2005-45

Final Report

Forensic Investigation Report For MnROAD Ultrathin Whitetopping Test Cells 93, 94 and 95

Research

Technical Report Documentation Page

1. Report No.	2.	3. Recipient's Accession No.
MN/RC - 2005-45		

4. Title and Subtitle	5. Report Date
FORENSIC INVESTIGATION REPORT FOR MN/ROAD ULTRATHIN WHITETOPPING TEST CELLS 93, 94, AND 95	September 2005
	6.
7. Author(s)	8. Performing Organization Report No.
Thomas R. Burnham	T9PR2004
9. Performing Organization Name and Address	10. Project/Task/Work Unit No.
Minnesota Department of Transportation Office of Materials and Road Research 1400 Gervais Avenue Maplewood, MN 55109	11. Contract © or (G)rant No.
12. Sponsoring Organization Name and Address	13. Type of Report and Period Covered
Minnesota Department of Transportation 395 John Ireland Boulevard Mail Stop 330 St. Paul,, MN 55155	Final Report
	14. Sponsoring Agency Code

15. Supplementary Notes

http://www.lrrb.org/PDF/2005-45

16. Abstract (Limit: 200 words)

Three instrumented ultra-thin whitetopping (UTW) pavement test sections were constructed in 1997 at the Minnesota Road Research facility (MnROAD). The sections were installed on the interstate highway portion of MnROAD to accelerate the traffic loadings compared to typical applications of UTW. By spring 2004, significant deterioration of the sections had occurred. Prior to replacement of the three test sections in fall 2004, a forensic investigation of the distresses was carried out. The focus of this report was to describe the forensic investigation procedures carried out, and to summarize findings from the investigation. The investigation revealed that the performance of ultra-thin whitetopping test cells at the MnROAD project was related to traffic volume, wheel placement, and layer bonding. Distresses were more frequent and severe in the higher-volume driving lane. Panel sizes that place wheelpaths near the edges of UTW slabs resulted in accelerated distress and poor performance. Bonding of UTW to the underlying asphalt layer was essential for long-term performance. Reflective cracking occurs in bonded concrete overlays for thicknesses less than 5 inches (over 6 inch minimum asphalt layer). Large polyolefin fibers did provide some benefit to crack containment in UTW, but added significant cost to the concrete mix.

17. Documentation Analysis/Descriptors	18. Availability Statement
Ultra-thin whitetopping Concrete pavement overlays, MnROAD project, Forensic Investigation, Fiber reinforced concrete	No restrictions. Document available from: National Technical Information Services, Springfield, VA 22161

19. Security Class (this report)	20. Security Class (this page)	21. No. Of Pages	22. Price
Unclassified	Unclassified	116	

FORENSIC INVESTIGATION REPORT FOR MN/ROAD ULTRATHIN WHITETOPPING TEST CELLS 93, 94, AND 95

Final Report

Prepared by

Thomas R. Burnham, P.E.

Minnesota Department of Transportation
Office of Materials
1400 Gervais Avenue
Maplewood, MN 55109-2043

September 2005

Published by

Minnesota Department of Transportation
Office of Research Services
First Floor
395 John Ireland Boulevard, MS 330
St. Paul, MN 55155

The contents of this report reflect the views of the author who is responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the views or policies of the Minnesota Department of Transportation at the time of publication. This report does not constitute a standard, specification, or regulation.

ACKNOWLEDGMENTS

The author would like to acknowledge the help of the following employees within the Minnesota Department of Transportation, Office of Materials, in conducting this investigation:
Bob Strommen, Jack Herdon, Doug Lindenfelser, Ron Mulvaney, Ben Worel.

Thanks also to Julie Vandenbossche (University of Pittsburgh, formerly with Mn/DOT) for the historical information she provided.

TABLE OF CONTENTS

LIST OF FIGURES, TABLES, AND PHOTOS

LIST OF FIGURES

LIST OF TABLES

LIST OF PHOTOS

LIST OF PHOTOS (con't.)

LIST OF PHOTOS (con't.)

EXECUTIVE SUMMARY

Three instrumented ultra-thin whitetopping (UTW) pavement test sections were constructed in 1997 on the interstate highway portion of the Minnesota Road Research facility (MnROAD). Installation of UTW on the interstate portion of MnROAD was done to accelerate the traffic loadings on the sections, therefore deriving performance trends sooner than in typical low-volume applications. By the spring of 2004, approximately 6,000,000 ESALs (Equivalent Single Axle Loads) had been applied to the test sections, resulting in significant enough deterioration to require reconstruction. Prior to replacement of the three test cells in the fall of 2004, a forensic investigation of the distresses was carried out. The principal focus of this report is to describe the forensic investigation procedures carried out, and to summarize the findings from the investigation.

This report begins with a history of the UTW test cells and a characterization of the traffic loading they experienced. Chapter 2 describes the performance of the UTW sections in terms of ride quality and surface distress. Test section 94, with the smallest panel size (4' x 4') and thinnest concrete section (3"), performed the worst, with extensive corner cracking progressing down both wheelpaths of the driving lane. Test section 95, with a larger panel size of 5'x 6', had fewer distressed panels, however they were severe enough to negatively impact the ride quality. All of the test sections were in service more than 5 years before exceeding the terminal serviceability level (PSR = 2.5). Each of the sections also experienced reflective cracking, a result of the bond with the underlying asphalt layer. Once cracking became significant enough, the heavy traffic loading contributed to more extensive cracking in the neighboring area.

Chapter 3 describes the field and laboratory forensic investigations carried out on the UTW sections. Extensive coring was done, predominantly over cracked areas, as well as a select number of locations were investigated through sawing and lifting of distressed panels. Fiber reinforcement contribution was estimated using pull-apart testing (using a universal testing machine) and split tensile testing techniques. An electronic spectral analysis was used to determine white precipitate found over several cracks. The as-built quantity of reinforcing fibers was estimated using crushing and weighing techniques in a laboratory.

The forensic investigation provided clear evidence that debonding of the UTW from the hot-mix asphalt layer leads to cracking, and eventually, significant surface distress. The cracking was found to begin from the top of the slab and progress downward. Once a UTW panel debonded and cracked significantly, the slab fragments were often depressed into the asphalt layer by repeated traffic loadings.

Both field observation and laboratory testing revealed that the larger polyolefin fibers provided some benefit in holding cracked UTW together. The significant increase in cost for the concrete mix with polyolefin fibers may counteract some of their benefit however. The smaller polypropylene fibers provided very little benefit to the containment of cracks. Both fiber types were well disbursed throughout the mixes, and were found to be within 15% of the specified volume. The precipitate found over several of the cracks was determined to be calcium carbonate (carbonation), and was not a major contributor to the distress in the UTW sections.

The conclusions of this investigation revealed that the performance of the ultra-thin whitetopping test cells at the MnROAD project was related to traffic volume, wheel placement, and layer bonding. The amount and severity of distress was significantly higher in the driving lanes (higher traffic volume) of each test cell. It was clear that UTW panel sizes that place wheelpaths near the edge of slabs, result in significant degradation from traffic loads. Bonding of UTW to the underlying asphalt is essential for long-term performance. However, reflective cracking generally occurs for slab thicknesses less than 5 inches (when bonded to a 6” minimum thickness HMA layer).

The lessons learned from the UTW and TWT test cells at MnROAD will contribute greatly toward the future development of rational design methods for whitetopping.

CHAPTER 1
INTRODUCTION

Project Background

In 1997, three ultra-thin whitetopping (UTW) and three thin whitetopping (TWT) pavement test sections were constructed on the mainline (interstate highway) portion of the Minnesota Road Research project (Mn/ROAD). Although not typically applied to high-volume interstate highway pavements, these UTW and TWT test sections were placed at MnROAD to measure the performance of lower volume type designs under accelerated traffic loading conditions. The sections were also constructed to evaluate the feasibility of the designs for high-volume applications. Ultimately the goal of the test sections was to provide comprehensive field performance data, which in the future will be utilized in the development of a rational design procedure for UTW and TWT.

By the spring of 2004, six and a half years of interstate traffic and exposure to Minnesota climate had been applied to the test sections. At that time, the three ultra-thin whitetopping test cells had significant enough deterioration to require removal of live traffic and warrant replacement. Since the neighboring MnROAD test cells remained capable of carrying live traffic, thin whitetopping test cells were designed and constructed in October 2004 to replace the UTW sections. Prior to the removal of the three UTW test cells, a forensic investigation was carried out.

This report begins with a history of the UTW test cells, followed by a short summary of their performance. The principal focus of this report is to describe the forensic investigation procedures carried out, and to summarize the findings from the investigation.

MnROAD Test Cells 93, 94, and 95

The ultra-thin whitetopping (UTW) test sections investigated in this report were designated as MnROAD project test cells 93, 94, and 95. These test cells were constructed in 1997 as inlays to a 13 inch (330 mm) thick full-depth asphalt pavement transition section, between the 5 and 10 year concrete pavement design test cells on the mainline section of the MnROAD facility. The transition section was originally designed to allow construction of a bypass around the 5-year design test cells if they failed early. Since the 5-year design test cells had very little distress in 1997 (after 3 years of traffic), the need for the transition section was deemed unnecessary. Therefore, it was decided the transition area could be utilized to conduct accelerated research on UTW and TWT designs. More detailed information on the MnROAD facility can be found at the web address: www.mnroad.dot.state.mn.us.

In addition to the three ultra-thin whitetopping test cells built in 1997, three thin whitetopping test cells (92, 96, and 97) were constructed at the same time. Both the ultra-thin and thin whitetopping test cells were constructed by inlaying them into the existing full-depth asphalt pavement, in order to maintain the original surface profile. The inlay process was accomplished by milling the asphalt surface to the depth of the corresponding whitetopping overlay.

The ultra-thin whitetopping test cells 93, 94, and 95 incorporate a number of pavement design variables. These include slab thickness, panel size, and fiber type. Table 1.1 describes the physical aspects of the UTW test cells at MnROAD.

Table 1.1. MnROAD ultra-thin whitetopping test cell design features.

Test Cell Number	Concrete surface thickness, inches (mm)	Panel size, feet (m)	Fiber reinforcement type
93	4 (102)	4 x 4 (1.2 x 1.2)	Polypropylene
94	3 (76)	4 x 4 (1.2 x 1.2)	Polypropylene
95	3 (76)	5 x 6 (1.5 x 1.8)	Polyolefin

In addition to the physical design variables incorporated into the test cells, comprehensive instrumentation was installed during their construction. Much more detail on the layout, material properties, and instrumentation in each of the whitetopping test cells at MnROAD can be found in the construction report (1).

Traffic Loading

Tests cells 93, 94, and 95 were located on the mainline test road of the MnROAD facility. The cells were therefore loaded by live interstate traffic diverted from westbound I-94 between Albertville and Monticello, Minnesota. The traffic consisted of approximately 26,400 AADT (annual average daily traffic), with 14% HCAADT (heavy commercial annual average daily traffic). This traffic information was last compiled in 2001, and therefore current volumes would be slightly higher. As of June 2004, the UTW test cells had received approximately 6 million CESALs (concrete equivalent single axle loads) in the driving (right) lane, and 1.5 million CESALs in the passing lane.

Performance Monitoring

The UTW test cells at MnROAD have a comprehensive history of performance monitoring and testing results. Falling Weight Deflectometer (FWD) testing was done on the hot-mix asphalt layer prior to placement of the UTW, as well as shortly thereafter. Seasonal and special research FWD testing was also performed throughout the life of each test cell. Ride quality and joint faulting measurements were taken seasonally, while surface distress surveys were performed on a regular basis. Data from the performance monitoring was loaded into the MnROAD database, and is available upon request.

(this page left intentionally blank)

CHAPTER 2

PERFORMANCE HISTORY

Condition of Test Cells

After approximately 6 million CESALs, and six and half years of exposure to Minnesota weather conditions, the ultra-thin whitetopping test cells had significant enough deterioration to require removal of live traffic. That determination was made based on pavement ride quality and the extensive surface distress that could potentially reduce the safety of the highway for the traveling public.

The following sections provide an overview of the performance history of the UTW test cells 93, 94, and 95. Since the focus of this report is the forensic investigation of the causes for the distresses in the test cells, only general statistics on the amount of cracking in each section is provided in this report. Additional information is, however, available upon request to the MnROAD project staff.

Ride Quality

The ride quality history for test cells 93, 94, and 95 is summarized in Figures 2.1-2.3. Several testing vehicles have been used throughout the analysis period, however all of the ride quality data has been configured into two principal indices. Those indices are the PSR (present serviceability rating) and the IRI (International Roughness Index). The PSR is a subjective "seat of the pants" measure of pavement roughness determined by a group of people riding in similar vehicles. The IRI is a measure of the cumulative rise and fall of the pavement surface, determined using lasers mounted on a special testing vehicle. A correlation between PSR and IRI is then developed and updated periodically by Mn/DOT's pavement management group. Currently, for concrete pavement surfaces, the PSR is calculated from the IRI rating by Equation 1.

(1) $PSR = 6.634 - (2.813)\sqrt{IRI}$, IRI = International Roughness Index, in m/km

As developed by the AASHO Road Test(2), the PSR is a measure of the serviceability and performance of a pavement. The index has a scale of 0 (poor) to 5 (excellent), and a pavement is declared to have terminal serviceability when it declines to a value of 2.5.

As shown in Figures 2.1-2.3, by the spring of 2004, the driving lane of test cells 93, 94, and 95 had all reached values far below 2.5. The cause of the low PSR numbers was predominantly due to the increasing amount of asphalt patching being placed on the distressed UTW surface. Cell 94 in particular was experiencing punchout type distress in the corners of the interior panels near the wheelpaths. See Photo 2.1 for an example.

Figure 2.1. MnROAD Test Cell 93 ride quality history.

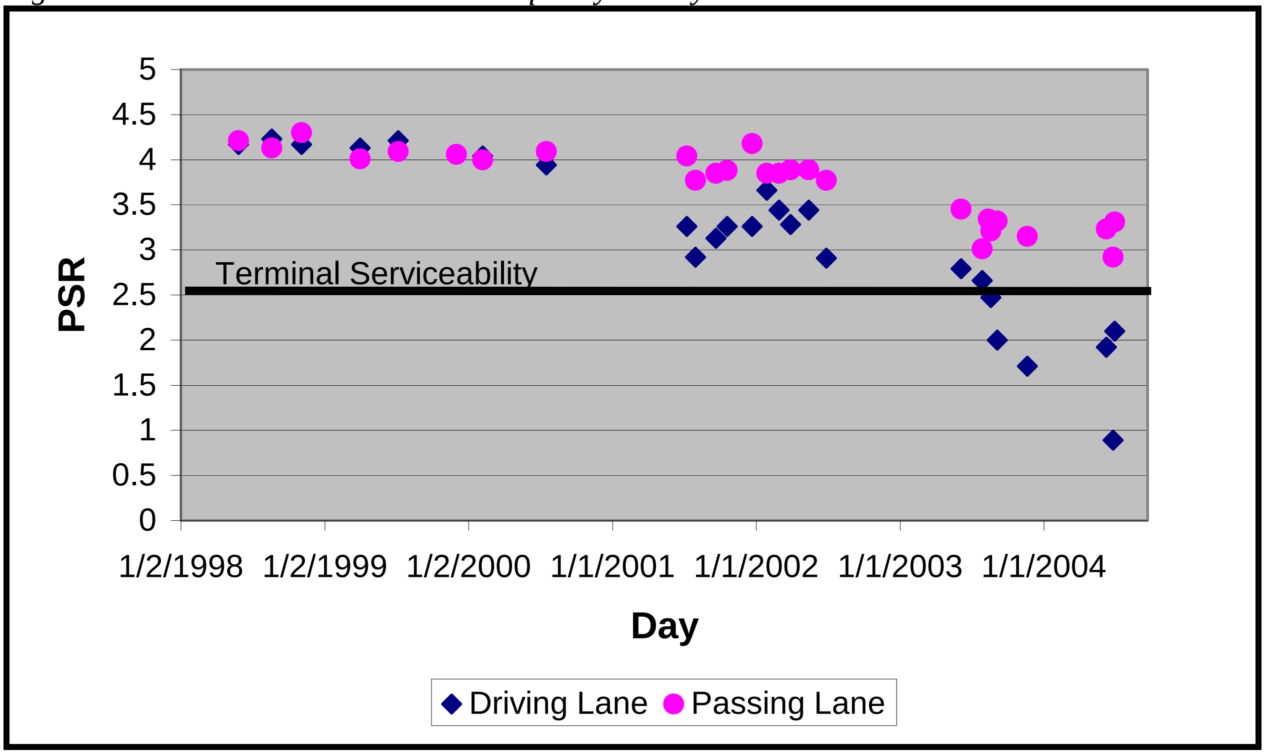


Figure 2.2. MnROAD Test Cell 94 ride quality history.

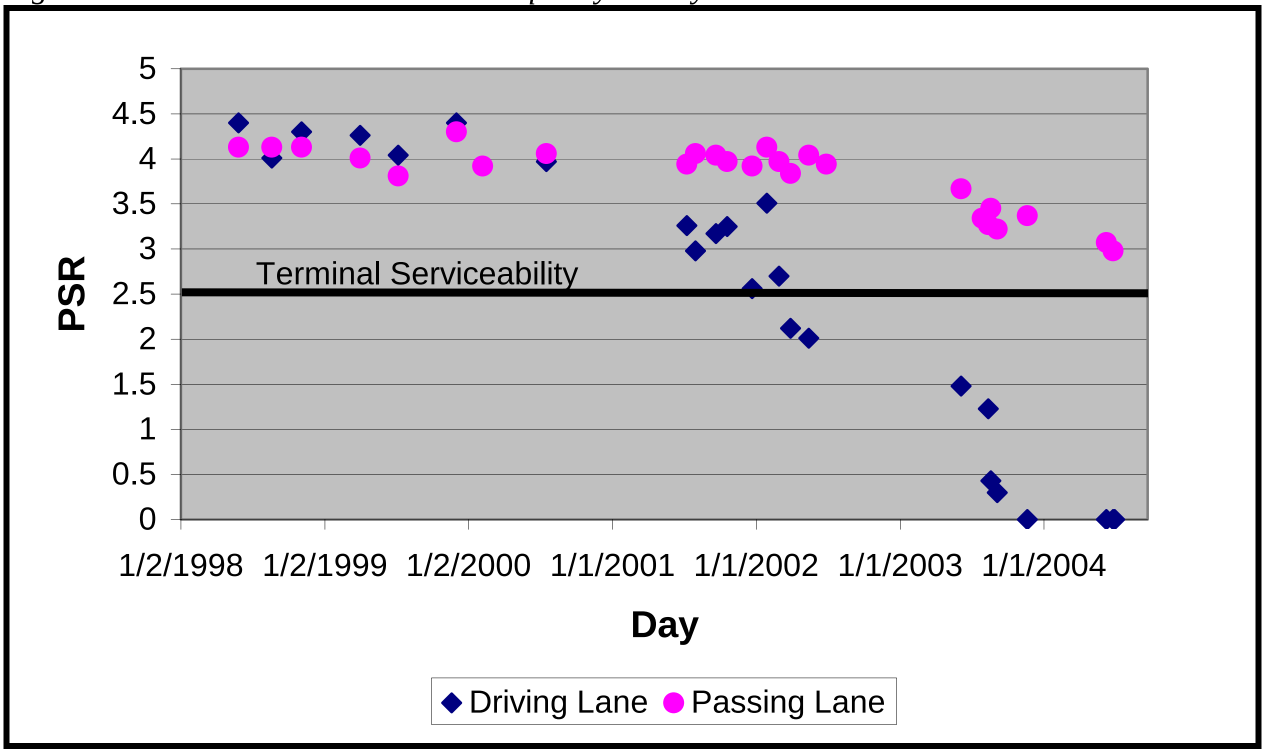


Figure 2.3. MnROAD Test Cell 95 ride quality history.

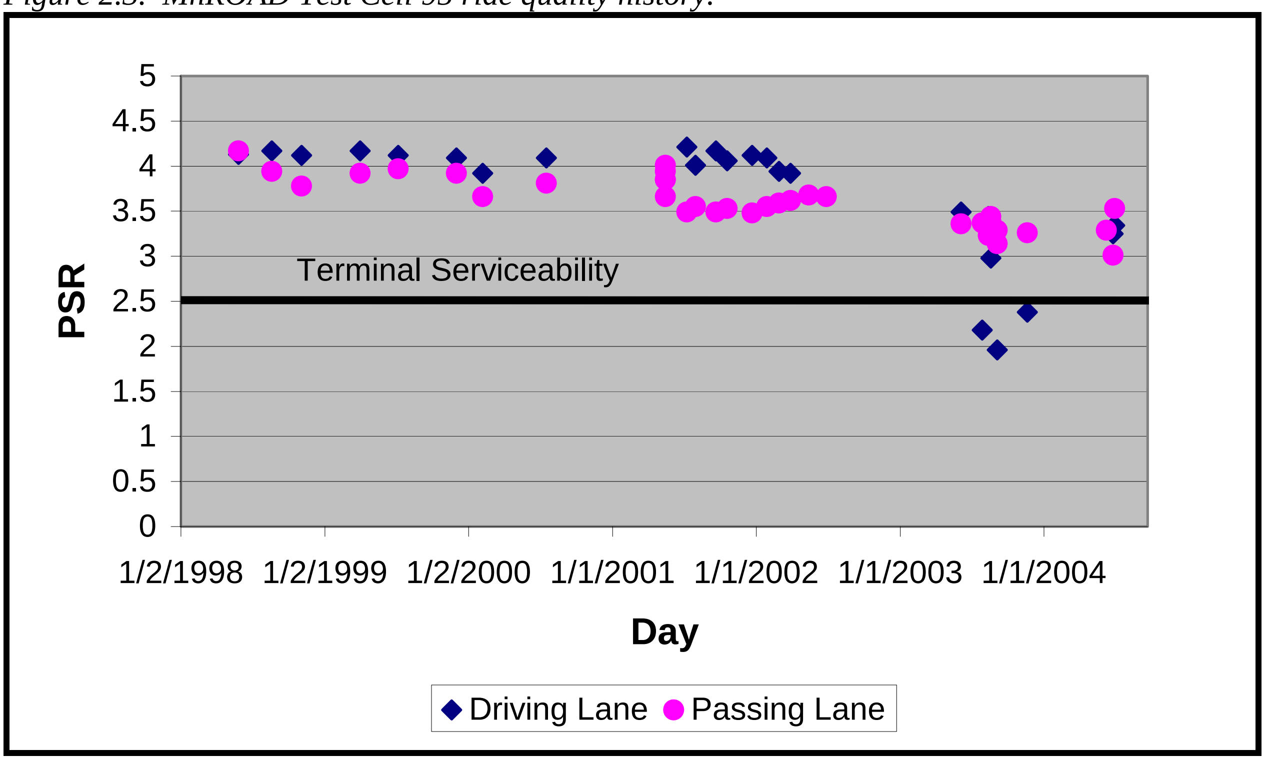


Photo 2.1. Corner cracked areas beginning to punch through the surface in November 2003. MnROAD Test Cell 94, driving lane.

It is interesting to note the difference in performance between the driving and passing lanes in the UTW test cells. Based on the significantly lower number and level of distresses in the passing lane, clearly the performance of UTW is strongly related, but not solely, to the volume of traffic loading. Other factors affecting the performance of UTW include the degree of bonding between the concrete overlay and the underlying asphalt, the presence of moisture (panel warp and curl, freeze/thaw action), and the geometry of the panels in relation to the traffic loading. The effect each of these factors had on the performance of the MnROAD UTW test cells will be addressed later in this report.

Surface distress

MnROAD test cells 93, 94, and 95 each experienced different levels and types of surface distress. This is not surprising, since each had different design aspects that could affect the performance of the test section. Additional information on the performance and repair of some of the early distresses experienced by the MnROAD UTW test cells can be found in reference 3.

Appendix A contains distress maps showing the final conditions of the UTW test cells in September 2004. The types and quantities of cracking distress are also summarized in Table 2.1.

Table 2.1. Types and quantities of distress for MnROAD ultra-thin whitetopping test cells.

Test Cell Number	Corner cracks		Transverse cracks		Panels cracked (%)*	
	Driving Lane	Passing Lane	Driving Lane	Passing Lane	Driving Lane	Passing Lane
93	43	6	9	4	23	4
94	391	84	8	8	94	34
95	30	16	5	2	32	16

* Panels repaired in 2001 not included.

Test Cell 93

Test cell 93, consisting of a 4 inch (102mm) thick UTW over 9 inches (228 mm) of hot-mix asphalt, experienced most surface distress in the form of corner cracking on the inside edge of the outer panels in the driving lane. Cracking was predominantly located on the approach side of panels, nearest the outside wheelpath of the driving lane. Photos 2.2 and 2.3 (not same location) show examples of the distress before and after patching done by Mn/DOT maintenance crews.

The other predominant distresses in test cell 93 were reflective cracking (from bond with the HMA) and load related cracking. All but a few of these distresses were located in the outer panels of the driving lane, nearest the shoulder. Photos 2.4-2.6 show examples of these types of distress.

Photo 2.2. Corner cracks near outside wheelpath, November 2003.
MnROAD Test Cell 93, driving lane.

Photo 2.3. Patched corner crack areas near outside wheelpath, May 2004.
MnROAD Test Cell 93, driving lane.

Photo 2.4. Cracks from underlying asphalt layer reflected through UTW overlay, April 2001. MnROAD Test Cell 93, driving lane.

Photo 2.5. Load related cracking and surface depression (punchout) near existing transverse crack in asphalt layer, April 2001. MnROAD Test Cell 93, driving lane.

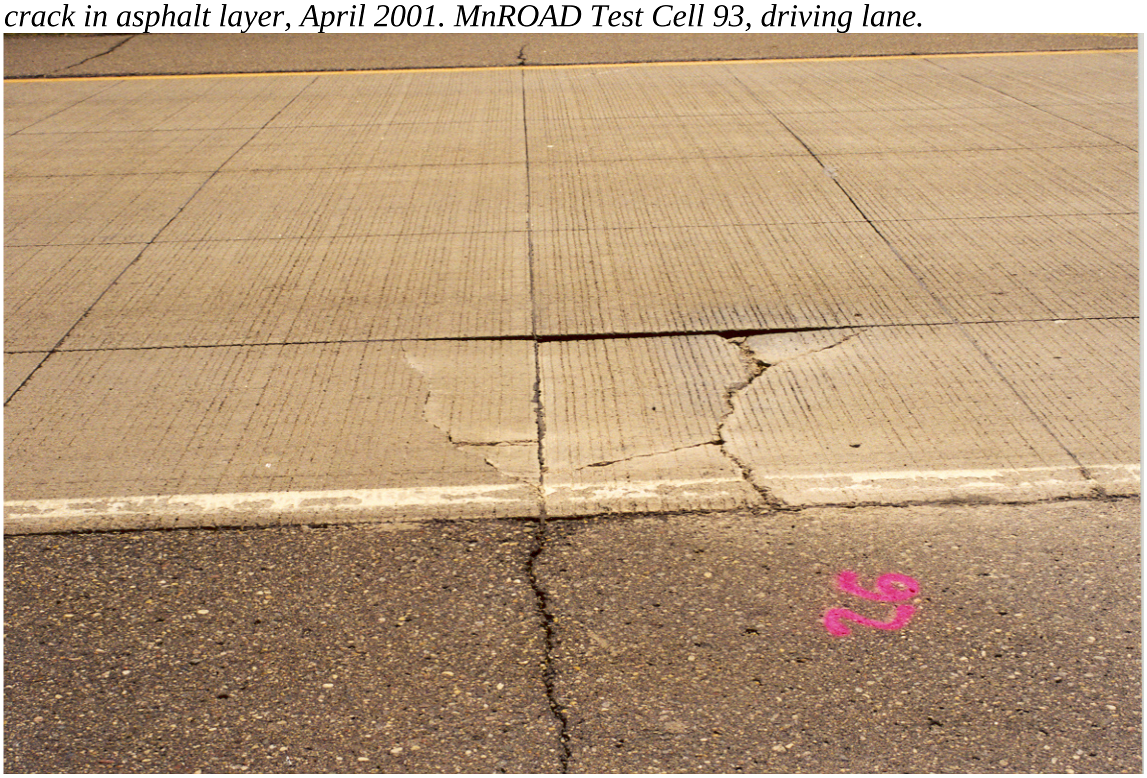


Photo 2.6. Load related cracking and large surface depression, November 2003. MnROAD Test Cell 93, driving lane.

<u>*Test Cell 94*</u>

Test cell 94, consisting of a 3 inch (76 mm) thick UTW over 10 inches (254 mm) of hot-mix asphalt, experienced most surface distress in the form of corner cracking near the longitudinal joints of the center panels in the driving lane. Corner cracking was very extensive, resulting in nearly every center panel having diamond shaped punchouts near the corners. In some cases, the corner cracks were connecting to each other, as shown in Photo 2.7. Photo 2.8 shows how extensive the corner crack patching was by the summer of 2004. The thinner panels of test cell 94 also demonstrated more reflective and load related transverse cracking than test cell 93.

By November of 2003, the inside wheelpath of the passing lane in test cell 94 was starting the exhibit similar distress as the driving lane. See Photo 2.9. The ride quality of the driving lane, however, became so low (PSR=0) that live interstate traffic was removed (for safety reasons) from the MnROAD mainline test sections on June 14, 2004.

Photo 2.7. Extensive corner cracking on edges of center panels (wheelpaths), beginning to connect to one another, November 2003. MnROAD Test Cell 94, driving lane.

Photo 2.8. Asphalt patching on nearly every panel in the driving lane of test cell 94, September 2004.

Photo 2.9. Passing lane of test cell 94, beginning to show similar corner cracking distress as driving lane, November 2003.

Test Cell 95

Test cell 95, consisting of a 3 inch (76 mm) thick UTW over 10 inches (254 mm) of hot-mix asphalt, experienced much less surface distress than test cell 94. The major difference can be attributed to the larger panel size in test cell 95. It is obvious that moving the wheelpath away from the longitudinal edges allows a thin 3 inch (102 mm) section to handle loads much more efficiently. Common theory in whitetopping design philosophy is that if panel sizes are small, curling stresses will be reduced, and the panels will deflect uniformly downward under the load. The performance of test cells 93 and 94 clearly demonstrate that a panel size of 4 feet by 4 feet is not a good design for high-volume applications.

Test cell 95 exhibited a fair amount of corner cracking, mostly on panel corners nearest the shoulder. This was true for both the driving and passing lanes. See photos 2.10 and 2.11. The corner cracking always initiated on the approach side of the panel. Test cell 95 also had a small number of reflective cracks that grew large enough to warrant patching.

Photo 2.10. Corner cracking on the outside edge of panels near the shoulder, November 2003. MnROAD Test Cell 95, driving lane.

Photo 2.11. Corner cracking on the outside edge of panels near the shoulder, November 2003. MnROAD Test Cell 95, passing lane.

Summary of performance

As described in this chapter, the performance of the UTW test cells at MnROAD was both different and similar. They were different by the fact they had distinct distress types and levels. Test cells 93 and 94, with the 4 feet x 4 feet (1.2 m x 1.2 m) panel sizes developed severe corner cracking under the wheelpaths of the driving lane. Test cell 95 developed most cracking in the panels near the driving lane shoulder. Similarities between the cells include reflective and load related cracking, and the dramatic demonstration of the effect interstate traffic volume has on UTW (driving versus passing lane). Despite the differences, all three of the test cells provided over 5 years of serviceability before having to be reconstructed.

CHAPTER 3

FORENSIC INVESTIGATION

3.1 Forensic Procedures

The distresses within MnROAD test cells 93-95 were investigated using standard concrete pavement forensic techniques. For this project, the techniques included coring, lifting pavement layers with a skid-loader, strength testing, chemical analysis, and photography.

The forensic examination areas were determined first by a group of pavement experts invited to the MnROAD project on August 20, 2004. A unique opportunity was provided to the experts in that they were asked to point out areas of interest that should be "dug up" or "cored into." Since there was a limited amount of time available on that day, several additional areas were determined by the author and investigated shortly thereafter.

This section describes the techniques used and the results from both the field and laboratory investigations.

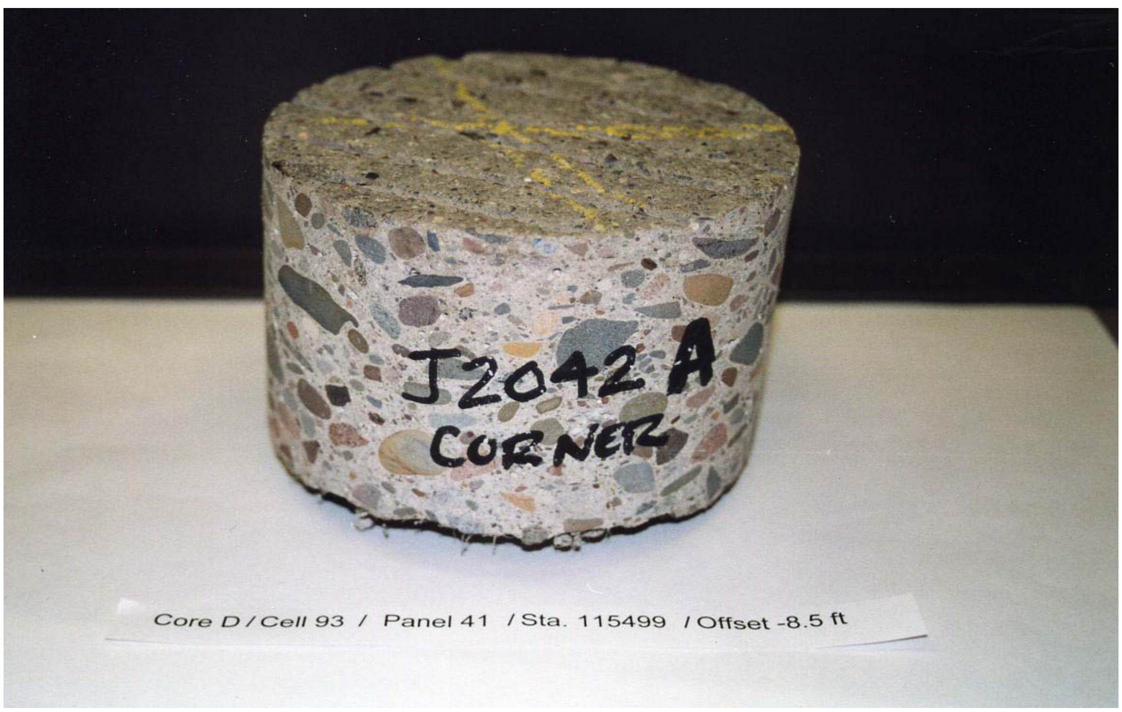
3.1.1 Field Investigation Equipment

The most effective piece of equipment used for the field investigation was the truck mounted coring machine. Both 4 inch and 6 inch (101 and 152 mm) diameter core barrels were used to extract the concrete and asphalt specimens. Most of the cores retrieved were not the full length (depth) of the pavement. This was predominantly due the overall depth of the pavement (12+ inches, 305+ mm) exceeding the length of the core barrels. If the concrete and asphalt layers were sufficiently bonded, at least half of the core was retrieved. If the core was unbonded between the layers, only the concrete portion was retrieved. Photos 3.1 and 3.2 show bonded and unbonded core samples. Care was taken to remove as few cores as necessary, since the underlying HMA layer was to be milled and used for replacement TWT sections.

Other equipment for the field investigation included a walk-behind concrete saw machine (dry blade) and a skid loader with a bucket attachment. These were used to examine four "test pit" locations. A field notebook and a camera were used to document core and test pit locations.

Photo 3.1. Core sample showing bonded layers of HMA and UTW.

Photo 3.2. Core sample showing unbonded UTW.



3.1.2 Laboratory Investigation Procedures

Several of the cores retrieved during the field investigation were subject to further tests in the laboratory. The general procedures used in the laboratory are summarized below.

The first laboratory investigation involved determining the benefit of the fiber reinforcement in keeping cracks tight. Several core samples (taken over cracks) from Cells 94 and 95 were tested using a 30,000 lb (133 kN) capacity screw driven universal testing machine (ATS Inc.). Steel anchor screws were inserted into the sides of cores (on either side of the crack) using epoxy. The tensile resistance across the crack was then determined using the machine. See Photos 3.3–3.5. For several samples from cell 95, the steel anchors were pulled out from the core before the fiber reinforcement would fail. Those cores were then tested using standard split tensile testing equipment as shown in Photo 3.6.

Photo 3.3. Steel anchor screws installed into core before testing.

Photo 3.4. Core sample during testing in universal testing machine.

Photo 3.5. Core sample during testing. Note fibers spanning crack.

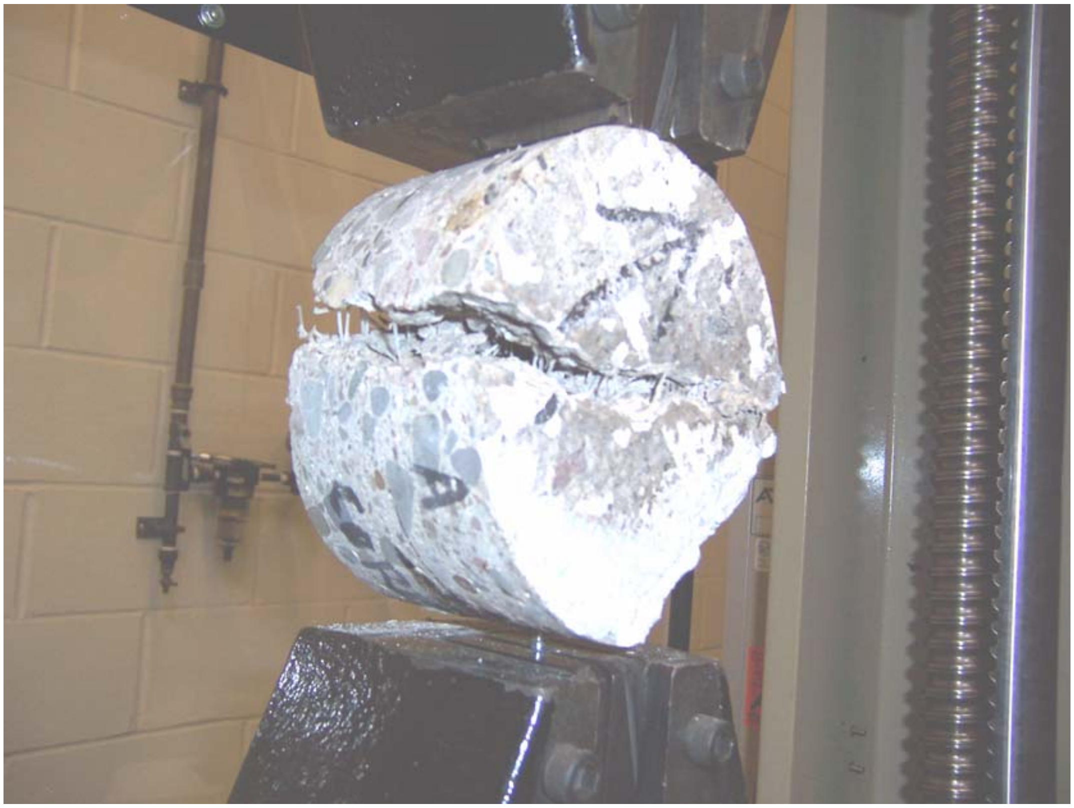
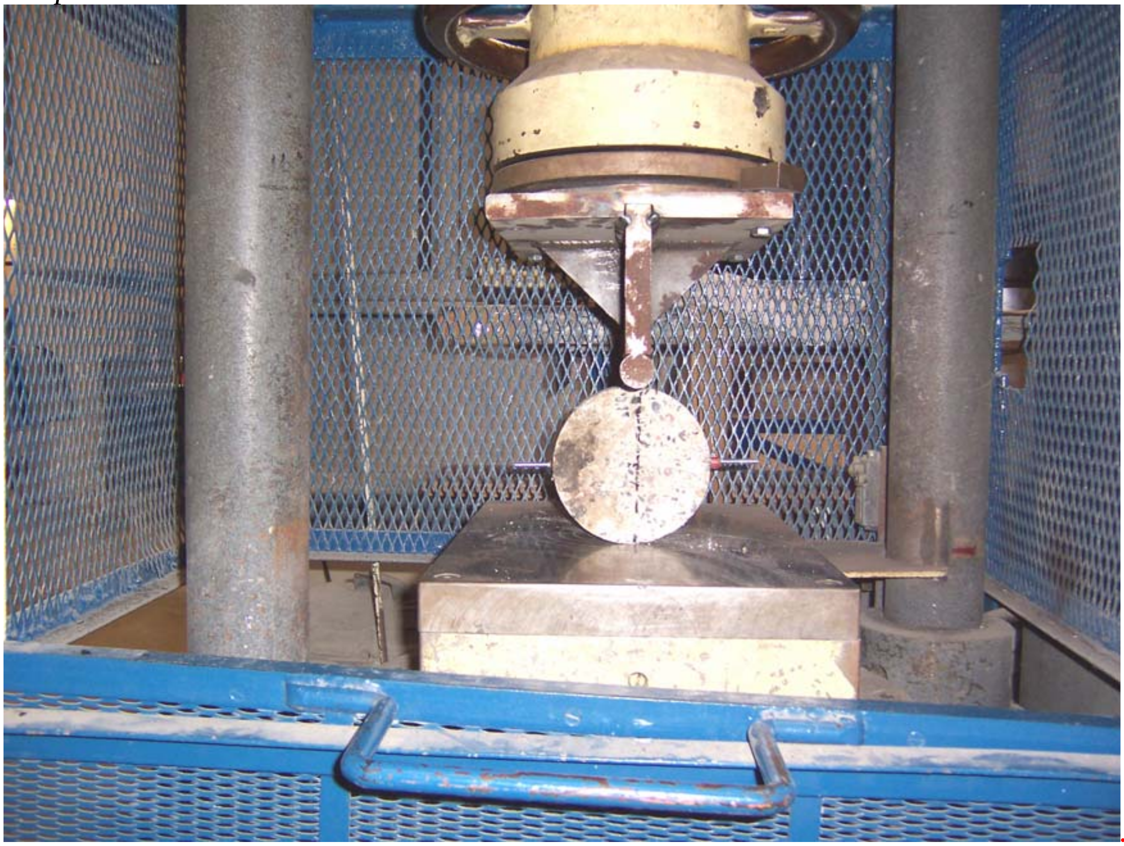


Photo 3.6 Split tensile testing equipment used to test strength of fibers across crack in core samples.



The second laboratory investigation examined the white precipitate substance found on the surface of many of the cracks in the cores. See Photo 3.7. An electronic spectral analysis was used to determine the substance.

The third laboratory investigation determined the amount of fibers actually found in the concrete mix placed in the whitetopping test cells. The determination was made using two techniques. For the larger polyolefin fibers, a concrete sample was crushed to pass through a No. 4 (4.75 mm) sieve. The fibers were then hand picked out of the sample and weighed. For the smaller polypropylene fibers, the concrete was again crushed, but was then subject to several increasing concentrations of hydrochloric acid to dissolve the cement paste. A series of screens was then used to separate out the fibers to be weighed. Photo 3.8 shows the fibers after removal from the core samples.

Photo 3.7 White precipitate over crack in core sample.

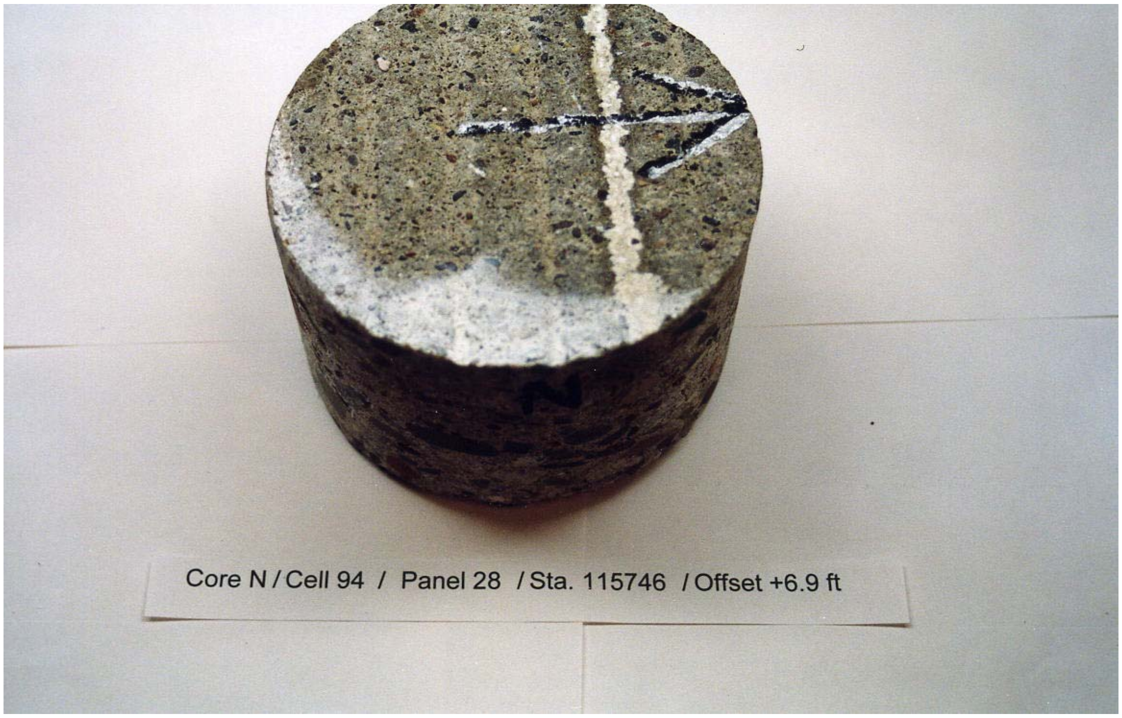


Photo 3.8 Fibers removed from core samples.
Large fibers (top 3) are polyolefin, small fibers (bottom) are polypropylene.

3.2 Forensic Investigation Results

This section describes the results from the forensic procedures outlined above. Based on the field observations and laboratory results, the following aspects of whitetopping behavior were examined:

1. Bond between the asphalt and concrete layers
2. Degree and location of cracking in the concrete layer
3. Behavior of reflective cracking from the asphalt layer
4. Effect of the fiber reinforcement.

3.2.1 <u>Bond between the asphalt and concrete layers</u>

Through examination of the core samples and test pits, there was clear evidence that debonding of the ultra-thin whitetopping from the hot-mix asphalt layer led to cracking, and eventually surface distress. Photos 3.9 through 3.11 show core and test pit samples with significant loss of bond. The location of these cores (Core F, Core N, Forensic Area "A") can be found on pages A-2 and A-4 of Appendix A. Debonding between the layers always occurred near panel edges or cracks, likely due to asphalt stripping and/or freezing and thawing action from the increased amount of available moisture. Photo 3.12 shows an area of debonding of approximately 6 inches from the edge of the shoulder.

Photo 3.9 Core sample "F" showing no bond between UTW and HMA. Core shown upside down.

Photo 3.10 Core sample "N" showing no bond between UTW and HMA. Core shown upside down.

Photo 3.11 Test pit "A" samples showing no bond between UTW and HMA. Pieces shown flipped over, adjacent to test pit.

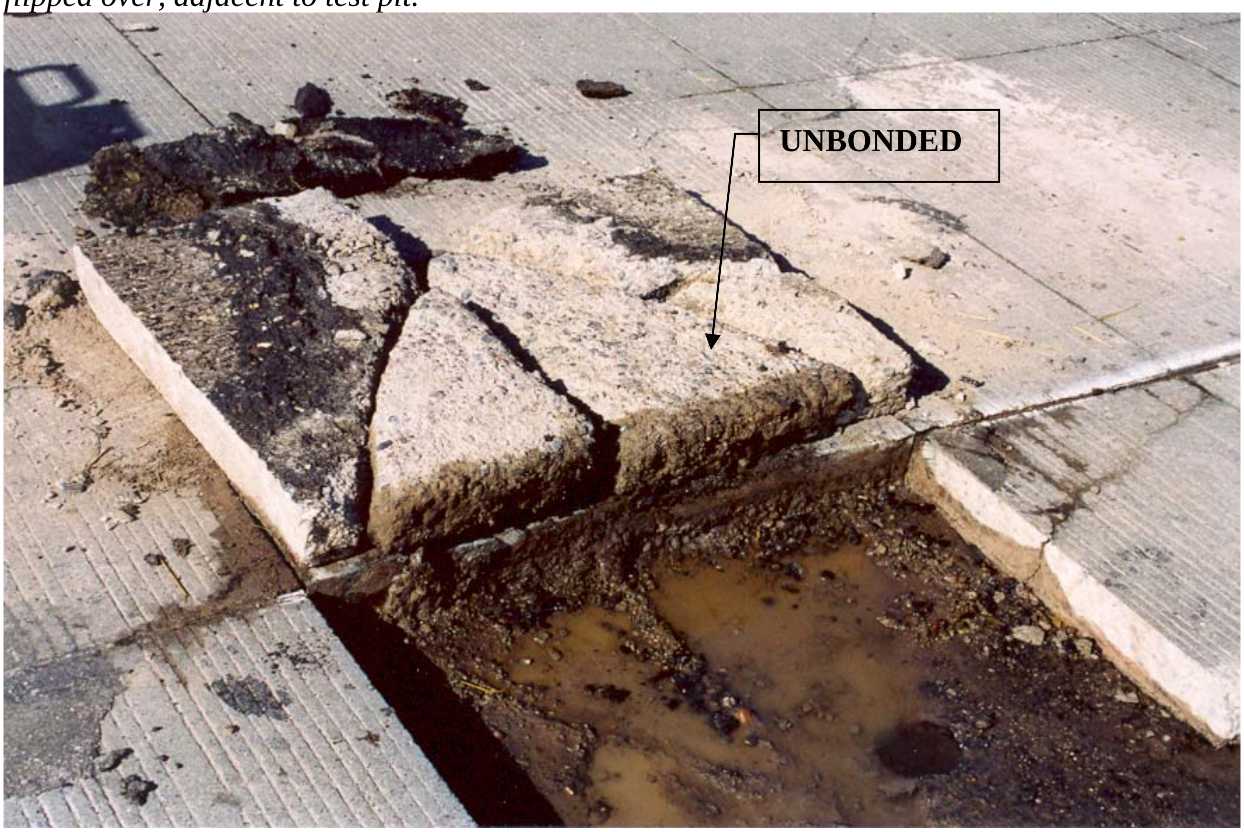


Photo 3.12 Test pit "A" samples showing an area of debonding near the shoulder edge of the panels. Pieces are shown flipped over in shoulder area, adjacent to test pit.

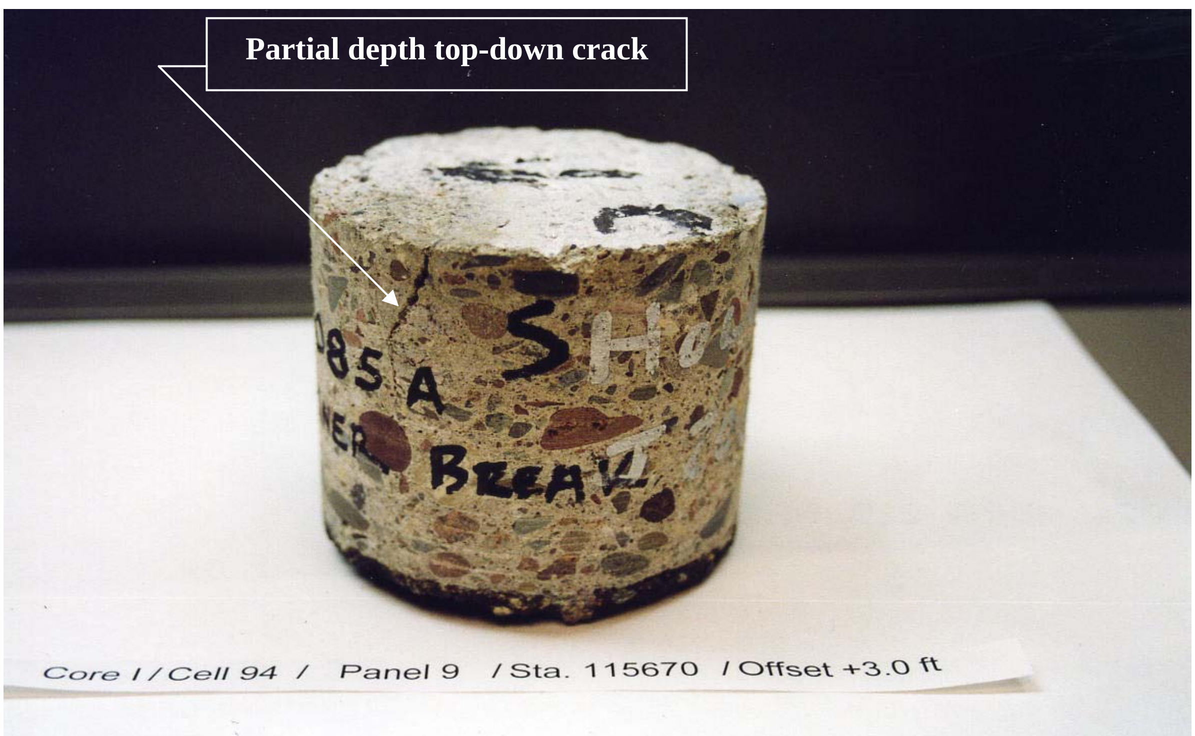
Near the center of panels, bond between the layers was usually found to be intact. Photos 3.1 and 3.13 show core samples with complete bond after 7 years of service.

3.2.2 <u>Degree and location of cracking in the concrete layer</u>

Both full-depth and partial-depth cracking were found in the core samples. Partial depth cracking was found to start from the top of the slab. An example is shown in Photo 3.14. It was also observed that cracking always started on the approach side of a panel. Figure 3.1 shows several examples. It is reasoned that as the UTW debonds from the HMA, the panel warps and curls up, and becomes more exposed to the impact load from tires. With the lack of support on such a thin concrete slab, cracking quickly follows.

Photo 3.13 Core sample "P" showing good bond between UTW and HMA. Also note top-down crack in UTW.

Photo 3.14 Core sample "I" showing top-down partial depth cracking.



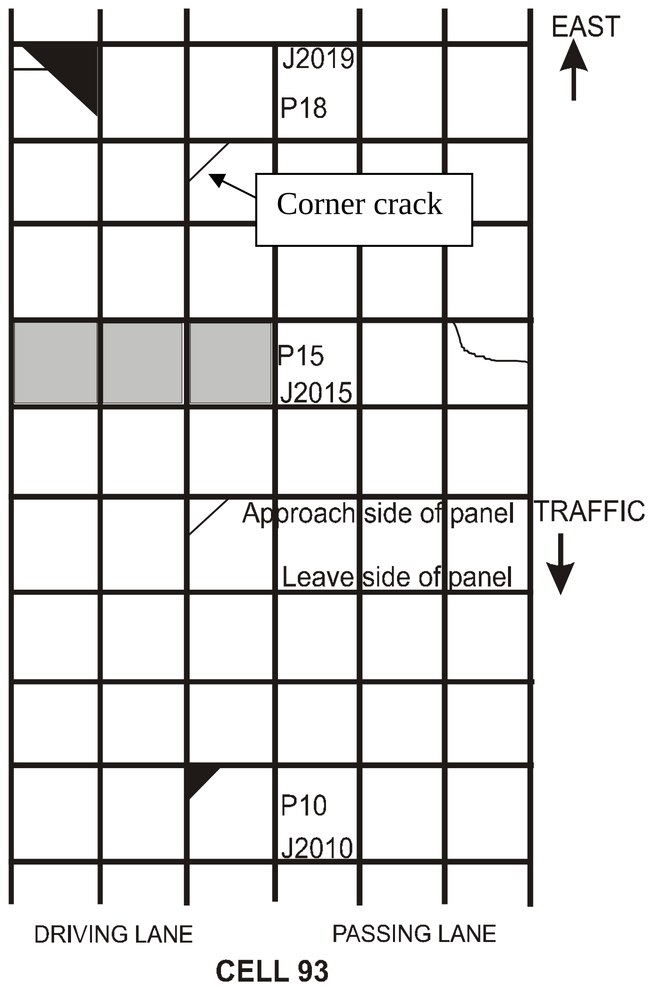


Figure 3.1. Plan view of Cell 93 showing corner cracks initiating on approach side of panel.

The close proximity of the tire loads to the panel edges in test cells 93 and 94 resulted in corner cracks on either side of the center panels within a lane. Corner cracks in the driving lane of test cell 94 deteriorated into "punchouts", which began to connect to one another (Photo 2.7). The distress maps in Appendix A show the extensive corner cracking that occurred in test cell 94.

Forensic Area "A" in test cell 93 revealed that the concrete pieces in a punchout are actually driven into the HMA. Photos 3.15 and 3.16 show the depression in the HMA after the UTW was removed (with a skidloader), and the deformation in the top of a core (Core B) pulled from the HMA layer.

Photo 3.15 Forensic Area "A" showing deformation in HMA from punchout in UTW.

Photo 3.16 Core sample "B" and close-up of forensic area "A" showing deformation in HMA from punchout in UTW.

3.2.3 Behavior of reflective cracking from the asphalt layer

Reflective cracks appeared in all three of the UTW cells, although were more prevalent in the 3 inch (76 mm) thick test cells 94 and 95. The distress maps in Appendix A indicate the locations of the major thermal cracks that were present before the UTW test cells were placed. Photos 3.10 and 3.17 show examples of reflective cracking through the UTW. Not every major thermal crack reflected through the UTW. Photo 3.18 shows an example without reflective cracking in test cell 95.

Photo 3.17 Major preexisting thermal crack in HMA reflected through UTW in Cell 93.

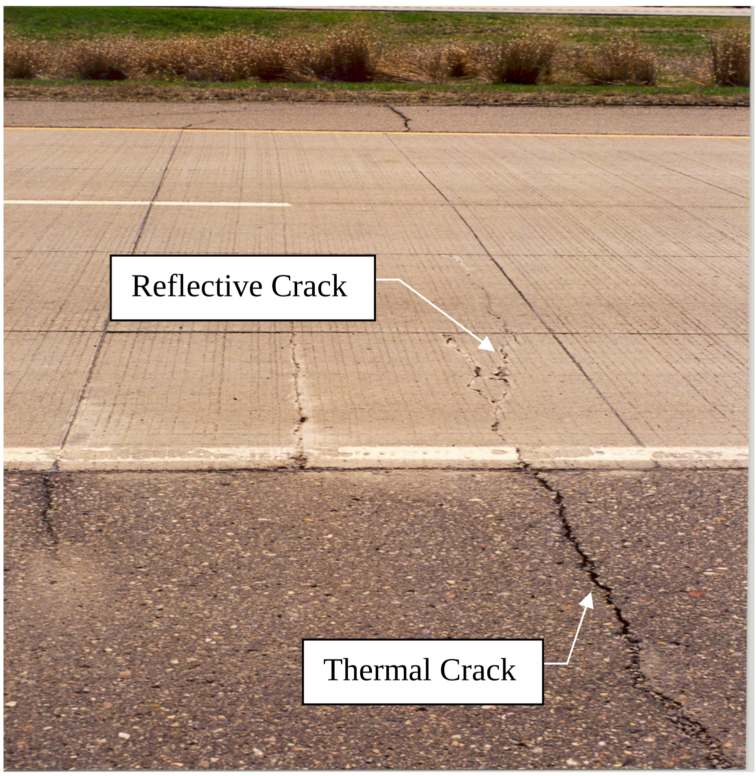
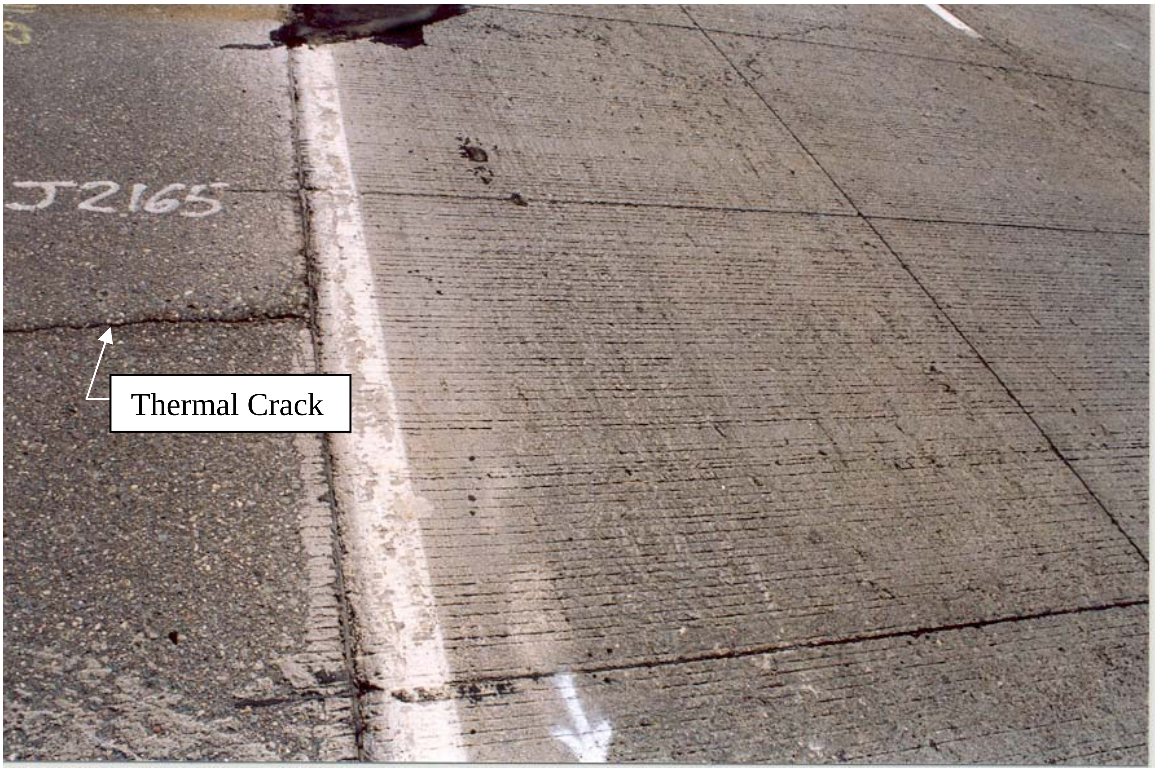


Photo 3.19 shows a side view of a core taken over a reflective crack in test cell 94. Note that the core was substantially debonded from the HMA, most likely due to the increased availability of moisture from the crack.

Recent experience (spring 2005) with the replacement TWT test cells at MnROAD (Cells 60-62), reveals that reflective cracking generally occurs in bonded concrete overlays for slab thicknesses less than 5 inches (when bonded to a 6” minimum thickness HMA layer). The theory is that for thinner bonded concrete overlays, the HMA becomes stiff enough in the winter that the thermal expansion forces exceed the tensile strength of the concrete overlay.

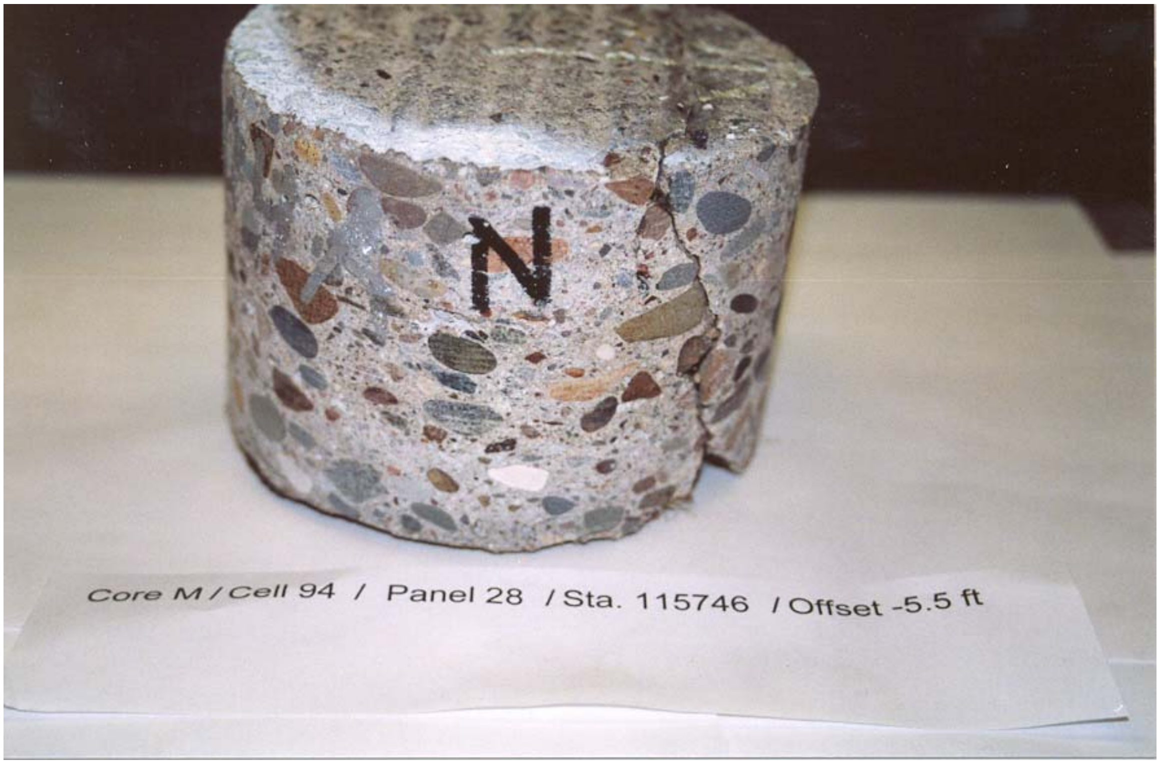
Photo 3.18 Major preexisting thermal crack in HMA that did not reflect through UTW in Cell 95.



3.2.4 <u>Effect of the fiber reinforcement</u>

Synthetic fibers were placed into the concrete mix for the UTW test cells at MnROAD for several reasons. The primary reasons were to control cracking and increase resistance to impact. Since UTWs are typically placed in lower volume and lower speed areas, the placement of the UTW test cells at MnROAD was of concern, due to the high volume and speed of the traffic stream. The fibers were provided to keep cracks tight, and potentially provide containment of UTW pieces that might come loose and become a safety hazard to the traveling public. There were few, if any, reports of loose UTW pieces, so it would be difficult to summarize whether the fibers contributed in that manner.

Photo 3.19 Core sample "M" showing reflective crack from HMA layer.



During removal of the UTW in the test pits, it was noticed that polyolefin fibers provided more resistance, and were more strongly held by the UTW pieces, than the polypropylene fibers. The polypropylene fibers, in fact, could easily be pulled off the surface of the UTW samples using your fingers. It is doubtful the smaller polypropylene fibers contributed to keeping the cracks together under the tremendous loading of interstate traffic.

To get a better understanding of the potential contribution of the fiber in keeping cracks tight, a laboratory investigation was carried out. As described previously, several core samples from the UTW test cells were subject to testing that might reveal at least the relative contribution of the fibers. Testing results confirmed the minimal contribution of the smaller polypropylene fibers in crack containment. In contrast, during testing of the larger polyolefin fibers, many steel anchors were pulled out of the sample due to the resistance the fibers provided across the cracks. Table 3.1 shows testing results from the pull-apart tests. Note again that several samples from cell 95 were tested using standard split tensile testing equipment, so comparison of the results is only subjective.

Based on the investigation here, it is the author's opinion that there is merit to using the larger polyolefin fibers in ultra-thin (4 inches and less) whitetopping applications. This must of course be balanced with the significant cost the fibers add to a concrete mix. Perhaps exploring newer, lower cost structural fibers might be the best way to balance cost and benefit when reinforcing UTW.

Cell / Core	Fiber Type	Test Type	Tensile Strength, psi (kPa)
94 / G	**Polypropylene**	**Machine pull**	**7 (48)**
94 / J	**Polypropylene**	**Machine pull**	**15 (103)**
94 / Q	**Polypropylene**	**Machine pull**	**16 (110)**
95 / T	**Polyolefin**	**Machine pull**	**47 (324)**
95 / U	**Polyolefin**	**Split Tensile [a]**	**180 (1241)**
95 / V	**Polyolefin**	**Split Tensile**	**371 (2559)**
95 / W	**Polyolefin**	**Split Tensile**	**270 (1862)**

Table 3.1 Laboratory tensile testing results. [a]ASTM C469.

3.2.5 Amount and distribution of fibers

Using fibers to reinforce UTW is only beneficial if the quantity of fibers, and their distribution in the mix, is as designed. Several UTW core samples were selected to examine the volume and distribution of the fiber reinforcement. The addition of fibers into the MnROAD UTW mixes was done by weight: polypropylene fibers = 3 lbs/yd^3 (1.8 kg/m^3), polyolefin fibers = 25 lbs/yd^3 (14.8 kg/m^3).

Using the laboratory methods described in section 3.1.2, the amount and distribution of fibers were determined for four core samples. The results are shown in Table 3.2. The as-built volume of fibers was measured to be approximately 15% below the design values. While it could not be quantified, the laboratory scientist did comment that the fibers were evenly distributed throughout the core samples.

Cell / Core	Fiber Type	Specified Volume (%)	Measured Volume (%)
93 / A	**Polypropylene**	**0.075 [(a)]**	**0.059**
95 / U	**Polyolefin**	**0.62 [(b)]**	**0.53**
95 / V	**Polyolefin**	**0.62**	**0.50**
95 / W	**Polyolefin**	**0.62**	**0.56**

Table 3.2 Volume of fiber reinforcement in UTW core samples.
[(a)] Polypropylene by weight = 3 lbs/yd^3 (1.8 kg/m^3).
[(b)] Polyolefin by weight = 25 lbs/yd^3 (14.8 kg/m^3).

3.2.6 <u>Determination of precipitate on crack surface</u>

During the field investigation, it was noticed that several of the cracks in the UTW panels had a band of precipitate over the crack. An example is shown in Photo 3.7. Several cores were taken to identify the precipitate.

A spectral analysis was done on the precipitate, which was determined to be calcium carbonate. The presence of calcium carbonate, also known as carbonation, is common and only affects the concrete's ability to protect embedded steel from corrosion (lower alkalinity). Carbonation in UTW is not a concern. More information on carbonation in concrete can be found in reference 4.

3.2.7 <u>Additional information from core and test pit samples</u>

This chapter provides only a portion of the information one could gain out of the core and test pit samples. Additional core and test pit information can be found in Appendix B. Additional photos and descriptions recorded during the forensic investigation can be found in Appendix C.

(this page left intentionally blank)

CHAPTER 4
CONCLUSIONS

Conclusions

Three instrumented ultra-thin whitetopping (UTW) pavement test sections were constructed in 1997 on the interstate highway portion of the Minnesota Road Research project (MnROAD). Installation of UTW on the interstate portion of MnROAD was done to accelerate the traffic loadings on the sections, therefore deriving performance trends sooner than in typical low-volume applications.

The performance of the ultra-thin whitetopping (UTW) test cells at the MnROAD project was clearly related to traffic volume, wheel load placement, and layer bonding. The amount and severity of distress was significantly higher in the driving lanes (higher traffic volume) of each test cell. Also, panel sizes that place wheelpaths near the edges of UTW slabs resulted in accelerated distress and poor performance.

The distresses in the MnROAD UTW sections confirm that bonding of UTW to the underlying asphalt is essential for long-term performance. Once a portion of a panel becomes unbonded, corner cracking begins on the approach side of the panel, and progresses from the top of the slab downward.

Each of the MnROAD UTW sections experienced reflective cracking, due to their bond with the asphalt below. Recent experience with newer thin-whitetopping (TWT) sections at MnROAD revealed that reflective cracking generally occurs for slab thicknesses less than 5 inches (when bonded to a 6” minimum thickness HMA layer).

Field performance and laboratory testing demonstrated that large polyolefin fibers provided benefit to the UTW at MnROAD, by holding cracks together. In the quantity specified and used in the MnROAD sections, however, polyolefin fibers also added significant cost to the concrete mix. Small polypropylene fibers did not appear to provide any benefit to the UTW test cells at MnROAD.

The lessons learned from the whitetopping test cells at MnROAD will contribute greatly toward the future development of rational design methods for whitetopping.

REFERENCES

1. Vandenbossche, J.M., Rettner, D. *The Construction of US-169 and I-94 Experimental Thin and Ultra-thin Whitetopping Sections in Minnesota.* Minnesota Department of Transportation Report No. 2001-07. April 1998.
2. *The AASHO Road Test, Report 5, Pavement Research.* Highway Research Board, Publication No. 954, National Academy of Sciences – National Research Council. Washington, D.C., 1962.
3. Vandenbossche, J.M.; Fagerness, A.J. *Performance, Analysis, and Repair of Ultrathin and Thin Whitetopping at Minnesota Road Research Facility.* Transportation Research Record No. 1809, Design and Rehabilitation of Pavements, 2002.
4. Kosmatka, S.H., Kerkhoff, B., Panarese, W.C. *Design and Control of Concrete Mixtures, Fourteenth Edition.* Portland Cement Association, Skokie, IL, 2002.

Appendix A

Distress Maps for MnROAD UTW Test Cells 93, 94 & 95

The following pages contain maps showing the final distresses in MnROAD ultra-thin whitetopping (UTW) test cells 93-95, as observed in September 2004. The test cells were replaced in October 2004.

The maps consist of side-by-side portions of each test cell. Joint and panel numbers are displayed for reference, and increase from the lower left to the upper right side of each page.

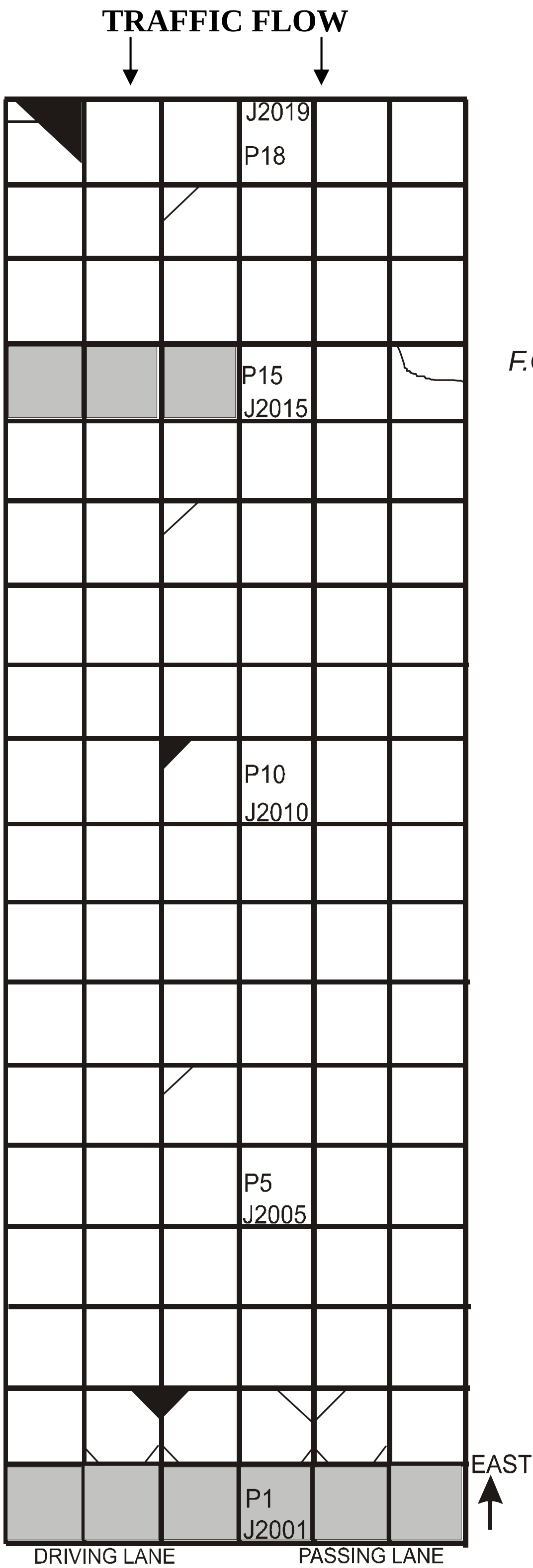
Distresses are displayed as follows:

- Single lines = Cracking on whitetopping surface.
- Shaded (light gray) panels = Panels replaced in June 2001.
- Dark (black) shaded area = Severely cracked areas and depressed panels overlaid by asphalt surface patches.

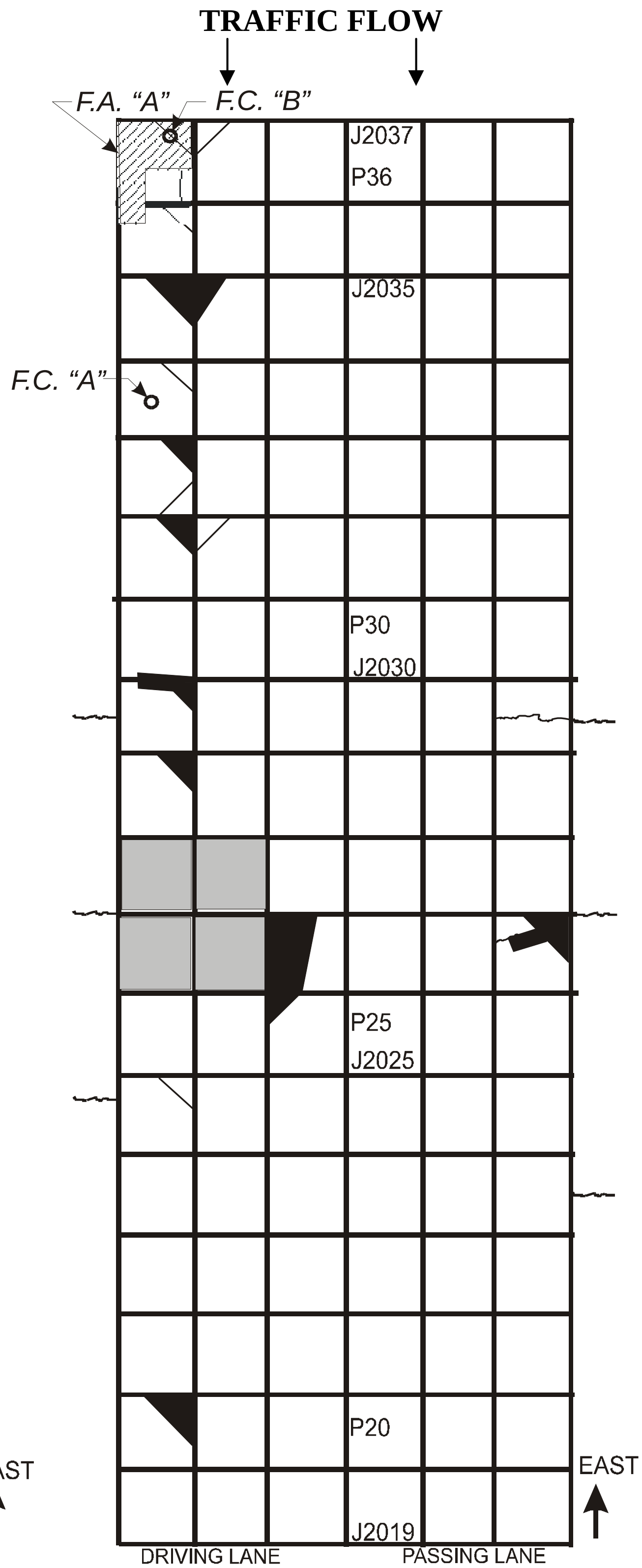
Other notes: The jagged lines adjacent to the lanes (in shoulder area) indicate the location of the major cracks that existed in the asphalt layers before the whitetopping was placed in 1997.

Forensic core (F.C.) locations are indicated by heavy black circular symbols. Similarly, forensic investigation areas (F.A.) are indicated by cross-hatched areas.

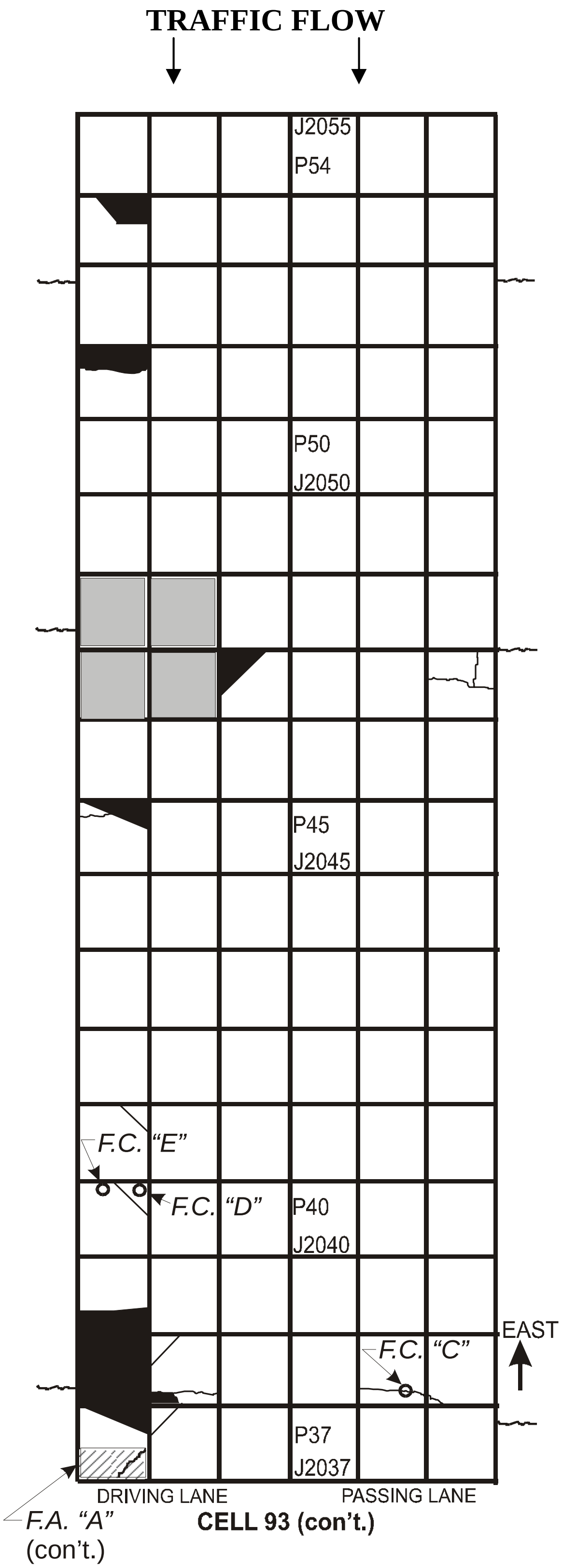
Select photos of the cores and forensic areas can be found in Appendix C.

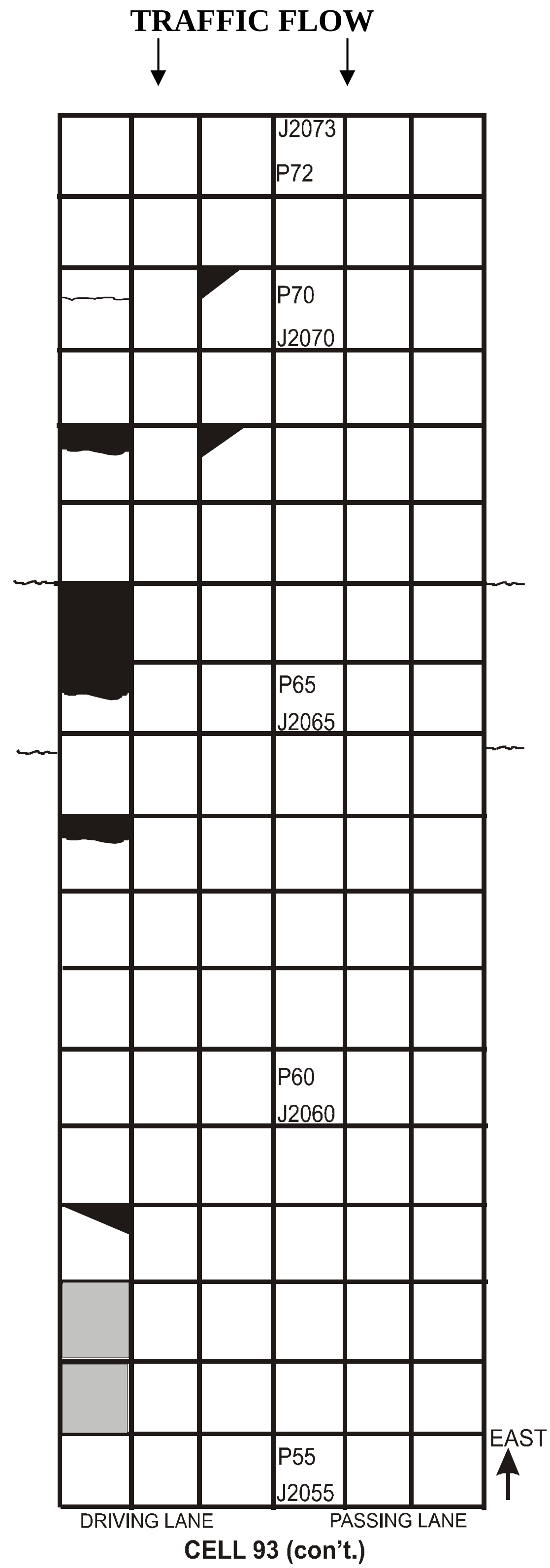


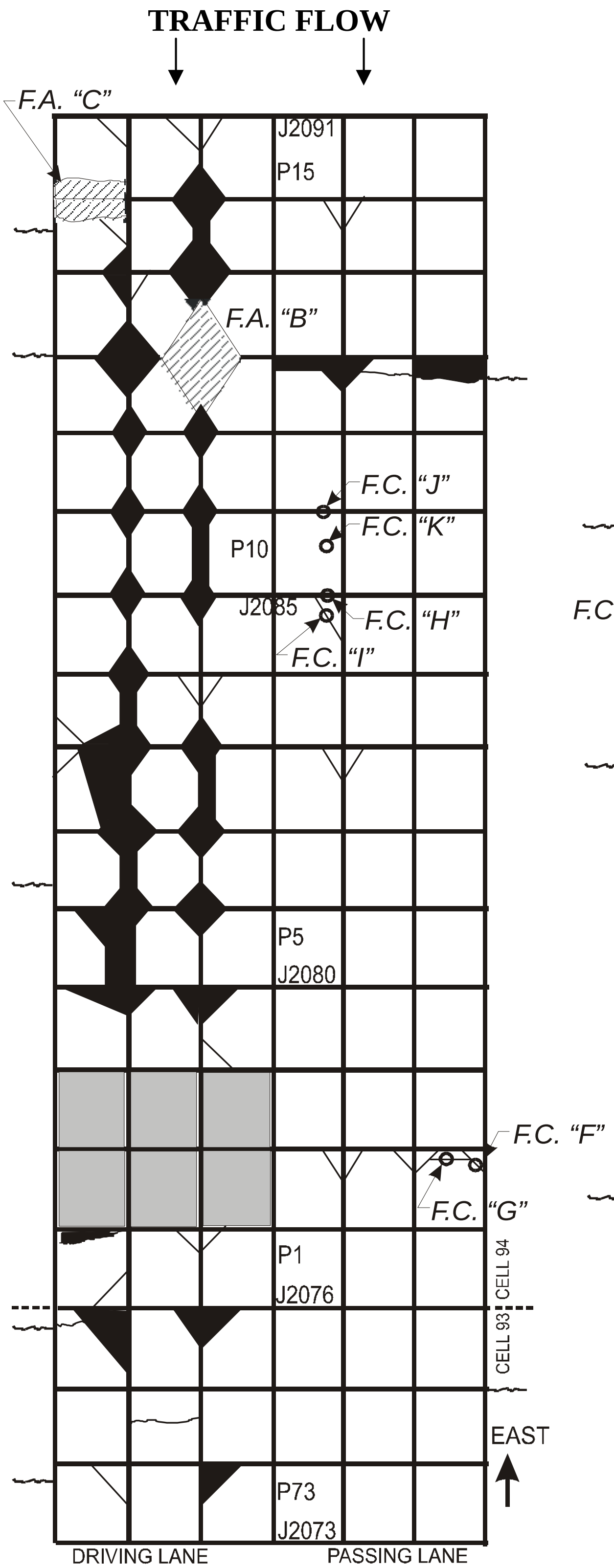
CELL 93



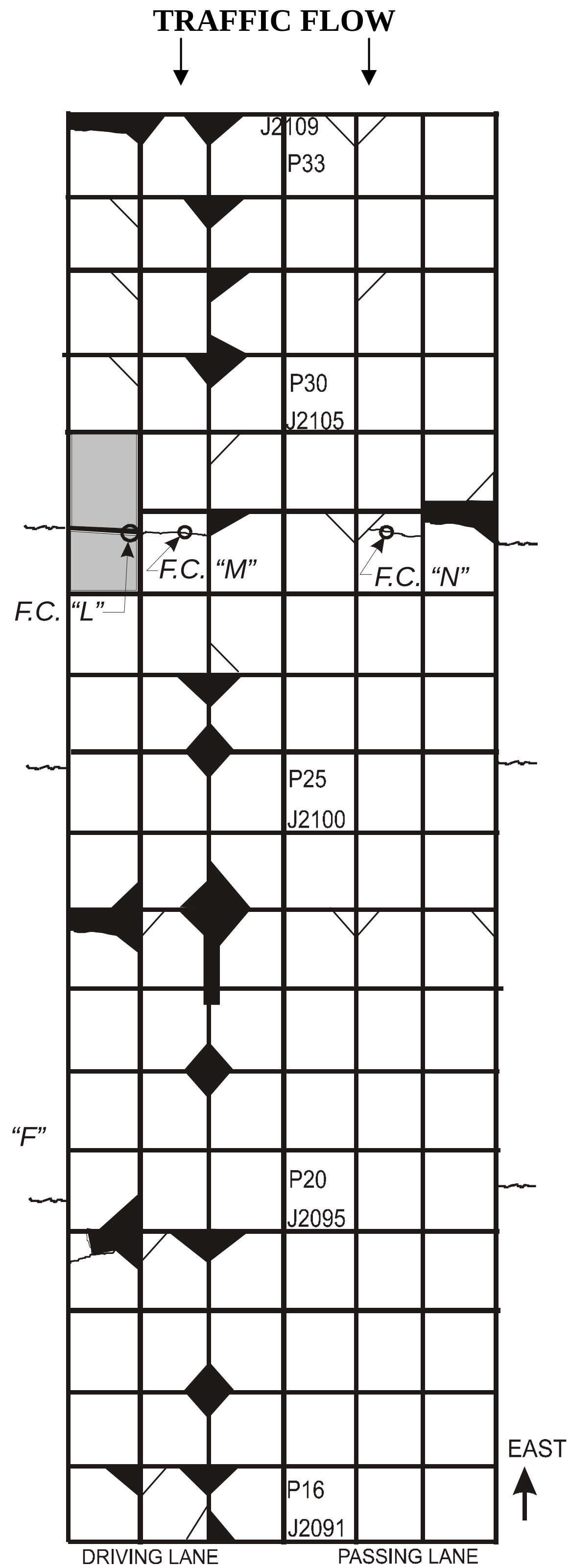
CELL 93 (con't.)


TRAFFIC FLOW
J2055
P54
P50
J2050
P45
J2045
F.C. "E"
F.C. "D"
P40
J2040
EAST
F.C. "C"
P37
J2037
DRIVING LANE
PASSING LANE
F.A. "A"
(con't.)
CELL 93 (con't.)

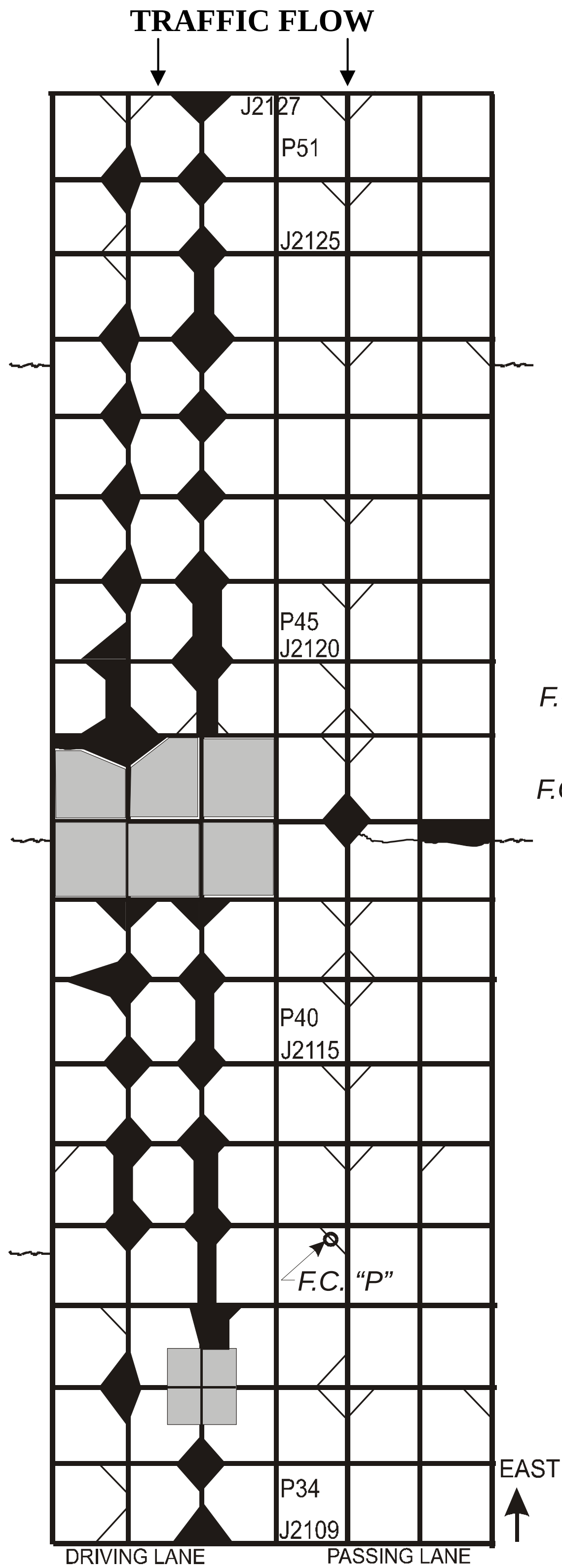

TRAFFIC FLOW
J2073
P72
P70
J2070
P65
J2065
P60
J2060
P55
J2055
EAST
DRIVING LANE
PASSING LANE
CELL 93 (con't.)



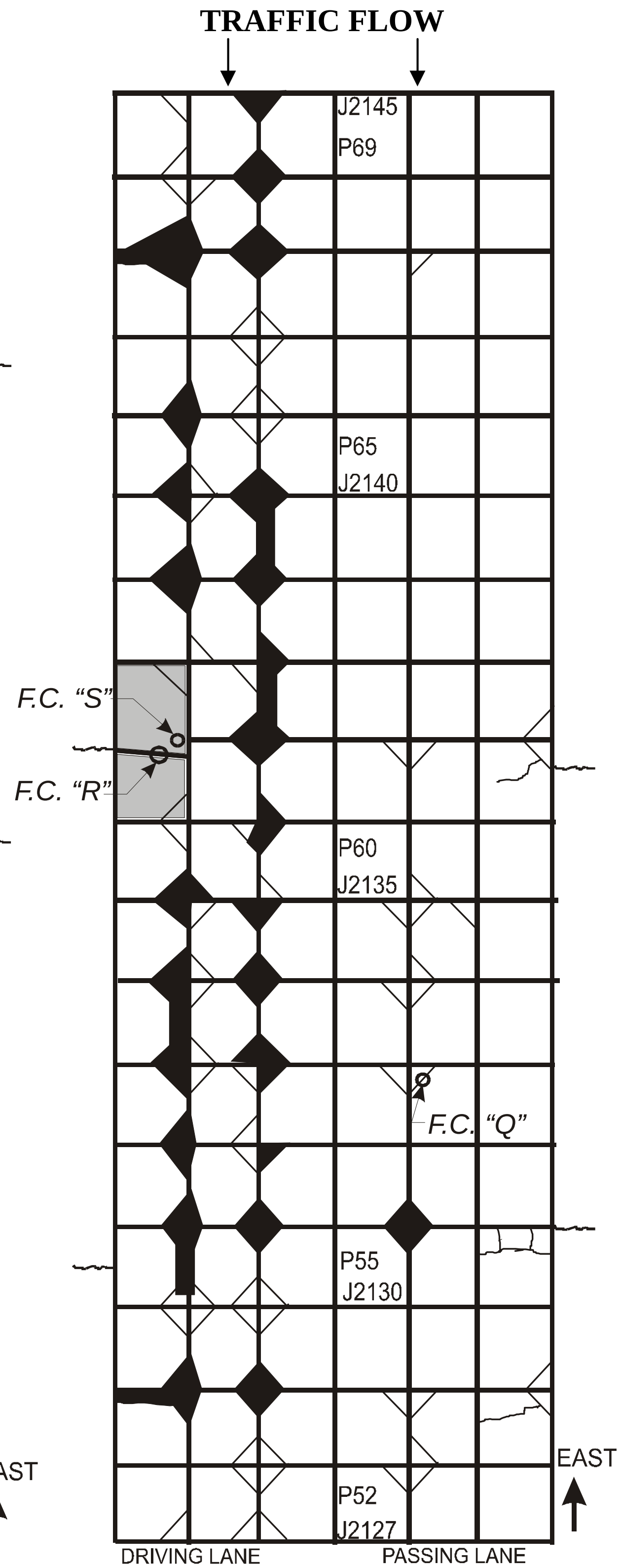
CELL 93 (con't.)/CELL 94



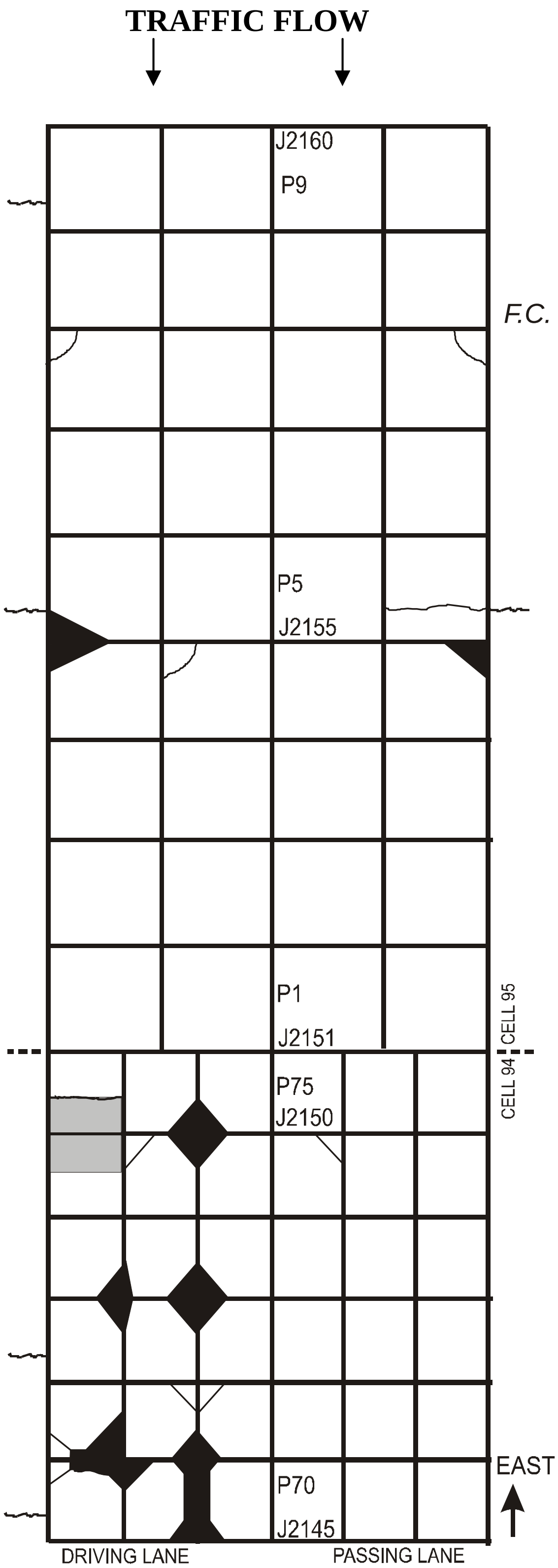
CELL 94 (con't.)



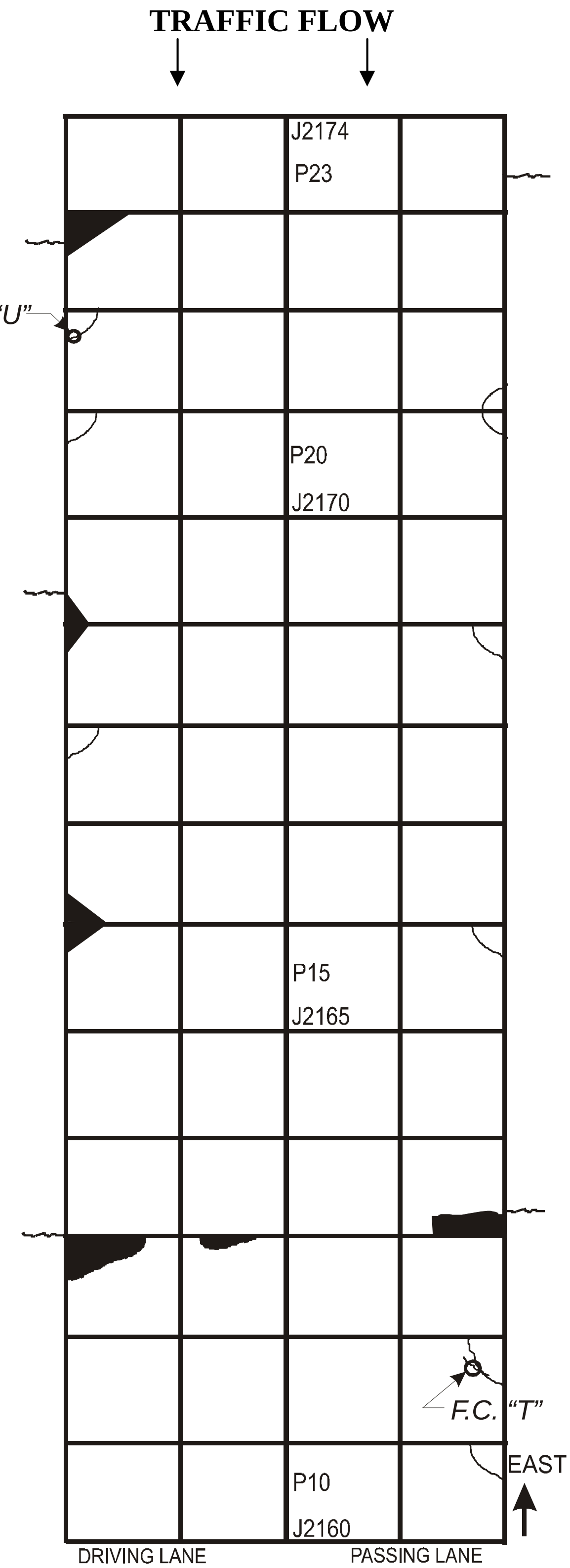
CELL 94 (con't.)



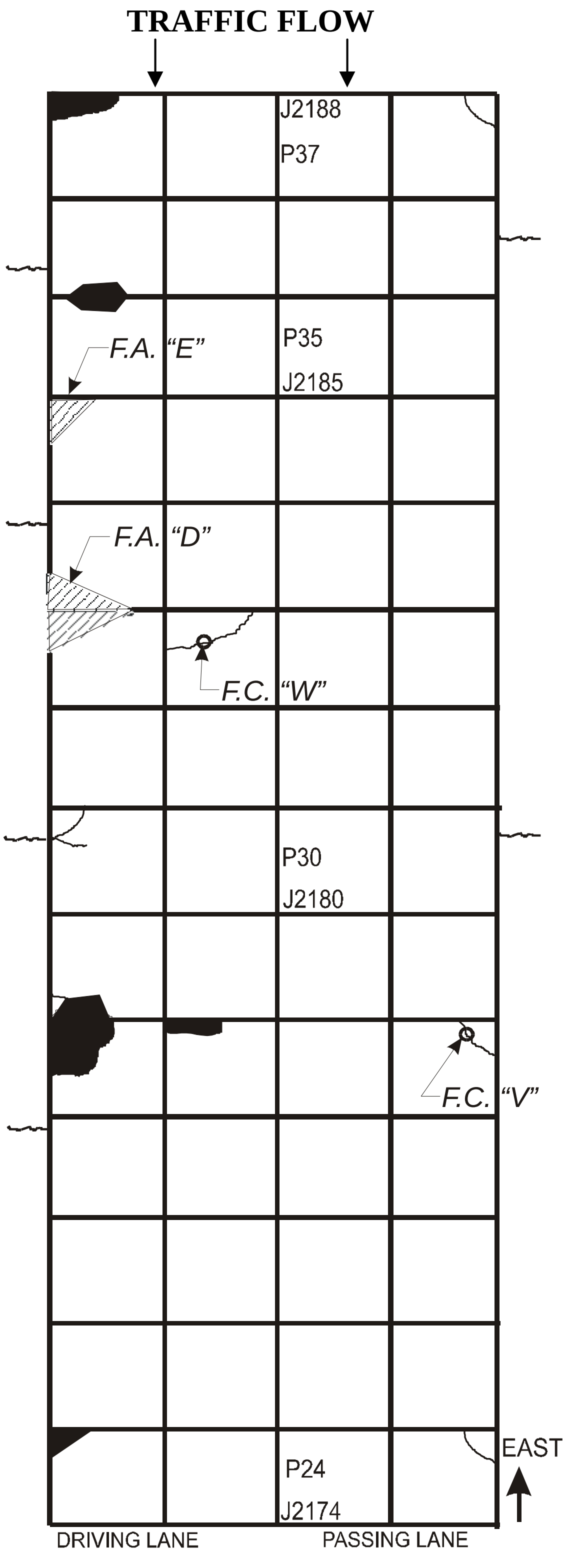
CELL 94 (con't.)



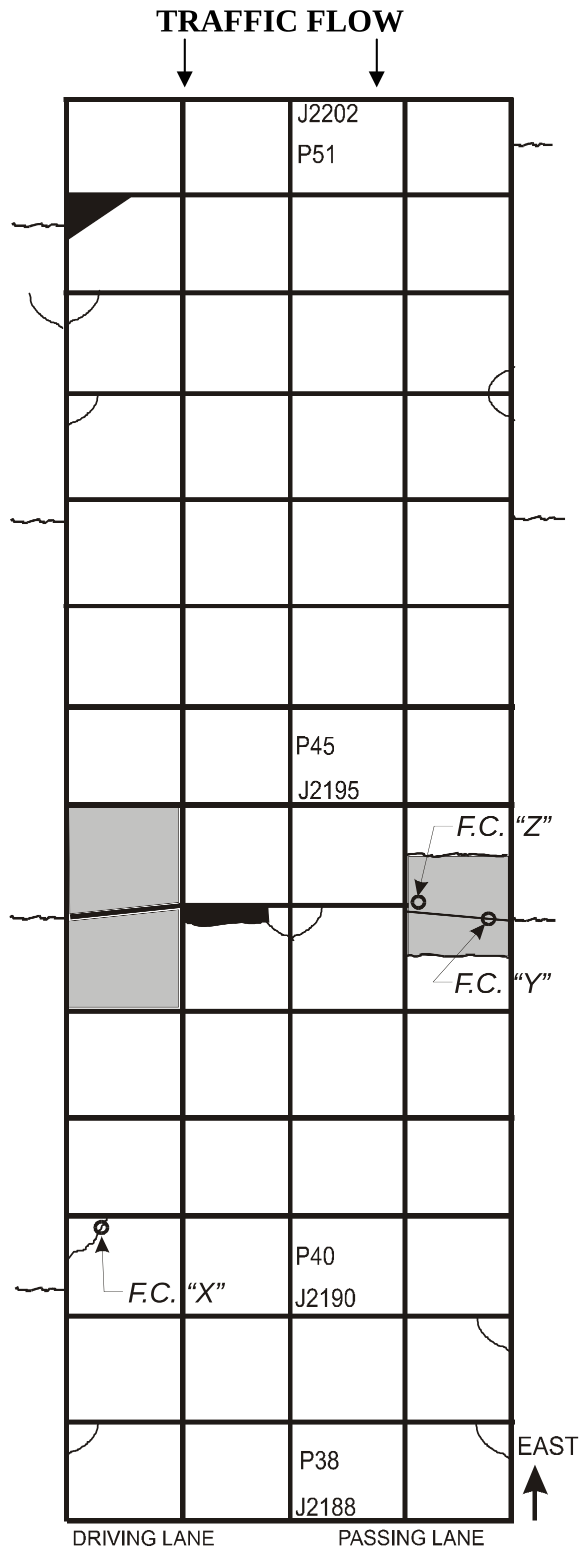
CELL 94 (con't.)/CELL 95



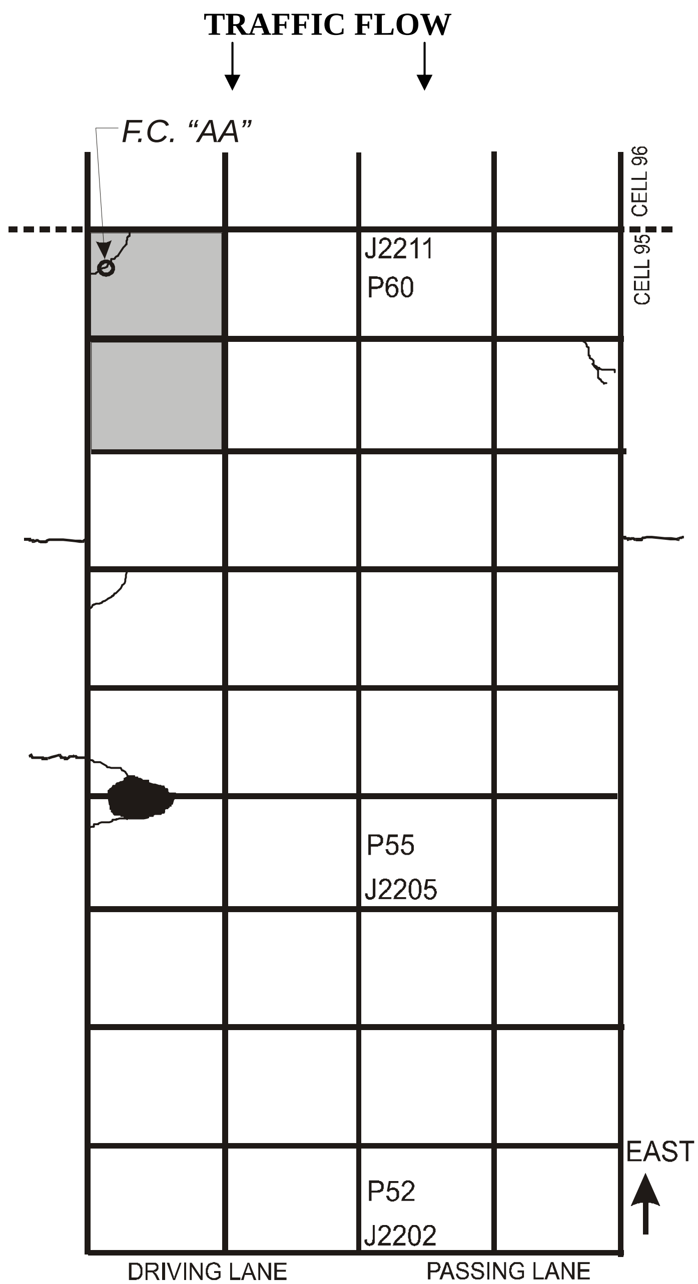
CELL 95 (con't.)



CELL 95 (con't.)



CELL 95 (con't.)


TRAFFIC FLOW
F.C. "AA"
CELL 96
CELL 95
J2211
P60
P55
J2205
P52
J2202
EAST
DRIVING LANE
PASSING LANE

CELL 95 (con't.)

APPENDIX B

Forensic Core Information

The following table provides the location and description of each core taken for the forensic investigation of MnROAD UTW test Cells 93, 94, and 95. For a graphical representation of the core locations, see Appendix A.

Core designation on distress maps	Test Cell	Field Core ID	MnROAD ID	Station (ft)	Offset (ft)	Approximate PCC thickness (in)	Core description
A	93	2033/2034	9304CC001	115465.09	-10.2	3.5	Core taken in middle of outside driving lane panel between J2033 and J2034. AC fully bonded to PCC. Total core length approximately 13".
B	93	2037	9304CC002		-9.5		AC core taken across (bisecting) area of depression found under PCC between J2036 and J2037. Depression in asphalt approximately 0.625" deep. AC is raveling near top of core.
C	93	2038	9304CC003	115484.22	7		
D	93	2042A	9304CC004	115499.47	-8.5	3.875	Core taken in middle of area bounded by a corner crack and panel joints on the southeast corner of panel between J2041 and J2042. AC only partially bonded to PCC.
E	93	2042B	9304CC005	115499.58	-10.3		Core taken near J2042 on the southeast corner of panel, between a corner crack and the shoulder. AC is debonding from PCC approximately half way across the core on the side nearest J2042 (approach side of panel J2041-J2042). AC is bonded good on the leave side of the core.
F	94	2078A	9404CC001	115641.94	11.2		
G	94	2078B	9404CC002	115642.36	9.9		

Core designation on distress maps	Test Cell	Field Core ID	MnROAD ID	Station (ft)	Offset (ft)	Approximate PCC thickness (in)	Core description
H	94	2085	9404CC003	115670.98	3	3.25	Core spanned transverse joint. Approximately 0.38" of PCC split off the bottom of the core. Joint is tight, with the fibers continuing to hold it together. Seal is not uniform, but is effective in keeping debris out of joint. AC not bonded to bottom of core.
I	94	2085A	9404CC004	115670.23	3	3.125	Core bisected a corner crack on the southeast corner of the panel between J2084 and J2085. Diagonal top-down crack 2" down at a slanted angle. AC partially bonded to bottom of core.
J	94	2086	9404CC005	115674.96	3	3.125	Core spanned transverse joint. Joint is tight, with the fibers continuing to hold it together. Seal is not uniform, but is effective in keeping debris out of joint. AC not bonded to bottom of core.
K	94	2085-2086	9404CC006	115673.21	3	3.125	Core taken from midpanel (no surface distress). Good bond between PCC and AC.
L	94	2104	9404CC007	115746.09	-8.1	4.25	Core spanned transverse joint in repair area. Joint is tight near surface, but significantly tented at the bottom. AC hot-pour material from an adjacent surface patch flowed into joint. Core not bonded to AC layer.
M	94	2104A	9404CC008	115746.09	-5.5		
N	94	2104B	9404CC009	115746.12	6.9		

Core designation on distress maps	Test Cell	Field Core ID	MnROAD ID	Station (ft)	Offset (ft)	Approximate PCC thickness (in)	Core description
P	94	2113	9404CC010	115778.31	3.5	2.875	Core bisected a corner crack on the southeast corner of the panel between J2112 and J2113. Diagonal top-down crack 2" down at a slanted angle. AC bonded well to bottom of core. Approximately 7" of AC recovered during coring.
Q	94	2133	9404CC011	115862.34	5		
R	94	2137	9404CC012	115878.70	-10	3.875	Core spanned transverse joint in repair area (reflected AC transverse crack). Joint is tight. Seal is fairly uniform and effective in keeping debris out of joint. AC not bonded to bottom of core.
S	94	2137B	9404CC013	115879.10	-8.5	3.75-4.75	Core spanned original UTW transverse joint (now a repair area). Variable depth PCC. AC is bonded to bottom of core.
T	95	2162	9504CC001	115988.38	10.7		
U	95	2172	9504CC002	116037.86	-11.8		
V	95	2179	9504CC003	116073.06	10		
W	95	2182	9504CC004	116092.74	-4		

Core designation on distress maps	Test Cell	Field Core ID	MnROAD ID	Station (ft)	Offset (ft)	Approximate PCC thickness (in)	Core description
X	95	2191	9504CC005	116133.70	-10.5	2.75	Core bisected a corner crack on the northeast corner of the panel between J2190 and J2191. Diagonal top-down crack 0.25" down. Good bond between PCC and AC.
Y	95	2194A	9504CC006	116148.37	11		Repaired area.
Z	95	2194B	9504CC007	116148.87	7		Repaired area.
AA	95	2210-2211	9504CC008		-11.8		

Appendix C

Forensic Investigation Photo Log

This appendix contains two parts. The first part is a spreadsheet listing the identification and general description of photos taken for the forensic investigation of MnROAD ultra-thin whitetopping (UTW) test cells 93, 94 and 95. The second part of this appendix contains select photos of cores and forensic investigation areas.

Most outdoor photos were taken facing east, which is against the flow of traffic. When facing east, the driving lane is to the left in the photos.

Most photos are labeled with the identification of the core or forensic area. This is followed by a photo identification code, which can be referenced using the spreadsheet located in the beginning of this appendix.

Photos are labeled with the following codes:
FC = Forensic core
FA = Forensic area
Photo ID example: 8-25-2004/A-2 = Date of photo/Photo Roll ID-photo number

MnROAD Ultra-thin whitetopping forensic photo log **9/09/2005**

Cell	Field Core ID	Date	Roll ID	Photo number	Description	Direction of photo
94		5/21/2003	AA	1	UTW patching	East
93		5/21/2003	AA	2	UTW patching	East
93		5/21/2003	AA	3	UTW patching (1st joint with patch is 2064)	East
93		5/21/2003	AA	4	UTW patching	East
95		11/20/2003	A	1	Joint 2174. Distress before patching on 11/21/2003.	East
95		11/20/2003	A	2	Joint 2172. Driving lane.	East
95		11/20/2003	A	3	Joint 2165. Driving lane.	East
95		11/20/2003	A	4	Joint 2162. Passing lane.	East
95		11/20/2003	A	5	Joint 2162. Driving lane.	East
95		11/20/2003	A	6	Joint 2157. Driving lane.	East
95		11/20/2003	A	7	Joint 2154. Driving lane.	East
95		11/20/2003	A	8	Joint 2154. Driving lane.	East
94		11/20/2003	A	9	Joint 2143. Driving lane.	East
94		11/20/2003	A	10	Joint 2138. Driving lane.	East
94		11/20/2003	A	11	Joint 2129. Driving lane.	East
94		11/20/2003	A	12	Joint 2130. Passing lane.	East
94		11/20/2003	A	13	Joint 2125. Driving lane.	East
94		11/20/2003	A	14	Joint 2123. Passing lane.	East
94		11/20/2003	A	15	Joint 2119. Driving lane.	East
94		11/20/2003	A	16	Joint 2114. Passing lane.	East
94		11/20/2003	A	17	Joint 2114. Driving lane.	East
94		11/20/2003	A	18	Joint 2110. Passing lane.	East
94		11/20/2003	A	19	Joint 2110. Driving lane.	East
94		11/20/2003	A	20	Joint 2105. Driving lane.	East
94		11/20/2003	A	21	Joint 2105. Driving lane.	East
94		11/20/2003	A	22	Joint 2098. Driving lane.	East
94		11/20/2003	A	23	Joint 2094. Driving lane.	North
94		11/20/2003	A	24	Joint 2094. Driving lane.	East
94		11/20/2003	A	25	Joint 2092. Driving lane.	East
94		11/20/2003	A	26	Joint 2084. Driving lane.	East
94		11/20/2003	A	27	Joint 2080. Driving lane.	East
94		11/20/2003	A	28	Joint 2077. Passing lane.	East
93		11/20/2003	A	29	Joint 2065. Driving lane.	North
93		11/20/2003	A	30	Joint 2065. Driving lane.	East
93		11/20/2003	A	31	Joint 2058. Driving lane.	East
93		11/20/2003	A	32	Joint 2036. Driving lane.	East
93		11/20/2003	A	33	Joint 2031. Driving lane.	East
93		11/20/2003	A	34	Joint 2026. Driving lane.	East
93		11/20/2003	A	35	Joint 2020. Driving lane.	East
93		11/20/2003	A	36	Joint 2010. Driving lane.	East

MnROAD Ultra-thin whitetopping forensic photo log (con't.)

Cell	Field Core ID	Date	Roll ID	Photo number	Description	Direction of photo
92		11/20/2003	B	13	Joint 2276. Passing lane.	East
92		11/20/2003	B	14	Joint 2272. Passing lane.	East
92		11/20/2003	B	15	Joint 2271. Driving lane.	East
97		11/20/2003	B	16	Joint 2259. Driving lane.	East
97		11/20/2003	B	17	Joint 2256. Driving lane.	East
97		11/20/2003	B	18	Joint 2250. Driving lane.	East
95		11/20/2003	B	19	Joint 2205. Driving lane.	East
95		11/20/2003	B	20	Joint 2187. Passing lane.	East
95		11/20/2003	B	21	Joint 2187. Driving lane.	East
95		11/20/2003	B	22	Joint 2182. Driving lane.	East
95		11/20/2003	B	23	Joint 2179. Driving lane.	North
95		11/20/2003	B	24	Joint 2178. Driving lane.	East
95		8/18/2004		DCP_1583	Overall view.	West
95		8/18/2004		DCP_1584	Transition between Cell 95 and Cell 96.	West
95		8/18/2004		DCP_1585	Overall view.	West
94		8/18/2004		DCP_1586	Overall view.	West
94		8/18/2004		DCP_1587	Transition between Cell 94 and Cell 95.	West
94		8/18/2004		DCP_1588	Overall view.	West
93		8/18/2004		DCP_1589	Overall view.	West
93		8/18/2004		DCP_1590	Transition between Cell 93 and Cell 94.	West
93		8/18/2004		DCP_1591	Overall view.	West
93	2113	8/25/2004	A	1	Corner break. Good bond with AC. Top-down crack.	
93	2033-2034	8/25/2004	A	2	Full length core. Good bond with AC.	
93	2033-2034	8/25/2004	A	3	Good bond with AC.	
93	2038	8/25/2004	A	4	Reflected transverse crack.	South
93	2038	8/25/2004	A	5	Reflected transverse crack.	North
93	2042A	8/25/2004	A	6	Core 2042A location	North
93		8/25/2004	A	7	Depressed AC area under distressed UTW. J2036-J2037.	Northwest
93		8/25/2004	A	8	Depressed AC area under distressed UTW. J2036-J2037.	South
93		8/25/2004	A	9	Distressed UTW flipped over. J2036-J2037.	South
93		8/25/2004	A	10	Distressed UTW flipped over. J2036-J2037. 6" unbonded zone.	
93		8/25/2004	A	11	Distressed UTW flipped over. J2036-J2037. 6" unbonded zone.	
95		8/25/2004	A	12	Corner break removed near J 2185. Note fibers.	Southwest
95		8/25/2004	A	13	Corner break removed near J 2185. Large fibers seem to hold pieces together.	East
95		8/25/2004	A	14	AC surface after PCC removal at location "CC".	
95		8/25/2004	A	15	AC surface and PCC edge after PCC removal at forensic location "CC".	
95		8/25/2004	A	16	AC surface and PCC edge after PCC removal at forensic location "CC".	
95		8/25/2004	A	17	PCC removed from forensic location "CC". Note: Large quantity of fibers.	
95	2191	8/25/2004	A	18	Bottom side of core near J2191. Note bonded AC layer.	
95	2191	8/25/2004	A	19	Top view of core near J2191. Note: Initial top-down crack.	
95		8/25/2004	A	20	Initial cracking on inner panel (driving lane) near J2183. Note: Approach side of panel.	West
95		8/25/2004	A	21	Distressed forensic area "CC" between J2182 and J2183.	West
95		8/25/2004	A	22	Distressed forensic area "CC" between J2182 and J2183.	East
95		8/25/2004	A	23	Distressed forensic area "CC" between J2182 and J2183.	North
94		8/25/2004	A	24	Underside of PCC panels removed near J2090. Adjacent bonded area could not be removed.	

MnROAD Ultra-thin whitetopping forensic photo log (con't.)

Cell	Field Core ID	Date	Roll ID	Photo number	Description	Direction of photo
94		8/25/2004	A	25	PCC panels removed near J2090. Note: Unbonded, wet AC surface.	South
94	2086	8/25/2004	A	26	Bottom side of core from J2086. Note: Not bonded to AC layer.	
94	2086	8/25/2004	A	27	Side view of core 2086 showing joint.	
94	2085-2086	8/25/2004	A	28	Side view of core taken between J2085 and J2086. Note: Good bond to AC layer. Not full core.	
94	2085	8/25/2004	A	29	Bottom of upper and lower pieces of core from J2085. Delaminated at .5" from bottom of PCC core.	
94	2085	8/25/2004	A	30	Pieces of core from J2085. Note: No bond to AC.	
94	2085A	8/25/2004	A	31	Bottom of core taken near J2085. Partial bond of AC. Not sure if coring operation caused debonding.	
94	2085A	8/25/2004	A	32	Side view of core 2085A. Shows top-down crack profile.	
94	2085A	8/25/2004	A	33	Side view of core 2085A. Shows top-down crack profile.	
94		8/25/2004	A	34	Forensic area "BB" before PCC removal. Near J2090.	West
94		8/25/2004	A	35	Forensic area "BB" before PCC removal. Near J2090.	East
94		8/25/2004	A	36	Forensic area "BB" before PCC removal. Near J2090.	North
95		8/25/2004	B	6	Pieces of PCC from forensic area "CC" near J2182.	
95		8/25/2004	B	7	Pieces of PCC from forensic area "CC" near J2182.	
95		8/25/2004	B	8	Forensic area "CC" after PCC removal. Near J2182.	
95		8/25/2004	B	9	Pieces of PCC from forensic area "CC" near J2182.	
95		8/25/2004	B	10	Test pit near J2185.	
97	2255	8/25/2004	B	11	Bottom view of core from faulted joint J2255. Note: High quantity of fibers.	
97	2255	8/25/2004	B	12	Side view of core from faulted joint J2255.	
97	2255	8/25/2004	B	13	Side view of core from faulted joint J2255. Note: Deterioration at bottom of joint.	
97	2258	8/25/2004	B	14	Bottom view of core from faulted joint J2258. Note: High quantity of fibers.	
97	2258	8/25/2004	B	15	Side view of core from faulted joint J2258. Note: Deterioration at bottom of joint.	
97	2258	8/25/2004	B	16	Side view of core from faulted joint J2258. Note: Deterioration at bottom of joint.	
94	2137B	8/25/2004	B	17	Side view of core from joint J2137. Note: PCC patch area. Some bonding of AC present.	
94	2137A	8/25/2004	B	18	Side view (split open) of core 2137A, to show joint sealant.	
94	2137A	8/25/2004	B	19	Side view of core from joint J2137.	
94	2104	8/25/2004	B	20	Side view of core 2104 taken from repaired PCC area near J2104.	
94	2104	8/25/2004	B	21	Side view of core 2104 taken from repaired PCC area near J2104.	
93	2042B	8/25/2004	B	22	Side view of core 2042B. Note: Bonded AC layer.	
93	2042B	8/25/2004	B	23	Side view of core 2042B. Note: Bonded AC layer. Approach side of panel.	
93	2042B	8/25/2004	B	24	Side view of core 2042B. Note: Bonded AC layer. Leave side of core.	
93	2042A	8/25/2004	B	25	Side and bottom view of core 2042B. Note: Unbonded from AC layer.	
93		8/25/2004	B	26	Coring area between J2041 and J2042.	West
93		8/25/2004	B	27	Bottom view of pieces near shoulder removed from area between J2036 and J2037.	North
93		8/25/2004	B	28	Bottom view of pieces near outside wheelpath removed from area between J2036 and J2037.	West
93		8/25/2004	B	29	Overall view of forensic area between J2036 and J2037.	Northeast
93		8/25/2004	B	30	Overall view of forensic area between J2036 and J2037.	North
93		8/25/2004	B	31	Overall view of forensic area between J2036 and J2037. Note: Bonded and unbonded areas.	Southwest
93		8/25/2004	B	32	Overall view of forensic area between J2036 and J2037. Note: Bonded and unbonded areas.	Northwest
93		8/25/2004	B	33	View of forensic area between J2036 and J2037 showing bonded pieces (could not lift with skid loader).	West
93		8/25/2004	B	34	View of forensic area between J2036 and J2037 showing water retained in depressed AC area.	Southwest
93		8/25/2004	B	35	Side view of AC core showing depressed area (approx 0.75") by J2037, caused by broken PCC above.	
93		8/25/2004	B	36	Side view of AC core showing depressed area by J2037. Note: Stripping of AC at top of core.	

MnROAD Ultra-thin whitetopping forensic photo log (con't.)

Cell	Field Core ID	Date	Roll ID	Photo number	Description	Direction of photo
95		9/2/2004	B	1	Corner cracking near J2175. After cracking on approach and leave sides, forms into "pothole".	Southwest
95		9/2/2004	B	2	Initial corner cracking. Note: Approach side of panel.	
95		9/2/2004	B	3	Initial corner cracking. Note: Approach side of panel.	
95		9/2/2004	B	4	Test pit near J2185.	
95		9/2/2004	B	5	Forensic area "CC" after PCC removal. Near J2182.	South
94		9/2/2004	C	1	Core locations near J2085 and J2086. Passing lane.	East
93		9/2/2004	C	2	Crack between J2015 and J2016. Passing lane.	East
93		9/2/2004	C	3	Core locaton near J2042. Core 2042B on left, 2042A on right. Driving lane.	East
93		9/2/2004	C	4	Core location near J2038. Passing lane. Note: reflective crack through UTW.	South
93		9/2/2004	C	5	Core location between J2033 and J2034. Driving lane.	East
93		9/2/2004	C	6	Core locations near J2078. Passing lane.	East
94		9/2/2004	C	7	Core locations near J2104. Core 2104A. Driving lane. Reflective crack.	East
94		9/2/2004	C	8	Core locations near J2104. Core 2104B. Passing lane. Reflective crack.	East
94		9/2/2004	C	9	Core location near J2133. Passing lane.	East
95		9/2/2004	C	10	Core location near J2172. Driving lane.	East
95		9/2/2004	C	11	Core location near J2162. Passing lane.	East
95		9/2/2004	C	12	Core location near J2179. Passing lane.	East
95		9/2/2004	C	13	Core location near J2182. Driving lane.	East
95		9/2/2004	C	14	Core locations near J2194. Core 2194A to right. Passing lane. Repaired area.	East
95		9/2/2004	C	15	Core locations near J2194. Core 2194A to right. Passing lane. Repaired area.	Southeast
93		9/2/2004	C	16	Shows old TC tree. Dpeth to top TC=0.5", seconf TC=1.0".	Northwest
93		9/2/2004	C	17	Reflective crack through outside panel of passing lane near J2030.	South
93		9/2/2004	C	18	Large corner cracked area near outside wheelpath of driving lane near J2019.	East
93		9/2/2004	C	19	Bottom view of pieces near shoulder removed from area between J2036 and J2037.	East
93		9/2/2004	C	20	Bottom view of pieces near outside wheelpath removed from area between J2036 and J2037.	East
93		9/2/2004	C	21	View of forensic area between J2036 and J2037. Shows AC core location.	Northeast
93		9/2/2004	C	22	View of forensic area between J2036 and J2037. Shows AC core location.	Southwest
93		9/2/2004	C	23	Distressed panels near J2071. Driving lane.	South
94		9/2/2004	C	24	Early corner cracking on inside wheelpath of driving lane. (in repair area)	Southeast
94		9/2/2004	C	25	Early corner cracking on inside wheelpath of driving lane.	South
95		9/2/2004	C	26	Near J2165. No reflective crack through UTW.	East
95		9/2/2004	C	27	Large distressed area. Possibly caused by reflective crack?	East
95		9/2/2004	C	28	Near J2159. No reflective crack through UTW.	Southeast
95		9/2/2004	C	29	Large distressed area near J2155. Possibly caused by reflective crack?	East
95		9/2/2004	C	30	Closeup of cracking, showing fibers (polyolefin). Near J2155.	
95		9/2/2004	C	31	Closeup of cracking, showing fibers (polyolefin). Near J2155.	
95		9/2/2004	C	32	Closeup of cracking, showing fibers (polyolefin). Near J2155.	
95		9/2/2004	C	33	Example of reflective cracking and AC patch on corner cracked area.	South
95		9/2/2004	C	34	Example of initial corner cracking on approach side of panel. Passing lane.	Northwest
95		9/2/2004	C	35	Example of initial corner cracking on approach side of panel. Passing lane.	North
95		9/2/2004	C	36	Example of initial corner cracking on approach and leave side of panel. Passing lane.	North

MnROAD Ultra-thin whitetopping forensic photo log (con't.)

Cell	Field Core ID	Date	Roll ID	Photo number	Description	Direction of photo
		9/9/2004	D	1	Core hole showing corner crack	
95		9/9/2004	D	2	Forensic core "Y" location	North
		9/9/2004	D	3	Core hole showing dowel used to support sensor	
		9/9/2004	D	4	Condition of dowel used to support sensors, after 7 years	
		9/9/2004	D	5	Condition of dowels used to support sensors, after 7 years	
95		9/9/2004	D	6	Final walk-through before milling	East
95		9/9/2004	D	7	Final walk-through before milling	East
95		9/9/2004	D	8	Final walk-through before milling	East
95		9/9/2004	D	9	Final walk-through before milling	East
95		9/9/2004	D	10	Final walk-through before milling	East
95		9/9/2004	D	11	Final walk-through before milling	East
95		9/9/2004	D	12	Final walk-through before milling	East
95		9/9/2004	D	13	Final walk-through before milling	East
95		9/9/2004	D	14	Final walk-through before milling	East
95		9/9/2004	D	15	Final walk-through before milling	East
95		9/9/2004	D	16	Final walk-through before milling	East
95		9/9/2004	D	17	Final walk-through before milling	East
94		9/9/2004	D	18	Final walk-through before milling	East
94		9/9/2004	D	19	Final walk-through before milling	East
94		9/9/2004	D	20	Final walk-through before milling	East
94		9/9/2004	D	21	Final walk-through before milling	East
94		9/9/2004	D	22	Final walk-through before milling	East
94		9/9/2004	D	23	Final walk-through before milling	East
94		9/9/2004	D	24	Final walk-through before milling	East
94		9/9/2004	D	25	Final walk-through before milling	East
94		9/9/2004	D	26	Final walk-through before milling	East
93		9/9/2004	D	27	Final walk-through before milling	East
93		9/9/2004	D	28	Final walk-through before milling	East
93		9/9/2004	D	29	Final walk-through before milling	East
93		9/9/2004	D	30	Final walk-through before milling	East
93		9/9/2004	D	31	Final walk-through before milling	East
93		9/9/2004	D	32	Final walk-through before milling	East
93		9/9/2004	D	33	Final walk-through before milling	East
93		9/9/2004	D	34	Final walk-through before milling	East
93		9/9/2004	D	35	Final walk-through before milling	East
93		9/9/2004	D	36	Final walk-through before milling	East

MnROAD Ultra-thin whitetopping forensic photo log (con't.)

Cell	Field Core ID	Date	Roll ID	Photo number	Description	Direction of photo
94		1/12/2005	A	1	Core "N". North side of core. (inverted core in photo)	
94		1/12/2005	A	2	Core "N". Bottom of core. (inverted core in photo)	
94		1/12/2005	A	3	Core "N". South side of core. Beginning of top-down crack.	
94		1/12/2005	A	4	Core "N". Approach side of core.	
94		1/12/2005	A	5	Core "N". South side of core. Beginning of top-down crack.	
94		1/12/2005	A	6	Core "N". North side of core.	
94		1/12/2005	A	7	Core "N". Top view.	
95		1/12/2005	A	8	Core "T". (inverted core in photo)	
95		1/12/2005	A	9	Core "T". Showing unbonded AC portion. (inverted core in photo)	
95		1/12/2005	A	10	Core "T". South side of core.	
95		1/12/2005	A	11	Core "T". Approach side of core.	
95		1/12/2005	A	12	Core "T". North side of core.	
95		1/12/2005	A	13	Core "T". Top view.	
95		1/12/2005	A	14	Core "Y". Leave side of core.	
95		1/12/2005	A	15	Core "Y". Bottom of core. (inverted core in photo)	
95		1/12/2005	A	16	Core "Y". South side of core.	
95		1/12/2005	A	17	Core "Y". Approach side of core.	
95		1/12/2005	A	18	Core "Y". North side of core.	
95		1/12/2005	A	19	Core "Y". Top view.	
95		1/12/2005	A	20	Sample of piece from Cell 95 taken near J2183.	
95		1/12/2005	A	21	Sample of piece from Cell 95 taken near J2183.	
95		1/12/2005	A	22	Sample of piece from Cell 95 taken near J2183. (inverted in photo)	
95		1/12/2005	A	23	Sample of piece from Cell 95. (inverted in photo)	
95		1/12/2005	A	24	Sample of piece from Cell 95. (inverted in photo)	
95		1/12/2005	B	1	Core "AA". Leave side of core.	
95		1/12/2005	B	2	Core "AA". North side of core.	
95		1/12/2005	B	3	Core "AA". Top view.	
94		1/12/2005	B	4	Core "Q". (inverted core in photo)	
94		1/12/2005	B	5	Core "Q". Leave side of core.	
94		1/12/2005	B	6	Core "Q". Bottom of core. (inverted core in photo)	
94		1/12/2005	B	7	Core "Q". Approach side of core.	
94		1/12/2005	B	8	Core "Q". South side of core.	
94		1/12/2005	B	9	Core "Q". Leave side of core.	
94		1/12/2005	B	10	Core "Q". North side of core.	
94		1/12/2005	B	11	Core "Q". Top of core. Arrow indicates west.	
95		1/12/2005	B	12	Core "V". Approach side of core. (inverted core in photo)	
95		1/12/2005	B	13	Core "V". Shows debonding of HMA on bottom of core on south side.	
95		1/12/2005	B	14	Core "V". Bottom of core. (inverted core in photo)	
95		1/12/2005	B	15	Core "V". South side of core.	
95		1/12/2005	B	16	Core "V". Leave side of core.	
95		1/12/2005	B	17	Core "V". North side of core.	
95		1/12/2005	B	18	Core "V". Top of core. Arrow indicates west.	
95		1/12/2005	B	19	Core "W". South side of core. (inverted core in photo)	
95		1/12/2005	B	20	Core "W". Bottom of core. (inverted core in photo)	

MnROAD Ultra-thin whitetopping forensic photo log (con't.)

Cell	Field Core ID	Date	Roll ID	Photo number	Description	Direction of photo
95		1/12/2005	B	21	Core "W". Approach side of core.	
95		1/12/2005	B	22	Core "W". South side of core.	
95		1/12/2005	B	23	Core "W". North side of core.	
95		1/12/2005	B	24	Core "W". Top of core. Arrow indicates west.	
95		1/12/2005	C	1	Core "U". Leave side of core.	
95		1/12/2005	C	2	Core "U". North side of core.	
95		1/12/2005	C	3	Core "U". Top of core. Arrow indicates west.	
94		1/12/2005	C	4	Core "G". South side of core. (inverted core in photo)	
94		1/12/2005	C	5	Core "G". North side of core. Close-up of crack.	
94		1/12/2005	C	6	Core "G". Bottom of core. (inverted core in photo)	
94		1/12/2005	C	7	Core "G". Approach side of core.	
94		1/12/2005	C	8	Core "G". South side of core.	
94		1/12/2005	C	9	Core "G". Leave side of core.	
94		1/12/2005	C	10	Core "G". North side of core.	
94		1/12/2005	C	11	Core "G". Top of core. Arrow indicates west.	
94		1/12/2005	C	12	Core "M". (inverted core in photo)	
94		1/12/2005	C	13	Core "M". South side, split apart for detail.	
94		1/12/2005	C	14	Core "M". Bottom of core. Close-up view of crack. (inverted core in photo)	
94		1/12/2005	C	15	Core "M". Bottom of core. (inverted core in photo)	
94		1/12/2005	C	16	Core "M". Approach side of core.	
94		1/12/2005	C	17	Core "M". South side of core.	
94		1/12/2005	C	18	Core "M". Leave side of core.	
94		1/12/2005	C	19	Core "M". North side of core.	
94		1/12/2005	C	20	Core "M". Top of core. Arrow indicates west.	
95		1/12/2005	C	21	Core "AA". (inverted core in photo)	
95		1/12/2005	C	22	Core "AA". Bottom of core. (inverted core in photo)	
95		1/12/2005	C	23	Core "AA". Approach side of core.	
95		1/12/2005	C	24	Core "AA". South side of core.	
94		1/12/2005	D	1	Core "J". Bottom of core. (inverted core in photo)	
94		1/12/2005	D	2	Core "J".	
94		1/12/2005	D	3	Core "J".	
95		1/12/2005	D	4	Core "X". Bottom of core. (inverted core in photo)	
95		1/12/2005	D	5	Core "X". Top of core.	
95		1/12/2005	D	6	Core "Z". Leave side of core. (inverted core in photo)	
95		1/12/2005	D	7	Core "Z". Bottom of core. (inverted core in photo)	
95		1/12/2005	D	8	Core "Z". Approach side of core.	
95		1/12/2005	D	9	Core "Z". South side of core.	
95		1/12/2005	D	10	Core "Z". Leave side of core.	
95		1/12/2005	D	11	Core "Z". Top of core. Arrow indicates west.	
94		1/12/2005	D	12	Core "F". Top of core. Close-up view of crack.	
94		1/12/2005	D	13	Core "F". (inverted core in photo)	
94		1/12/2005	D	14	Core "F". Bottom of core. (inverted core in photo)	
94		1/12/2005	D	15	Core "F". Approach side of core.	
94		1/12/2005	D	16	Core "F". South side of core.	

MnROAD Ultra-thin whitetopping forensic photo log (con't.)

Cell	Field Core ID	Date	Roll ID	Photo number	Description	Direction of photo
94		1/12/2005	D	17	Core "F". Leave side of core.	
94		1/12/2005	D	18	Core "F". North side of core.	
94		1/12/2005	D	19	Core "F". Top of core. Arrow indicates west.	
95		1/12/2005	D	20	Core "U". Close-up of fibers holding joint together. (inverted core in photo)	
95		1/12/2005	D	21	Core "U". (inverted core in photo)	
95		1/12/2005	D	22	Core "U". Bottom of core. (inverted core in photo)	
95		1/12/2005	D	23	Core "U". Approach side of core.	
95		1/12/2005	D	24	Core "U". South side of core.	
94		1/12/2005	E	1	Core "L". (inverted core in photo)	
94		1/12/2005	E	2	Core "L". (inverted core in photo)	
94		1/12/2005	E	3	Core "R". (inverted core in photo)	
94		1/12/2005	E	4	Core "R". (inverted core in photo)	
94		1/12/2005	E	5	Core "R". (inverted core in photo)	
94		1/12/2005	E	6	Core "P". Shows partial-depth top-down crack in UTW.	
94		1/12/2005	E	7	Core "P". Shows partial-depth top-down crack in UTW.	
94		1/12/2005	E	8	Core "P". Shows partial-depth top-down crack in UTW.	
94		1/12/2005	E	9	Core "S". (inverted core in photo)	
94		1/12/2005	E	10	Core "S". (inverted core in photo)	
94		1/12/2005	E	11	Core "S". Top of core.	
93		1/12/2005	E	12	Core "A".	
93		1/12/2005	E	13	Core "A".	
94		1/12/2005	E	14	Core "K".	
94		1/12/2005	E	15	Core "K".	
94		1/12/2005	E	16	Core "I". (inverted core in photo)	
94		1/12/2005	E	17	Core "I". Bottom of core. (inverted core in photo)	
94		1/12/2005	E	18	Core "I". Approach side of core. Shows partial-depth top-down crack in UTW.	
94		1/12/2005	E	19	Core "I". South side of core. Shows partial-depth top-down crack in UTW.	
94		1/12/2005	E	20	Core "I". Leave side of core.	
94		1/12/2005	E	21	Core "I". North side of core.	
94		1/12/2005	E	22	Core "I". North side of core. Arrow indicates west.	
95		1/12/2005	E	23	Core "X". (inverted core in photo)	
94		1/12/2005	E	24	Core "J". (inverted core in photo)	
95		1/12/2005	F	1	Core "95D".	
95		1/12/2005	F	2	Core "95C". (inverted core in photo)	
93		1/12/2005	F	3	Core 93. (inverted core in photo)	
94		1/12/2005	F	4	Core "A". (inverted core in photo)	
94		1/12/2005	F	5	Core "B".	
95		1/12/2005	F	6	Sample from Cell 95 showing polyolefin fibers.	
93		1/12/2005	F	7	Core "E". North side of core. (inverted core in photo)	
93		1/12/2005	F	8	Core "E". North side of core. (inverted core in photo)	

MnROAD Ultra-thin whitetopping forensic photo log (con't.)

Cell	Field Core ID	Date	Roll ID	Photo number	Description	Direction of photo
93		1/12/2005	F	9	Core "D. (inverted core in photo)	
93		1/12/2005	F	10	Core "D". Bottom of core. (inverted core in photo)	
93		1/12/2005	F	11	Core "D". Bottom of core. (inverted core in photo)	
93		1/12/2005	F	12	Core "D".	
93		1/12/2005	F	13	Core "D".	
93		1/12/2005	F	14	Core "E". Bottom of core.	
93		1/12/2005	F	15	Core "E". Approach side of core. Close-up showing start of debonding from HMA.	
93		1/12/2005	F	16	Core "E". Approach side of core.	
93		1/12/2005	F	17	Core "E". South side of core.	
93		1/12/2005	F	18	Core "E". Leave side of core.	
93		1/12/2005	F	19	Core "E". Top of core. Arrow indicates west.	
93		1/12/2005	F	20	Core "B". Shows depression in HMA from UTW fragments.	
93		1/12/2005	F	21	Core "B". Shows depression in HMA from UTW fragments.	
93		1/12/2005	F	22	Core "B". Shows depression in HMA from UTW fragments.	
94		1/12/2005	F	23	Core "L". Top of core. Arrow indicates west.	
94		1/12/2005	F	24	Core "L". (inverted core in photo)	
93				DCP_1624	Overall view of F.A. "A".	

FC "A", Cell 93 **8-25-2004/A-2**

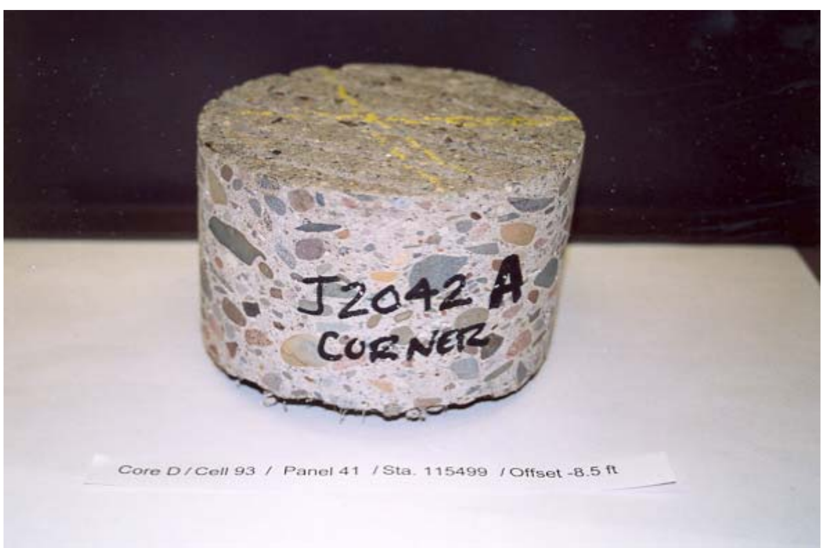
FC "A", Cell 93 **1-12-2005/E-12**

FC "B", Cell 93 **1-12-2005/F-20**

FC "C", Cell 93 **9-02-2004/C-4**

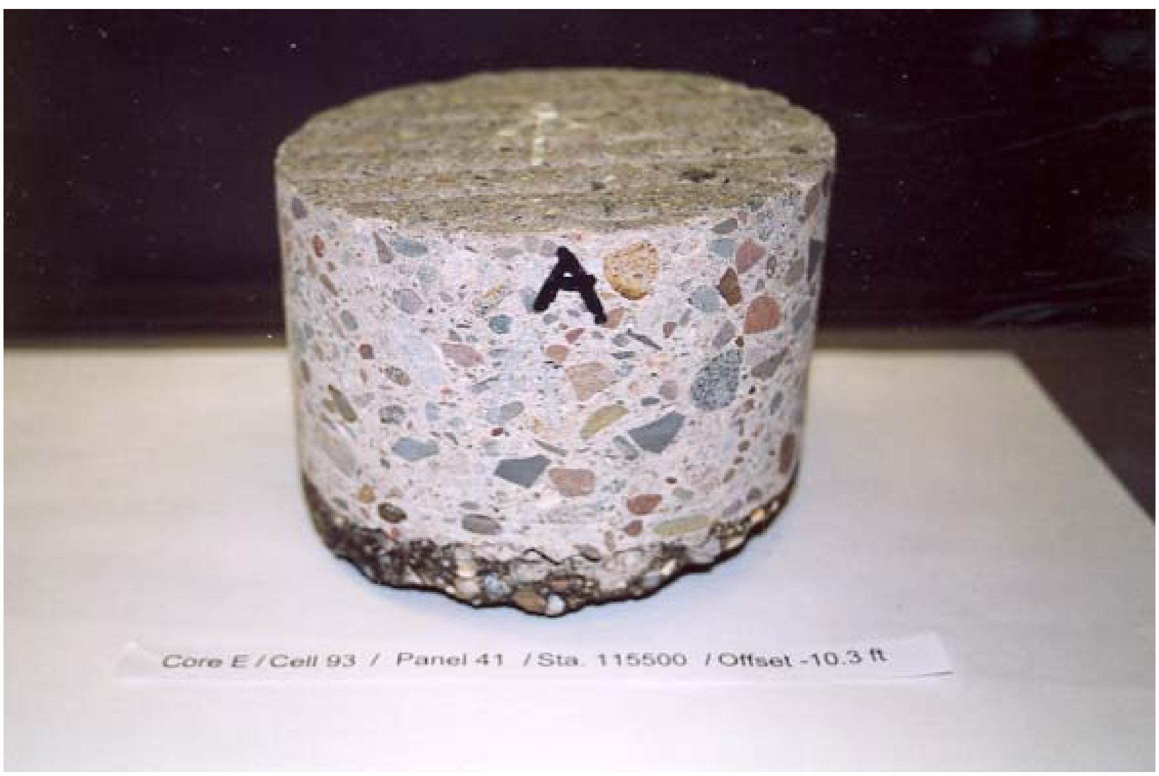
FC "D", Cell 93
9-02-2004/C-3

FC "D", Cell 93
1-12-2005/F-13



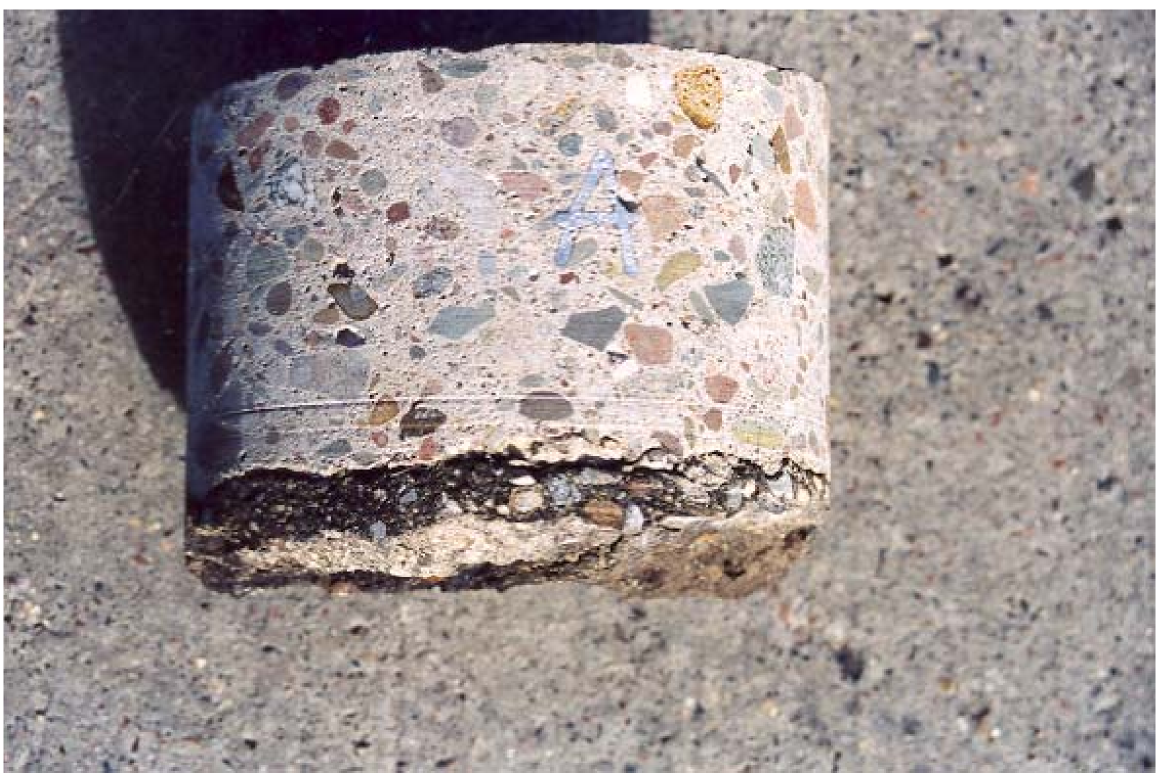
FC "D", Cell 93
1-12-2005/F-11

FC "E", Cell 93 **1-12-2005/F-7**



FC "E", Cell 93 **1-12-2005/F-16**

FC "E", Cell 93 **8-25-2004/B-24**



FC "E", Cell 93 **8-25-2004/B-23**

FC “F”, Cell 94
9-02-2004/C-6

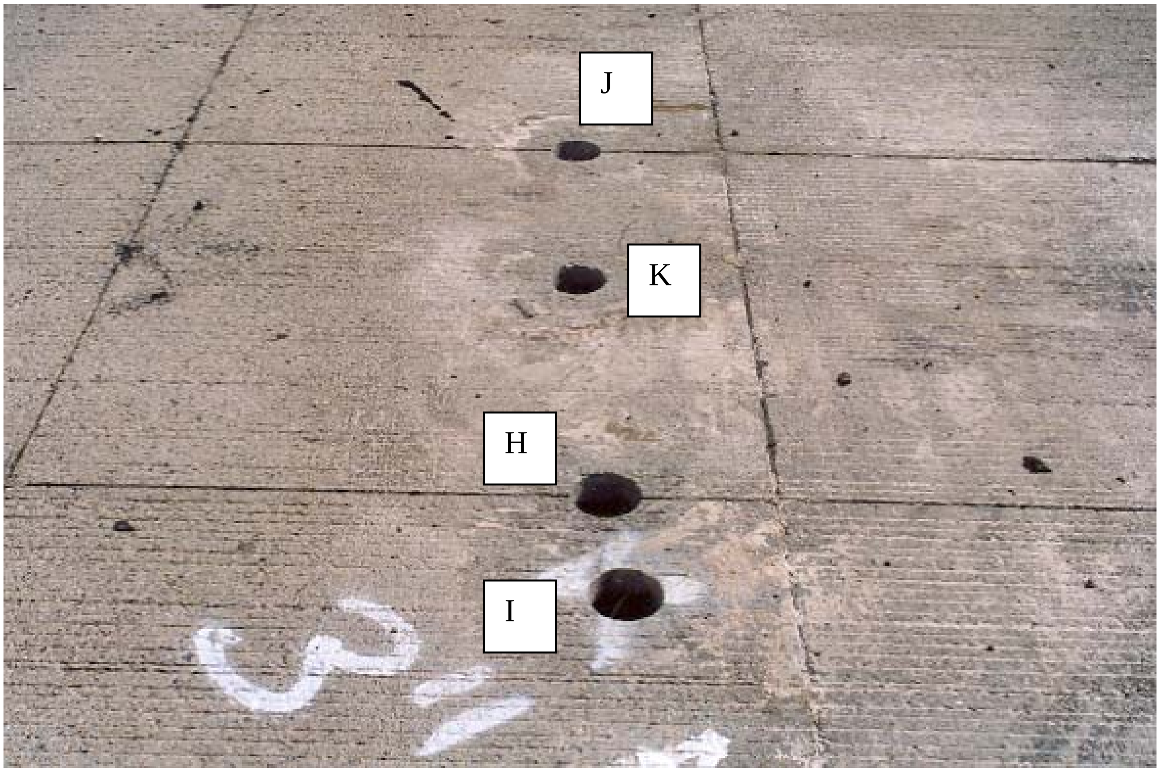
FC “F”, Cell 94
1-12-2005/D-19

FC “F”, Cell 94
1-12-2005/D-13

FC "G", Cell 94
1-12-2005/C-4

FC "G", Cell 94
1-12-2005/C-10

FC "G", Cell 94
1-12-2005/C-5



FC "H", "I", "J", "K", Cell 94 9-02-2004/C-1

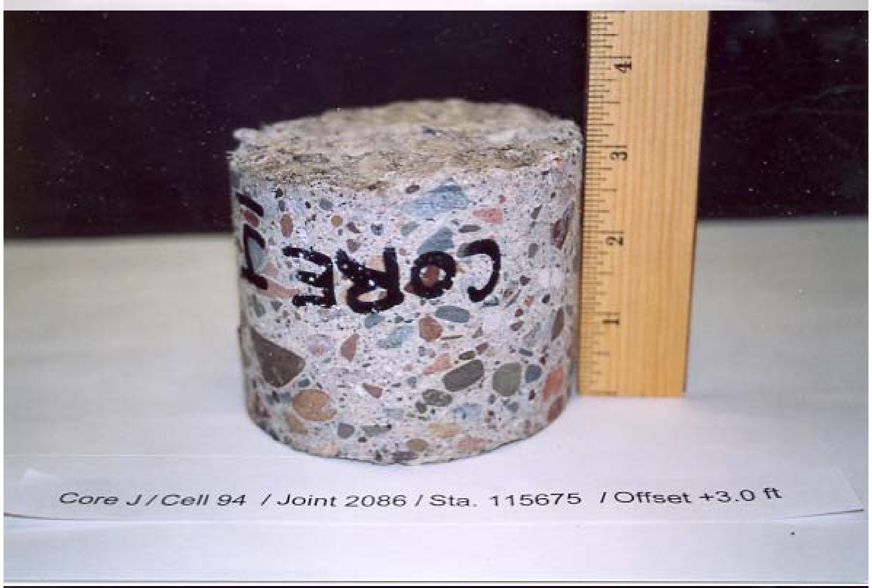
FC "H", Cell 94 8-25-2004/A-30

FC "I", Cell 94
1-12-2005/E-19

FC "I", Cell 94
1-12-2005/E-18

FC "I", Cell 94
1-12-2005/E-17

FC "J", Cell 94
1-12-2005/D-3



FC "J", Cell 94
1-12-2005/E-24

FC "J", Cell 94
1-12-2005/D-1

FC "K", Cell 94 **1-12-2005/E-14**

FC “L”, Cell 94
8-25-2004/B-20

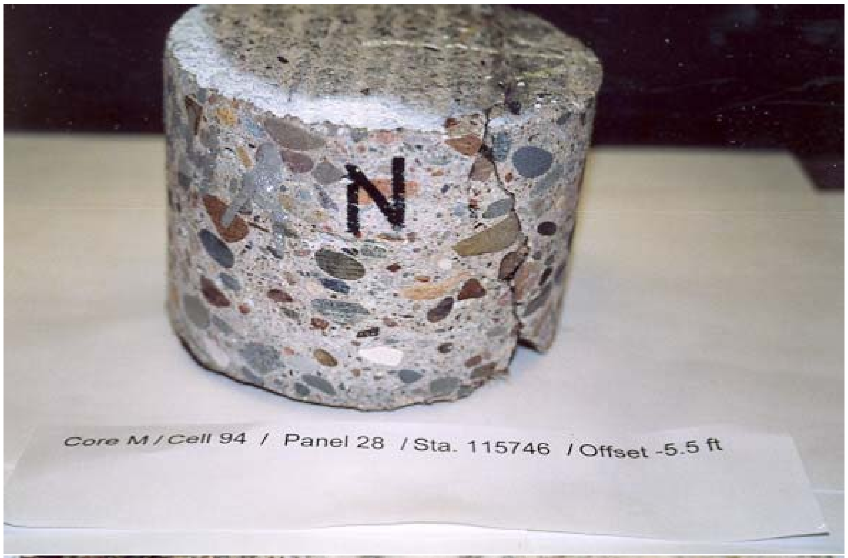
FC “L”, Cell 94
1-12-2005/F-24

FC “L”, Cell 94
1-12-2005/E-2

FC "M", Cell 94
9-02-2004/C-7

FC "M", Cell 94
1-12-2005/C-12

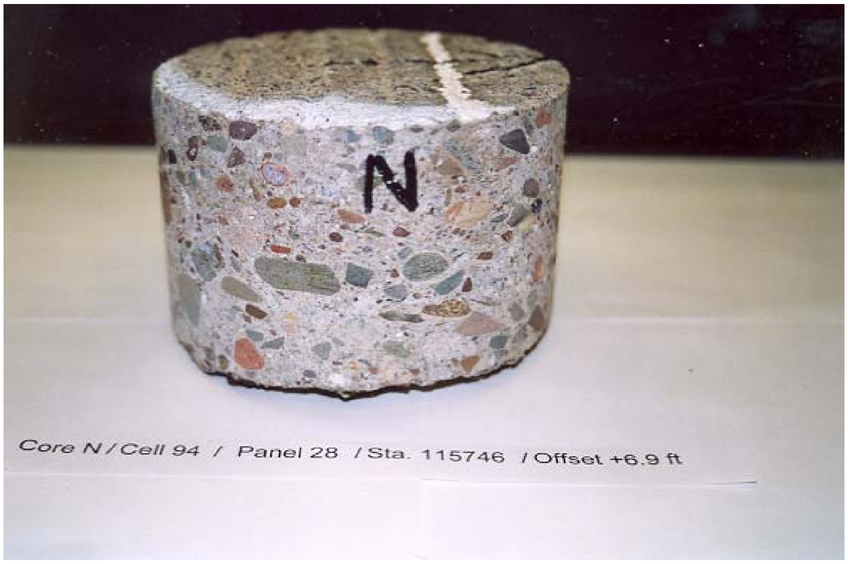
FC "M", Cell 94
1-12-2005/C-17



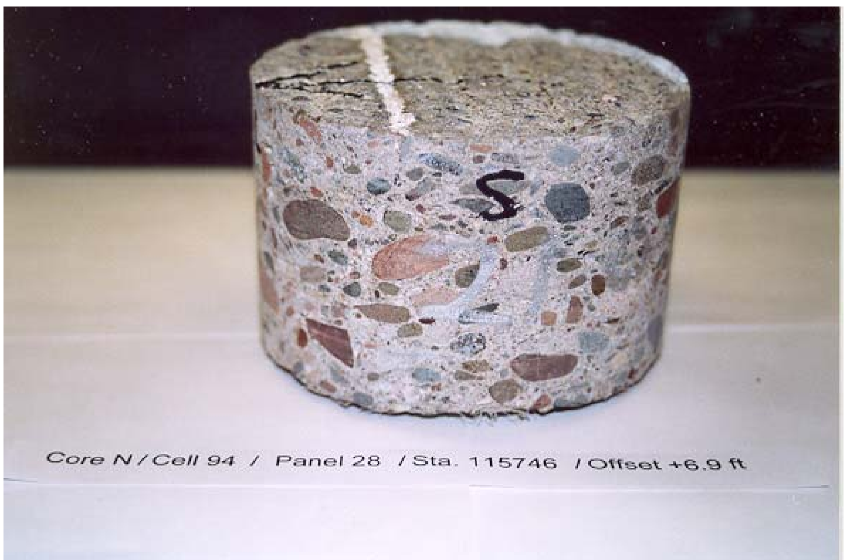
FC "M", Cell 94
1-12-2005/C-19

FC "M", Cell 94
1-12-2005/C-14

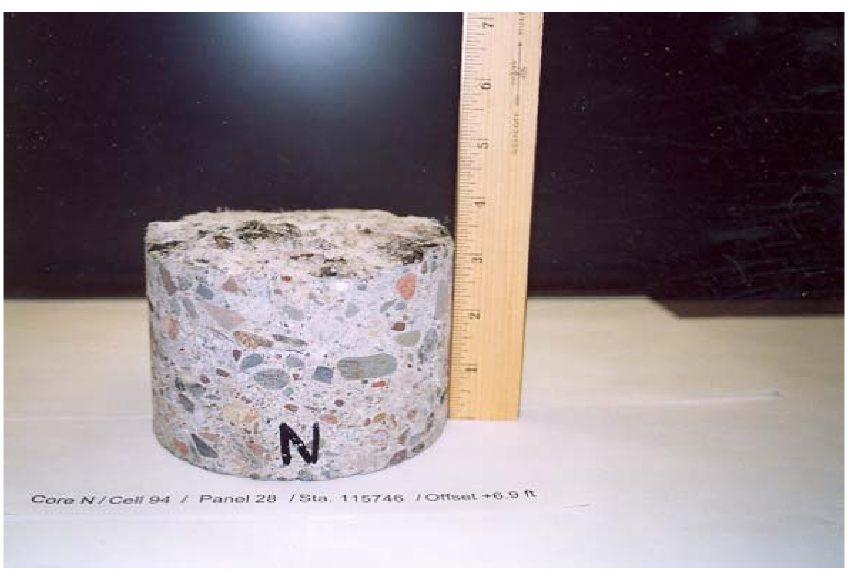
FC "M", Cell 94
1-12-2005/C-13



FC "N", Cell 94
1-12-2005/A-6



FC "N", Cell 94
1-12-2005/A-5



FC "N", Cell 94
1-12-2005/A-1

FC "P", Cell 94 **1-12-2005/E-6**

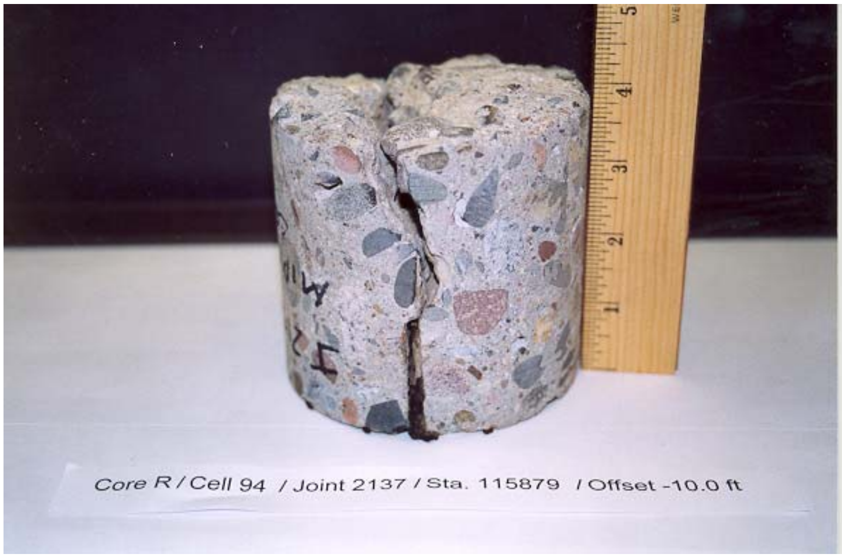
FC "P", Cell 94 **1-12-2005/E-8**

FC "Q", Cell 94 9-2-2004/C-9

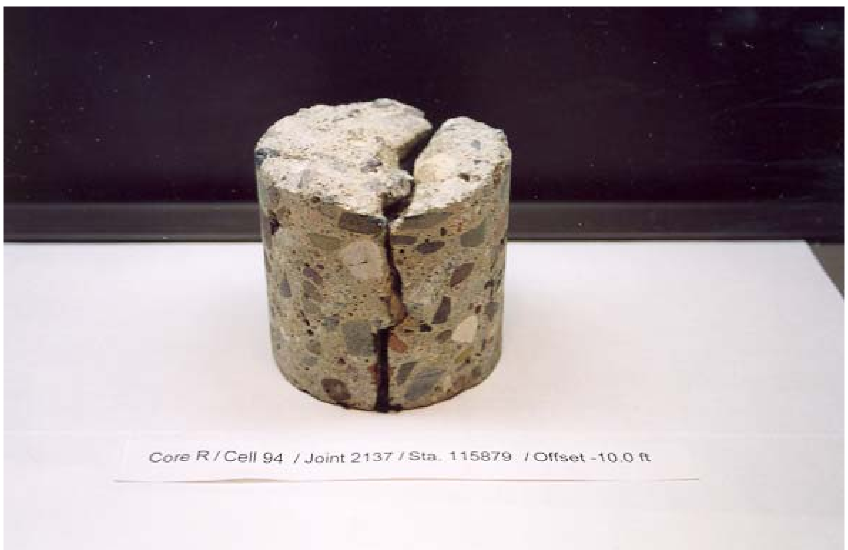
FC "Q", Cell 94 1-12-2005/B-6

FC "Q, Cell 94 **1-12-2005/B-9**

FC "Q", Cell 94 **1-12-2005/B-8**



FC "R", Cell 94
1-12-2005/E-3



FC "R", Cell 94
1-12-2005/E-5

FC "R", Cell 94
1-12-2005/B-18

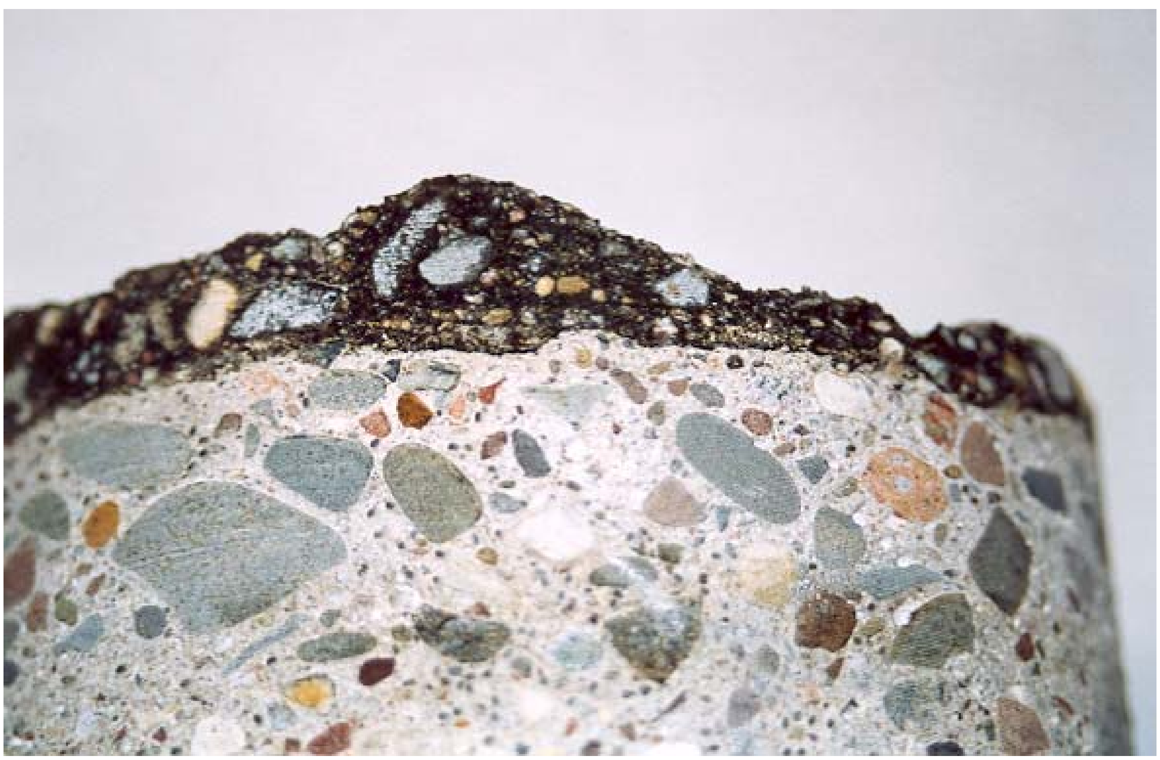
FC "S", Cell 94 **8-25-2004/B-17**

FC "S", Cell 94 **1-12-2005/E-9**

FC "T", Cell 95 **9-02-2004/C-11**

FC "T", Cell 95 **1-12-2005/A-8**

FC "T", Cell 95 **1-12-2005/A-11**



FC "T", Cell 95 **1-12-2005/A-9**

FC “U”, Cell 95 **9-02-2004/C-10**

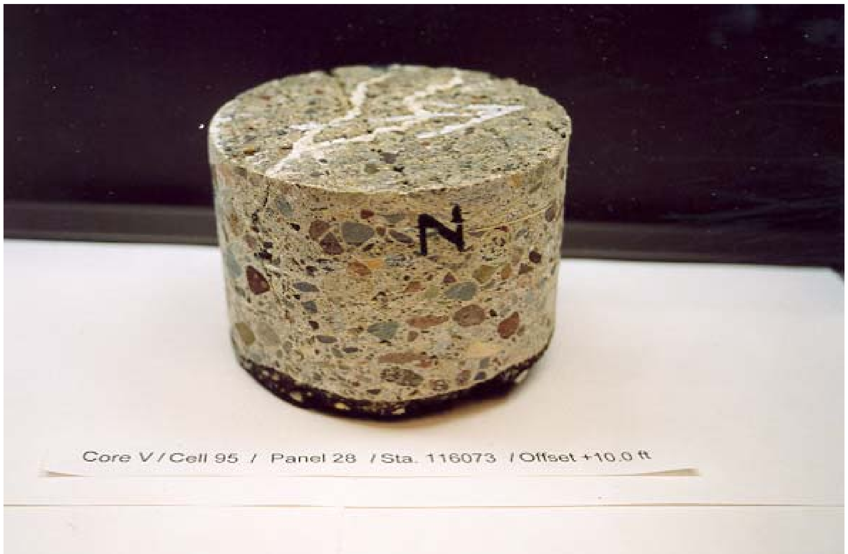
FC “U”, Cell 95 **1-12-2005/D-21**

FC "U", Cell 95 1-12-2005/C-1

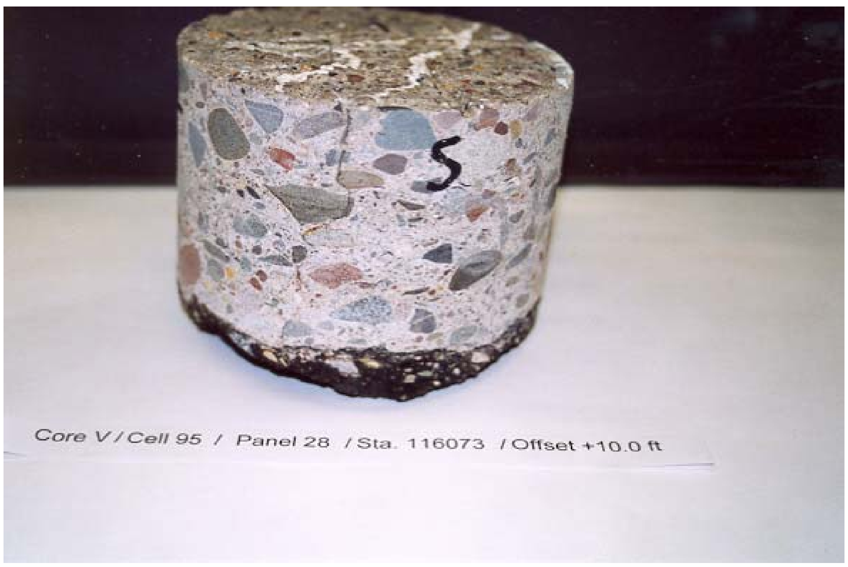
FC "U", Cell 95 1-12-2005/D-20

FC "V", Cell 95 9-02-2004/C-12

FC "V", Cell 95 1-12-2005/B-12



FC "V", Cell 95
1-12-2005/B-17



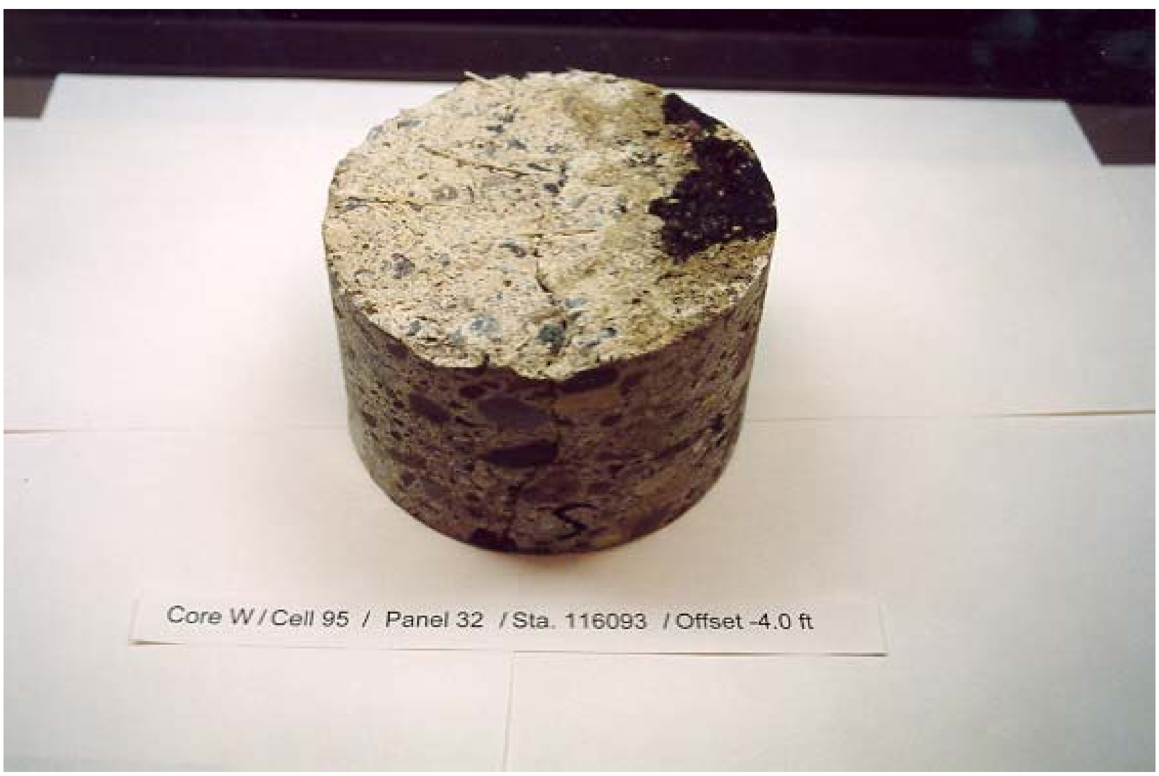
FC "V, Cell 95
1-12-2005/B-15

FC "V", Cell 95
1-12-2005/B-13

FC "W", Cell 95 **9-02-2004/C-13**

FC "W", Cell 95 **1-12-2005/B-19**

FC "W", Cell 95 **1-12-2005/B-23**



FC "W", Cell 95 **1-12-2005/B-20**

FC "X", Cell 95
8-25-2004/A-19

FC "X", Cell 95
1-12-2005/E-23

FC "X", Cell 95
1-12-2005/D-4

FC “Y” & “Z”, Cell 95 **9-02-2004/C-15**

FC “Y” & “Z”, Cell 95 **1-12-2005/A-14**

FC "Y", Cell 95 **1-12-2005/A-18**

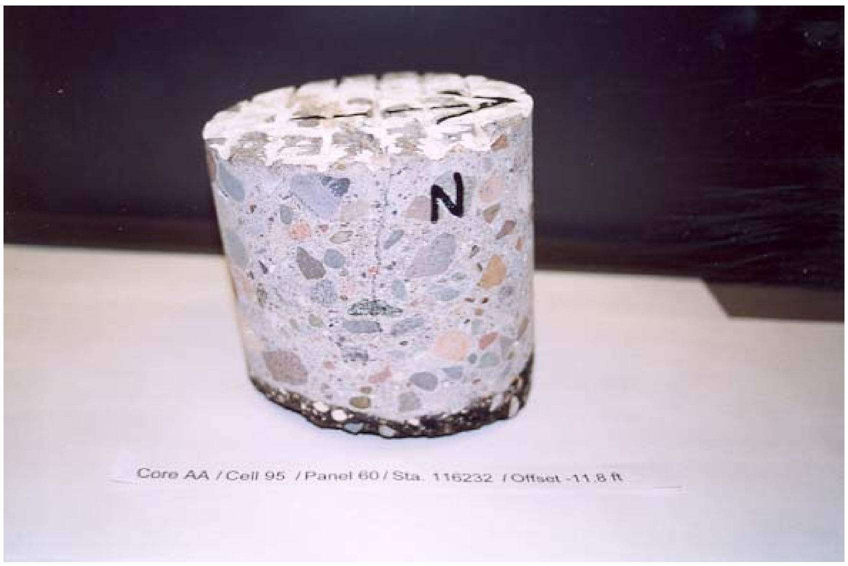
FC "Y", Cell 95 **1-12-2005/A-15**

FC “Z”, Cell 95
1-12-2005/D-6

FC “Z”, Cell 95
1-12-2005/D-8

FC “Z”, Cell 95
1-12-2005/D-7

FC "AA", Cell 95
1-12-2005/C-21



FC "AA", Cell 95
1-12-2005/B-2

FC "AA", Cell 95
1-12-2005/C-23

Cell 95 Joint cracking near joint 2155. **9-02-2004/C-31**

Cell 95 Corner crack near joint 2155. **9-02-2004/C-32**


Cell 95 Initial approach panel cracking in passing lane. 9-02-2004/C-34


Cell 94 Early corner cracking on inside wheelpath of driving lane. 9-02-2004/C-24

FA "A", Cell 93 **8-25-2004/B-30**

FA "A", Cell 93 **8-25-2004/A-10**

FA "A", Cell 93 8-25-2004/A-9

FA "A", Cell 93 Remaining portions of slab still bonded to HMA. 8-25-2004/B-33

FA "C", Cell 94 8-25-2004/A-36

FA "C", Cell 94 8-25-2004/A-25

FA "D", Cell 95 8-25-2004/A-23

FA "D", Cell 95 9-02-2004/B-5

FA "D", Cell 95 8-25-2004/B-7

FA "D", Cell 95 8-25-2004/B-9

FA "E", Cell 95   8-25-2004/A-12

Cell 95 corner crack forming into "pothole".   9-2-2004/B-1

Cell 93 reflective cracking. Facing north (left photo) and south (right photo).
8-25-2004/A-5 **8-25-2004/A-4**