3.7	3.9	3.7	3.7
2014	3.8	3.6	3.7	3.7	3.9	3.8	3.7
2015	3.8	3.6	3.7	3.6	4.0	3.6	3.7

Table B.76. Measured SR for selected sections of project 2480-91, constructed in 2000. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)						
	20 +0.113	21 +0.000	22 +0.000	23 +0.000	24 +0.000	25 +0.000	26 +0.000
Year	I	I	I	I	I	I	I
2000	2.2	2.0	1.6	2.5	2.2	1.7	1.8
2001	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2002	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2003	4.0		4.0	4.0	4.0	4.0	4.0
2004	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2005	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2006	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2007	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2008	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2009	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2010	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2011	4.0	3.9	4.0	4.0	4.0	4.0	4.0
2012	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2013	4.0	3.9	4.0	4.0	4.0	4.0	4.0
2014	4.0	4.0	4.0	3.9	4.0	4.0	4.0
2015	4.0	3.9	4.0	3.9	4.0	4.0	4.0

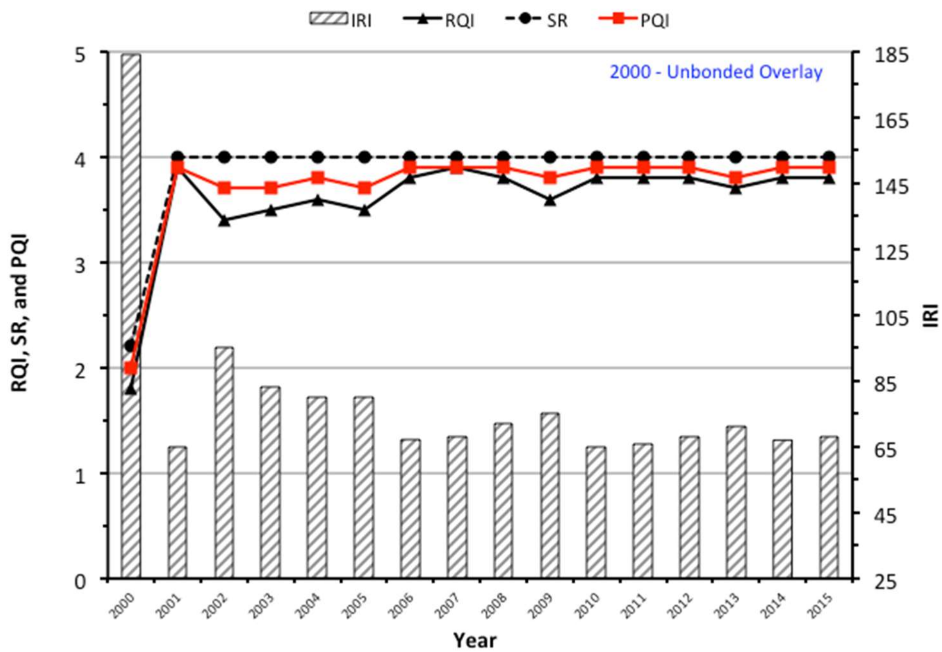


Figure B.150. Pavement management system data for section 20+0.113, direction I, of project 2480–91 constructed in 2000. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

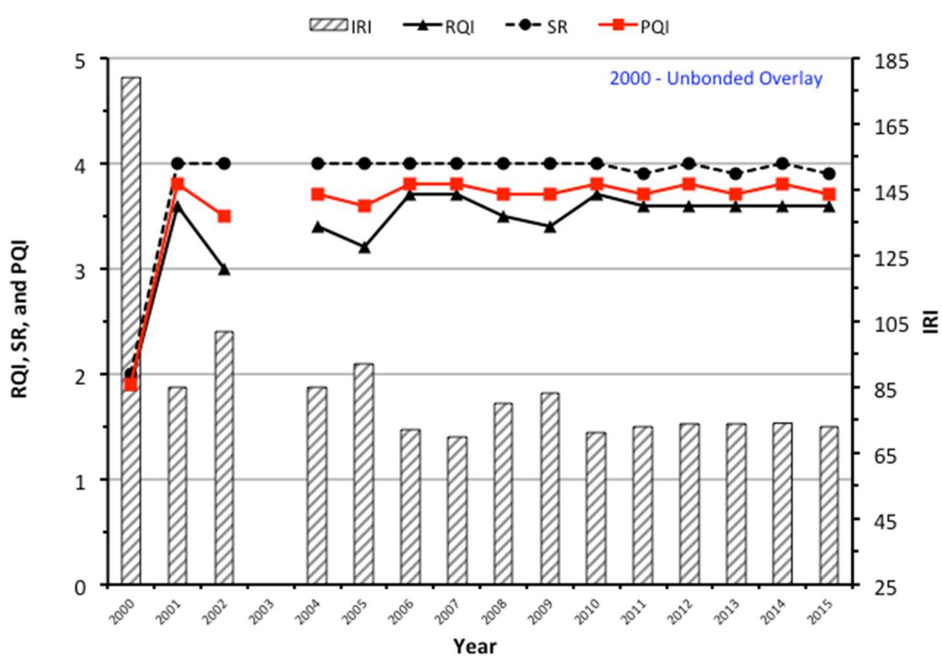


Figure B.151. Pavement management system data for section 21+0.000, direction I, of project 2480–91 constructed in 2000. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

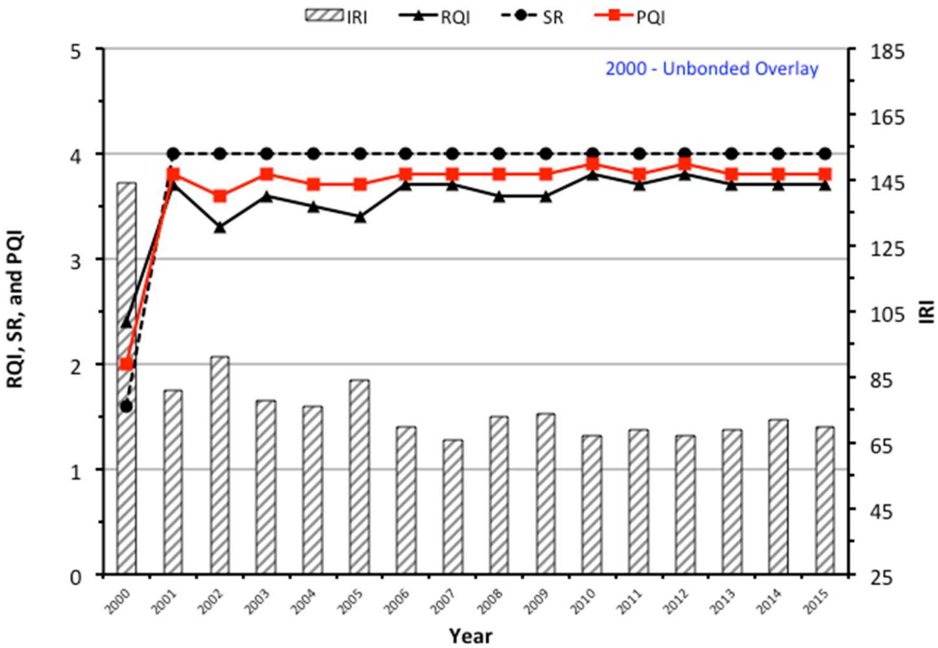


Figure B.152. Pavement management system data for section 22+0.000, direction I, of project 2480–91 constructed in 2000. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

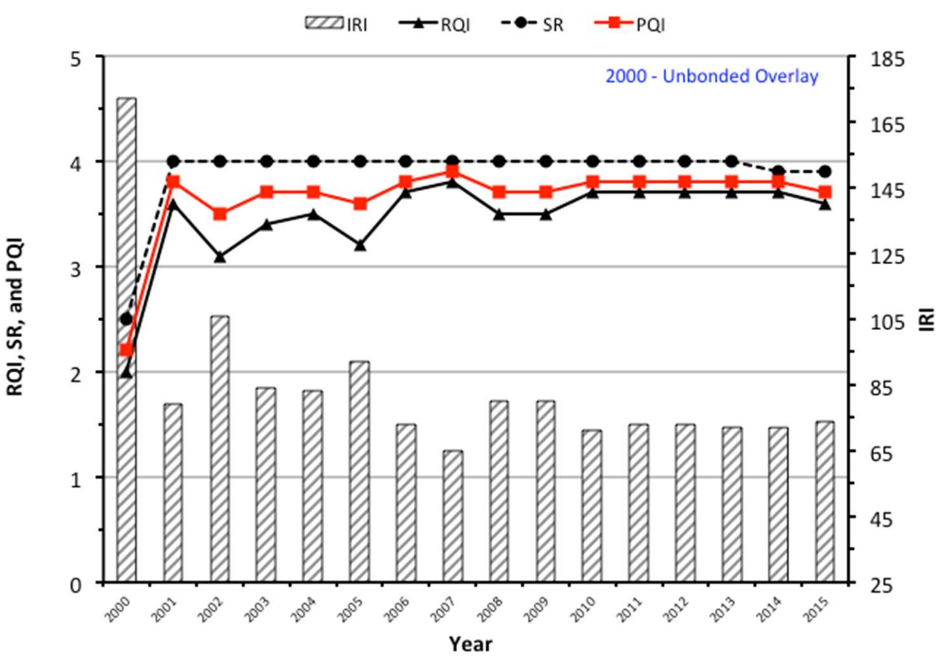


Figure B.153. Pavement management system data for section 23+0.000, direction I, of project 2480–91 constructed in 2000. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

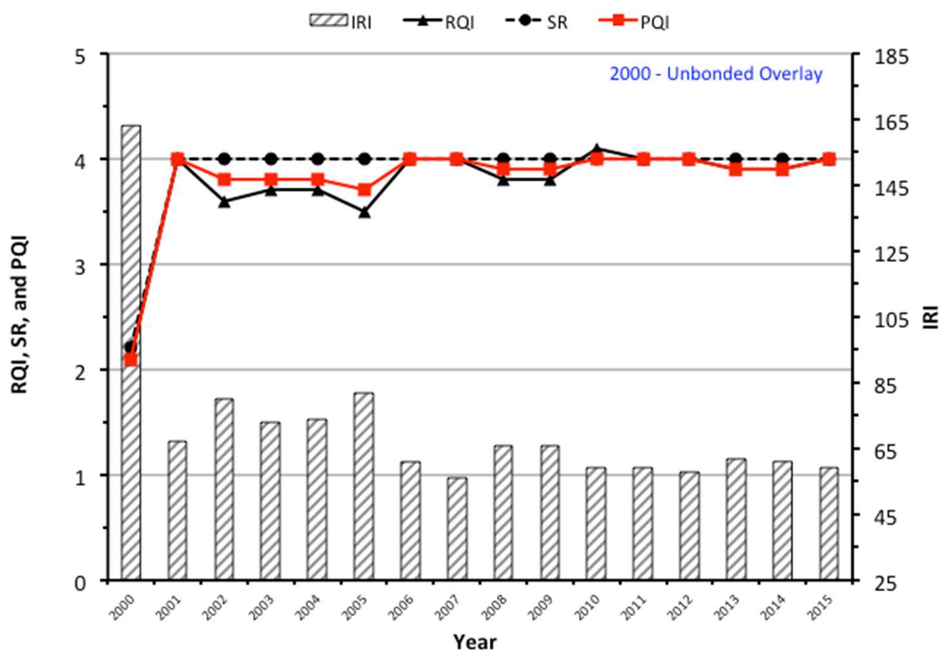


Figure B.154. Pavement management system data for section 24+0.000, direction I, of project 2480–91 constructed in 2000. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

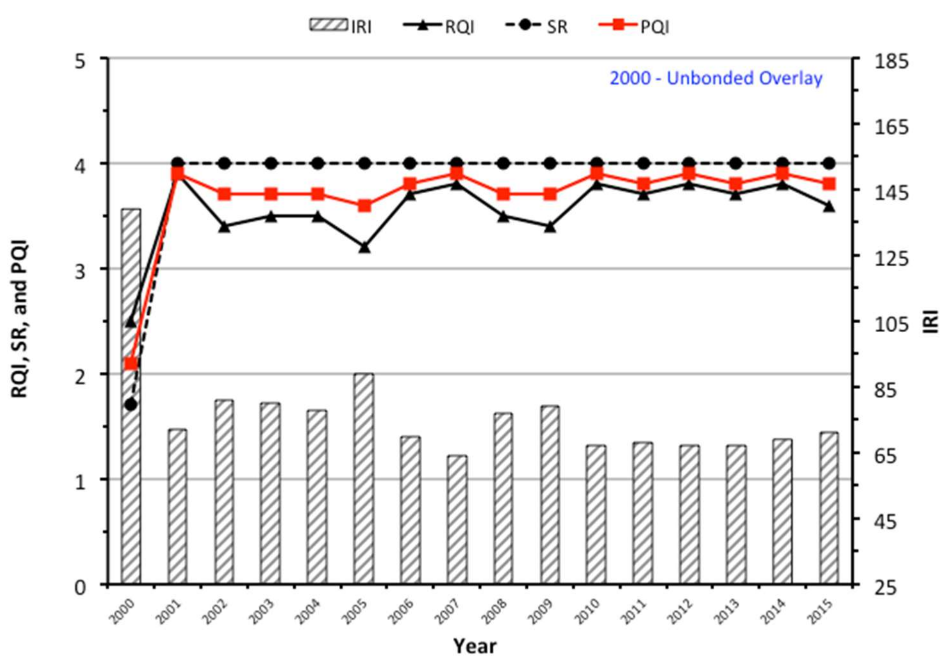


Figure B.155. Pavement management system data for section 25+0.000, direction I, of project 2480–91 constructed in 2000. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

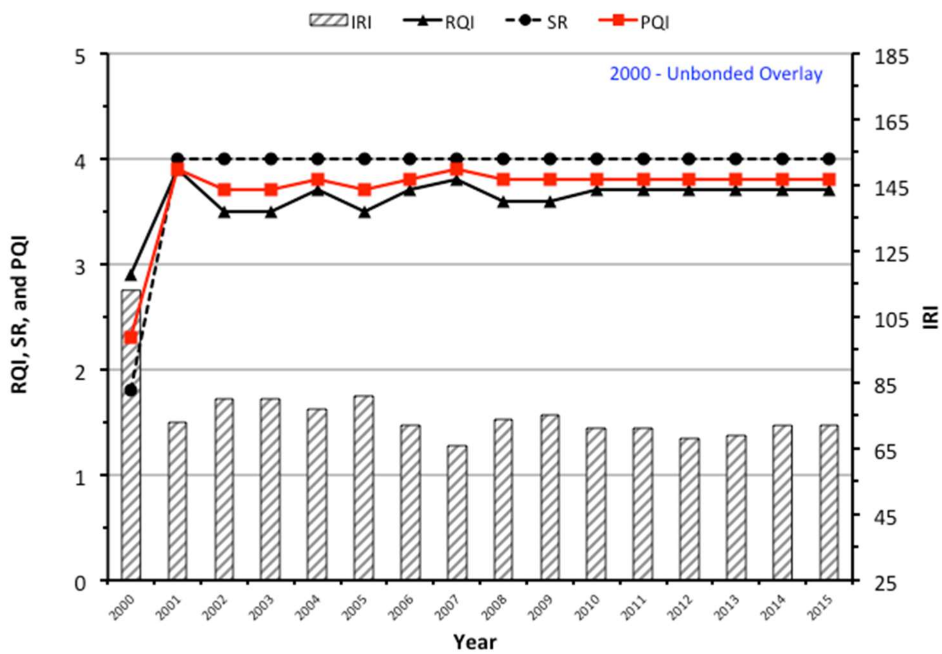


Figure B.156. Pavement management system data for section 26+0.000, direction I, of project 2480–91 constructed in 2000. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

District 7 – 0702-98

Table B.77. Measured IRI for selected sections of project 0702-98, constructed in 1997. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)														
	134 +0.020	135 +0.000	136 +0.000	137 +0.000	138 +0.000	139 +0.000	140 +0.000	133 +0.370	134 +0.382	135 +0.000	136 +0.000	137 +0.000	138 +0.000	139 +0.000	140 +0.000
Year	D	D	D	D	D	D	D	I	I	I	I	I	I	I	I
1997															
1998	63	44	65	49	47	47	49	59	59	45	60	49	48	44	49
2000	64	47	70	54	53	51	54	70	66	49	67	60	56	49	53
2001	61	37	89	61	54	50	68	73	72	42	76	64	61	53	56
2002	63	37	97	62	57	54	62	91	89	50	92	79	76	62	61
2003	87	79	98	86	84	80	91	97	97	80	96	89	84	77	80
2004	91	79	99	88	87	81	86	96	105	86	99	95	90	83	81
2005	97	63	90	73	73	70	76	76	95	84	99	92	88	80	79
2006	76	59	84	66	71	68	68	80	85	86	99	96	90	82	81
2007	79	68	90	78	78	72	77	84	91	87	100	97	92	82	80
2008	85	71	96	85	86	80	83	85	96	69	84	79	78	66	71
2009	112	67	98	77	81	78	83	104	116	94	109	107	104	90	90
2010	98	80	103	89	92	86	89	98	106	82	98	94	92	80	84
2011	118	86	114	94	98	92	91	94	104	86	105	99	104	84	87
2012	73	69	102	78	85	79	87	109	119	88	106	99	103	82	85
2013	87	74	103	80	86	79	86	109	136	86	105	92	100	76	80
2014	80	108	77	84	78	88	66	123	91	112	106	105	87	88	82
2015	80	112	87	93	85	106	82	122	88	107	98	99	81	84	83

Table B.78. Measured PQI for selected sections of project 0702-98, constructed in 1997. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)														
	134 +0.020	135 +0.000	136 +0.000	137 +0.000	138 +0.000	139 +0.000	140 +0.000	133 +0.370	134 +0.382	135 +0.000	136 +0.000	137 +0.000	138 +0.000	139 +0.000	140 +0.000
Year	D	D	D	D	D	D	D	I	I	I	I	I	I	I	I
1997															
1998	3.9	4.1	3.9	4.0	4.1	4.1	4.1	3.9	3.9	4.1	3.9	4.0	4.1	4.1	4.1
2000	3.9	4.1	3.8	4.0	4.0	4.0	4.0	3.8	3.9	4.1	3.9	3.9	4.0	4.1	4.0
2001	3.9	4.2	3.6	4.0	4.0	4.0	3.8	3.8	3.8	4.2	3.8	3.9	3.9	4.0	4.0
2002	3.9	4.2	3.6	3.9	4.0	4.0	3.9	3.6	3.6	4.1	3.6	3.7	3.8	3.9	3.9
2003	3.7	3.8	3.6	3.7	3.7	3.7	3.7	3.6	3.6	3.8	3.6	3.7	3.7	3.8	3.7
2004	3.6	3.8	3.6	3.7	3.7	3.7	3.7	3.6	3.5	3.7	3.6	3.6	3.6	3.7	3.7
2005	3.6	3.9	3.6	3.8	3.8	3.8	3.8	3.8	3.6	3.7	3.6	3.6	3.7	3.8	3.8
2006	3.8	3.9	3.7	3.9	3.8	3.8	3.8	3.7	3.7	3.7	3.6	3.6	3.7	3.7	3.8
2007	3.7	3.8	3.6	3.8	3.8	3.8	3.7	3.7	3.6	3.7	3.5	3.6	3.6	3.7	3.8
2008	3.7	3.8	3.6	3.7	3.7	3.7	3.7	3.7	3.6	3.9	3.7	3.7	3.7	3.9	3.8
2009	3.3	3.8	3.5	3.7	3.7	3.7	3.7	3.5	3.3	3.6	3.4	3.5	3.5	3.6	3.6
2010	3.5	3.7	3.5	3.6	3.6	3.7	3.6	3.6	3.5	3.7	3.6	3.6	3.6	3.7	3.7
2011	3.3	3.7	3.4	3.6	3.6	3.6	3.6	3.6	3.5	3.7	3.5	3.5	3.5	3.7	3.7
2012	3.8	3.8	3.5	3.7	3.7	3.7	3.6	3.4	3.2	3.7	3.5	3.5	3.5	3.7	3.7
2013	3.6	3.8	3.5	3.7	3.7	3.7	3.6	3.5	3.0	3.7	3.5	3.6	3.5	3.8	3.7
2014	3.7	3.4	3.7	3.7	3.7	3.6	3.8	3.1	3.6	3.4	3.5	3.4	3.6	3.6	3.7
2015	3.7	3.4	3.6	3.6	3.7	3.4	3.7	3.0	3.7	3.4	3.6	3.5	3.7	3.7	3.7

Table B.79. Measured RQI for selected sections of project 0702-98, constructed in 1997. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)														
	134 +0.020	135 +0.000	136 +0.000	137 +0.000	138 +0.000	139 +0.000	140 +0.000	133 +0.370	134 +0.382	135 +0.000	136 +0.000	137 +0.000	138 +0.000	139 +0.000	140 +0.000
Year	D	D	D	D	D	D	D	I	I	I	I	I	I	I	I
1997															
1998	3.8	4.3	3.8	4.1	4.2	4.2	4.2	3.9	3.9	4.3	3.9	4.1	4.2	4.3	4.2
2000	3.8	4.2	3.7	4.0	4.1	4.1	4.0	3.7	3.8	4.2	3.8	3.9	4.0	4.2	4.1
2001	3.9	4.5	3.3	4.0	4.0	4.1	3.7	3.6	3.7	4.4	3.6	3.8	3.9	4.1	4.0
2002	3.8	4.5	3.2	3.8	4.0	4.0	3.8	3.3	3.3	4.2	3.2	3.5	3.6	3.8	3.9
2003	3.4	3.6	3.2	3.4	3.5	3.5	3.4	3.3	3.2	3.6	3.3	3.4	3.5	3.6	3.5
2004	3.3	3.6	3.2	3.4	3.4	3.5	3.4	3.3	3.1	3.5	3.2	3.3	3.3	3.5	3.5
2005	3.2	3.8	3.3	3.7	3.6	3.7	3.6	3.6	3.2	3.5	3.2	3.3	3.4	3.6	3.6
2006	3.6	3.9	3.4	3.8	3.7	3.7	3.7	3.5	3.4	3.5	3.2	3.2	3.4	3.5	3.6
2007	3.5	3.7	3.3	3.6	3.6	3.7	3.5	3.5	3.3	3.4	3.1	3.2	3.3	3.5	3.6
2008	3.5	3.7	3.2	3.4	3.4	3.5	3.4	3.5	3.3	3.8	3.5	3.5	3.5	3.8	3.7
2009	2.8	3.7	3.1	3.5	3.4	3.4	3.4	3.0	2.8	3.2	2.9	3.0	3.0	3.3	3.3
2010	3.1	3.5	3.1	3.3	3.3	3.4	3.3	3.2	3.0	3.5	3.2	3.2	3.2	3.5	3.5
2011	2.8	3.4	2.9	3.2	3.2	3.3	3.3	3.2	3.1	3.4	3.0	3.1	3.0	3.4	3.4
2012	3.6	3.7	3.1	3.5	3.4	3.5	3.4	2.9	2.7	3.4	3.0	3.1	3.0	3.5	3.4
2013	3.3	3.6	3.0	3.5	3.4	3.5	3.4	3.0	2.4	3.4	3.1	3.3	3.1	3.6	3.5
2014	3.5	2.9	3.5	3.4	3.5	3.3	3.7	2.7	3.3	2.9	3.0	3.0	3.3	3.3	3.4
2015	3.5	2.9	3.3	3.2	3.4	3.0	3.5	2.7	3.4	2.9	3.2	3.1	3.5	3.4	3.4

Table B.80. Measured SR for selected sections of project 0702-98, constructed in 1997. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)														
	134 +0.020	135 +0.000	136 +0.000	137 +0.000	138 +0.000	139 +0.000	140 +0.000	133 +0.370	134 +0.382	135 +0.000	136 +0.000	137 +0.000	138 +0.000	139 +0.000	140 +0.000
Year	D	D	D	D	D	D	D	I	I	I	I	I	I	I	I
1997															
1998	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2000	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2001															
2002	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2003															
2004	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2005															
2006	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2007															
2008	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2009															
2010	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2011															
2012	4.0	4.0	4.0	4.0	4.0	4.0	3.8	4.0	3.7	4.0	4.0	4.0	4.0	4.0	4.0
2013															
2014	4.0	4.0	4.0	4.0	4.0	3.9	4.0	3.5	4.0	3.9	4.0	3.9	4.0	4.0	4.0
2015	4.0	4.0	4.0	4.0	4.0	3.8	4.0	3.4	4.0	4.0	4.0	4.0	4.0	4.0	4.0

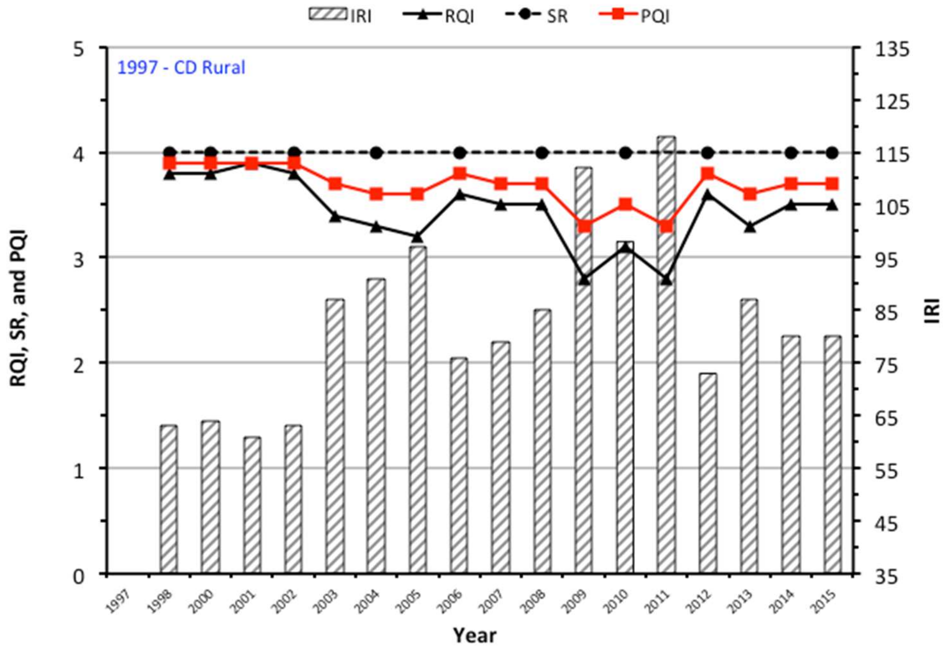


Figure B.157. Pavement management system data for section 134+0.020, direction D, of project 0702–98 constructed in 1997. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

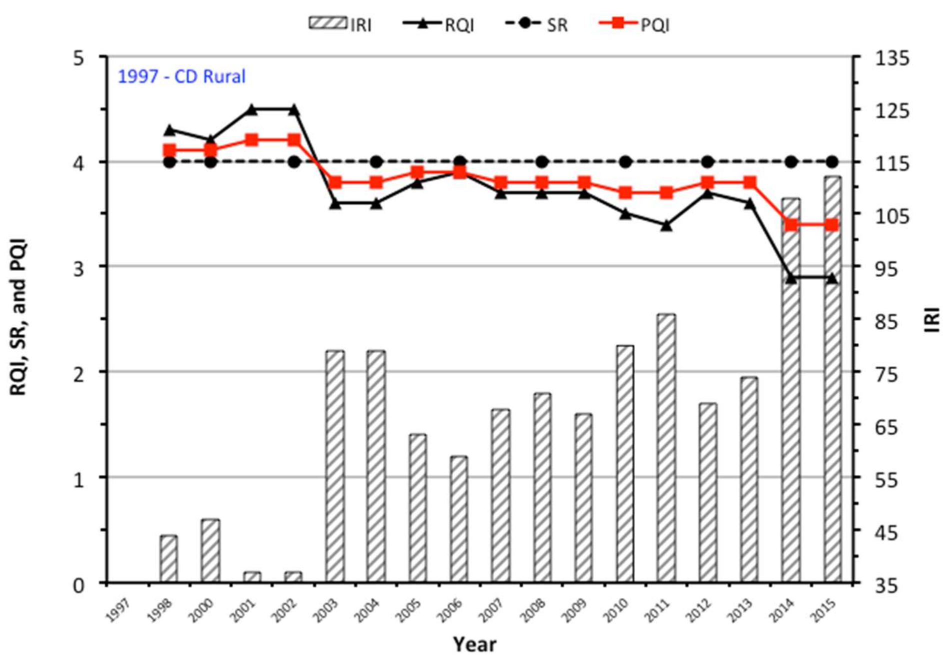


Figure B.158. Pavement management system data for section 135+0.000, direction D, of project 0702–98 constructed in 1997. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

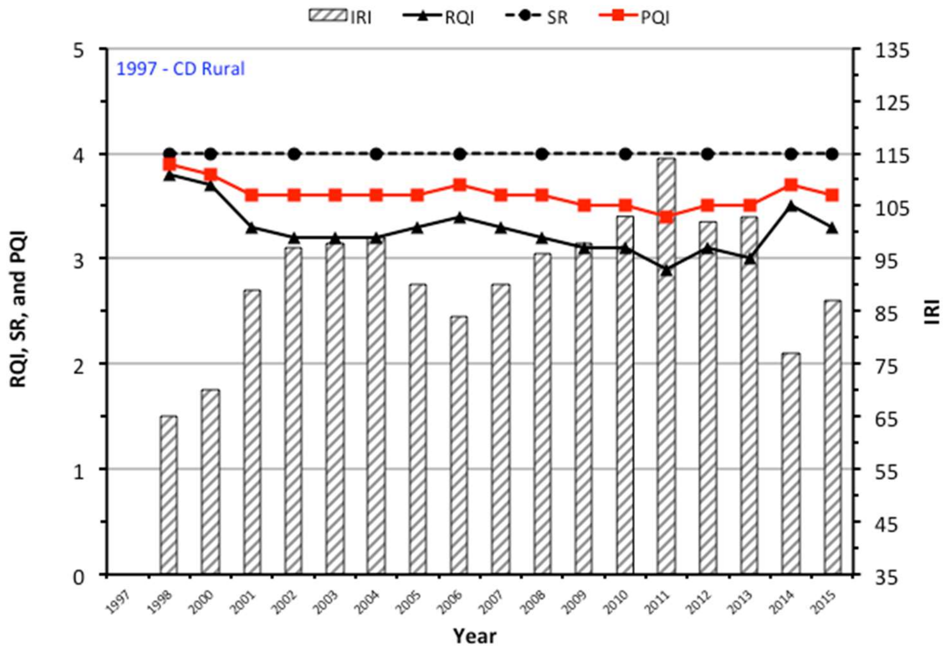


Figure B.159. Pavement management system data for section 136+0.000, direction D, of project 0702–98 constructed in 1997. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

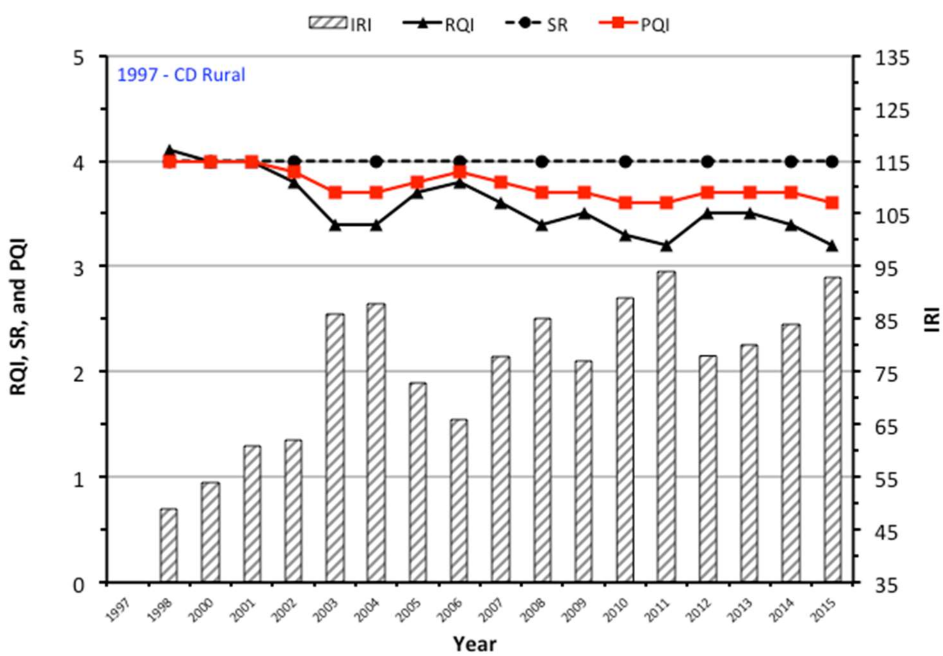


Figure B.160. Pavement management system data for section 137+0.000, direction D, of project 0702–98 constructed in 1997. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

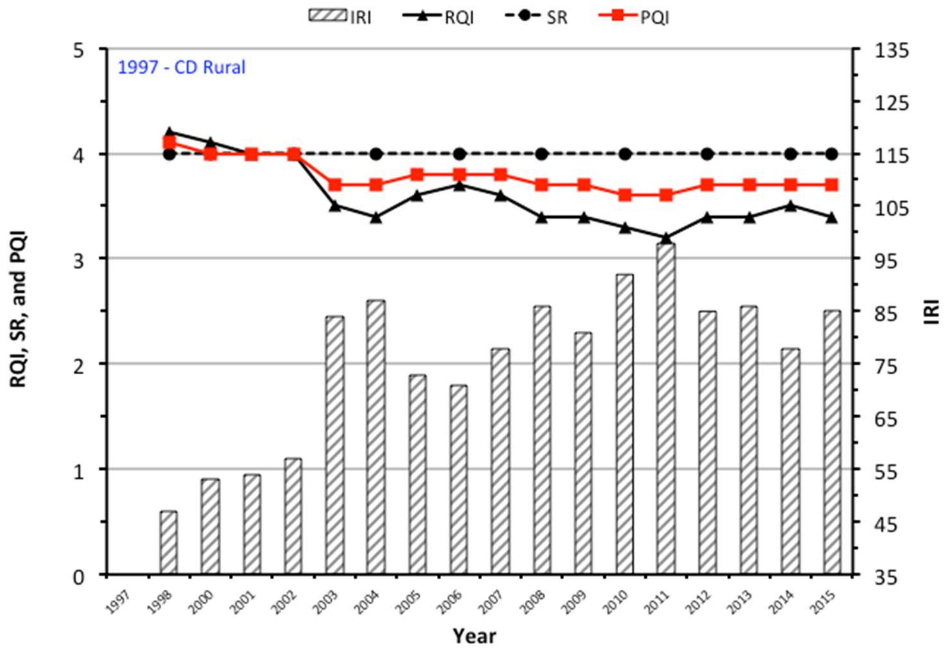


Figure B.161. Pavement management system data for section 138+0.000, direction D, of project 0702–98 constructed in 1997. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

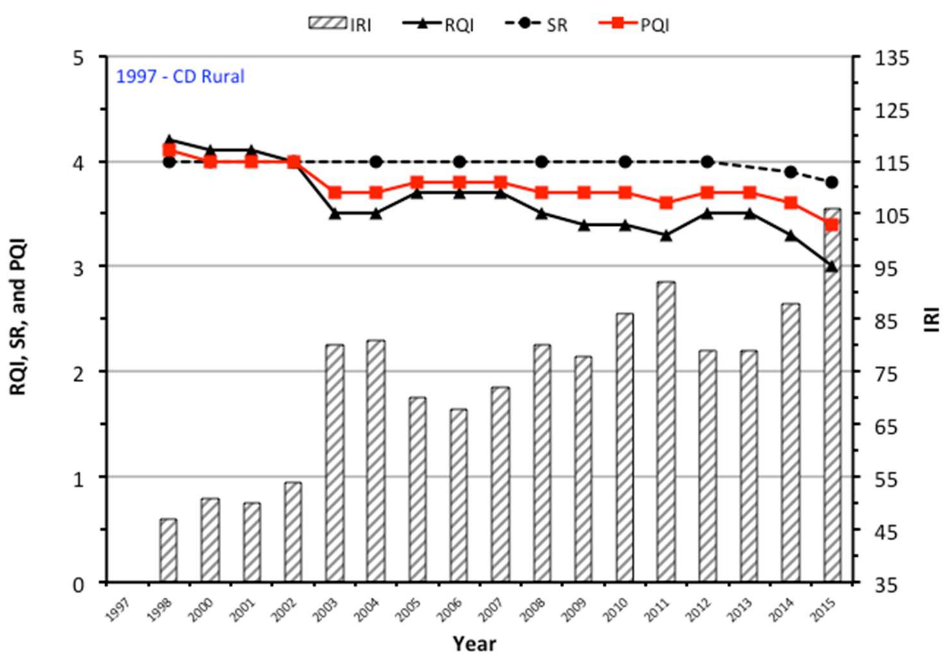


Figure B.162. Pavement management system data for section 139+0.000, direction D, of project 0702–98 constructed in 1997. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

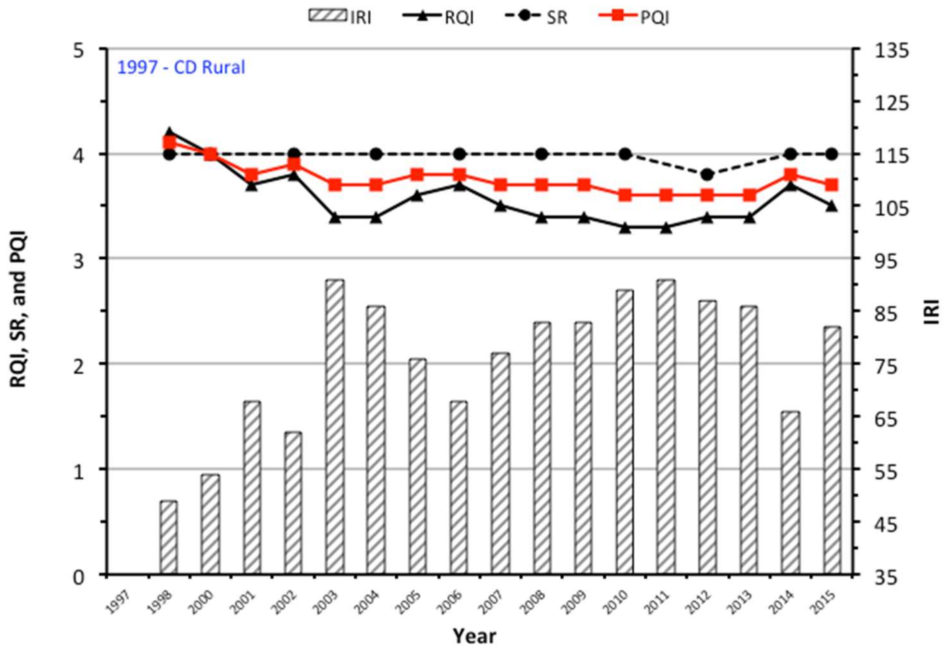


Figure B.163. Pavement management system data for section 140+0.000, direction D, of project 0702–98 constructed in 1997. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

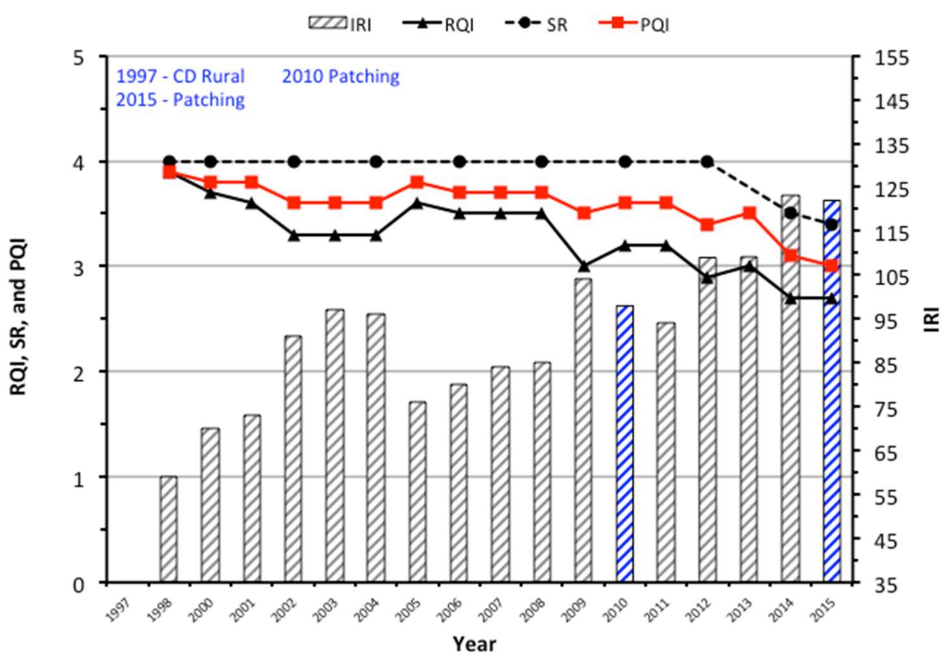


Figure B.164. Pavement management system data for section 133+0.370, direction I, of project 0702–98 constructed in 1997. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

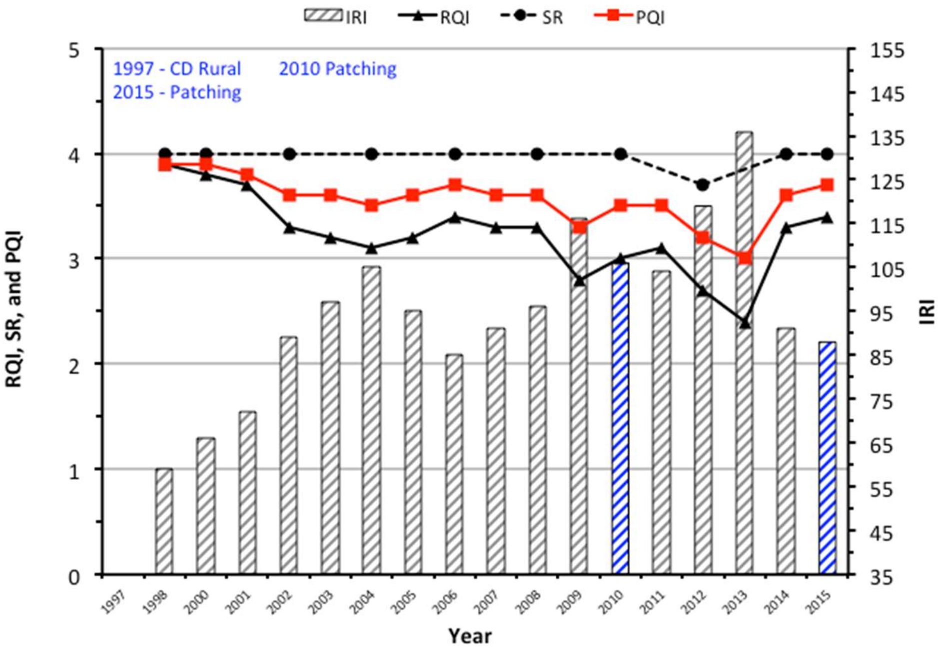


Figure B.165. Pavement management system data for section 134+0.382, direction I, of project 0702–98 constructed in 1997. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

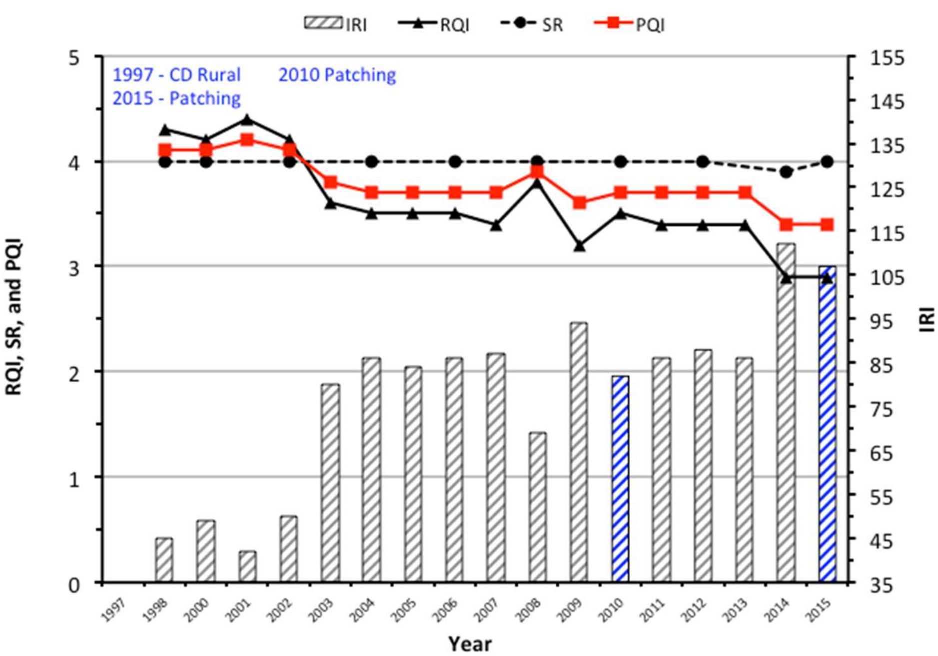


Figure B.166. Pavement management system data for section 135+0.000, direction I, of project 0702–98 constructed in 1997. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

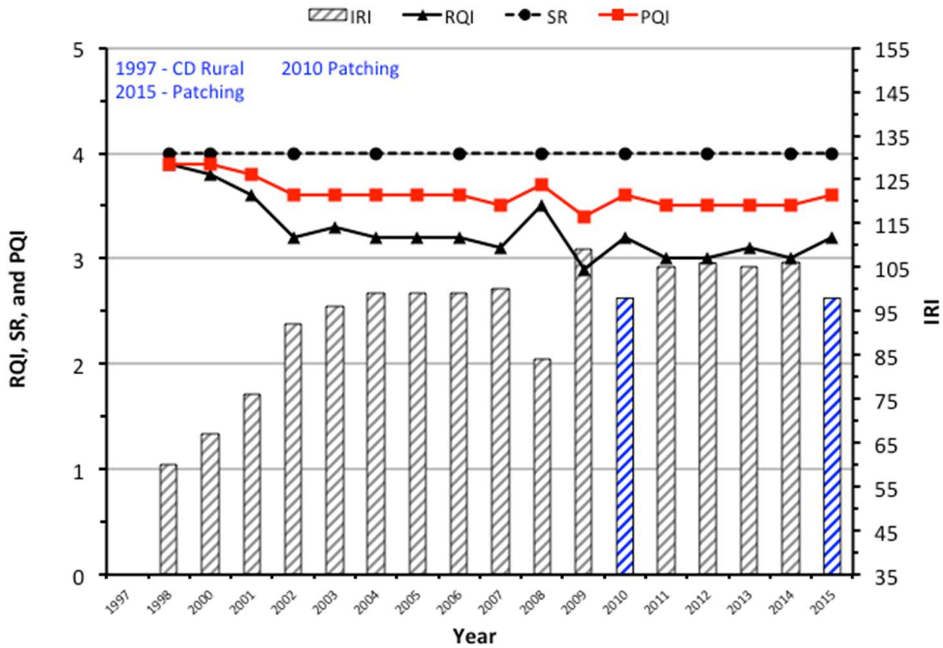


Figure B.167. Pavement management system data for section 136+0.000, direction I, of project 0702–98 constructed in 1997. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

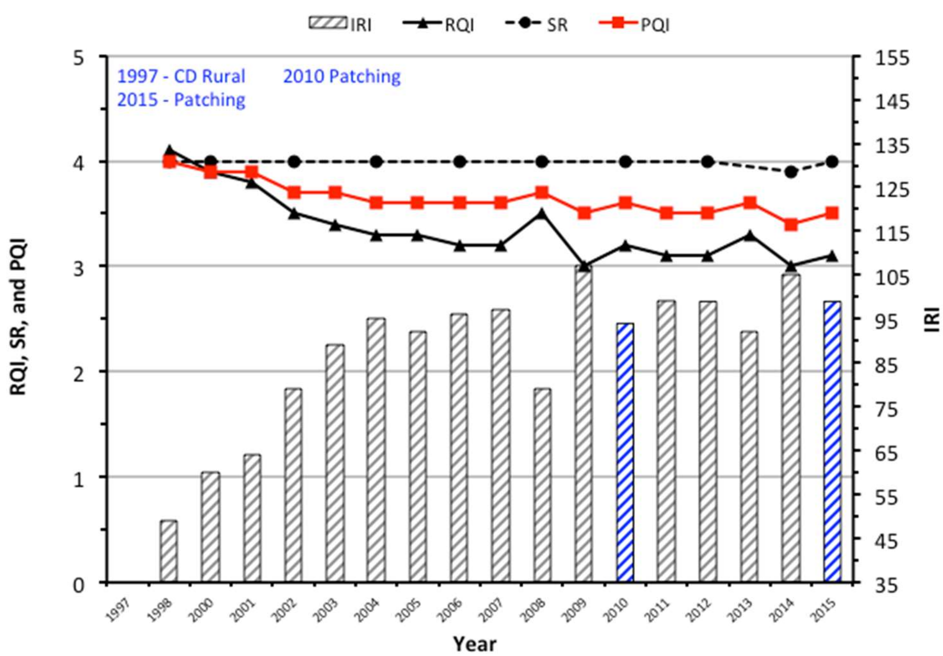


Figure B.168. Pavement management system data for section 137+0.000, direction I, of project 0702–98 constructed in 1997. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

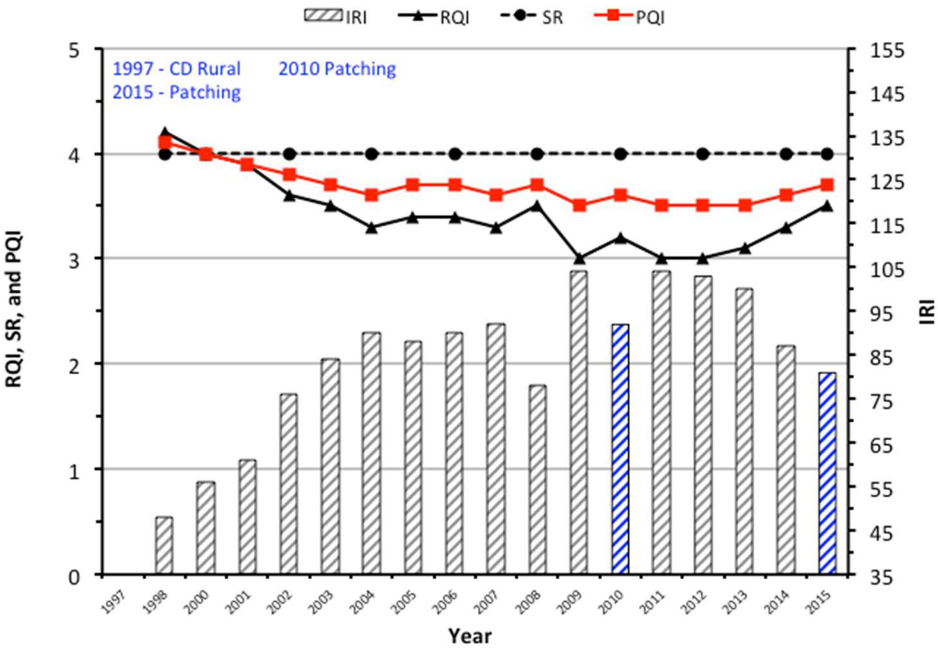


Figure B.169. Pavement management system data for section 138+0.000, direction I, of project 0702–98 constructed in 1997. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

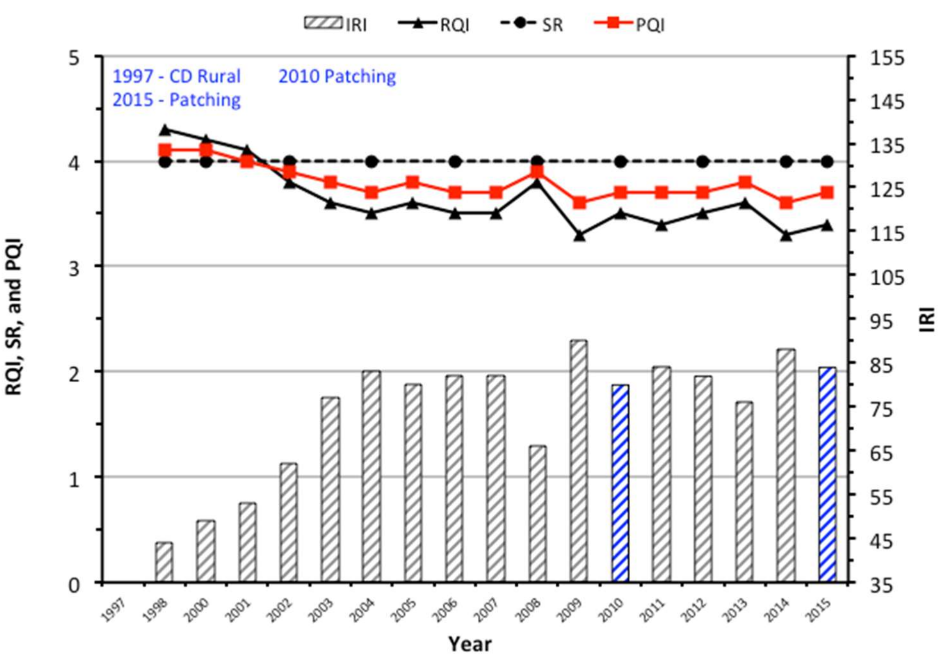


Figure B.170. Pavement management system data for section 139+0.000, direction I, of project 0702–98 constructed in 1997. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

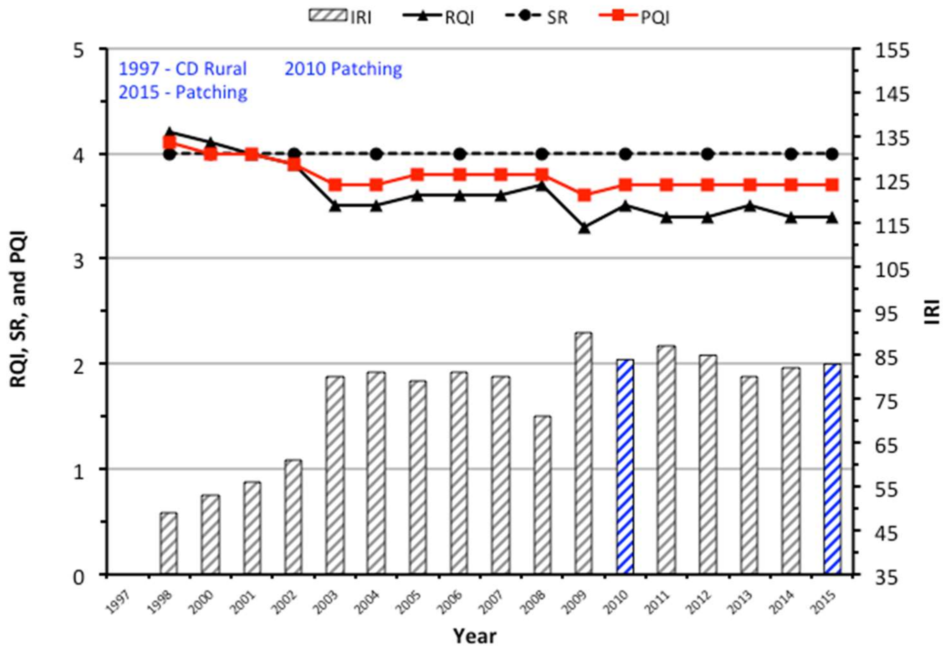


Figure B.171. Pavement management system data for section 140+0.000, direction I, of project 0702–98 constructed in 1997. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

District 7 – 0712-30

Table B.81. Measured IRI for selected sections of project 0712-30, constructed in 1992. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_REFP) and Direction (DIR)									
	28 +0.242	29 +0.000	30 +0.000	31 +0.000	32 +0.000	33 +0.000	34 +0.000	35 +0.000	36 +0.000	37 +0.000
Year	U	U	U	U	U	U	U	U	U	U
1992										
1994	106	133	125	112	120	125	124	113	118	98
1996	90	95	86	90	89	122	95	91	95	82
1998	78	72	66	68	71	109	75	67	73	64
2000	79	79	73	79	85	111	87	77	80	68
2001	86	92	61	57	81	140	83	72	72	52
2002	77	78	54	56	80	133	82	67	70	47
2003	91	108	104	108	113	141	109	107	104	92
2004	94	102	100	106	109	140	111	108	105	91
2005	100	102	97	103	107	144	101	96	97	85
2006	90	96	92	95	96	132	93	90	93	80
2007	100	102	96	100	103	134	99	98	98	87
2008	97	100	94	101	104	135	103	101	99	87
2009	105	108	105	109	113	146	110	108	105	93
2010	99	102	98	103	111	137	109	109	100	93
2011	112	107	99	99	104	145	103	100	99	91
2012	107	104	98	104	107	150	105	104	100	90
2013	102	105	98	102	108	148	108	106	101	94
2014	111	107	99	100	105	149	108	106	103	98
2015	119	108	99	104	112	156	112	112	104	100

Table B.82. Measured PQI for selected sections of project 0712-30, constructed in 1992. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_REFP) and Direction (DIR)									
	28 +0.242	29 +0.000	30 +0.000	31 +0.000	32 +0.000	33 +0.000	34 +0.000	35 +0.000	36 +0.000	37 +0.000
Year	U	U	U	U	U	U	U	U	U	U
1992										
1994	3.7	3.5	3.6	3.7	3.6	3.6	3.6	3.7	3.6	3.8
1996	3.9	3.8	3.9	3.9	3.9	3.6	3.8	3.9	3.8	3.9
1998	3.7	3.8	3.9	3.8	3.8	3.4	3.8	3.9	3.8	3.9
2000	3.7	3.7	3.8	3.7	3.7	3.4	3.6	3.7	3.7	3.8
2001	3.6	3.6	4.0	4.0	3.8	3.2	3.7	3.9	3.8	4.0
2002	3.8	3.8	4.1	4.0	3.8	3.3	3.7	3.9	3.8	4.1
2003	3.6	3.5	3.6	3.5	3.4	3.2	3.5	3.5	3.5	3.6
2004	3.5	3.6	3.6	3.5	3.5	3.2	3.5	3.5	3.5	3.7
2005	3.5	3.5	3.6	3.5	3.5	3.2	3.6	3.6	3.6	3.7
2006	3.6	3.6	3.6	3.6	3.6	3.3	3.6	3.7	3.7	3.8
2007	3.5	3.5	3.6	3.6	3.5	3.2	3.6	3.6	3.6	3.7
2008	3.5	3.6	3.6	3.6	3.6	3.3	3.6	3.6	3.6	3.7
2009	3.3	3.5	3.5	3.5	3.4	3.1	3.5	3.5	3.5	3.6
2010	3.5	3.6	3.6	3.5	3.5	3.2	3.5	3.4	3.6	3.6
2011	3.3	3.5	3.6	3.5	3.5	3.2	3.6	3.5	3.6	3.6
2012	3.3	3.5	3.6	3.5	3.5	3.0	3.4	3.5	3.6	3.7
2013	3.3	3.5	3.6	3.5	3.5	3.1	3.3	3.5	3.6	3.6
2014	3.2	3.5	3.6	3.5	3.5	2.9	3.1	3.4	3.5	3.6
2015	3.2	3.5	3.6	3.5	3.4	2.8	3.1	3.4	3.5	3.6

Table B.83. Measured RQI for selected sections of project 0712-30, constructed in 1992. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_REFP) and Direction (DIR)									
	28 +0.242	29 +0.000	30 +0.000	31 +0.000	32 +0.000	33 +0.000	34 +0.000	35 +0.000	36 +0.000	37 +0.000
Year	U	U	U	U	U	U	U	U	U	U
1992										
1994	3.5	3.1	3.2	3.4	3.3	3.2	3.2	3.4	3.3	3.6
1996	3.8	3.7	3.9	3.8	3.8	3.3	3.7	3.8	3.7	3.9
1998	3.5	3.6	3.8	3.7	3.7	2.9	3.6	3.8	3.6	3.8
2000	3.5	3.5	3.6	3.5	3.4	2.9	3.3	3.5	3.5	3.7
2001	3.3	3.3	4.0	4.1	3.6	2.5	3.5	3.8	3.7	4.1
2002	3.6	3.6	4.2	4.1	3.6	2.7	3.5	3.9	3.7	4.2
2003	3.3	3.1	3.2	3.1	2.9	2.5	3.1	3.1	3.1	3.3
2004	3.1	3.2	3.2	3.1	3.0	2.6	3.0	3.0	3.1	3.4
2005	3.1	3.1	3.2	3.1	3.0	2.5	3.2	3.3	3.2	3.5
2006	3.2	3.2	3.3	3.3	3.3	2.7	3.3	3.4	3.4	3.6
2007	3.0	3.1	3.2	3.2	3.1	2.6	3.2	3.2	3.2	3.5
2008	3.0	3.2	3.3	3.2	3.2	2.7	3.2	3.2	3.2	3.4
2009	2.8	3.0	3.0	3.0	2.9	2.4	3.0	3.0	3.0	3.2
2010	3.0	3.2	3.3	3.2	3.0	2.6	3.1	3.0	3.2	3.3
2011	2.8	3.1	3.2	3.2	3.1	2.5	3.2	3.2	3.2	3.3
2012	2.9	3.1	3.2	3.1	3.0	2.4	3.1	3.1	3.2	3.4
2013	2.9	3.1	3.2	3.2	3.0	2.5	3.0	3.1	3.2	3.3
2014	2.8	3.0	3.2	3.2	3.1	2.4	3.0	3.1	3.1	3.2
2015	2.7	3.0	3.2	3.1	2.9	2.3	3.0	3.0	3.1	3.2

Table B.84. Measured SR for selected sections of project 0712-30, constructed in 1992. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_REFP) and Direction (DIR)									
	28 +0.242	29 +0.000	30 +0.000	31 +0.000	32 +0.000	33 +0.000	34 +0.000	35 +0.000	36 +0.000	37 +0.000
Year	U	U	U	U	U	U	U	U	U	U
1992										
1994	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
1996	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
1998	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2000	4.0	4.0	4.0	3.9	4.0	4.0	4.0	4.0	4.0	4.0
2001	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2002	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2003										
2004	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2005										
2006	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2007										
2008	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2009										
2010	4.0	4.0	4.0	3.9	4.0	4.0	4.0	3.9	4.0	4.0
2011										
2012	3.7	4.0	4.0	3.9	4.0	3.8	3.7	4.0	4.0	4.0
2013										
2014	3.7	4.0	4.0	3.9	4.0	3.5	3.3	3.8	4.0	4.0
2015										

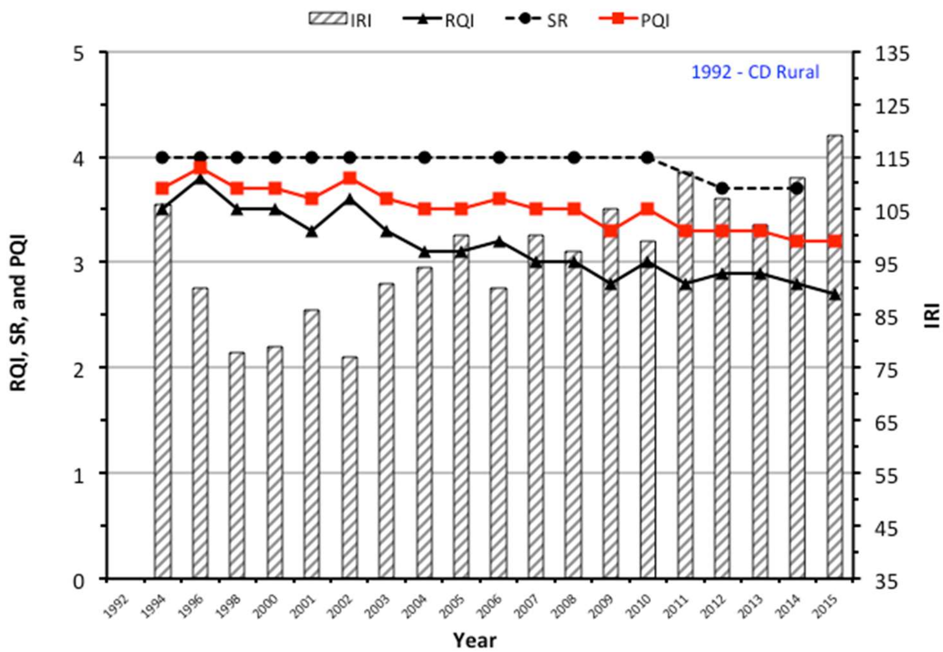


Figure B.172. Pavement management system data for section 28+0.242, direction U, of project 0712–30 constructed in 1992. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

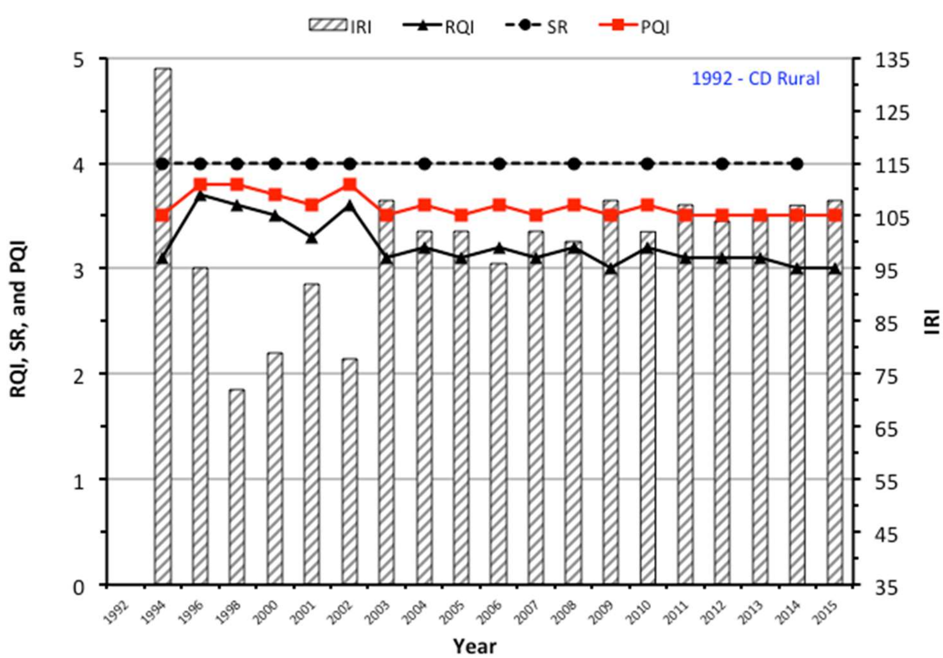


Figure B.173. Pavement management system data for section 29+0.000, direction U, of project 0712–30 constructed in 1992. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

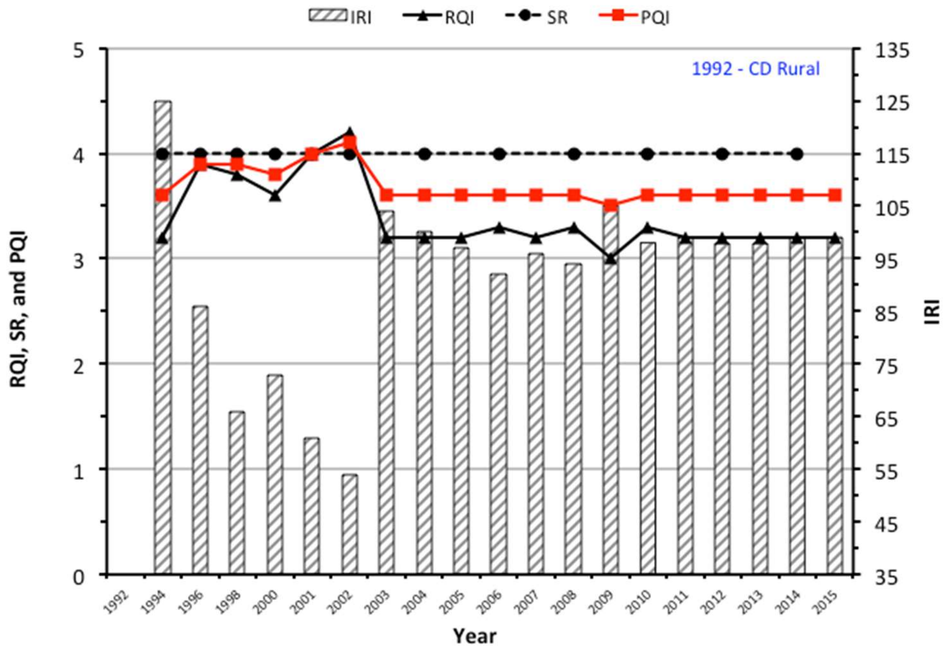


Figure B.174. Pavement management system data for section 30+0.000, direction U, of project 0712–30 constructed in 1992. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

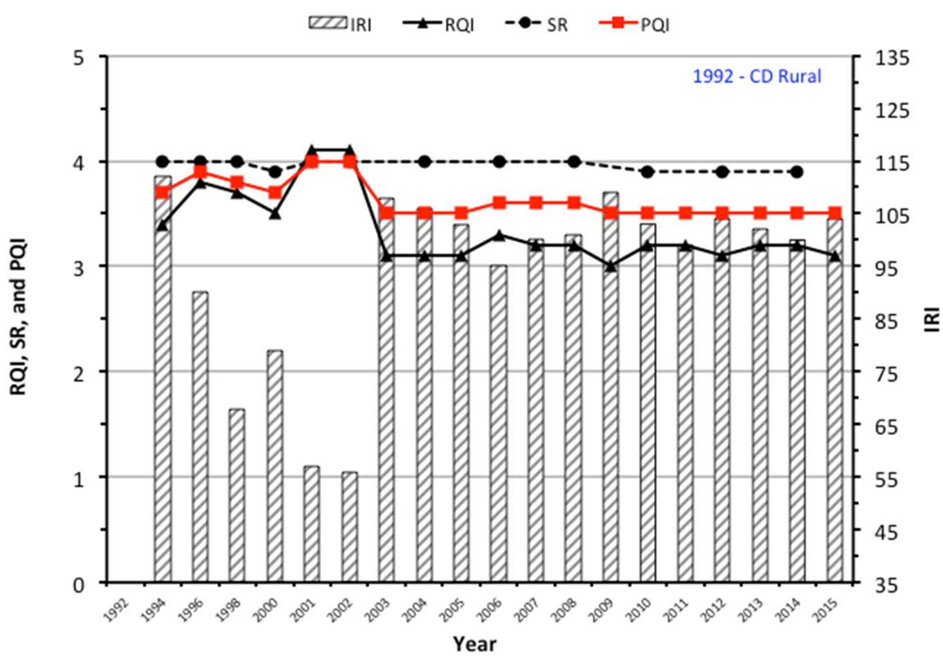


Figure B.175. Pavement management system data for section 31+0.000, direction U, of project 0712–30 constructed in 1992. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

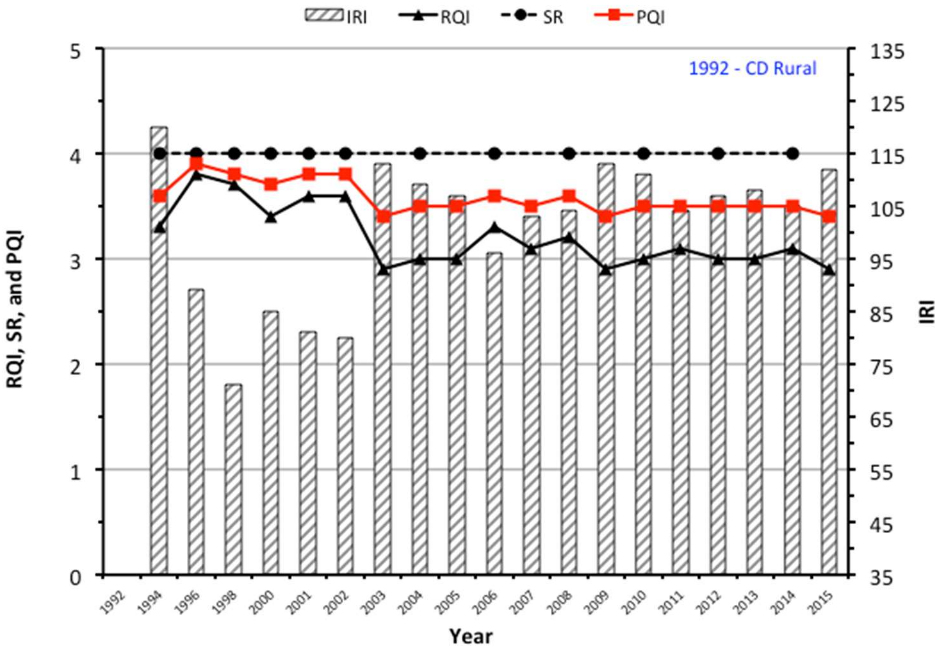


Figure B.176. Pavement management system data for section 32+0.000, direction U, of project 0712–30 constructed in 1992. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

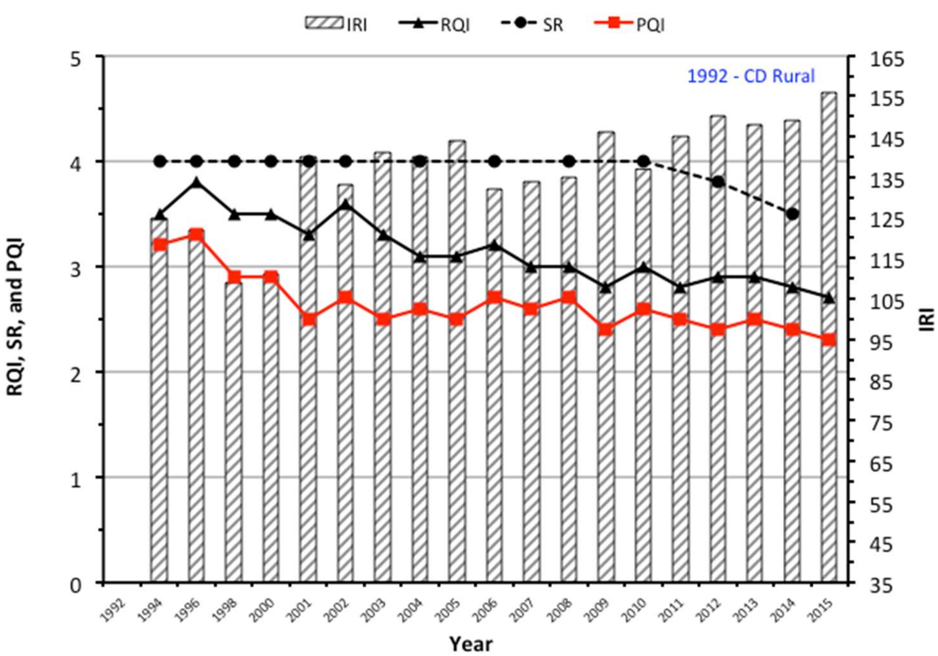


Figure B.177. Pavement management system data for section 33+0.000, direction U, of project 0712–30 constructed in 1992. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

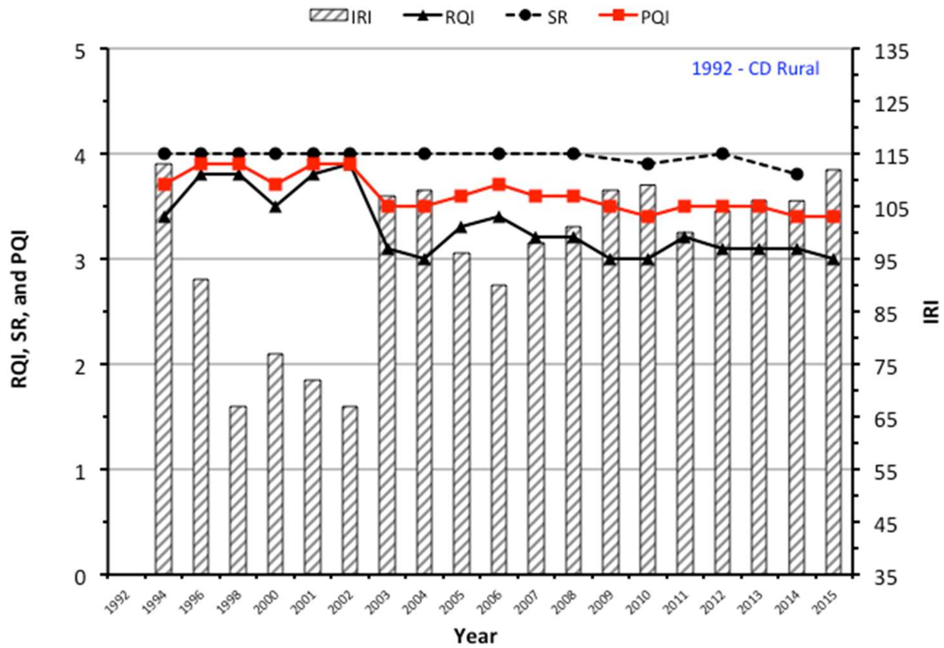


Figure B.178. Pavement management system data for section 34+0.000, direction U, of project 0712–30 constructed in 1992. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

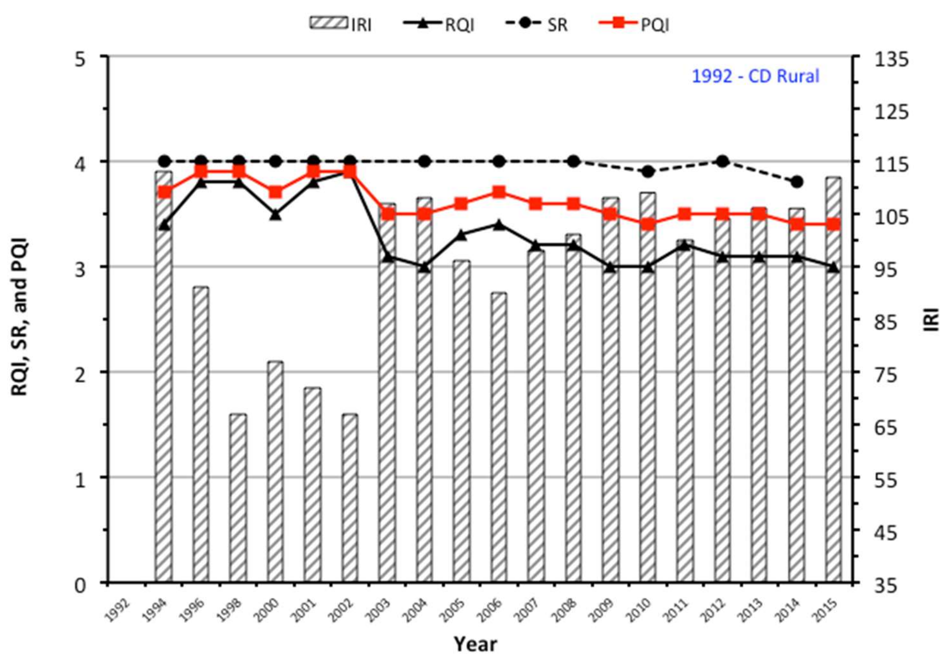


Figure B.179. Pavement management system data for section 35+0.000, direction U, of project 0712–30 constructed in 1992. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

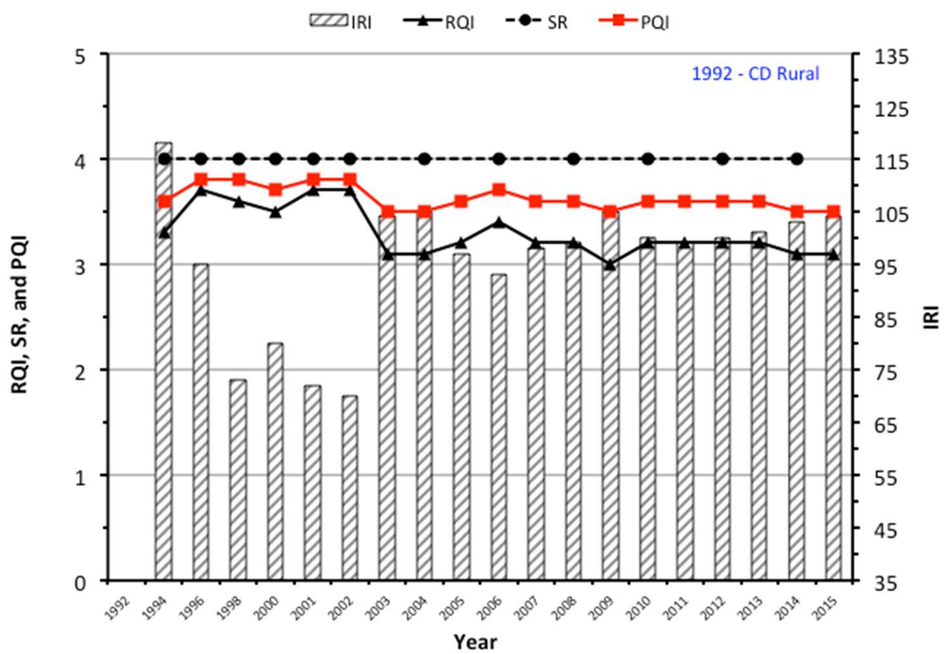


Figure B.180. Pavement management system data for section 36+0.000, direction U, of project 0712–30 constructed in 1992. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

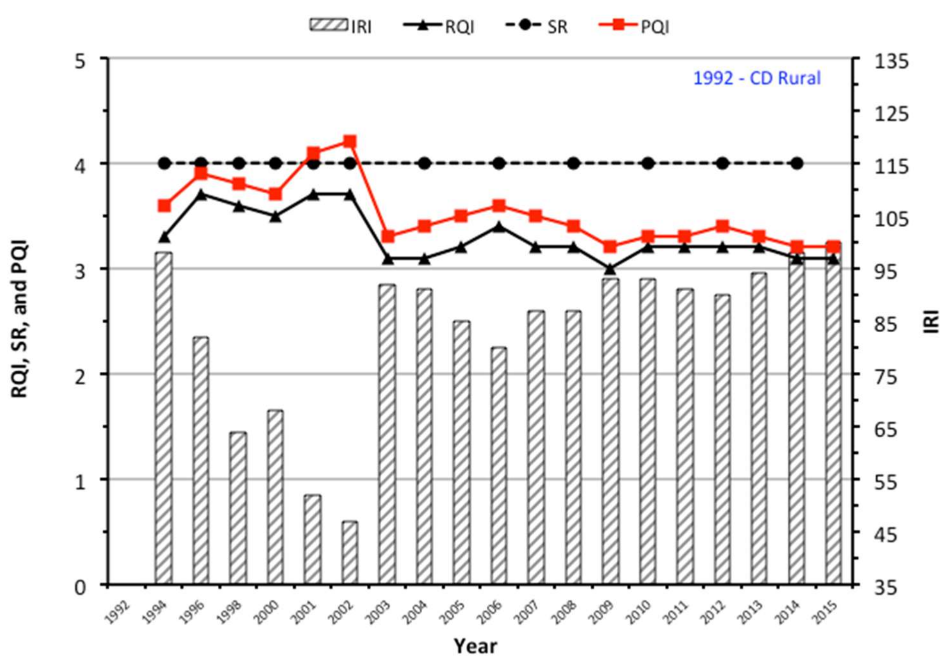


Figure B.181. Pavement management system data for section 37+0.000, direction U, of project 0712–30 constructed in 1992. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

<u>District 7 – 0712-32</u>

Table B.85. Measured IRI for selected sections of project 0712-32, constructed in 1994. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)									
	38 +0.280	39 +0.000	40 +0.000	41 +0.000	42 +0.000	43 +0.000	44 +0.000	45 +0.000	46 +0.000	47 +0.000
Year	U	U	U	U	U	U	U	U	U	U
1998	70	92	72	53	52	51	48	52	49	52
2000	72	97	75	59	56	56	52	56	54	59
2001	72	101	97	51	57	68	52	56	59	56
2002	70	97	92	49	47	58	50	54	48	70
2003	89	115	96	86	77	75	72	80	77	86
2004	90	116	98	84	76	75	72	79	77	82
2005	91	107	96	76	77	68	67	73	69	80
2006	85	112	83	74	70	63	61	70	62	91
2007	89	112	89	76	73	68	64	71	66	76
2008	88	113	98	79	74	68	63	70	67	78
2009	94	123	100	87	82	73	70	78	74	81
2010	89	113	99	86	82	73	69	76	73	80
2011	94	115	102	80	76	71	69	75	71	90
2012	93	119	105	85	80	74	69	76	74	81
2013	92	120	104	85	80	73	67	75	73	88
2014	94	121	104	86	79	72	68	76	72	85
2015	96	123	108	87	80	71	67	75	73	86

Table B.86. Measured PQI for selected sections of project 0712-32, constructed in 1994. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)									
	38	39	40	41	42	43	44	45	46	47
	+0.280	+0.000	+0.000	+0.000	+0.000	+0.000	+0.000	+0.000	+0.000	+0.000
Year	U	U	U	U	U	U	U	U	U	U
1994										
1996	3.8	3.7	3.8	4.0	4.0	4.1	4.1	4.1	4.1	4.0
1998	3.8	3.6	3.8	4.0	4.0	4.0	4.1	4.0	4.1	4.0
2000	3.8	3.6	3.8	3.9	4.0	4.0	4.0	4.0	4.0	3.9
2001	3.8	3.4	3.6	4.0	4.0	3.8	4.0	4.0	4.0	3.8
2002	3.8	3.5	3.6	4.1	4.1	4.0	4.1	4.0	4.1	3.8
2003	3.6	3.3	3.6	3.6	3.8	3.8	3.8	3.8	3.8	3.7
2004	3.6	3.3	3.6	3.7	3.8	3.8	3.8	3.8	3.8	3.7
2005	3.6	3.4	3.6	3.7	3.8	3.9	3.9	3.8	3.8	3.7
2006	3.6	3.4	3.7	3.8	3.8	3.9	3.9	3.9	3.9	3.7
2007	3.6	3.3	3.6	3.7	3.8	3.9	3.9	3.8	3.9	3.8
2008	3.6	3.3	3.5	3.7	3.8	3.9	3.9	3.9	3.9	3.8
2009	3.5	3.2	3.5	3.6	3.7	3.8	3.8	3.7	3.7	3.7
2010	3.6	3.3	3.5	3.6	3.7	3.8	3.9	3.8	3.8	3.7
2011	3.5	3.3	3.5	3.7	3.8	3.8	3.8	3.8	3.8	3.6
2012	3.5	3.1	3.4	3.6	3.7	3.7	3.8	3.8	3.8	3.7
2013	3.6	3.1	3.4	3.6	3.7	3.7	3.8	3.8	3.8	3.6
2014	3.5	3.1	3.4	3.6	3.7	3.8	3.8	3.8	3.8	3.7
2015	3.5	3.0	3.3	3.6	3.7	3.8	3.8	3.8	3.7	3.7

Table B.87. Measured RQI for selected sections of project 0712-32, constructed in 1994. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)									
	38 +0.280	39 +0.000	40 +0.000	41 +0.000	42 +0.000	43 +0.000	44 +0.000	45 +0.000	46 +0.000	47 +0.000
Year	U	U	U	U	U	U	U	U	U	U
1998	3.7	3.2	3.6	4.1	4.1	4.1	4.2	4.1	4.2	4.1
2000	3.6	3.2	3.6	3.9	4.0	4.0	4.1	4.0	4.0	3.9
2001	3.6	2.9	3.2	4.1	4.0	3.7	4.1	4.1	4.0	3.8
2002	3.6	3.1	3.2	4.2	4.3	4.0	4.2	4.1	4.2	3.7
2003	3.2	2.7	3.2	3.3	3.6	3.7	3.7	3.6	3.6	3.4
2004	3.2	2.7	3.2	3.4	3.6	3.7	3.7	3.6	3.6	3.5
2005	3.2	2.9	3.2	3.5	3.6	3.8	3.8	3.7	3.7	3.5
2006	3.3	2.9	3.4	3.6	3.7	3.9	3.9	3.8	3.8	3.4
2007	3.2	2.7	3.3	3.5	3.6	3.8	3.9	3.7	3.8	3.6
2008	3.2	2.7	3.1	3.5	3.7	3.8	3.9	3.8	3.8	3.6
2009	3.1	2.6	3.0	3.3	3.5	3.6	3.7	3.5	3.5	3.4
2010	3.2	2.8	3.1	3.3	3.5	3.7	3.8	3.7	3.6	3.5
2011	3.1	2.7	3.0	3.5	3.6	3.7	3.7	3.6	3.7	3.3
2012	3.1	2.6	3.0	3.4	3.5	3.6	3.7	3.6	3.6	3.5
2013	3.2	2.6	3.0	3.4	3.5	3.6	3.8	3.7	3.6	3.3
2014	3.1	2.6	3.0	3.4	3.5	3.7	3.8	3.6	3.7	3.4
2015	3.1	2.5	2.9	3.3	3.5	3.7	3.8	3.7	3.6	3.4

Table B.88. Measured SR for selected sections of project 0712-32, constructed in 1994. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)									
	38 +0.280	39 +0.000	40 +0.000	41 +0.000	42 +0.000	43 +0.000	44 +0.000	45 +0.000	46 +0.000	47 +0.000
Year	U	U	U	U	U	U	U	U	U	U
1994										
1996	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
1998	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2000	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2001	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.9
2002	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2003										
2004	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2005										
2006	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2007	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2008										
2009	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2010	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2011										
2012	4.0	3.8	3.9	3.9	4.0	3.8	3.9	4.0	4.0	4.0
2013										
2014	3.9	3.7	3.8	3.9	4.0	3.9	3.9	4.0	3.9	4.0
2015										

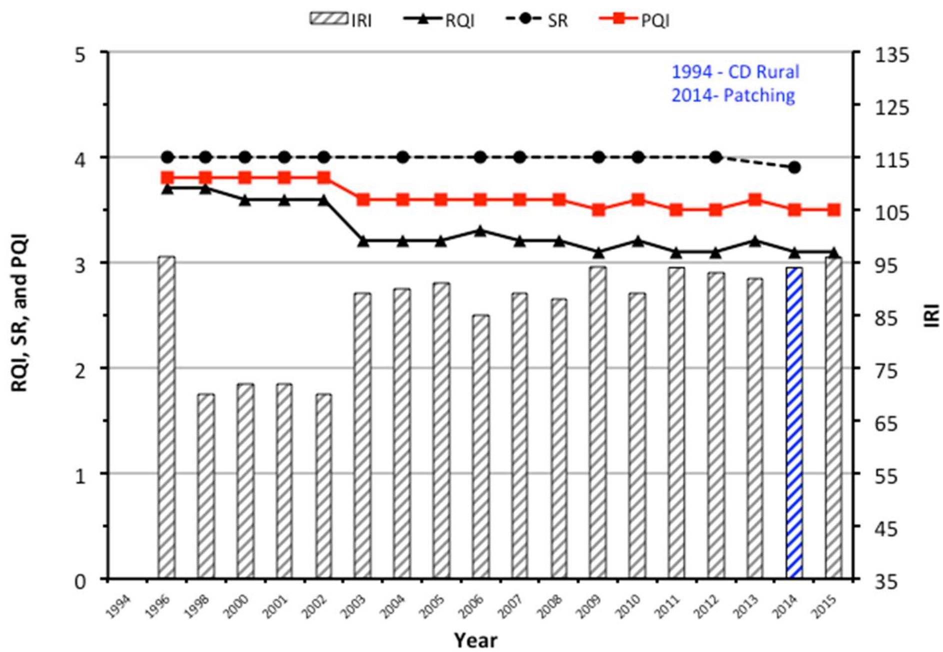


Figure B.182. Pavement management system data for section 38+0.280, direction U, of project 0712–32 constructed in 1994. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

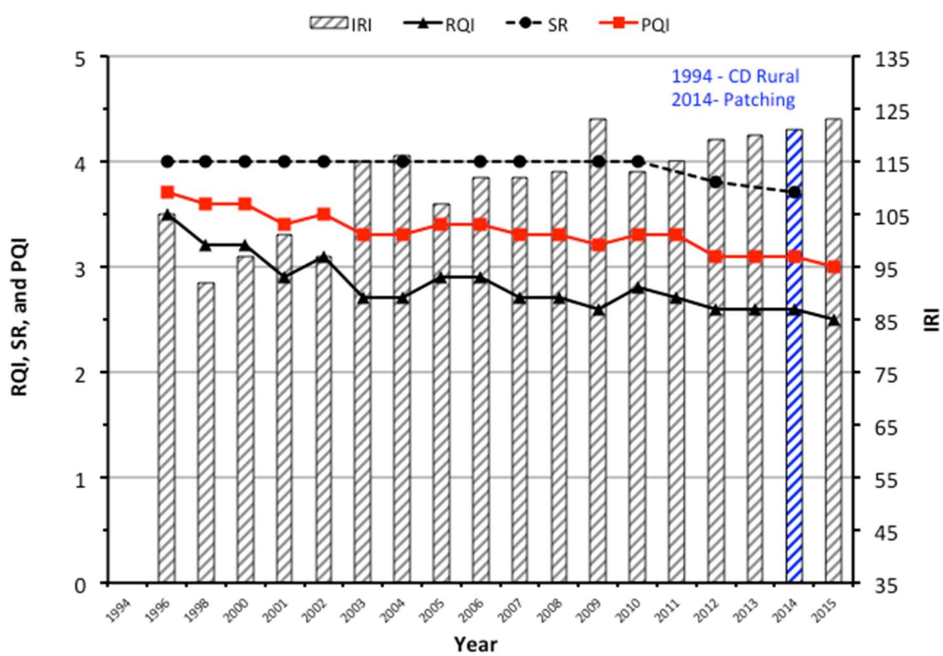


Figure B.183. Pavement management system data for section 39+0.000, direction U, of project 0712–32 constructed in 1994. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

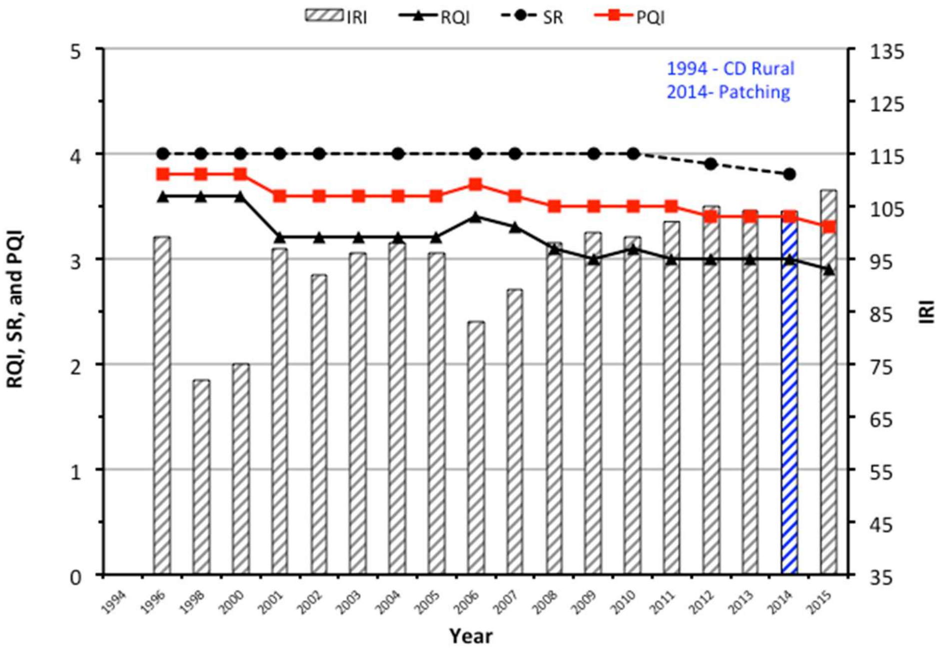


Figure B.184. Pavement management system data for section 40+0.000, direction U, of project 0712–32 constructed in 1994. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

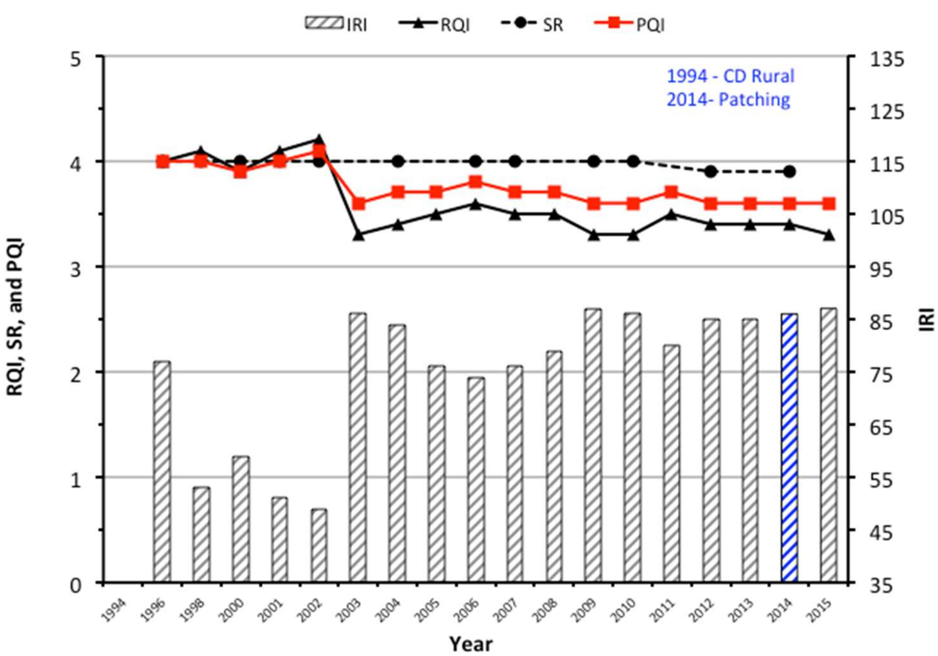


Figure B.185. Pavement management system data for section 41+0.000, direction U, of project 0712–32 constructed in 1994. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

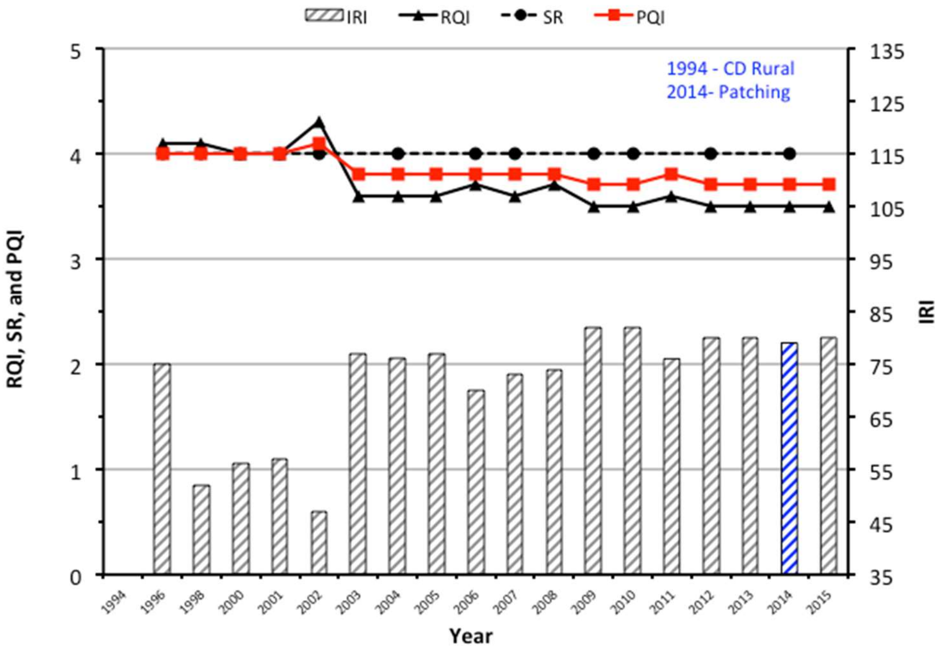


Figure B.186. Pavement management system data for section 42+0.000, direction U, of project 0712–32 constructed in 1994. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

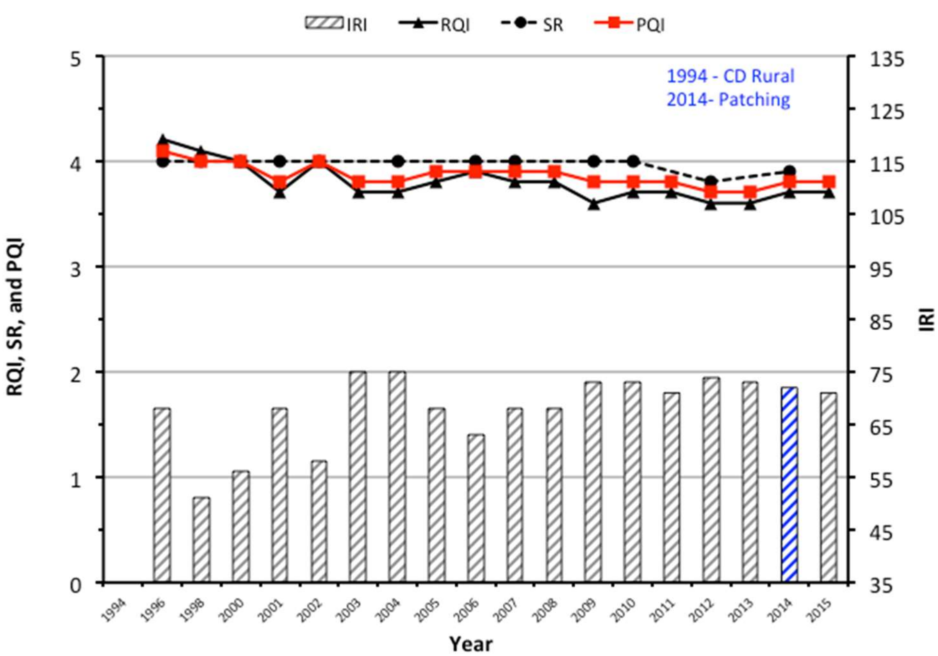


Figure B.187. Pavement management system data for section 43+0.000, direction U, of project 0712–32 constructed in 1994. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

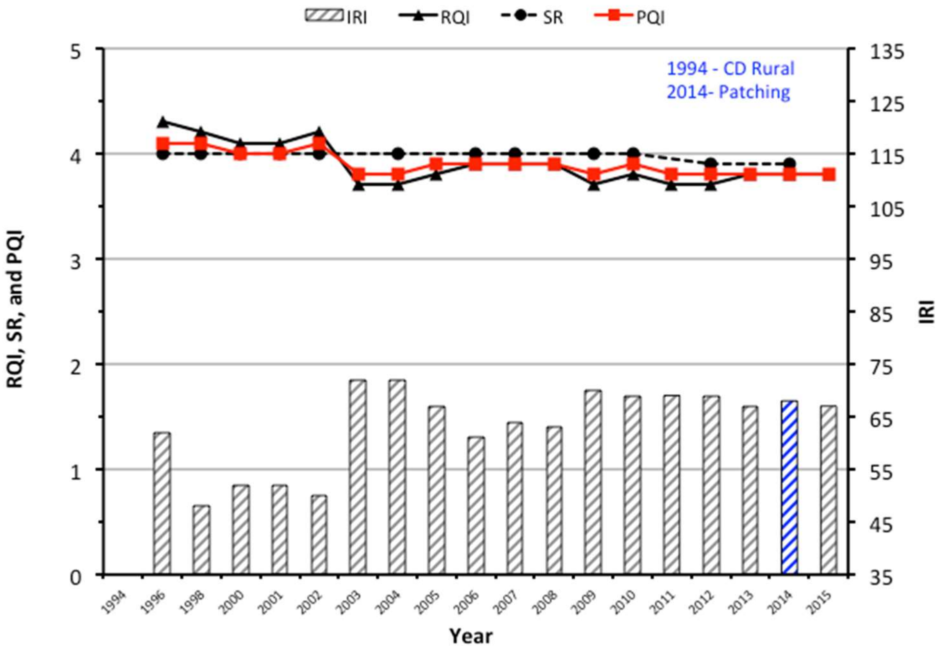


Figure B.188. Pavement management system data for section 44+0.000, direction U, of project 0712–32 constructed in 1994. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

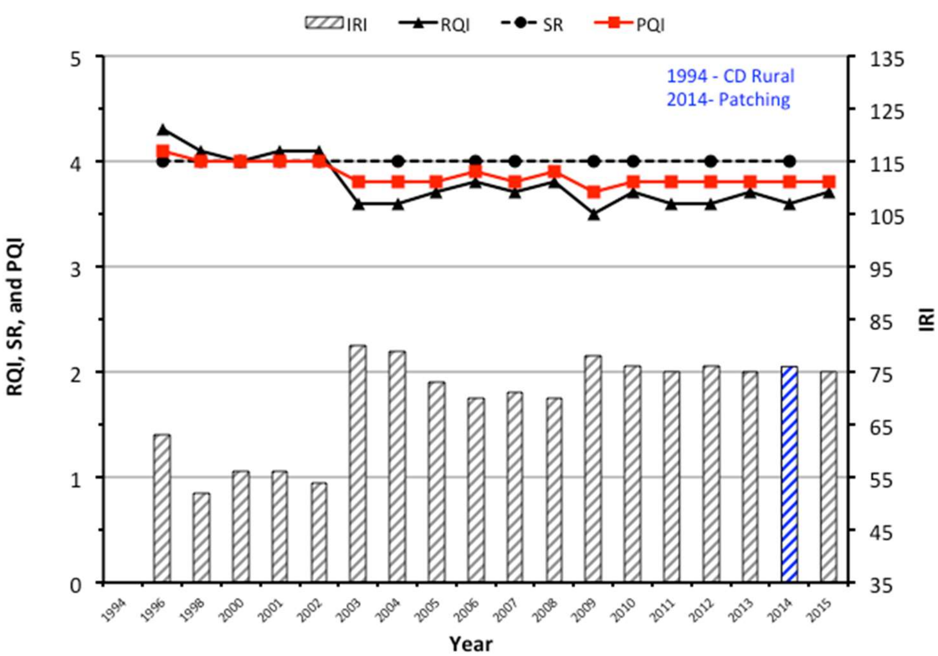


Figure B.189. Pavement management system data for section 45+0.000, direction U, of project 0712–32 constructed in 1994. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

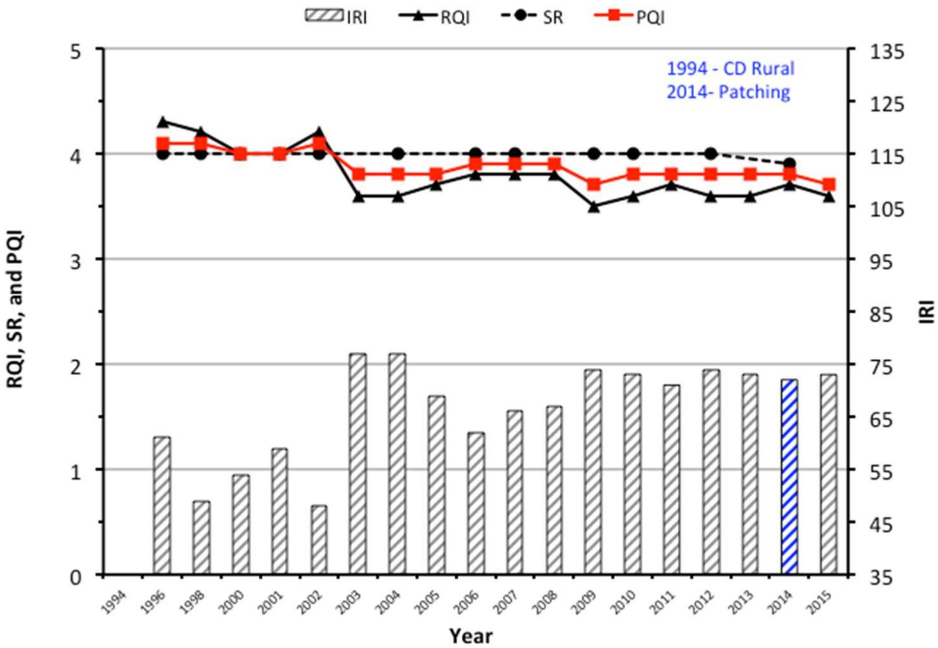


Figure B.190. Pavement management system data for section 46+0.000, direction U, of project 0712–32 constructed in 1994. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

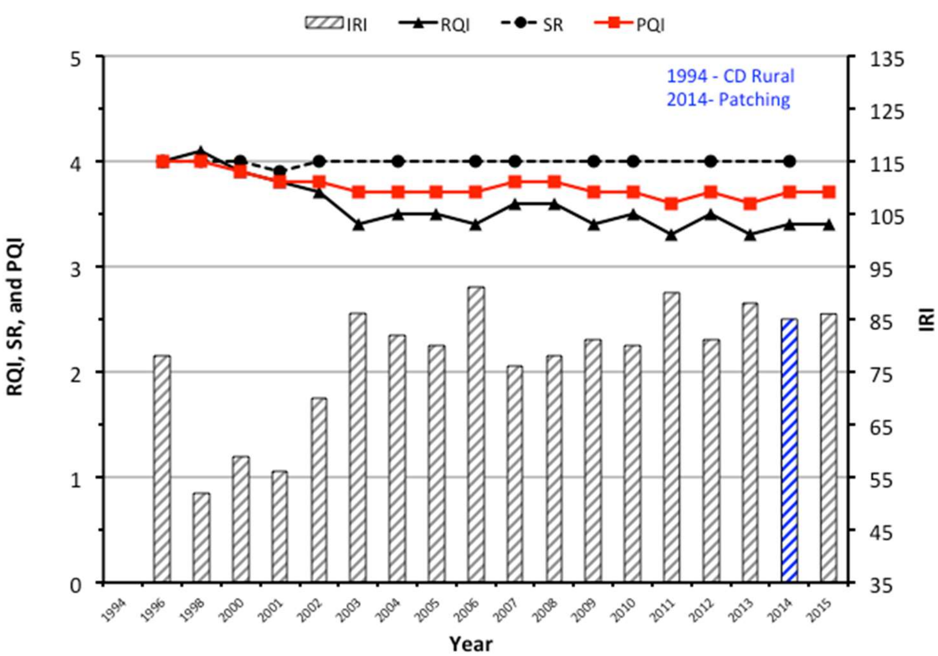


Figure B.191. Pavement management system data for section 47+0.000, direction U, of project 0712–32 constructed in 1994. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

District 7 – 2208-35

Table B.89. Measured IRI for selected sections of project 2208-35, constructed in 1992. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)								
	12 +0.619	13 +0.000	14 +0.000	15 +0.000	16 +0.000	17 +0.000	18 +0.000	19 +0.141	20 +0.000
Year	U	U	U	U	U	U	U	U	U
1992									
1994	138	122	122	113	96	137	124	131	148
1996	110	98	103	96	82	111	97	134	155
1998	70	82	80	71	65	92	80	116	120
2000	91	84	85	75	70	103	94	116	123
2001	91	93	81	76	70	94	78	127	146
2002	106	95	80	79	70	94	82	127	145
2003	106	96	100	95	91	140	123	153	176
2004	105	85	93	87	83	118	112	156	178
2005	114	98	99	92	86	125	118	162	182
2006	106	88	96	83	81	110	97	150	176
2007	118	89	95	86	86	116	110	156	187
2008									166
2009	98	66	96	93	89	76	70	176	188
2010	120	80	90	87	85	72	67	163	190
2011	105	126	109	94	92	95	89	182	207
2012	101	76	106	97	92	94	89	185	193
2013	112	78	95	96	91	80	70	176	209
2014	108	99	104	96	93	99	76	180	222
2015	125	88	103	98	96	109	80	191	206

Table B.90. Measured IRI for selected sections of project 2208-35, constructed in 1992. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)								
	12 +0.619	13 +0.000	14 +0.000	15 +0.000	16 +0.000	17 +0.000	18 +0.000	19 +0.141	20 +0.000
Year	U	U	U	U	U	U	U	U	U
1992									
1994	3.5	3.6	3.6	3.7	3.8	3.5	3.6	3.5	3.4
1996	3.7	3.8	3.8	3.8	3.9	3.7	3.8	3.5	3.3
1998	3.6	3.7	3.7	3.8	3.9	3.6	3.7	3.3	3.3
2000	3.6	3.7	3.7	3.8	3.8	3.5	3.6	3.3	3.2
2001	3.6	3.6	3.7	3.7	3.8	3.6	3.8	3.2	3.0
2002	3.3	3.5	3.6	3.7	3.8	3.6	3.7	3.2	3.1
2003	3.3	3.5	3.5	3.6	3.6	3.2	3.3	3.0	2.8
2004	3.4	3.6	3.5	3.6	3.7	3.3	3.4	2.9	2.6
2005	3.3	3.4	3.5	3.6	3.6	3.2	3.3	2.9	2.6
2006	3.4	3.6	3.5	3.7	3.7	3.4	3.5	3.0	2.7
2007	3.3	3.6	3.5	3.7	3.7	3.3	3.4	2.9	2.6
2008									2.8
2009	3.1	3.8	3.4	3.6	3.5	3.7	3.7	2.8	2.5
2010	3.1	3.8	3.6	3.6	3.6	3.8	3.9	2.8	2.4
2011	3.2	3.4	3.3	3.6	3.5	3.5	3.6	2.6	2.4
2012	2.9	3.1	2.7	3.3	2.9	2.9	3.0	2.4	2.5
2013	2.8	3.1	2.8	3.2	3.0	3.1	3.2	2.5	2.3
2014	2.7	2.9	2.3	3.2	2.9	2.7	2.9	2.3	2.1
2015	2.6	2.9	2.3	3.2	2.9	2.6	2.8	2.2	2.2

Table B.91. Measured RQI for selected sections of project 2208-35, constructed in 1992. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)								
	12 +0.619	13 +0.000	14 +0.000	15 +0.000	16 +0.000	17 +0.000	18 +0.000	19 +0.141	20 +0.000
Year	U	U	U	U	U	U	U	U	U
1992									
1994	3.0	3.3	3.3	3.4	3.7	3.0	3.2	3.1	2.9
1996	3.5	3.6	3.6	3.7	3.9	3.4	3.7	3.1	2.8
1998	3.5	3.4	3.5	3.7	3.8	3.2	3.5	2.8	2.8
2000	3.3	3.4	3.4	3.6	3.7	3.1	3.2	2.8	2.7
2001	3.3	3.2	3.4	3.5	3.7	3.3	3.6	2.6	2.3
2002	3.0	3.0	3.3	3.5	3.6	3.2	3.5	2.6	2.4
2003	3.0	3.0	3.0	3.2	3.3	2.5	2.8	2.3	2.0
2004	2.9	3.3	3.1	3.3	3.4	2.8	2.9	2.2	1.9
2005	2.8	2.9	3.0	3.3	3.3	2.6	2.8	2.2	1.9
2006	2.9	3.2	3.0	3.4	3.4	2.9	3.1	2.3	1.9
2007	2.7	3.2	3.1	3.4	3.4	2.8	2.9	2.2	1.8
2008									2.2
2009	3.1	3.7	3.1	3.2	3.3	3.5	3.6	2.0	1.7
2010	2.8	3.6	3.3	3.3	3.4	3.6	3.8	2.2	1.7
2011	3.0	2.9	2.8	3.2	3.2	3.1	3.3	1.9	1.6
2012	3.0	3.5	2.9	3.2	3.1	3.2	3.3	1.8	1.8
2013	2.8	3.5	3.1	3.1	3.2	3.5	3.7	1.9	1.5
2014	2.9	3.1	3.0	3.0	3.1	3.1	3.6	1.8	1.5
2015	2.7	3.2	3.0	3.0	3.1	2.9	3.5	1.7	1.6

Table B.92. Measured RQI for selected sections of project 2208-35, constructed in 1992. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)								
	12	13	14	15	16	17	18	19	20
	+0.619	+0.000	+0.000	+0.000	+0.000	+0.000	+0.000	+0.141	+0.000
Year	U	U	U	U	U	U	U	U	U
1992									
1994	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
1996	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
1998	3.7	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2000	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.9
2001	3.9	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.9
2002	3.7	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.9
2003									
2004	3.9	4.0	4.0	4.0	4.0	4.0	4.0	3.9	3.5
2005									
2006	4.0	4.0	4.0	4.0	4.0	4.0	3.9	3.8	3.8
2007									
2008									3.6
2009	3.2	4.0	3.8	4.0	3.8	4.0	3.9		
2010	3.4	4.0	4.0	4.0	3.9	4.0	4.0	3.6	3.5
2011									
2012	2.8	2.8	2.5	3.4	2.8	2.7	2.7	3.3	3.5
2013									
2014	2.5	2.7	1.8	3.5	2.8	2.3	2.3	2.9	3.0
2015									

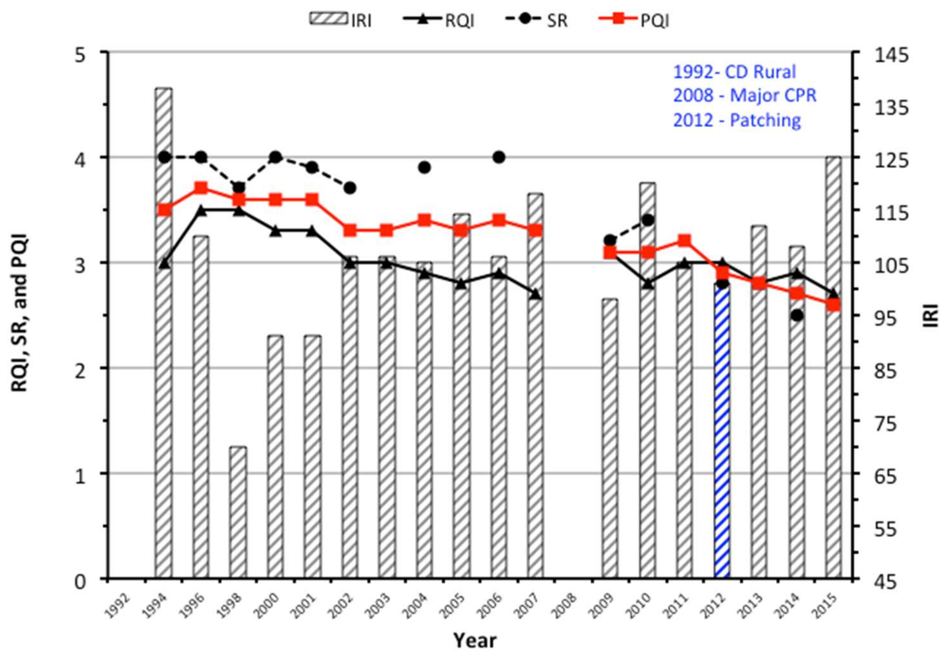


Figure B.192. Pavement management system data for section 12+0.619, direction U, of project 2208–35 constructed in 1992. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

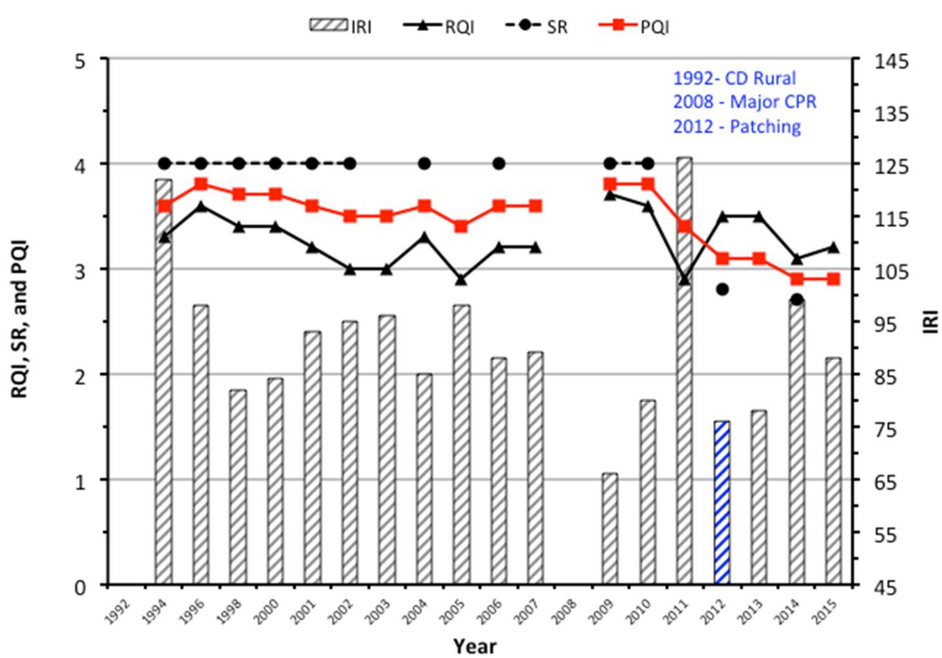


Figure B.193. Pavement management system data for section 13+0.000, direction U, of project 2208–35 constructed in 1992. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

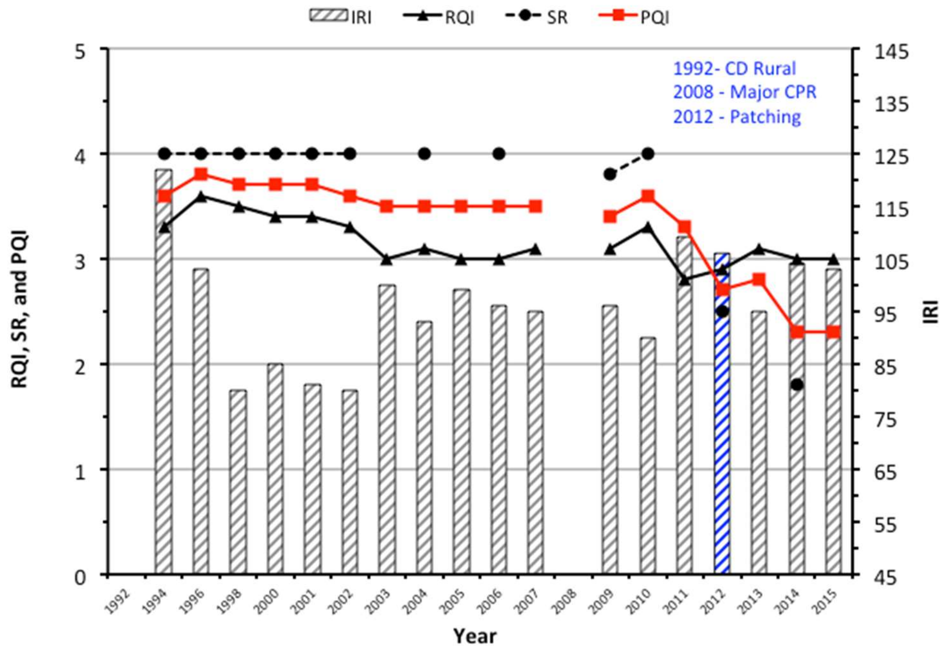


Figure B.194. Pavement management system data for section 14+0.000, direction U, of project 2208–35 constructed in 1992. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

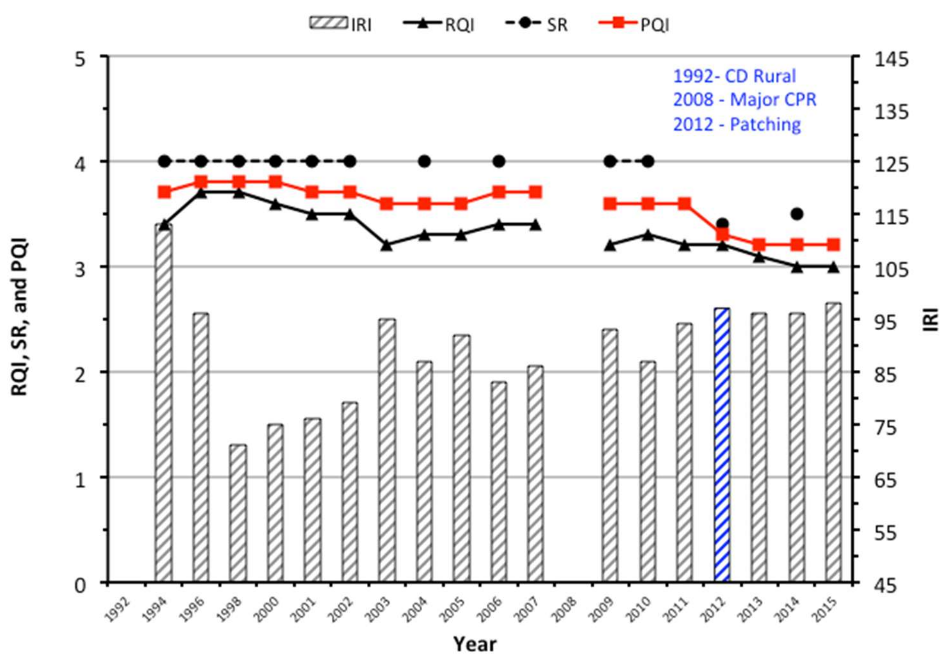


Figure B.195. Pavement management system data for section 15+0.000, direction U, of project 2208–35 constructed in 1992. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

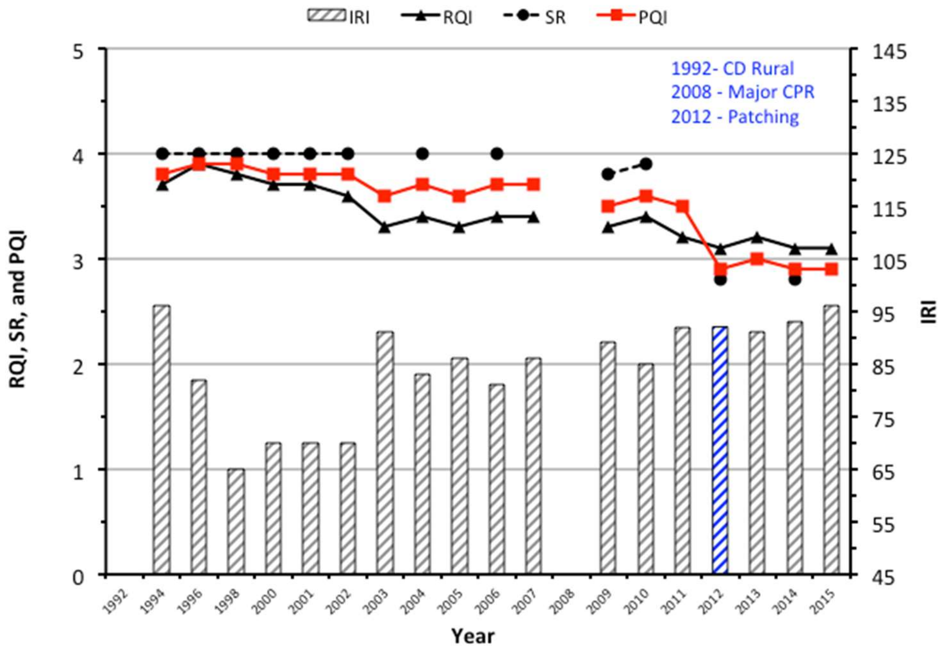


Figure B.196. Pavement management system data for section 16+0.000, direction U, of project 2208–35 constructed in 1992. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

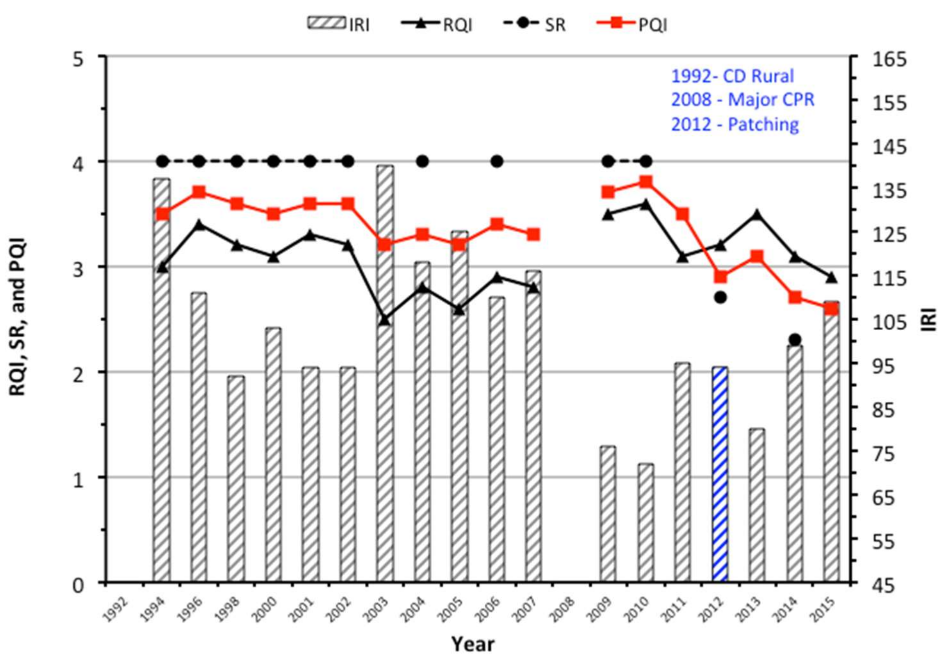


Figure B.197. Pavement management system data for section 17+0.000, direction U, of project 2208–35 constructed in 1992. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

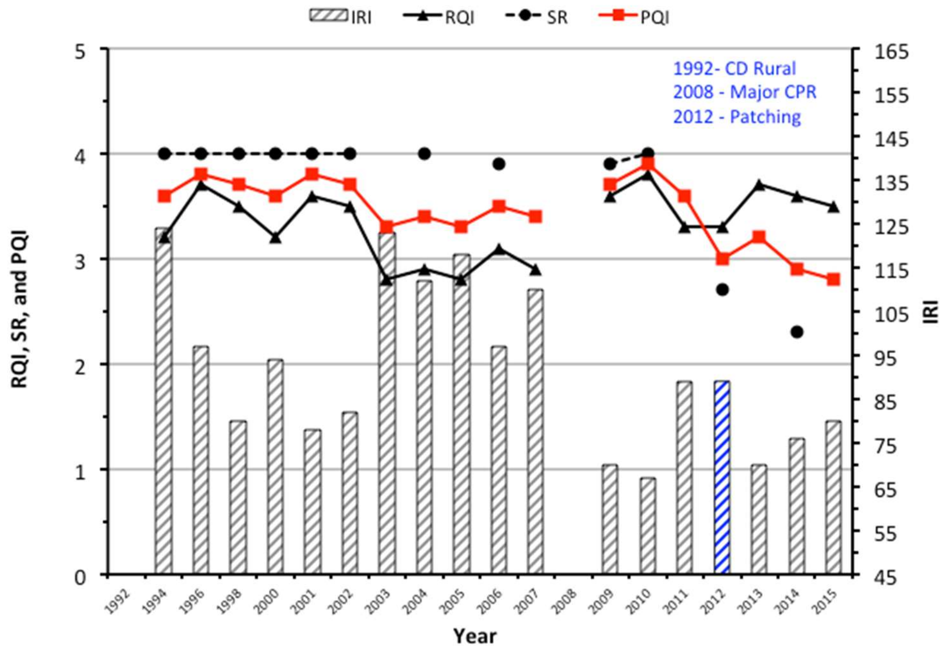


Figure B.198. Pavement management system data for section 18+0.000, direction U, of project 2208–35 constructed in 1992. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

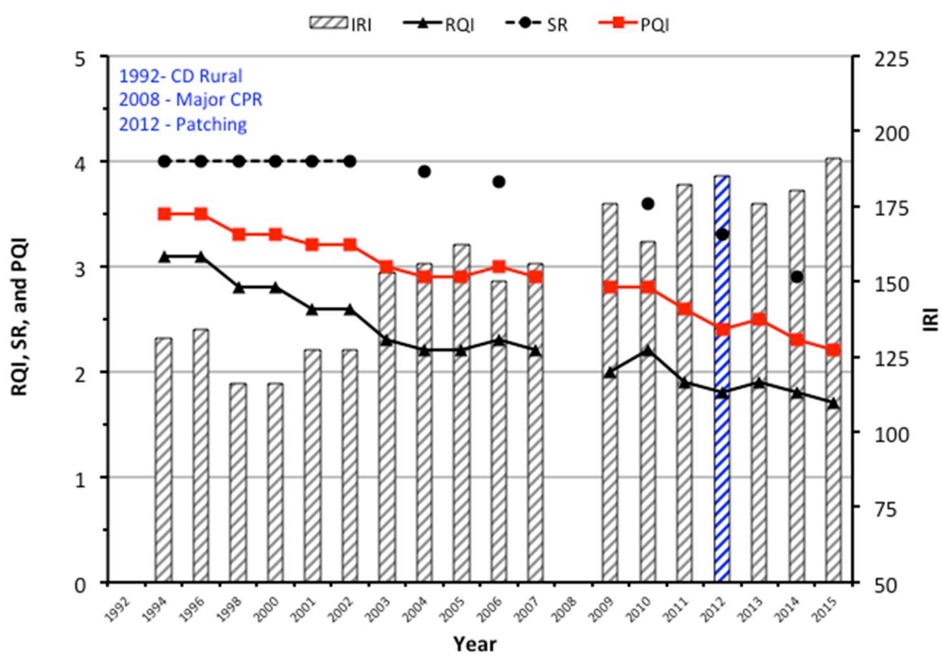


Figure B.199. Pavement management system data for section 19+0.000, direction U, of project 2208–35 constructed in 1992. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

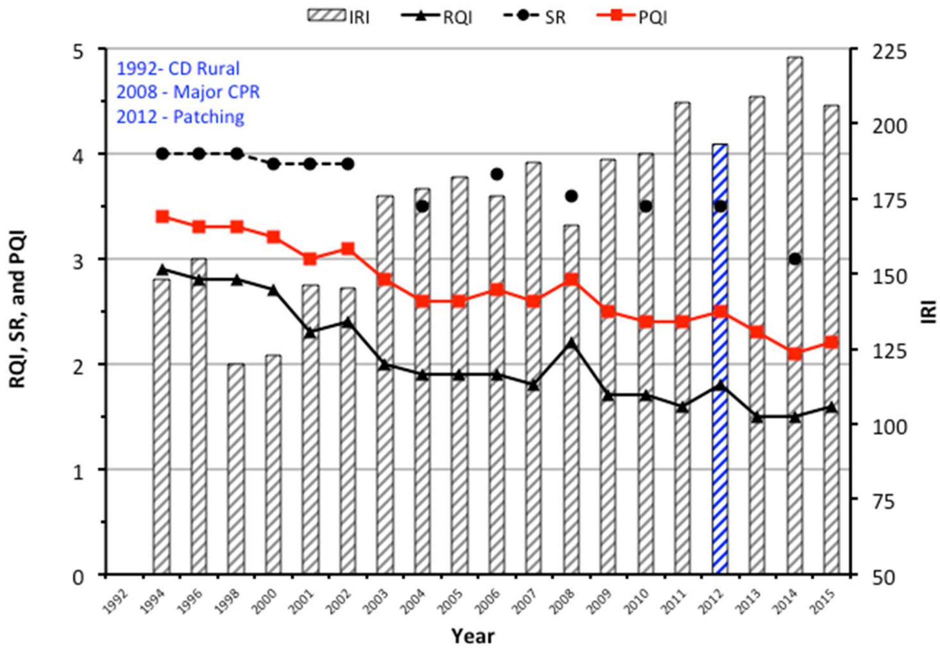


Figure B.200. Pavement management system data for section 20+0.000, direction U, of project 2208–35 constructed in 1992. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

District 7 – 2208-36

Table B.93. Measured IRI for selected sections of project 2208-36, constructed in 1991. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)							
	20	21	22	23	24	25	26	27
	+0.282	+0.000	+0.000	+0.000	+0.000	+0.000	+0.000	+0.000
Year	U	U	U	U	U	U	U	U
1991								
1994	101	103	94	106	99	96	107	110
1996	84	88	80	86	82	76	84	85
1998	67	75	70	66	67	58	68	71
2000	65	75	75	79	78	68	79	78
2001	73	89	69	70	79	59	72	67
2002	79	88	67	67	71	57	68	63
2003	88	94	99	108	100	98	106	109
2004	85	94	93	98	93	86	99	103
2005	87	97	94	97	91	82	97	97
2006	87	95	89	88	84	78	90	92
2007	92	100	94	94	89	84	98	99
2008	92	100	95	96	88	83	94	99
2009	109	117	110	106	98	90	108	109
2010	93	110	107	99	95	91	104	106
2011	114	116	104	100	98	90	99	103
2012	124	122	107	100	101	93	101	108
2013	98	122	118	103	100	92	106	109
2014	111	111	108	108	116	95	108	112
2015	117	114	106	106	110	93	108	110

Table B.94. Measured PQI for selected sections of project 2208-36, constructed in 1991. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)							
	20 +0.282	21 +0.000	22 +0.000	23 +0.000	24 +0.000	25 +0.000	26 +0.000	27 +0.000
Year	U	U	U	U	U	U	U	U
1991								
1994	3.8	3.8	3.8	3.7	3.8	3.8	3.7	3.7
1996	3.9	3.9	4.0	3.9	3.9	4.0	3.9	3.9
1998	3.9	3.8	3.8	3.9	3.9	4.0	3.8	3.8
2000	3.9	3.8	3.8	3.7	3.7	3.8	3.7	3.7
2001	3.8	3.7	3.8	3.9	3.7	4.0	3.9	3.9
2002	3.8	3.7	3.9	3.9	3.8	4.0	3.9	3.9
2003	3.7	3.6	3.6	3.5	3.6	3.6	3.6	3.5
2004	3.7	3.6	3.6	3.6	3.6	3.7	3.6	3.6
2005	3.7	3.6	3.6	3.6	3.6	3.8	3.7	3.6
2006	3.7	3.6	3.7	3.7	3.7	3.8	3.7	3.6
2007	3.6	3.6	3.6	3.6	3.6	3.8	3.6	3.6
2008	3.7	3.5	3.2	3.6	3.7	3.7	3.7	3.6
2009	3.3	3.3	3.0	3.5	3.5	3.6	3.5	3.4
2010	3.2	3.3	3.0	3.6	3.6	3.7	3.5	3.4
2011	3.0	3.3	3.1	3.6	3.5	3.7	3.5	3.4
2012	2.6	3.1	2.8	3.1	3.1	3.5	3.4	3.2
2013	2.9	3.1	2.7	3.1	3.1	3.5	3.4	3.2
2014	2.5	2.8	2.6	2.9	2.6	3.0	3.1	2.9
2015	2.4	2.7	2.6	3.0	2.7	3.1	3.1	2.9

Table B.95. Measured RQI for selected sections of project 2208-36, constructed in 1991. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)							
	20 +0.282	21 +0.000	22 +0.000	23 +0.000	24 +0.000	25 +0.000	26 +0.000	27 +0.000
Year	U	U	U	U	U	U	U	U
1991								
1994	3.6	3.6	3.7	3.5	3.6	3.7	3.5	3.5
1996	3.9	3.8	4.0	3.9	3.9	4.0	3.9	3.9
1998	3.8	3.6	3.7	3.8	3.8	4.0	3.7	3.7
2000	3.8	3.6	3.6	3.5	3.5	3.7	3.5	3.5
2001	3.6	3.4	3.7	3.8	3.5	4.1	3.8	3.9
2002	3.6	3.4	3.8	3.9	3.7	4.1	3.9	3.9
2003	3.4	3.3	3.3	3.1	3.2	3.3	3.2	3.1
2004	3.5	3.3	3.3	3.3	3.3	3.5	3.3	3.2
2005	3.4	3.2	3.3	3.3	3.3	3.6	3.4	3.3
2006	3.4	3.2	3.4	3.4	3.5	3.7	3.5	3.3
2007	3.2	3.2	3.3	3.3	3.3	3.6	3.3	3.2
2008	3.4	3.1	3.2	3.3	3.4	3.5	3.4	3.3
2009	2.8	2.7	2.9	3.1	3.1	3.3	3.1	3.0
2010	3.2	2.7	2.8	3.2	3.2	3.4	3.2	3.1
2011	2.7	2.7	3.0	3.2	3.1	3.4	3.2	3.1
2012	2.6	2.6	2.9	3.2	3.1	3.2	3.2	3.0
2013	3.2	2.6	2.6	3.2	3.1	3.3	3.2	3.0
2014	2.8	2.9	2.9	2.9	2.7	3.1	3.0	2.9
2015	2.7	2.8	2.9	3.0	2.8	3.2	3.0	2.9

Table B.96. Measured SR for selected sections of project 2208-36, constructed in 1991. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)							
	20 +0.282	21 +0.000	22 +0.000	23 +0.000	24 +0.000	25 +0.000	26 +0.000	27 +0.000
Year	U	U	U	U	U	U	U	U
1991								
1994	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
1996	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
1998	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2000	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2001	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2002	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2003								
2004	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2005								
2006	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2007								
2008	4.0	4.0	3.2	4.0	4.0	3.9	4.0	3.9
2009								
2010	3.3	4.0	3.2	4.0	4.0	4.0	3.8	3.8
2011								
2012	2.6	3.6	2.8	3.0	3.2	3.8	3.7	3.4
2013								
2014	2.2	2.7	2.4	3.0	2.6	3.0	3.3	3.0
2015								

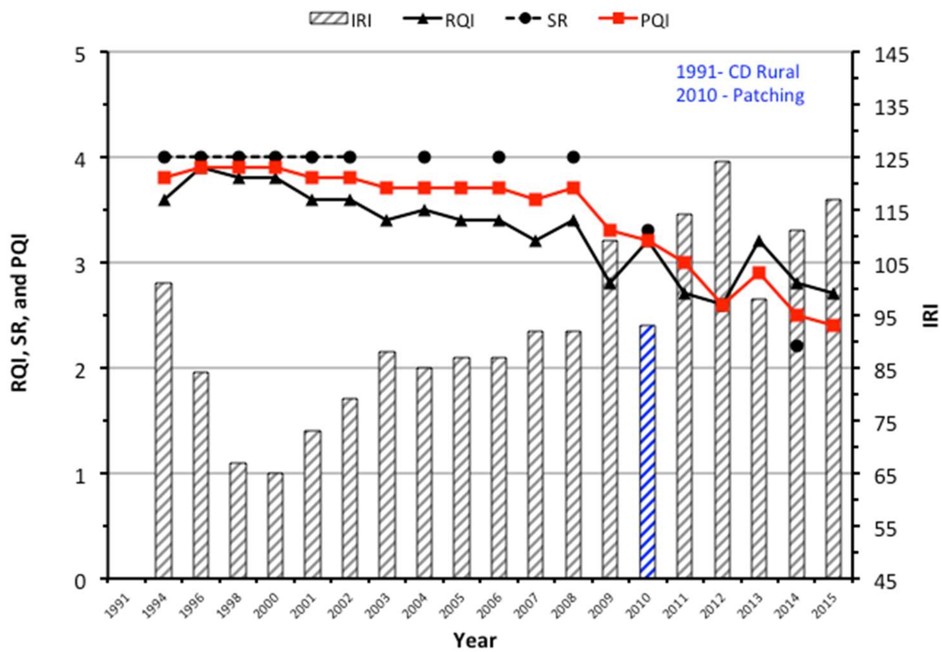


Figure B.201. Pavement management system data for section 20+0.282, direction U, of project 2208–36 constructed in 1991. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

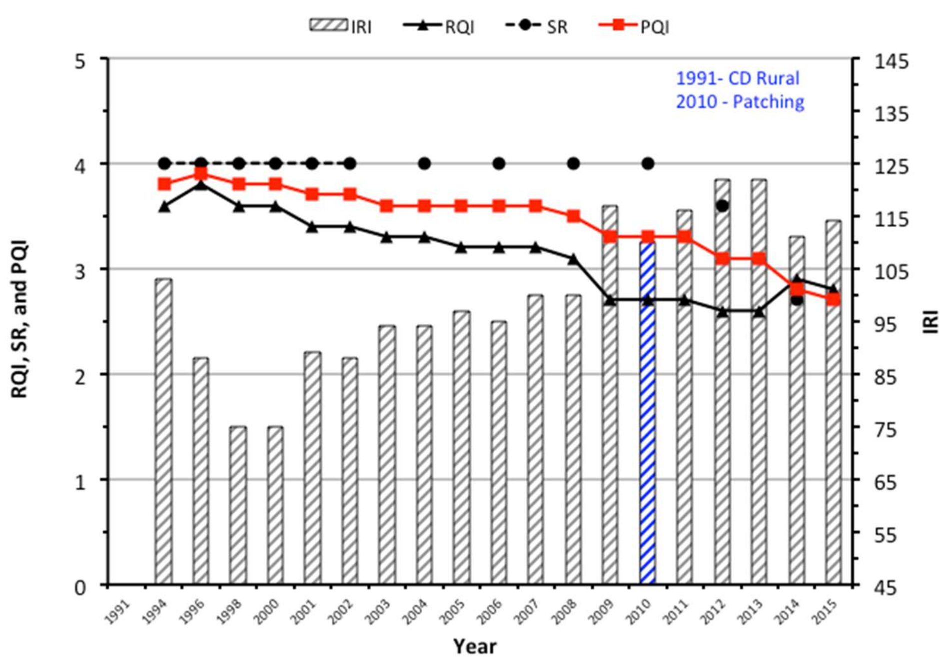


Figure B.202. Pavement management system data for section 21+0.000, direction U, of project 2208–36 constructed in 1991. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

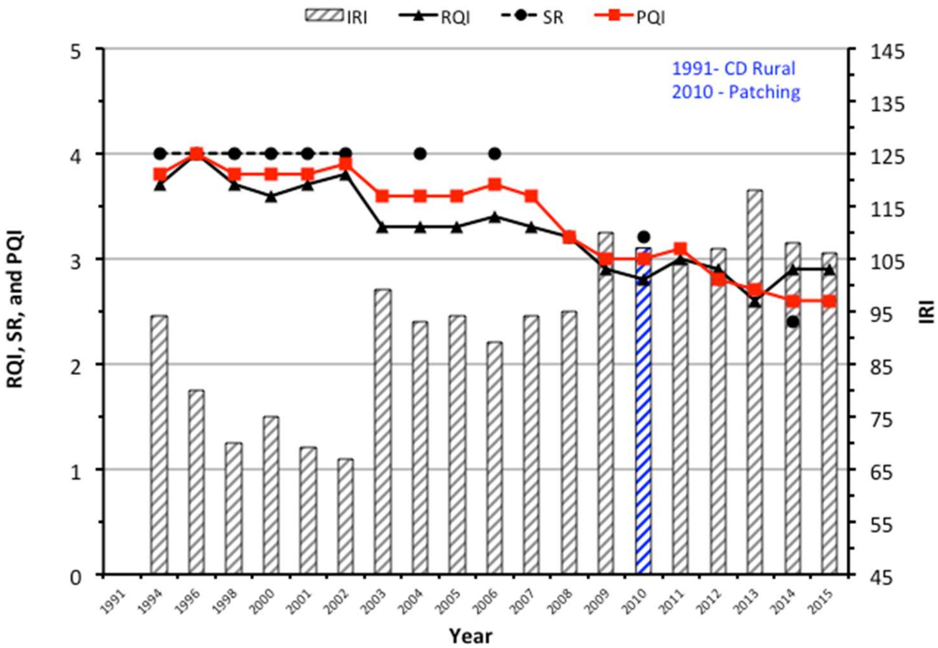


Figure B.203. Pavement management system data for section 22+0.000, direction U, of project 2208–36 constructed in 1991. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

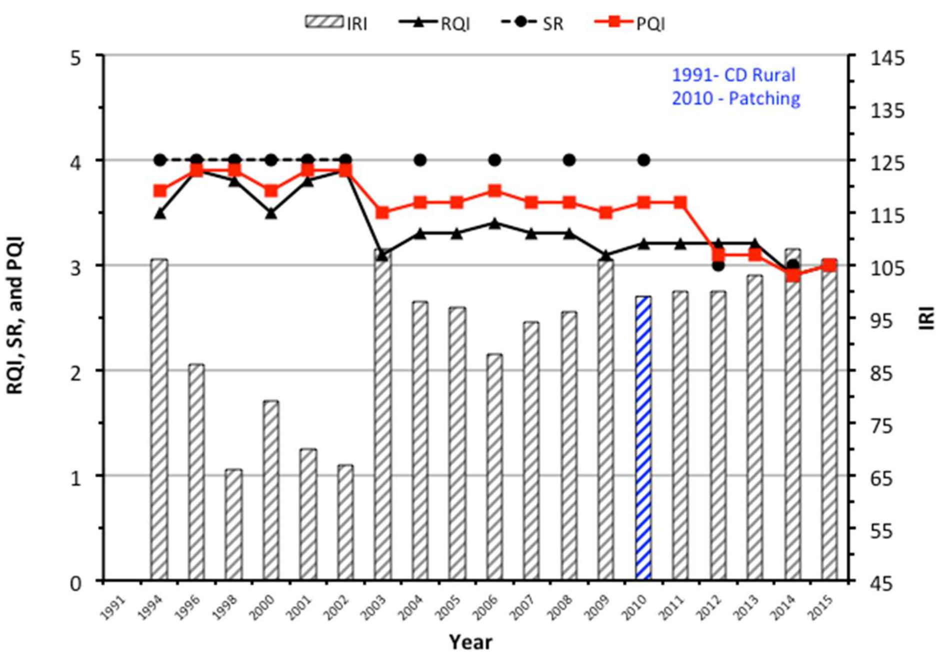


Figure B.204. Pavement management system data for section 23+0.000, direction U, of project 2208–36 constructed in 1991. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

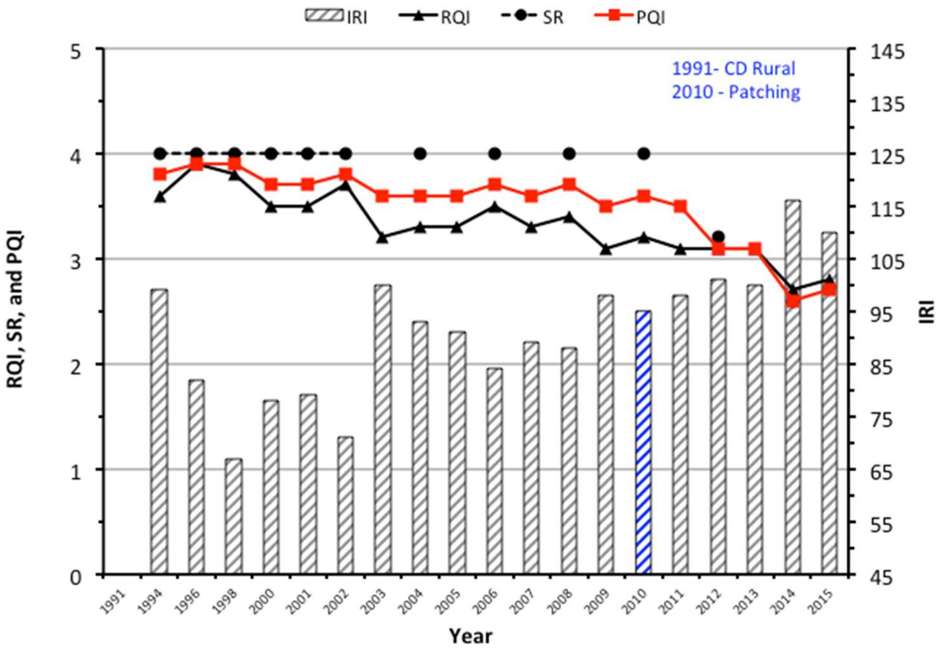


Figure B.205. Pavement management system data for section 24+0.000, direction U, of project 2208–36 constructed in 1991. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

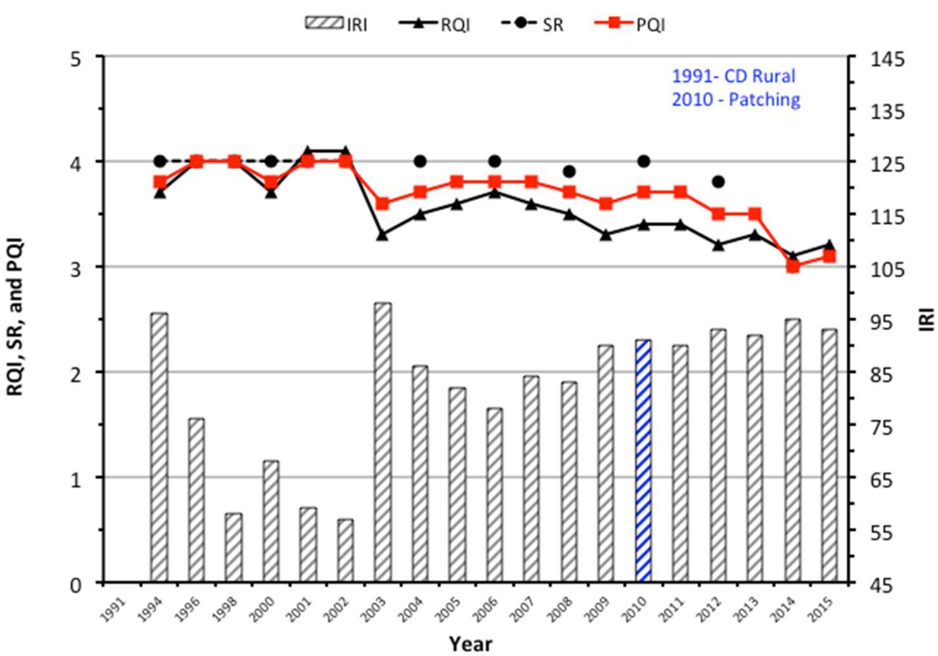


Figure B.206. Pavement management system data for section 25+0.000, direction U, of project 2208–36 constructed in 1991. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

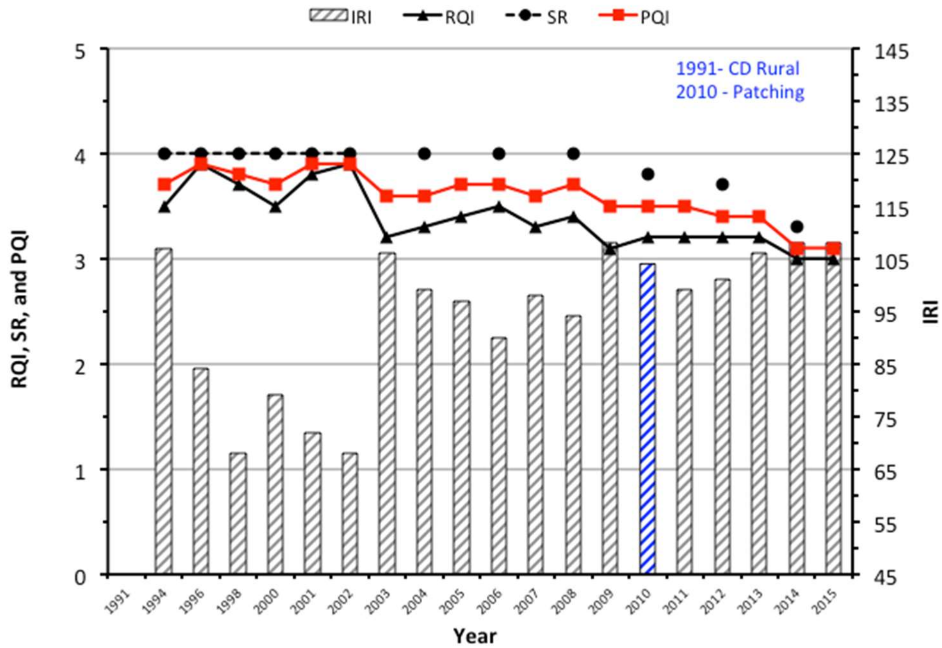


Figure B.207. Pavement management system data for section 26+0.000, direction U, of project 2208–36 constructed in 1991. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

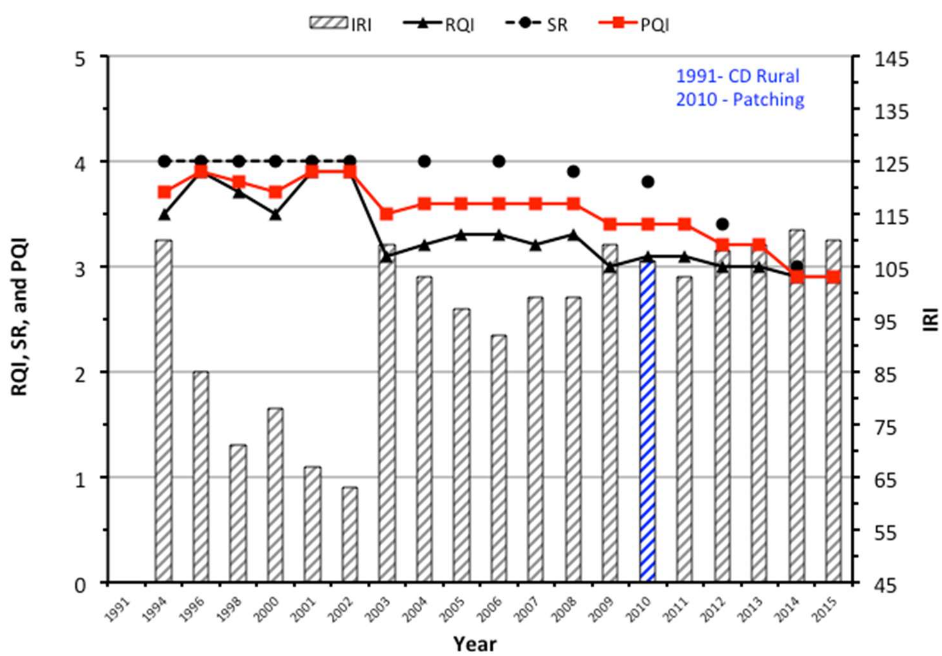


Figure B.208. Pavement management system data for section 27+0.000, direction U, of project 2208–36 constructed in 1991. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

District 7 – 4013-41

Table B.97. Measured IRI for selected sections of project 4013-41, constructed in 1996. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)					
	78 +0.806	79 +0.000	80 +0.000	78 +0.806	79 +0.000	80 +0.000
Year	D	D	D	I	I	I
1996						
1998	120	73	65	92	61	61
2000	115	75	63	94	64	66
2001	127	93	93	111	73	78
2002	148	109	79	129	87	87
2003	163	121	102	135	92	90
2004	159	117	101	136	93	97
2005	155	114	88	139	91	84
2006	143	106	86	131	83	87
2007	152	109	89	168	90	85
2008	154	125	117	139	100	109
2009	175	123	100	158	108	115
2010	170	127	122	145	101	120
2011	175	118	93	153	98	107
2012	187	131	118	156	100	105
2013	178	124	104	149	102	96
2014	178	127	114	150	106	105
2015	181	125	112	144	106	106

Table B.98. Measured PQI for selected sections of project 4013-41, constructed in 1996. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)					
	78 +0.806	79 +0.000	80 +0.000	78 +0.806	79 +0.000	80 +0.000
Year	D	D	D	I	I	I
1996						
1998	3.3	3.8	3.9	3.6	3.9	3.9
2000	3.3	3.8	3.9	3.5	3.9	3.9
2001	3.2	3.6	3.6	3.3	3.8	3.8
2002	3.0	3.4	3.7	3.1	3.7	3.6
2003	3.0	3.3	3.5	3.1	3.7	3.6
2004	3.0	3.3	3.5	3.1	3.7	3.6
2005	3.0	3.4	3.6	2.9	3.7	3.7
2006	3.2	3.5	3.7	3.1	3.7	3.7
2007	3.1	3.5	3.6	2.9	3.7	3.7
2008	3.0	3.3	3.3	3.2	3.6	3.5
2009	2.7	3.3	3.5	3.0	3.5	3.3
2010	2.7	3.3	3.3	2.9	3.6	3.3
2011	2.7	3.3	3.6	2.8	3.6	3.4
2012	2.7	3.1	3.3	2.7	3.5	3.4
2013	2.7	3.2	3.4	2.8	3.4	3.5
2014	2.5	3.2	3.3	2.8	3.3	3.3
2015	2.5	3.2	3.3	2.9	3.3	3.3

Table B.99. Measured RQI for selected sections of project 4013-41, constructed in 1996. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)					
	78 +0.806	79 +0.000	80 +0.000	78 +0.806	79 +0.000	80 +0.000
Year	D	D	D	I	I	I
1996						
1998	2.8	3.6	3.8	3.2	3.9	61
2000	2.8	3.6	3.8	3.2	3.8	66
2001	2.7	3.3	3.3	2.9	3.7	78
2002	2.3	2.9	3.5	2.6	3.5	87
2003	2.2	2.8	3.1	2.6	3.4	90
2004	2.2	2.8	3.1	2.6	3.4	97
2005	2.3	2.9	3.3	2.4	3.4	84
2006	2.5	3.0	3.4	2.6	3.5	87
2007	2.4	3.0	3.3	2.2	3.5	85
2008	2.3	2.7	2.8	2.6	3.2	109
2009	1.9	2.7	3.1	2.2	3.0	115
2010	2.1	2.7	2.8	2.4	3.2	120
2011	2.1	2.8	3.2	2.3	3.2	107
2012	2.0	2.6	2.8	2.2	3.1	105
2013	2.0	2.7	3.0	2.3	3.0	96
2014	2.0	2.7	2.9	2.3	3.0	105
2015	2.0	2.7	2.9	2.4	3.0	106

Table B.100. Measured SR for selected sections of project 4013-41, constructed in 1996. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)					
	78 +0.806	79 +0.000	80 +0.000	78 +0.806	79 +0.000	80 +0.000
Year	D	D	D	I	I	I
1996						
1998	4.0	4.0	4.0	4.0	4.0	4.0
2000	4.0	4.0	4.0	3.9	4.0	4.0
2001	3.9	4.0	4.0	3.8	4.0	4.0
2002	4.0	4.0	4.0	3.7	4.0	4.0
2003						
2004	4.0	4.0	4.0	3.6	4.0	4.0
2005						
2006	4.0	4.0	4.0	3.7	4.0	4.0
2007						
2008	3.9	4.0	4.0	4.0	4.0	4.0
2009						
2010	3.5	4.0	4.0	3.5	4.0	4.0
2011						
2012	3.6	3.8	3.9	3.3	3.9	3.9
2013						
2014	3.1	3.9	3.7	3.4	3.6	3.7
2015						

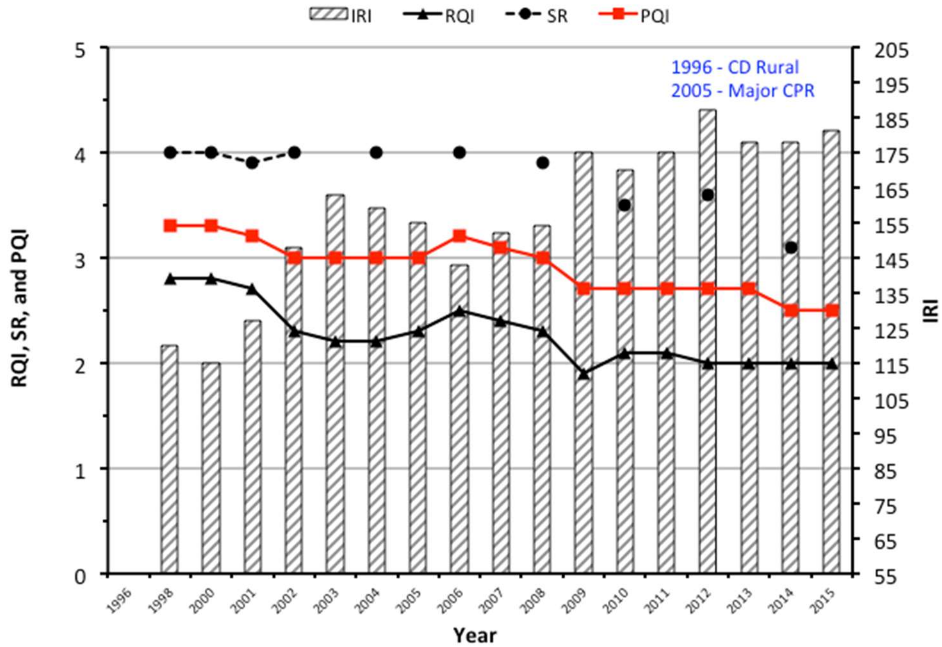


Figure B.209. Pavement management system data for section 78+0.806, direction D, of project 4013–41 constructed in 1996. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

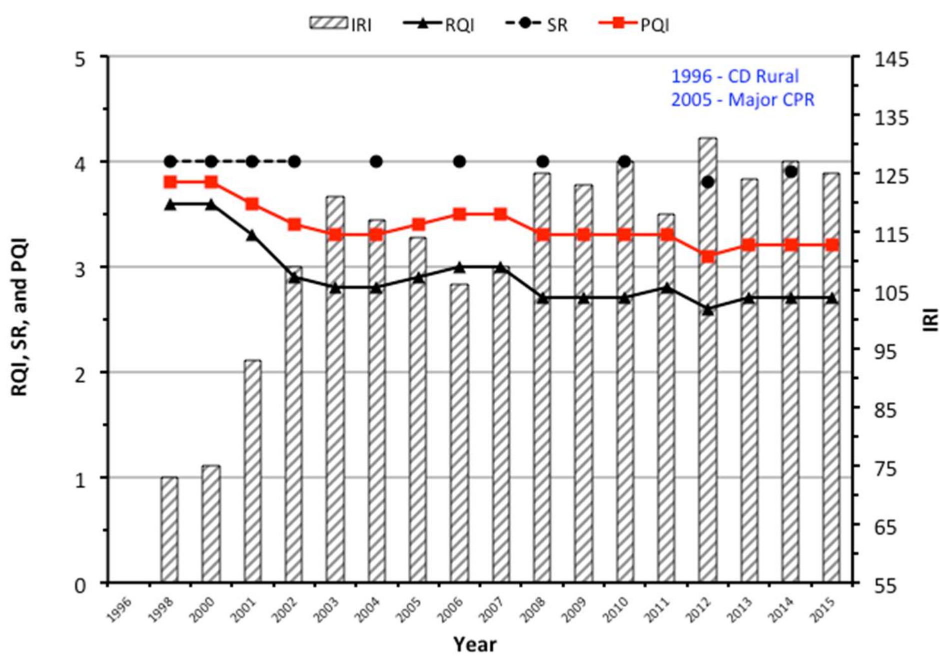


Figure B.210. Pavement management system data for section 79+0.000, direction D, of project 4013–41 constructed in 1996. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

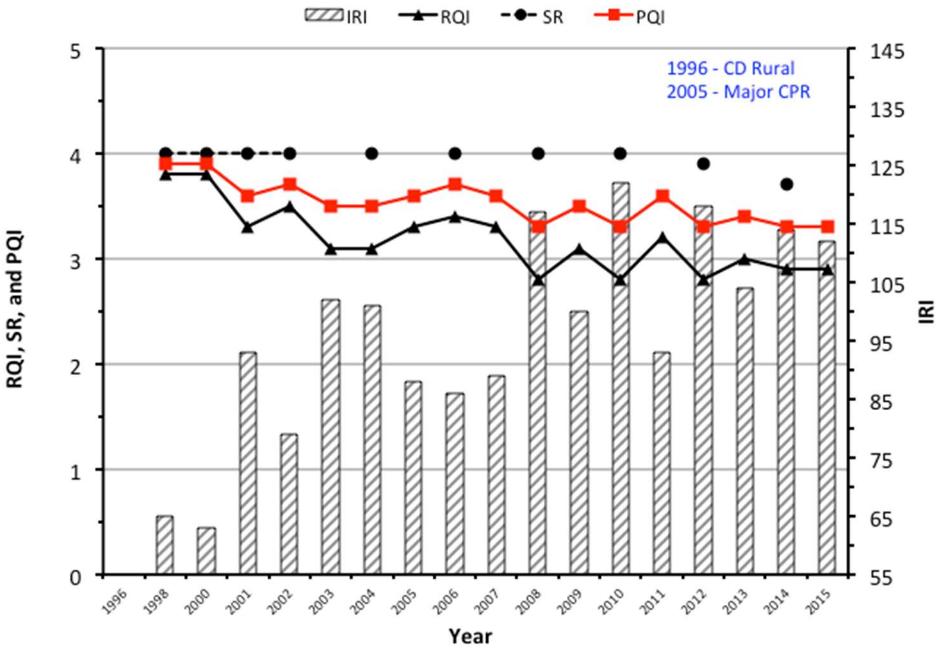


Figure B.211. Pavement management system data for section 80+0.000, direction D, of project 4013–41 constructed in 1996. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

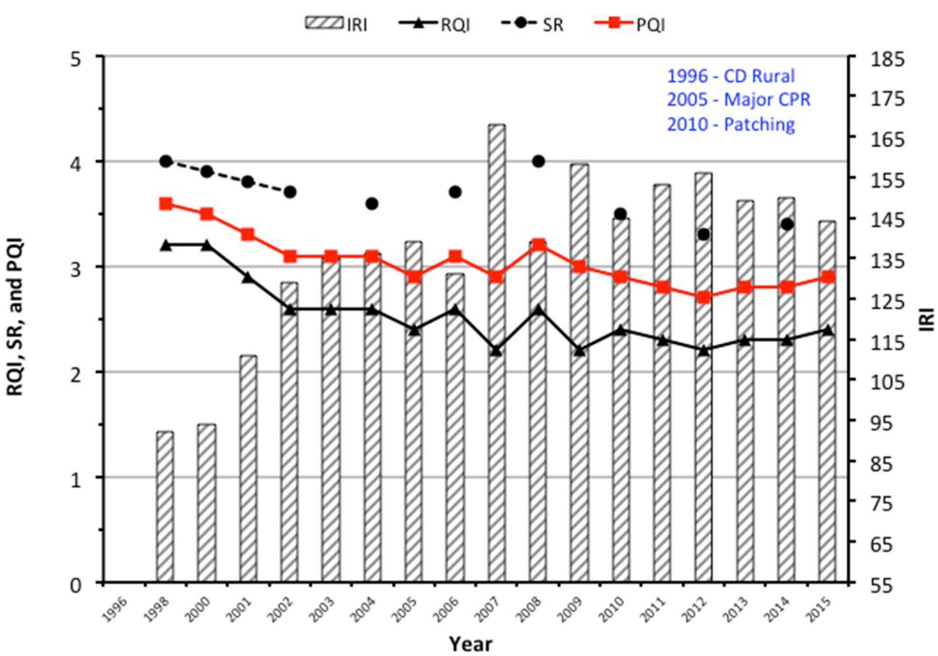


Figure B.212. Pavement management system data for section 78+0.806, direction I, of project 4013–41 constructed in 1996. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

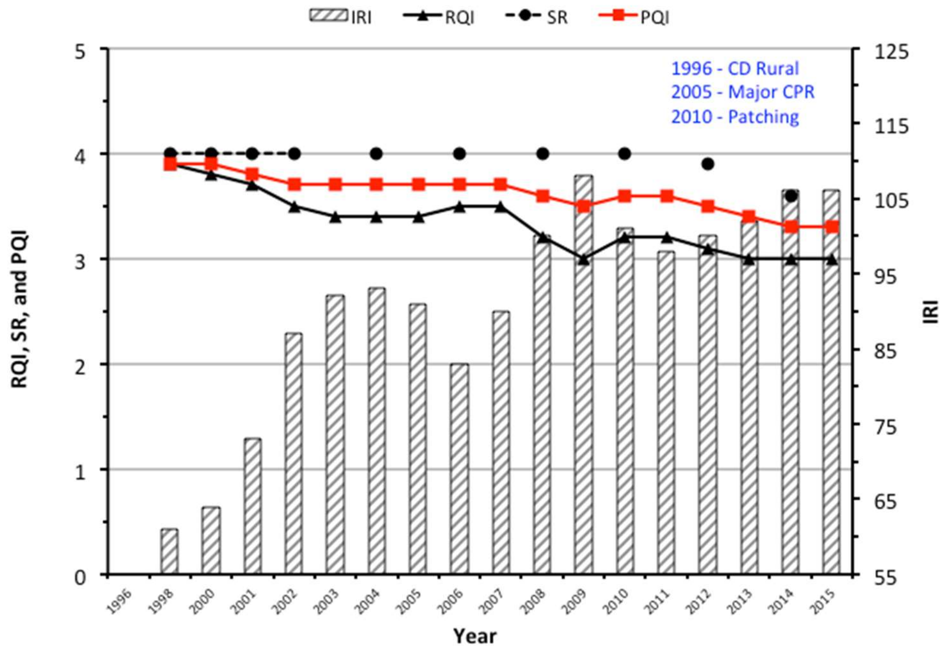


Figure B.213. Pavement management system data for section 79+0.000, direction I, of project 4013–41 constructed in 1996. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

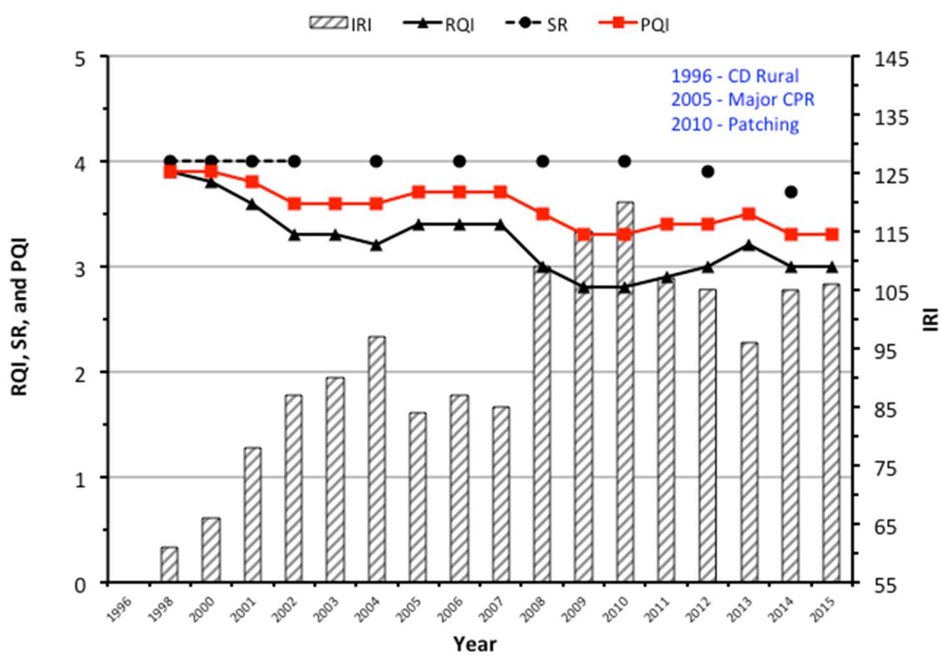


Figure B.214. Pavement management system data for section 80+0.000, direction I, of project 4013–41 constructed in 1996. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

District 7 – 5306-37

Table B.101. Measured IRI for selected sections of project 5306-37, constructed in 1996. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)							
	12 +0.478	13 +0.000	14 +0.000	15 +0.000	16 +0.000	17 +0.000	18 +0.000	19 +0.000
Year	D	D	D	D	D	D	D	D
1996								
1997	48	42	48	42	42	51	42	46
1999	54	51	56	52	49	60	51	66
2001	57	44	56	49	47	67	50	61
2002	54	37	48	41	40	54	44	35
2003	87	83	85	89	80	99	92	86
2004	67	63	64	68	60	77	68	68
2005	66	62	65	65	57	75	63	67
2006	85	82	82	83	78	92	88	85
2007	74	67	66	72	60	77	72	71
2008	85	86	89	87	80	96	92	89
2009	105	107	112	109	103	118	116	112
2010	100	99	104	100	96	110	109	106
2011	94	87	93	90	83	99	97	94
2012	81	84	86	84	78	96	90	87
2013	128	96	99	98	89	104	102	100
2014	103	112	105	99	114	115	112	95
2015	95	102	96	92	108	105	103	91

Table B.102. Measured PQI for selected sections of project 5306-37, constructed in 1996. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)							
	12 +0.478	13 +0.000	14 +0.000	15 +0.000	16 +0.000	17 +0.000	18 +0.000	19 +0.000
Year	D	D	D	D	D	D	D	D
1996								
1997	4.1	4.1	4.1	4.1	4.1	4.0	4.1	4.1
1999	4.0	4.0	4.0	4.0	4.1	3.9	4.0	3.9
2001	4.0	4.1	4.0	4.1	4.1	3.9	4.0	3.9
2002	4.0	4.2	4.1	4.2	4.2	4.0	4.1	4.3
2003	3.7	3.7	3.7	3.7	3.7	3.6	3.6	3.7
2004	3.9	3.9	3.9	3.9	3.9	3.8	3.9	3.9
2005	3.9	3.9	3.9	3.9	4.0	3.8	3.9	3.8
2006	3.7	3.7	3.7	3.7	3.8	3.6	3.6	3.7
2007	3.8	3.9	3.9	3.8	3.9	3.8	3.8	3.8
2008	3.7	3.7	3.6	3.7	3.7	3.6	3.6	3.6
2009	3.5	3.4	3.3	3.4	3.5	3.3	3.3	3.3
2010	3.5	3.5	3.5	3.5	3.6	3.5	3.5	3.5
2011	3.6	3.6	3.6	3.6	3.7	3.5	3.6	3.6
2012	3.7	3.7	3.7	3.7	3.7	3.6	3.6	3.7
2013	3.3	3.6	3.5	3.6	3.6	3.5	3.5	3.5
2014	3.5	3.4	3.5	3.5	3.4	3.4	3.4	3.5
2015	3.6	3.5	3.6	3.6	3.5	3.5	3.5	3.5

Table B.103. Measured RQI for selected sections of project 5306-37, constructed in 1996. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)							
	12 +0.478	13 +0.000	14 +0.000	15 +0.000	16 +0.000	17 +0.000	18 +0.000	19 +0.000
Year	D	D	D	D	D	D	D	D
1996								
1997	4.2	4.3	4.2	4.3	4.3	4.1	4.3	4.2
1999	4.0	4.1	4.0	4.1	4.2	3.9	4.1	3.8
2001	4.0	4.3	4.0	4.2	4.2	3.8	4.1	3.9
2002	4.1	4.5	4.2	4.4	4.4	4.1	4.3	4.6
2003	3.4	3.4	3.4	3.4	3.5	3.2	3.3	3.4
2004	3.8	3.8	3.8	3.8	3.9	3.6	3.8	3.8
2005	3.8	3.8	3.8	3.8	4.0	3.6	3.8	3.7
2006	3.4	3.4	3.4	3.4	3.6	3.3	3.3	3.4
2007	3.6	3.8	3.8	3.7	3.9	3.6	3.6	3.7
2008	3.4	3.4	3.3	3.4	3.5	3.2	3.3	3.3
2009	3.0	2.9	2.8	2.9	3.0	2.8	2.8	2.8
2010	3.1	3.1	3.0	3.1	3.2	3.0	3.0	3.0
2011	3.2	3.3	3.2	3.3	3.4	3.1	3.2	3.2
2012	3.5	3.4	3.4	3.4	3.5	3.2	3.3	3.4
2013	2.7	3.2	3.1	3.2	3.3	3.1	3.1	3.1
2014	3.0	2.9	3.0	3.1	2.9	2.9	2.9	3.0
2015	3.2	3.1	3.2	3.3	3.0	3.0	3.0	3.0

Table B.104. Measured SR for selected sections of project 5306-37, constructed in 1996. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)							
Year	12 +0.478 D	13 +0.000 D	14 +0.000 D	15 +0.000 D	16 +0.000 D	17 +0.000 D	18 +0.000 D	19 +0.000 D
1996								
1997	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
1999	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2001	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2002								
2003	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2004								
2005	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2006								
2007	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2008								
2009	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2010								
2011	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2012								
2013	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2014								
2015	4.0	4.0	4.0	3.9	4.0	4.0	4.0	4.0

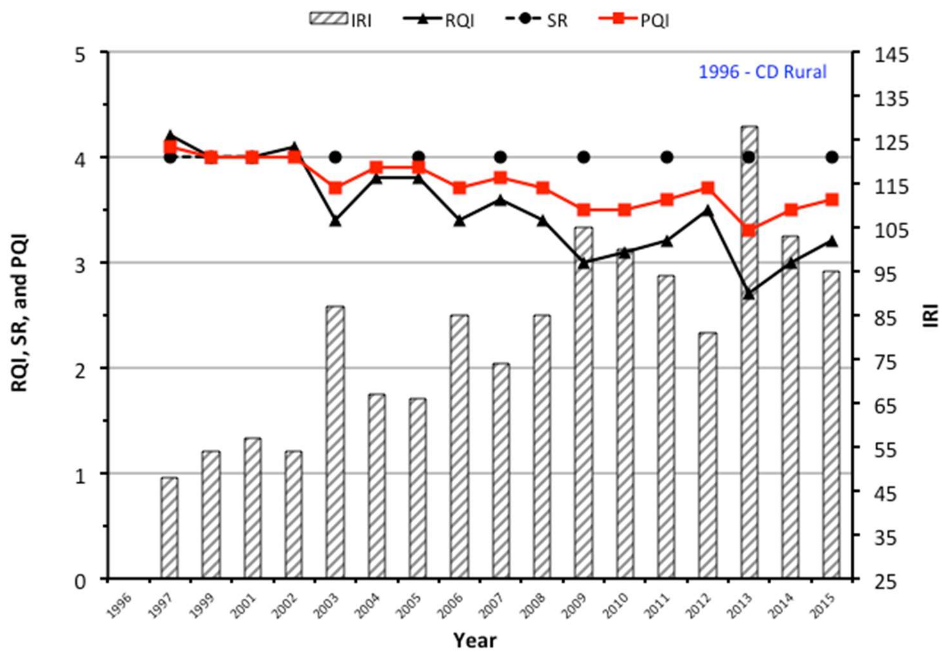


Figure B.215. Pavement management system data for section 12+0.478, direction D, of project 5306–37 constructed in 1996. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

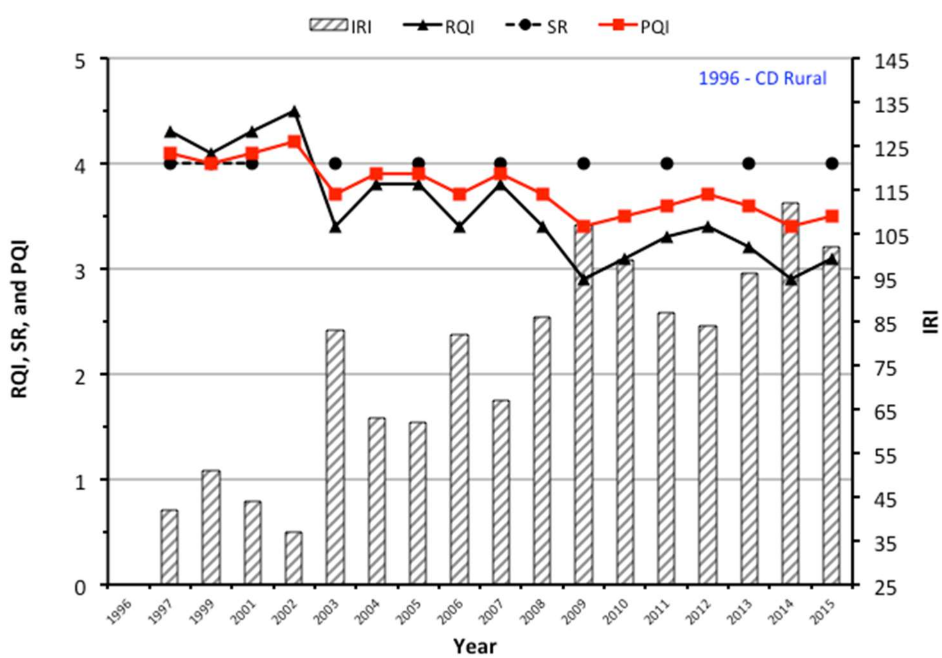


Figure B.216. Pavement management system data for section 13+0.000, direction D, of project 5306–37 constructed in 1996. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

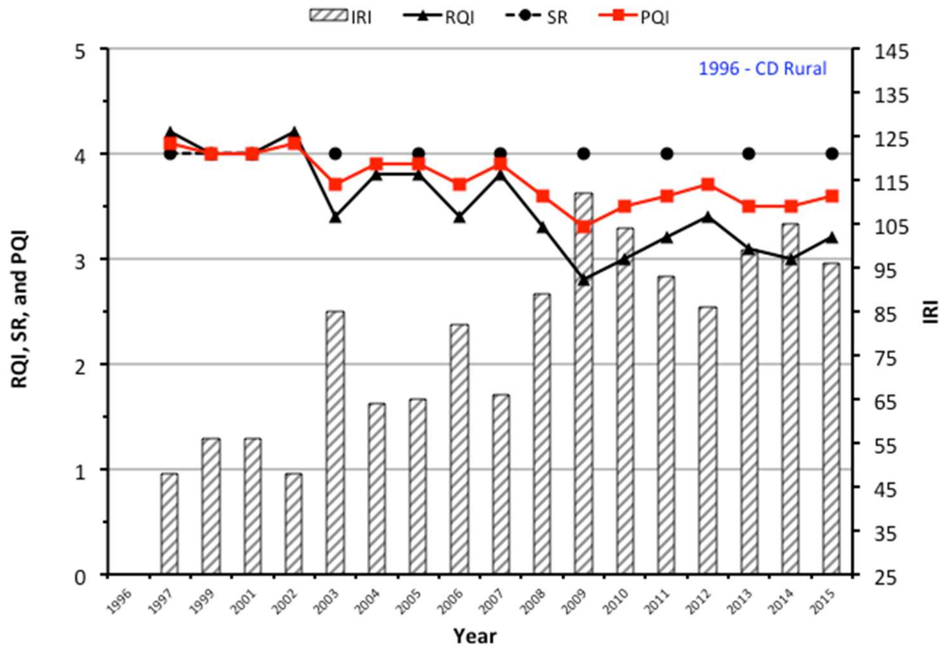


Figure B.217. Pavement management system data for section 14+0.000, direction D, of project 5306–37 constructed in 1996. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

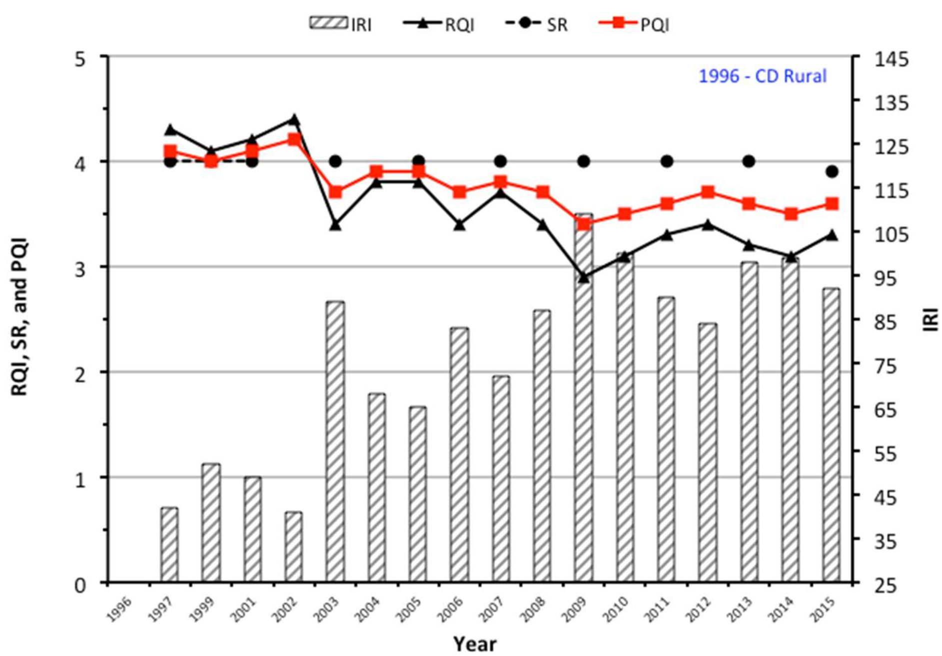


Figure B.218. Pavement management system data for section 15+0.000, direction D, of project 5306–37 constructed in 1996. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

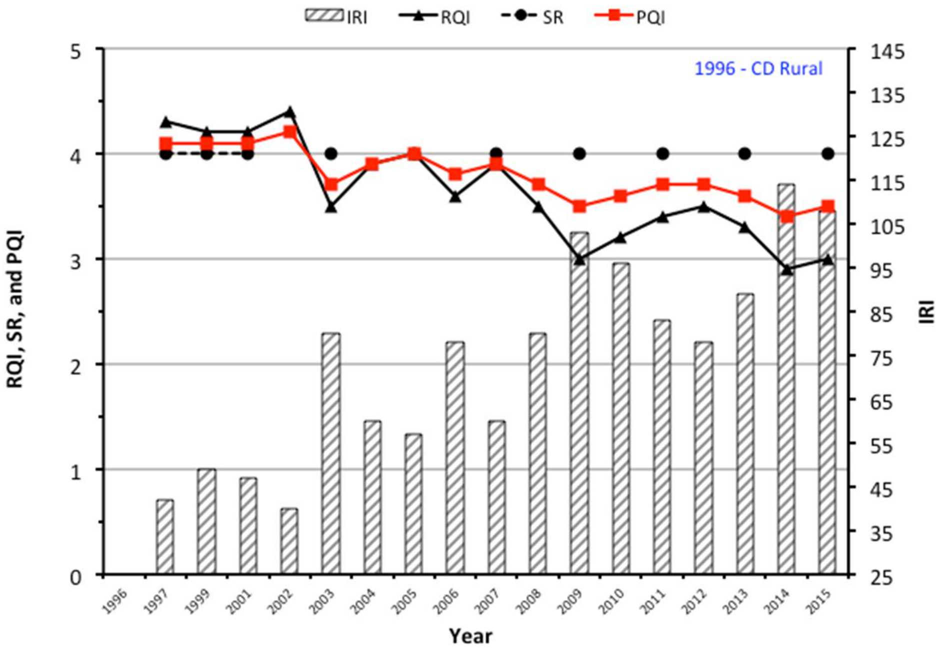


Figure B.219. Pavement management system data for section 16+0.000, direction D, of project 5306–37 constructed in 1996. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

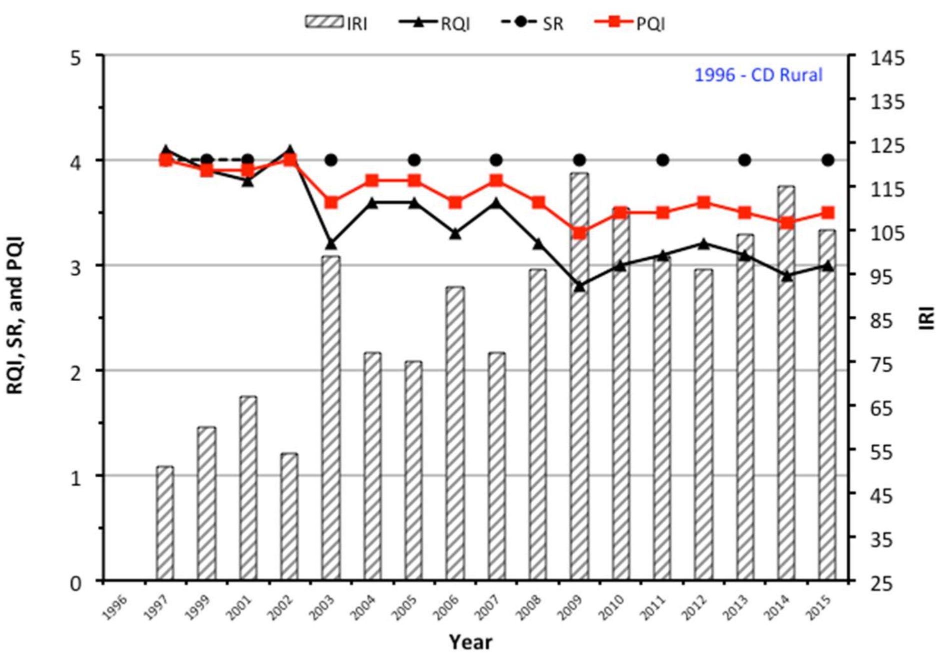


Figure B.220. Pavement management system data for section 17+0.000, direction D, of project 5306–37 constructed in 1996. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

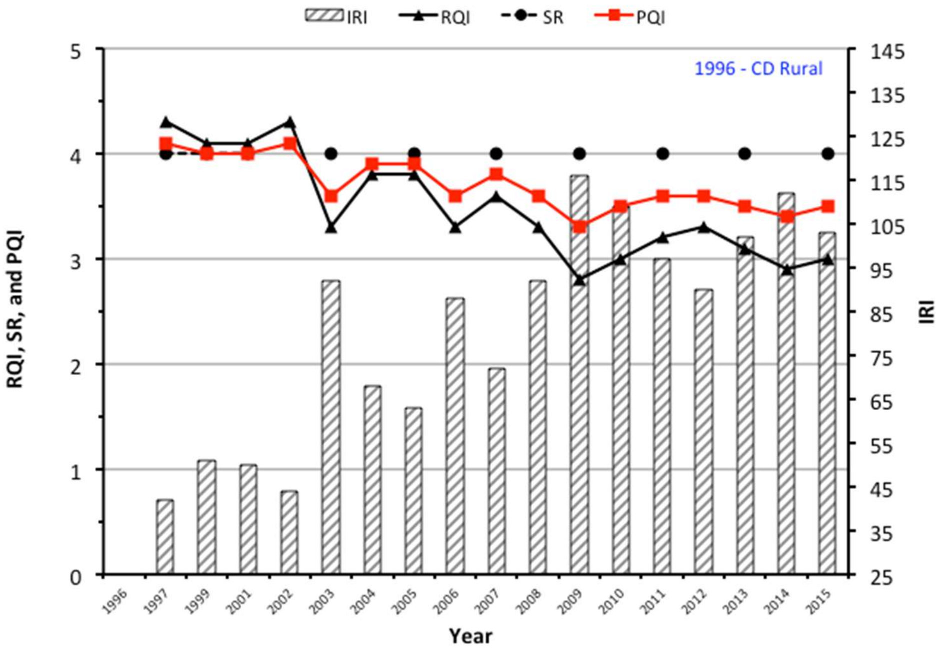


Figure B.221. Pavement management system data for section 18+0.000, direction D, of project 5306–37 constructed in 1996. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

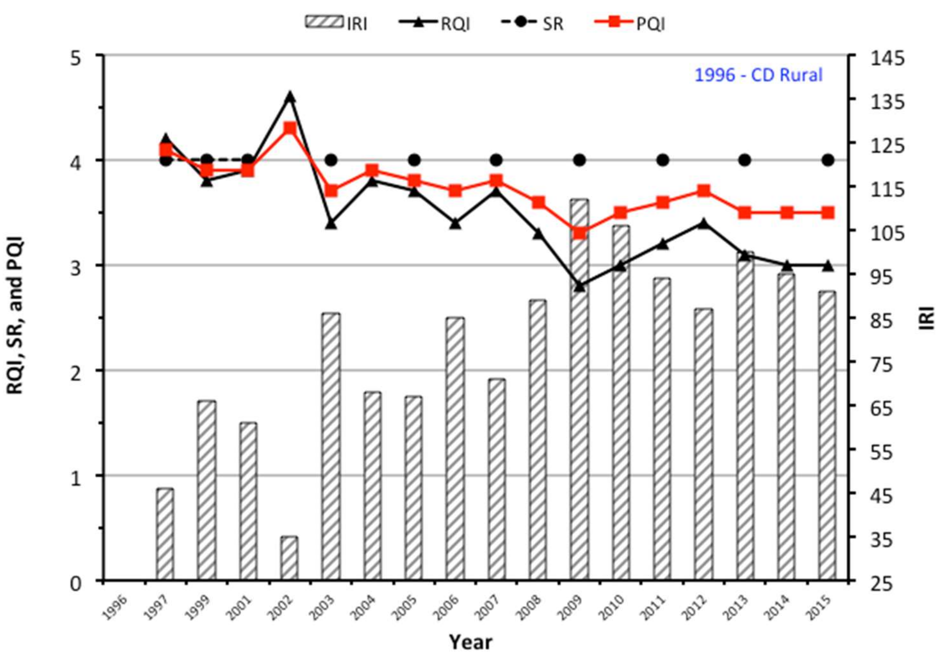


Figure B.222. Pavement management system data for section 19+0.000, direction D, of project 5306–37 constructed in 1996. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

District 7 – 6507-04

Table B.105. Measured IRI for selected sections of project 6507-04, constructed in 1993. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)			
	92 +0.983	94 +0.000	95 +0.000	96 +0.000
Year	U	U	U	U
1993				
1994	67	69	75	74
1996	76	79	86	83
1998	61	63	66	70
2000	60	60	63	68
2001	72	58	71	74
2002	76	56	71	72
2003	77	73	80	90
2004	87	79	83	93
2005	74	70	79	90
2006	73	70	79	87
2007	73	69	79	92
2008	79	72	80	94
2009	80	74	82	99
2010	81	76	79	94
2011	80	74	83	99
2012	86	83	85	102
2013	78	73	87	102
2014	84	75	84	100
2015	83	75	89	107

Table B.106. Measured PQI for selected sections of project 6507-04, constructed in 1993. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)			
	92 +0.983	94 +0.000	95 +0.000	96 +0.000
Year	U	U	U	U
1993				
1994	4.0	4.1	4.0	4.0
1996	3.9	4.0	3.9	3.9
1998	3.9	3.9	3.9	3.8
2000	3.9	3.9	3.9	3.8
2001	3.7	4.0	3.9	3.8
2002	3.6	4.0	3.9	3.8
2003	3.6	3.8	3.8	3.7
2004	3.6	3.8	3.7	3.6
2005	3.8	3.8	3.8	3.7
2006	3.6	3.8	3.8	3.7
2007	3.6	3.8	3.8	3.6
2008	3.6	3.8	3.8	3.6
2009	3.5	3.8	3.7	3.5
2010	3.6	3.8	3.8	3.6
2011	3.6	3.8	3.7	3.6
2012	3.5	3.5	3.4	3.1
2013	3.6	3.6	3.3	3.1
2014	3.4	3.6	3.5	3.1
2015	3.4	3.6	3.4	3.0

Table B.107. Measured SR for selected sections of project 6507-04, constructed in 1993. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)			
	92 +0.983	94 +0.000	95 +0.000	96 +0.000
Year	U	U	U	U
1993				
1994	3.9	4.0	4.0	4.0
1996	3.9	4.0	4.0	4.0
1998	3.9	4.0	4.0	4.0
2000	3.9	4.0	4.0	4.0
2001	3.8	4.0	4.0	4.0
2002	3.7	4.0	4.0	4.0
2003				
2004	3.9	4.0	4.0	4.0
2005				
2006	3.6	4.0	4.0	4.0
2007				
2008	3.6	4.0	4.0	4.0
2009				
2010	3.7	4.0	4.0	4.0
2011				
2012	3.6	3.7	3.3	3.2
2013				
2014	3.5	3.6	3.5	3.1
2015				

Table B.108. Measured RQI for selected sections of project 6507-04, constructed in 1993. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)			
	92 +0.983	94 +0.000	95 +0.000	96 +0.000
Year	U	U	U	U
1993				
1994	4.2	4.2	4.1	4.1
1996	4.0	4.0	3.9	3.9
1998	3.9	3.8	3.8	3.7
2000	3.9	3.9	3.8	3.7
2001	3.7	4.1	3.8	3.7
2002	3.6	4.0	3.8	3.7
2003	3.6	3.7	3.6	3.4
2004	3.4	3.6	3.5	3.3
2005	3.7	3.7	3.6	3.4
2006	3.7	3.7	3.6	3.4
2007	3.7	3.7	3.6	3.3
2008	3.6	3.7	3.6	3.3
2009	3.5	3.6	3.5	3.1
2010	3.5	3.6	3.6	3.3
2011	3.6	3.6	3.5	3.2
2012	3.4	3.4	3.5	3.1
2013	3.6	3.6	3.4	3.1
2014	3.4	3.6	3.5	3.2
2015	3.4	3.6	3.4	3.0

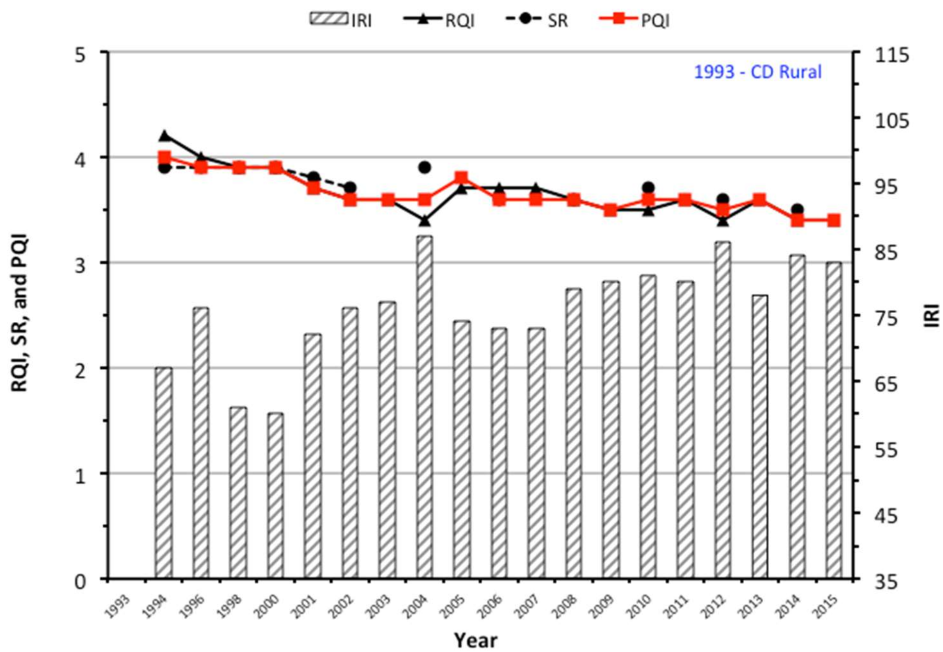


Figure B.223. Pavement management system data for section 92+0.983, direction U, of project 6507–04 constructed in 1993. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

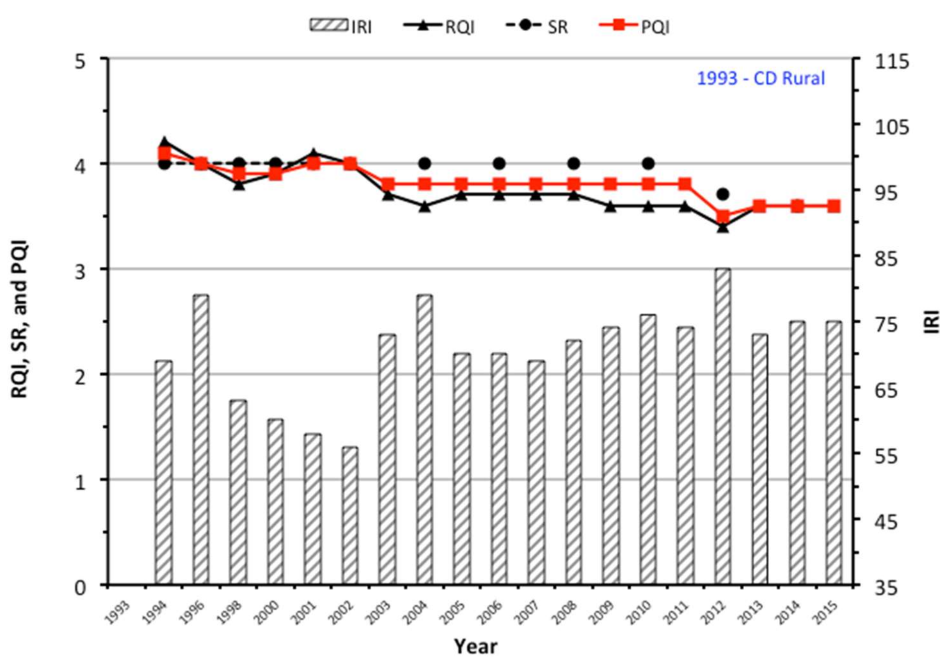


Figure B.224. Pavement management system data for section 94+0.000, direction U, of project 6507–04 constructed in 1993. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

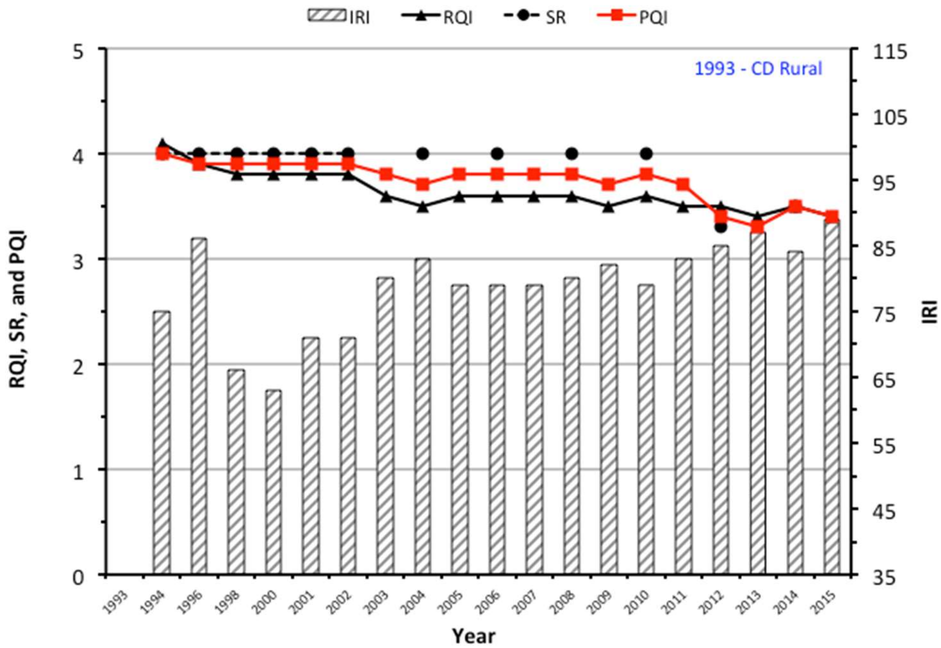


Figure B.225. Pavement management system data for section 95+0.000, direction U, of project 6507–04 constructed in 1993. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

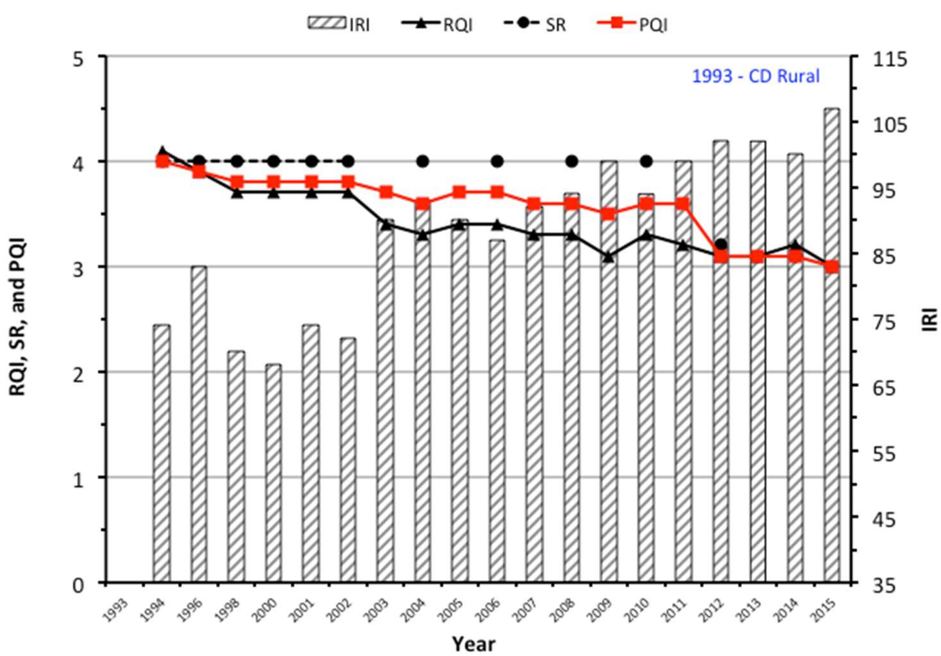


Figure B.226. Pavement management system data for section 96+0.000, direction U, of project 6507–04 constructed in 1993. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

District 7 – 7204-13

Table B.109. Measured IRI for selected sections of project 7204-13, constructed in 1992. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)							
	102 +0.000	10 3+0.000	104 +0.000	105 +0.000	106 +0.000	107 +0.000	108 +0.000	109 +0.000
Year	U	U	U	U	U	U	U	U
1992								
1994	107	84	77	73	62	71	73	89
1996	120	87	80	75	71	77	70	89
1998	96	73	67	66	59	65	58	66
2000	101	72	68	66	56	61	59	71
2001	101	125	80	73	59	72	71	76
2002	96	76	78	79	48	58	66	62
2003	118	82	81	79	66	78	68	86
2004	121	84	91	86	72	77	72	95
2005	119	80	76	76	64	75	65	80
2006	112	74	74	74	63	73	66	82
2007	118	77	73	76	66	77	69	82
2008	119	80	78	80	66	78	71	86
2009	124	83	83	84	71	84	74	93
2010	118	82	85	82	69	78	73	95
2011	121	82	80	81	70	85	75	96
2012	131	90	101	94	82	90	80	103
2013	127	84	77	84	71	89	80	84
2014	128	87	86	86	74	90	80	94
2015	128	86	81	88	76	99	85	90

Table B.110. Measured PQI for selected sections of project 7204-13, constructed in 1992. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)							
	102 +0.000	103+0.000	104 +0.000	105 +0.000	106 +0.000	107 +0.000	108 +0.000	109 +0.000
Year	U	U	U	U	U	U	U	U
1992								
1994	3.5	3.9	4.0	4.0	4.1	4.0	4.0	3.9
1996	3.4	3.9	4.0	4.0	4.0	4.0	4.1	3.9
1998	3.3	3.8	3.9	3.9	3.9	3.9	4.0	3.9
2000	3.3	3.8	3.8	3.9	4.0	3.9	3.9	3.8
2001	3.2	3.2	3.8	3.8	3.9	3.8	3.8	3.6
2002	3.3	3.7	3.7	3.7	4.0	3.9	3.7	3.9
2003	3.1	3.6	3.7	3.7	3.7	3.7	3.7	3.6
2004	3.0	3.6	3.6	3.7	3.7	3.7	3.5	3.6
2005	3.0	3.7	3.7	3.7	3.8	3.7	3.6	3.7
2006	3.2	3.7	3.8	3.8	3.8	3.8	3.6	3.7
2007	3.1	3.7	3.8	3.7	3.8	3.7	3.6	3.7
2008	3.1	3.6	3.7	3.7	3.8	3.7	3.6	3.6
2009	3.0	3.6	3.6	3.6	3.7	3.6	3.6	3.5
2010	3.0	3.6	3.7	3.7	3.8	3.7	3.5	3.6
2011	3.0	3.6	3.7	3.7	3.7	3.6	3.4	3.5
2012	2.8	3.4	3.5	3.6	3.6	3.6	3.4	3.4
2013	2.8	3.4	3.7	3.7	3.7	3.6	3.4	3.6
2014	2.8	3.5	3.6	3.6	3.7	3.6	3.4	3.5
2015	2.8	3.5	3.7	3.6	3.6	3.5	3.3	3.5

Table B.111. Measured RQI for selected sections of project 7204-13, constructed in 1992. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR))							
Year	102 +0.000 U	10 3+0.000 U	104 +0.000 U	105 +0.000 U	106 +0.000 U	107 +0.000 U	108 +0.000 U	109 +0.000 U
1992								
1994	3.5	3.9	4.0	4.1	4.3	4.1	4.1	3.8
1996	3.3	3.8	4.0	4.1	4.1	4.0	4.2	3.8
1998	3.2	3.6	3.8	3.8	3.9	3.8	4.0	3.8
2000	3.1	3.6	3.7	3.8	4.0	3.9	3.9	3.7
2001	3.0	2.5	3.6	3.7	4.0	3.7	3.8	3.3
2002	3.1	3.5	3.5	3.5	4.2	3.9	3.7	3.8
2003	2.7	3.3	3.4	3.5	3.7	3.4	3.7	3.3
2004	2.7	3.3	3.2	3.4	3.6	3.5	3.6	3.2
2005	2.7	3.4	3.5	3.5	3.8	3.5	3.7	3.4
2006	2.8	3.5	3.6	3.6	3.8	3.6	3.7	3.4
2007	2.7	3.4	3.6	3.5	3.7	3.4	3.6	3.4
2008	2.7	3.3	3.5	3.5	3.7	3.5	3.6	3.3
2009	2.5	3.2	3.3	3.3	3.6	3.3	3.5	3.1
2010	2.7	3.3	3.4	3.4	3.7	3.4	3.6	3.2
2011	2.6	3.3	3.4	3.4	3.6	3.3	3.5	3.1
2012	2.5	3.2	3.0	3.2	3.4	3.2	3.4	3.0
2013	2.5	3.3	3.4	3.4	3.6	3.2	3.4	3.3
2014	2.5	3.2	3.3	3.3	3.6	3.2	3.5	3.2
2015	2.5	3.2	3.4	3.3	3.5	3.0	3.3	3.2

Table B.112. Measured SR for selected sections of project 7204-13, constructed in 1992. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)							
	102 +0.000	103 +0.000	104 +0.000	105 +0.000	106 +0.000	107 +0.000	108 +0.000	109 +0.000
Year	U	U	U	U	U	U	U	U
1992								
1994	3.6	4.0	4.0	4.0	4.0	4.0	4.0	4.0
1996	3.6	4.0	4.0	4.0	4.0	4.0	4.0	4.0
1998	3.5	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2000	3.5	4.0	4.0	4.0	4.0	4.0	3.9	4.0
2001	3.5	4.0	4.0	4.0	3.8	4.0	3.8	4.0
2002	3.5	4.0	4.0	4.0	3.8	4.0	3.8	4.0
2003								
2004	3.4	4.0	4.0	4.0	3.9	4.0	3.5	4.0
2005								
2006	3.6	4.0	4.0	4.0	3.9	4.0	3.6	4.0
2007								
2008	3.6	4.0	4.0	4.0	3.9	4.0	3.7	4.0
2009								
2010	3.4	4.0	4.0	4.0	3.9	4.0	3.4	4.0
2011								
2012	3.2	3.6	4.0	4.0	3.8	4.0	3.4	3.9
2013								
2014	3.1	3.8	4.0	4.0	3.8	4.0	3.4	3.8
2015								

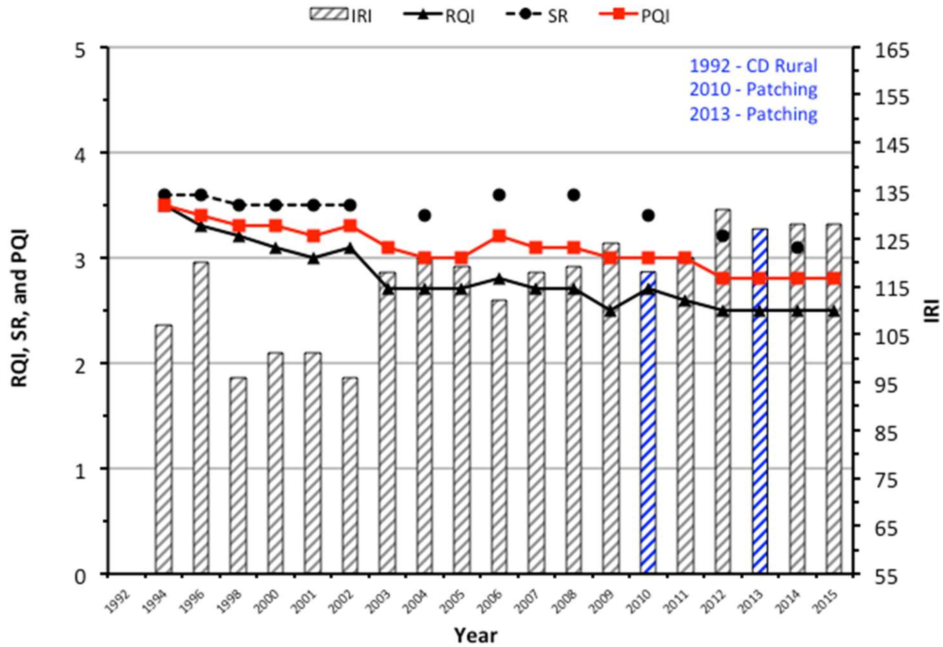


Figure B.227. Pavement management system data for section 102+0.000, direction U, of project 7204–13 constructed in 1992. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

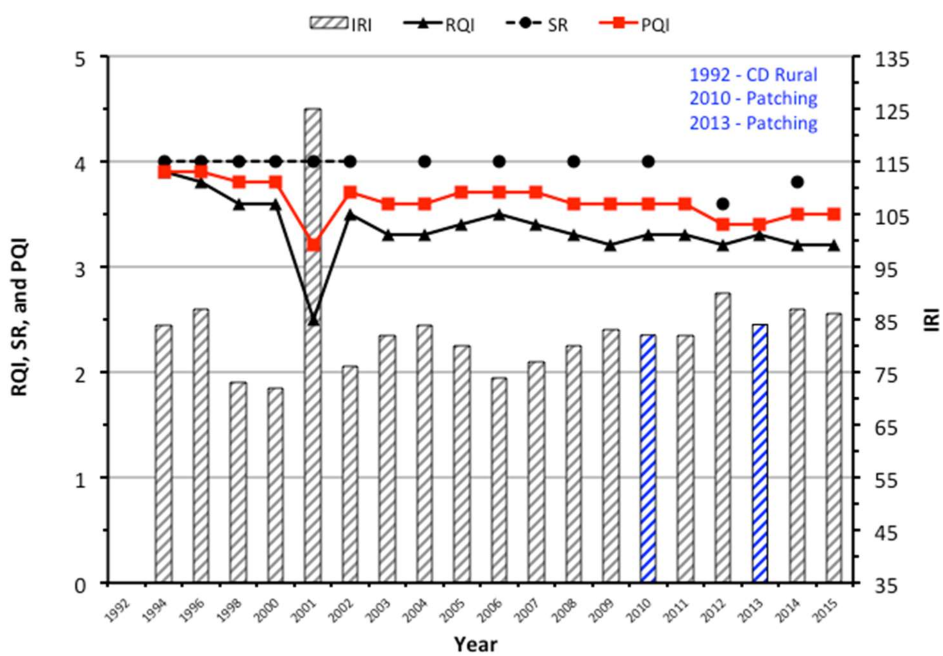


Figure B.228. Pavement management system data for section 103+0.000, direction U, of project 7204–13 constructed in 1992. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

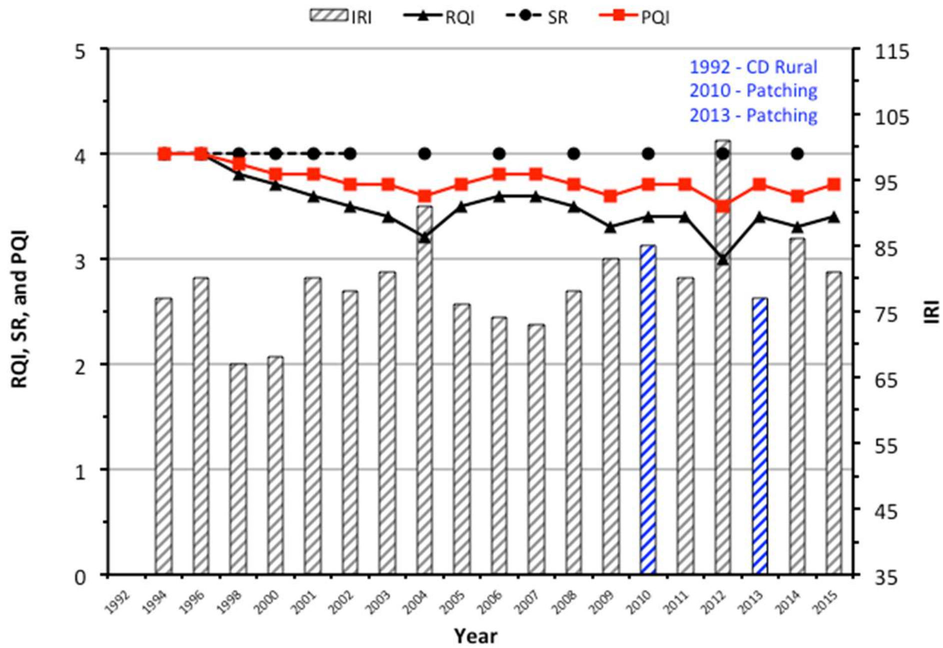


Figure B.229. Pavement management system data for section 104+0.000, direction U, of project 7204–13 constructed in 1992. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

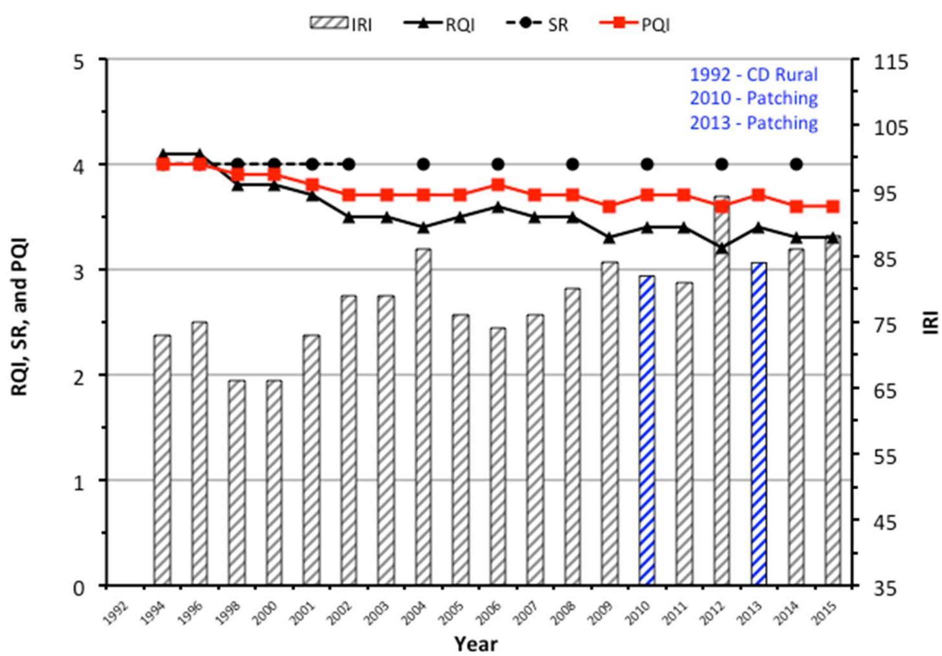


Figure B.230. Pavement management system data for section 105+0.000, direction U, of project 7204–13 constructed in 1992. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

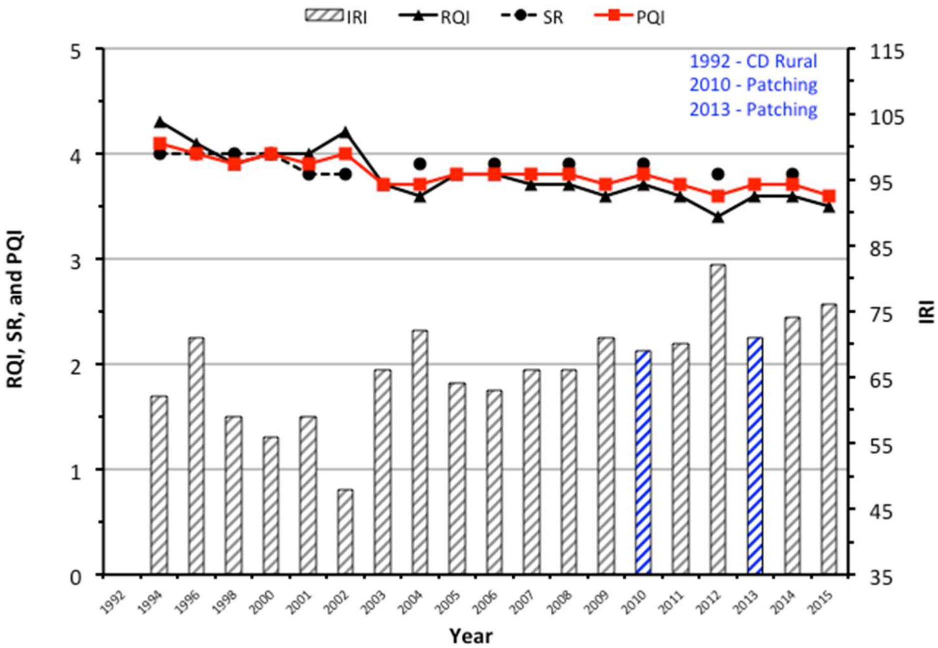


Figure B.231. Pavement management system data for section 106+0.000, direction U, of project 7204–13 constructed in 1992. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

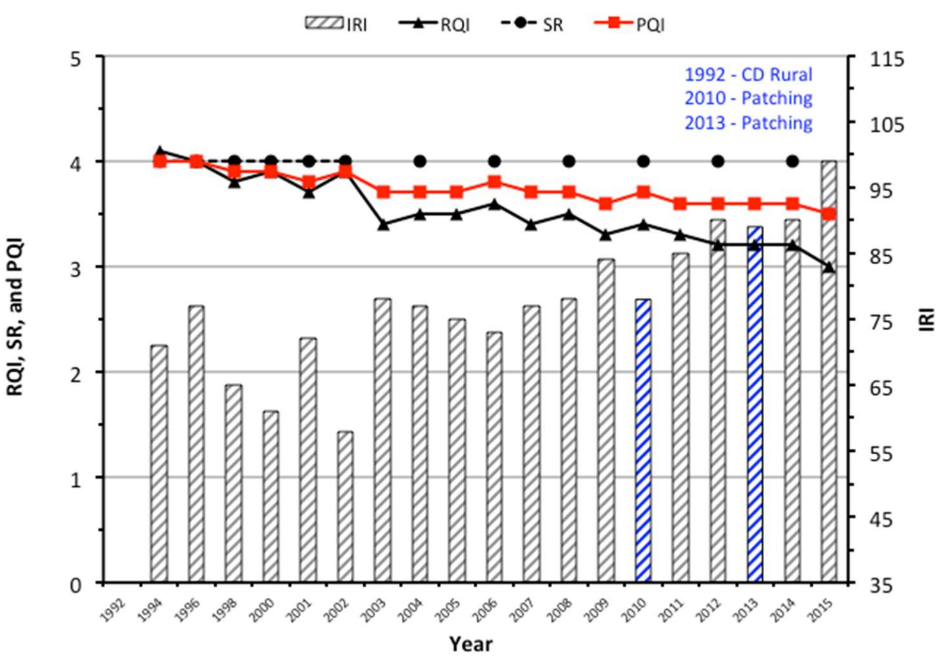


Figure B.232. Pavement management system data for section 107+0.000, direction U, of project 7204–13 constructed in 1992. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

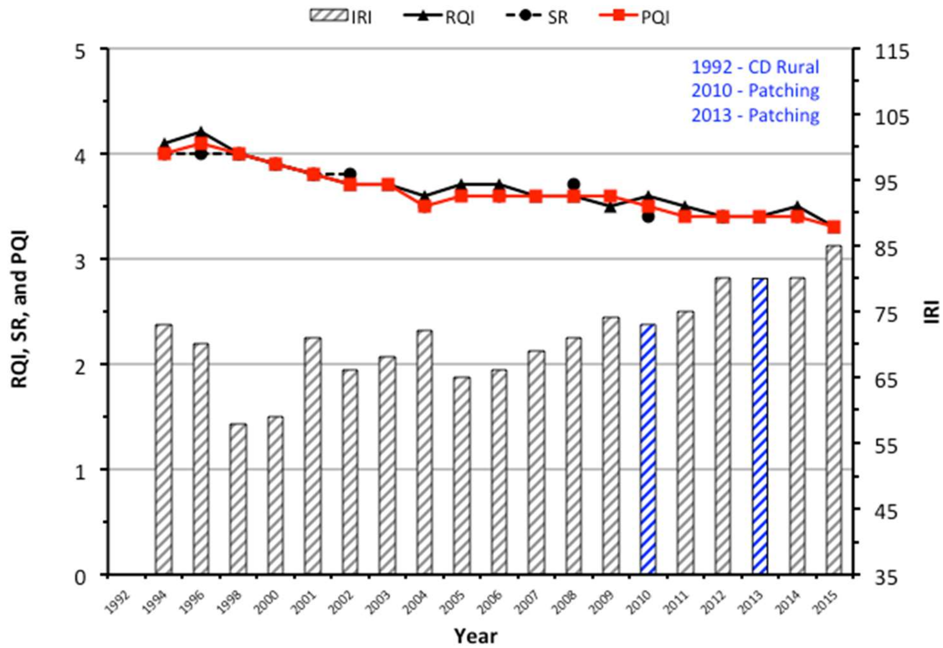


Figure B.233. Pavement management system data for section 108+0.000, direction U, of project 7204–13 constructed in 1992. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

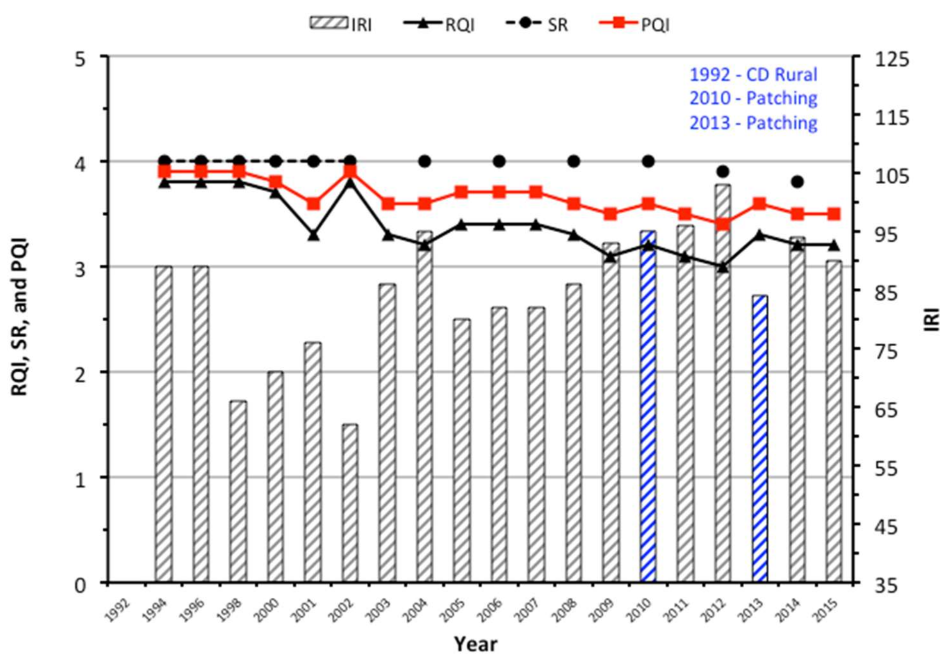


Figure B.234. Pavement management system data for section 109+0.000, direction U, of project 7204–13 constructed in 1992. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

District 7 – 3204-59

Table B.113. Measured IRI for selected sections of project 3204-59, constructed in 2002. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)										
Year	27 +0.885 D	29 +0.000 D	30 +0.000 D	31 +0.000 D	32 +0.000 D	33 +0.000 D	34 +0.000 D	35 +0.000 D	27 +0.885 I	29 +0.000 I	30 +0.000 I
2002											
2003	77	76	71	70	70	60	64	79	79	73	73
2004	83	74	77	72	72	62	67	81	77	73	71
2005	88	79	81	78	78	67	73	84	80	72	76
2006	86	80	80	80	80	70	74	80	74	65	67
2007	90	80	82	80	80	66	75	79	81	69	74
2008	93	86	88	89	89	77	83	86	82	72	83
2009	107	101	103	103	103	91	96	97	92	81	84
2010	100	95	96	96	96	87	89	93	77	69	73
2011	98	90	91	92	92	80	86	92	87	78	79
2012	95	89	90	90	90	80	86	90	105	94	96
2013	98	93	92	94	102	87	89	98	92	80	83
2014	100	100	102	111	93	97	99	105	73	78	63
2015	96	98	98	106	86	92	95	95	85	88	68

Table B.114. Measured PQI for selected sections of project 3204-59, constructed in 2002. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)										
	27 +0.885	29 +0.000	30 +0.000	31 +0.000	32 +0.000	33 +0.000	34 +0.000	35 +0.000	27 +0.885	29 +0.000	30 +0.000
Year	D	D	D	D	D	D	D	D	I	I	I
2002											
2003	3.8	3.8	3.8	3.8	3.8	3.9	3.9	3.8	3.2	3.3	3.3
2004	3.7	3.8	3.8	3.8	3.8	3.9	3.9	3.8	3.2	3.3	3.4
2005	3.6	3.7	3.7	3.8	3.8	3.8	3.8	3.7	3.1	3.2	3.2
2006	3.7	3.7	3.7	3.7	3.7	3.8	3.8	3.7	3.2	3.4	3.4
2007	3.6	3.7	3.7	3.7	3.7	3.9	3.8	3.7	3.7	3.8	3.8
2008	3.6	3.7	3.6	3.6	3.6	3.7	3.7	3.7	3.7	3.8	3.7
2009	3.4	3.5	3.5	3.5	3.5	3.6	3.5	3.5	3.6	3.7	3.7
2010	3.5	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.8	3.8	3.8
2011	3.6	3.6	3.6	3.6	3.6	3.7	3.7	3.6	3.7	3.7	3.8
2012	3.6	3.6	3.6	3.6	3.6	3.7	3.7	3.6	3.5	3.6	3.6
2013	3.5	3.6	3.6	3.6	3.5	3.6	3.6	3.5	3.6	3.7	3.7
2014	3.5	3.5	3.5	3.4	3.6	3.5	3.5	3.3	3.8	3.8	3.6
2015	3.6	3.6	3.5	3.5	3.6	3.6	3.6	3.4	3.7	3.7	3.7

Table B.115. Measured RQI for selected sections of project 3204-59, constructed in 2002. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)										
	27 +0.885	29 +0.000	30 +0.000	31 +0.000	32 +0.000	33 +0.000	34 +0.000	35 +0.000	27 +0.885	29 +0.000	30 +0.000
Year	D	D	D	D	D	D	D	D	I	I	I
2002											
2003	3.7	3.6	3.7	3.7	3.7	3.9	3.8	3.6	3.6	3.7	3.7
2004	3.5	3.6	3.6	3.7	3.7	3.9	3.8	3.6	3.6	3.7	3.8
2005	3.3	3.5	3.5	3.6	3.6	3.7	3.6	3.4	3.5	3.6	3.6
2006	3.4	3.5	3.5	3.5	3.5	3.7	3.6	3.5	3.6	3.8	3.8
2007	3.3	3.5	3.4	3.5	3.5	3.8	3.6	3.5	3.5	3.7	3.7
2008	3.2	3.4	3.3	3.3	3.3	3.5	3.4	3.4	3.4	3.7	3.5
2009	2.9	3.1	3.0	3.0	3.0	3.2	3.1	3.1	3.2	3.4	3.4
2010	3.1	3.2	3.2	3.2	3.2	3.3	3.3	3.2	3.6	3.7	3.7
2011	3.2	3.3	3.3	3.3	3.3	3.5	3.4	3.3	3.4	3.5	3.6
2012	3.2	3.3	3.3	3.3	3.3	3.5	3.4	3.3	3.0	3.2	3.2
2013	3.1	3.2	3.2	3.2	3.1	3.3	3.3	3.1	3.2	3.5	3.5
2014	3.1	3.1	3.0	2.9	3.2	3.1	3.1	3.0	3.6	3.6	3.7
2015	3.2	3.2	3.1	3.0	3.3	3.3	3.2	3.2	3.4	3.4	3.6

Table B.116. Measured SR for selected sections of project 3204-59, constructed in 2002. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)										
	27 +0.885	29 +0.000	30 +0.000	31 +0.000	32 +0.000	33 +0.000	34 +0.000	35 +0.000	27 +0.885	29 +0.000	30 +0.000
Year	D	D	D	D	D	D	D	D	I	I	I
2002											
2003	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0			
2004	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0			
2005								4.0			
2006											
2007	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2008											
2009	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2010											
2011	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2012											
2013	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2014											
2015	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.7	4.0	4.0	3.9

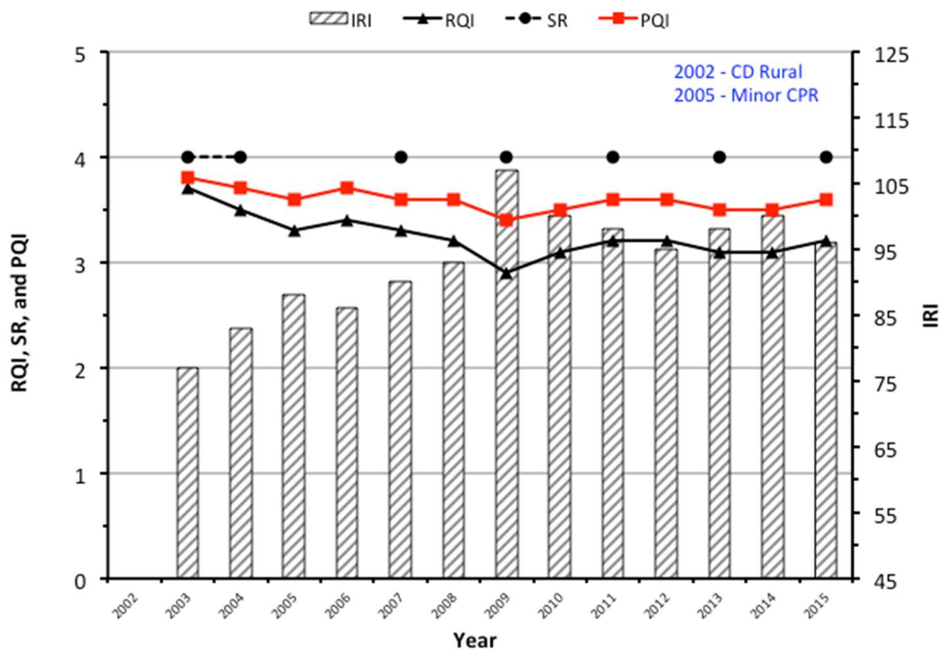


Figure B.235. Pavement management system data for section 27+0.885, direction D, of project 3204–59 constructed in 2002. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

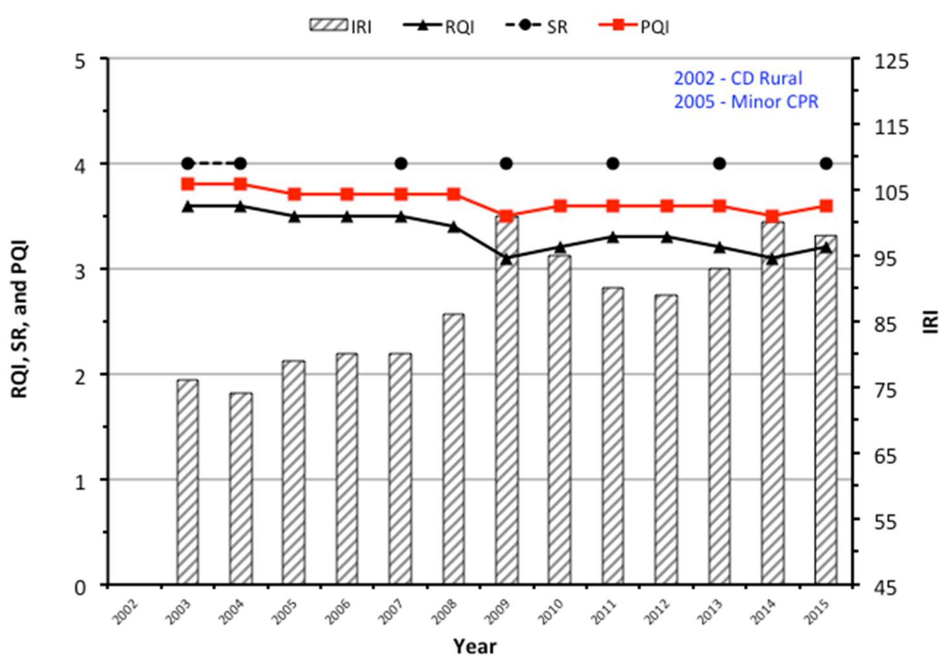


Figure B.236. Pavement management system data for section 29+0.000, direction D, of project 3204–59 constructed in 2002. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

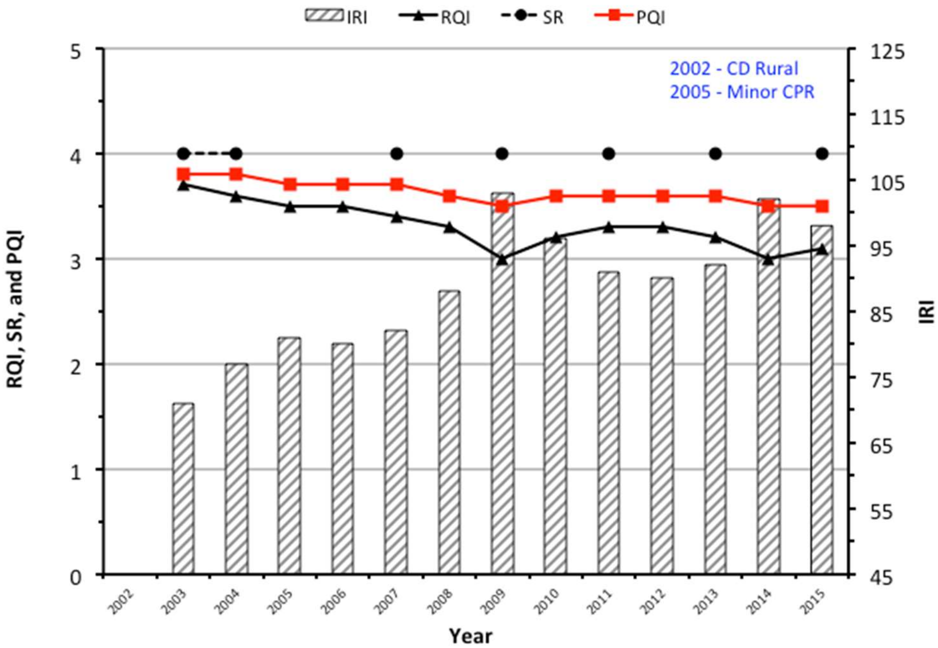


Figure B.237. Pavement management system data for section 30+0.000, direction D, of project 3204–59 constructed in 2002. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

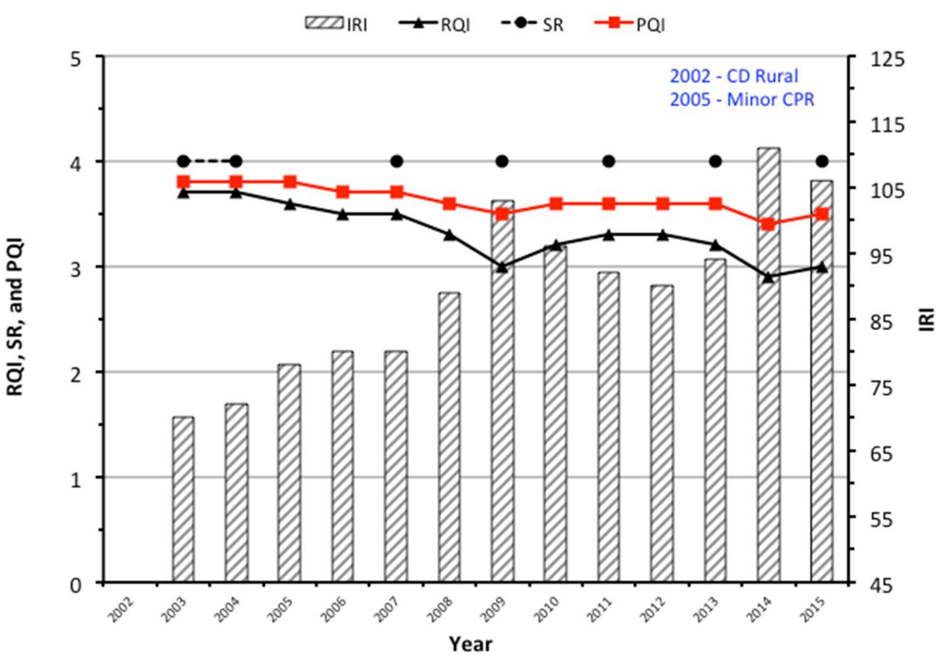


Figure B.238. Pavement management system data for section 31+0.000, direction D, of project 3204–59 constructed in 2002. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

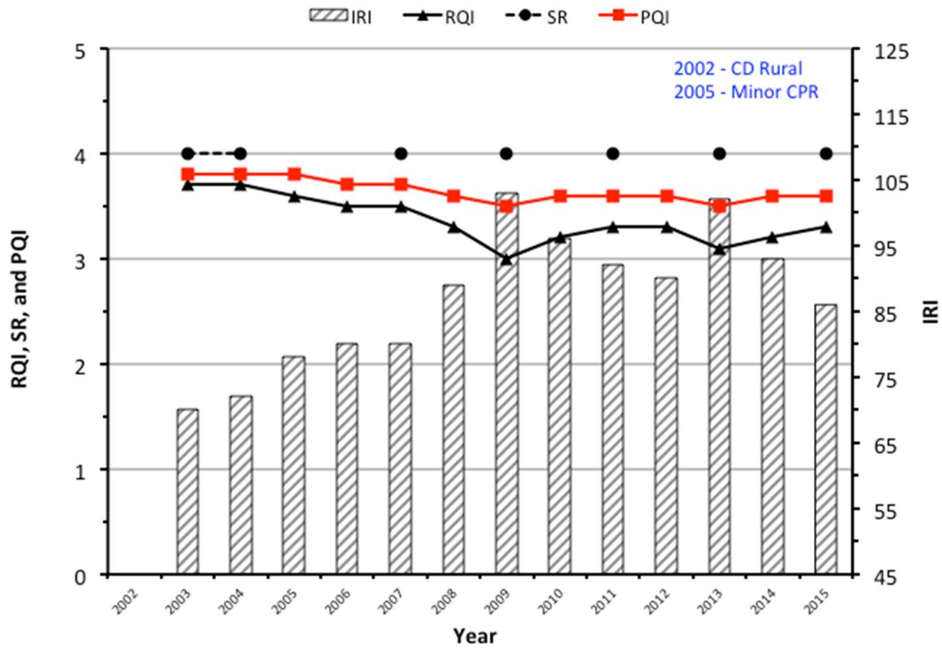


Figure B.239. Pavement management system data for section 32+0.000, direction D, of project 3204–59 constructed in 2002. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

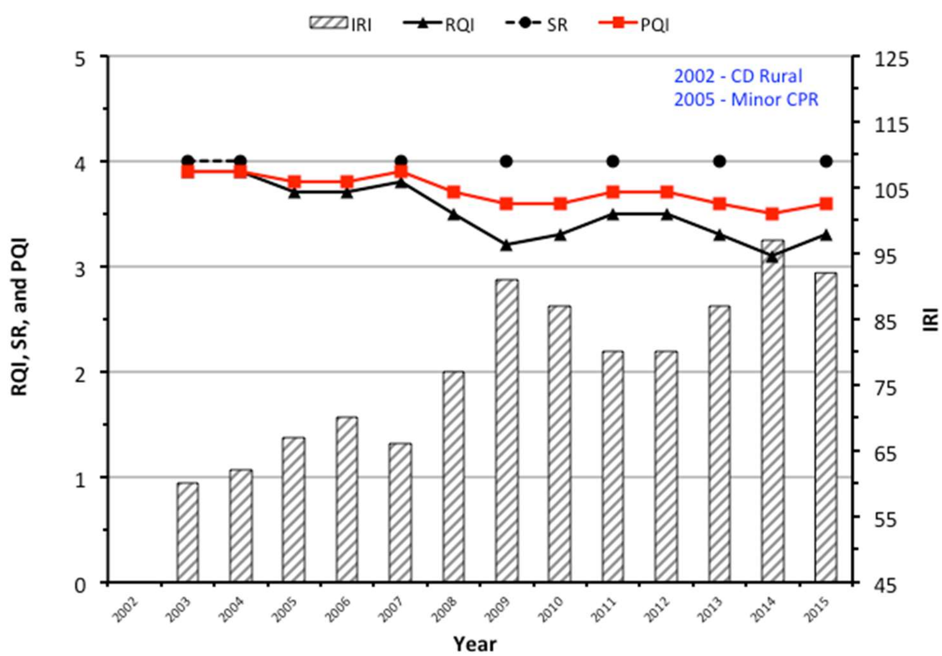


Figure B.240. Pavement management system data for section 33+0.000, direction D, of project 3204–59 constructed in 2002. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

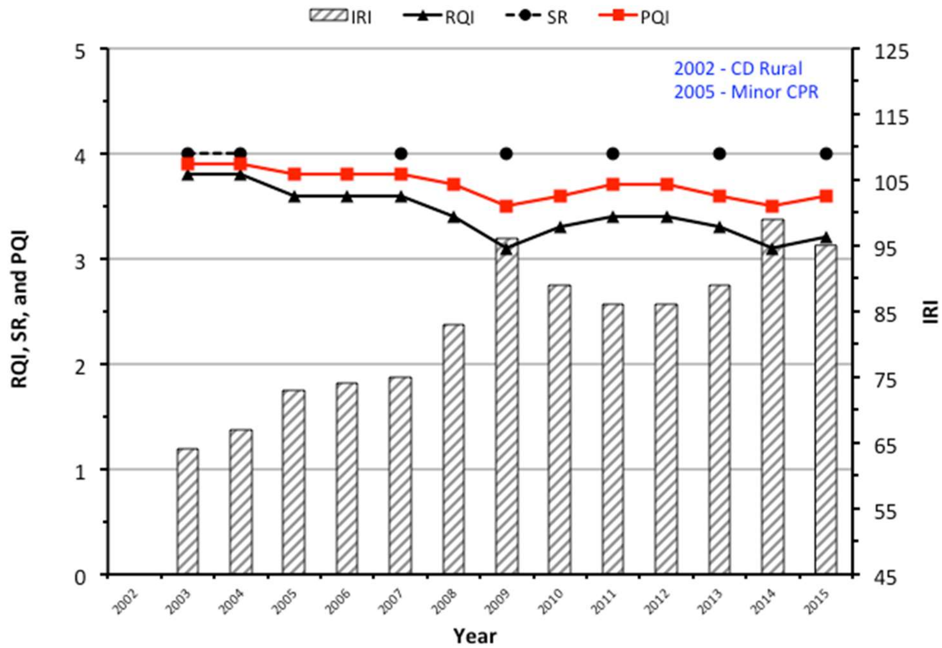


Figure B.241. Pavement management system data for section 34+0.000, direction D, of project 3204–59 constructed in 2002. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

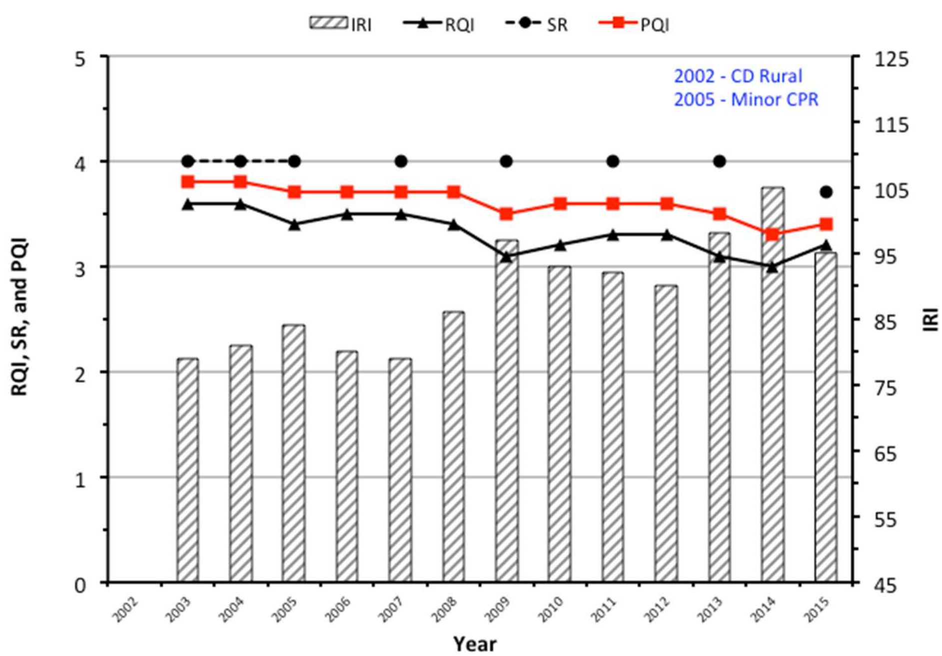


Figure B.242. Pavement management system data for section 35+0.000, direction D, of project 3204–59 constructed in 2002. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

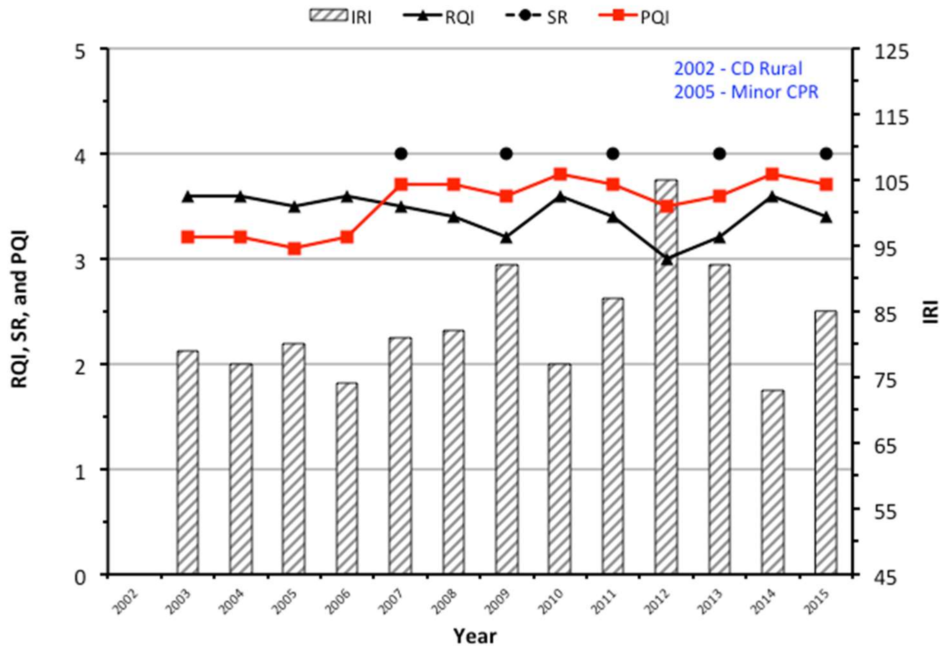


Figure B.243. Pavement management system data for section 27+0.885, direction I, of project 3204–59 constructed in 2002. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

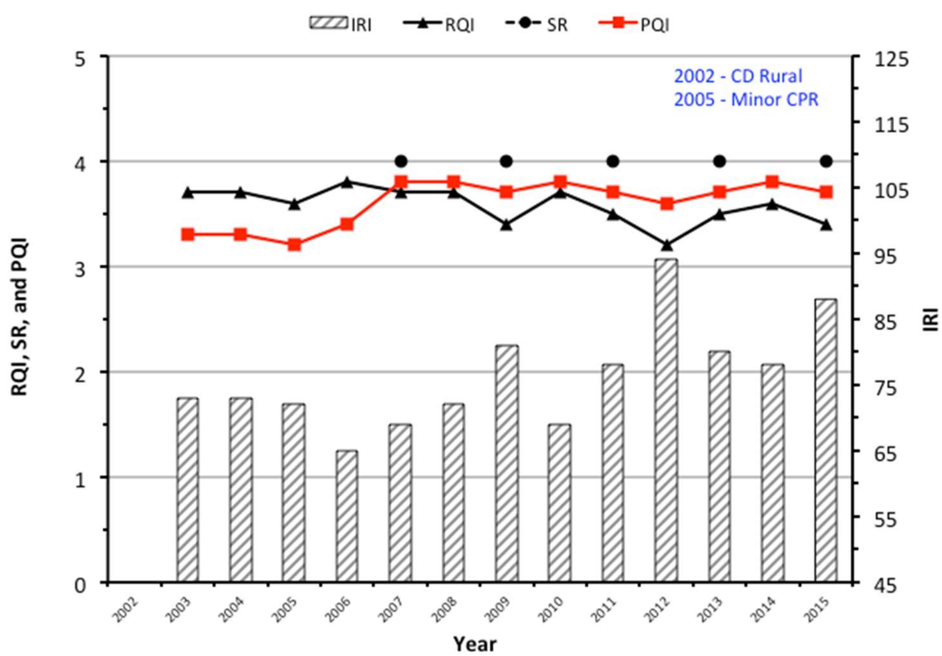


Figure B.244. Pavement management system data for section 29+0.000, direction I, of project 3204–59 constructed in 2002. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

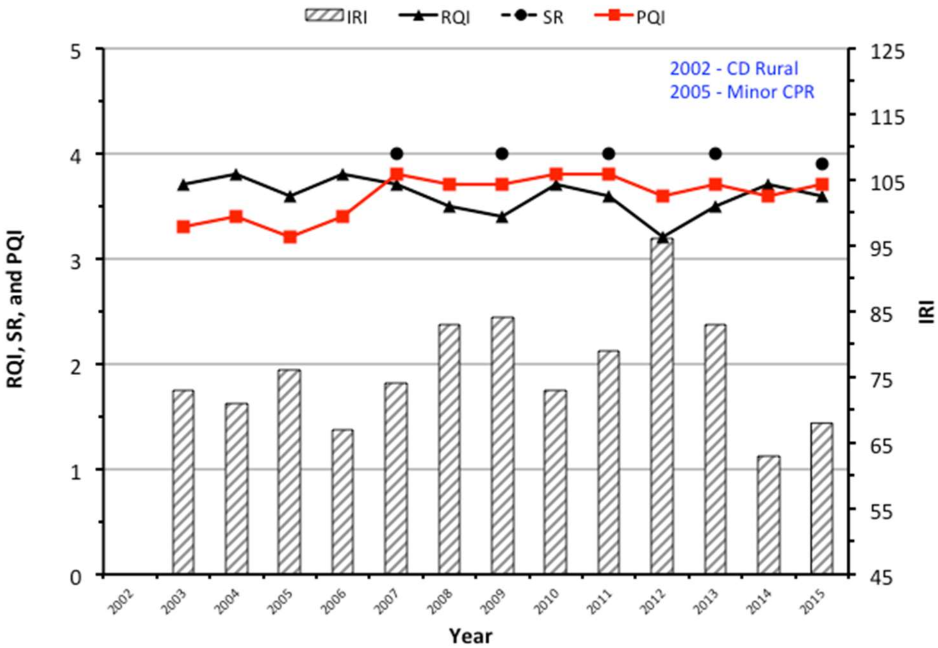


Figure B.245. Pavement management system data for section 30+0.000, direction I, of project 3204–59 constructed in 2002. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

District 7 – 3204-62

Table B.117. Measured IRI for selected sections of project 3204-62, constructed in 2000. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)								
	19 +0.663	20 +0.000	21 +0.000	22 +0.000	23 +0.000	24 +0.000	25 +0.000	26 +0.000	27 +0.000
Year	D	D	D	D	D	D	D	D	D
2000									
2001									
2002	49	51	49	58	53	75	67	86	57
2003	91	88	89	93	86	106	99	108	93
2004	84	78	80	85	79	97	88	109	91
2005	89	82	86	91	84	103	95	113	91
2006	89	85	81	90	80	98	90	109	87
2007	83	79	81	84	80	94	86	107	91
2008	91	88	86	94	86	105	97	115	93
2009	101	100	96	106	94	113	107	124	102
2010	99	95	89	102	89	108	102	119	96
2011	92	87	86	94	85	105	96	118	95
2012	87	85	86	91	85	103	94	114	92
2013	92	89	86	97	86	103	96	115	95
2014	93	89	100	89	106	101	118	98	107
2015	90	87	96	87	106	98	118	97	105

Table B.118. Measured PQI for selected sections of project 3204-62, constructed in 2000. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)								
	19 +0.663	20 +0.000	21 +0.000	22 +0.000	23 +0.000	24 +0.000	25 +0.000	26 +0.000	27 +0.000
Year	D	D	D	D	D	D	D	D	D
2000									
2001									
2002	3.3	3.3	3.2	3.1	3.2	2.9	3.0	2.8	3.1
2003	3.5	3.5	3.5	3.5	3.6	3.3	3.4	3.3	3.4
2004	3.6	3.6	3.6	3.5	3.6	3.4	3.5	3.3	3.5
2005	3.5	3.6	3.5	3.5	3.5	3.3	3.4	3.3	3.5
2006	3.5	3.6	3.6	3.5	3.6	3.4	3.5	3.3	3.6
2007	3.5	3.6	3.6	3.6	3.6	3.4	3.5	3.3	3.5
2008	3.5	3.6	3.5	3.5	3.5	3.3	3.4	3.3	3.5
2009	3.3	3.4	3.4	3.3	3.5	3.2	3.3	3.1	3.3
2010	3.4	3.5	3.5	3.4	3.5	3.3	3.4	3.2	3.5
2011	3.5	3.6	3.5	3.5	3.5	3.3	3.5	3.2	3.5
2012	3.5	3.6	3.5	3.5	3.5	3.3	3.5	3.2	3.5
2013	3.5	3.5	3.6	3.4	3.5	3.3	3.5	3.3	3.5
2014	3.5	3.5	3.4	3.5	3.3	3.4	3.3	3.5	3.5
2015	3.5	3.5	3.4	3.5	3.3	3.4	3.2	3.5	3.5

Table B.119. Measured RQI for selected sections of project 3204-62, constructed in 2000. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)								
	19 +0.663	20 +0.000	21 +0.000	22 +0.000	23 +0.000	24 +0.000	25 +0.000	26 +0.000	27 +0.000
Year	D	D	D	D	D	D	D	D	D
2000									
2001									
2002	3.7	3.7	3.6	3.5	3.6	3.2	3.4	3.1	3.5
2003	3.1	3.1	3.1	3.0	3.2	2.8	2.9	2.7	2.9
2004	3.2	3.3	3.2	3.1	3.2	2.9	3.1	2.7	3.0
2005	3.0	3.2	3.1	3.0	3.1	2.7	2.9	2.7	3.1
2006	3.1	3.2	3.2	3.1	3.3	2.9	3.1	2.8	3.2
2007	3.1	3.3	3.2	3.2	3.2	2.9	3.1	2.7	3.1
2008	3.1	3.2	3.1	3.0	3.1	2.8	2.9	2.7	3.1
2009	2.8	2.9	2.9	2.7	3.0	2.6	2.7	2.4	2.8
2010	2.9	3.0	3.1	2.9	3.1	2.8	2.9	2.6	3.0
2011	3.0	3.2	3.1	3.0	3.1	2.7	3.0	2.6	3.0
2012	3.1	3.2	3.1	3.0	3.1	2.8	3.0	2.6	3.0
2013	3.0	3.1	3.2	2.9	3.1	2.8	3.0	2.7	3.0
2014	3.1	3.1	2.9	3.1	2.8	2.9	2.7	3.0	3.0
2015	3.1	3.1	2.9	3.1	2.8	2.9	2.6	3.0	3.0

Table B.120. Measured SR for selected sections of project 3204-62, constructed in 2000. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)								
	19 +0.663	20 +0.000	21 +0.000	22 +0.000	23 +0.000	24 +0.000	25 +0.000	26 +0.000	27 +0.000
Year	D	D	D	D	D	D	D	D	D
2000									
2001									
2002									
2003	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2004									
2005	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2006									
2007	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2008									
2009	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2010									
2011	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2012									
2013	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2014									
2015	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0

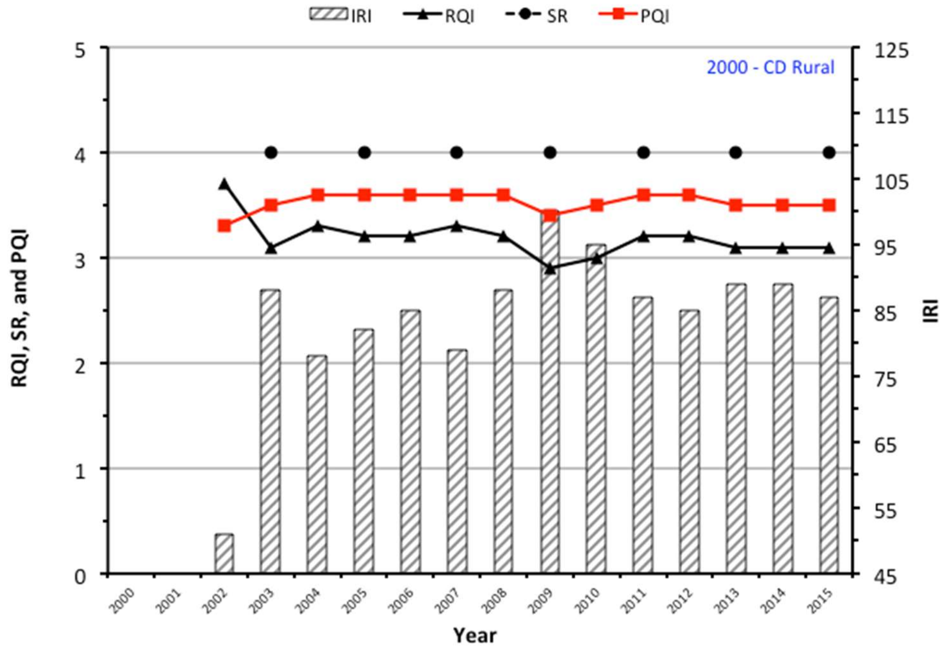


Figure B.246. Pavement management system data for section 19+0.663, direction DIU, of project 3204–62 constructed in 2000. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

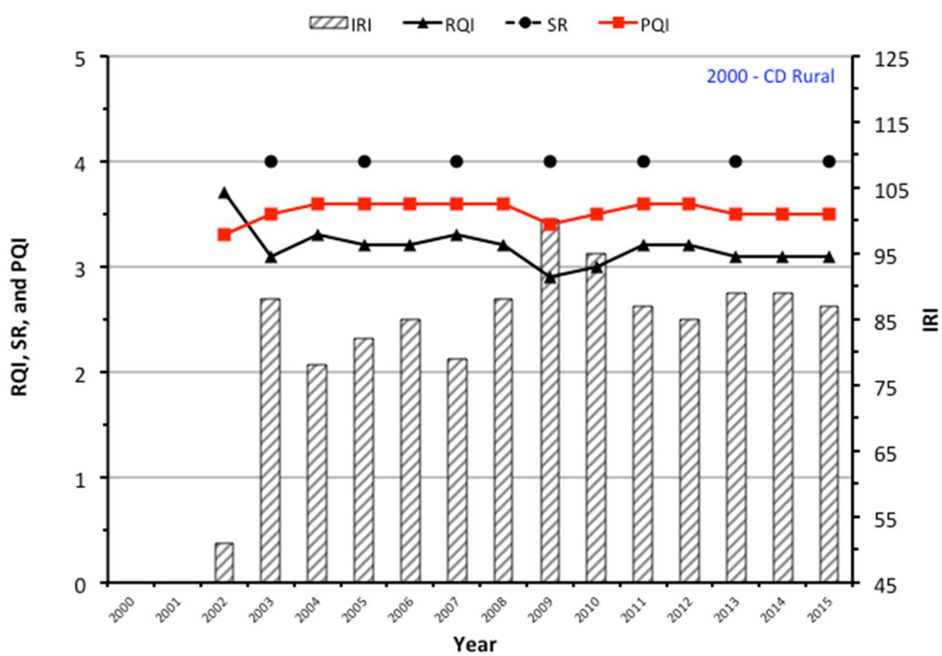


Figure B.247. Pavement management system data for section 20+0.000, direction DIU, of project 3204–62 constructed in 2000. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

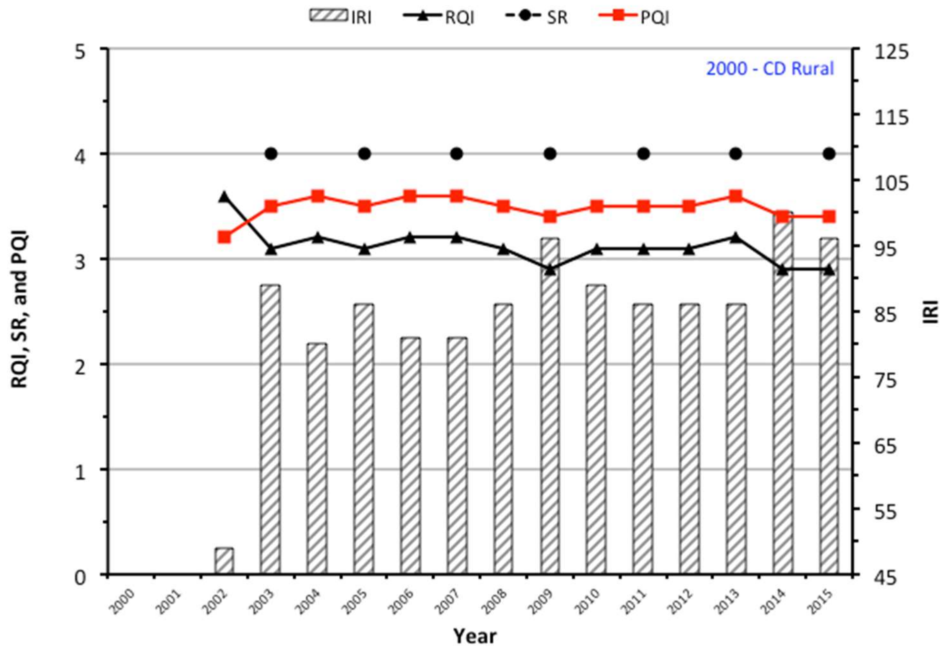


Figure B.248. Pavement management system data for section 21+0.000, direction DIU, of project 3204–62 constructed in 2000. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

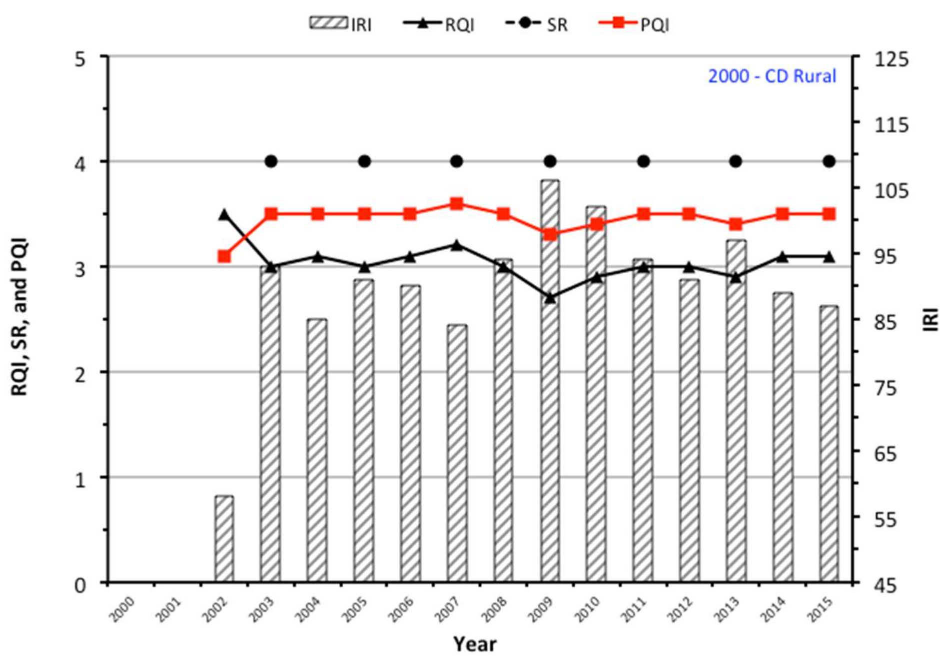


Figure B.249. Pavement management system data for section 22+0.000, direction DIU, of project 3204–62 constructed in 2000. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

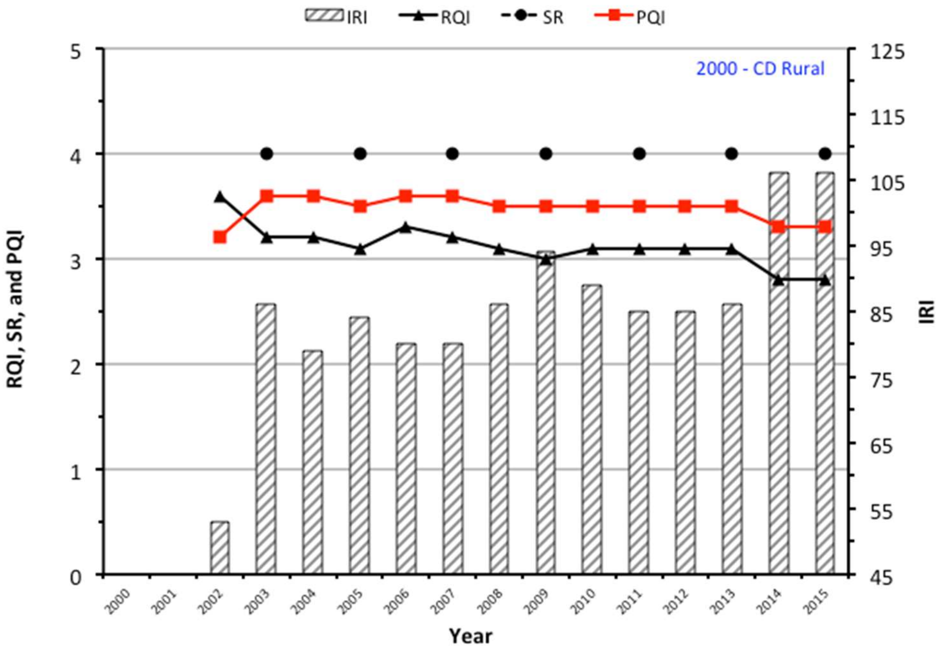


Figure B.250. Pavement management system data for section 23+0.000, direction DIU, of project 3204–62 constructed in 2000. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

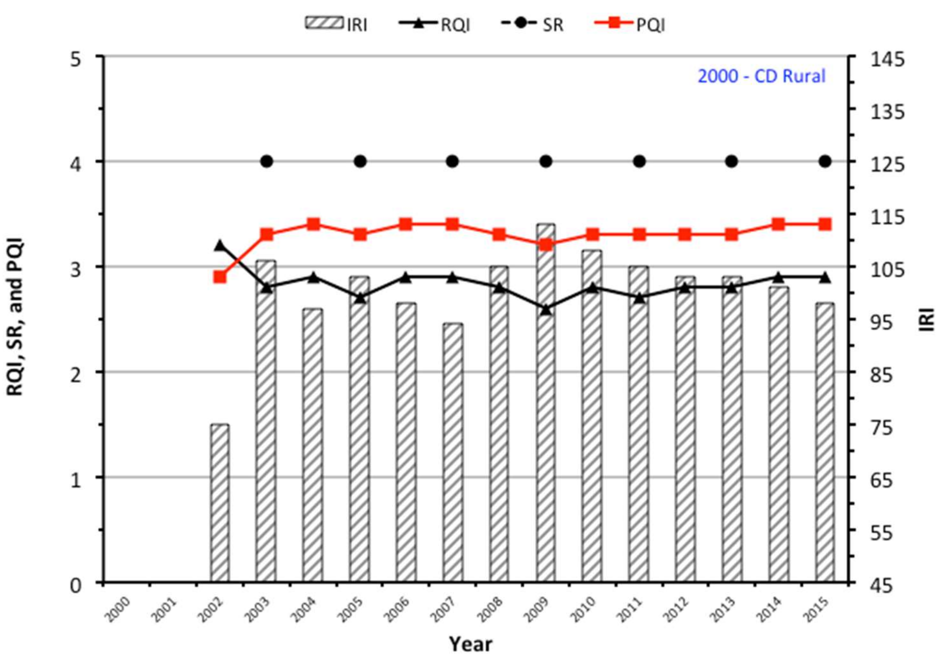


Figure B.251. Pavement management system data for section 24+0.000, direction DIU, of project 3204–62 constructed in 2000. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

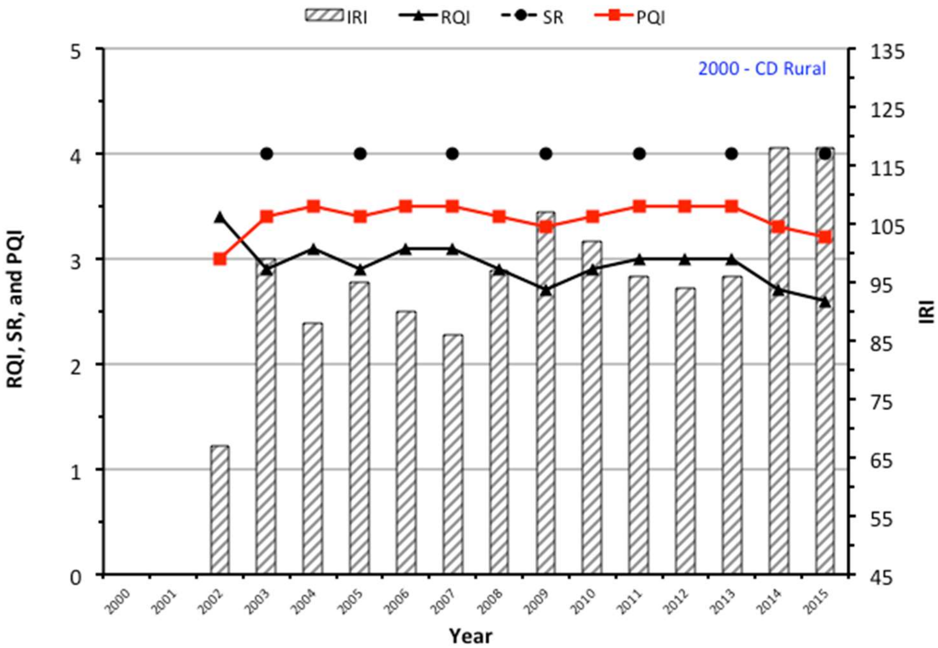


Figure B.252. Pavement management system data for section 25+0.000, direction DIU, of project 3204–62 constructed in 2000. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

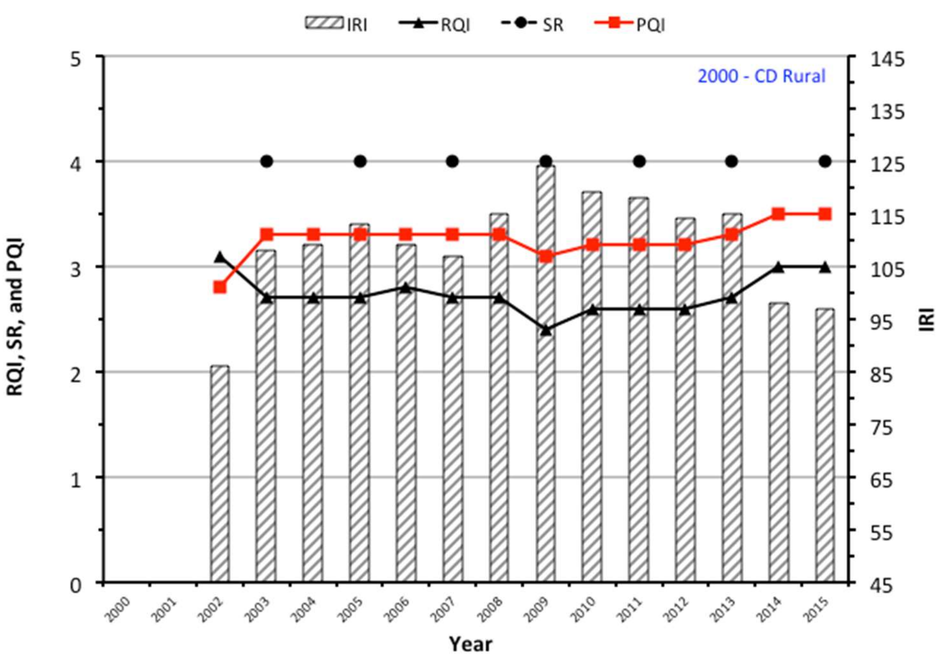


Figure B.253. Pavement management system data for section 26+0.000, direction DIU, of project 3204–62 constructed in 2000. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

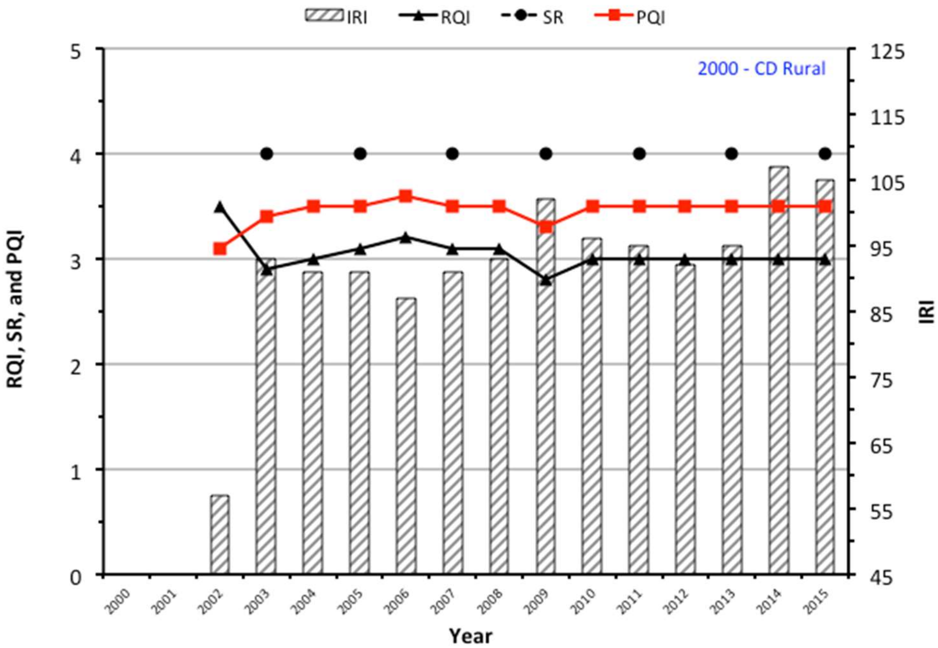


Figure B.254. Pavement management system data for section 27+0.000, direction DIU, of project 3204–62 constructed in 2000. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

District 8 – 4705-30

Table B.121. Measured IRI for selected sections of project 4705-30, constructed in 1996. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)			
	111 +0.482	112 +0.000	113 +0.000	114 +0.000
Year	U	U	U	U
1996				
1997	92	99	64	54
1999	94	101	68	58
2001	109	111	70	73
2002	103	106	71	70
2003	111	120	80	77
2004	113	123	88	78
2005	125	130	102	90
2006	109	115	83	76
2007	117	122	87	83
2008	114	122	87	82
2009	125	131	105	97
2010	112	120	85	83
2011	118	129	102	95
2012	122	129	101	94
2013	117	129	96	92
2014	123	133	106	100
2015	120	131	101	97

Table B.122. Measured PQI for selected sections of project 4705-30, constructed in 1996. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)			
	111 +0.482	112 +0.000	113 +0.000	114 +0.000
Year	U	U	U	U
1996				
1997	3.6	3.5	3.9	4.0
1999	3.6	3.5	3.8	4.0
2001	3.4	3.3	3.8	3.8
2002	3.4	3.4	3.7	3.8
2003	3.3	3.3	3.7	3.7
2004	3.3	3.3	3.6	3.7
2005	3.2	3.2	3.5	3.6
2006	3.3	3.3	3.7	3.7
2007	3.3	3.3	3.6	3.6
2008	3.3	3.3	3.6	3.7
2009	3.2	3.2	3.5	3.5
2010	3.4	3.3	3.6	3.6
2011	3.3	3.2	3.5	3.6
2012	3.2	3.2	3.5	3.6
2013	3.3	3.2	3.6	3.6
2014	3.3	3.2	3.5	3.5
2015	3.3	3.2	3.5	3.6

Table B.123. Measured RQI for selected sections of project 4705-30, constructed in 1996. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)			
	111 +0.482	112 +0.000	113 +0.000	114 +0.000
Year	U	U	U	U
1996				
1997	3.2	3.1	3.8	4.0
1999	3.2	3.1	3.7	4.0
2001	2.9	2.8	3.6	3.6
2002	2.9	2.9	3.5	3.7
2003	2.8	2.7	3.5	3.5
2004	2.8	2.7	3.3	3.5
2005	2.6	2.6	3.1	3.3
2006	2.8	2.8	3.4	3.5
2007	2.7	2.7	3.3	3.3
2008	2.8	2.7	3.3	3.4
2009	2.6	2.5	3.0	3.0
2010	2.9	2.7	3.3	3.3
2011	2.7	2.6	3.1	3.2
2012	2.6	2.6	3.1	3.2
2013	2.7	2.6	3.2	3.2
2014	2.7	2.5	3.0	3.1
2015	2.7	2.5	3.1	3.2

Table B.124. Measured SR for selected sections of project 4705-30, constructed in 1996. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)			
	111 +0.482	112 +0.000	113 +0.000	114 +0.000
Year	U	U	U	U
1996				
1997	4.0	4.0	4.0	4.0
1999	4.0	4.0	4.0	4.0
2001	4.0	4.0	4.0	4.0
2002				
2003	4.0	4.0	4.0	4.0
2004				
2005	4.0	4.0	4.0	4.0
2006				
2007	4.0	4.0	4.0	4.0
2008				
2009	4.0	4.0	4.0	4.0
2010				
2011	4.0	4.0	4.0	4.0
2012				
2013	4.0	4.0	4.0	4.0
2014				
2015	4.0	4.0	4.0	4.0

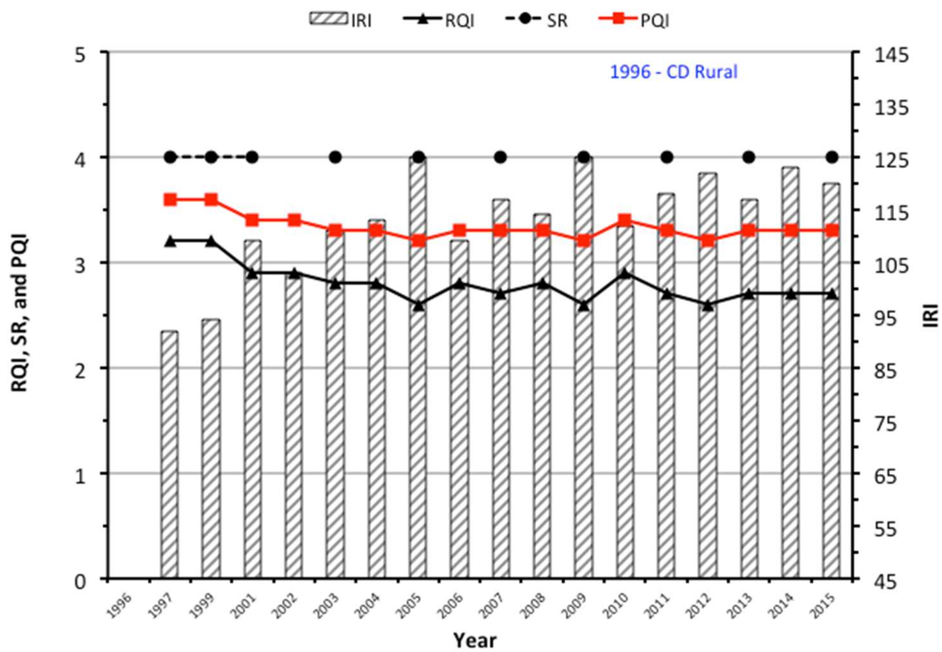


Figure B.255. Pavement management system data for section 11+0.482, direction U, of project 4705–30 constructed in 1996. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

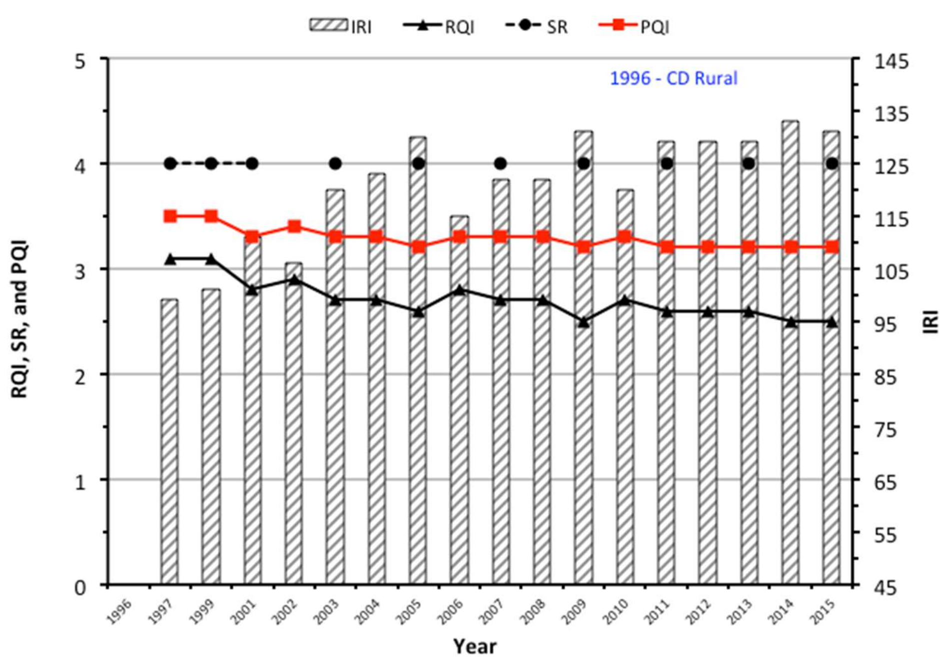


Figure B.256. Pavement management system data for section 12+0.000, direction U, of project 4705–30 constructed in 1996. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

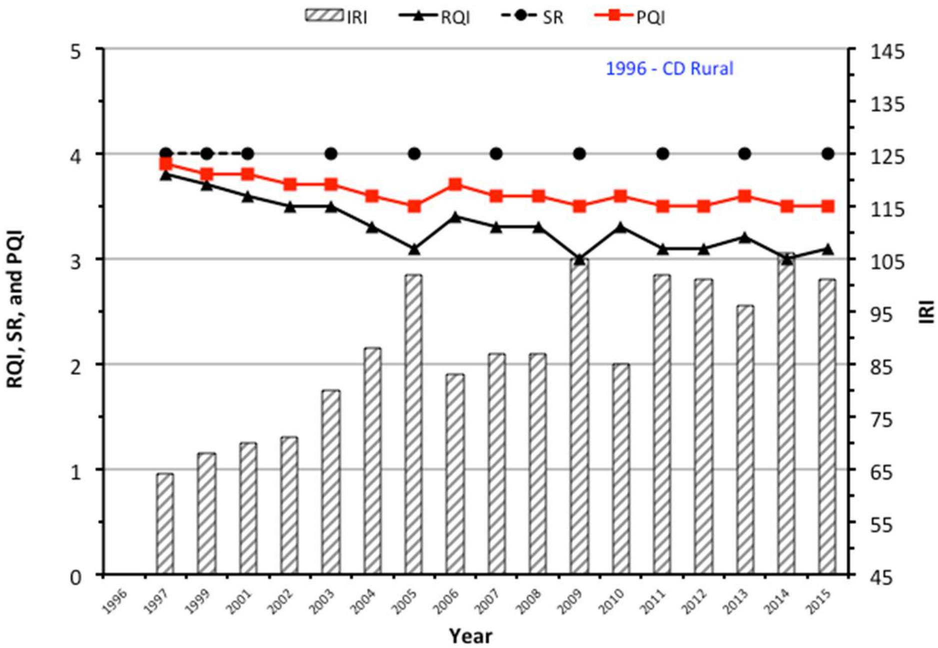


Figure B.257. Pavement management system data for section 13+0.000, direction U, of project 4705–30 constructed in 1996. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

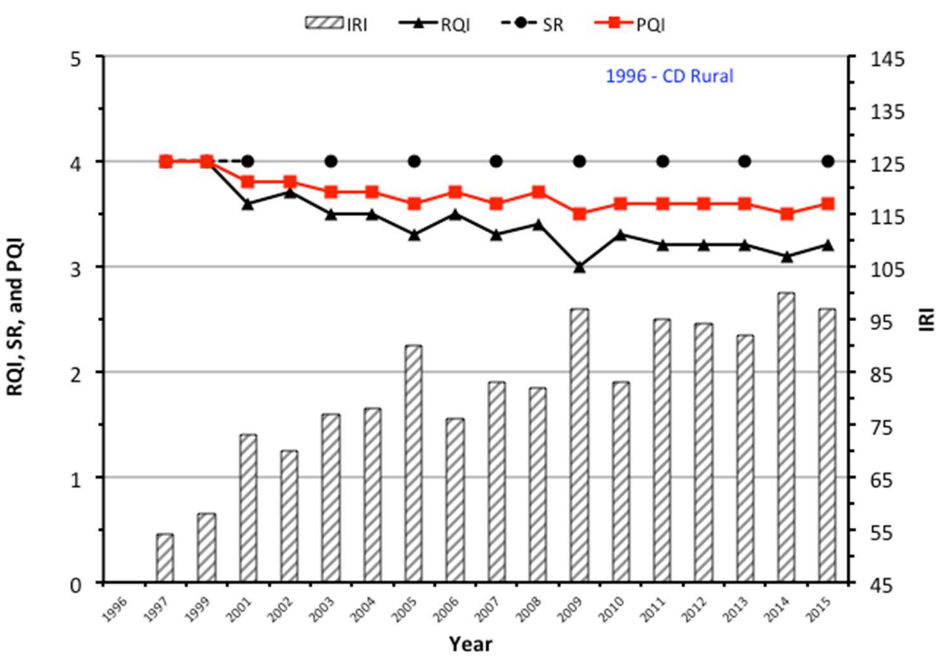


Figure B.258. Pavement management system data for section 14+0.000, direction U, of project 4705–30 constructed in 1996. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

District 8 – 6404-32

Table B.125. Measured IRI for selected sections of project 6404-32, constructed in 1997. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)						
	73 +0.691	74 +0.000	75 +0.202	76 +0.000	77 +0.000	78 +0.000	78 +0.439
Year	U	U	U	U	U	U	U
1997							
1999	54	54	67	77	70	67	87
2001	40	36	85	103	85	95	102
2002	51	42	103	118	94	99	110
2003	62	61	95	107	107	102	102
2004	60	61	97	108	109	105	102
2005	66	64	99	105	105	94	102
2006	55	60	92	94	101	88	103
2007	69	62	104	111	109	94	104
2008	82	86	107	119	118	104	119
2009	73	68	108	121	124	111	112
2010	61	60	99	109	116	97	112
2011	67	76	120	134	137	124	112
2012	72	68	106	118	121	100	116
2013	83	70	100	116	125	101	121
2014	84	94	105	119	120	100	117
2015	74	64	103	122	123	101	106

Table B.126. Measured PQI for selected sections of project 6404-32, constructed in 1997. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)						
	73 +0.691	74 +0.000	75 +0.202	76 +0.000	77 +0.000	78 +0.000	78 +0.439
Year	U	U	U	U	U	U	U
1997							
1999	4.0	4.0	3.9	3.7	3.8	3.9	3.6
2001	4.2	4.1	3.7	3.5	3.7	3.6	3.5
2002	3.9	4.1	3.6	3.3	3.6	3.5	3.4
2003	3.8	3.8	3.6	3.5	3.5	3.5	3.5
2004	3.9	3.8	3.7	3.6	3.5	3.5	3.5
2005	3.8	3.8	3.6	3.5	3.5	3.6	3.5
2006	3.9	3.8	3.7	3.6	3.6	3.7	3.5
2007	3.8	3.8	3.6	3.5	3.4	3.6	3.5
2008	3.7	3.8	3.5	3.4	3.3	3.5	3.4
2009	3.7	3.8	3.5	3.3	3.2	3.4	3.4
2010	3.8	3.8	3.6	3.5	3.3	3.6	3.4
2011	3.8	3.8	3.5	3.4	3.3	3.5	3.4
2012	3.7	3.8	3.6	3.4	3.3	3.6	3.4
2013	3.7	3.8	3.6	3.3	3.2	3.6	3.3
2014	3.6	3.8	3.5	3.3	3.2	3.5	3.4
2015	3.7	3.8	3.5	3.3	3.3	3.6	3.4

Table B.127. Measured RQI for selected sections of project 6404-32, constructed in 1997. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)						
	73 +0.691	74 +0.000	75 +0.202	76 +0.000	77 +0.000	78 +0.000	78 +0.439
Year	U	U	U	U	U	U	U
1997							
1999	4.0	4.0	3.8	3.5	3.7	3.8	3.3
2001	4.5	4.3	3.5	3.1	3.4	3.3	3.0
2002	3.9	4.2	3.2	2.8	3.2	3.1	2.9
2003	3.7	3.7	3.3	3.0	3.1	3.1	3.0
2004	3.8	3.7	3.4	3.2	3.1	3.0	3.0
2005	3.6	3.7	3.2	3.0	3.0	3.2	3.0
2006	3.8	3.7	3.4	3.2	3.2	3.5	3.1
2007	3.6	3.6	3.2	3.0	2.9	3.2	3.0
2008	3.5	3.7	3.0	2.9	2.8	3.1	2.9
2009	3.4	3.6	3.0	2.7	2.6	2.9	3.0
2010	3.7	3.7	3.3	3.0	2.8	3.2	3.0
2011	3.6	3.7	3.1	2.9	2.8	3.0	3.0
2012	3.5	3.7	3.2	2.9	2.8	3.2	2.9
2013	3.5	3.7	3.2	2.8	2.7	3.2	2.8
2014	3.4	3.7	3.0	2.8	2.7	3.0	2.9
2015	3.5	3.7	3.2	2.8	2.8	3.2	2.9

Table B.128. Measured SR for selected sections of project 6404-32, constructed in 1997. Sections are indicated by their starting reference point and direction as indicated in the MnDOT pavement management system database.

	Beginning Reference Point (BEGIN_RFP) and Direction (DIR)						
Year	73 +0.691 U	74 +0.000 U	75 +0.202 U	76 +0.000 U	77 +0.000 U	78 +0.000 U	78 +0.439 U
1997							
1999	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2001	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2002							
2003	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2004							
2005	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2006							
2007	4.0	4.0	4.0	4.0	4.0	4.0	4.0
2008							
2009	4.0	4.0	4.0	4.0	4.0	4.0	3.9
2010							
2011	4.0	3.9	4.0	4.0	4.0	4.0	3.9
2012							
2013	3.9	3.9	4.0	4.0	3.9	4.0	3.9
2014							
2015	3.9	4.0	3.9	3.8	4.0	4.0	4.0

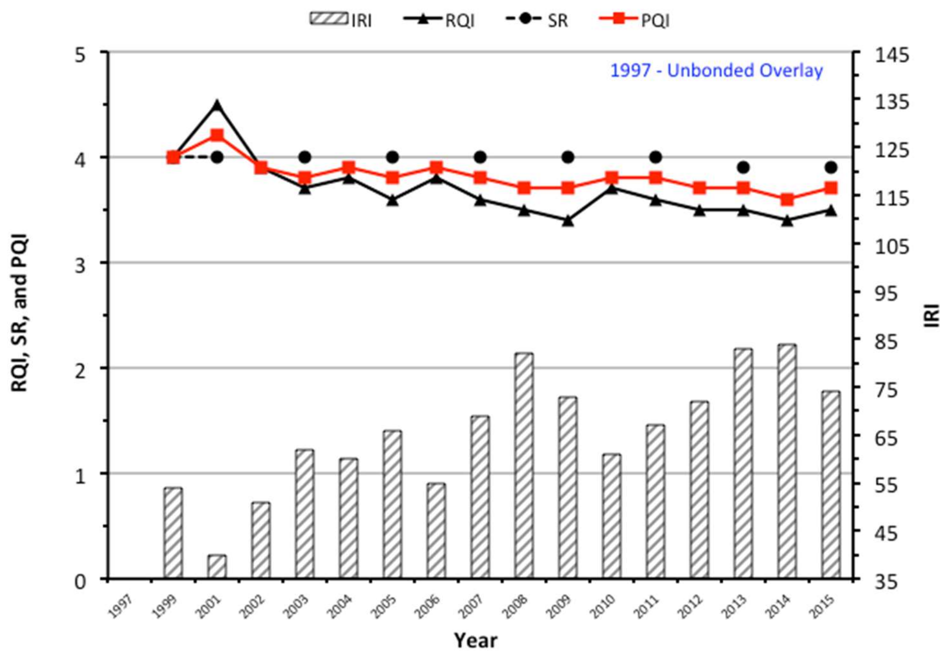


Figure B.259. Pavement management system data for section 73+0.691, direction U, of project 6404–32 constructed in 1997. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

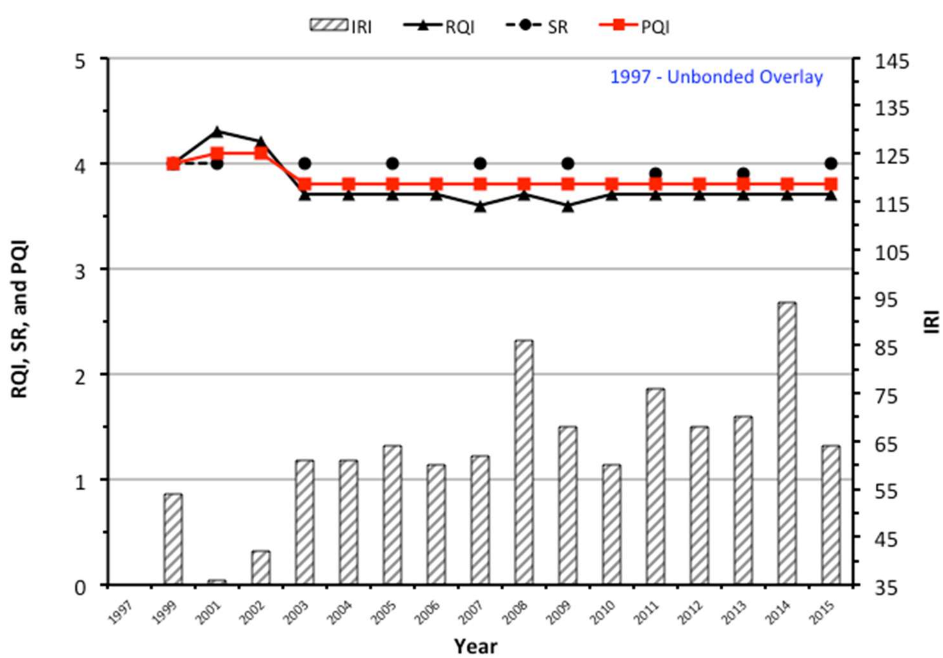


Figure B.260. Pavement management system data for section 74+0.000, direction U, of project 6404–32 constructed in 1997. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

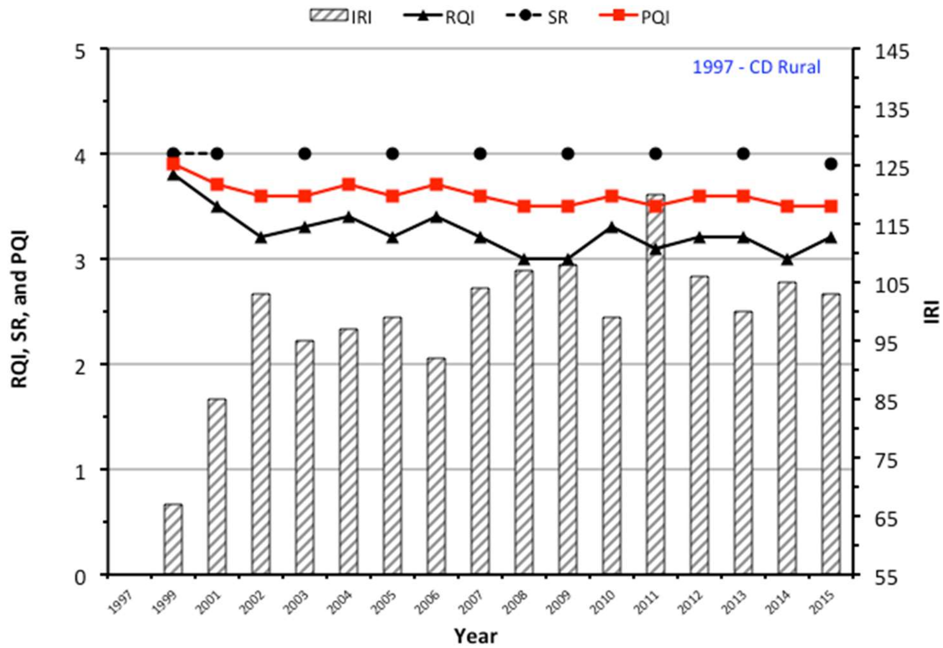


Figure B.261. Pavement management system data for section 75+0.202, direction U, of project 6404–32 constructed in 1997. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

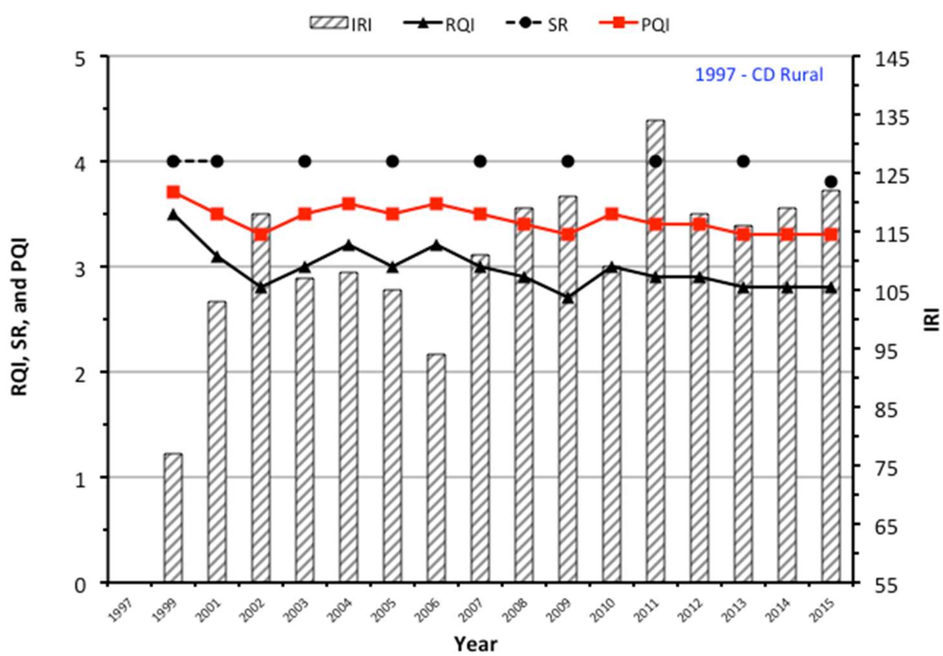


Figure B.262. Pavement management system data for section 76+0.000, direction U, of project 6404–32 constructed in 1997. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

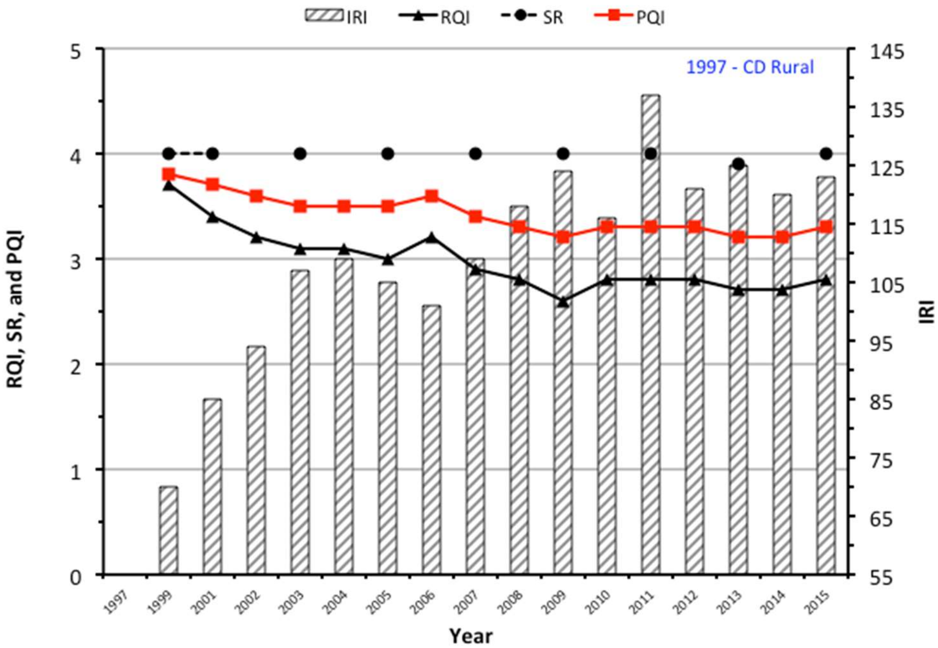


Figure B.263. Pavement management system data for section 77+0.000, direction U, of project 6404–32 constructed in 1997. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

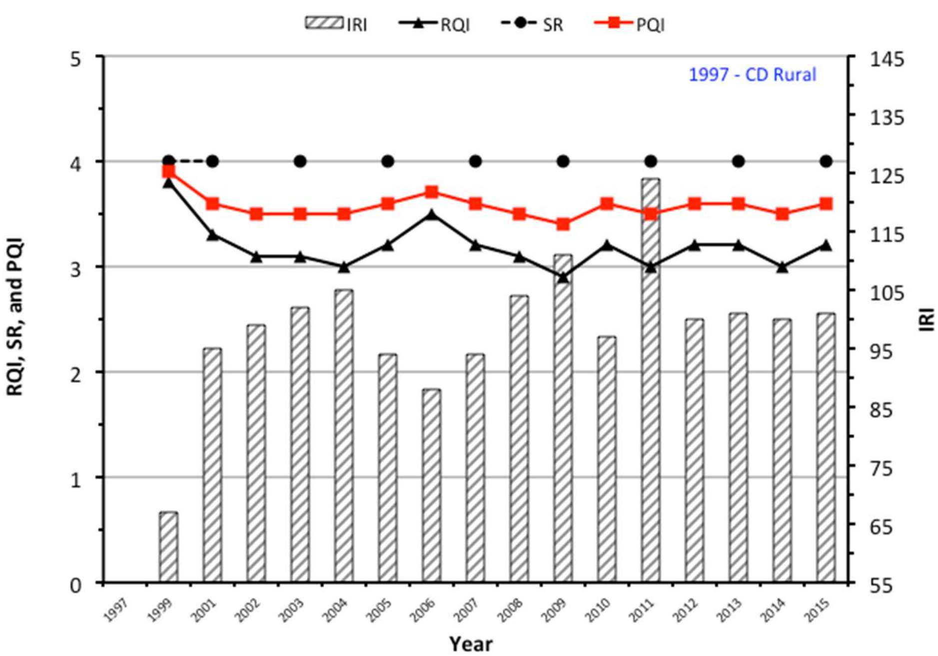


Figure B.264. Pavement management system data for section 78+0.000, direction U, of project 6404–32 constructed in 1997. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.

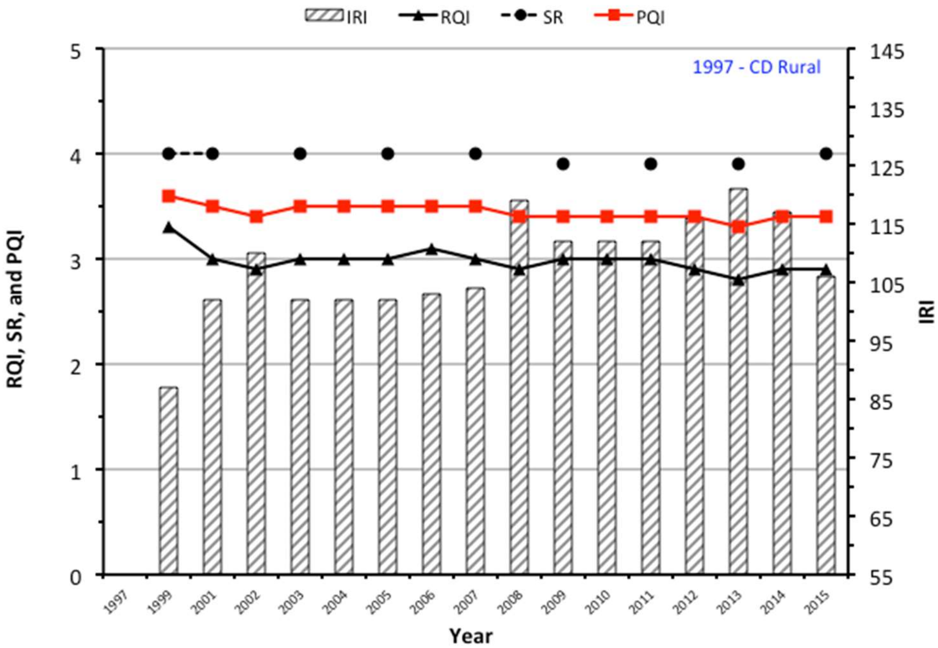


Figure B.265. Pavement management system data for section 78+0.439, direction U, of project 6404–32 constructed in 1997. Blue shaded IRI data bars indicate years when activities shown in the legend occurred.