PERFORMANCE EVALUATION OF COLD IN-PLACE RECYCLING PROJECTS IN ARIZONA

Final Report 460

Prepared By:
J. Mallela, H.L. Von Quintus, and K.L. Smith
Applied Research Associates, Inc.
505 W. University Avenue
Champaign, IL 61820

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Arizona Department of Transportation
206 S. 17th Avenue
Mail Drop 075R
Phoenix, AZ 85007

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16. Abstract
The Arizona Department of Transportation (ADOT) has been using cold in-place recycling (CIR) as a rehabilitation strategy for over two decades. Several highway pavements throughout the State have been rehabilitated using CIR, typically in conjunction with an asphalt overlay or a double application of seal coat. As with any other aspect of design and construction method, practices used to assess the feasibility of CIR on a given project, the CIR construction process, and the materials used to produce CIR materials have evolved over time. The primary objective of this investigation was to evaluate and document the performance of selected CIR projects in Arizona.

To satisfy this objective, detailed design, construction, performance, and traffic data on 17 CIR projects were compiled and summarized. In-depth profiles of each project, including historical trends of key distresses (cracking, rutting, flushing), ride quality, and maintenance costs, were developed and are presented in this report. The 17 CIR projects were constructed on low to moderate volume roads between 1981 and 2001. The projects involved one of the following types of applications:

- CIR for the top 2 to 3 inches of an existing HMA surface layer.
- CIR for the top 2 to 3 inches of an existing HMA surface layer, followed by a 2- to 3-inch HMAC overlay.

Overall performance of the CIR projects was found to be good, with most projects showing low to moderate levels of distress and roughness after many years. Both application types were deemed to be viable forms of pavement preservation for low- to moderate-volume roadways, with the CIR/overlay application noted as providing greater assurance of adequate performance and reduced likelihood of premature failure.

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Cold In-Place Recycling (CIR), Milling, Mixing, Emulsified Binder, Pavement Performance, Distress, Ride Quality, Maintenance Cost	Document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161		
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SI (MODERN METRIC) CONVERSION FACTORS*

APPROXIMATE CONVERSIONS TO SI UNITS					APPROXIMATE CONVERSIONS FROM SI UNITS				
Symbol	When You Know	Multiply By	To Find	Symbol	Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH					**LENGTH**		
in	inches	25.4	millimeters	mm	mm	millimeters	0.039	inches	in
ft	feet	0.305	meters	m	m	meters	3.28	feet	ft
yd	yards	0.914	meters	m	m	meters	1.09	yards	yd
mi	miles	1.61	kilometers	km	km	kilometers	0.621	miles	mi
		AREA					**AREA**		
in^2	square inches	645.2	square millimeters	mm^2	mm^2	Square millimeters	0.0016	square inches	in^2
ft^2	square feet	0.093	square meters	m^2	m^2	Square meters	10.764	square feet	ft^2
yd^2	square yards	0.836	square meters	m^2	m^2	Square meters	1.195	square yards	yd^2
ac	acres	0.405	hectares	ha	ha	hectares	2.47	acres	ac
mi^2	square miles	2.59	square kilometers	km^2	km^2	Square kilometers	0.386	square miles	mi^2
		VOLUME					**VOLUME**		
fl oz	fluid ounces	29.57	milliliters	mL	mL	milliliters	0.034	fluid ounces	fl oz
gal	gallons	3.785	liters	L	L	liters	0.264	gallons	gal
ft^3	cubic feet	0.028	cubic meters	m^3	m^3	Cubic meters	35.315	cubic feet	ft^3
yd^3	cubic yards	0.765	cubic meters	m^3	m^3	Cubic meters	1.308	cubic yards	yd^3
	NOTE: Volumes greater than 1000L shall be shown in m^3.								
		MASS					**MASS**		
oz	ounces	28.35	grams	g	g	grams	0.035	ounces	oz
lb	pounds	0.454	kilograms	kg	kg	kilograms	2.205	pounds	lb
T	short tons (2000lb)	0.907	megagrams (or “metric ton”)	mg (or “t”)	Mg	megagrams (or “metric ton”)	1.102	short tons (2000lb)	T
		TEMPERATURE (exact)					**TEMPERATURE (exact)**		
°F	Fahrenheit temperature	5(F-32)/9 or (F-32)/1.8	Celsius temperature	°C	°C	Celsius temperature	1.8C + 32	Fahrenheit temperature	°F
		ILLUMINATION					**ILLUMINATION**		
fc	foot candles	10.76	lux	lx	lx	lux	0.0929	foot-candles	fc
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2	cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE AND PRESSURE OR STRESS					**FORCE AND PRESSURE OR STRESS**		
lbf	poundforce	4.45	newtons	N	N	newtons	0.225	poundforce	lbf
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa	kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380

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CHAPTER 1. INTRODUCTION

BACKGROUND

Hot-mix asphalt (HMA) is one of the most recycled materials in the United States. It is estimated that approximately 100 million tons of HMA is milled off the roadways each year during resurfacing and widening projects.[1,2] Of this amount, approximately 80 million tons qualify as "reclaimed asphalt pavement" or RAP.[1,2]

There are a number of uses for RAP, including as a recycled asphalt layer, a granular base layer, or as a fill or embankment layer. In terms of using RAP as an asphalt layer, two options are available: hot recycling and cold recycling. Within each of these categories, the RAP can be recycled in a controlled plant environment or it can be recycled in place. This report deals primarily with cold in-place recycled asphalt materials.

Cold in-place recycling (CIR) is the processing and treatment with bituminous and/or chemical additives of existing HMA pavements without heating to produce a restored pavement layer.[1,3] The typical CIR process involves seven basic steps: [1,3]

1. **Milling –** A milling machine pulverizes a thin surface layer of pavement, usually from 2 to 4 inches deep.
2. **Gradation control –** The pulverized material is further crushed and graded to produce the desired gradation and maximum particle size. On some jobs, this step is omitted; however, on others a trailer-mounted screening and crushing plant is used to further crush and grade the pulverized pavement. If needed, virgin aggregate can be added to the recycled material.
3. **Additive incorporation –** The graded pulverized material is mixed with a binding additive (usually emulsified asphalt on CIR jobs). On some jobs, this is done by the milling machine, but on others a trailer-mounted pugmill mixer is used.
4. **Mixture placement –** The pulverized, graded pavement and additive combination is placed back over the previously milled pavement and graded to the final elevation. The mixture is most often placed with a traditional asphalt paver (either through windrow pickup or by depositing the mixture directly into the paver hopper), but on some very low traffic applications, the mixture can be placed by a motor grader. Because of the larger maximum aggregate sizes of the graded mixture, the minimum lift thickness for placement is usually around 2 inches.
5. **Compaction –** The placed mixture is compacted to the desired density. Typical compaction efforts involve a large pneumatic tire roller and a large vibratory steel-wheel roller. If an emulsion additive is used, rolling is typically delayed until the emulsion begins to break.
6. **Seal coat –** If the newly placed material is to operate as a high-quality gravel road, a seal coat (chip seal in addition to fog seal) is usually applied over the top to delay surface raveling of the cold recycled mix.
7. **Surface course construction –** On higher volume roads, the cold recycled mix is overlaid with a thin HMA overlay. A tack coat should be used to provide a good bond

between the cold recycled mix and the surface course. The performance of HMA overlays in other agencies has been found to be sensitive to a good bond between the overlay and CIR layer. Without a good bond, fatigue cracking can be expected. [4]

CIR is generally applied to older pavements that are structurally adequate but require a new wear course due to poor rideability. This rehabilitation treatment may be applied in conjunction with an overlay or with a seal coat, depending on the anticipated traffic levels on the roadway under consideration.

Some of the significant advantages of CIR are that (a) it drastically reduces both haul costs and materials costs, especially when virgin aggregate materials are in short supply, (b) it is cost-competitive when compared to conventional asphalt overlays when life-cycle costs are used as a basis, (c) it offers substantial environmental and societal benefits, and (d) it eliminates the occurrence of reflective cracks in the new wearing surface.

Significant disadvantages of using CIR include (a) performance is heavily dependent on contractor experience, (b) quality control is more difficult, (c) no nationally established mix design procedures are available to characterize the materials, and (d) performance benefits still are quantified empirically.

STUDY OBJECTIVES

The Arizona Department of Transportation (ADOT) has been using CIR as a rehabilitation strategy for over two decades. Several highway pavements throughout the State have been rehabilitated using CIR, typically in conjunction with an asphalt overlay or a double application of seal coat. As with any other aspect of design and construction method, practices used to assess the feasibility of CIR on a given project, the CIR construction process, and the materials used to produce CIR materials have evolved over time. The primary objective of this investigation was to evaluate and document the performance of selected CIR projects in Arizona. To satisfy this objective, the following three tasks were performed:

1. Prepare CIR Project Profiles—Preparation of project descriptions and design and construction summaries for 17 CIR projects, based on ADOT records and discussions with appropriate ADOT personnel.

2. Evaluate CIR Performance—Development and evaluation of pavement performance trends for each CIR project and the CIR strategy, in general, using the ADOT pavement management system database.

3. Prepare CIR Report—Development of a comprehensive report featuring the project profiles and performance trends of the selected CIR projects, and any noteworthy findings and recommendations regarding CIR as a preservation technique in Arizona.

SCOPE OF THE REPORT

This report presents profiles and performance summaries for 17 CIR projects selected by ADOT for review. Each summary is written to serve as a "stand alone" account of a given project and contains a brief description of the following:

- Project location.
- Traffic data in the form of average daily traffic (ADT) taken from the ADOT pavement management database and annual average daily traffic (AADT) and truck percentages taken from the ADOT Highway Log file.
- Quantities and types of CIR work performed, along with other rehabilitation activities undertaken.
- Cross-section details and materials information.
- Construction specifications, as well as observations, where available.
- Pavement performance data since CIR was performed in terms of total cracking, rutting, flushing, potholes, patching, and ride. These data are presented on a per-mile basis as well as an averaged section basis.
- Annual and cumulative maintenance costs for the entire duration for which data are available in the database. These data are presented on a per-mile basis as well as an averaged section basis.

The report also includes a more general evaluation of CIR as a rehabilitation strategy, using information from the 17 profiled projects.

CHAPTER 2. PROJECT SUMMARIES

ADOT identified 17 projects for detailed evaluation and documentation. For most of these projects, detailed profile information and pavement management system data (including project summaries, materials information, construction equipment, method specifications, pavement condition information, design recommendations, and post-construction observations) were available. However, some projects lacked much of the noted information, due to their physical location (e.g., frontage roads, shoulders, ramps) and/or age. It should also be noted that, for some projects, information was unavailable as to whether the distress/ride data reported for the same year as the CIR construction occurred before or after the construction event. Moreover, for some projects, CIR was performed in conjunction with a structural HMA overlay, thereby making it difficult to properly assess the effect of CIR alone on pavement performance.

Table 1 lists basic information about each project. In the sections that follow, each project is summarized, presenting the information in as much detail as was available. In the graphs, the per cent trucks is expressed as a decimal.

CIR PROJECT 1—US 70 EB, GILA COUNTY

Project Overview

This project, located on US 70 eastbound between mileposts (MP) 266.0 and 271.0, was constructed in 1981 by the Ashton Company (subcontractor Valentine) under ADOT Project No. F-022-4-517. The project entailed CIR of the existing asphalt pavement to a depth of 2.5 inches, followed by the placement of a 0.5 inch asphalt concrete (AC) friction course. No additional information about the design and construction of the project was available.

Traffic

Figure 1 presents a plot of ADT versus time for this project; figure 2 presents plots of AADT and percent trucks versus time. It is apparent that while the ADT and AADT increased over time, the percentage of trucks has remained fairly constant. Furthermore, the magnitude of trucks is very low.

Pavement Performance Observations

Pavement distress data (e.g., block cracking, transverse cracking, alligator cracking, potholes, rutting, patching, and flushing), ride quality data, and maintenance costs were extracted from the pavement management database and examined. This information is reported on a mile-by-mile basis in the pavement management system database. For example, ride data at MP 200 on a given project convey the condition of the roadway between MP 200 and 201. The last condition survey on the roadway was performed in March 2002.

Table 1. Summary of basic information for projects evaluated.

CIR Proj. No.	ADOT Construction Project No.	Highway No.	Year of Const.	Location	Rehabilitation Treatments [a]	Data Availability	
						Detailed Project Info	Detailed Pvt. Mgmt. Data
1	F-022-4-517	US 70 EB	1981	MP 266.0 to 271.0	2.5 in RC + 0.5 in FC	No	Yes
2	BP-022-4-519	US 70 EB	1983	MP 257.2 to 266.0	2.5 in RC + 1.5 in AC + SC	No	Yes
3	FR-055-1(4)	SR 87 NB	1983	MP 115.77 to 121.01	2 to 3.5 in RC + SC	No	Yes
4	I-10-4-939	I 10 WB Frontage Road	1987	MP 212.75 to 221.00	2 in RC + FL	No	No
5	IR-19-1(101)	I 19 NB and SB Shoulders	1988	MP 58.48 to 60.02	2 in RC	No	No
6	S244-513	SR 87	1992	MP 361.95 to 268.0	2 in RC + SC	Yes	Yes
7	STP-077-1(9)P	US 191	1995	MP 482-500.96	2.5 in RC + SC	Yes	Yes
8	STP-022-3(79)P	US 60 EB	1996	MP 199.35 to 208.44	3 in RC + 2 in AC + 0.5 FC	Yes	Yes
9	STP-213(5)P	SR 389	1996	MP 0.0 to 27.0	2.5 in RC + 2 in AC + SC	Yes	Yes
10	STP-215(4)P	SR 73	1998	MP 350.67 to 357.56	3 in RC + 2 in AC	Yes	Yes
11	STP-244(4)P	SR 87	1998	MP 393.5 to 406.04	2.5 in RC + 2 in AC + SC	Yes	Yes
12	STP-060-1(6)P	SR 264	1999	MP 340.0 to 359.6	2.5 in RC + 2 in AC + SC	Yes	Yes
13	STP-244(6)P	SR 87	1999	MP 368.0 to 385.0	2 in RC + SC	Yes	Yes
14	S-244(5)P	SR 87	1999	MP 385.0 to 393.5	2.5 in RC + 2 in AC	Yes	Yes
15	STP-077-1(10)P	US 191	2001	MP 468.03 to 482.0	3 in RC + 2 in AC	Yes	Yes
16	STP-064-1(10)P	US 160	2000	MP 322.2 to 331.0	3 in RC + 2 in AC	Yes	Yes
17	STP-051-1(17)P	US 180	1998	MP 324.96 to 338.40	3 in RC + 1.5 in AR + FC	No	Yes

[a] ADOT Material Codes:

AC = Asphaltic Concrete
AR = AC with Asphaltic Rubber
FC = Asphaltic Concrete Friction Course
FL = Flush Coat (Fog Seal)
RC = Recycled AC (Asphalt Removed and Rejuvenated)
SC = Seal Coat (Cover Materials with Emulsified Asphalt)

MP = Milepost

NB = Northbound
SB = Southbound
EB = Eastbound
WB = Westbound

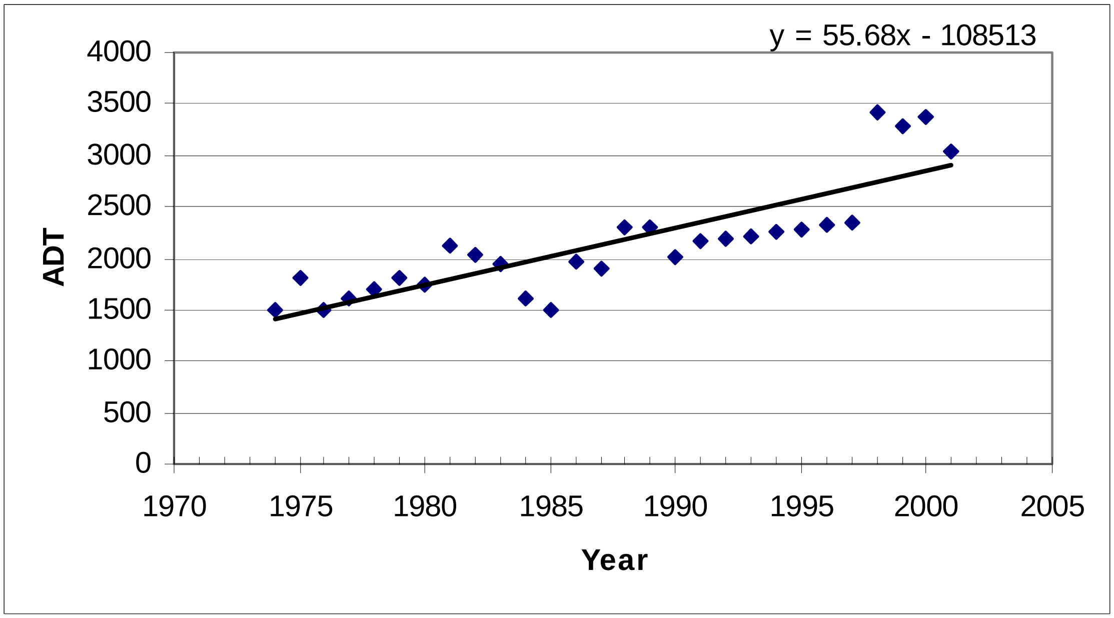

Figure 1. ADT data for CIR Project 1—US 70 EB (ADOT Project No. F-22-4-517).

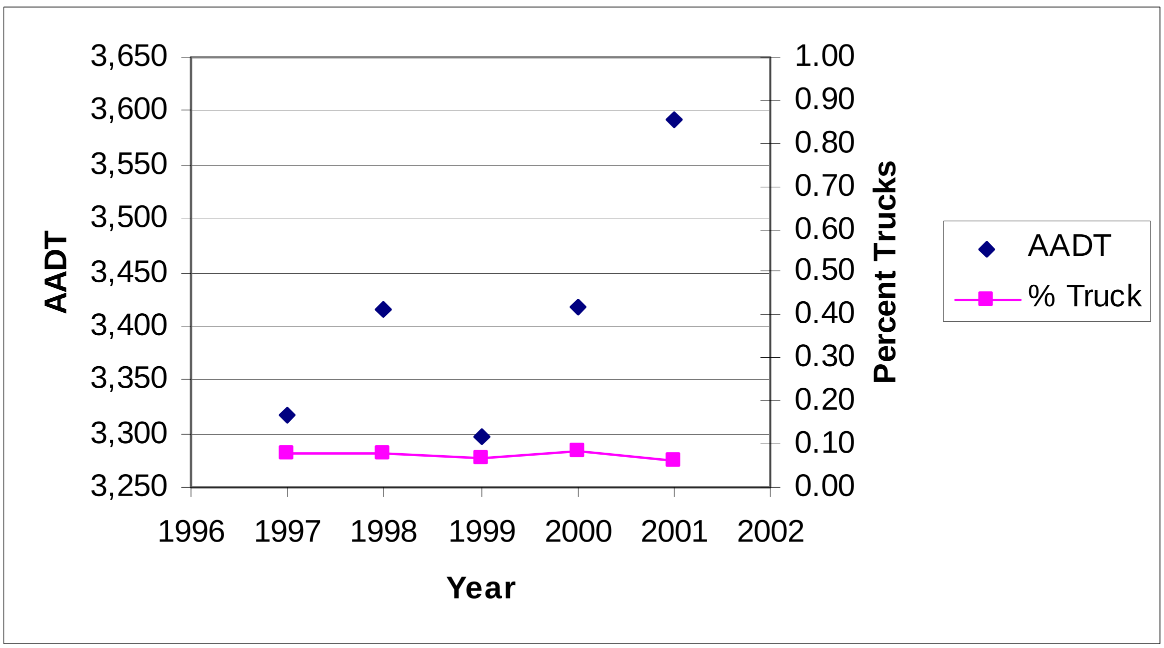

Figure 2. AADT data for CIR Project 1—US 70 EB (ADOT Project No. F-22-4-517).

The following is the extent of information available for each performance category considered in this report:

- Cracking – 1979 to 2002.
- Potholes – at the time of last condition survey.
- Rutting – 1989 to 2002.
- Patching – 1979 to 2002.
- Flushing – 1979 to 2002.
- Ride – 1972 to 2002.
- Maintenance costs – 1979 to 2002.

Based on the distress, ride, and cost data examined, it appears that this CIR project, originally constructed in 1981, was rehabilitated around the year 2000. The nature of this rehabilitation is unknown, but it does have a definite impact on the pavement performance, as shown below.

Figures 3 through 5 present the cracking, rutting, and flushing data since this CIR project was constructed. Pothole and patching data are not plotted because these quantities were zero over the entire reporting period. Figure 6 presents the ride quality data. Note that all the distress and ride data are presented on both a mile-by-mile basis and an averaged per-mile basis for the entire project (solid line). Performance-related observations are typically made using the average per-mile quantities as the basis.

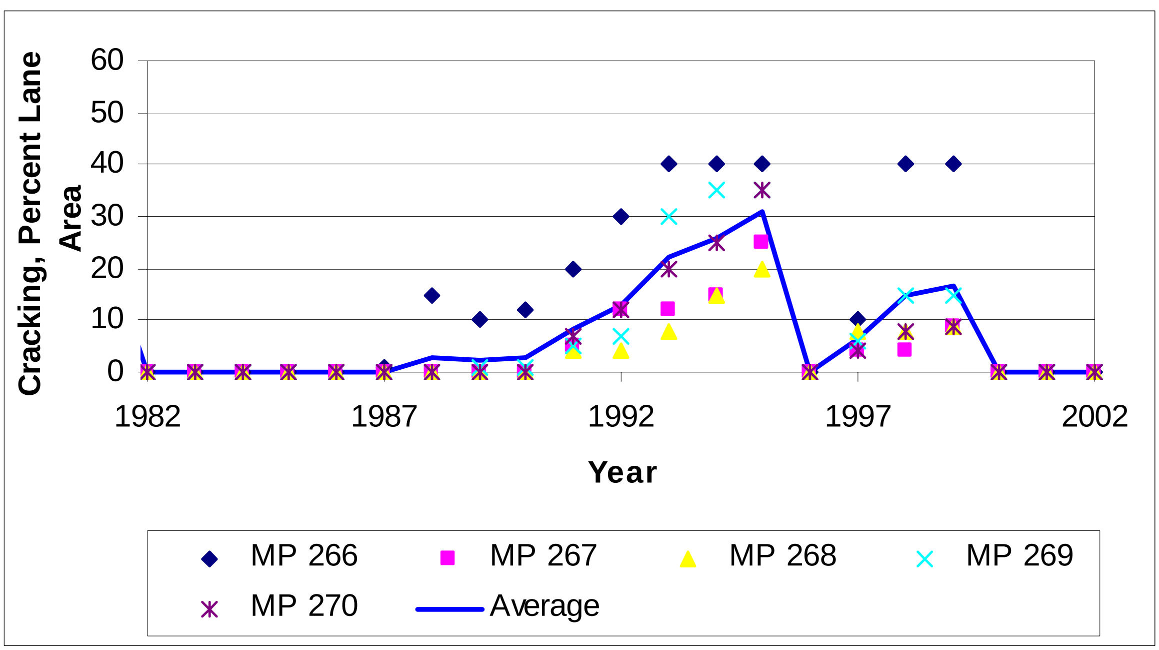

Figure 3. Cracking data for CIR Project 1—US 70 EB (ADOT Project No. F-22-4-517).

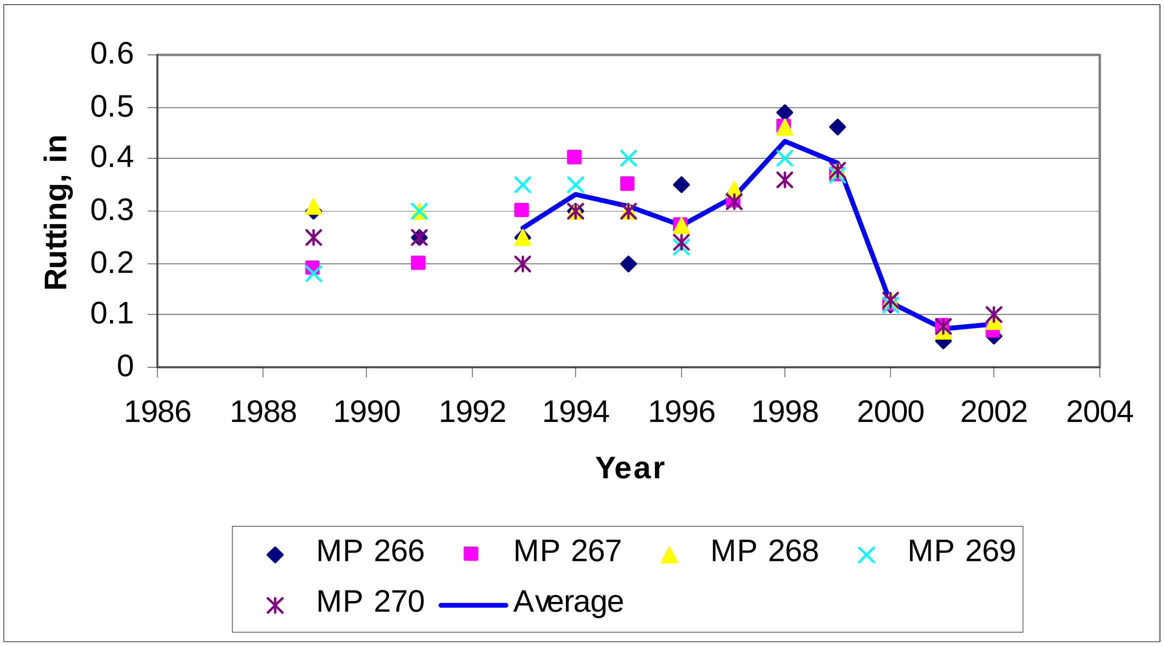

Figure 4. Rutting data for CIR Project 1—US 70 EB (ADOT Project No. F-22-4-517).

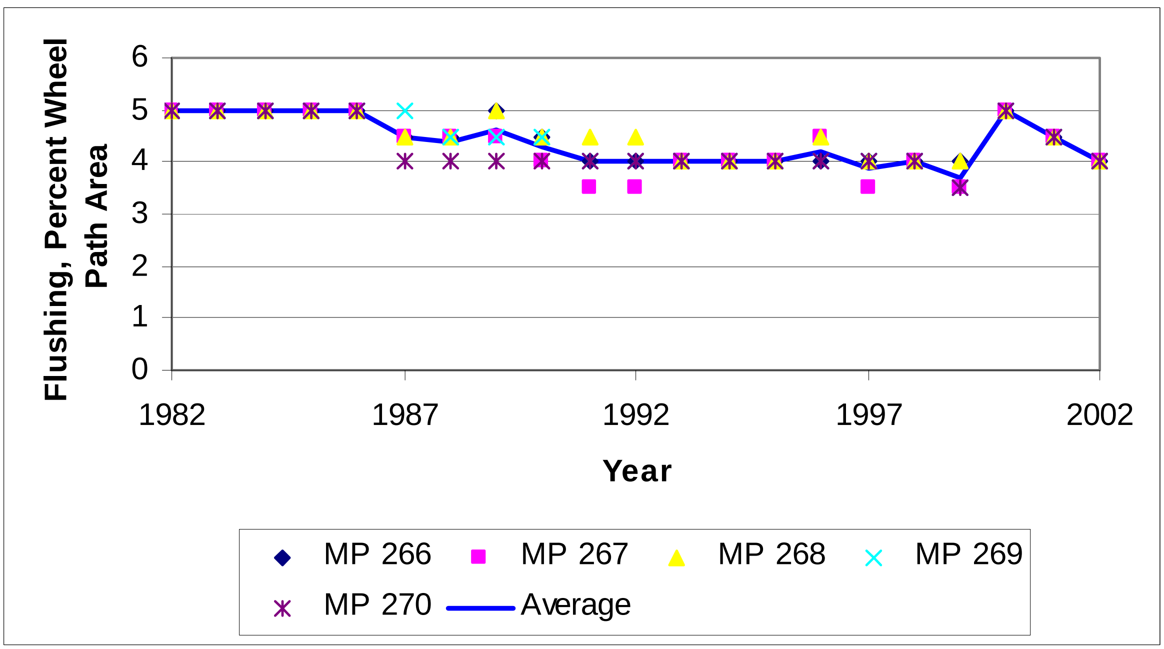

Figure 5. Flushing data for CIR Project 1—US 70 EB (ADOT Project No. F-22-4-517).

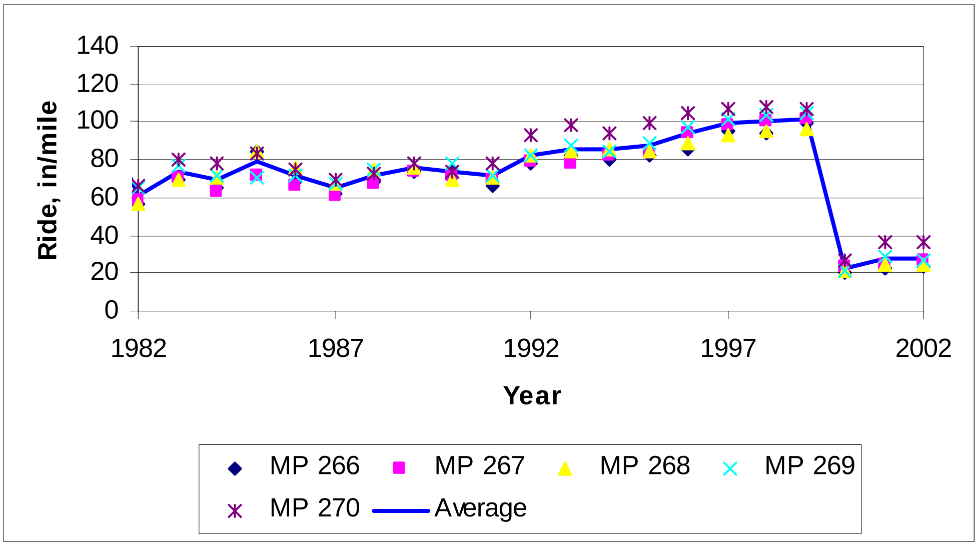

Figure 6. Ride quality information (Mays Ridemeter) for CIR Project 1—US 70 EB (ADOT Project No. F-22-4-517).

Figure 7 presents the annual maintenance costs on a mile-by-mile basis as well as on an averaged per-mile basis for the entire project length. Figure 8 presents the cumulative maintenance costs a on a mile-by-mile basis as well as on an averaged per-mile basis.

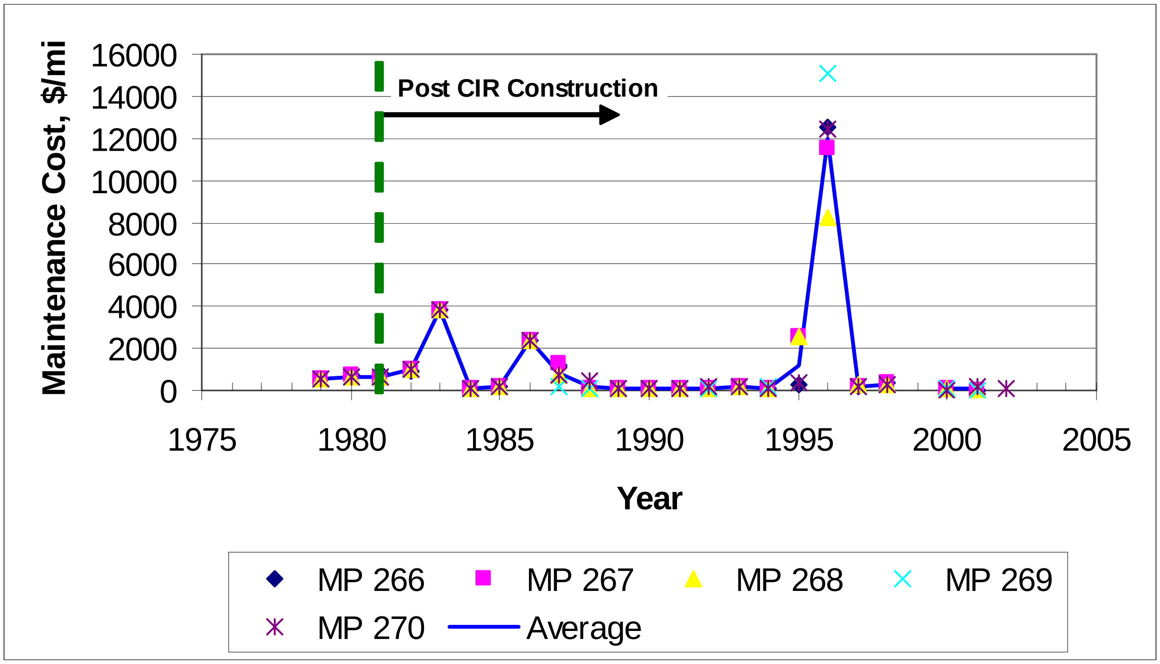

Figure 7. Maintenance costs for CIR Project 1—US 70 EB (ADOT Project No. F-22-4-517).

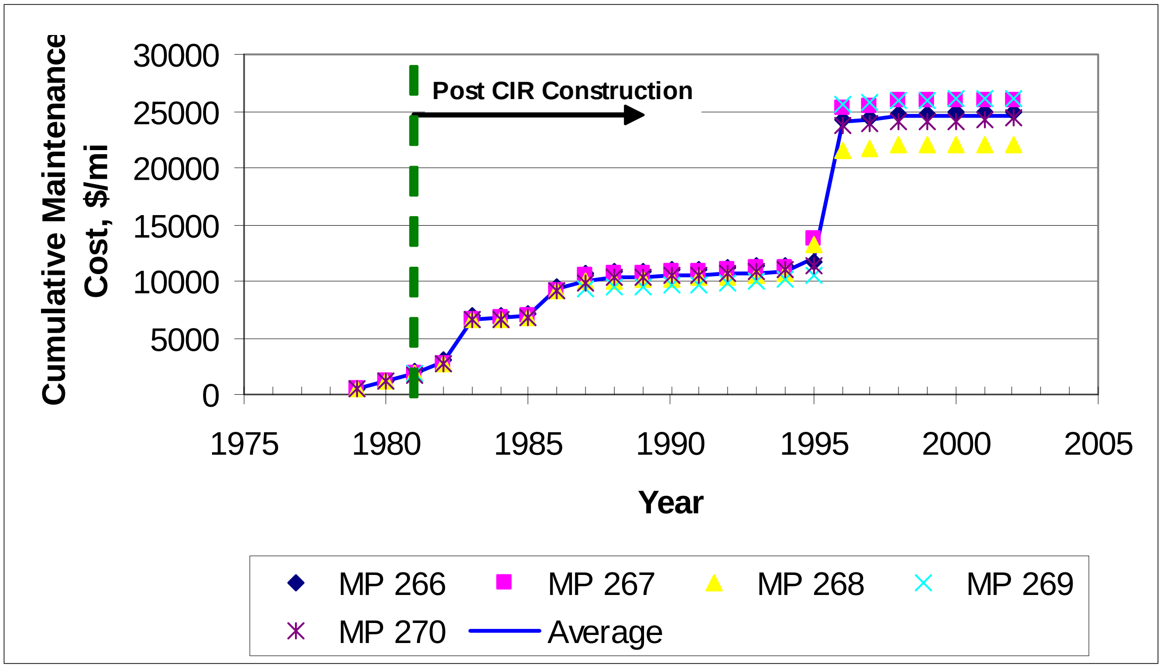

Figure 8. Cumulative maintenance costs for CIR Project 1—US 70 EB (ADOT Project No. F-22-4-517).

Summary of Performance Observations

The following observations can be made from the performance data presented:

- It is clear from figure 3 that the cracking quantities are negligible until about 1989 and thereafter increase sharply. The values drop significantly in 1996, perhaps due to routine maintenance. The cracking quantities increase thereafter, only to drop again in 2000, suggesting another maintenance or rehabilitation action.
- The magnitude of rutting, shown in figure 4, also increases with time and assumes relatively high magnitudes towards the end of the project. The quantities drop in 2000, suggesting that a major rehabilitation occurred at this time.
- The ride values also show a generally increasing trend until 2000, with a sharp improvement noticed at this time.
- The flushing quantities shown in figure 5 remain fairly uniform over time, except when maintenance is applied or rehabilitation work is performed.
- Figure 7 suggests that maintenance costs have been relatively low over time, except in 1996, in which significant costs were incurred. The cumulative maintenance cost shown in figure 8 generally increases over time, reaching a sharp peak value in 1996, which is perhaps due to the routine maintenance action taken to address the increased cracking. After 2000, the costs remained relatively stable, pointing to the efficacy of the rehabilitation undertaken at this time.

Overall, the CIR seemed to have a relatively short life. It is difficult to explain why this was the case and to reach definitive conclusions, lacking additional information on the materials and methods used in the CIR work.

CIR PROJECT 2—US 70 EB, GILA COUNTY

Project Overview

This project, located on US 70 eastbound between MP 257.2 and 266.0, was constructed in 1983 by Sundt Construction (subcontractor Valentine) under ADOT Project No. BP-22-4-519. The project entailed CIR of the existing asphalt pavement to a depth of 2.5 inches, followed by the placement of a 1.5 inch AC surface course and a fog seal. No additional information about the design and construction of the project was available.

Traffic

Figure 9 presents a plot of ADT versus time for this project, and figure 10 presents plots of AADT and percent trucks versus time. It is apparent that while the ADT and AADT increased over time, the percentage of trucks has remained fairly constant. Further, the magnitude of trucks is also very low.

Pavement Performance Observations

Pavement distress data, ride quality data, and maintenance costs were extracted from the pavement management database and examined. The following is the extent of information available for each performance category considered in this report:

- Cracking – 1979 to 2002.
- Potholes – at the time of last condition survey.
- Rutting – 1989 to 2002.
- Patching – 1979 to 2002.
- Flushing – 1979 to 2002.
- Ride – 1972 to 2002.
- Maintenance costs – 1979 to 2002.

Based on the distress, ride, and cost data examined, it appears that this CIR project, originally constructed in 1983, was rehabilitated around 2000. The nature of this rehabilitation is unknown, but it does have a definite impact on the pavement performance, as shown below.

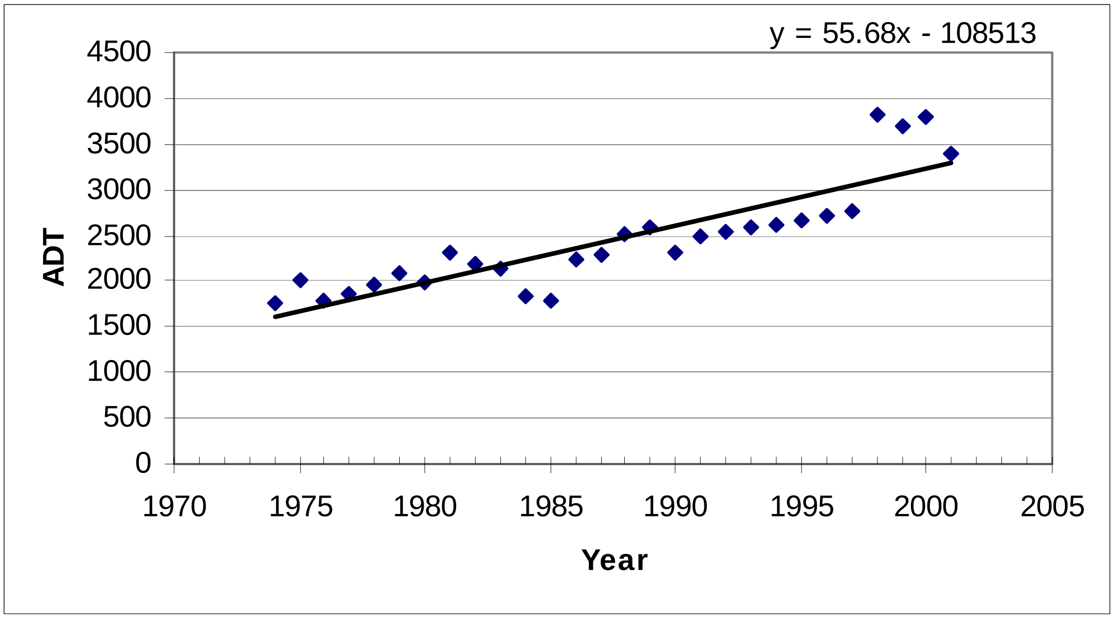

Figure 9. ADT data for CIR Project 2—US 70 EB (ADOT Project No. BP-22-4-519).

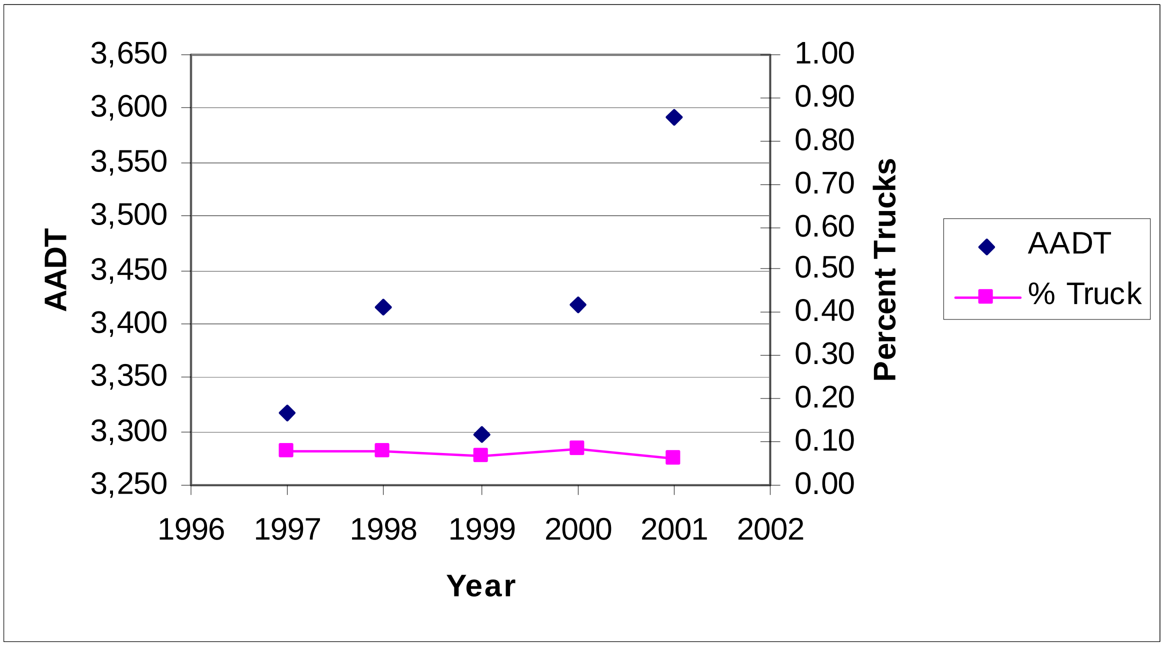

Figure 10. AADT data for CIR Project 2—US 70 EB (ADOT Project No. BP-22-4-519).

Figures 11 through 13 present the cracking, rutting, and flushing data since this CIR project was constructed. Pothole and patching data are not plotted since these quantities were zero over the reporting period. Figure 14 presents the ride quality data. Note that all the distress and ride data are presented on both a mile-by-mile basis and an averaged per-mile basis for the entire project (solid line). Performance-related observations are typically made using the average per-mile quantities as the basis.

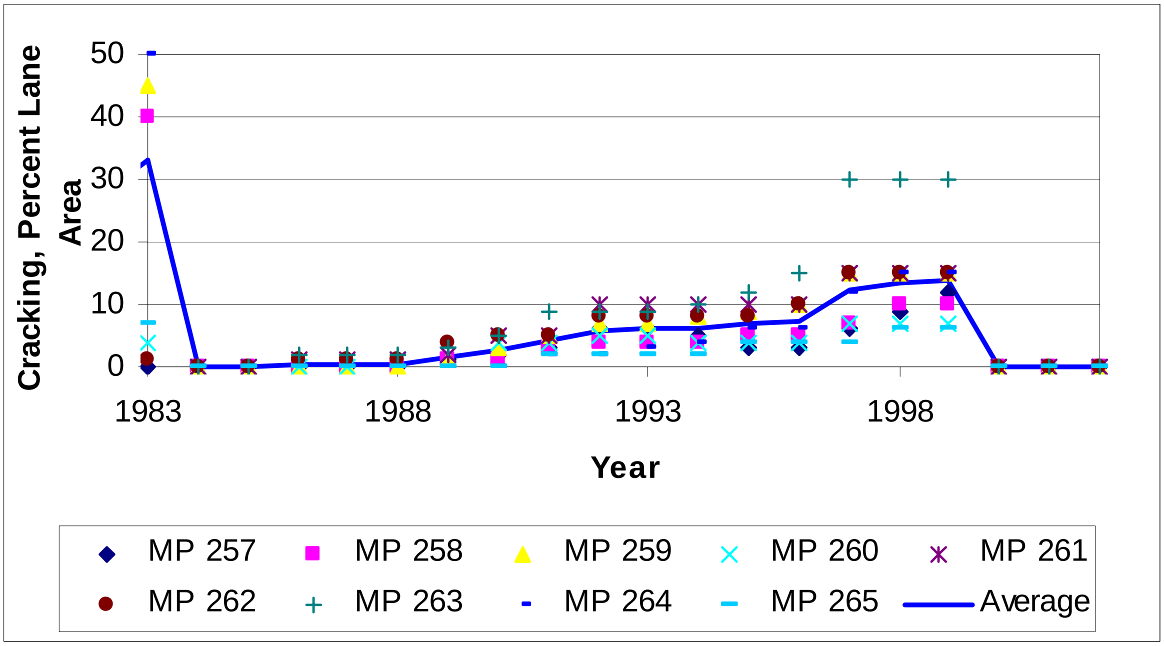

Figure 11. Cracking data for CIR Project 2—US 70 EB (ADOT Project No. BP-22-4-519).

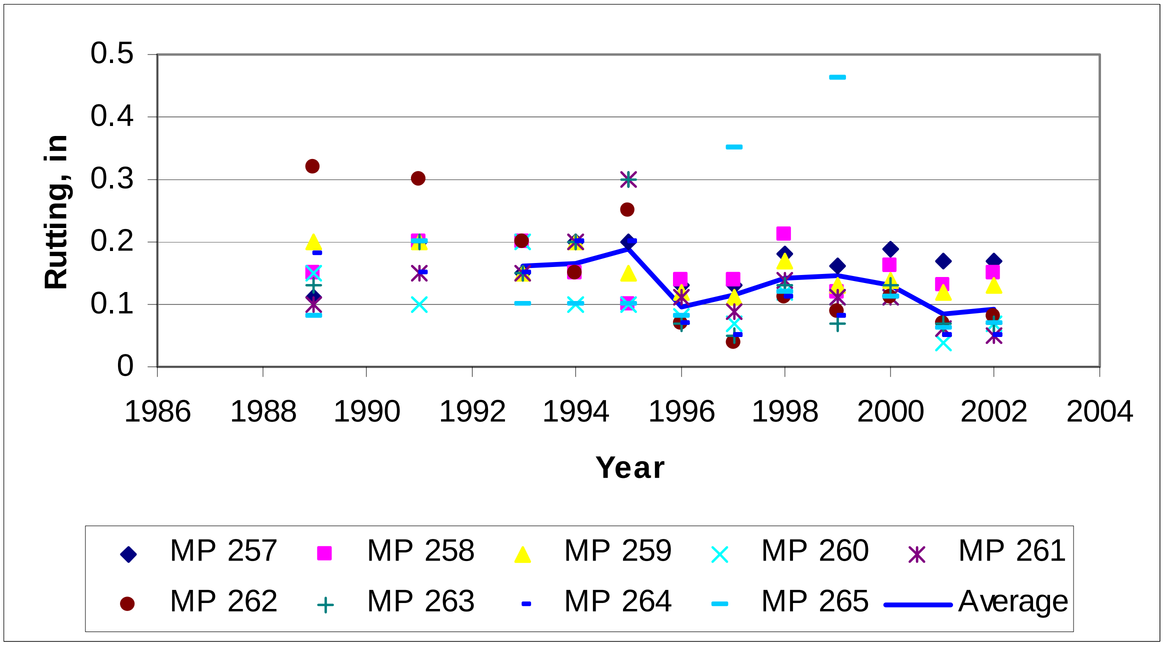

Figure 12. Rutting data for CIR Project 2—US 70 EB (ADOT Project No. BP-22-4-519).

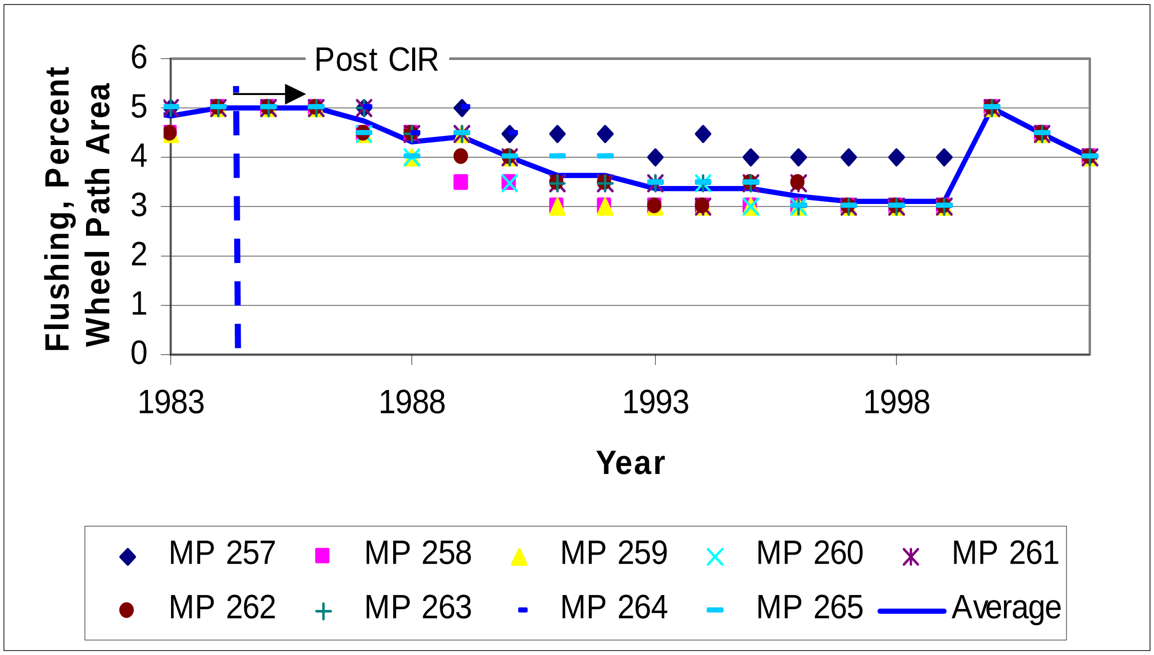

Figure 13. Flushing data for CIR Project 2—US 70 EB (ADOT Project No. BP-22-4-519).

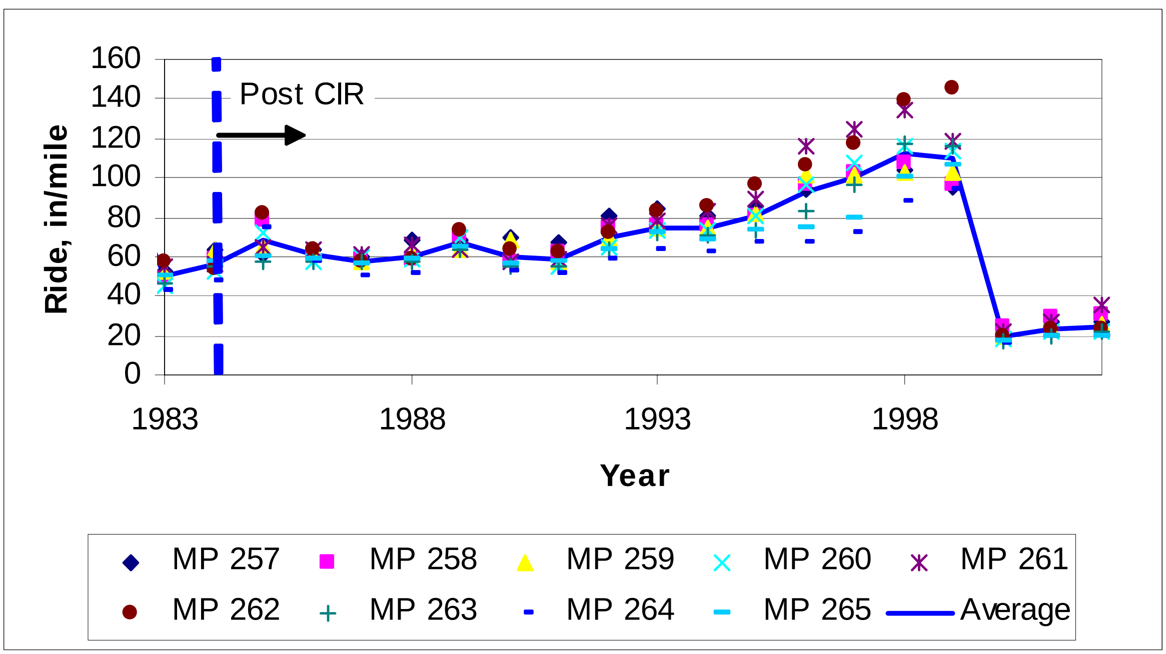

Figure 14. Ride quality information (Mays Ridemeter) for CIR Project 2—US 70 EB (ADOT Project No. BP-22-4-519).

Figure 15 presents the annual maintenance costs on a mile-by-mile basis as well as on an averaged per-mile basis for the entire project length. Figure 16 presents the cumulative maintenance costs a on a mile-by-mile basis as well as on an averaged per-mile basis.

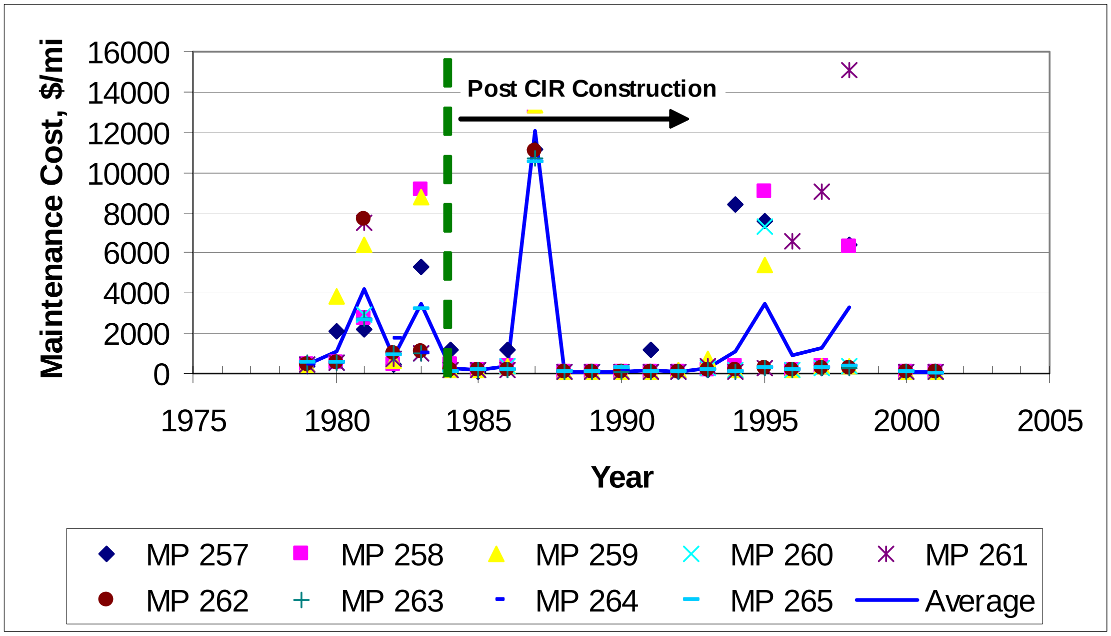

Figure 15. Maintenance costs for CIR Project 2—US 70 EB (ADOT Project No. BP-22-4-519).

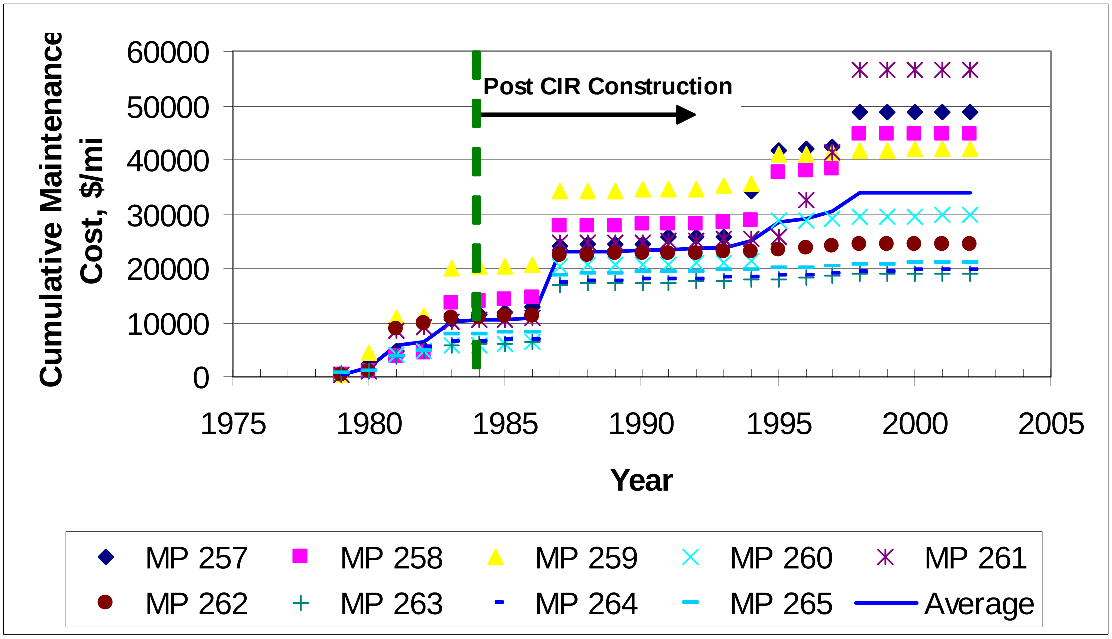

Figure 16. Cumulative maintenance costs for CIR Project 2—US 70 EB (ADOT Project No. BP-22-4-519).

Summary of Performance Observations

The following observations can be made from the performance data presented:

- It is clear from figure 11 that the cracking quantities are negligible until about 1990 and sharply increase thereafter. The values drop significantly in 2000, suggesting that either a maintenance or rehabilitation action may have been taken at this time.
- The rutting values plotted in figure 12 generally decrease with time, with relatively noticeable drops occurring in 1996 and 2000; this confirms that a relatively major rehabilitation action was likely undertaken in 2000.
- Figure 13 shows that the flushing quantities increase with time, with a noticeable increase occurring in 2000—the approximate year when a rehabilitation action is assumed to have taken place.
- The ride values shown in figure 14 show a generally increasing trend until the year 2000, with a sharp improvement noticed at this time.
- Figure 15 suggests that, after the CIR work, maintenance costs remained relatively low over time, except in 1987, when significant costs were incurred. Figure 16 suggests that the cumulative maintenance cost generally increased over time, reaching a sharp peak value in 1987, perhaps due to the routine maintenance action taken to address the increasing cracking. Two relatively stable periods—between 1986 and 1994 and between 1999 and 2002—are observed in terms of cumulative maintenance cost. This is perhaps a reflection on the efficacy of the maintenance or rehabilitation work undertaken immediately preceding these time intervals in response to increasing pavement distress.

Overall, the CIR seemed to have a relatively short life. However, as with CIR Project 1, it is difficult to ascertain the reasons for this due to insufficient information regarding the materials and methods used in the CIR work.

CIR PROJECT 3—SR 87 NB, PINAL COUNTY

Project Overview

This project, located on SR 87 northbound between MP 115.8 and 121.0, was constructed in 1983 by the Bentson Contracting Company (subcontractor Valentine) under ADOT Project No. FR-55-1(4). The project entailed CIR of the existing asphalt pavement to a depth of 3.5 inches, followed by the placement of a seal coat. No additional information about the design and construction of the project was available.

Traffic

Figure 17 presents a plot of ADT versus time for this project, and figure 18 presents plots of AADT and percent trucks versus time. It is apparent from the traffic information presented in figures 17 and 18 that while the ADT is generally increasing over time, the AADT has been fairly constant since 1997, and the percentage of trucks has been dropping over time. Further, the magnitude of trucks is also very low.

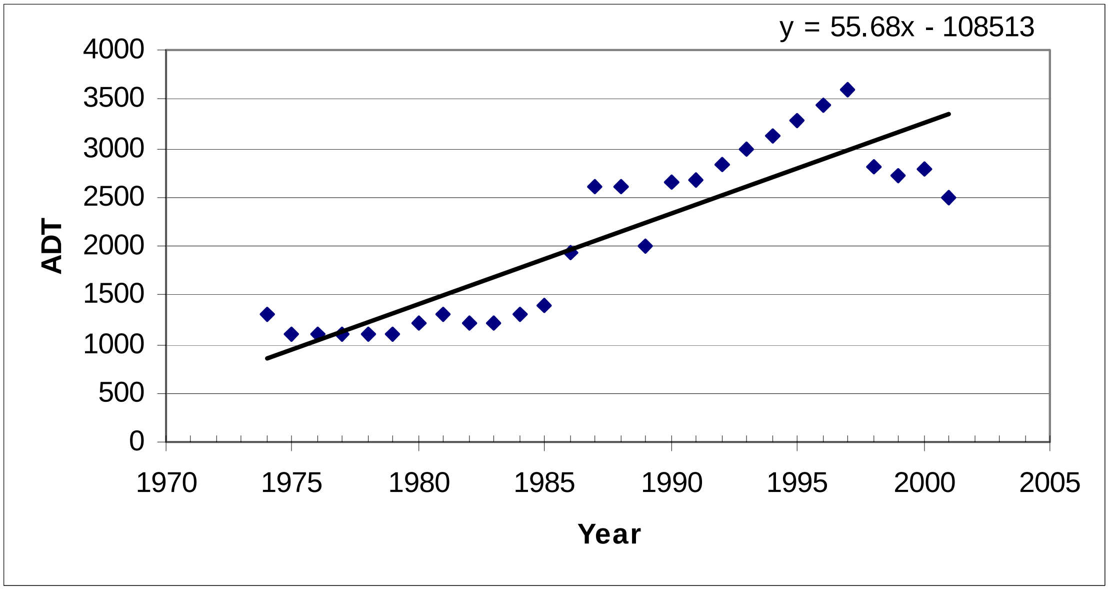

Figure 17. ADT data for CIR Project 3—US 70 EB (ADOT Project No. FR-55-1(4)).

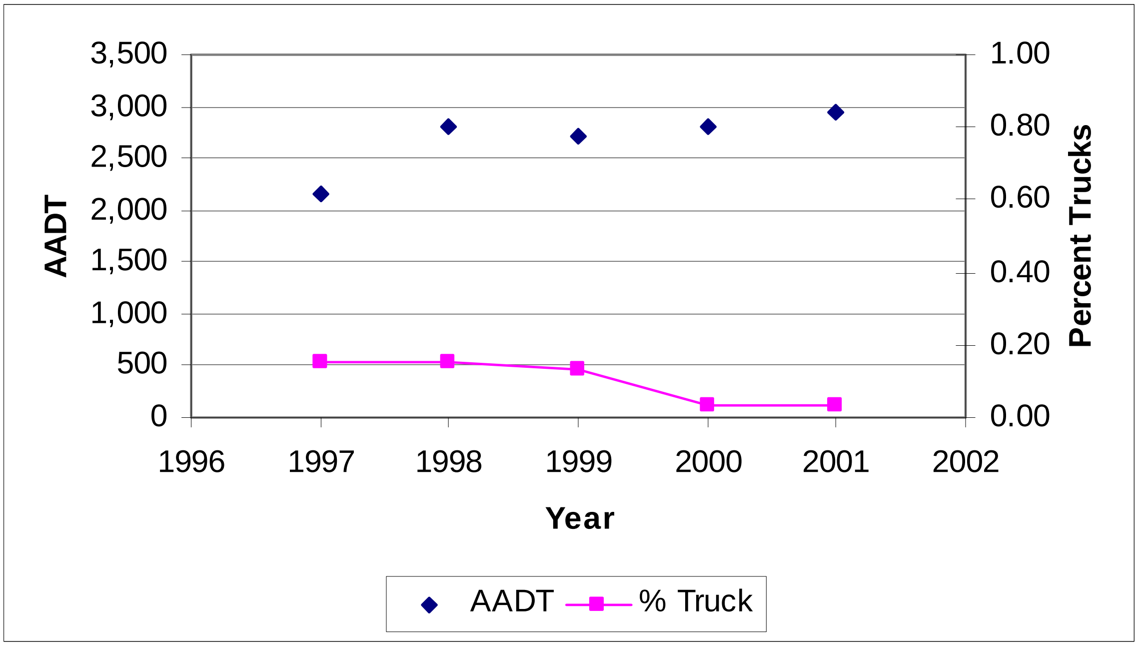

Figure 18. AADT data for CIR Project 3—SR 87 NB (ADOT Project No. FR-55-1(4)).

Pavement Performance Observations

Pavement distress data, ride quality data, and maintenance costs were extracted from the pavement management database and examined. The last condition survey on the roadway was performed in June 2002. The following is the extent of information available for each performance category considered in this report:

- Cracking – 1980 to 2002.
- Potholes – at the time of last condition survey.
- Rutting – 1989 to 2002.
- Patching – 1979 to 2002.
- Flushing – 1980 to 2002.
- Ride – 1972 to 2002.
- Maintenance costs – 1979 to 2002.

Figures 19 through 21 present the cracking, rutting, and flushing data since this CIR project was constructed. Pothole and patching data are not plotted since these quantities were zero over the reporting period under consideration. Figure 22 presents the ride quality data. Note that all the distress and ride data are presented on both a mile-by-mile basis and an averaged per-mile basis for the entire project (solid line). Performance-related observations are typically made using the average per-mile quantities as the basis.

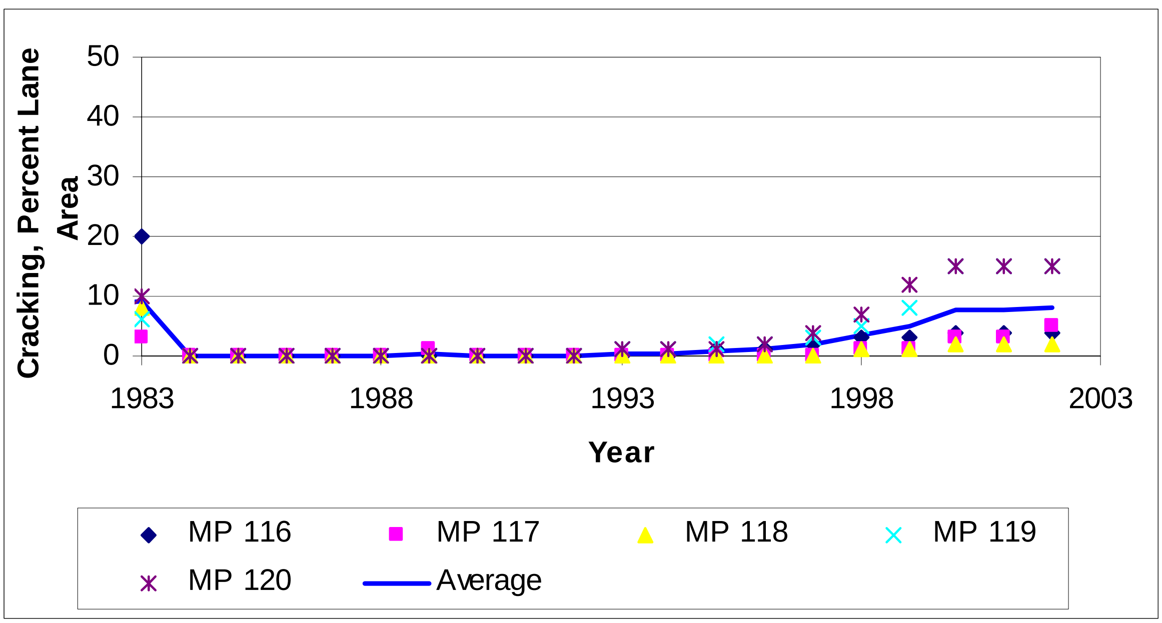

Figure 19. Cracking data for CIR Project 3— SR 87 NB (ADOT Project No. FR-55-1(4)).

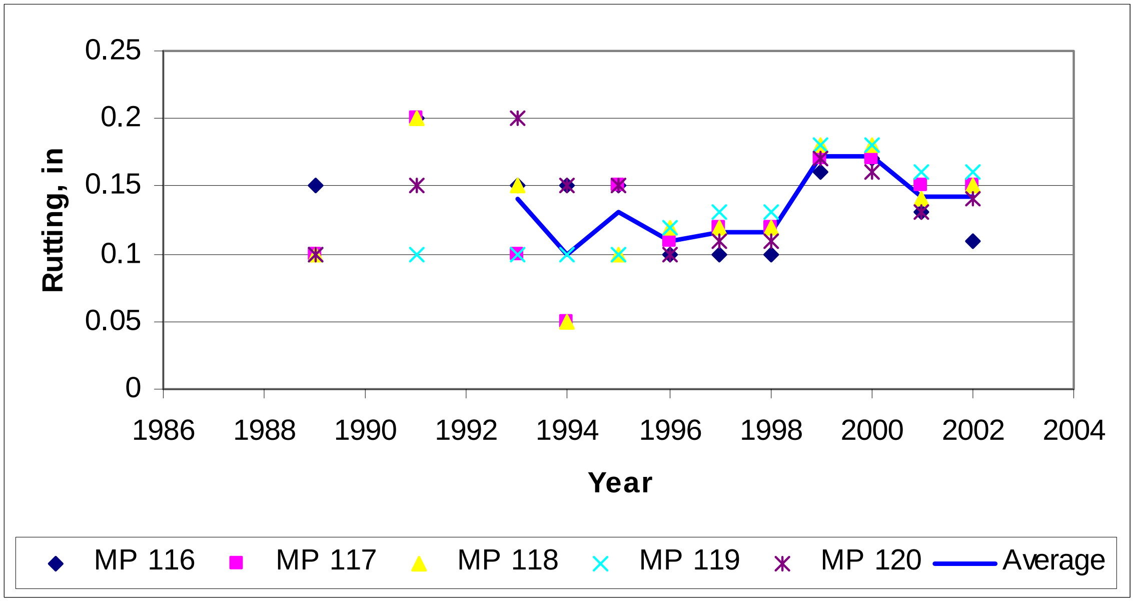

Figure 20. Rutting data for CIR Project 3— SR 87 NB (ADOT Project No. FR-55-1(4)).

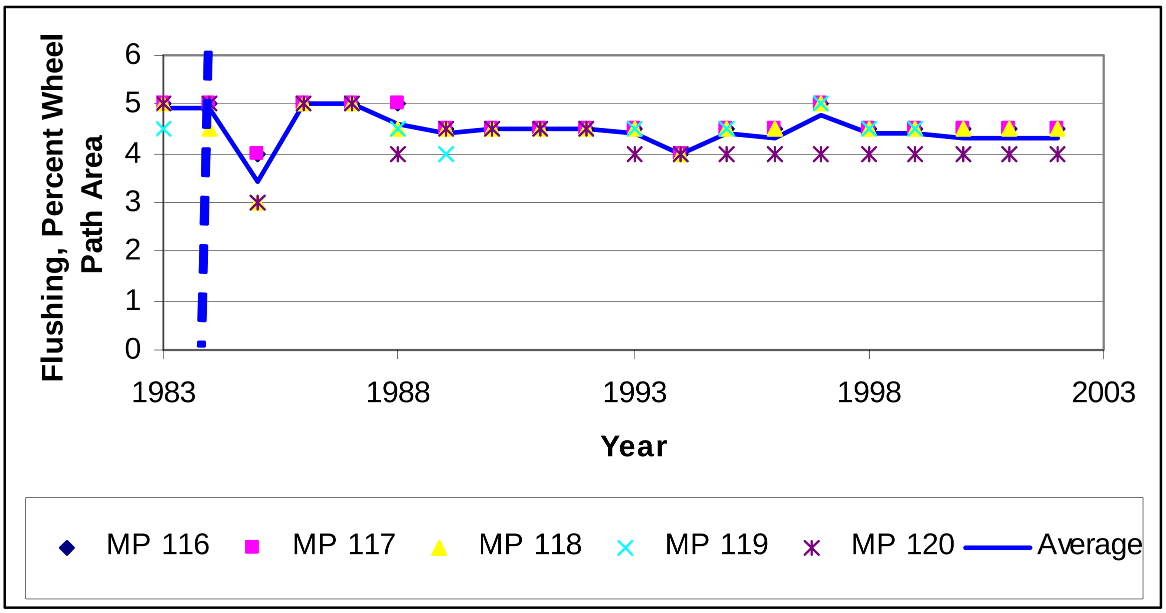

Figure 21. Flushing data for CIR Project 3— SR 87 NB (ADOT Project No. FR-55-1(4)).

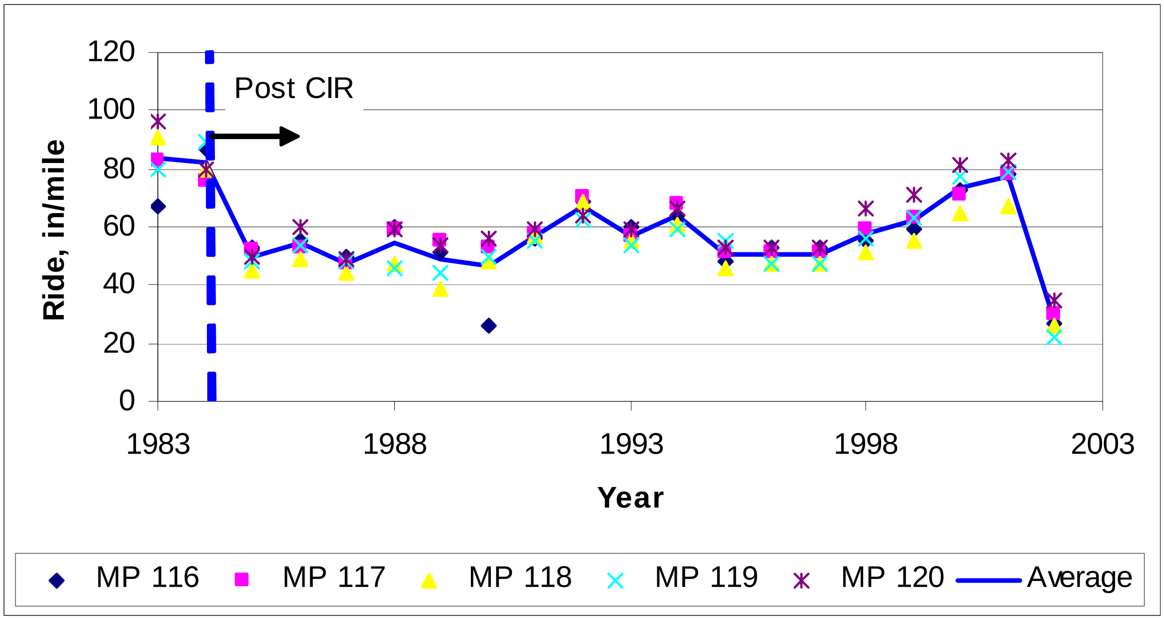

Figure 22. Ride quality information (Mays Ridemeter) for CIR Project 3— SR 87 NB (ADOT Project No. FR-55-1(4)).

Figure 23 presents the annual maintenance costs on a mile-by-mile basis as well as on an averaged per-mile basis for the entire project length. Figure 24 presents the cumulative maintenance costs a on a mile-by-mile basis as well as on an averaged per-mile basis.

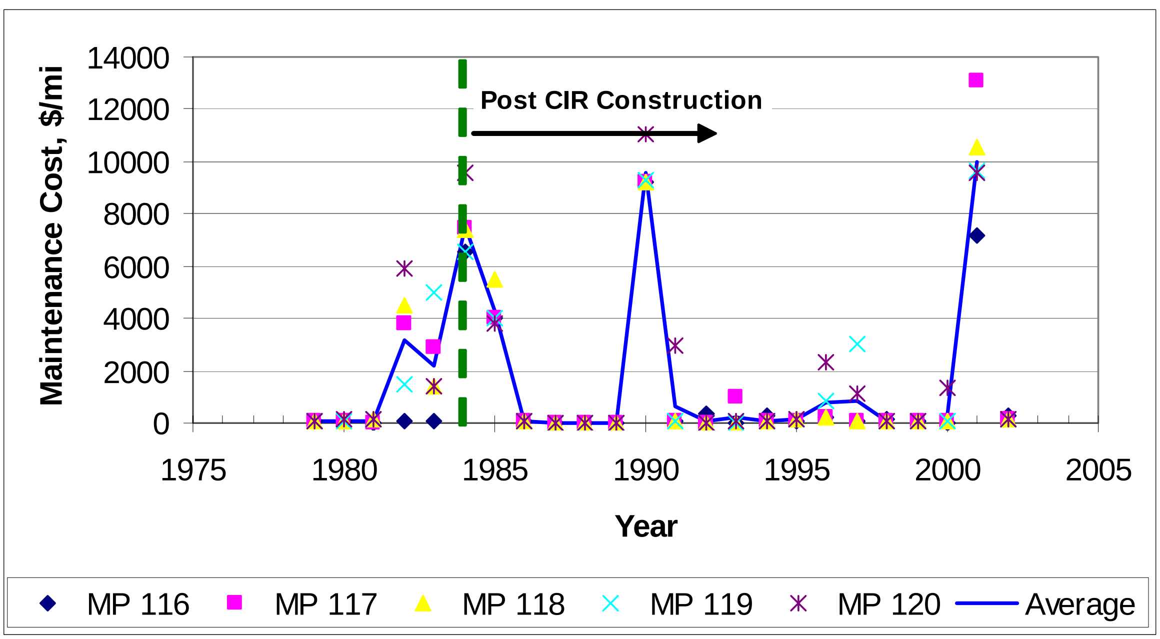

Figure 23. Maintenance costs for CIR Project 3— SR 87 NB (ADOT Project No. FR-55-1(4)).

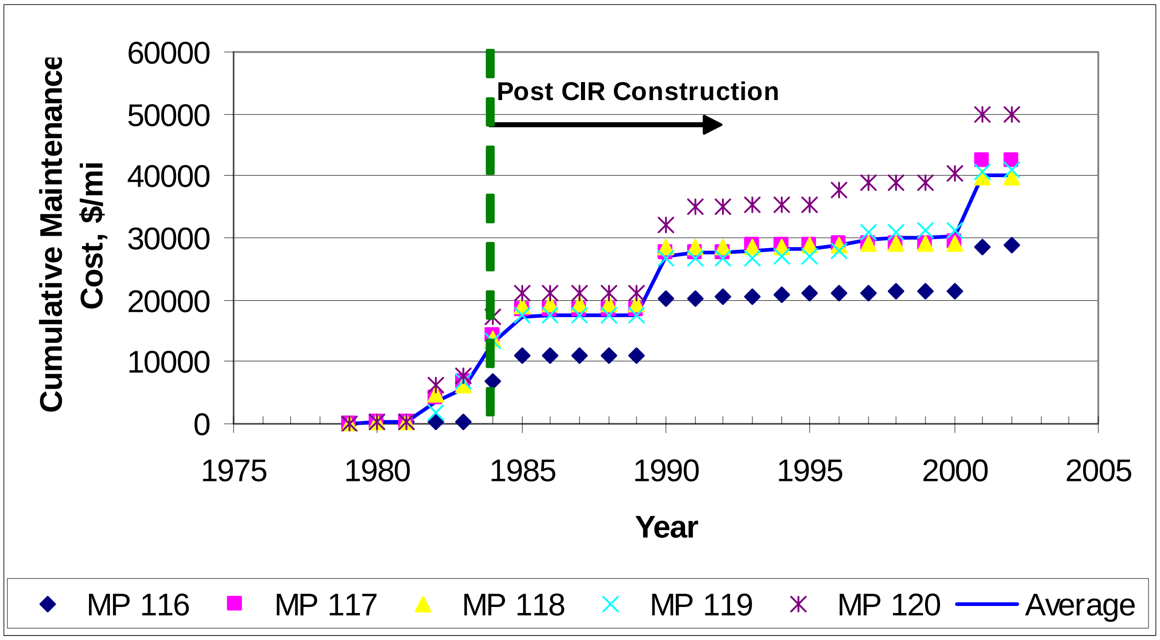

Figure 24. Cumulative maintenance costs for CIR Project 3— SR 87 NB (ADOT Project No. FR-55-1(4)).

Summary of Performance Observations

The following observations can be made from the performance data presented:

- Figure 19 clearly shows that that the cracking quantities are negligible, even during the 2002 field inspection.
- Similar observations can be made regarding rutting from figure 20.
- Figure 21 shows that the flushing quantities remain low and stable over time.
- Figure 22 shows that immediately following the CIR work in 1983, the ride quality improved and stayed relatively stable until 2002. In 2002, perhaps due to some rehabilitation action, the ride quality appears to have improved dramatically. The cracking and rutting values also register a "flattening" of slope around this time, supporting this presumption.
- Figure 23 suggests that mile-by-mile maintenance costs register an increase in 1990 and then again in 2001. The cumulative maintenance costs generally increase with time but, as shown in figure 24, they level off between 1990 and 2001. The rate of increase in averaged maintenance costs post-CIR is lower than that compared to the pre-CIR work.

Overall, as expected, the CIR of this pavement section led to significant improvements in performance.

CIR PROJECT 4—I-10 WB FRONTAGE, PINAL COUNTY

Project Overview

This project is located on the westbound frontage road of I-10 between MP 212.75 and 221.0. The project entailed CIR of the existing asphalt pavement to a depth of 2.5 inches. Traffic conditions encountered for the majority of the project included primarily low-volume traffic with a low percentage of trucks. The east end of the project, however, included Picacho Peak businesses, which produced a high traffic volume with a large percentage of trucks.

Construction

The project was constructed in October and November 1987 by Brown and Brown Contractors, Inc., under ADOT Project No. I-10-4-939. The roadway was primarily closed to traffic for the duration of the resurfacing operations, with the exception of the business area at Picacho Peak and approximately 0.1 mi beginning at the west end of the project. Lane closures were specified during the day, with the full roadway width open to traffic during the evening hours.

A paving train was employed for the handling and production of the cold-recycled pavement materials on the job, which included milling, processing, placement, and compaction equipment. The following materials were placed with a standard laydown machine and compacted with vibratory and pneumatic rollers:

- CMI 1000 Rotomill.
- Screen Deck.
- Pugmill.
- Blawknox PF 220 Laydown Machine.
- Ferguson SP 1100 Pneumatic Roller (24-ton).
- CAT CB 614 Steel-Wheel Roller (12-ton).
- BOMAG BW 220 AD Steel-Wheel Roller (12-ton).

The contract specifications required that 100 percent of the RAP pass the 1 inch sieve. The maximum moisture content specified was 3 percent of the total weight of the mixed aggregate material, measured prior to the addition of the emulsified bituminous materials.

The compactive effort that produced the most stable pavement and highest density utilized the following rolling pattern:

- Steel-wheel roller (vibratory) – 5 passes.
- Pneumatic roller – 6 passes.

Finish rolling with a static steel-wheel roller was deleted from the rolling pattern due to formation of transverse cracks. The combination of vibratory steel-wheel and pneumatic rollers is now routinely employed in ADOT CIR work.

The average density values for the new roadway ranged from 117.1 lb/ft^3 for the sections recycled using High Float Emulsion (HFE) 150S to 119.2 lb/ft^3 for the sections recycled using the emulsified recycling agent Cyclogen® ME.

Materials

The initial dosage rate of the Cyclogen® ME reagent (see appendix B for specifications) was specified at 2.5 percent by weight. However, this was adjusted to a maximum of 4.19 percent to ensure that adequate bituminous material was available to bind the RAP and provide stability under traffic loading. Likewise, the dosage rate of the HFE 150S (see appendix A for specifications) was increased from 2.5 percent by weight to 4.0 percent.

Traffic

No detailed traffic data, in terms of ADT and AADT, were available for this project.

Pavement Performance Observations

No pavement management data were available for this project.

CIR PROJECT 5—I-19 NB AND SB SHOULDERS, PIMA COUNTY

Project Overview

This project is located on I-19 between MP 58.48 and 60.02 and was constructed under ADOT Project No. IR-19-1(101)C. The project entailed full-width CIR of the existing northbound and southbound asphalt shoulders to a depth of 2.0 inches, followed by the placement of a 1 inch asphalt rubber friction course.

Construction

The exact construction sequencing, methods employed, and equipment used during construction of this CIR project are not known. Presented below are excerpts from the method specification included as part of the project documents.

The project was constructed in summer 1988 by Granite Construction Company. The existing shoulder was specified to be scarified or milled to a depth of 2 inches. All material was specified to be broken up so that 100 percent of the material passes the 1.25 inch sieve. The contractor was given an option of either crushing the material at a central location or pulverizing it in place. The crushed or pulverized material and 1.5 percent mixing water (by weight of RAP) was then specified to be mixed with the recycling agent either in a stationary or a traveling mixer (no blade mixing allowed).

The specification called for all traffic to be kept off the compacted recycled asphalt concrete for a minimum of 24 hours after construction.

The compaction equipment included vibratory steel-wheeled rollers for initial rolling, pneumatic tired rollers (for intermediate rolling), and static steel-wheel rollers for finish rolling. The minimum number of specified passes for the initial, intermediate, and finish rollers were 5, 6, and 3, respectively. The minimum weight for the steel-wheel roller was 12 tons, and that for the pneumatic tired roller was 24 tons.

Materials

The recycling agent for this project was the emulsion-based Cyclogen® ME. It was specified that the recycling agent be used at the rate of 2 percent by total weight of the mixture. However, the final decision on the exact rate was left to the project engineer.

Traffic

No detailed traffic data, in terms of ADT and AADT, are available for this project.

Pavement Performance Observations

No pavement management data were available for this project.

CIR PROJECT 6—SR 87 NB, NAVAJO COUNTY

Project Overview

Located on SR 87 between MP 361.95 and 368.0, this project was constructed under ADOT Project No. S-244-513. The project involved CIR of the existing asphalt pavement to a depth of 2.0 inches, followed by placement of a double chip seal coat. The number of days specified for the work, which included other items such as guardrail installation, drainage structures, and paint marking the roadway, was 80 days.

The existing SR 87 highway had an HMA surfacing that varied in depth from approximately 2 inches to greater than 6 inches in areas overlaid with cold mix. The roadway surface was alligator cracked approximately 6 to 12 inches from the pavement edge and in many areas was completely broken off. The total roadway width was 28 feet. There were numerous maintenance patches containing materials with higher asphalt content. The asphalt was dry, brittle, and in need of rejuvenation.

The traffic on the roadway was low, with an ADT of 1,250 vehicles/day, comprised mainly of passenger cars and light trucks.

Construction

The project was constructed in July 1992 by Four Mile Construction, Inc. (subcontractor Arizona Pavement Profiling). The existing roadway was specified to be pulverized in place, in a single pass, to a depth of 2 inches. All material was specified to be broken up so that 100 percent of the material passed the 1inch sieve. The specified moisture content of the pavement prior to the seal coat operation was 1.5 percent by weight of the aggregate mixture.

The compaction equipment specified on this project was 12-ton steel-wheel rollers and 30-ton pneumatic rollers. The rolling sequence and number of passes were specified in the method specification as part of the project plans.

The sequence of operations for this project consisted of milling the existing asphalt pavement to a depth of 2 inches using a CAT PR1000 milling machine, reprocessing (screening, crushing, mixing, and rejuvenating with HFE) the milled material, placing it back in a 2 inch mat, and capping the recycled pavement with a double chip seal coat. The laydown equipment consisted of a Barber-Greene KoKal and a Caterpiller, AP1050, laydown machine. Two 30-ton Bomag pneumatic rollers were used for breakdown, while a Caterpillar CB-534 steel-wheel roller was used for finishing.

Materials

The type of emulsion specified initially was HFE-150P, which was changed to HFE-300P (see appendix A for specifications). This grade of emulsion was believed to result in better coating of aggregate particles. An application rate of 1.5 percent was specified, but 1.14 percent was eventually realized.

Traffic

Figure 25 presents a plot of ADT versus time for this project, and figure 26 presents plots of AADT and percent trucks versus time. The traffic, in terms of ADT and AADT, has steadily increased since the time the CIR work was done on this project. However, the total number of trucks on this roadway is low, and when expressed as a percentage of AADT, the volume of trucks has remained relatively unchanged for the period over which data are available.

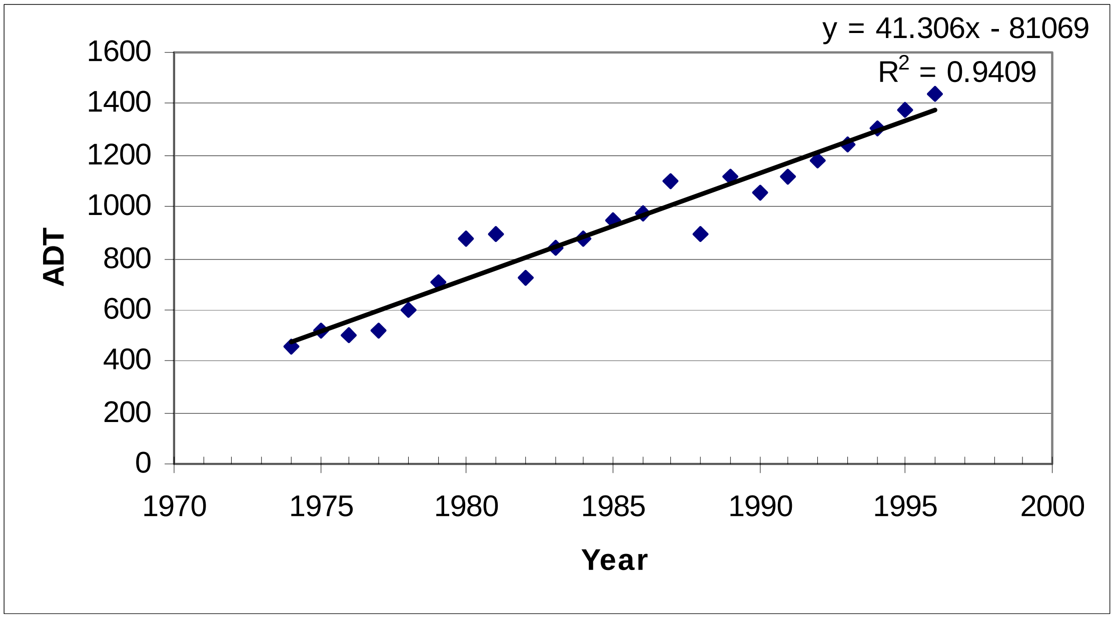

Figure 25. ADT data for CIR Project 6—SR 87 NB (ADOT Project No. S-244-513).

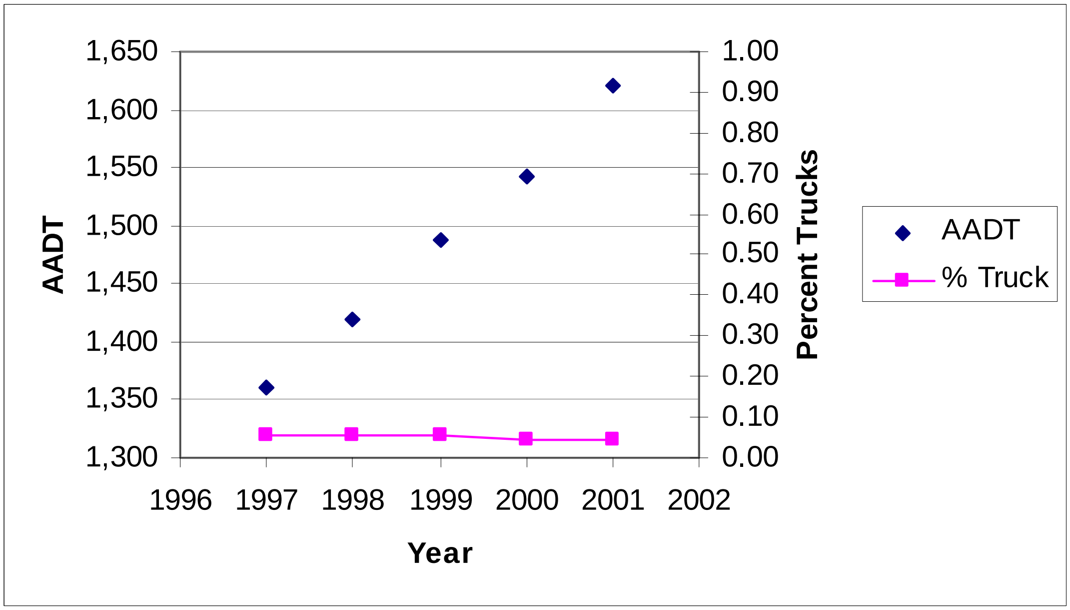

Figure 26. AADT data for CIR Project 6— SR 87 NB (ADOT Project No. S-244-513).

Pavement Performance Observations

Pavement distress data, ride quality data, and maintenance costs were extracted from the pavement management database and examined. The last condition survey on the roadway was performed in August 2002. The following is the extent of information available for each performance category considered in this report:

- Cracking – 1980 to 2002.
- Potholes – at the time of last condition survey.
- Rutting – 1988 to 2002.
- Patching – 1980 to 2002.
- Flushing – 1980 to 2002.
- Ride – 1972 to 2002.
- Maintenance costs – 1979 to 2002.

Figures 27 through 29 present the cracking, rutting, and flushing data since this project was constructed. Pothole and patching data are not plotted since these quantities were zero over the reporting period. Figure 30 presents the ride quality data. Note that all the distress and ride data are presented on both a mile-by-mile basis and an averaged per-mile basis for the entire project (solid line). Performance-related observations are typically made using the average per-mile quantities as the basis.

Figure 31 presents the annual maintenance costs on a mile-by-mile basis as well as on an averaged per-mile basis for the entire project length. Figure 32 presents the cumulative maintenance costs a on a mile-by-mile basis as well as on an averaged per-mile basis.

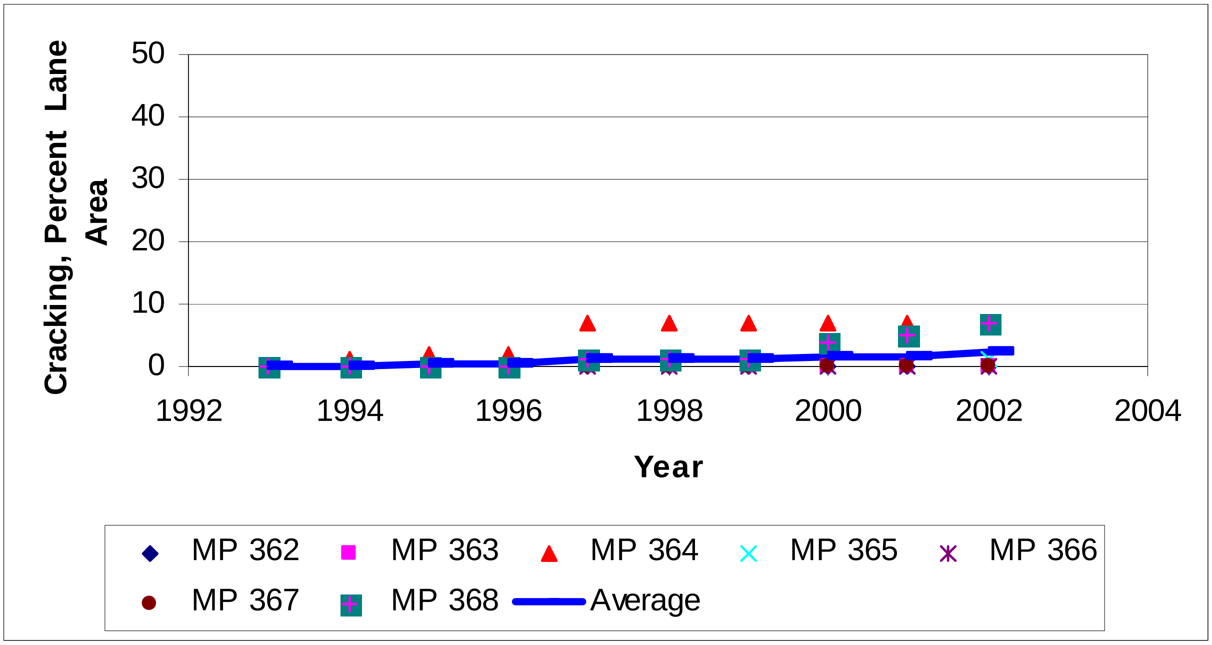

Figure 27. Cracking data for CIR Project 6— SR 87 NB (ADOT Project No. S-244-513).

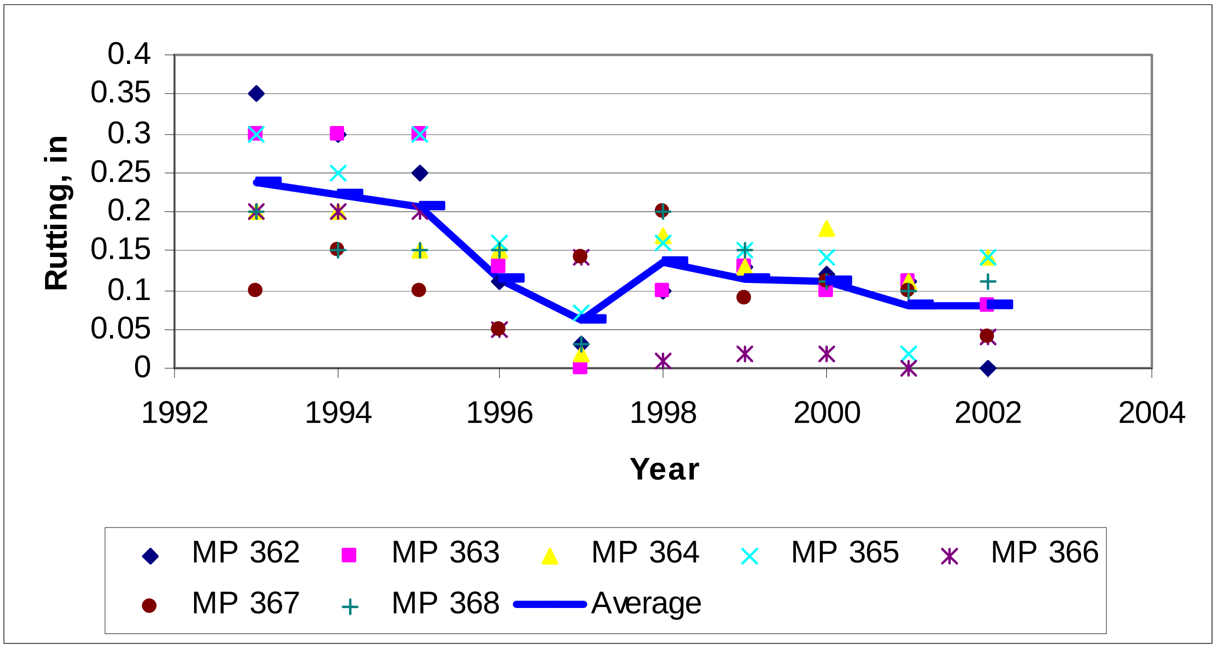

Figure 28. Rutting data for CIR Project 6— SR 87 NB (ADOT Project No. S-244-513).

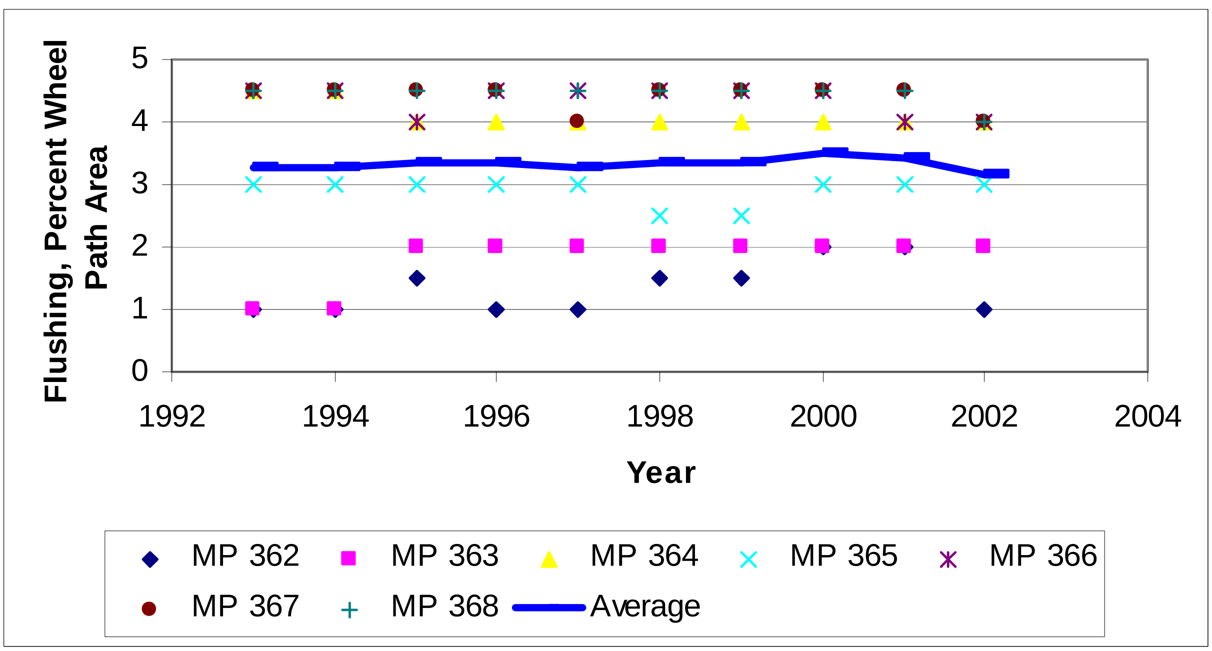

Figure 29. Flushing data for CIR Project 6— SR 87 NB (ADOT Project No. S-244-513).

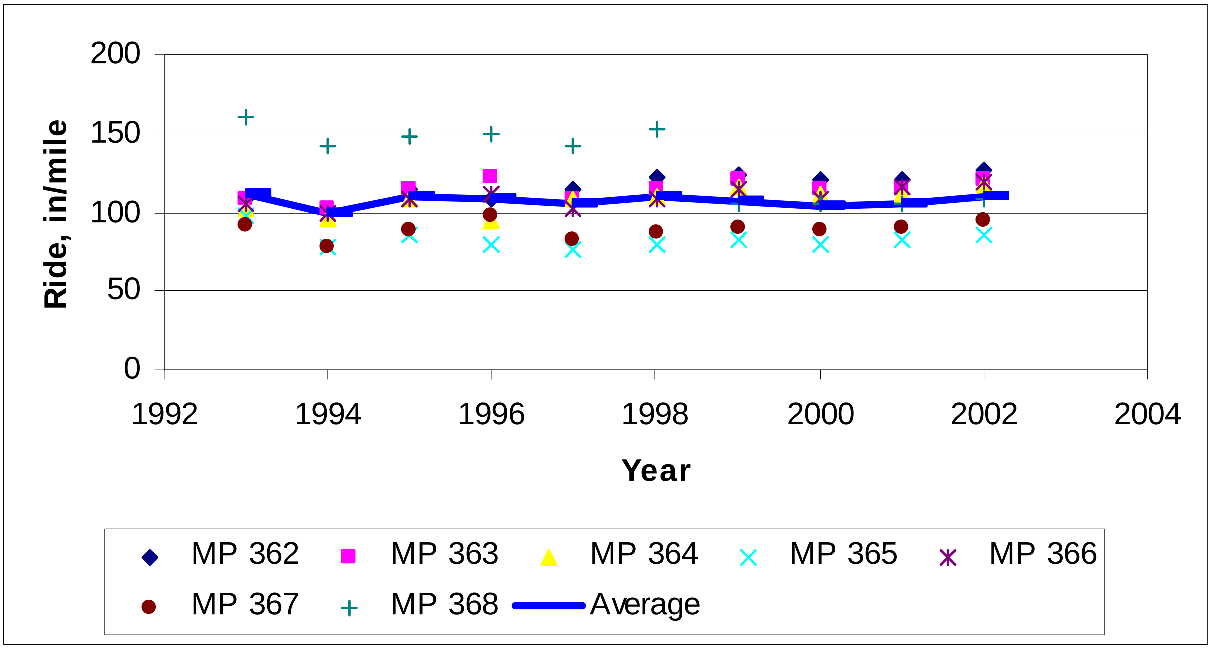

Figure 30. Ride quality information (Mays Ridemeter) for CIR Project 6— SR 87 NB (ADOT Project No. S-244-513).

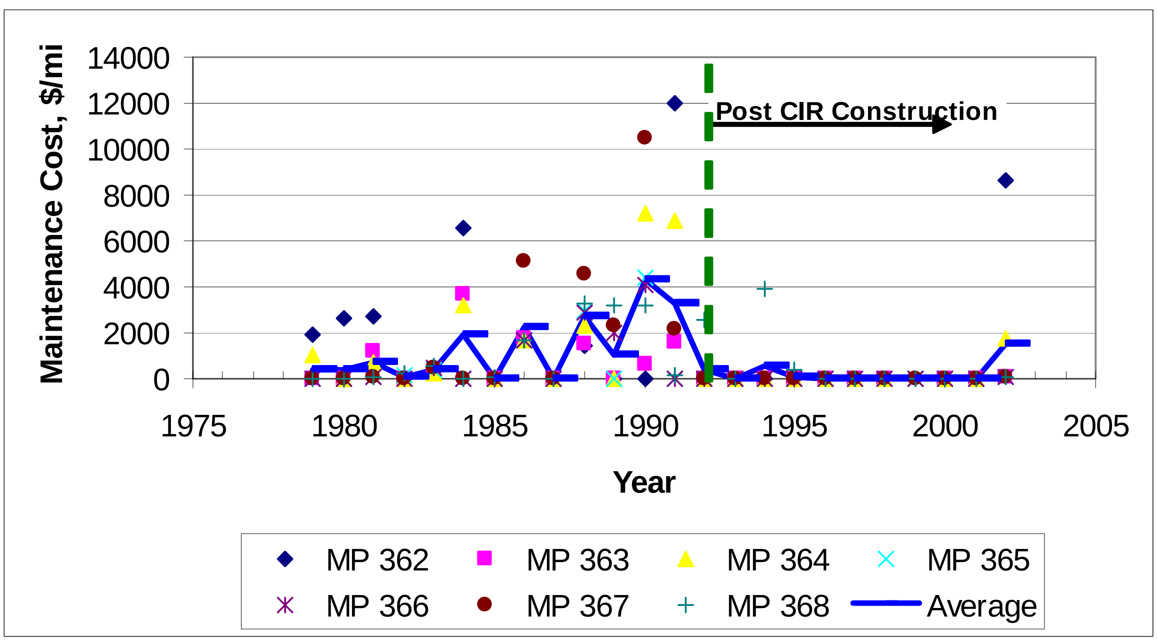

Figure 31. Maintenance costs for CIR Project 6— SR 87 NB (ADOT Project No. S-244-513).

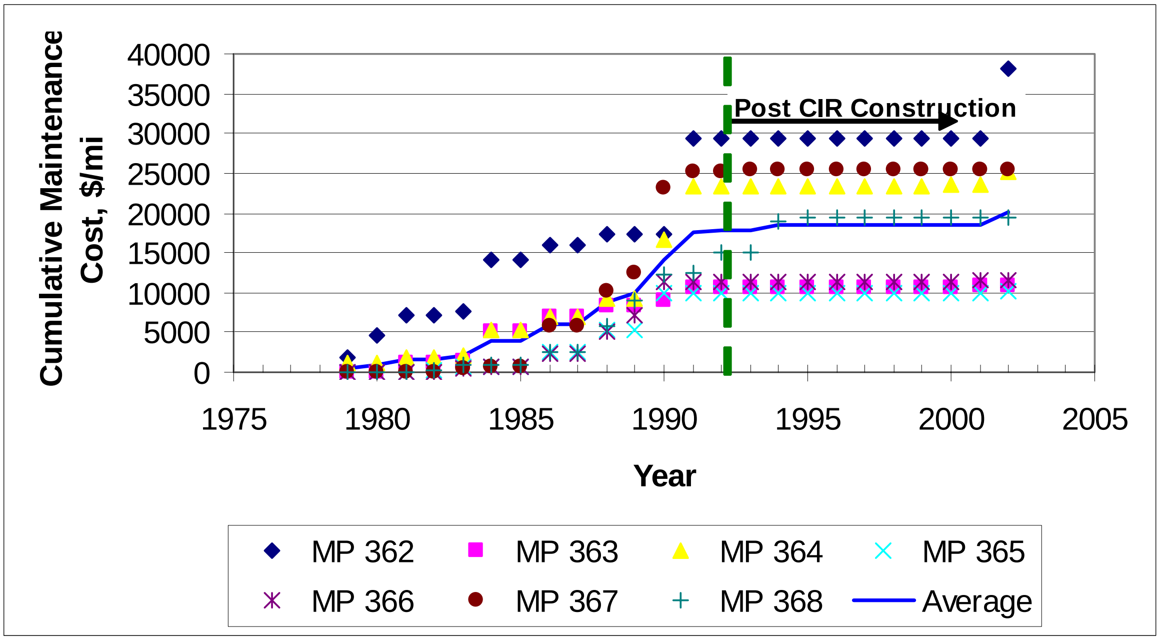

Figure 32. Cumulative maintenance costs for CIR Project 6— SR 87 NB (ADOT Project No. S-244-513).

Summary of Performance Observations

The following observations can be made from the performance data presented:

- Figure 27 clearly shows that that the cracking quantities are close to zero over a majority of the monitoring period. However, they increase slightly towards the end of the reporting period.
- Figure 28 shows that rutting generally decreases over time—an unexpected occurrence. There appears to be a sharp fall in the rutting values in 1997 (this observation was also noted on most other projects where pre- and post-1997 data are available). The project history database does not indicate any major maintenance or rehabilitation action around this time that would cause rutting to decrease.
- Figure 29 shows that the flushing quantities remain relatively low and stable over time.
- Figure 30 shows a relatively stable ride quality level over the entire reporting period after CIR.
- Figure 31 suggests that mile-by-mile maintenance costs after the CIR work remain very low—close to negligible. Likewise, the cumulative maintenance cost, shown in figure 32, levels off after the CIR work, only to increase slightly at the end of the reporting period. An interesting comparison in figure 32 is the rate cumulative cost accumulation pre- and post-CIR. The figure clearly demonstrates the value of CIR as a viable pavement preservation strategy.

This project provides an excellent opportunity to study the effectiveness of CIR as a pavement preservation strategy over a relatively long period of time. Overall, this pavement section seems to be performing satisfactorily. However, the reasons for the decreasing trend in the rutting data need to be investigated and explained further. A plausible reason could be changes in the way rutting data were collected or interpreted post-1997.

CIR PROJECT 7—US 191 NB, APACHE COUNTY

Project Overview

Located on the two-lane US 191 NB between MP 482.00 and 500.96 (old MP 108.00 and 126.96), this project was constructed under ADOT Project No. STP-077-1(9)P. The project entailed CIR of the existing asphalt pavement to a depth of 2.5 inches, followed by the application of a double seal coat.

The existing pavement surface showed 0 to 60 percent cracks. The type of cracking was small to large block pattern and alligator cracks. The ride quality was fair to poor. The shoulders were in fair to poor condition. Rutting appeared to be in the relatively medium range, averaging 0.27 inches in 1991. The CIR work was required to eliminate cracking and other pavement distress prevalent on this section of the roadway.

Construction

The project was constructed in August 1995 by Show Low Construction. The exact construction sequencing, methods employed, and equipment used during construction of this CIR project are not known. Presented below are excerpts from the specification included as part of the project documents.

The construction work consisted of milling the existing pavement to the depths specified in the plans. The materials were specified to be broken up using a single pass, in-place pulverization technique so that 100 percent of the end product passes the 1.25 inch sieve. The pulverized material and 1.5 percent mixing water (as a percentage of total weight of the aggregate material) were then to be mixed in a self-propelled traveling mixer with adequate metering controls for the addition of binder agent. The moisture content in the aggregate was not allowed to exceed 3 percent by weight of the mixed aggregate materials prior to the addition of the emulsion. The aggregate material was then to be mixed with the emulsified binder agent applied at a pre-specified rate until adequate coating of particles was obtained.

Self-propelled paving machines equipped with automatic controls and screeds were specified for laydown, taking care to prevent segregation. Compaction was not to commence until the emulsion began to break or for 2 hours, whichever was first. Initial rolling was to be accomplished with 30-ton pneumatic rollers, while 12-ton steel-wheeled rollers were used for finish rolling. All compaction equipment was required to meet standard ADOT specifications. After the CIR overlay was in place, the double seal coat, including a chip seal and fog seal, was to be applied.

Materials

The type of emulsion specified was HFE-150P or HFE-300P containing polymer modified asphalt, water, 1 percent liquid anti-stripping agent (by weight of emulsion), and emulsifier, blended to specific requirements. An application rate of 1.5 percent was specified, with the final rate of application left to the discretion of the project engineer.

Traffic

Figure 33 presents a plot of ADT versus time for this project, and figures 34(a) and 34(b) present plots of AADT and percent trucks versus time. The traffic, in terms of ADT, has steadily increased over time on this project. Figure 34(a) presents the AADT and percent truck information between MP 482.0 and 495.0, and figure 34(b) presents the same information between MP 495.0 and 501.0. It is apparent from these figures that the AADT has not increased appreciably since 1996. Furthermore, the percentage of trucks over the project length is low.

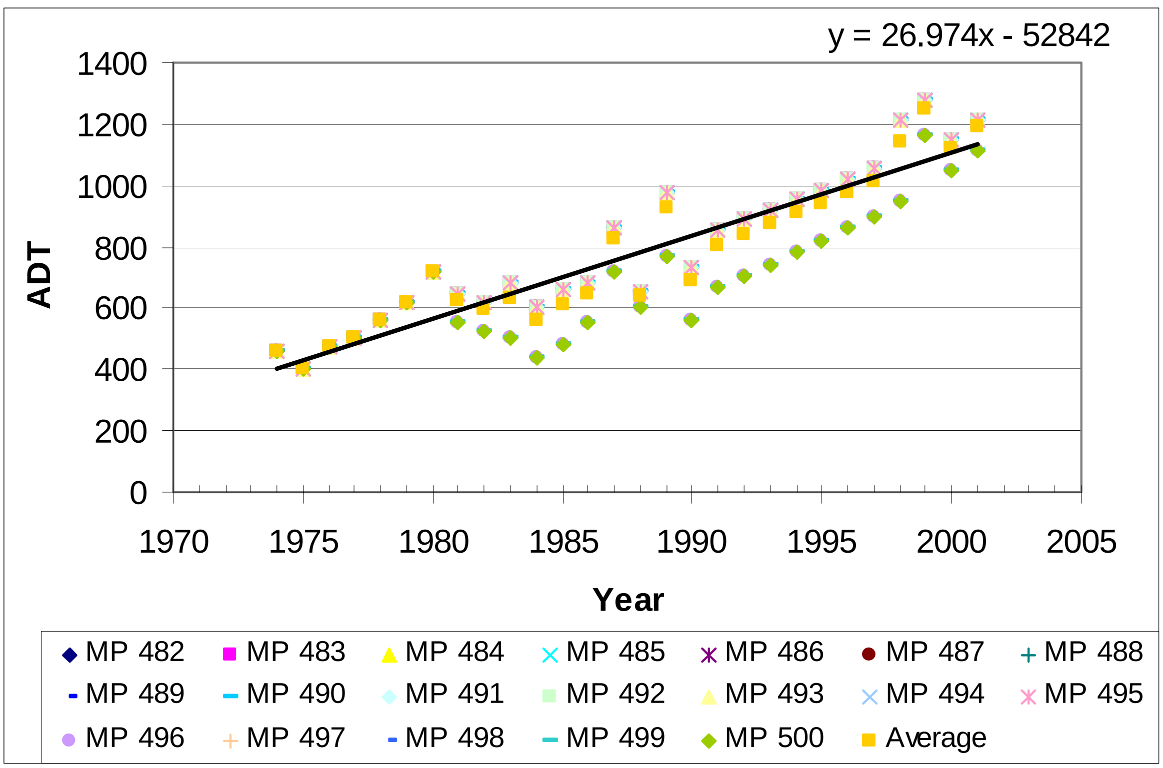

Figure 33. ADT data for CIR Project 7—US 191 NB (ADOT Project No. STP-077-1(9)P).

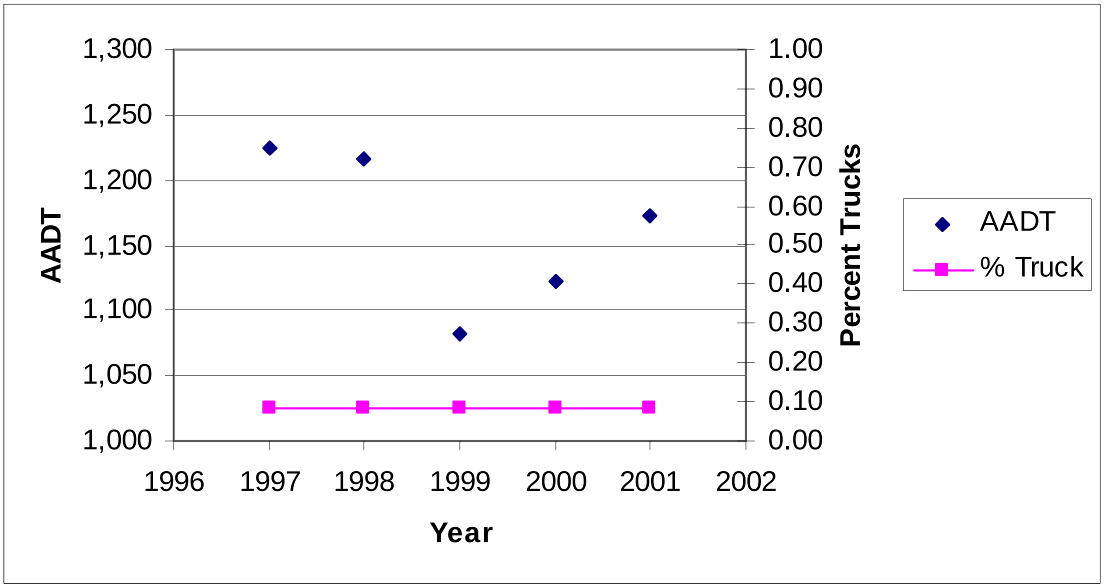

Figure 34(a). AADT data for CIR Project 7—US 191 NB (ADOT Project No. STP-077-1(9)P). (From MP 482.0 to MP 495.0)

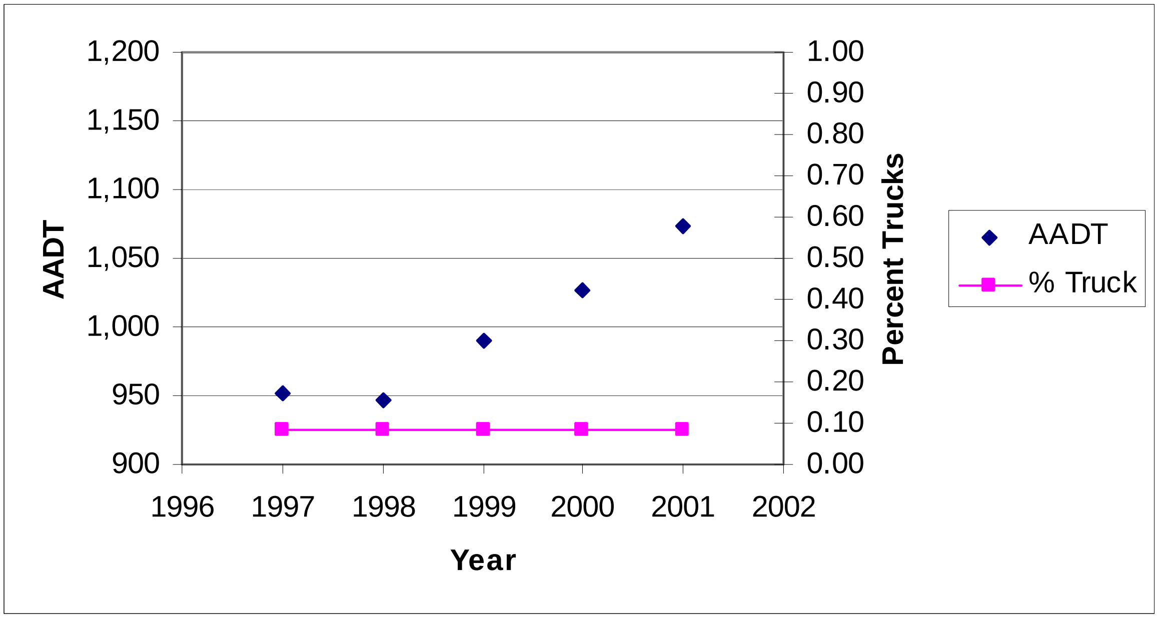

Figure 34(b). AADT data for CIR Project 7—US 191 NB (ADOT Project No. STP-077-1(9)P). (From MP 495.0 to 501.0)

Pavement Performance Observations

Pavement distress data, ride quality data, and maintenance costs were extracted from the pavement management database and examined. The last condition survey on the roadway was performed in November 2002. The following is the extent of information available for each performance category considered in this report:

- Cracking – 1979 to 2002.
- Potholes – at the time of last condition survey.
- Rutting – 1989 to 2002.
- Patching – 1979 to 2002.
- Flushing – 1979 to 2002.
- Ride – 1973 to 2002.
- Maintenance costs – 1979 to 2002.

Figures 35 through 37 present the cracking, rutting, and flushing data since this CIR project was constructed in 1995. Pothole and patching data are not plotted since these quantities were zero over the reporting period. Figure 38 presents the ride quality data. Note that all the distress and ride data are presented on both a mile-by-mile basis and an averaged per-mile basis for the entire project (solid line). Performance-related observations are typically made using the average per-mile quantities as the basis.

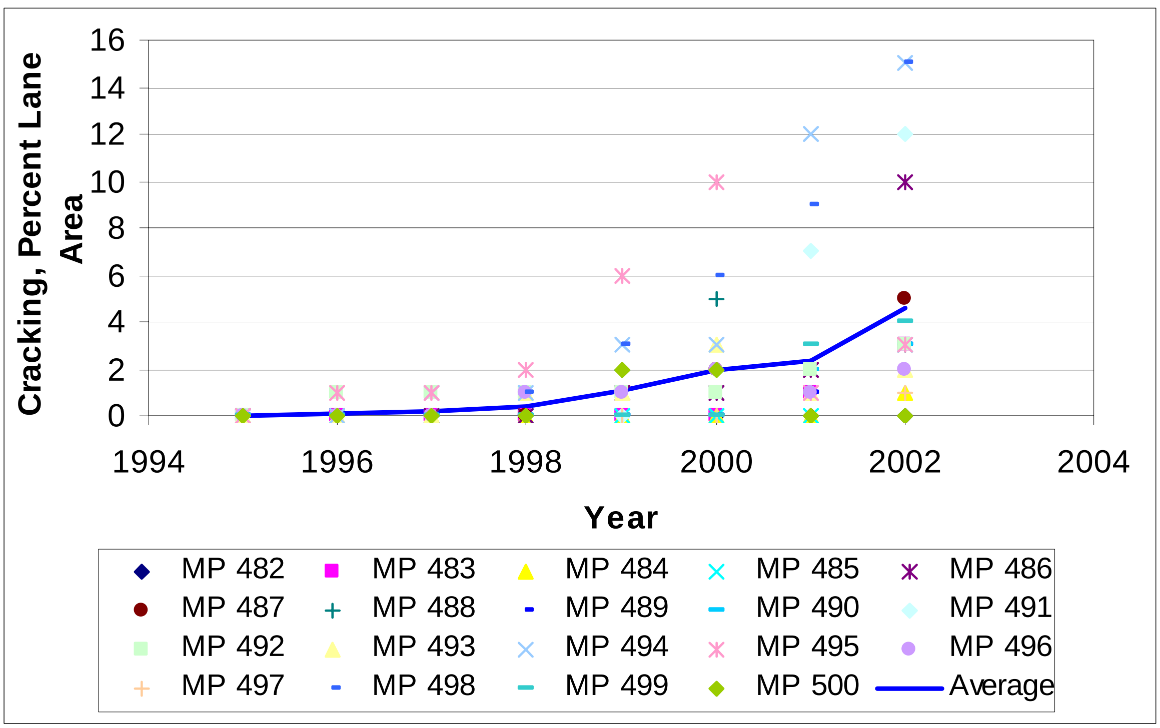

Figure 35. Cracking data for CIR Project 7— US 191 NB (ADOT Project No. STP-077-1(9)P).

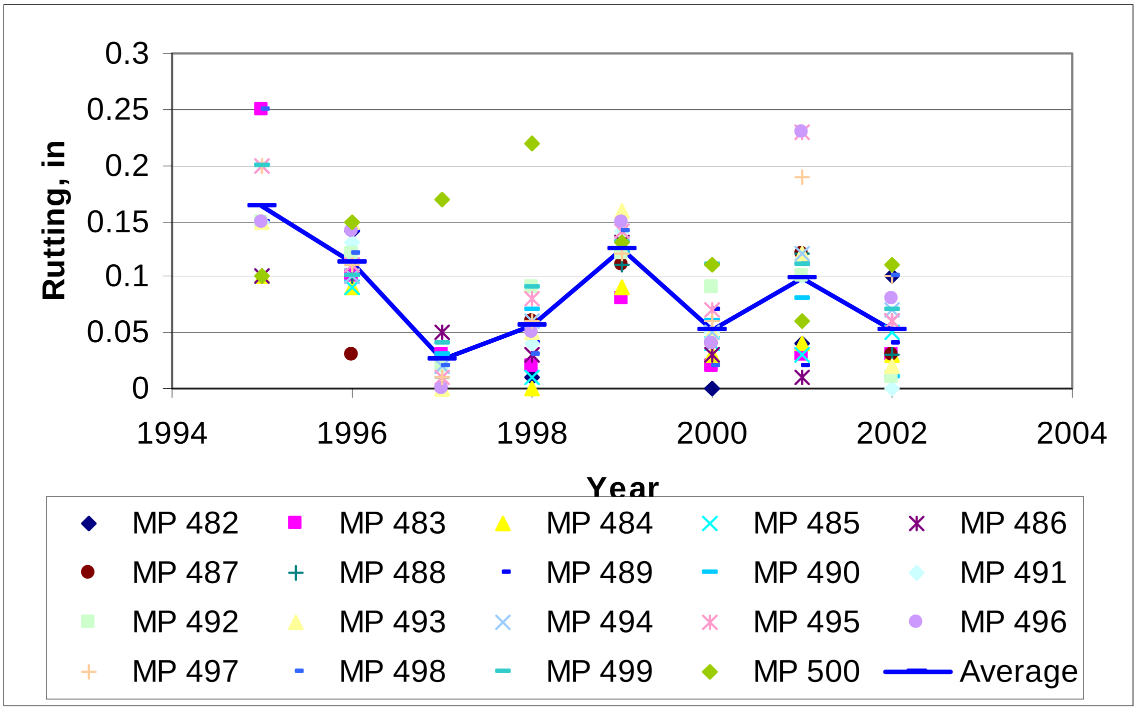

Figure 36. Rutting data for CIR Project 7— US 191 NB (ADOT Project No. STP-077-1(9)P).

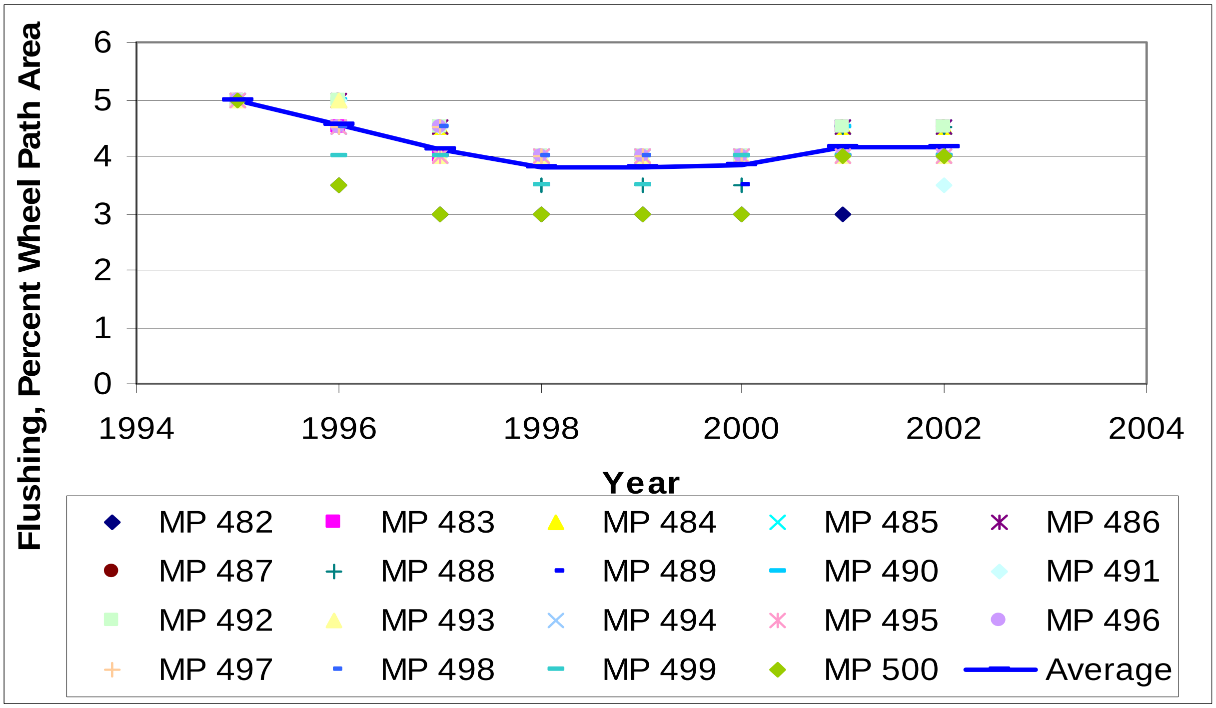

Figure 37. Flushing data for CIR Project 7— US 191 NB (ADOT Project No. STP-077-1(9)P).

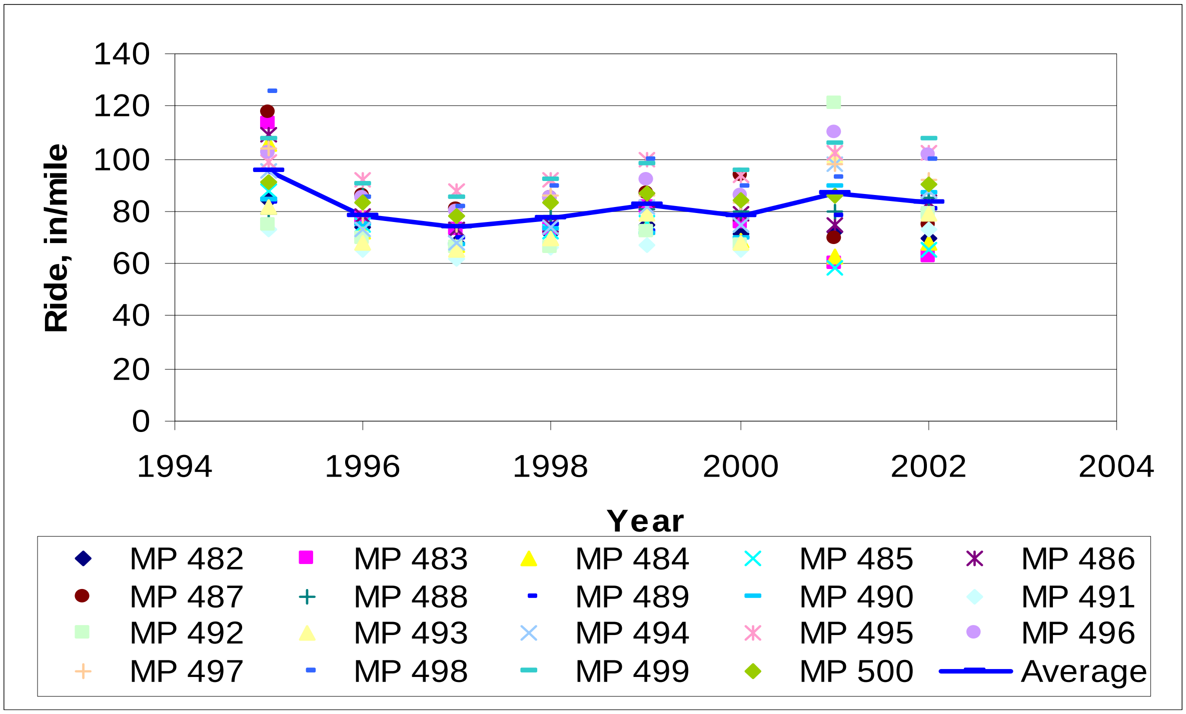

Figure 38. Ride quality information (Mays Ridemeter) for CIR Project 7— US 191 NB (ADOT Project No. STP-077-1(9)P).

Figure 39 presents the annual maintenance costs on a mile-by-mile basis as well as on an averaged per-mile basis for the entire project length. Figure 40 presents the cumulative maintenance costs a on a mile-by-mile basis as well as on an averaged per-mile basis.

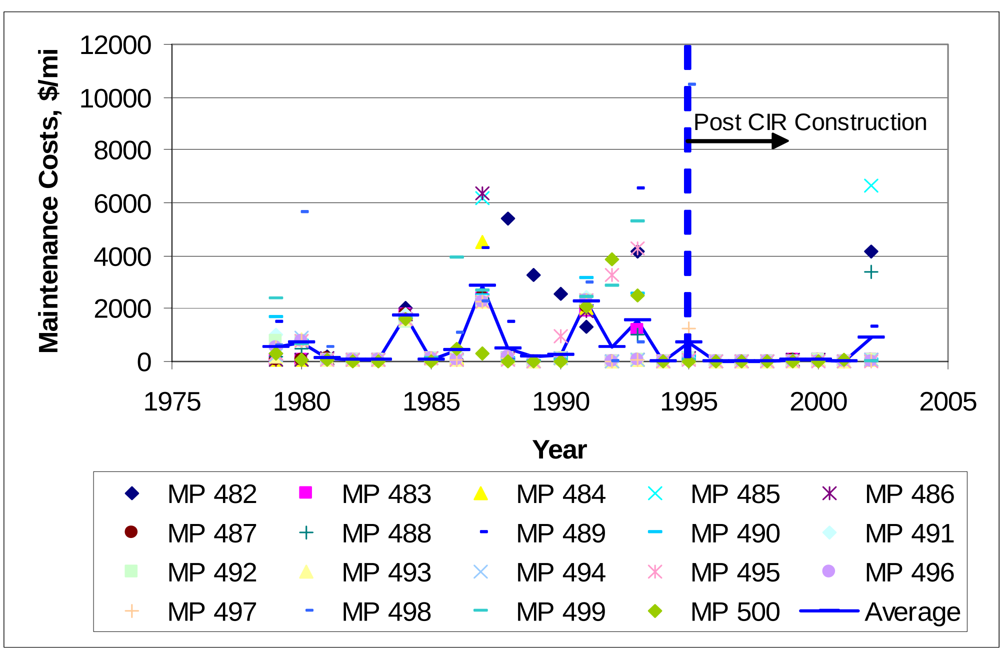

Figure 39. Maintenance costs for CIR Project 7— US 191 NB (ADOT Project No. STP-077-1(9)P).

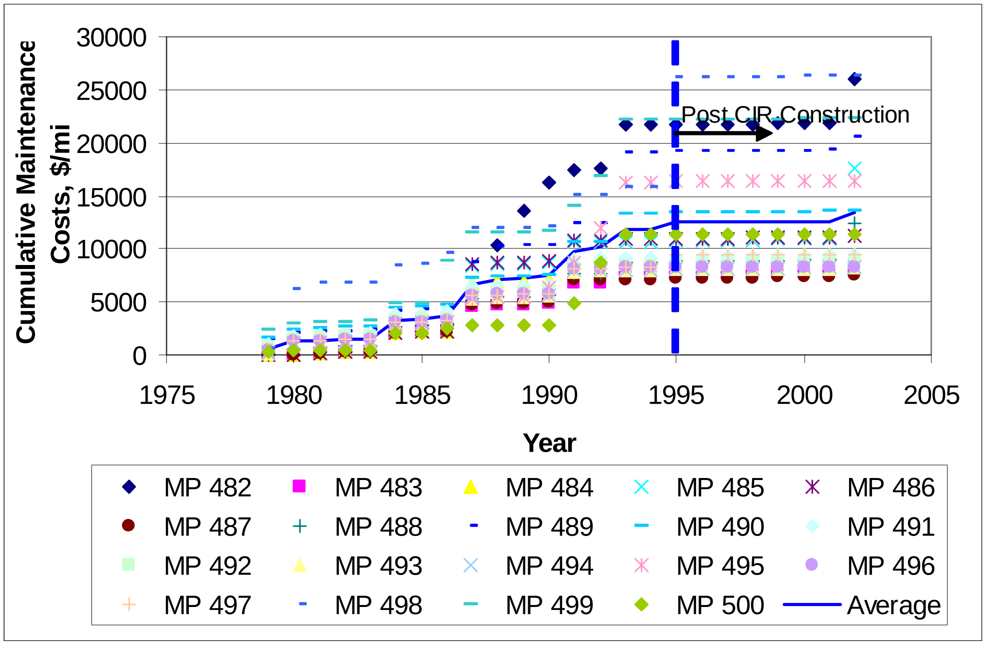

Figure 40. Cumulative maintenance costs for CIR Project 7— US 191 NB (ADOT Project No. STP-077-1(9)P).

Summary of Performance Observations

The following observations can be made from the performance data presented:

- Figure 35 shows that that the cracking quantities are increasing steadily since the time the CIR work was completed. The section average is around 6 percent of the lane area; however, the cracking quantities for four, 1 mi-long sections are above 10 percent of the lane area.
- The rutting quantities presented in figure 36 show a fluctuation from year to year, but these fluctuations are within the range of the measurement error. Generally speaking, rutting seems to decrease over time—an unexpected occurrence. Also, there appears to be a sharp fall in the rutting values in 1997. The project history data do not reflect any maintenance or rehabilitation action that would explain this trend.
- Figure 37 shows that the flushing quantities remain relatively low and stable over time.
- Figure 38 shows that the ride quality over the entire section remains relatively stable over the entire reporting period.
- Figure 39 suggests that the mile-by-mile maintenance costs after the CIR work have been dramatically lower compared to the earlier years. A marked increase in costs is observed between select mileposts immediately prior to the CIR work being performed.
- The cumulative maintenance costs, shown in figure 40, rise steadily leading up to the time the CIR was performed and level off considerably after the CIR work is completed. However, a marked increase in costs is observed at select locations along the project towards the end of the reporting period, causing a slight increase in the average cumulative cost for the entire project.

- An interesting comparison in figure 40 is the rate of cumulative cost accumulation before and after the CIR overlay construction. The figure clearly demonstrates the value of CIR as a viable pavement preservation strategy.

Overall, the CIR seemed to have performed fairly well on this project. An area of concern is the increasing cracking on the project. Further, additional investigation is required to explain the decreasing rutting over time.

CIR PROJECT 8—US 60 EB, PINAL COUNTY

Project Overview

This project, located on US 60 eastbound between MP 199.85 and 208.44, was constructed under ADOT Project No. STP-022-3(79)P. The project entailed CIR of the existing asphalt concrete to a depth of 3.0 inches, followed by the placement of a 2.0 inches conventional asphalt overlay and a 0.5 inch asphalt rubber friction course.

Eastbound US 60 within the project limits is a two-lane one-way roadway consisting of two 12 ft travel lanes and 6 ft shoulders. The original roadway was built in 1941 with a bituminous surface course and an aggregate base. The project received overlays in 1965 and 1966, which included 2.5 inch HMA layers followed by the application of a 0.5 inch friction course. Various other rehabilitation activities also took place between 1965 and 1979, including heater scarification, fog seals, or chip seals.

Field reviews of the project were conducted in September 1993 and January 1995. The pavement surface showed 5 to 20 percent cracking, a majority of which was either transverse or medium to large block cracking. Some alligator cracking was also observed in the right wheel path of both lanes. Some pumping and moderate pavement rutting was also observed along the project. Flushing was moderate to severe, and some raveling was also evident.

Construction

The project was constructed in fall 1996 by FNF Construction (subcontractor Arizona Pavement Profiling). The exact construction sequencing, methods employed, and equipment used during construction of this CIR project are not known. Presented below are excerpts from the specification included as part of the project documents.

The construction work consisted of milling the existing pavement to the depths specified in the plans. The materials were specified to be broken up using a single pass, in-place pulverization technique so that 100 percent of the end product passes the 1.25 in sieve. The pulverized material and 1.5 percent mixing water (as a percentage of total weight of the aggregate material) were then to be mixed in a self-propelled traveling mixer with adequate metering controls for the addition of binder agent. The allowable moisture content in the aggregate was not allowed to exceed 3 percent by weight of the mixed aggregate materials prior to the addition of the emulsion. The aggregate material was then to be mixed with the emulsified binder agent applied at a pre-specified rate until adequate coating of particles was obtained.

Self-propelled paving machines equipped with automatic controls and screeds were specified for laydown, taking care to prevent segregation. Compaction was not to commence until the emulsion began to break or for 2 hours, whichever was first. Initial rolling was to be accomplished with 30-ton pneumatic rollers, while 12-ton steel-wheeled rollers were used for finish rolling. All compaction equipment was required to meet standard ADOT specifications.

After the CIR overlay was in place, the double seal coat, including a chip seal and fog seal, was to be applied.

Materials

The type of emulsion specified was HFE-300P containing polymer modified asphalt, water, 1 percent liquid anti-stripping agent (by weight of emulsion), and emulsifier, blended to specific requirements. An application rate of 1.1 percent was specified as a start point based on extensive laboratory testing by ADOT, which included density, asphalt content, and strength (tensile strength ratio) testing.

Traffic

Figure 41 presents a plot of ADT versus time for this project, and figure 42 presents plots of AADT and percent trucks versus time.

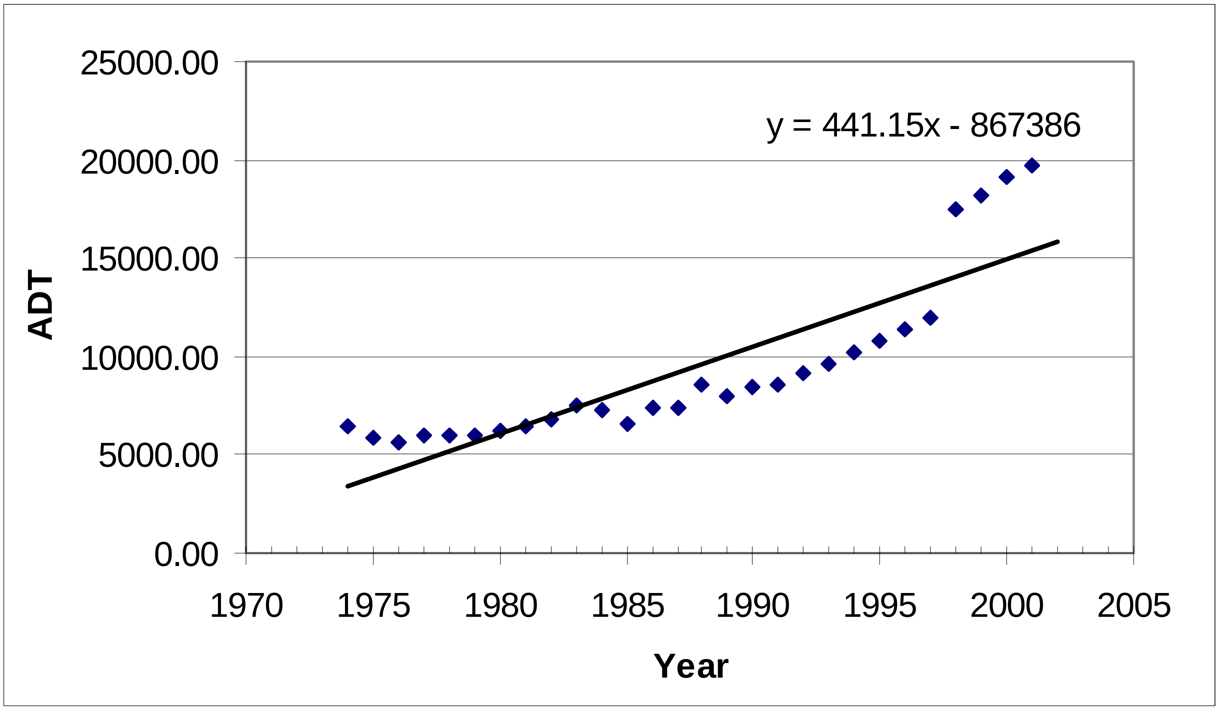

Figure 41. ADT data for CIR Project 8—US 60 EB (ADOT Project No. STP-022-3(79)P).

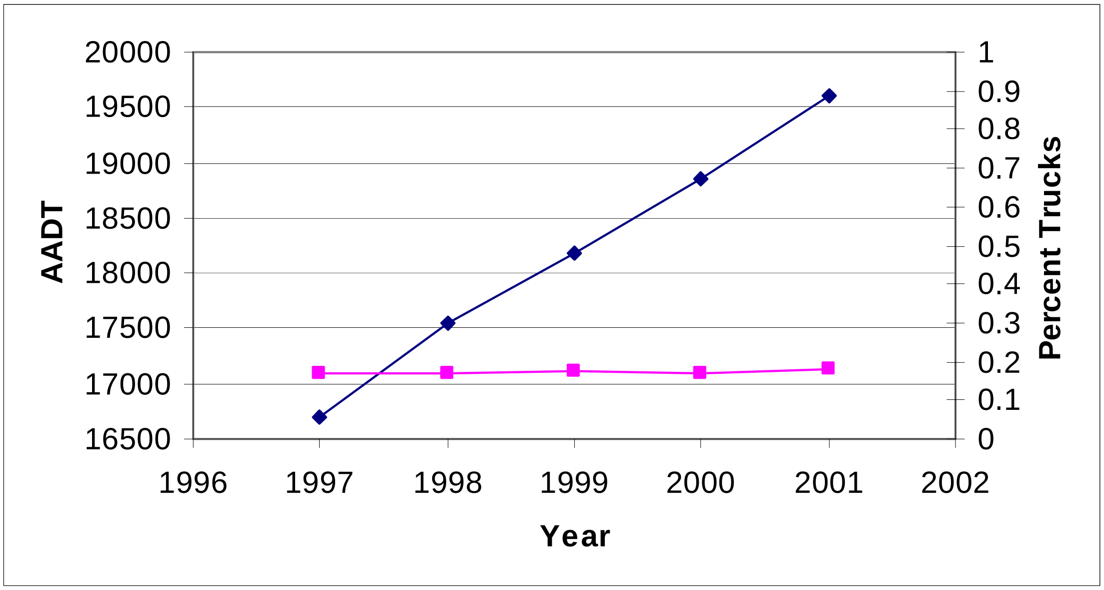

Figure 42. AADT data for CIR Project 8— US 60 EB (ADOT Project No. STP-022-3(79)P).

The traffic, in terms of ADT and AADT, has increased steadily since the time the CIR work was done on this project. However, the total number of trucks on this roadway is low, and when expressed as a percentage of AADT, the volume of trucks has remained relatively unchanged for the period over which data are available.

Pavement Performance Observations

Pavement distress data, ride quality data, and maintenance costs were extracted from the pavement management database and examined. The last condition survey on the roadway was performed in March 2002. The following is the extent of information available for each performance category considered in this report:

- Cracking – 1980 to 2002.
- Potholes – at the time of last condition survey.
- Rutting – 1989 to 2002.
- Patching – 1980 to 2002.
- Flushing – 1980 to 2002.
- Ride – 1972 to 2002.
- Maintenance costs – 1972 to 2002.

Figures 43 through 45 present the cracking, rutting, and flushing data since this CIR project was constructed in 1996. Pothole and patching data are not plotted since these quantities were zero over the reporting period. Figure 46 presents the ride quality data. Note that all the distress and ride data are presented on both a mile-by-mile basis and an averaged per-mile basis for the entire project (solid line). Performance-related observations are typically made using the average per-mile quantities as the basis.

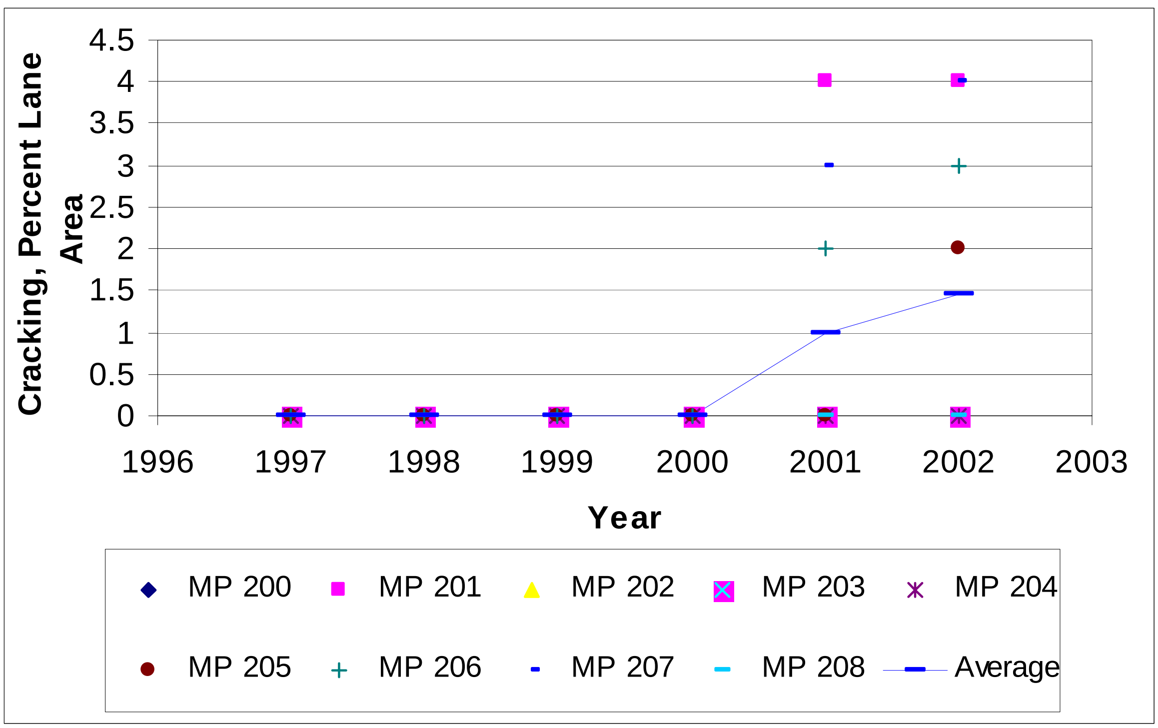

Figure 43. Cracking data for CIR Project 8— US 191 NB (ADOT Project No. STP-077-1(9)P).

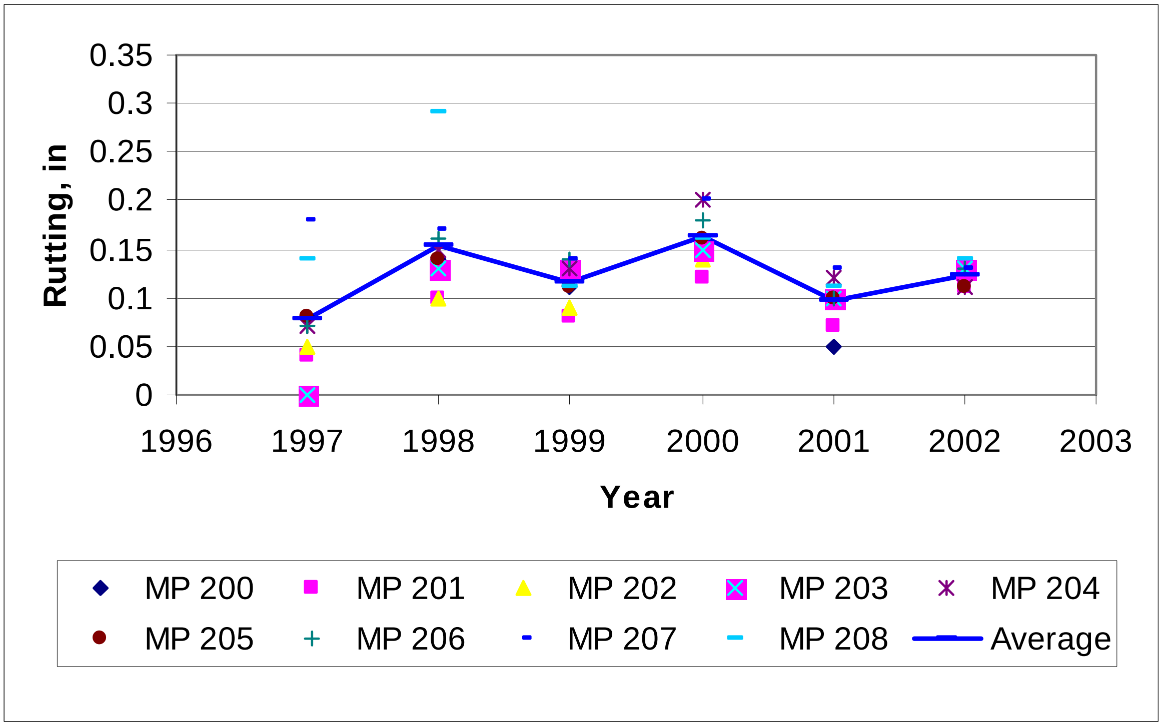

Figure 44. Rutting data for CIR Project 8—US 60 EB (ADOT Project No. STP-022-3(79)P).

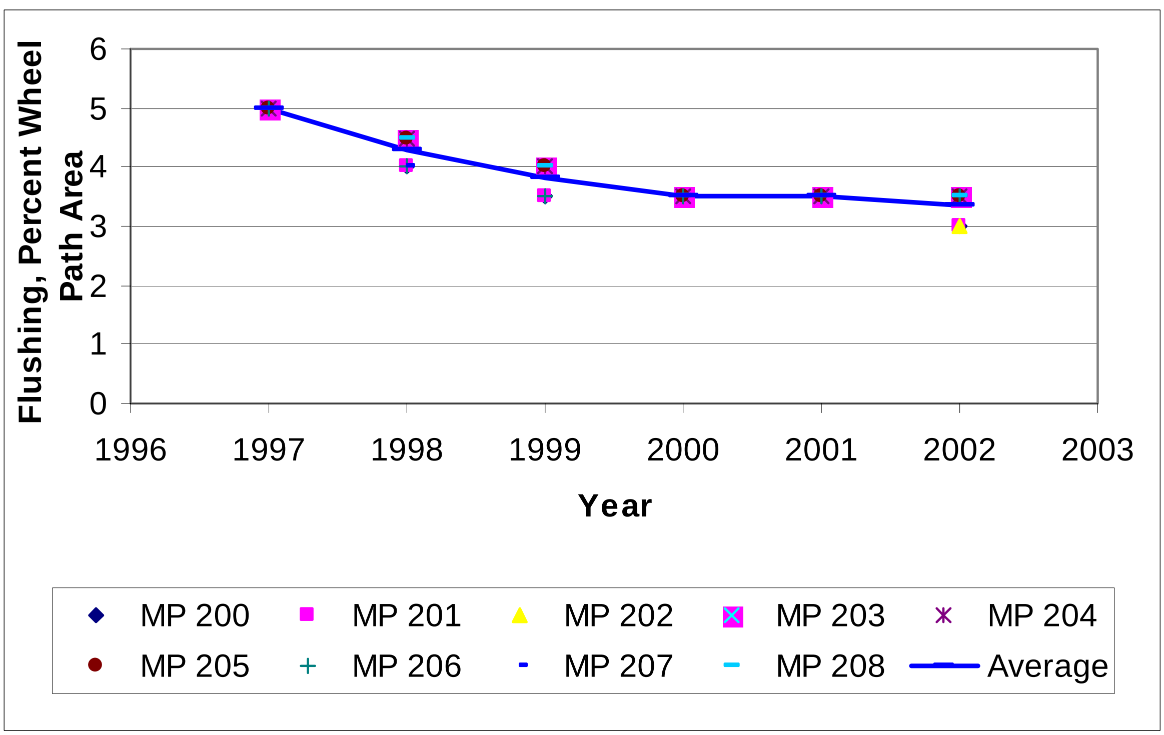

Figure 45. Flushing data for CIR Project 8— US 60 EB (ADOT Project No. STP-022-3(79)P).

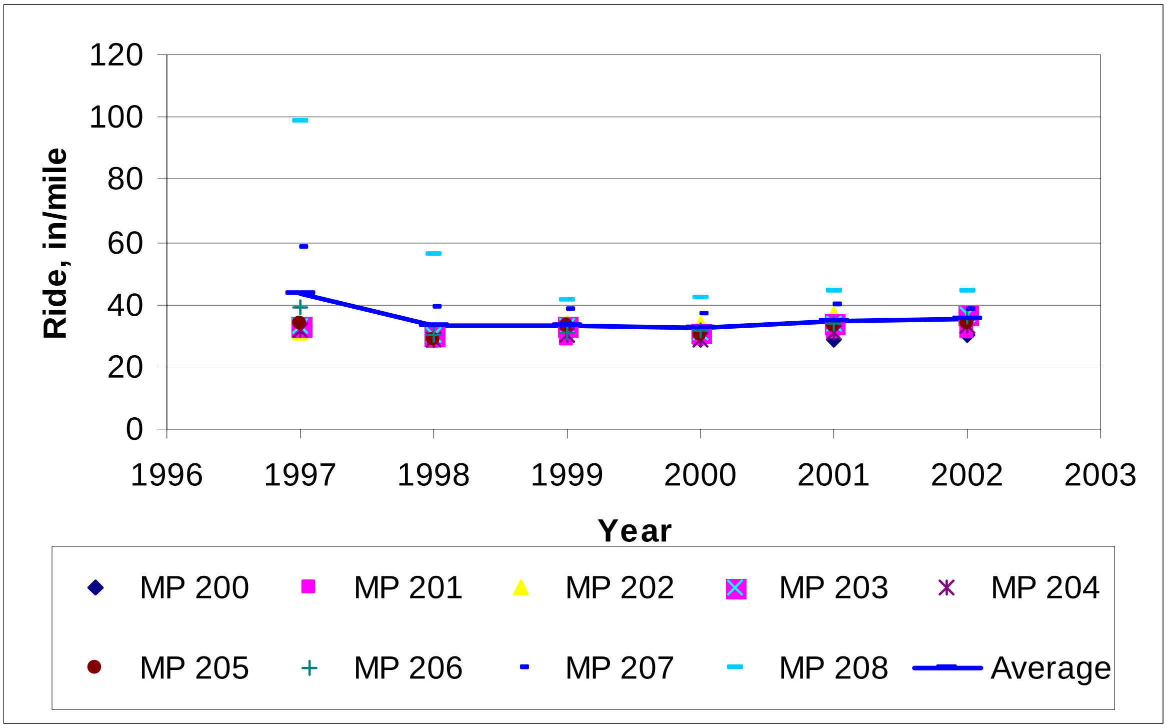

Figure 46. Ride quality information (Mays Ridemeter) for CIR Project 8— US 60 EB (ADOT Project No. STP-022-3(79)P).

Figure 47 presents the annual maintenance costs on a mile-by-mile basis as well as on an averaged per-mile basis for the entire project length. Figure 48 presents the cumulative maintenance costs a on a mile-by-mile basis as well as on an averaged per-mile basis.

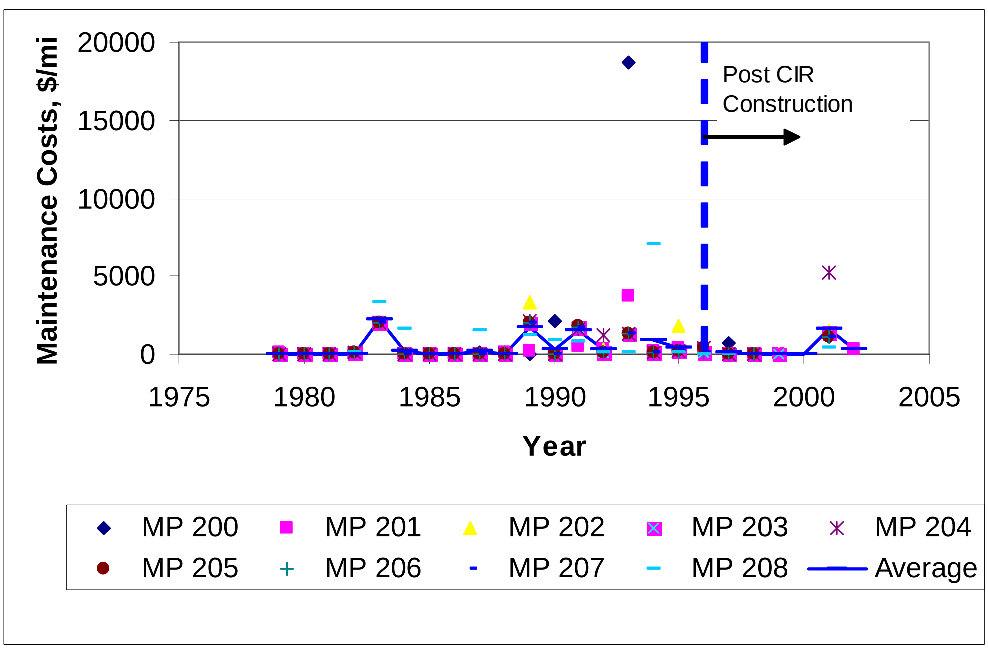

Figure 47. Maintenance costs for CIR Project 8— US 60 EB (ADOT Project No. STP-022-3(79)P).

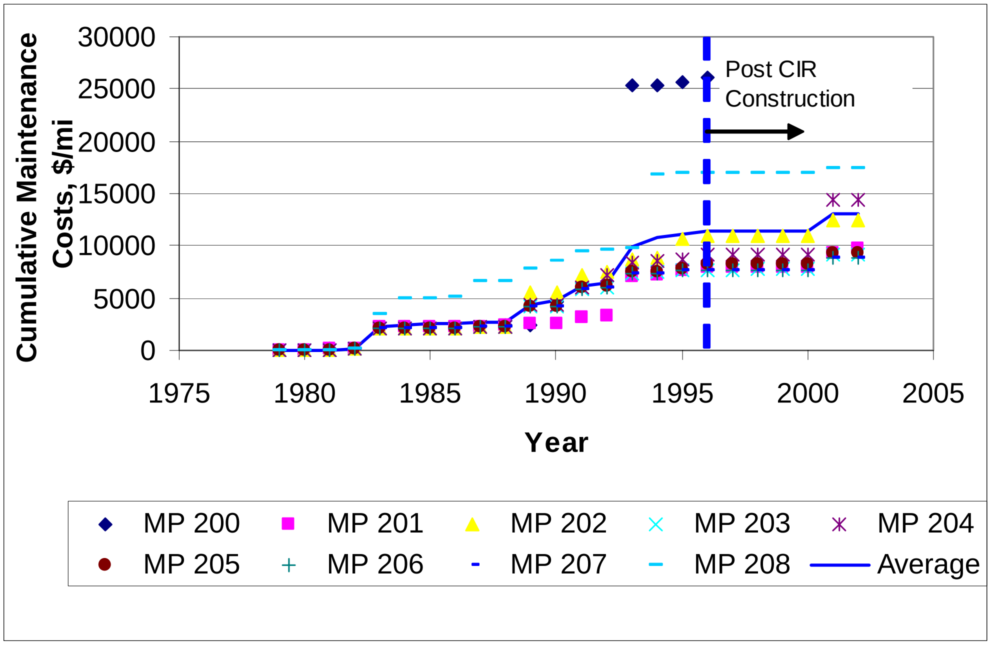

Figure 48. Cumulative maintenance costs for CIR Project 8— US 60 EB (ADOT Project No. STP-022-3(79)P).

Summary of Performance Observations

The following observations can be made from the performance data presented:

- Figure 43 shows that no cracking developed on the project until 2000. However, over one-third of the project showed small amounts of cracking by the last condition survey date. Overall the cracking performance seems satisfactory.
- Figure 44 shows that rutting has remained low and more or less constant along the project over the reporting period. The rutting performance appears to be satisfactory.
- Figure 45 indicates that the flushing quantities remain relatively low and decrease slightly with time.
- Figure 46 shows that the ride values, particularly between MP 208 and 209, remained high in 1997, immediately following the CIR and HMA overlay work in 1996. The reasons for this are unknown. However, on an average basis, the ride quality remained stable over the reporting period and in a relatively satisfactory condition.
- Figure 47 suggests that the mile-by-mile maintenance costs after the CIR work have been dramatically lower compared to the earlier years.
- The cumulative maintenance costs, shown in figure 48, rise steadily leading up to the time the CIR work was performed in conjunction with the HMA overlay and level off considerably after that. The effect is marked when considering the sections between MP 200 and 201 and MP 208 and 209.
- An interesting comparison in figure 48 is the rate of cumulative cost accumulation, on both an average basis and mile-by-mile basis, before and after the CIR plus HMA overlay construction. The figure clearly demonstrates the value of the rehabilitation work in minimizing routine maintenance costs.

The data presented, although not long-term, are sufficient to judge the effectiveness of the rehabilitation work undertaken. Overall, the CIR in conjunction with the HMA overlay seemed to have performed satisfactorily on this project.

CIR PROJECT 9—SR 389 NB, MOHAVE COUNTY

Project Overview

This project, located on SR 389 NB between MP 0.0 and 27.0, was constructed under ADOT Project No. STP-213-(5)P. The project involved CIR of the existing asphalt concrete to a depth of 3 inches (1996), followed by the placement of a 2.0 inch conventional asphalt overlay and a double chip seal coat (1997). The purpose of the project was to improve the rideability by correcting pavement rutting and cracking.

The original roadway located in a rural area was built in early to mid 1960s. The cross section was comprised of varying thicknesses of a bituminous surface course, aggregate base material, and select fill material. Between 1967 and 1986 the pavement received various rehabilitation activities, including an overlay and multiple chip seals.

At the time of the pavement condition evaluation in 1995, the roadway exhibited medium to severe cracking ranging from 5 to 35 percent of the project. The type of cracking was large and small block patterns, with some spider web and transverse thermal cracking. Two locations showed major subgrade failure. The roadway had evidence of extensive cracking over the last 25 years. Materials from the numerous maintenance seals and overlays were bleeding. Minor rutting was evident throughout the project.

Construction

The project was constructed in two stages: the CIR work was done in the summer of 1996, followed by a conventional overlay and an application of double chip seal coat in the summer of 1997. Construction was undertaken by Bear River Construction (subcontractor Arizona Pavement Profiling). The construction details presented herein describe the CIR work only. The exact construction sequencing, methods employed, and equipment used during construction of this CIR project are not known. Presented below are excerpts from the specification included as part of the project documents.

The construction work consisted of milling the existing pavement to the depths specified in the plans. The materials were specified to be broken up using a single pass, in-place pulverization technique so that 100 percent of the end product passes the 1.25 in sieve. The pulverized material and 1.5 percent mixing water (as a percentage of total weight of the aggregate material) were then to be mixed in a self-propelled traveling mixer with adequate metering controls for the addition of binder agent. The allowable moisture content in the aggregate was not allowed to exceed 3 percent by weight of the mixed aggregate materials prior to the addition of the emulsion. The aggregate material was then to be mixed with the emulsified binder agent applied at a pre-specified rate until adequate coating of particles was obtained.

Self-propelled paving machines equipped with automatic controls and screeds were specified for laydown, taking care to prevent segregation. Compaction was not to commence until the emulsion began to break or for 2 hours, whichever was first. Initial rolling was to be accomplished with 30-ton pneumatic rollers, while 12-ton steel-wheeled rollers were used for finish rolling. All compaction equipment was required to meet standard ADOT specifications.

Materials

The type of emulsion specified was HFE-300P containing polymer modified asphalt, water, 1 percent liquid anti-stripping agent (by weight of emulsion), and emulsifier, blended to specific requirements. An application rate of 1.0 percent was specified as a start point based on extensive laboratory testing by ADOT, which included density, asphalt content, and strength (tensile strength ratio) testing.

Traffic

Figure 49 presents a plot of ADT versus time for this project, and figure 50 presents plots of AADT and percent trucks versus time. The traffic appears to be steadily increasing over time, in terms of ADT and AADT. However, the ADT appears to have dropped off since 1996 when compared to previous years. The percentage of trucks on this roadway is low and appears to be on a slightly increasing trend towards the end of the reporting period.

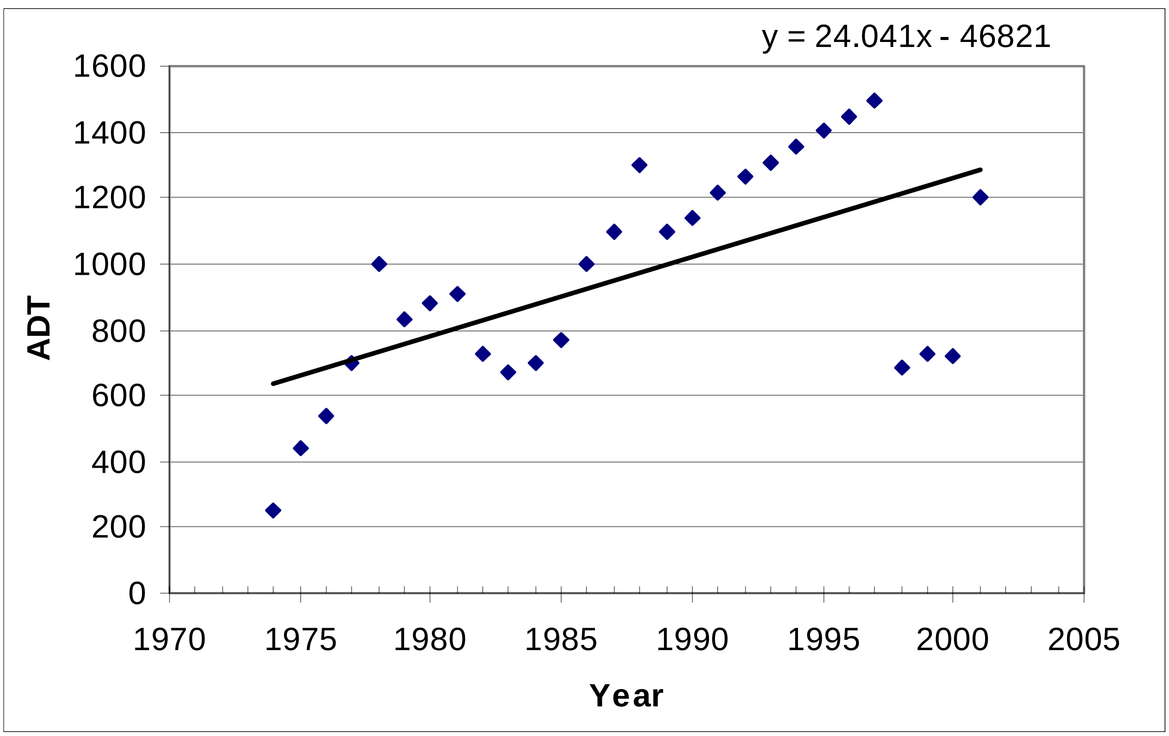

Figure 49. ADT data for CIR Project 9—SR 389 NB (ADOT Project No. STP-213-(5)P).

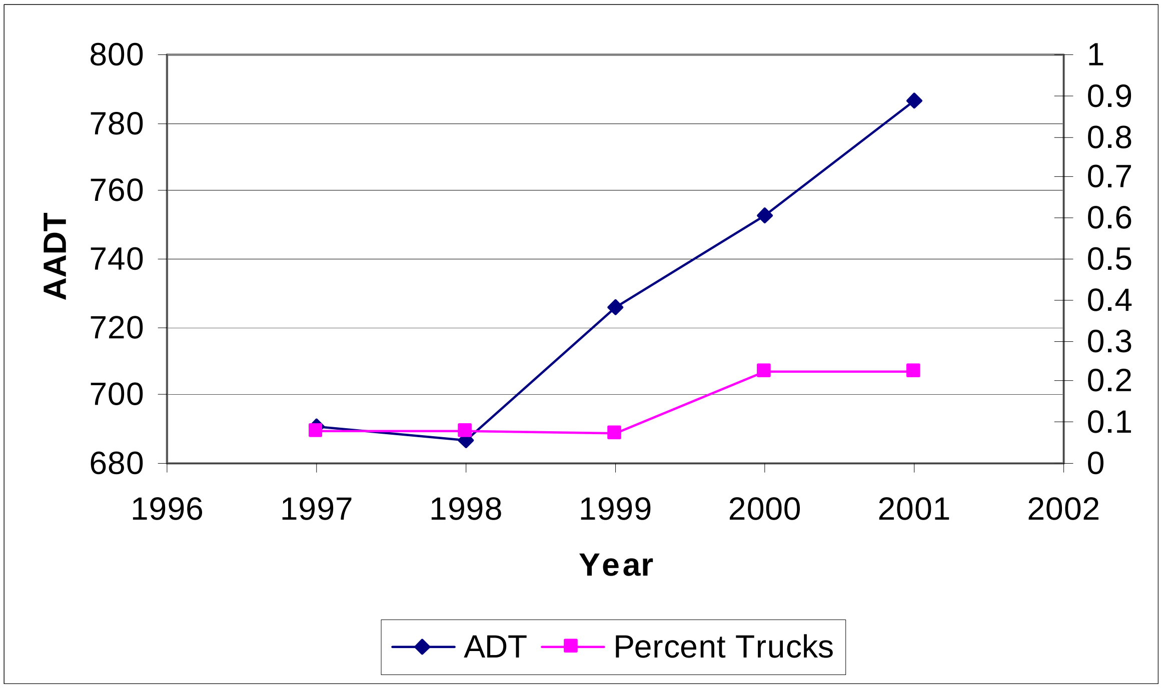

Figure 50. AADT data for CIR Project 9—SR 389 NB (ADOT Project No. STP-213-(5)P).

Pavement Performance Observations

Pavement distress data, ride quality data, and maintenance costs were extracted from the pavement management database and examined. The last condition survey on the roadway was performed in September 2002. The following is the extent of information available for each performance category considered in this report:

- Cracking – 1980 to 2002.
- Potholes – at the time of last condition survey.
- Rutting – 1988 to 2002.
- Patching – 1980 to 2002.
- Flushing – 1980 to 2002.
- Ride – 1972 to 2002.
- Maintenance costs – 1979 to 2002.

Figures 51 through 53 present the cracking, rutting, and flushing data since the CIR project was constructed in 1996. Pothole and patching data are not plotted since these quantities were zero over the reporting period under consideration. Figure 54 presents the ride quality data. Note that all the distress and ride data are presented on both a mile-by-mile basis and an averaged per-mile basis for the entire project (solid line). Performance-related observations are typically made using the average per-mile quantities as the basis.

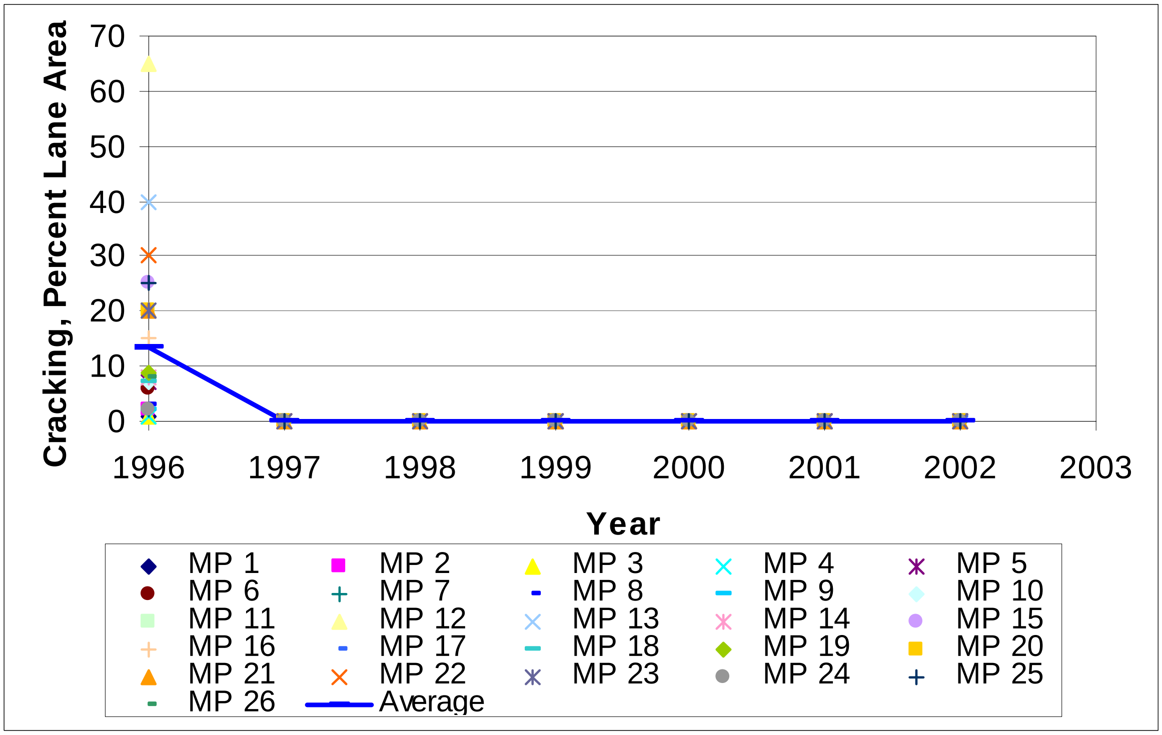

Figure 51. Cracking data for CIR Project 9—SR 389 NB (ADOT Project No. STP-213-(5)P).

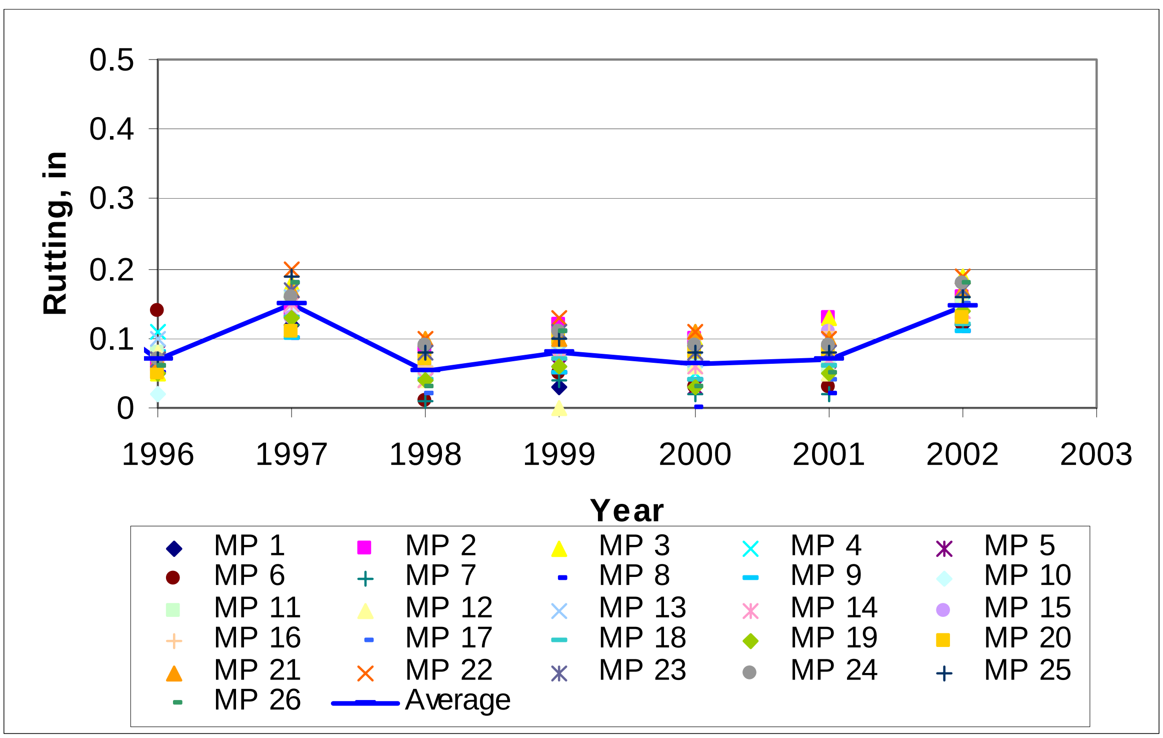

Figure 52. Rutting data for CIR Project 9—SR 389 NB (ADOT Project No. STP-213-(5)P).

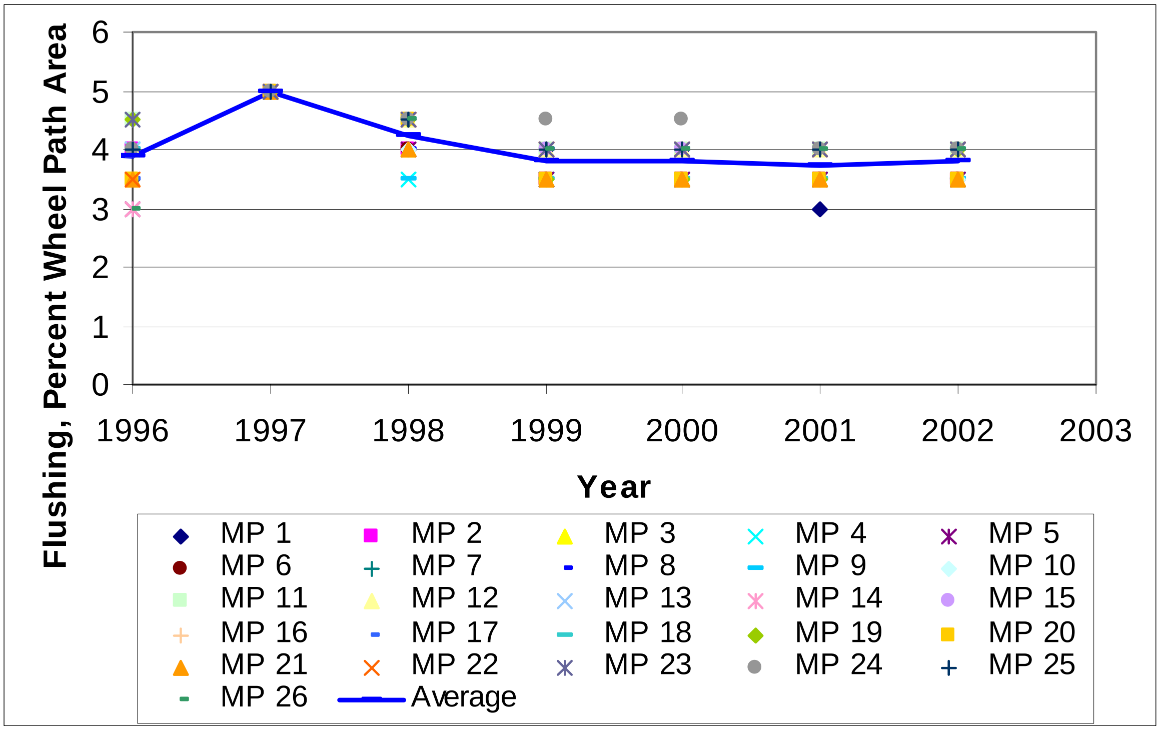

Figure 53. Flushing data for CIR Project 9—SR 389 NB (ADOT Project No. STP-213-(5)P).

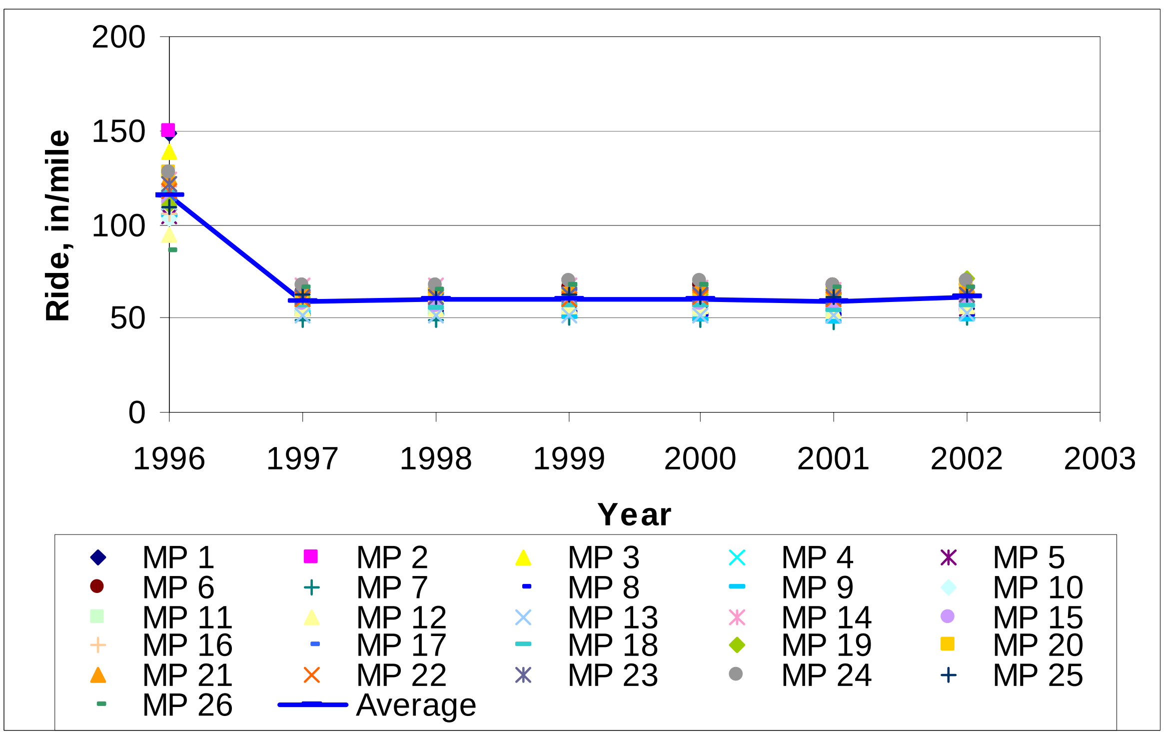

Figure 54. Ride quality information (Mays Ridemeter) for CIR Project 9—SR 389 NB (ADOT Project No. STP-213-(5)P).

Figure 55 presents the annual maintenance costs on a mile-by-mile basis as well as on an averaged per-mile basis for the entire project length. Figure 56 presents the cumulative maintenance costs a on a mile-by-mile basis as well as on an averaged per-mile basis.

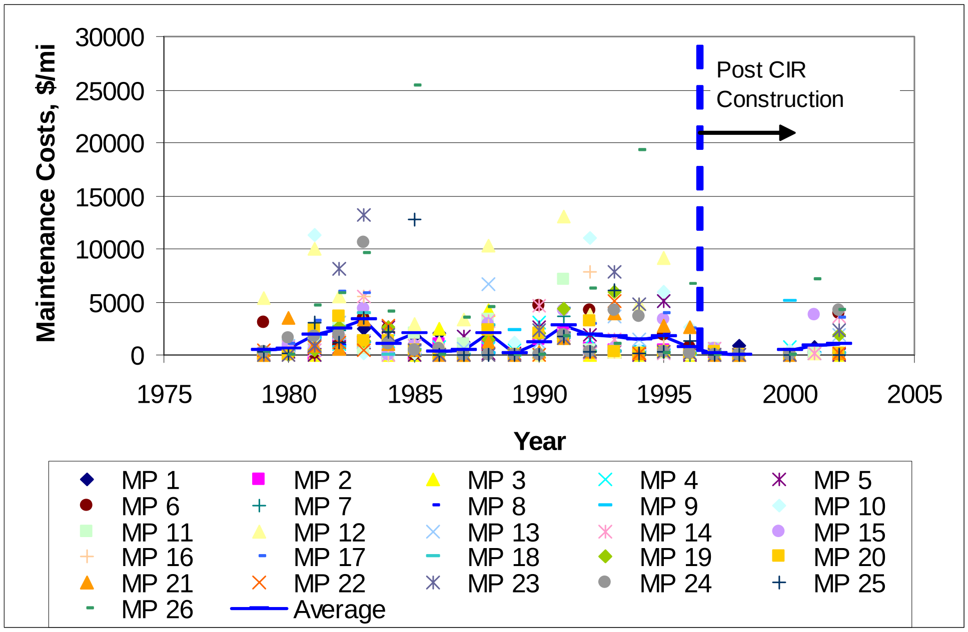

Figure 55. Maintenance costs for CIR Project 9—SR 389 NB (ADOT Project No. STP-213-(5)P).

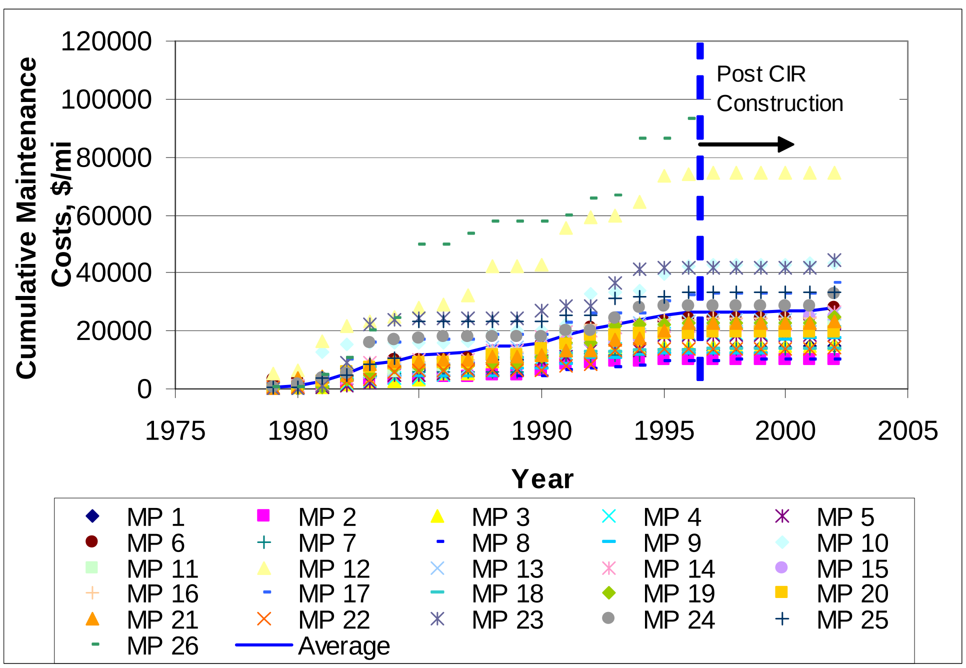

Figure 56. Cumulative maintenance costs for CIR Project 9—SR 389 NB (ADOT Project No. STP-213-(5)P).

Summary of Performance Observations

The following observations can be made from the performance data presented:

- Based on a visual examination of the data, the pavement shows a marked improvement in cracking, rutting, and ride quality in 1997, compared to data from 1996. This significant short-term improvement in performance is perhaps due to the overlay and double chip seal applied in 1997.
- Figure 51 shows that the cracking quantities are close to zero over the entire reporting period after the placement of the conventional overlay in 1997.
- Figure 52 shows that rutting is generally low and stable over the reporting period, with a slight increasing trend towards the end.
- Figure 53 shows that flushing quantities remain relatively low over time.
- Figure 54 shows that, immediately following the CIR work in 1996, the ride quality was still relatively poor; however, based on the information contained in the pavement management system database, it is unknown if the 1996 condition data were collected before or after the CIR work was completed. There was a marked improvement in ride values after the conventional overlay was placed in 1997.
- Figure 55 suggests that the mile-by-mile maintenance costs after the CIR work remain very low—close to negligible—until towards the end of the reporting period, where they increase slightly. Likewise, the cumulative maintenance costs, shown in figure 56, level off after the CIR work and increase slightly at the end of the reporting period. An interesting comparison in figure 56 is the rate cumulative cost accumulation pre- and post-CIR. The figure clearly demonstrates the value of CIR in conjunction with conventional overlay as a viable rehabilitation strategy.

The data presented, although not long-term, are sufficient to judge the effectiveness of the rehabilitation work undertaken. Overall, the CIR in conjunction with the conventional overlay seemed to have performed satisfactorily on this project, and the improvement in pavement performance is in line with what is expected from this combination of rehabilitation activities.

CIR PROJECT 10—SR 73 NB, NAVAJO COUNTY

Project Overview

This project, located on SR 73 between MP 350.69 and 357.64, was constructed under ADOT Project No. STP-215-(4)P. The project is located in Navajo County, approximately 4 mi east of Pinetop Lakeside on SR 73.

The project involved CIR of the existing AC to a depth of 3 inches (1998), followed by the placement of a 2.0 inch conventional asphalt overlay and a double chip seal coat (1999). Other construction items considered as part of the project include guardrail and drainage installation, signing and striping, and miscellaneous items.

The original roadway section within the limits of this project was a “grade and drain” section built in 1951 utilizing a 4 inch select material. In 1952, another project completed the roadway with 3 to 12 inches of select material, 3 inches of aggregate base, and 2 inches of bituminous surfacing. In 1956, a portion of the roadway (between MP 357.5 and 356.8, and MP 353.3 and 352.3) was reconstructed utilizing new 9 to 12 inches of select material, a new 3 inch aggregate base, and a new 2 inch bituminous surfacing. In 1975, the entire roadway was overlaid with a 2 inch HMA surfacing and a seal coat.

At the time of the condition evaluation in 1996, the project consisted of two 12 to15 foot travel lanes, 2 to 6 foot paved shoulders, plus passing lanes of 0.85 and 1.3 miles in length. Pavement widths varied from 30 to 40 feet. The pavement distress varied and was characterized as minor rutting, minor bleeding in the wheelpaths, and 5 to 25 percent transverse, block, and alligator cracking. The purpose of the rehabilitation was to improve the rideability by correcting pavement rutting and cracking.

Construction

The project was constructed in two stages: the CIR work was done in 1998, followed by a conventional overlay and an application of double chip seal coat in 1999. Construction was undertaken by Bear River Construction (Arizona Pavement Profiling was the subcontractor). The construction details discussed herein describe the CIR work only. The exact construction sequencing, methods employed, and equipment used during construction of this CIR project are not known at this time. Presented below are excerpts from the specification included as part of the project documents.

The construction work consisted of milling the existing pavement to the depths specified in the plans. The materials were specified to be broken up using a single pass, in-place pulverization technique so that 100 percent of the end product passes the 1.25 inch sieve. The pulverized material and 1.5 percent mixing water (as a percentage of total weight of the aggregate material) were then to be mixed in a self-propelled traveling mixer with adequate metering controls for the addition of binder agent. The allowable moisture content in the aggregate was not allowed to exceed 3 percent by weight of the mixed aggregate materials prior to the addition of the emulsion. The aggregate material was then to be mixed with the emulsified binder agent applied at a pre-specified rate until adequate coating of particles was obtained.

Self-propelled paving machines equipped with automatic controls and screeds were specified for laydown taking care to prevent segregation. Compaction was not to commence until the emulsion began to break or for 2 hours, whichever was first. Initial rolling was to be accomplished with 30-ton pneumatic rollers, while 12-ton steel-wheeled rollers were used for finish rolling. All compaction equipment was required to meet standard ADOT specifications.

Materials

The type of emulsion specified was HFE-300P containing polymer modified asphalt, water, 1 percent liquid anti-stripping agent (by weight of emulsion), and emulsifier, blended to specific requirements. An application rate of 1.1 percent was specified as a starting point based on extensive laboratory testing by ADOT, which included density, asphalt content, and strength (tensile strength ratio) testing.

Traffic

Figure 57 presents a plot of ADT versus time for this project, and figure 58 presents plots of AADT and percent trucks versus time. The traffic, in terms of ADT and AADT, has steadily increased over time. The traffic levels on this project can be considered moderate. The percentage of trucks is low.

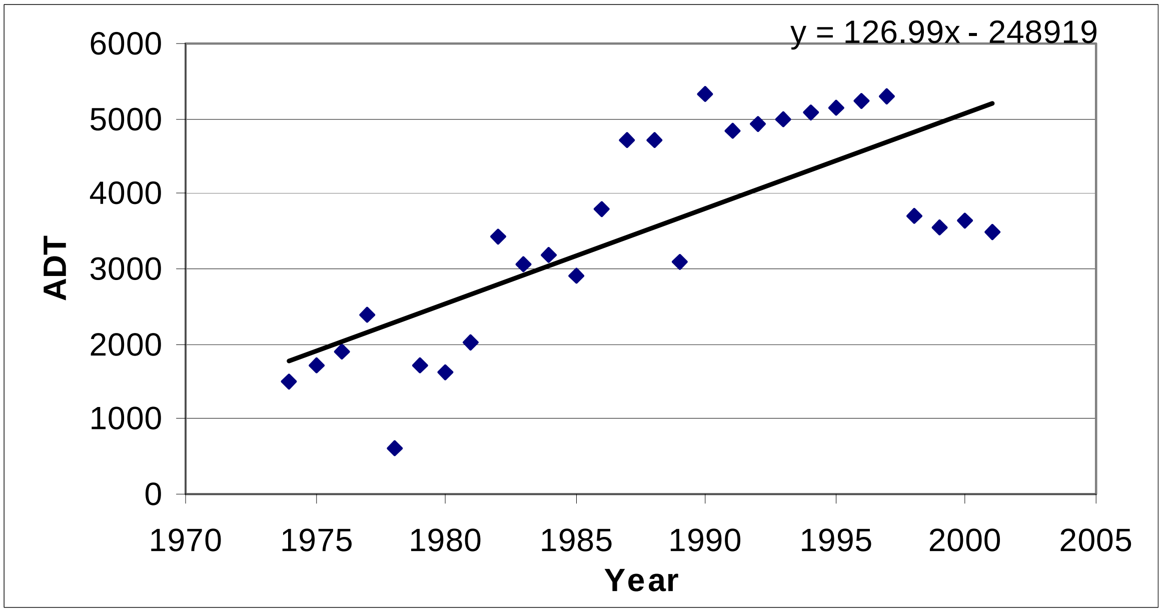

Figure 57. ADT data for CIR Project 10—SR 73 NB (ADOT Project No. STP-215-(4)P).

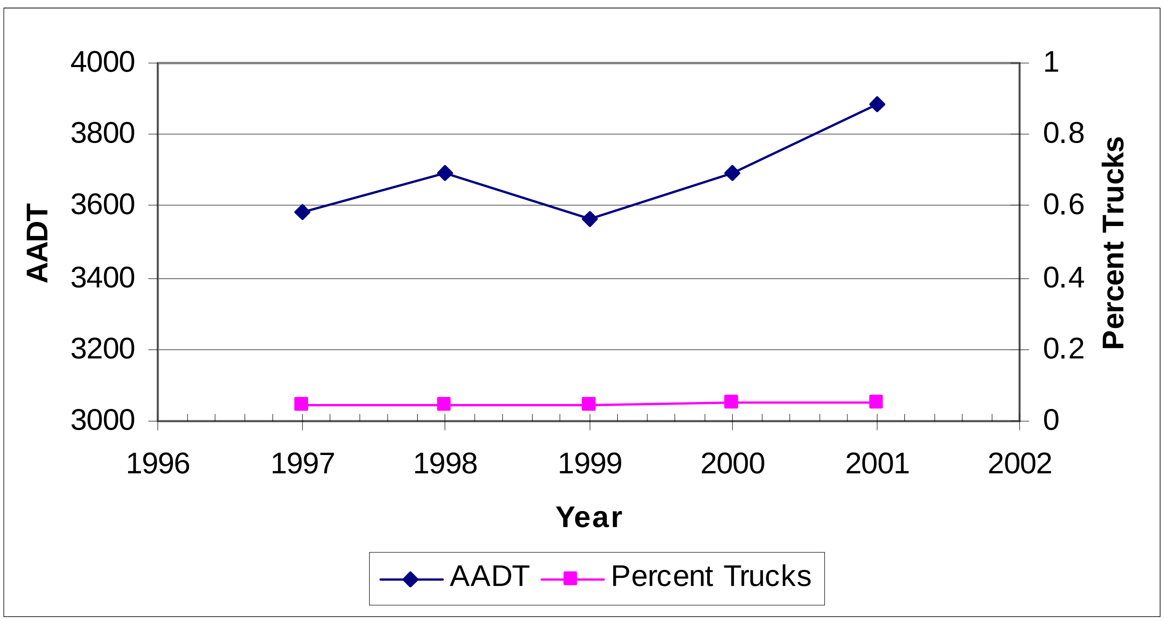

Figure 58. AADT data for CIR Project 10—SR 73 NB (ADOT Project No. STP-215-(4)P).

Pavement Performance Observations

Pavement distress data, ride quality data, and maintenance costs were extracted from the pavement management database and examined. The last condition survey on the roadway was performed in July 2002. The following is the extent of information available for each performance category considered in this report:

- Cracking – 1980 to 2002.
- Potholes – at the time of last condition survey.
- Rutting – 1989 to 2002.
- Patching – 1980 to 2002.
- Flushing – 1980 to 2002.
- Ride – 1972 to 2002.
- Maintenance costs – 1979 to 2002.

Figures 59 through 61 present the cracking, rutting, and flushing data since the CIR project was constructed in 1998. Pothole and patching data are not plotted since these quantities were zero over the reporting period under consideration. Figure 62 presents the ride quality data. Note that all the distress and ride data are presented on both a mile-by-mile basis and an averaged per-mile basis for the entire project (solid line). Performance-related observations are typically made using the average per-mile quantities as the basis.

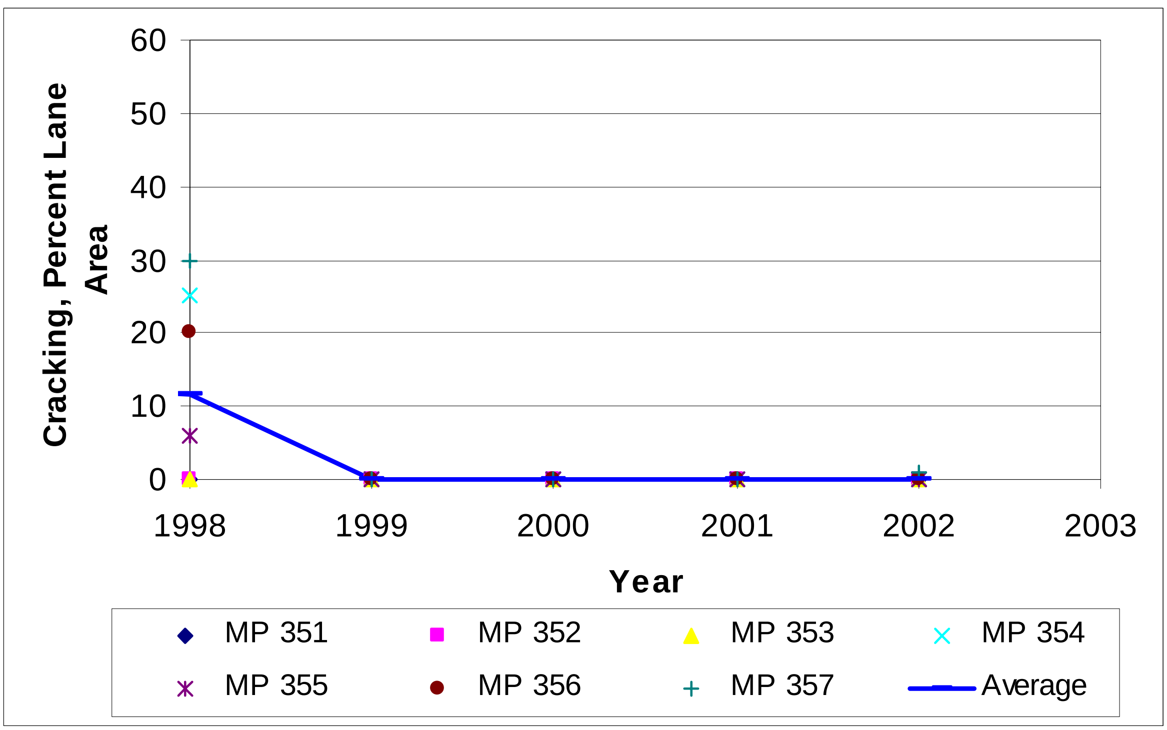

Figure 59. Cracking data for CIR Project 10—SR 73 NB (ADOT Project No. STP-215-(4)P).

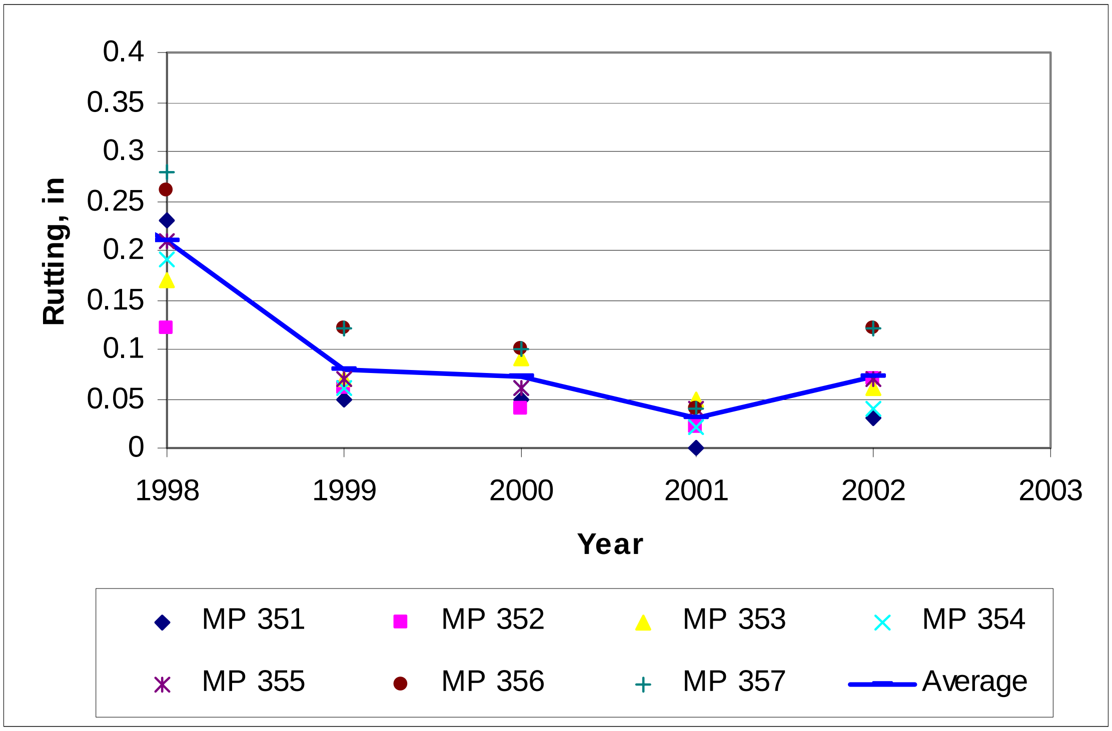

Figure 60. Rutting data for CIR Project 10—SR 73 NB (ADOT Project No. STP-215-(4)P).

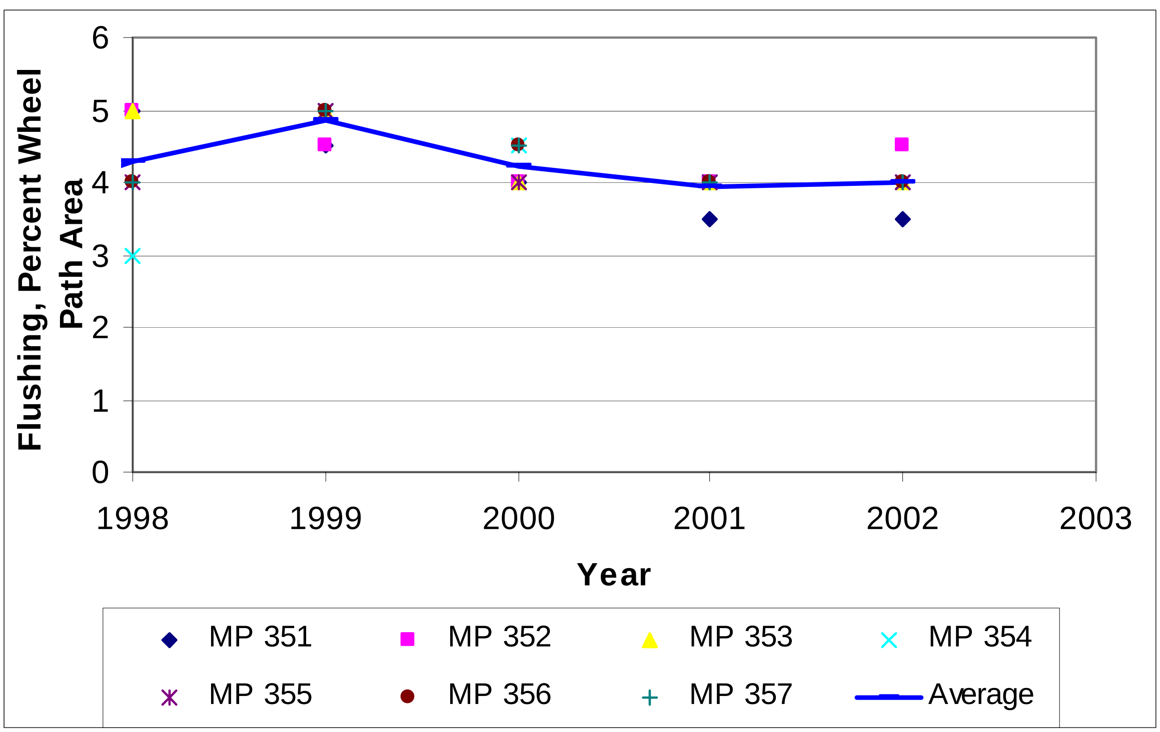

Figure 61. Flushing data for CIR Project 10—SR 73 NB (ADOT Project No. STP-215-(4)P).

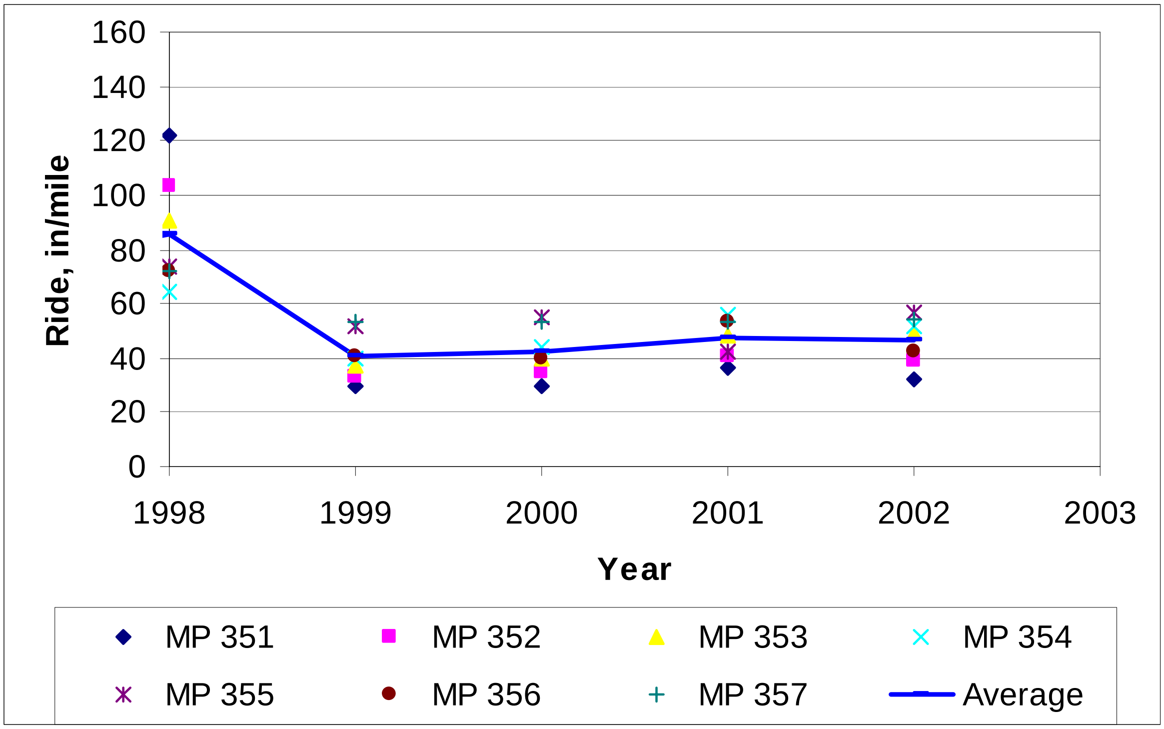

Figure 62. Ride quality information (Mays Ridemeter) for CIR Project 10—SR 73 NB (ADOT Project No. STP-215-(4)P).

Figure 63 presents the annual maintenance costs on a mile-by-mile basis as well as on an averaged per-mile basis for the entire project length. Figure 64 presents the cumulative maintenance costs a on a mile-by-mile basis as well as on an averaged per-mile basis.

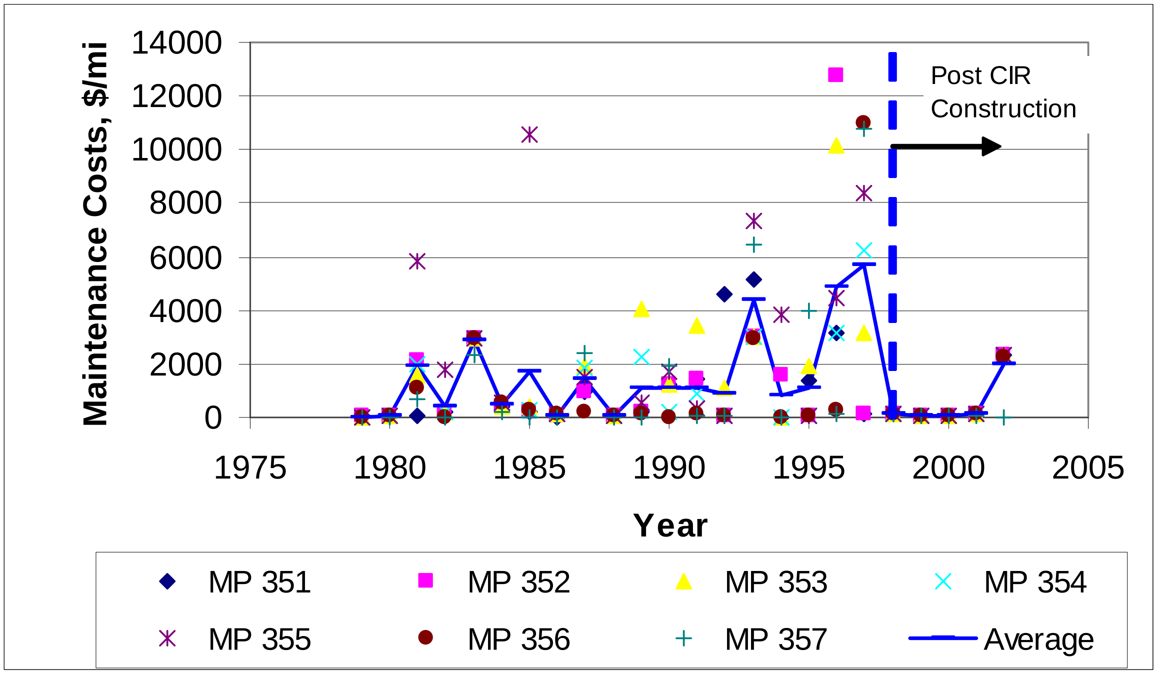

Figure 63. Maintenance costs for CIR Project 10—SR 73 NB (ADOT Project No. STP-215-(4)P).

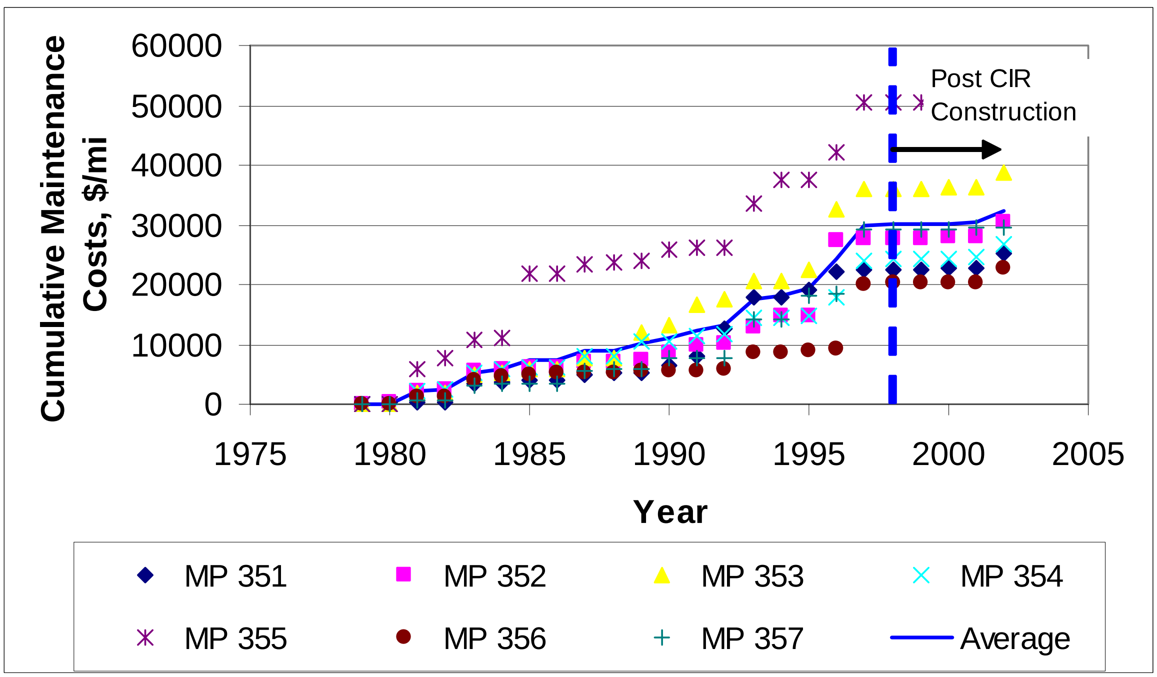

Figure 64. Cumulative maintenance costs for CIR Project 10—SR 73 NB (ADOT Project No. STP-215-(4)P).

Summary of Performance Observations

The following observations can be made from the performance data presented:

- Based on a visual examination of the data, the pavement shows a marked improvement in cracking, rutting, and ride quality in 1999, compared to data from 1998. This significant short-term improvement in performance is perhaps due to the conventional overlay and double chip seal placed in 1999.
- Figure 59 shows that the cracking quantities are close to zero over the entire reporting period after the placement of the conventional overlay in 1999.
- Figure 60 shows that rutting is generally low over the reporting period, with a slight decreasing trend. The latter finding is unexpected.
- Figure 61 shows that the flushing quantities remain relatively low and stable over time.
- Figure 62 shows that, immediately following the CIR work in 1998, the ride quality was still relatively poor; however, it is unknown if the 1998 condition data were collected before or after the CIR work was completed). There was a marked improvement in ride values after the conventional overlay was placed in 1999.
- Figure 63 suggests that the mile-by-mile maintenance costs after the CIR work remain very low—close to negligible—until towards the end of the reporting period, where they increase slightly. Likewise, the cumulative maintenance costs, shown in figure 56, level off after the CIR work only to increase slightly at the end of the reporting period.
- An interesting comparison in figure 56 is the rate cumulative cost accumulation pre- and post-CIR. The figure clearly demonstrates the value of CIR in conjunction with conventional overlay as a viable rehabilitation strategy.

The data presented can be considered short-term (less than 5 years) and may be insufficient to predict the long-term impact of the rehabilitation activity. However, it appears that the CIR in conjunction with the conventional HMA overlay has performed satisfactorily to date.

CIR PROJECT 11—SR 87 NB, NAVAJO COUNTY

Project Overview

This project is located on a two-lane portion of SR 87 between MP 393.5 and 406.04 in Navajo County north of the City of Winslow and extending north approximately 12.5 miles. It was constructed under ADOT Project No. STP-244-(4)P. The project involved CIR of the existing asphalt concrete to a depth of 2.5 inches, followed by the placement of a 2.0 inch conventional asphalt overlay and a double chip seal coat. Other construction items considered as part of the project include guardrail, pavement marking, and miscellaneous incidental items.

The roadway section within the limits of this project was a "grade and drain" section built in 1960 with a 5 inch select material, a 4 inch aggregate base, and a 2 inch plant-mixed HMA course finished with a seal coat. The project has been seal coated extensively since the 1960s but endured over 30 years without major improvement until it was considered for rehabilitation.

At the time of the condition evaluation in 1996, the existing 28 foot roadway consisted of two 12 foot travel lanes and two 2 foot shoulders. Just prior to rehabilitation, the pavement was characterized as having rough rideability, sand and seal maintenance patching, 20 to 25 percent small block cracking, and minor rutting. In 1994, cracking along the project varied from 4 to 75 percent, and averaged 39 percent. The measured rutting at the same time varied from 0.20 to 0.45 inches, with a project average of 0.29 inches. The Mays roughness values varied between 105 and 186 inches/mile, with an average of 147 inches/mile. The purpose of the rehabilitation was to improve the rideability by correcting pavement rutting and cracking.

Construction

The project was constructed in summer 1998 by FNF Construction (subcontractor Arizona Pavement Profiling). The construction details discussed herein describe the CIR work only. The exact construction sequencing, methods employed, and equipment used during construction of this CIR project are not known. Presented below are excerpts from the specification included as part of the project documents.

The construction work consisted of milling the existing pavement to the depths specified in the plans. The materials were specified to be broken up using a single pass, in-place pulverization technique so that 100 percent of the end product passes the 1.25 inch sieve. The pulverized material and 1.5 percent mixing water (as a percentage of total weight of the aggregate material) were then to be mixed in a self-propelled traveling mixer with adequate metering controls for the addition of binder agent. The allowable moisture content in the aggregate was not allowed to exceed 3 percent by weight of the mixed aggregate materials prior to the addition of the emulsion. The aggregate material was then to be mixed with the emulsified binder agent applied at a pre-specified rate until adequate coating of particles was obtained.

Self-propelled paving machines equipped with automatic controls and screeds were specified for laydown, taking care to prevent segregation. Compaction was not to commence until the emulsion began to break or for 2 hours, whichever was first. Initial rolling was to be accomplished with 30-ton pneumatic rollers, while 12-ton steel-wheeled rollers were used for finish rolling. All compaction equipment was required to meet standard ADOT specifications.

Materials

The type of emulsion specified was HFE-300P containing polymer modified asphalt, water, 1 percent liquid anti-stripping agent (by weight of emulsion), and emulsifier, blended to specific requirements. An application rate of 1.3 percent was specified as a start point based on extensive laboratory testing by ADOT, which included density, asphalt content, and strength (tensile strength ratio) testing.

Traffic

Figure 65 presents a plot of ADT versus time for this project, and figure 66 presents plots of AADT and percent trucks versus time. The traffic, in terms of ADT, has steadily increased over time. The AADT, since the CIR work, has remained relatively unchanged. The traffic levels on this project can be considered low, and the percentage of trucks is also low.

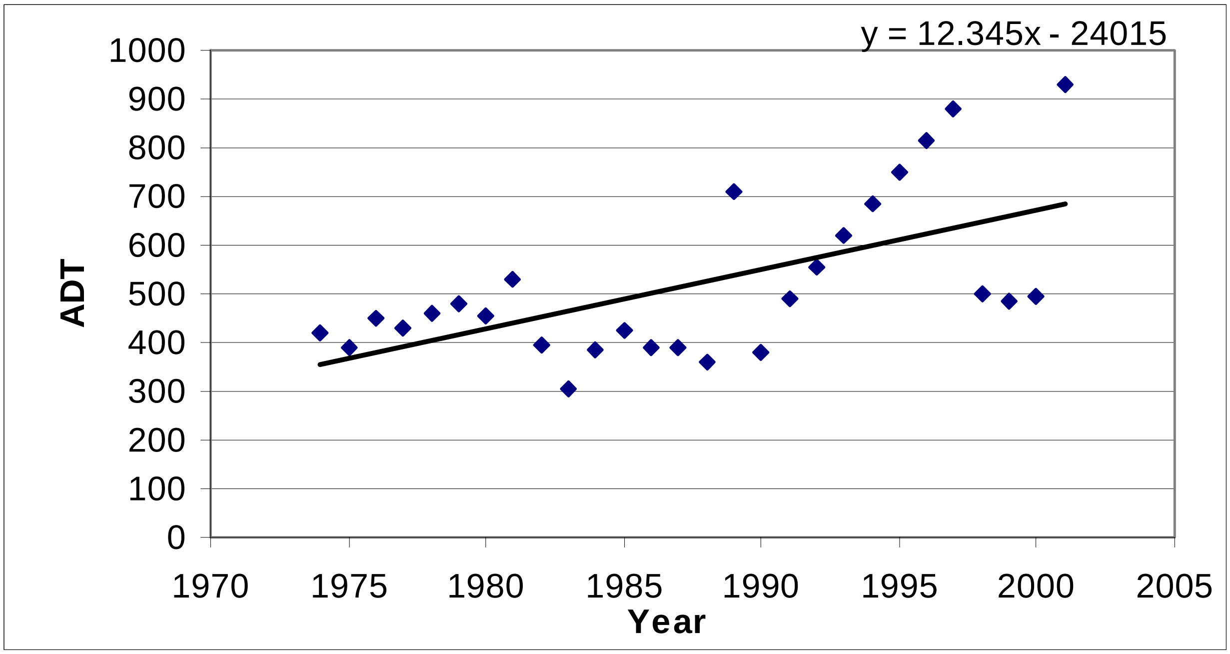

Figure 65. ADT data for CIR Project 11—SR 87 NB (ADOT Project No. STP-244-(4)P).

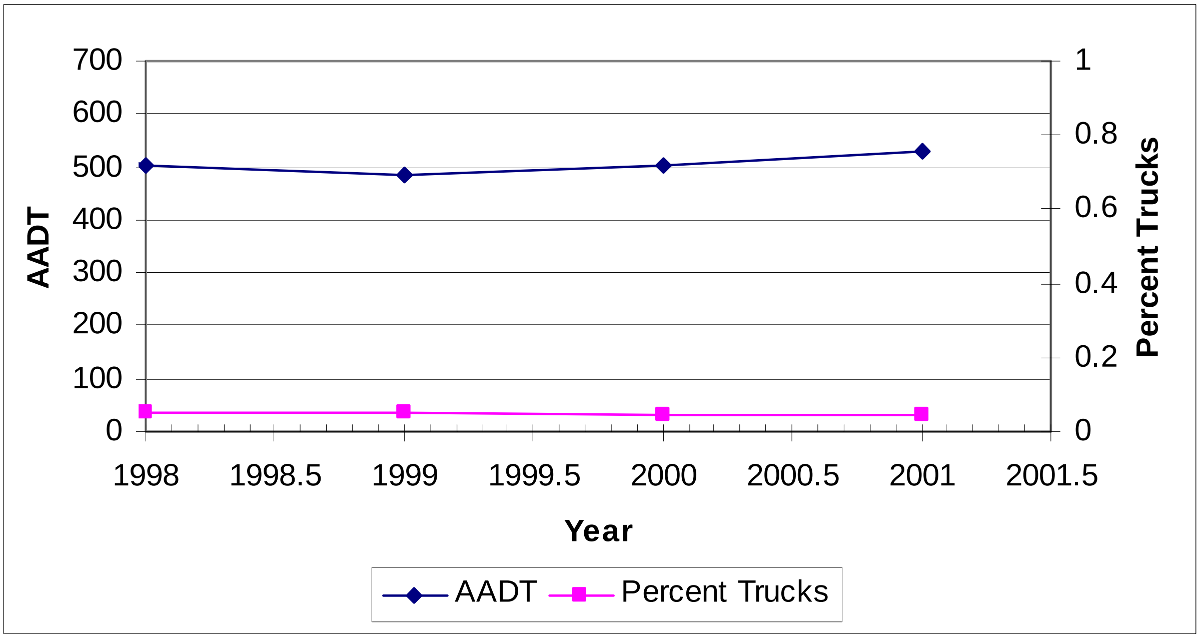

Figure 66. AADT data for CIR Project 11—SR 87 NB (ADOT Project No. STP-244-(4)P).

Pavement Performance Observations

Pavement distress data, ride quality data, and maintenance costs were extracted from the pavement management database and examined. The last condition survey on the roadway was performed in August 2002. The following is the extent of information available for each performance category considered in this report:

- Cracking – 1980 to 2002.
- Potholes – at the time of last condition survey.
- Rutting – 1988 to 2002.
- Patching – 1980 to 2002.
- Flushing – 1980 to 2002.
- Ride – 1972 to 2002.
- Maintenance costs – 1979 to 2002.

Figures 67 through 69 present the cracking, rutting, and flushing data since this CIR project was constructed in 1998. Pothole and patching data are not plotted since these quantities were zero over the reporting period under consideration. Figure 70 presents the ride quality data. Note that all the distress and ride data are presented on both a mile-by-mile basis and an averaged per-mile basis for the entire project (solid line). Performance-related observations are typically made using the average per-mile quantities as the basis.

Figure 71 presents the annual maintenance costs on a mile-by-mile basis as well as on an averaged per-mile basis for the entire project length. Figure 72 presents the cumulative maintenance costs a on a mile-by-mile basis as well as on an averaged per-mile basis.

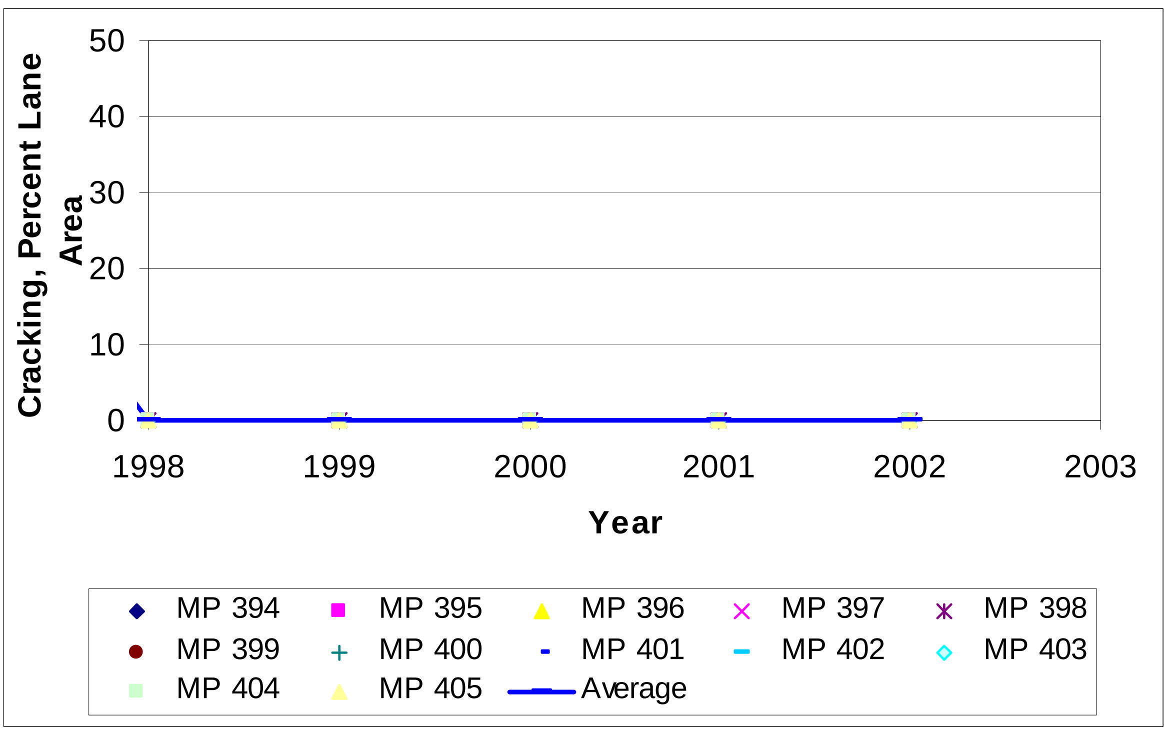

Figure 67. Cracking data for CIR Project 11—SR 87 NB (ADOT Project No. STP-244-(4)P).

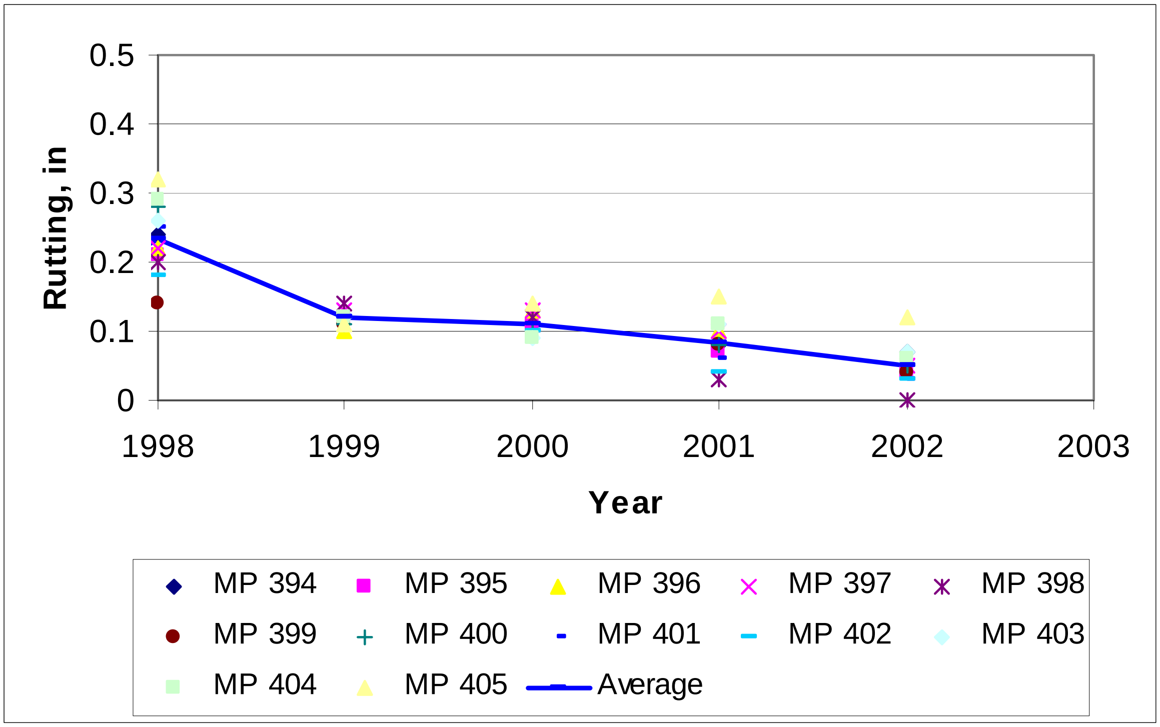

Figure 68. Rutting data for CIR Project 11—SR 87 NB (ADOT Project No. STP-244-(4)P).

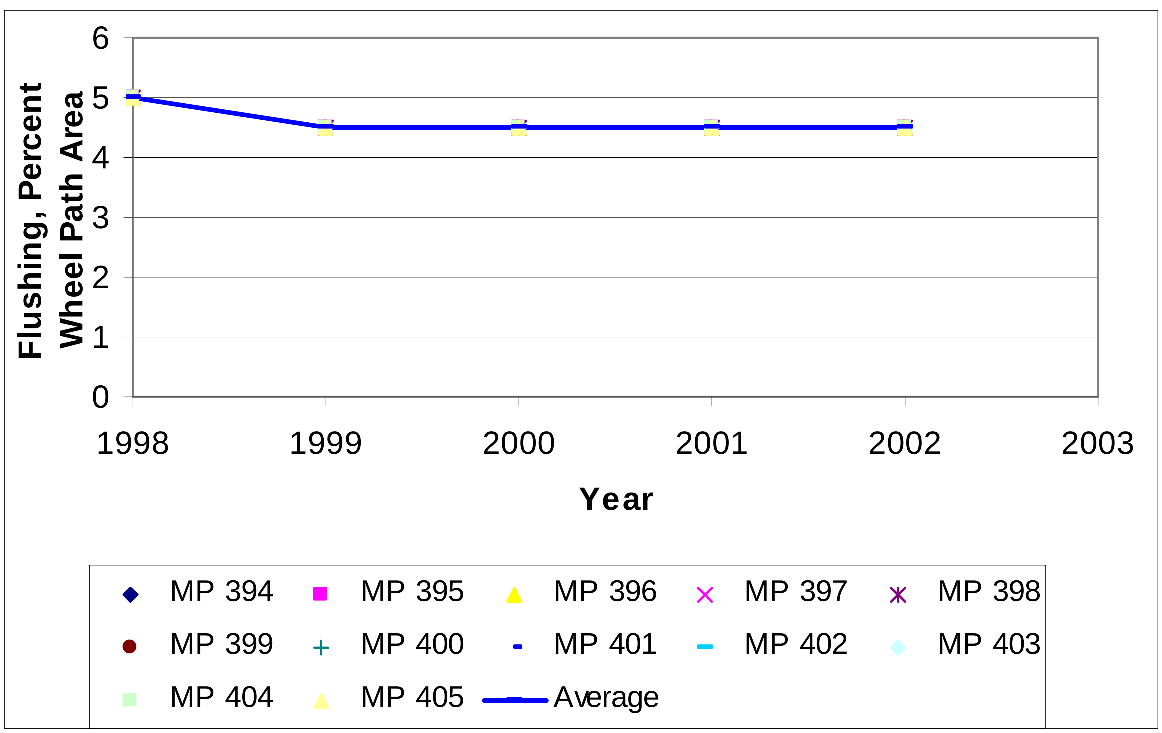

Figure 69. Flushing data for CIR Project 11—SR 87 NB (ADOT Project No. STP-244-(4)P).

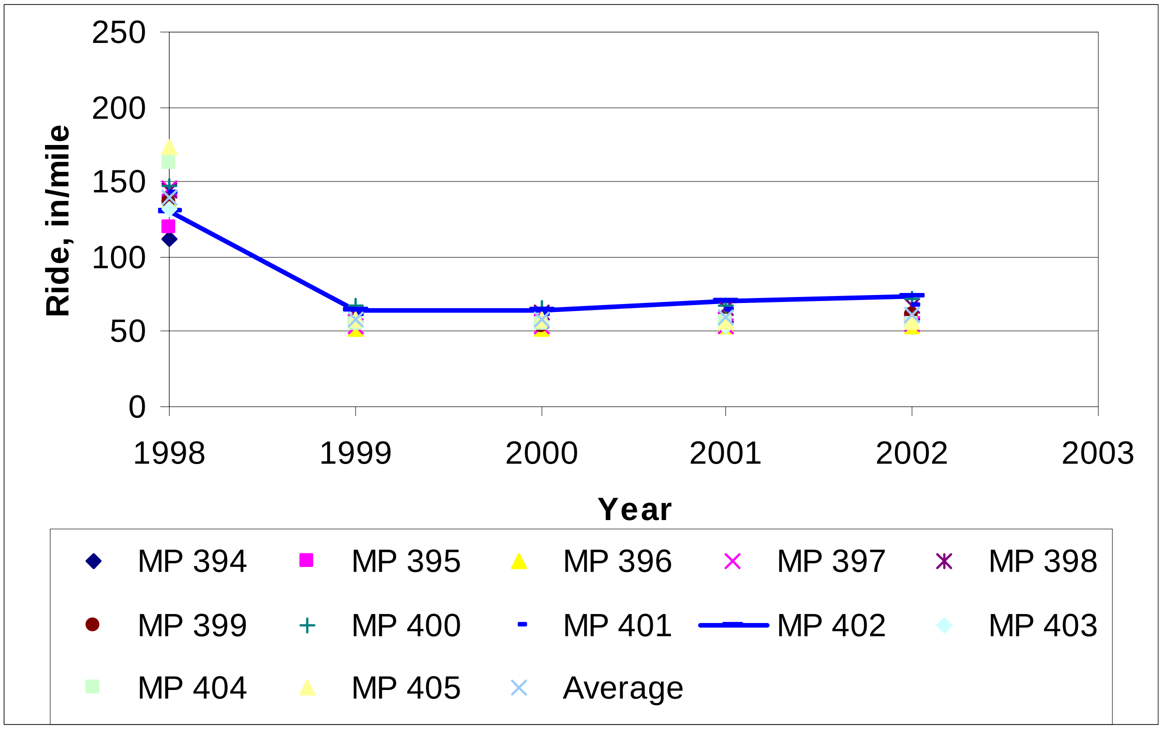

Figure 70. Ride quality information (Mays Ridemeter) for CIR Project 11—SR 87 NB (ADOT Project No. STP-244-(4)P).

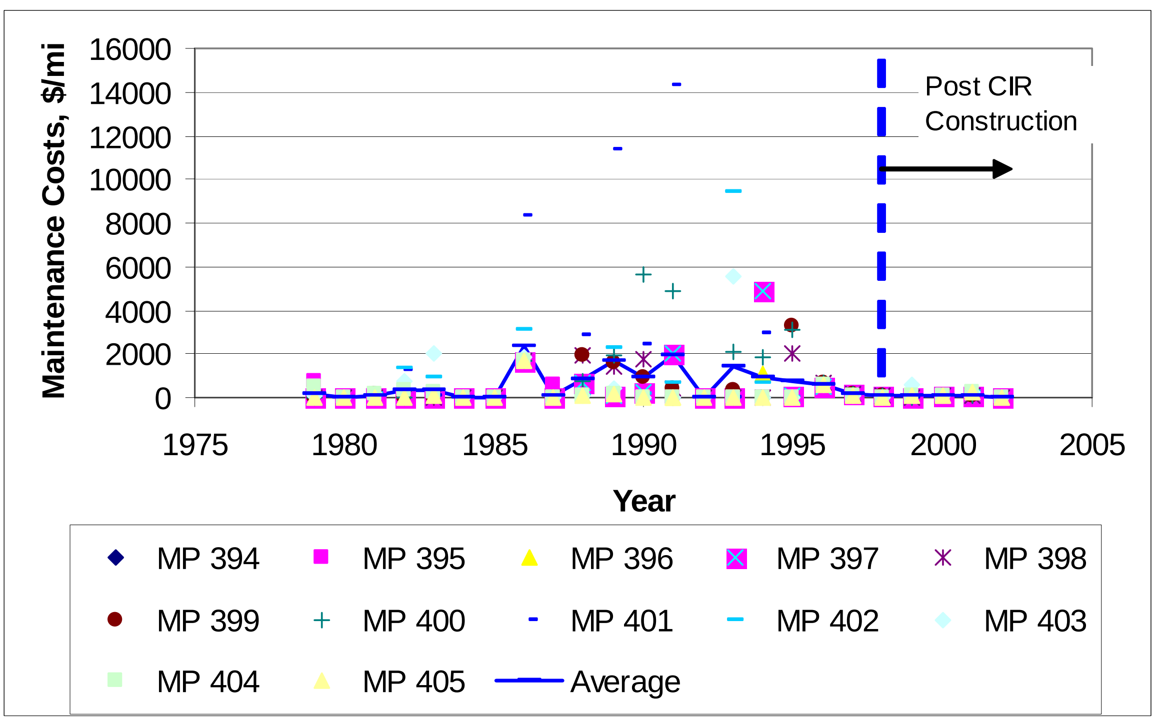

Figure 71. Maintenance costs for CIR Project 11—SR 87 NB (ADOT Project No. STP-244-(4)P).

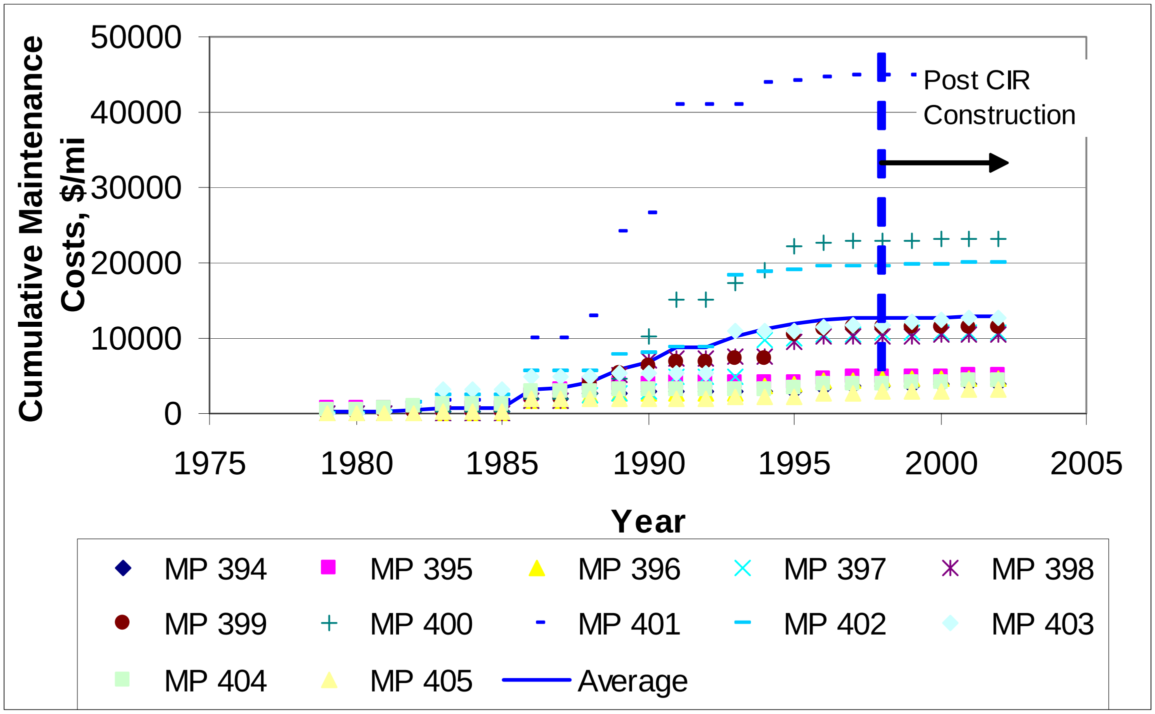

Figure 72. Cumulative maintenance costs for CIR Project 11—SR 87 NB (ADOT Project No. STP-244-(4)P).

Summary of Performance Observations

The following observations can be made from the performance data presented:

- Based on a visual examination of the data, it appears that the condition data in 1998 may have been taken prior to the CIR work being performed. Therefore, data from 1999 onwards will be used for performance evaluation.
- Figure 67 shows that no cracking, of any kind, was observed over the entire reporting period.
- Figure 68 shows that rutting is generally low. Further rutting values decrease slightly over time—an unexpected trend.
- Figure 69 shows that the flushing quantities remain relatively low and stable over time.
- Figure 70 shows that the ride quality improved significantly after the CIR work was performed and the conventional HMA overlay placed. The ride quality is satisfactory over the entire monitoring period.
- Figure 71 suggests that the mile-by-mile maintenance costs are zero after the CIR work was done and the HMA overlay placed. Likewise, the cumulative maintenance costs, shown in figure 72, level off after 1999.

The data presented can be considered short-term (less than 5 years), and they may be insufficient to predict the long-term impact of the rehabilitation activity. However, it appears that the CIR in conjunction with the conventional HMA overlay has performed satisfactorily to date.

CIR PROJECT 12—SR 264 EB, COCONINO COUNTY

Project Overview

This project, constructed under ADOT Project No. ACSTP-060-1(6)P, was a pavement preservation project on SR 264 from MP 340.0 to 359.6 on the Navajo Indian Reservation approximately 22 miles east of Tuba City. The project involved CIR of the existing asphalt concrete to a depth of 2.5 inches, followed by the placement of a 2.0 inch conventional asphalt overlay and a double chip seal coat.

The original roadway was a two-lane, 24 foot-wide section built in 1948. The roadway was widened with a new AC surface in 1960. Several overlays and seal coats were placed through the 1970s, with the last major HMA overlay occurring in 1994.

Field observations on this project in 1996 showed the pavement surface with 20 to 30 percent large to small block cracking progressing into alligator cracking with a fair to poor ride and some rutting. The purpose of this project is to rehabilitate the pavement and improve safety between these mileposts, matching another project (F-060-1-508) built in 1994.

Construction

This project was constructed in June 1999 by Show Low Construction, Inc. CIR was done only for the section of the project between MP 344.0 to 359.6 because the existing AC in the section between MP 340.0 and 344.0 was a "sand mix" and was not considered to be sound enough for CIR. The construction details discussed herein describe the CIR work only. The exact construction sequencing, methods employed, and equipment used during construction of this CIR project are not known. Presented below are excerpts from the specification included as part of the project documents.

The construction work consisted of milling the existing pavement to the depths specified in the plans. The materials were specified to be broken up using a single pass, in-place pulverization technique so that 100 percent of the end product passes the 1.25 inch sieve. The pulverized material and 1.5 percent mixing water (as a percentage of total weight of the aggregate material) were then to be mixed in a self-propelled traveling mixer with adequate metering controls for the addition of binder agent. The allowable moisture content in the aggregate was not allowed to exceed 3 percent by weight of the mixed aggregate materials prior to the addition of the emulsion. The aggregate material was then to be mixed with the emulsified binder agent applied at a pre-specified rate until adequate coating of particles was obtained.

Self-propelled paving machines equipped with automatic controls and screeds were specified for laydown, taking care to prevent segregation. Compaction was not to commence until the emulsion began to break or for 2 hours, whichever was first. Initial rolling was to be accomplished with 30-ton pneumatic rollers, while 12-ton steel-wheeled rollers were used for finish rolling. All compaction equipment was required to meet standard ADOT specifications.

A 2 inch conventional HMA overlay (0.75 inch mix) was placed over the recycled layers along with a double application of chip seal. The chip seal layers were applied to the surface to produce an adequate level of surface texture. Placement techniques were similar to that of the recycled layer.

Materials

The type of emulsion specified was HFE-300P containing polymer modified asphalt, water, 1 percent liquid anti-stripping agent (by weight of emulsion), and emulsifier, blended to specific requirements. An application rate of 1.3 percent was specified as a start point based on extensive laboratory testing, which included density, asphalt content, and strength (tensile strength ratio) testing.

Traffic

Figure 73 presents a plot of ADT versus time for this project, and figure 74 presents plots of AADT and percent trucks versus time.

The general trend in the ADT and AADT data suggests they are increasing. However, the ADT data show considerable variability. The percentage of trucks is low and shows a slight increase over the reporting period. The level of traffic on this roadway can be considered low.

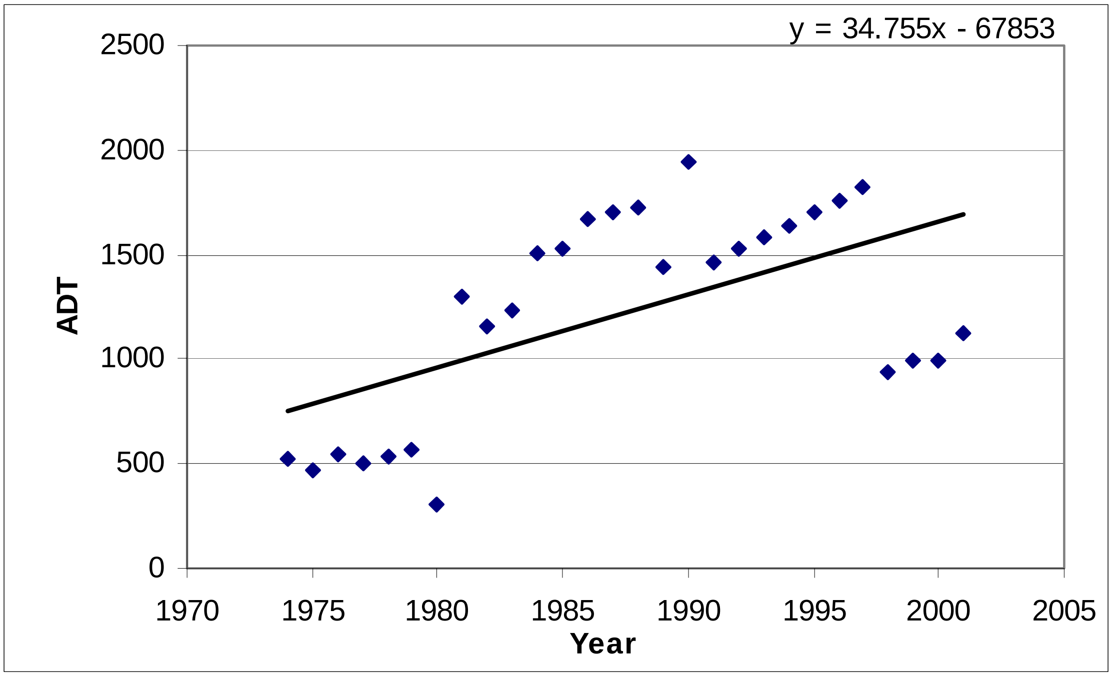

Figure 73. ADT data for CIR Project 12—SR 264 (ADOT Project No. ACSTP-060-1(6)P).

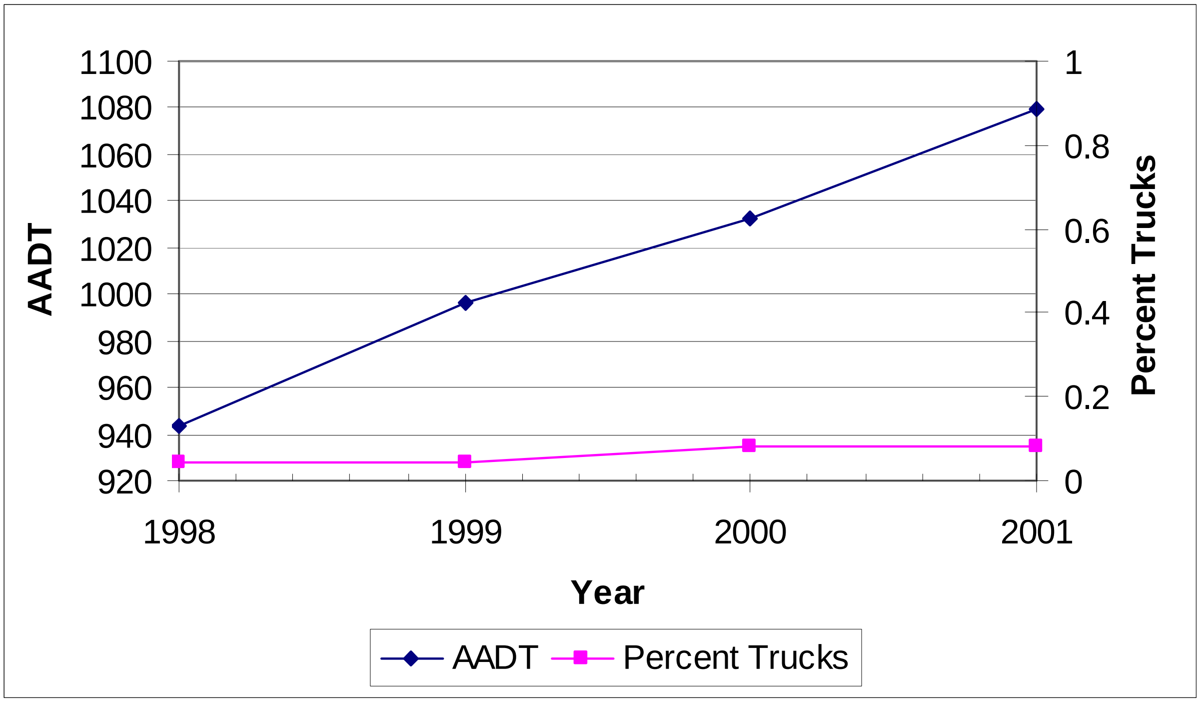

Figure 74. AADT data for CIR Project 12—SR 264 (ADOT Project No. ACSTP-060-1(6)P).

Pavement Performance Observations

Pavement distress data, ride quality data, and maintenance costs were extracted from the pavement management database and examined. The last condition survey on the roadway was performed in October 2002. The following is the extent of information available for each performance category considered in this report:

- Potholes – at the time of last condition survey.
- Cracking – 1999 to 2002.
- Ride – 1999 to 2002.
- Rutting – 1999 to 2002.
- Patching – 1999 to 2002.
- Flushing – 1998 to 2002.
- Maintenance costs – 1980 to 2000.

This project was constructed in 1999, and no significant maintenance or rehabilitation has been reported since construction. Figures 75 through 77 present the cracking, ride quality, and rutting data since 1999. Note that pothole and patching data are not plotted since these quantities were zero over the entire performance reporting period. Figure 78 presents the flushing data. Note that all the distress and ride data are presented on both a mile-by-mile basis and an averaged per-mile basis for the entire project (solid line). Performance-related observations are typically made using the average per-mile quantities as the basis.

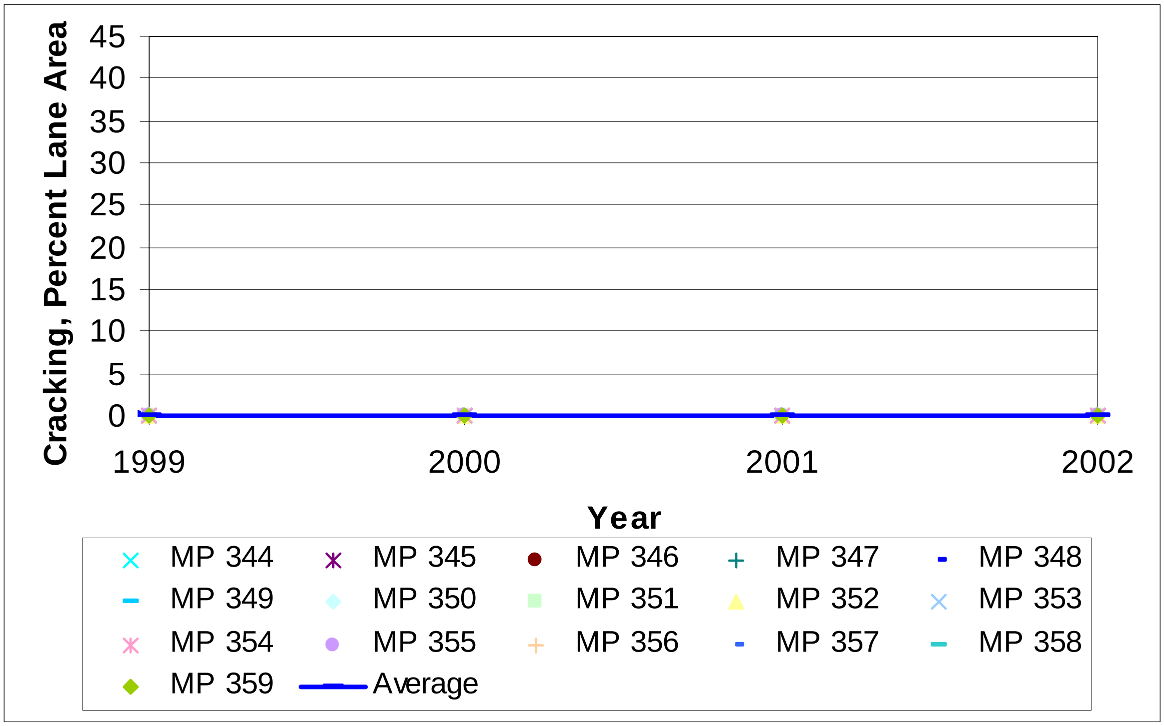

Figure 75. Cracking data for CIR Project 12—SR 264 (ADOT Project No. ACSTP-060-1(6)P).

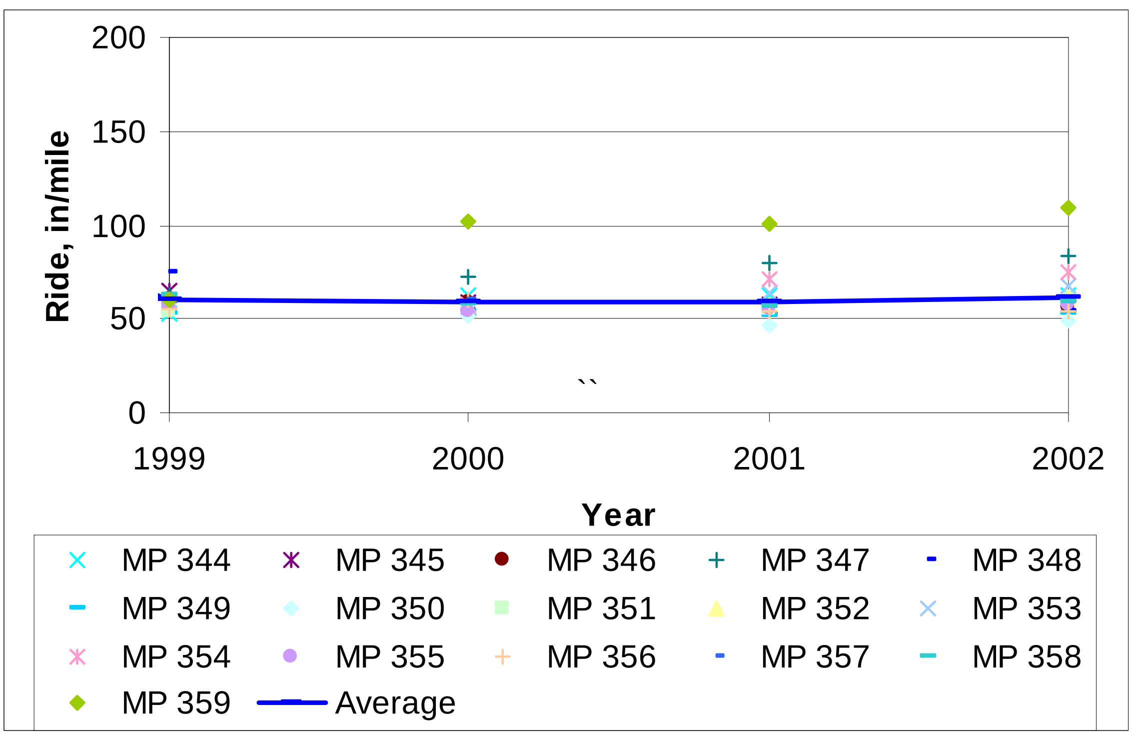

Figure 76. Ride quality information (Mays Ridemeter) for CIR Project 12—SR 264 (ADOT Project No. ACSTP-060-1(6)P).

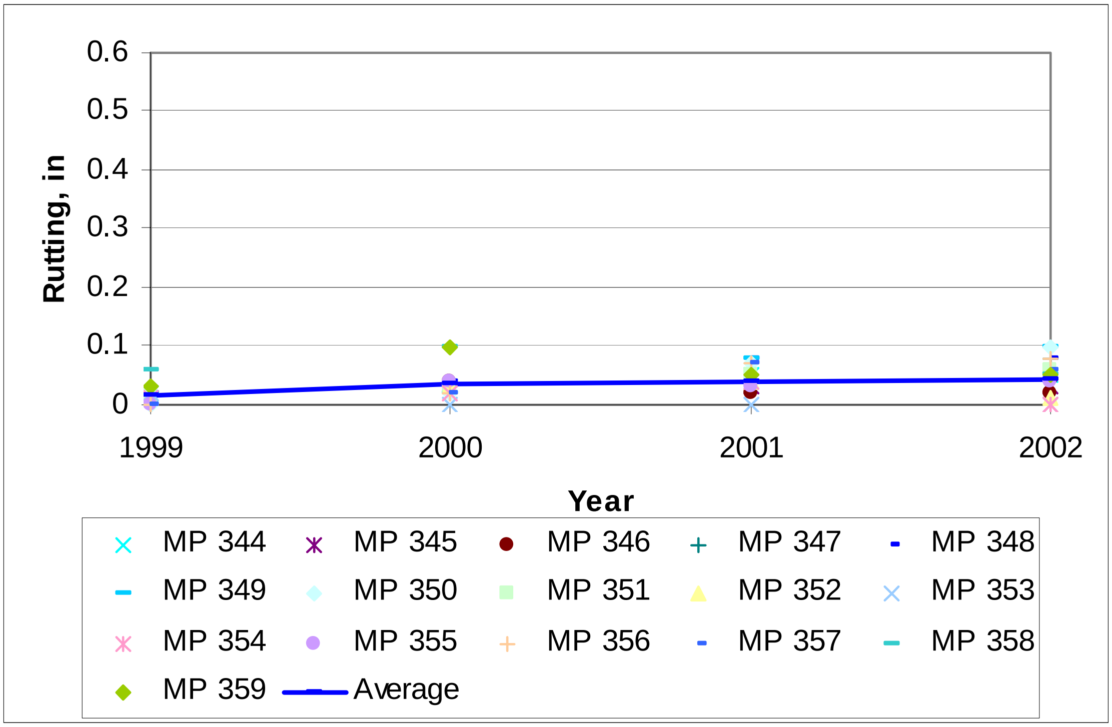

Figure 77. Rutting data for CIR Project 12—SR 264 (ADOT Project No. ACSTP-060-1(6)P).

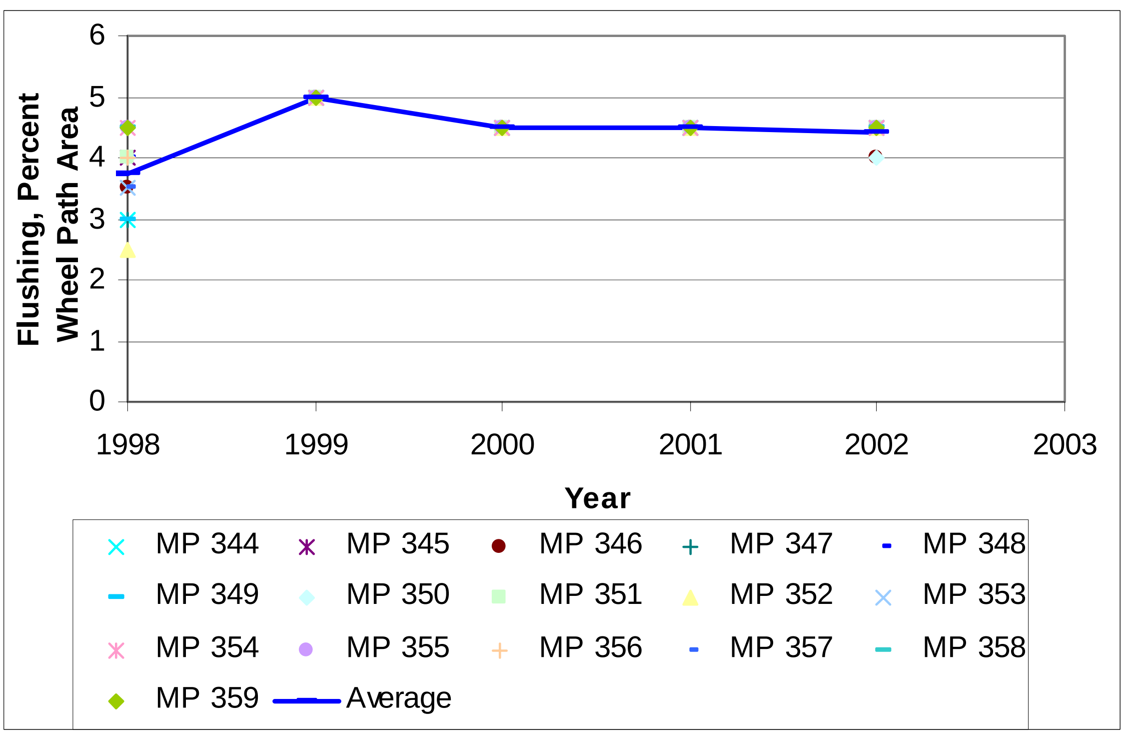

Figure 78. Flushing data for CIR Project 12—SR 264 (ADOT Project No. ACSTP-060-1(6)P).

Figure 79 presents the annual maintenance costs on a mile-by-mile basis and on an averaged per-mile basis for the entire project length. Figure 80 presents the cumulative maintenance costs a on a mile-by-mile basis and on an averaged per-mile basis.

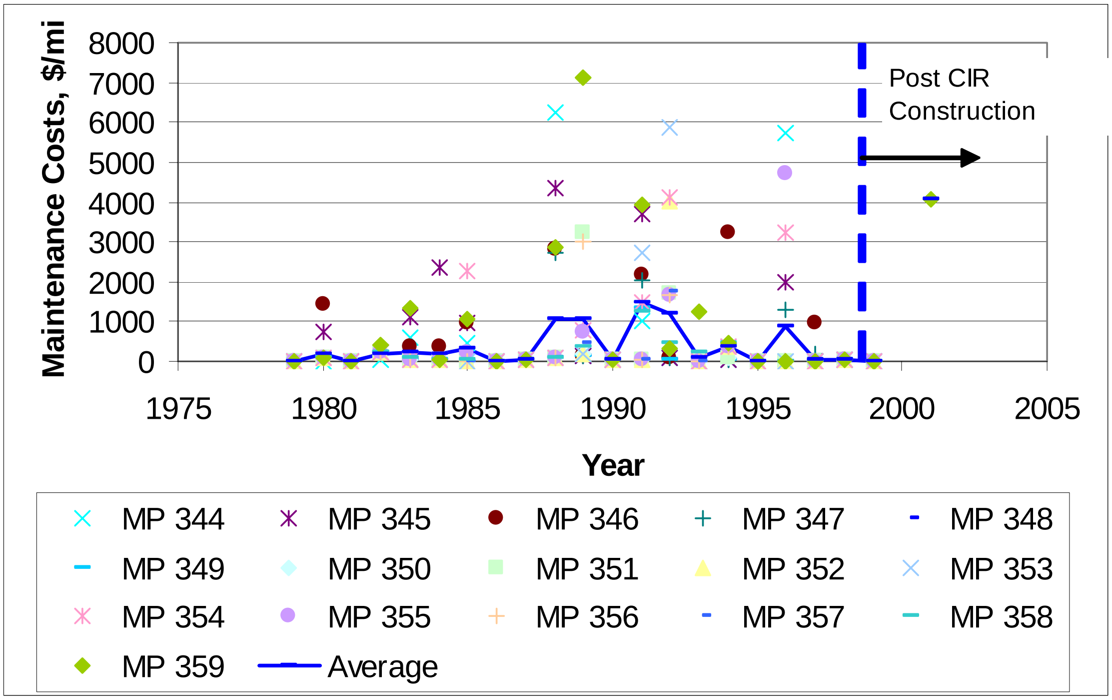

Figure 79. Maintenance costs for CIR Project 12—SR 264
(ADOT Project No. ACSTP-060-1(6)P).

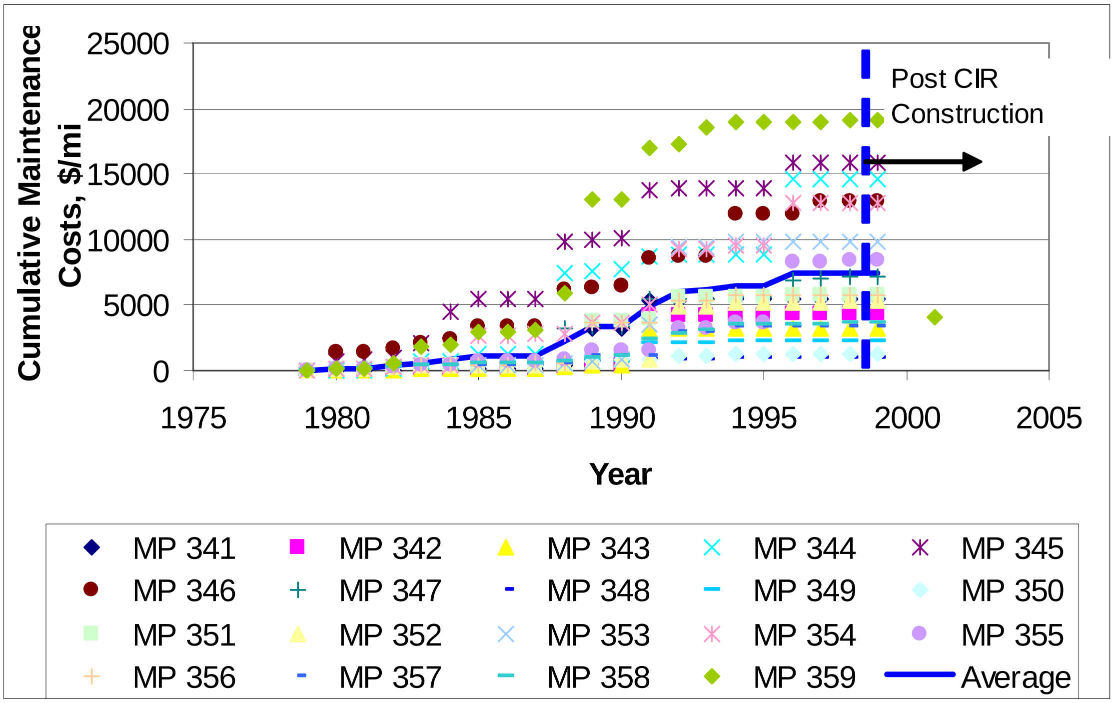

Figure 80. Cumulative maintenance costs for CIR Project 12—SR 264 (ADOT Project No. ACSTP-060-1(6)P).

Summary of Performance Observations

The following observations can be made from the performance data presented:

- Figures 75, 77, and 78 show that the amount of distress present is negligible, with no significant increases since CIR. Also, there are no potholes or maintenance/rehabilitation activities that would result in patching.
- Figure 76 shows that, as expected, the ride quality remained low and unchanged over the reporting period. The low ride values suggest that the data were collected after the CIR work was completed.
- Figure 79 suggests a very significant drop in maintenance costs after CIR. This is in agreement with the distress, ride, and maintenance information presented in figures 75 through 78. The cumulative maintenance costs shown in figure 80 generally increase over time, reaching a sharp peak in 1999; this is perhaps due to the routine maintenance performed to address pavement deterioration prior to CIR. Post-CIR increases in maintenance costs are not significant.

Because of the relatively young age of this project, it was not possible to reach any definitive conclusions. However, initial observations show very little distress, and further monitoring of this project will determine whether this trend will be sustained for a significant period.

CIR PROJECT 13—SR 87 NB, NAVAJO COUNTY

Project Overview

This project is located on SR 87 between MP 368.0 and 385.0 in Navajo County south of the city of Second Mesa. The project was constructed under ADOT Project No. STP-244-(6)P. Construction involved CIR of the existing asphalt layer to a depth of 2.0 inches, followed by the placement of a double chip seal coat (fog seal and chip seal), as recommended.

The roadway section within the limits of this project was originally built in 1965 and consisted of 4 inch select material, 4 inch aggregate base, and a 2 inch HMA surface. The project had two chip seal coats in 1970 and 1976 and a double seal coat application in 1990.

At the time of evaluation in 1997, the original pavement exhibited 15 to 50 percent transverse, block, and isolated alligator cracking. Isolated minor spalling was also noted at crack intersections. Block-type cracks were developing around some of the transverse cracks. Loss of cover material was also noticeable in some areas. However, the serviceability of the existing pavement was considered to be fair, and nondestructive Falling Weight Deflectometer (FWD) testing indicated that, although the pavement was weak, it did not require an overlay because anticipated future traffic was light. As such, the recommended rehabilitation strategy was CIR.

Construction

The project was constructed in summer 1999 by FNF Construction, Inc. (subcontractor Valentine Construction, Inc). The exact construction sequencing, methods employed, and equipment used during construction of this CIR project are not known. Presented below are excerpts from the specification included as part of the project documents.

The construction work consisted of milling the existing pavement to the depths specified in the plans. The materials were specified to be broken up using a single pass, in-place pulverization technique so that 100 percent of the end product passes the 1.25 inch sieve. The pulverized material and 1.5 percent mixing water (as a percentage of total weight of the aggregate material) were then to be mixed in a self-propelled traveling mixer with adequate metering controls for the addition of binder agent. The allowable moisture content in the aggregate was not allowed to exceed 3 percent by weight of the mixed aggregate materials prior to the addition of the emulsion. The aggregate material was then to be mixed with the emulsified binder agent applied at a pre-specified rate until adequate coating of particles was obtained.

Self-propelled paving machines equipped with automatic controls and screeds were specified for laydown, taking care to prevent segregation. Compaction was not to commence until the emulsion began to break or for 2 hours, whichever was first. Initial rolling was to be accomplished with 30-ton pneumatic rollers, while 12-ton steel-wheeled rollers were used for finish rolling. All compaction equipment was required to meet standard ADOT specifications.

Materials

The type of emulsion specified was HFE-300P containing polymer modified asphalt, water, 1 percent liquid anti-stripping agent (by weight of emulsion), and emulsifier, blended to specific requirements. An application rate of 1.3 percent was specified.

Traffic

Figure 81 presents a plot of ADT versus time for this project, and figure 82 presents plots of AADT and percent trucks versus time. It can be observed that the ADT and AADT are increasing over time. The percentage of trucks is low and shows no significant change over the reporting period. Overall, the level of traffic on this roadway can be considered as being low.

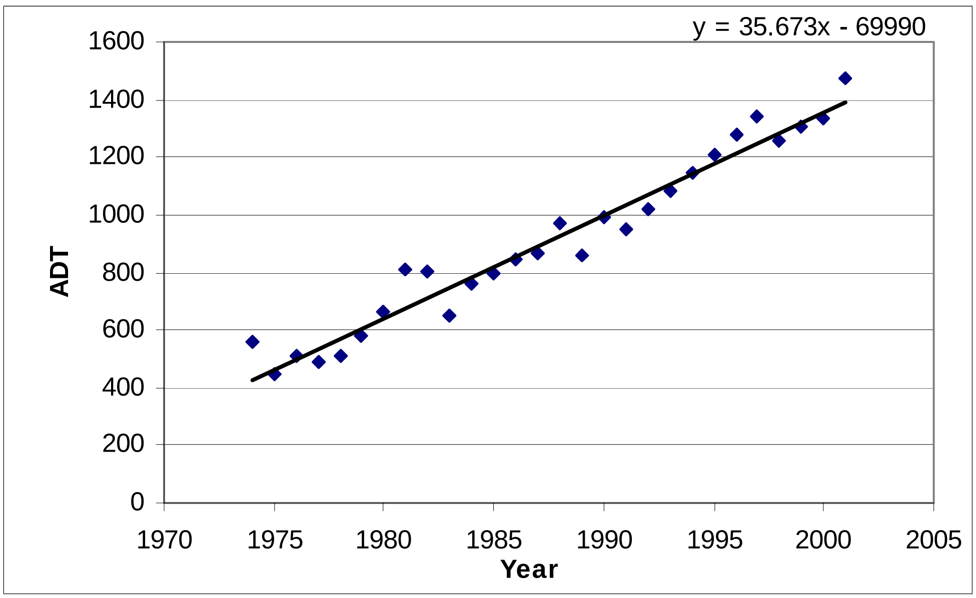

Figure 81. ADT data for CIR Project 13—SR 87 (ADOT Project No. STP-244-(6)P).

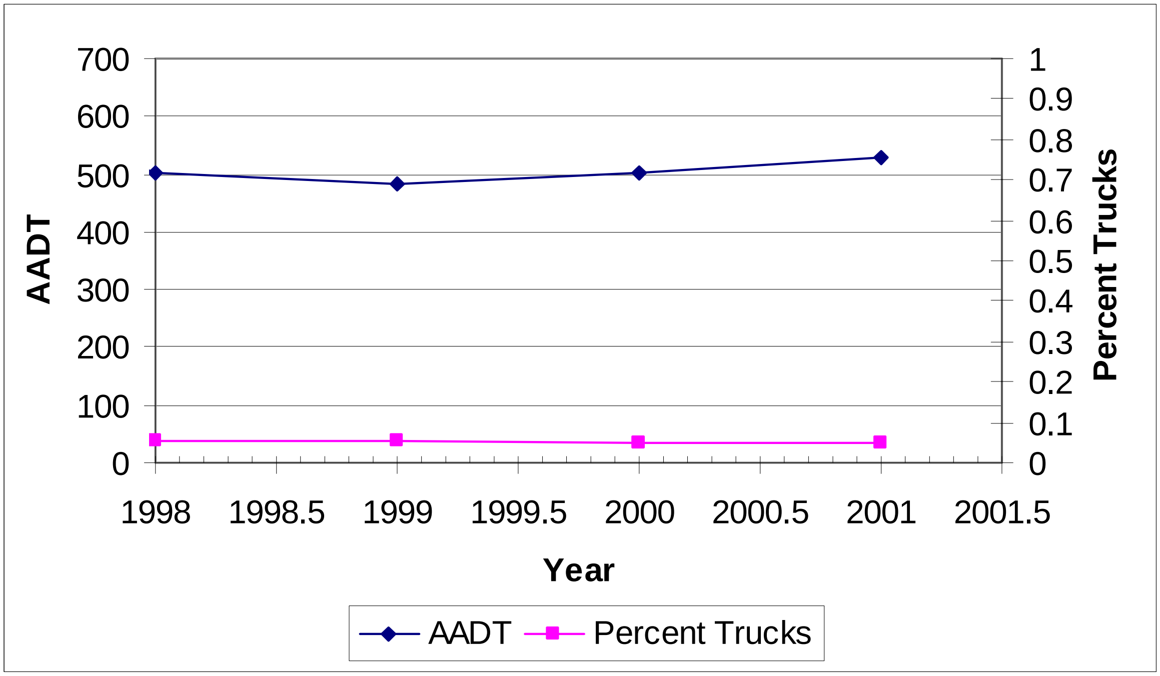

Figure 82. AADT data for CIR Project 13—SR 87 (ADOT Project No. STP-244-(6)P).

Pavement Performance Observations

Pavement distress data, ride quality data, and maintenance costs were extracted from the pavement management database and examined. The last condition survey on the roadway was performed in August 2002. The following is the extent of information available for each performance category considered in this report:

- Potholes – at the time of last condition survey.
- Cracking – 2000 to 2002.
- Ride – 2000 to 2002.
- Rutting – 2000 to 2002.
- Patching – 2000 to 2002.
- Flushing – 2000 to 2002.
- Maintenance costs – 1979 to 2000.

This project was constructed in 1999, and no significant maintenance or rehabilitation has been reported since construction. Figures 83 through 85 present the cracking, ride quality, and rutting data since the project was constructed in 1999. Note that pothole and patching data are not plotted since these quantities were zero over the entire performance reporting period.

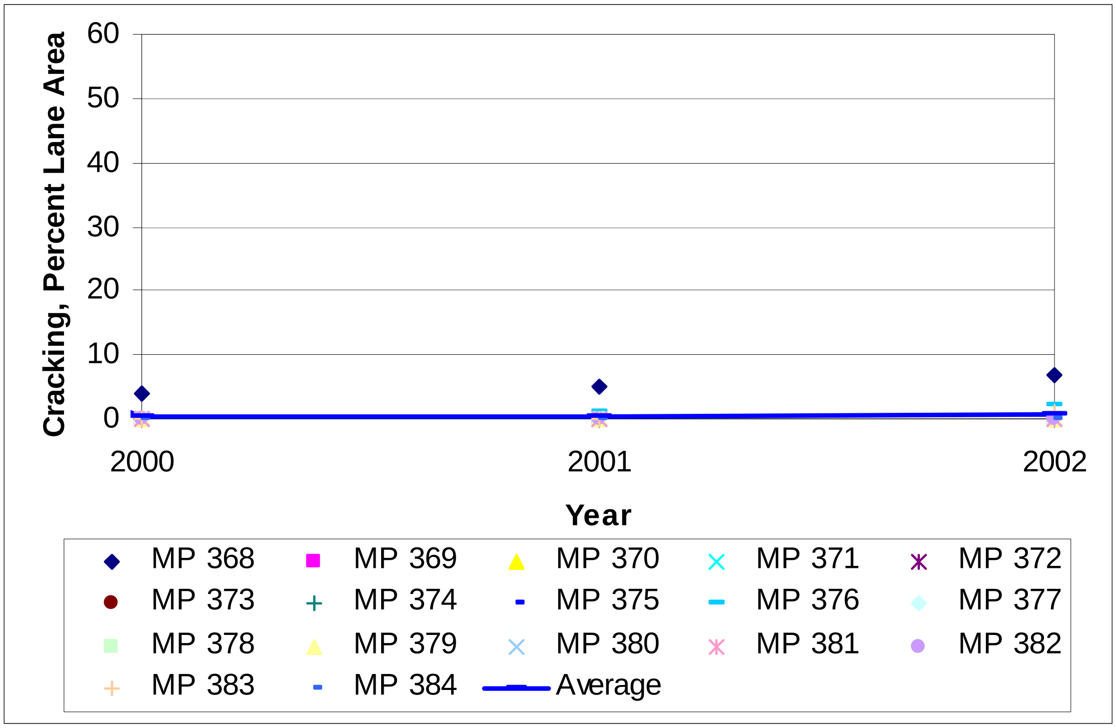

Figure 83. Cracking data for CIR Project 13—SR 87 (ADOT Project No. STP-244-(6)P).

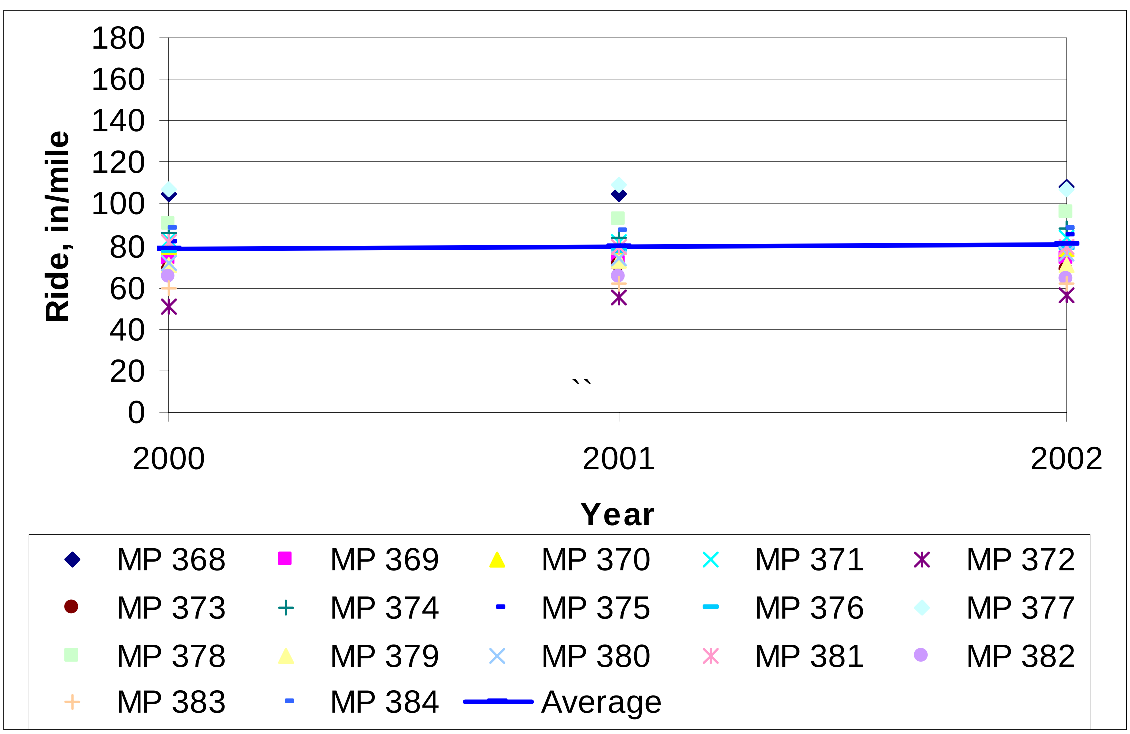

Figure 84. Ride quality information (Mays Ridemeter) for CIR Project 13—SR 87 (ADOT Project No. STP-244-(6)P).

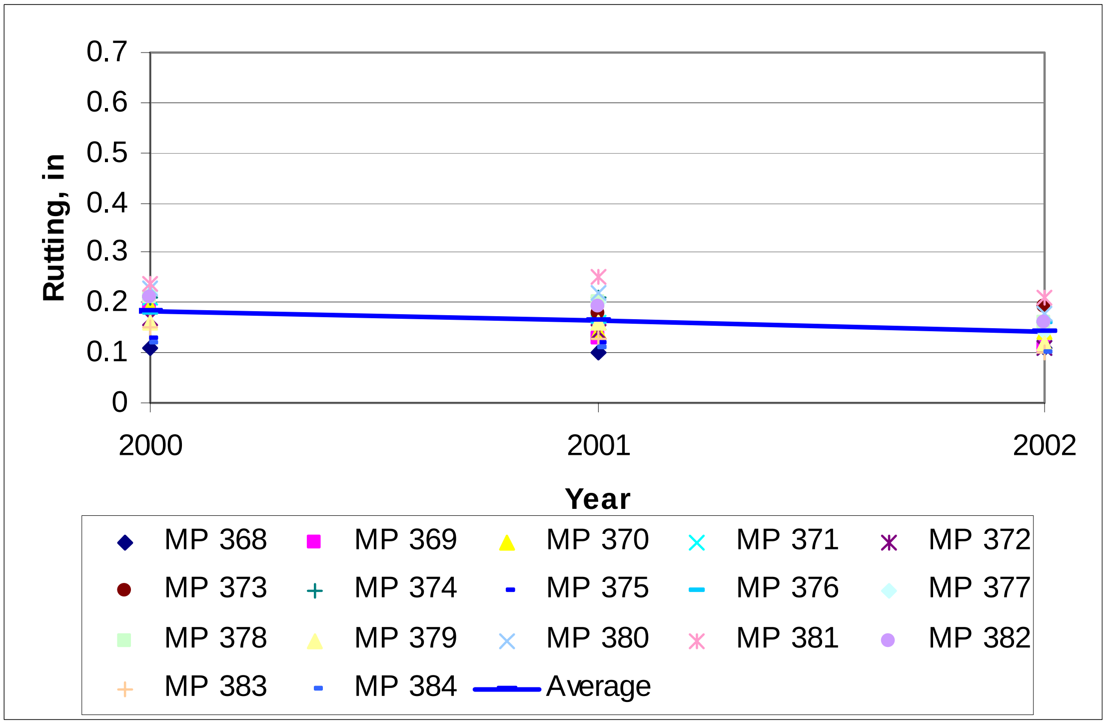

Figure 85. Rutting data for CIR Project 13—SR 87 (ADOT Project No. STP-244-(6)P).

Figure 86 presents the flushing data. Note that all the distress and ride data are presented on both a mile-by-mile basis and an averaged per-mile basis for the entire project (solid line). Performance-related observations are typically made using the average per-mile quantities as the basis. Figure 87 presents the annual maintenance costs on a mile-by-mile basis as well as on an averaged per-mile basis for the entire project length. Figure 88 presents the cumulative maintenance costs on a mile-by-mile basis as well as on an averaged per-mile basis.

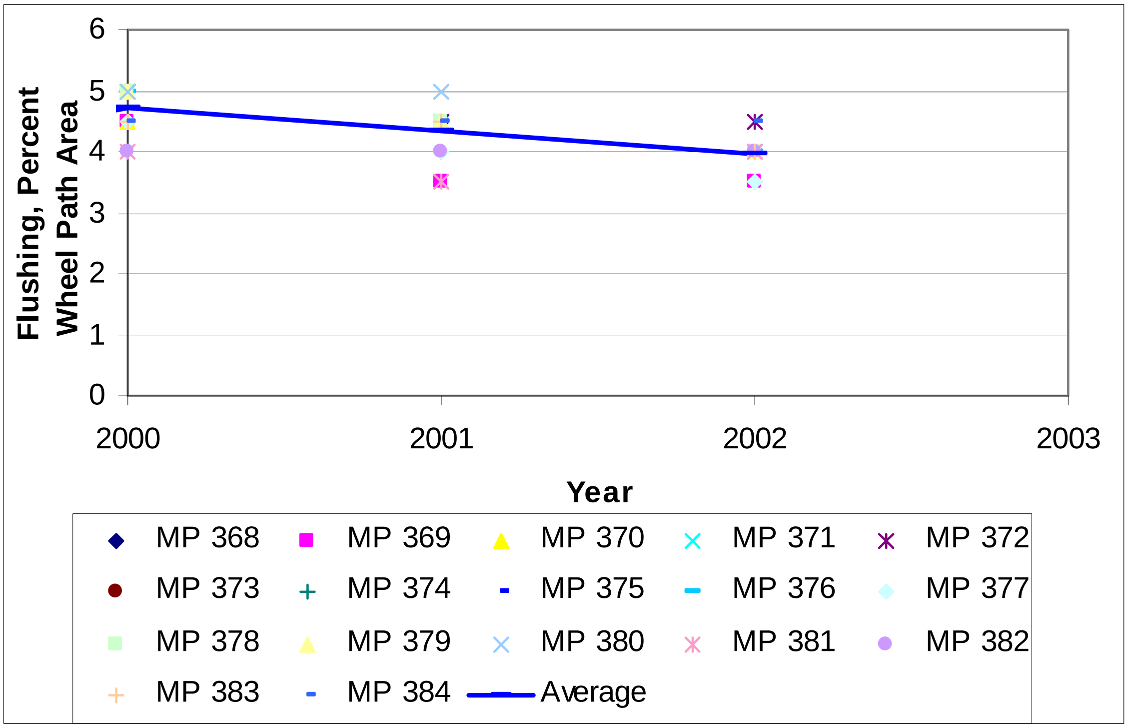

Figure 86. Flushing data for CIR Project 13—SR 87 (ADOT Project No. STP-244-(6)P).

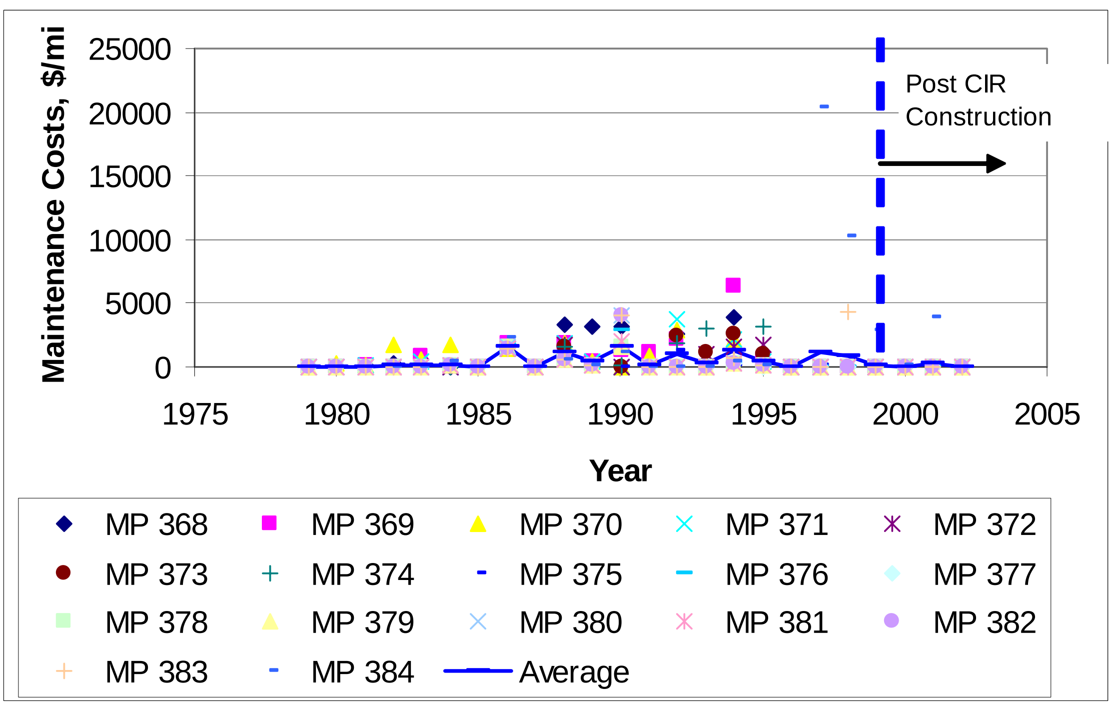

Figure 87. Maintenance costs for CIR Project 13—SR 87 (ADOT Project No. STP-244-(6)P).

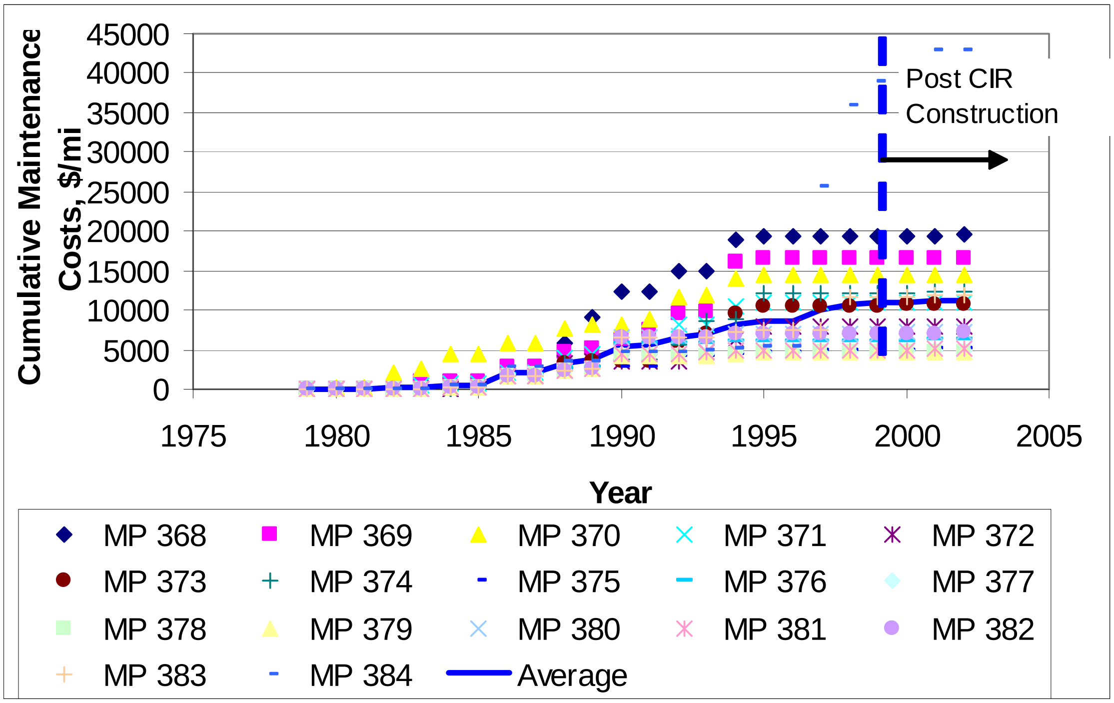

Figure 88. Cumulative maintenance costs for CIR Project 13—SR 87 (ADOT Project No. STP-244-(6)P).

Summary of Performance Observations

The following observations can be made from the performance data presented:

- Figures 83, 85, and 86 show no significant increases in distress, and the amount of distress present is negligible. In fact, the amount of rutting and flushing actually decreases with time. Also, there are no potholes or maintenance/rehabilitation activities that would result in patching being present.
- Figure 84 shows no significant change in ride quality since the CIR construction project.
- Figure 87 shows a considerable drop in maintenance cost after CIR. Figures 83 through 86 also show that the distress data are low to non-existent and the ride is smooth, and have not required any maintenance.

Because of the relatively young age of this project, it was not possible to reach any definitive conclusions. However, initial observations show very little distress, and further monitoring of this project will determine whether this trend will be sustained for a significant period.

CIR PROJECT 14—SR 87, NAVAJO COUNTY

Project Overview

This project, located on SR 87 between MP 385.0 and 393.5, was constructed under ADOT Project No. STP-244-(5)P. It involved CIR of the existing asphalt pavement to a depth of 2.5 inches, followed by the placement of a 2 inch conventional HMA overlay and a chip seal coat.

The roadway section within the limits of this project was originally constructed in 1960 as a "grade and drain" section consisting of 5 inch select material and 4 inch aggregate base. A 2 inch plant-mixed HMA layer was placed shortly after completion of the base and finished with a seal coat. Although the roadway was seal coated extensively in the 1990s, the original construction endured over 30 years without major improvement.

Visual inspection of the roadway in 1994, prior to rehabilitation, revealed significant amounts of cracking, patching, and rutting. The amount of cracking in 1994 ranged from 4 to 75 percent along the project and averaged 43 percent. Rutting measurements made in 1994 averaged 7 millimeters over the entire project; thus, rutting was not considered a serious problem. Ride values ranged from 84 to 128 inches/mile and averaged 110 inches/mile over the entire project. An average of 110 inches/mile was deemed "tolerable." The extent of patching was rated as moderate and averaged 10 percent over the project. However, field observations revealed a much greater percentage of patching along specific portions of the project. The overall condition of the pavement section was determined to be unsatisfactory, which is why rehabilitation was proposed.

Construction

This project was constructed in summer 1999 by FNF Construction, Inc. (subcontractor Valentine Construction, Inc.). The construction details discussed herein pertain to the CIR work only. The exact construction sequencing, methods employed, and equipment used during construction of this CIR project are not known. Presented below are excerpts from the specification included as part of the project documents.

The construction work consisted of milling the existing pavement to the depths specified in the plans. The materials were specified to be broken up using a single pass, in-place pulverization technique so that 100 percent of the end product passes the 1.25 inch sieve. The pulverized material and 1.5 percent mixing water (as a percentage of total weight of the aggregate material) were then to be mixed in a self-propelled traveling mixer with adequate metering controls for the addition of binder agent. The allowable moisture content in the aggregate was not allowed to exceed 3 percent by weight of the mixed aggregate materials prior to the addition of the emulsion. The aggregate material was then to be mixed with the emulsified binder agent applied at a pre-specified rate until adequate coating of particles was obtained.

Self-propelled paving machines equipped with automatic controls and screeds were specified for laydown, taking care to prevent segregation. Compaction was not to commence until the emulsion began to break or for 2 hours, whichever was first. Initial rolling was to be accomplished with 30-ton pneumatic rollers, while 12-ton steel-wheeled rollers were used for finish rolling. All compaction equipment was required to meet standard ADOT specifications.

A 2 inch conventional HMA overlay (0.75 inch mix) was placed over the recycled layers along with a double application of chip seal. The chip seal layers were applied to the surface to produce an adequate level of surface texture. Placement techniques were similar to that of the recycled layer.

Materials

The type of emulsion specified was HFE-300P containing polymer modified asphalt, water, 1 percent liquid anti-stripping agent (by weight of emulsion), and emulsifier, blended to specific requirements. The application rate is of the emulsion was not reported.

Traffic

Figure 89 presents a plot of ADT versus time for this project, and figure 90 presents plots of AADT and percent trucks versus time.

The ADT is increasing over time; however, the data show considerable variability. The AADT remained constant over the reporting period. The percentage of trucks is low and shows no significant change over the reporting period. The level of traffic on this roadway can be considered low.

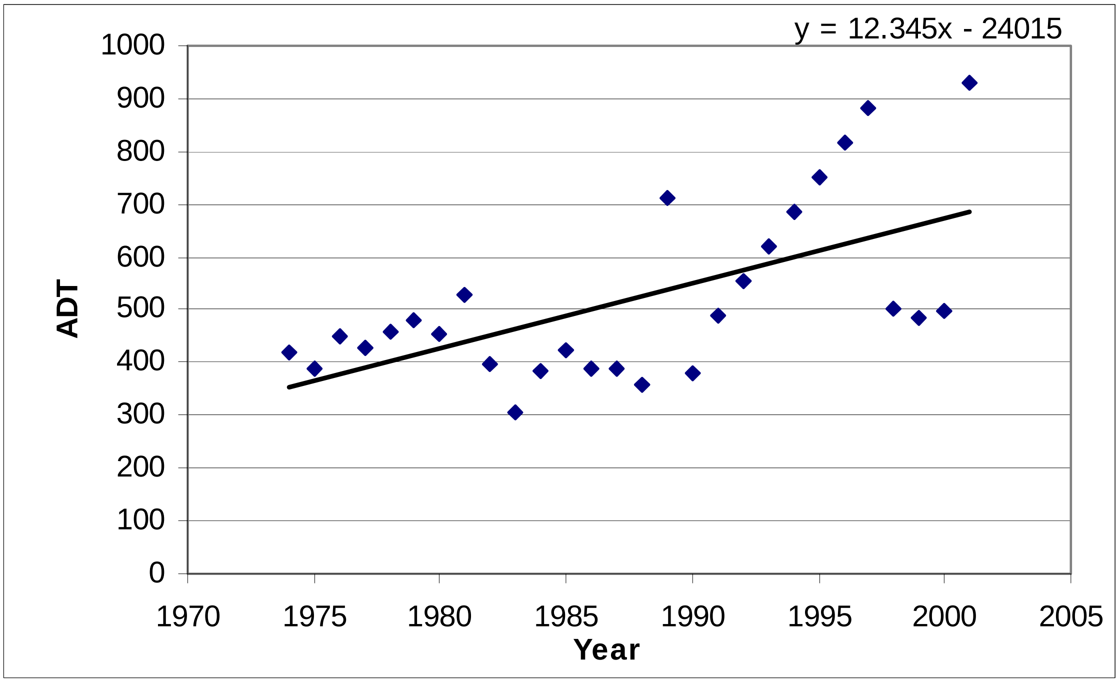

Figure 89. ADT data for CIR Project 14—SR 87 (ADOT Project No. STP-244-(5)P).

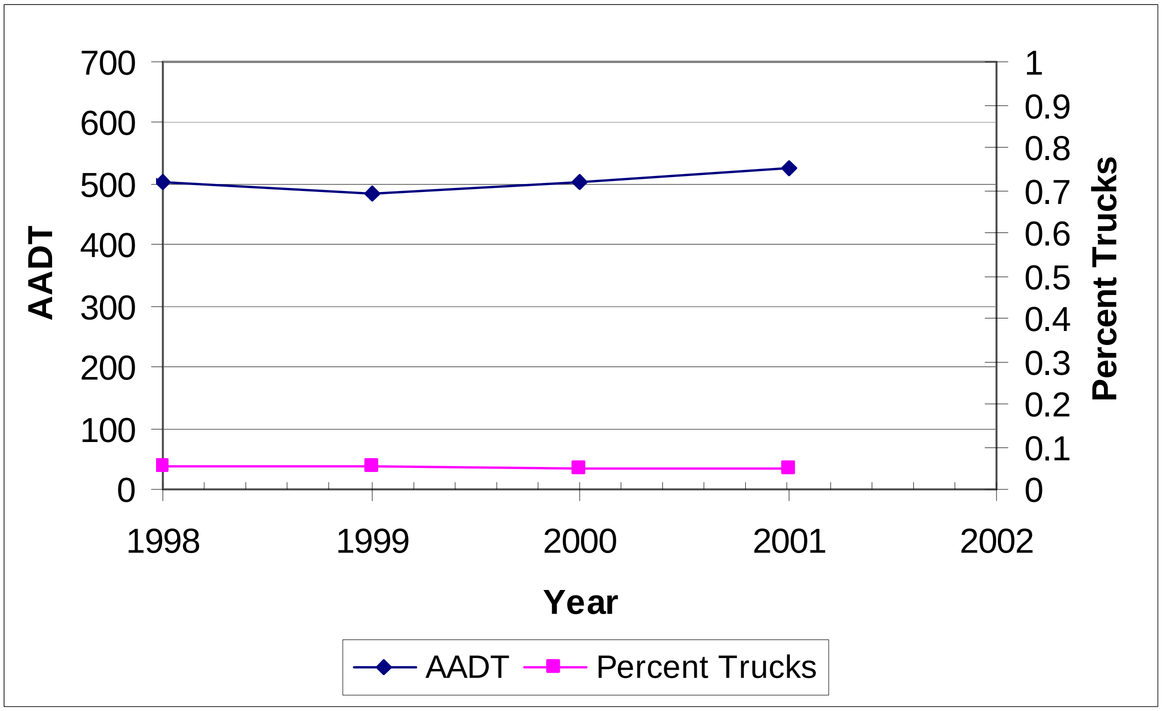

Figure 90. AADT data for CIR Project 14—SR 87 (ADOT Project No. STP-244-(5)P).

Pavement Performance Observations

Pavement distress data, ride quality data, and maintenance costs were extracted from the pavement management database and examined. The last condition survey on the roadway was performed in August 2002. The following is the extent of information available for each performance category considered in this report:

- Potholes – at the time of last condition survey.
- Cracking – 2000 to 2002.
- Ride – 2000 to 2002.
- Rutting – 2000 to 2002.
- Patching – 2000 to 2002.
- Flushing – 2000 to 2002.
- Maintenance costs – 1979 to 2000.

This project was constructed in 1999, and no significant maintenance or rehabilitation has been reported since construction. Figures 91 through 93 present the cracking, ride quality, and rutting data since CIR project was constructed in 1999. Note that pothole and patching data are not plotted since these quantities were zero over the entire performance reporting period. Figure 94 presents the flushing data. Note that all the distress and ride data are presented on both a mile-by-mile basis and an averaged per-mile basis for the entire project (solid line). Performance-related observations are typically made using the average per-mile quantities as the basis.

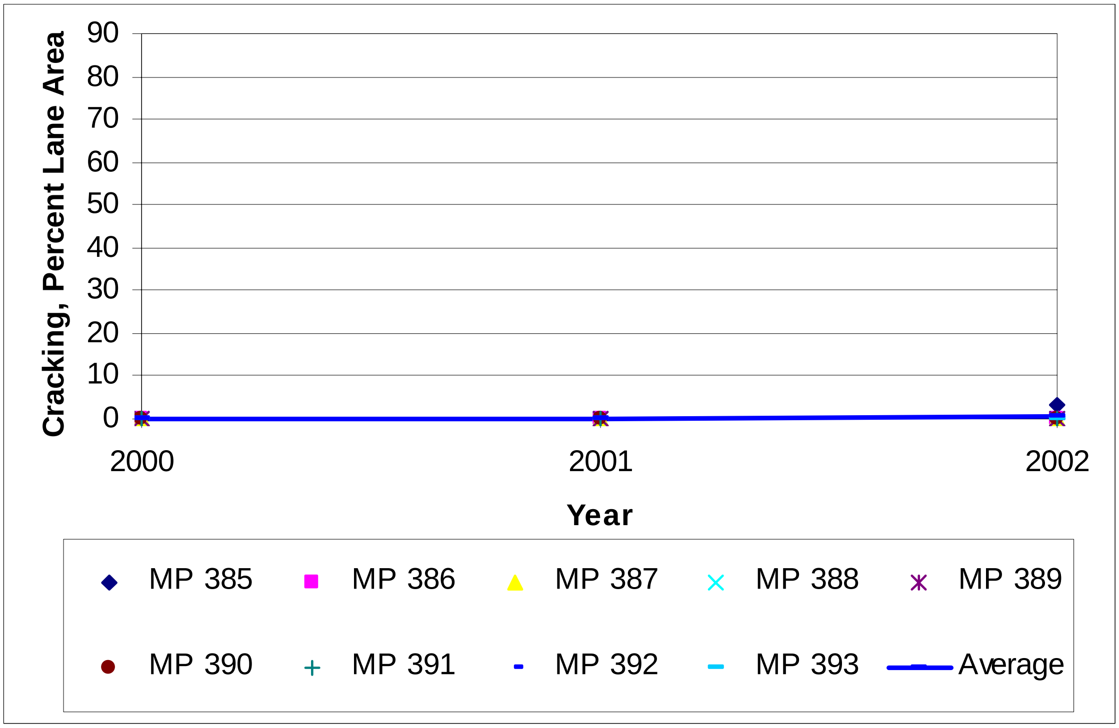

Figure 91. Cracking data for CIR Project 14—SR 87 (ADOT Project No. STP-244-(5)P).

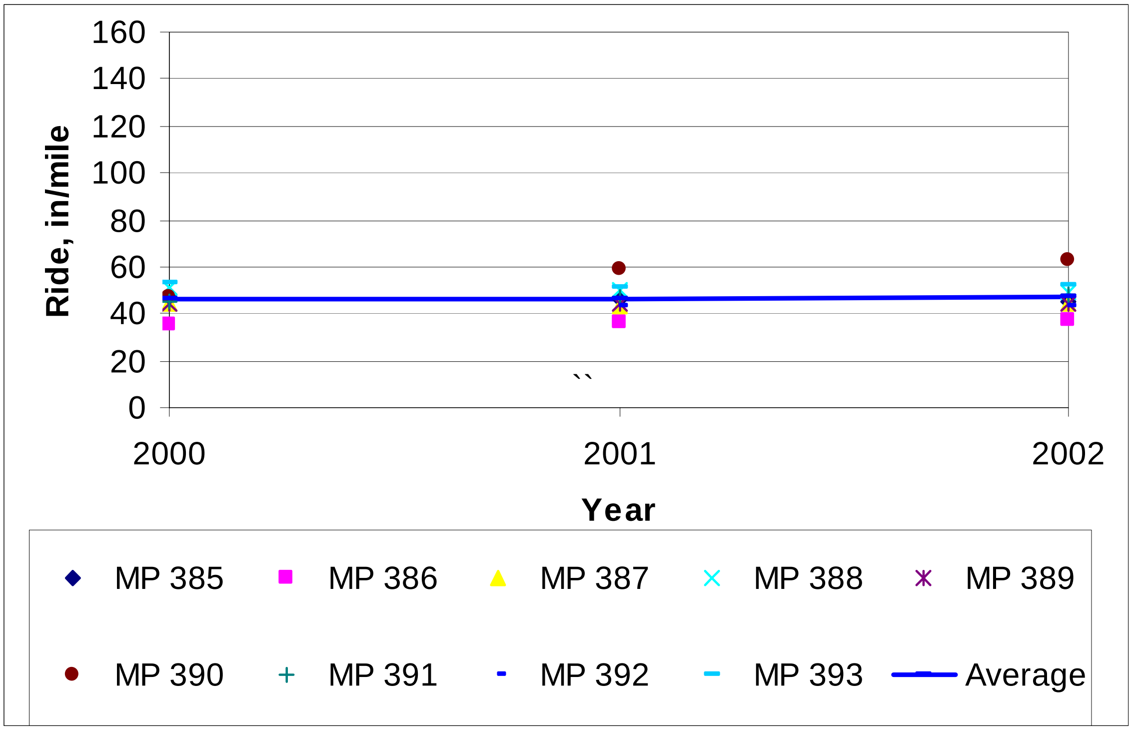

Figure 92. Ride quality information (Mays Ridemeter) for CIR Project 14—SR 87 (ADOT Project No. STP-244-(5)P).

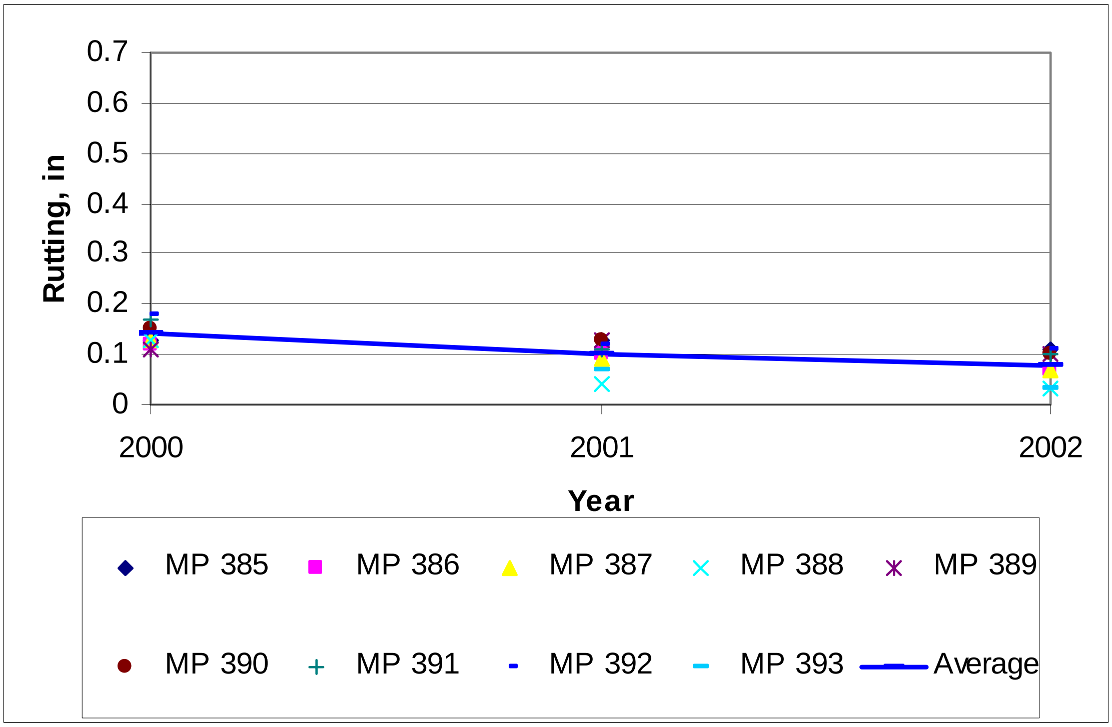

Figure 93. Rutting data for CIR Project 14—SR 87 (ADOT Project No. STP-244-(5)P).

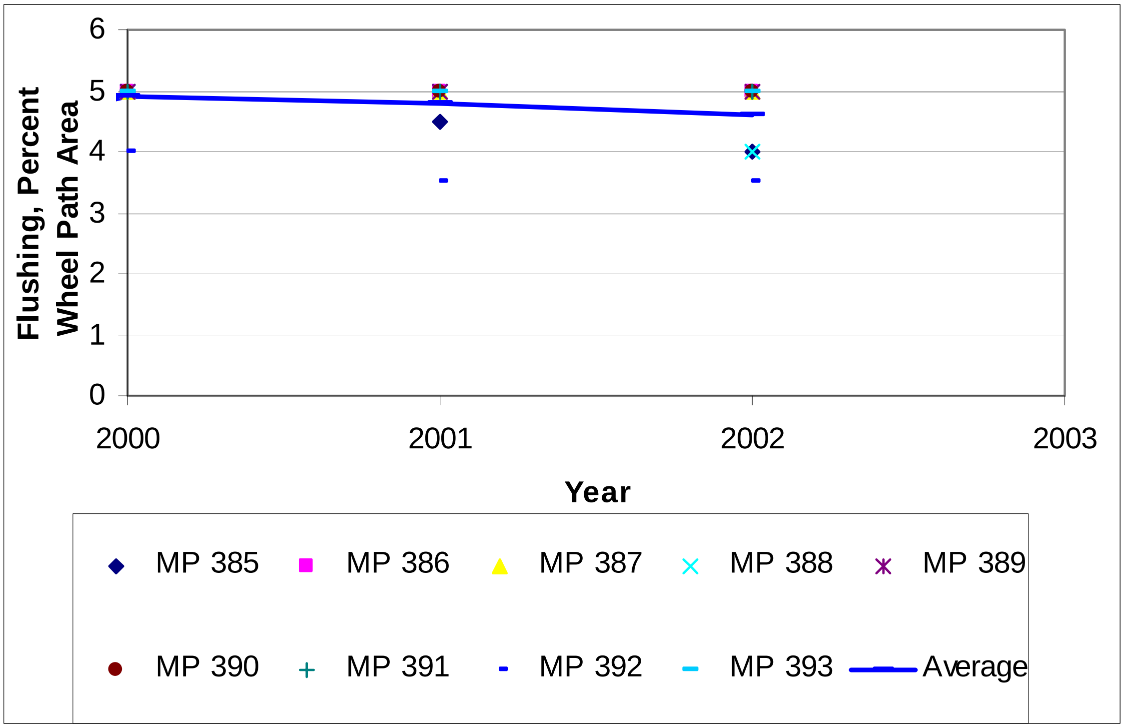

Figure 94. Flushing data for CIR Project 14—SR 87 (ADOT Project No. STP-244-(5)P).

Figure 95 presents the annual maintenance costs on a mile-by-mile basis and on an averaged per-mile basis for the entire project length. Figure 96 presents the cumulative maintenance costs a on a mile-by-mile basis and on an averaged per-mile basis.

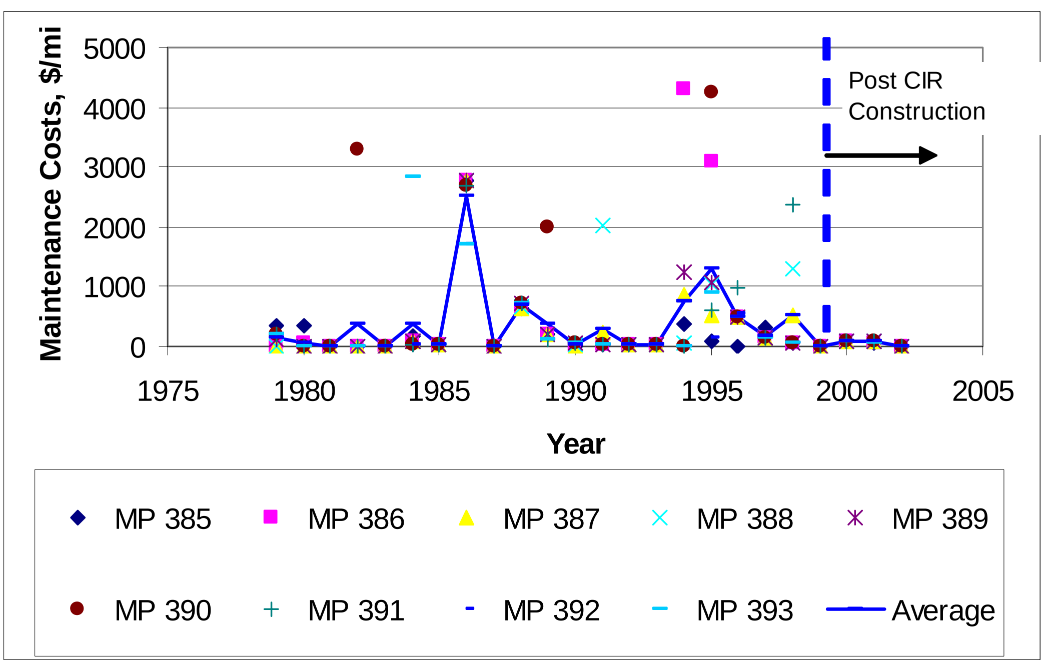

Figure 95. Maintenance costs for CIR Project 14—SR 87 (ADOT Project No. STP-244-(5)P).

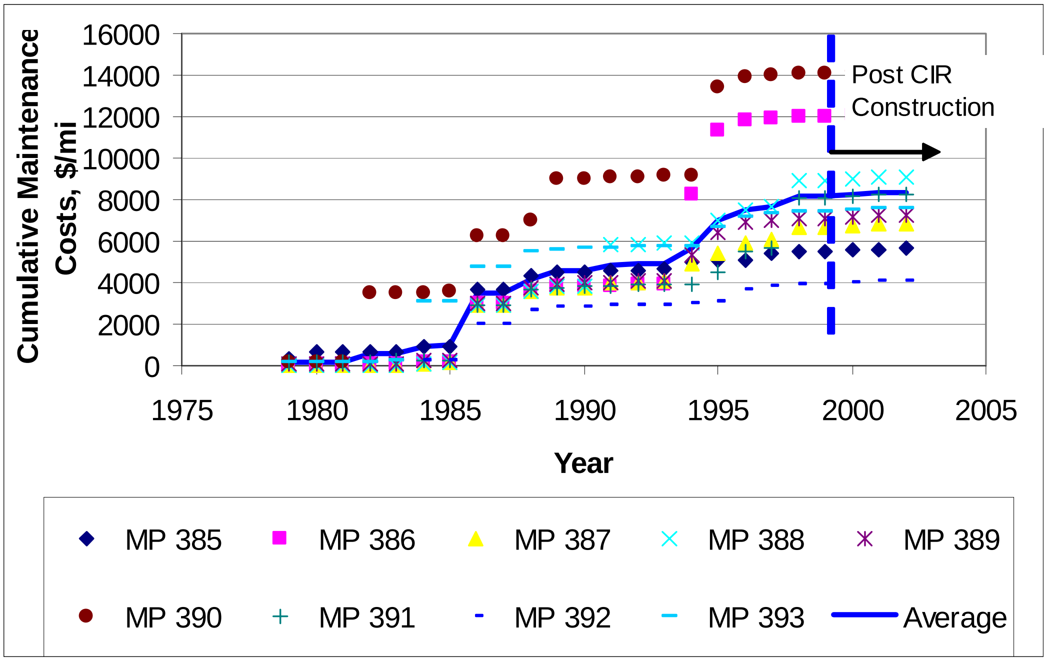

Figure 96. Cumulative maintenance costs for CIR Project 14—SR 87 (ADOT Project No. STP-244-(5)P).

Summary of Performance Observations

The following observations can be made from the performance data presented:

- Figures 91, 93, and 94 show no significant changes in distress, and the amount of distress present is negligible. Also, there are no potholes or maintenance/rehabilitation activities that would result in patching being present.
- Figure 92 shows no significant change in ride quality after CIR.
- Figure 95 suggests a very significant drop in maintenance cost after CIR. This is in agreement with the distress, ride, and maintenance information presented in figures 91 through 94. The cumulative maintenance costs shown in figure 96 generally increase over time, reaching a sharp peak value in 1999, which is perhaps due to the routine maintenance action taken to address pavement deterioration prior to CIR. The post-CIR increases in maintenance cost are not significant.

Because of the relatively young age of this project, it was not possible to reach any definitive conclusions. However, initial observations show very little distress, and further monitoring of this project will determine whether this trend will be sustained for a significant period.

CIR PROJECT 15—US 191, APACHE COUNTY

Project Overview

This project, located on US 191 between MP 468.0 and 482.0 in Apache County, was constructed under ADOT Project No. STP-077-1(10)P. The project involved CIR of the existing asphalt pavement to a depth of 3.0 inches, followed by the placement of a 2 inch conventional HMA asphalt overlay and a double seal coat. The purpose of the project was to rehabilitate the pavement and improve safety.

The roadway section within the limits of this project was originally constructed in the 1950s with a 2 inch bituminous surfacing. Several seal coats were applied in the 1970s. The last major reported rehabilitation took place in 1979 in the form of a 2 inch HMA overlay and a seal coat.

At the time of condition evaluation in 1996, the project roadway revealed 0 to 40 percent large to small block and alligator cracking with a fair to poor ride and some rutting. It was recommended that cold recycling the existing pavement followed by the placement of a conventional AC overlay would restore the existing pavement rideability and structural integrity.

Construction

The project was constructed in summer 2001 by FNF Construction, Inc. The construction details discussed herein pertain to the CIR work only. The exact construction sequencing, methods employed, and equipment used during construction of this CIR project are not known. Presented below are excerpts from the specification included as part of the project documents.

The construction work consisted of milling the existing pavement to the depths specified in the plans. The materials were specified to be broken up using a single pass, in-place pulverization technique so that 100 percent of the end product passes the 1.25 inch sieve. The pulverized material and 1.5 percent mixing water (as a percentage of total weight of the aggregate material) were then to be mixed in a self-propelled traveling mixer with adequate metering controls for the addition of binder agent. The allowable moisture content in the aggregate was not allowed to exceed 3 percent by weight of the mixed aggregate materials prior to the addition of the emulsion. The aggregate material was then to be mixed with the emulsified binder agent applied at a pre-specified rate until adequate coating of particles was obtained.

Self-propelled paving machines equipped with automatic controls and screeds were specified for laydown, taking care to prevent segregation. Compaction was not to commence until the emulsion began to break or for 2 hours, whichever was first. Initial rolling was to be accomplished with 30-ton pneumatic rollers, while 12-ton steel-wheeled rollers were used for finish rolling. All compaction equipment was required to meet standard ADOT specifications.

A 2 inch conventional HMA overlay was placed over the recycled layers along with a double application of chip seal. The chip seal layers were applied to the surface to produce an adequate level of surface texture. Placement techniques were similar to that of the recycled layer described.

Materials

The type of emulsion specified was HFE-300P containing polymer modified asphalt, water, 1 percent liquid anti-stripping agent (by weight of emulsion), and emulsifier, blended to specific requirements. An application rate of 1.6 percent was specified for between MP 468.0 and 470.0 and 1.3 percent for between MP 470.0 and 482.0 based on extensive laboratory testing by ADOT, which included density, asphalt content, and strength (tensile strength ratio) testing.

Traffic

Figure 97 presents a plot of ADT versus time for this project, and figures 98(a) and 98(b) present plots of AADT and percent trucks versus time.

The ADT is increasing over time; however, the data show considerable variability. The AADT between MP 468 and 472 is also increasing significantly, whereas the AADT between MP 472 and 482 remained constant. Overall, the percentage of trucks is low and shows no significant change over the reporting period. The level of traffic on this roadway can be considered low.

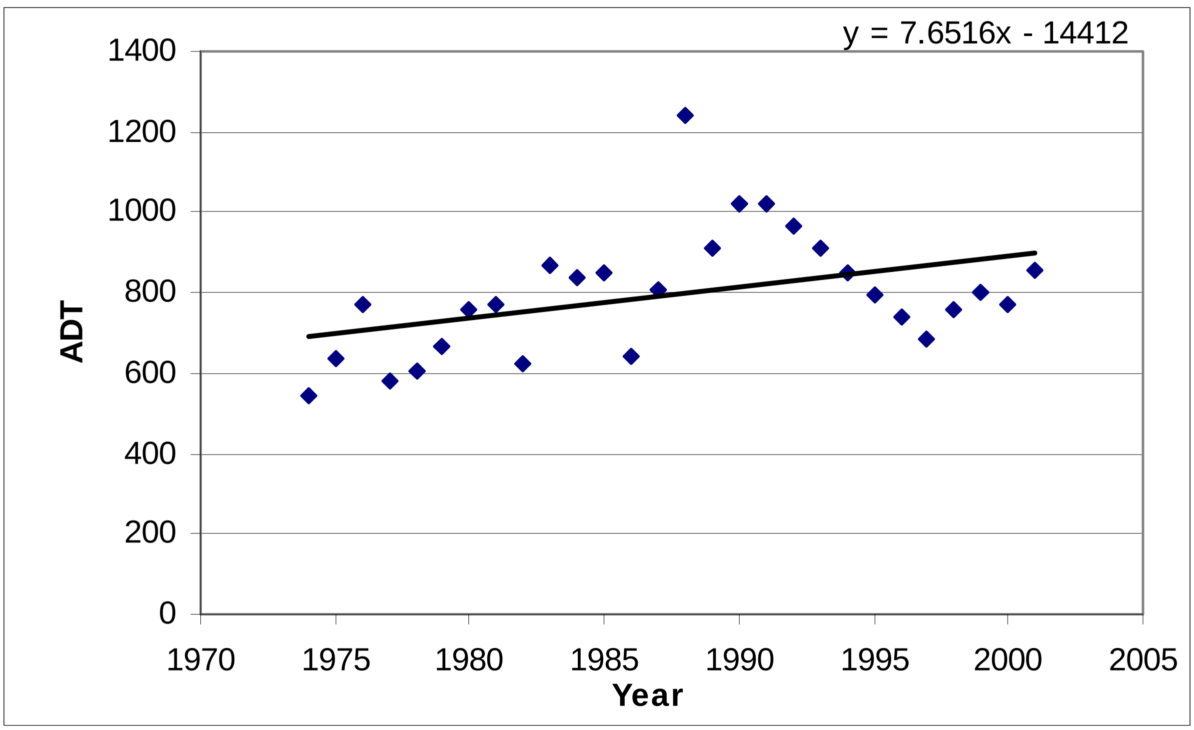

Figure 97. ADT data for CIR Project 15—US 191 (ADOT Project No. STP-077-1(10)P).

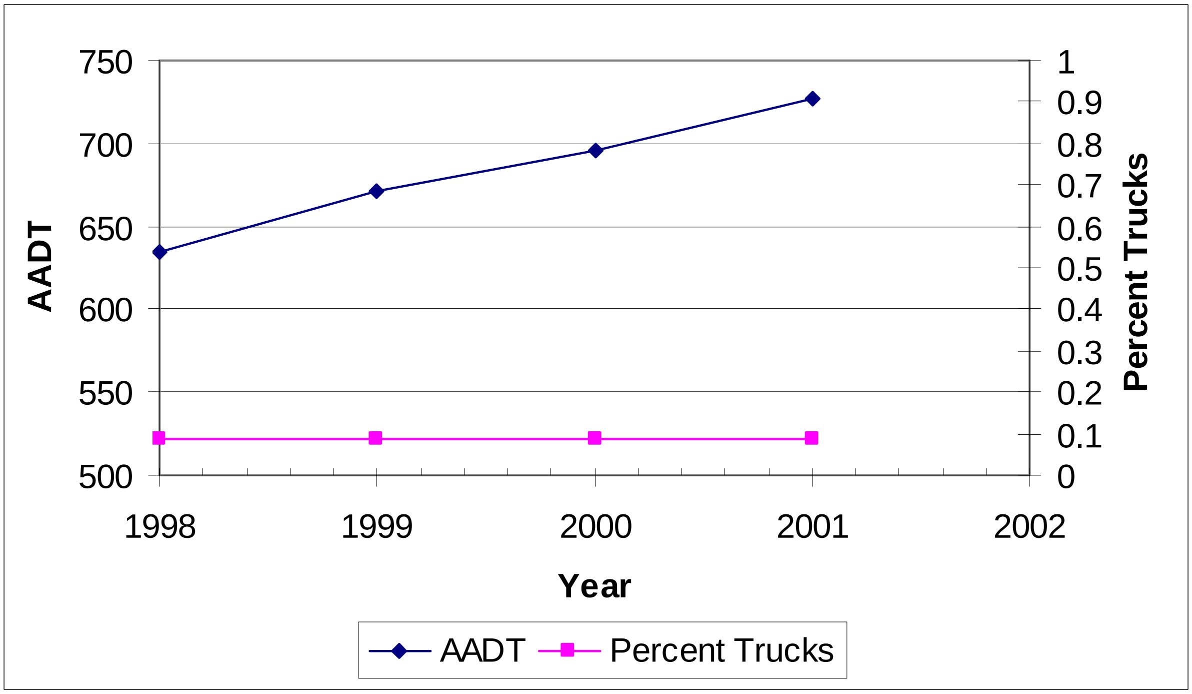

Figure 98(a). AADT data for CIR Project 15—US 191 (ADOT Project No. STP-077-1(10)P). (Between MP 468 and 472)

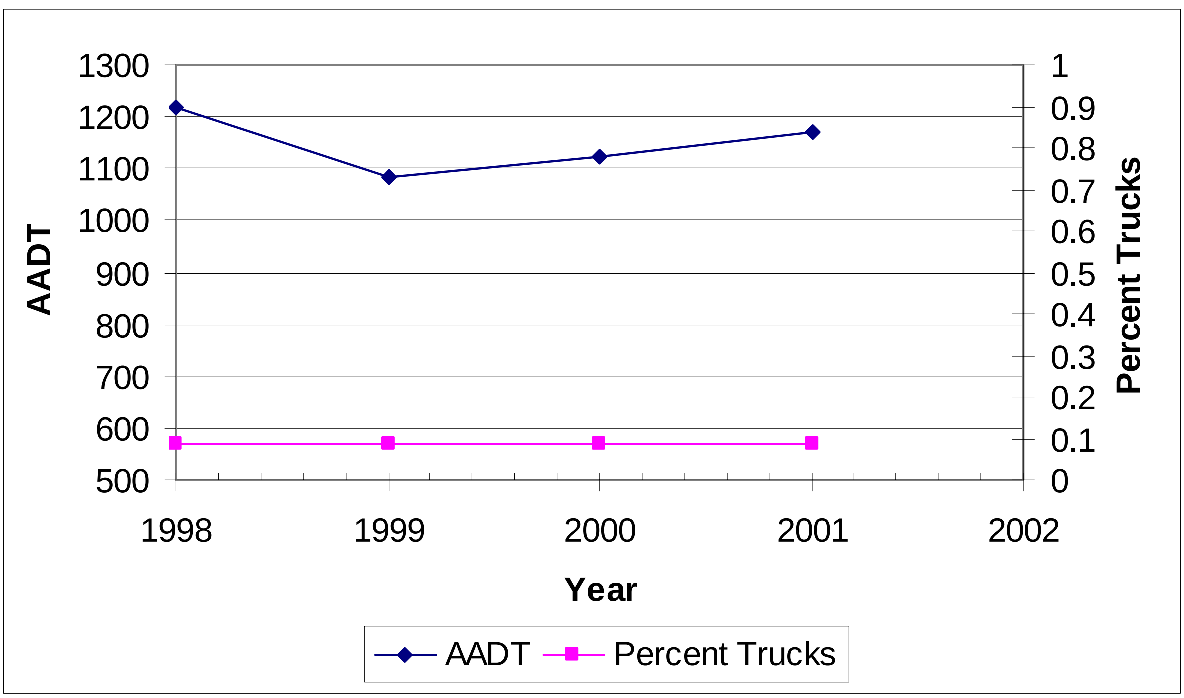

Figure 98(b). AADT data for CIR Project 15—US 191 (ADOT Project No. STP-077-1(10)P). (Between MP 472 and 482)

Pavement Performance Observations

Pavement distress data, ride quality data, and maintenance costs were extracted from the pavement management database and examined. The last condition survey on the roadway was performed in November 2002. The following is the extent of information available for each performance category considered in this report:

- Potholes – at the time of last condition survey.
- Cracking – 2000 to 2002.
- Ride – 2000 to 2002.
- Rutting – 2000 to 2002.
- Patching – 2000 to 2002.
- Flushing – 2000 to 2002.
- Maintenance costs – 1979 to 2000.

This project was constructed in 2001, and no significant maintenance or rehabilitation has been reported since construction. Figures 99 through 101 present the cracking, ride quality, and rutting data since 2000. Note that pothole and patching data are not plotted since these quantities were zero over the entire performance reporting period. Figure 102 presents the flushing data. Note that all the distress and ride data are presented on both a mile-by-mile basis and an averaged per-mile basis for the entire project (solid line). Performance-related observations are typically made using the average per-mile quantities as the basis.

Figure 103 presents the annual maintenance costs on a mile-by-mile basis as well as on an averaged per-mile basis for the entire project length. Figure 104 presents the cumulative maintenance costs a on a mile-by-mile basis as well as on an averaged per-mile basis.

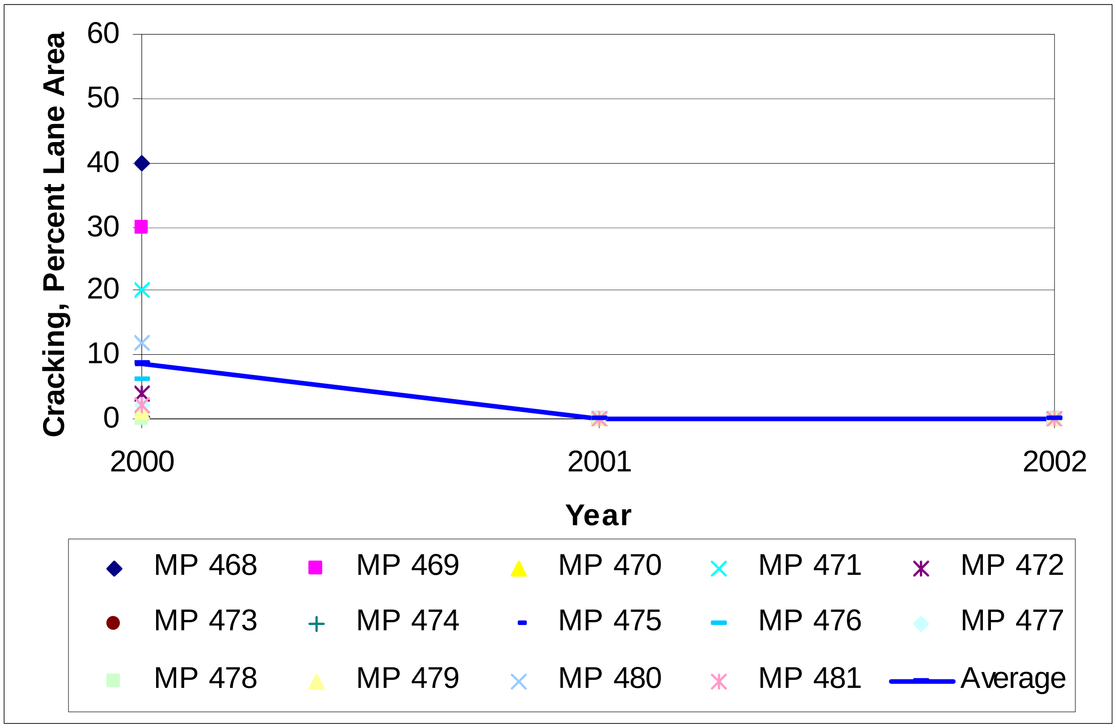

Figure 99. Cracking data for CIR Project 15—US 191 (ADOT Project No. STP-077-1(10)P).

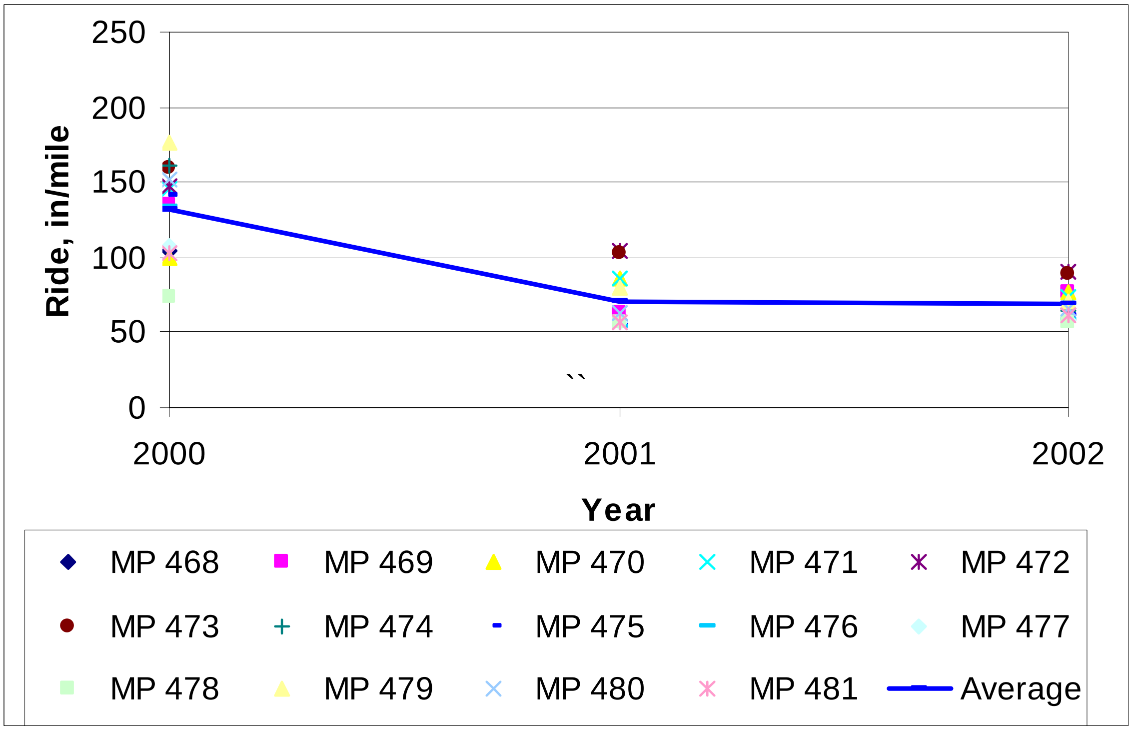

Figure 100. Ride quality information (Mays Ridemeter) for CIR Project 15—US 191 (ADOT Project No. STP-077-1(10)P).

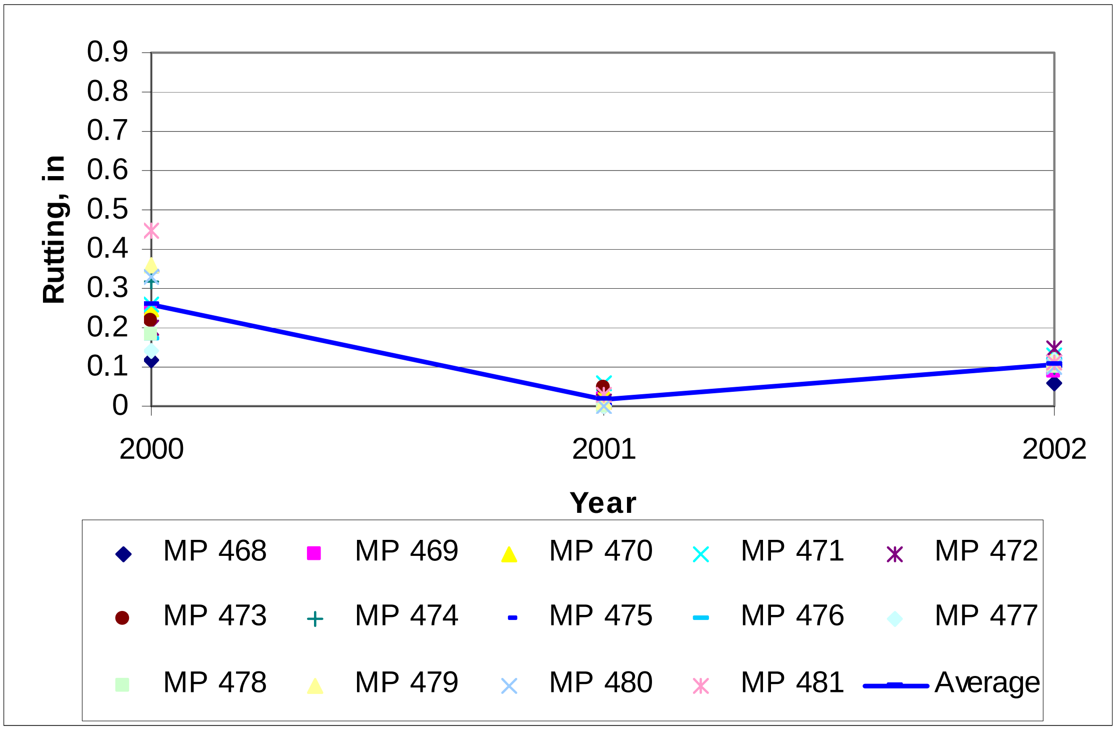

Figure 101. Rutting data for CIR Project 15—US 191 (ADOT Project No. STP-077-1(10)P).

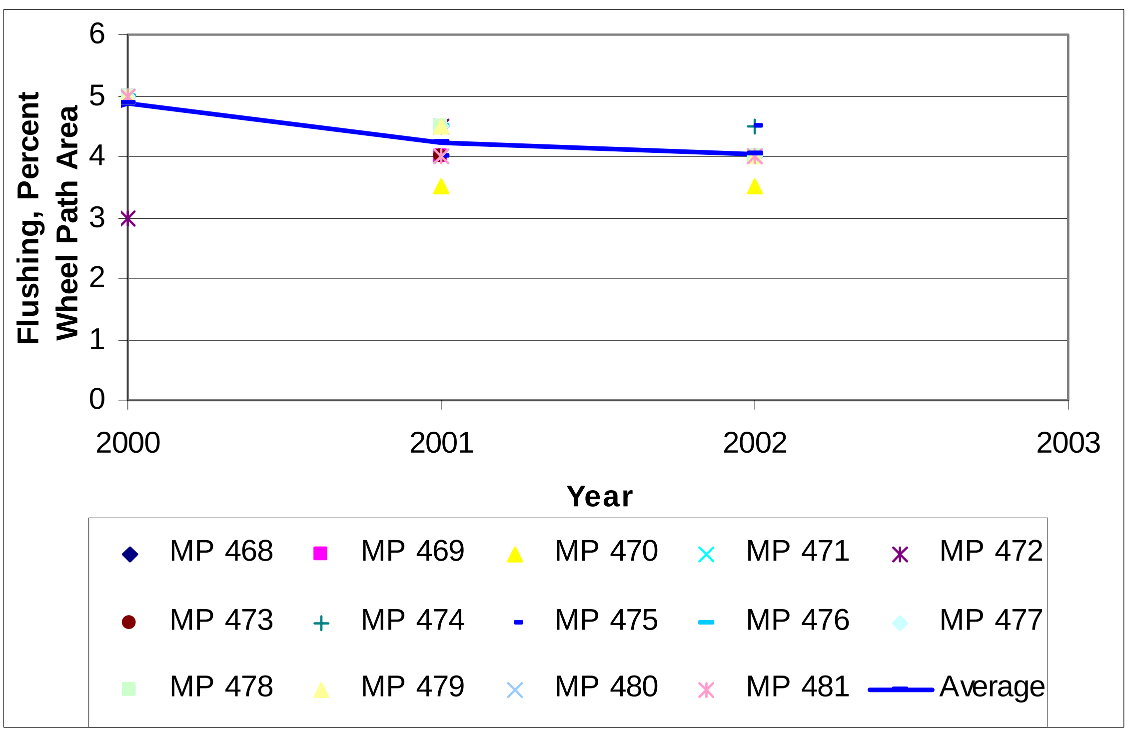

Figure 102. Flushing data for CIR Project 15—US 191 (ADOT Project No. STP-077-1(10)P).

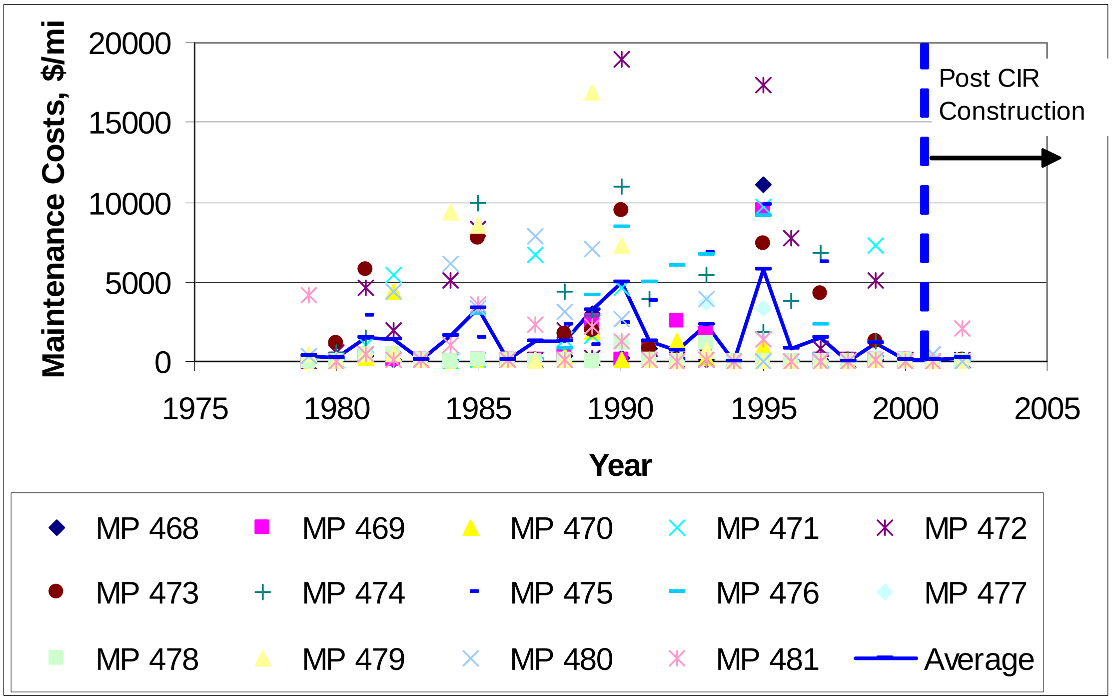

Figure 103. Maintenance cost for CIR Project 15—US 191
(ADOT Project No. STP-077-1(10)P).

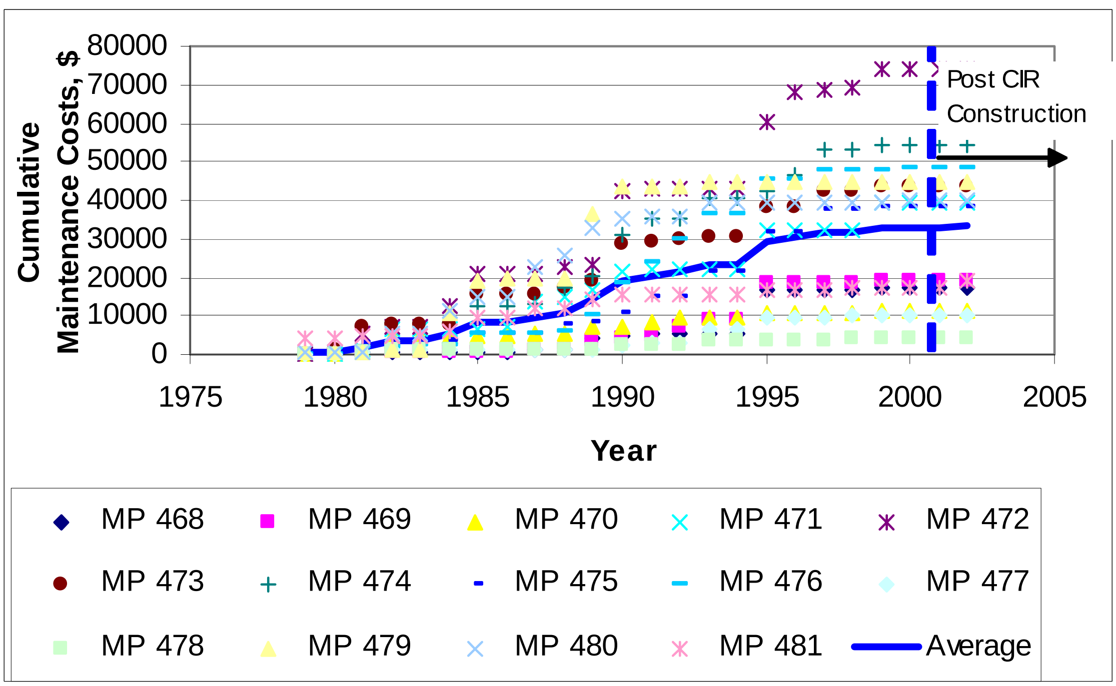

Figure 104. Cumulative maintenance cost for CIR Project 15—US 191
(ADOT Project No. STP-077-1(10)P).

Summary of Performance Observations

The following observations can be made from the performance data presented:

- Figures 99, 101, and 102 show no significant increases in distress, and the amount of distress present is negligible. In fact, the amounts of cracking and rutting actually decrease with time. Also, there are no potholes or maintenance/rehabilitation activities that would result in patching being present.
- Figure 100 shows no significant change in ride quality after CIR.
- Figure 103 suggests a very significant drop in maintenance cost after CIR. This is in agreement with the distress, ride, and maintenance information presented in figures 99 through 102. The cumulative maintenance cost shown in figure 104 generally increases over time, reaching a sharp peak value in 1999, which is perhaps due to the routine maintenance action taken to address pavement deterioration prior to CIR. The post-CIR increases in maintenance cost are not significant.

Because of the relatively young age of this project, it was not possible to reach any definitive conclusions regarding the effectiveness of the CIR in improving pavement performance. However, initial observations show very little distress. Further monitoring of this project will determine whether this trend will be sustained over time.

CIR PROJECT 16—US 160 EB, COCONINO COUNTY

Project Overview

This project, located between MP 322.2 and 331.0, was constructed under ADOT Project No. STP-064-1(P). The project involved CIR of the existing roadway to a depth of 3 inches, a 2 inch conventional HMA overlay, and a double application of seal coat. The purpose of this project was to rehabilitate the pavement and improve safety. Other construction items considered as part of this project included replacing guardrails, new construction of a right turn lane, and other miscellaneous incidental work.

The roadway section within the limits of this project was originally constructed in 1960 and consisted of 3 inches of aggregate base and a 2 inch bituminous surface. The project received several seal coats between 1970 and 1993.

The project is a two-lane, two-way roadway for the most part. The condition survey performed in 1996 revealed 20 to 30 percent large block cracking progressing into small block and alligator cracking. The cracks were approximately 0.5 inches wide, producing a fair to poor ride, with some rutting also noted.

Construction

The project was constructed in 2000. The construction details discussed herein pertain to the CIR work only. The exact construction sequencing, methods employed, and equipment used during construction of this CIR project are not known. Presented below are excerpts from the specification included as part of the project documents.

The construction work consisted of milling the existing pavement to the depths specified in the plans. The materials were specified to be broken up using a single pass, in-place pulverization technique so that 100 percent of the end product passes the 1.25 inch sieve. The pulverized material and 1.5 percent mixing water (as a percentage of total weight of the aggregate material) were then to be mixed in a self-propelled traveling mixer with adequate metering controls for the addition of binder agent. The allowable moisture content in the aggregate was not allowed to exceed 3 percent by weight of the mixed aggregate materials prior to the addition of the emulsion. The aggregate material was then to be mixed with the emulsified binder agent applied at a pre-specified rate until adequate coating of particles was obtained.

Self-propelled paving machines equipped with automatic controls and screeds were specified for laydown, taking care to prevent segregation. Compaction was not to commence until the emulsion began to break or for 2 hours, whichever was first. Initial rolling was to be accomplished with 30-ton pneumatic rollers, while 12-ton steel-wheeled rollers were used for finish rolling. All compaction equipment was required to meet standard ADOT specifications.

A 2 inch conventional HMA overlay (0.75 inch mix) was placed over the recycled layers along with a double application of chip seal. The chip seal layers were applied to the surface to produce an adequate level of surface texture. Placement techniques were similar to that of the recycled layer.

Materials

The type of emulsion specified was HFE-300P containing polymer modified asphalt, water, 1 percent liquid anti-stripping agent (by weight of emulsion), and emulsifier, blended to specific requirements. An application rate of 1.2 percent was specified for the entire project based on extensive laboratory testing by ADOT, which included density, asphalt content, and strength (tensile strength ratio) testing. However, the following rates were realized during construction (determined from field cores):

- 1.2 percent between MP 322.5 to 323.0
- 1.6 percent between MP 324.0 to 325.0
- 1.7 percent between 325.0 to 330.0
- 1.8 percent between 330.0 to 331.0

Traffic

Figure 105 presents a plot of ADT versus time for this project, and figure 106 presents plots of AADT and percent trucks versus time.

The general trend in the ADT data is that it is increasing over time. The AADT and percent trucks show no significant change over the reporting period. Overall, the level of traffic on this roadway can be considered moderate.

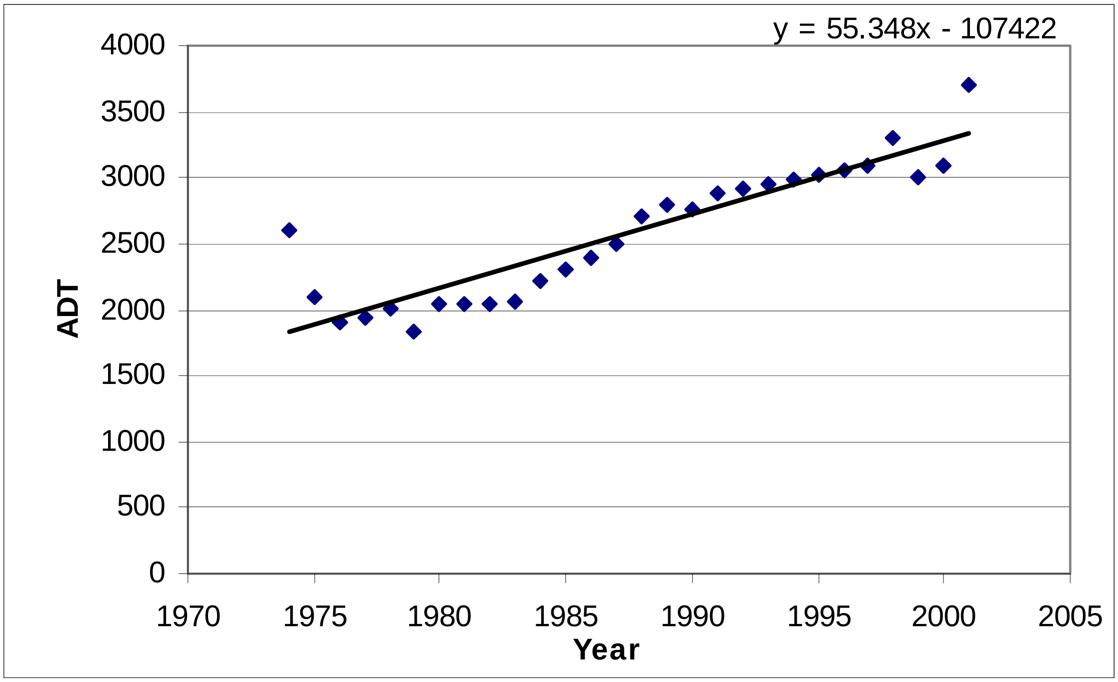

Figure 105. ADT for CIR Project 16—US 160 (ADOT Project No. STP-064-1(P)).

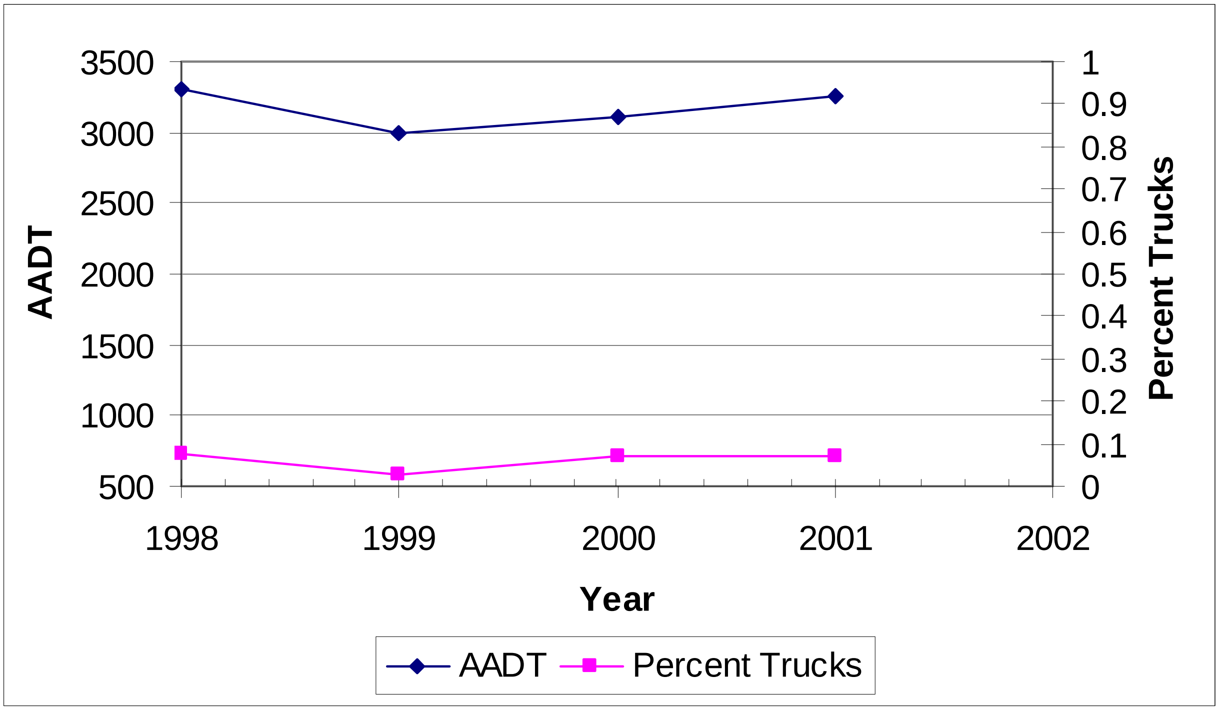

Figure 106. AADT for CIR Project 16—US 160 (ADOT Project No. STP-064-1(P)).

Pavement Performance Observations

Pavement distress data, ride quality data, and maintenance costs were extracted from the pavement management database and examined. The last condition survey on the roadway was performed in July 2002. The following is the extent of information available for each performance category considered in this report:

- Potholes – at the time of last condition survey.
- Cracking – 2000 to 2002.
- Ride – 2000 to 2002.
- Rutting – 2000 to 2002.
- Patching – 2000 to 2002.
- Flushing – 2000 to 2002.
- Maintenance costs – 1979 to 2000.

This project was constructed in 2000, and no significant maintenance or rehabilitation has been reported since construction. Figures 107 through 109 present the cracking, ride quality, and rutting data since the CIR project was constructed. Note that pothole and patching data are not plotted since these quantities were zero over the entire performance reporting period. Figure 110 presents the flushing data. Note that all the distress and ride data are presented on both a mile-by-mile basis and an averaged per-mile basis for the entire project (solid line). Performance-related observations are typically made using the average per-mile quantities as the basis.

Figure 111 presents the annual maintenance costs on a mile-by-mile basis as well as on an averaged per-mile basis for the entire project length. Figure 112 presents the cumulative maintenance costs a on a mile-by-mile basis as well as on an averaged per-mile basis.

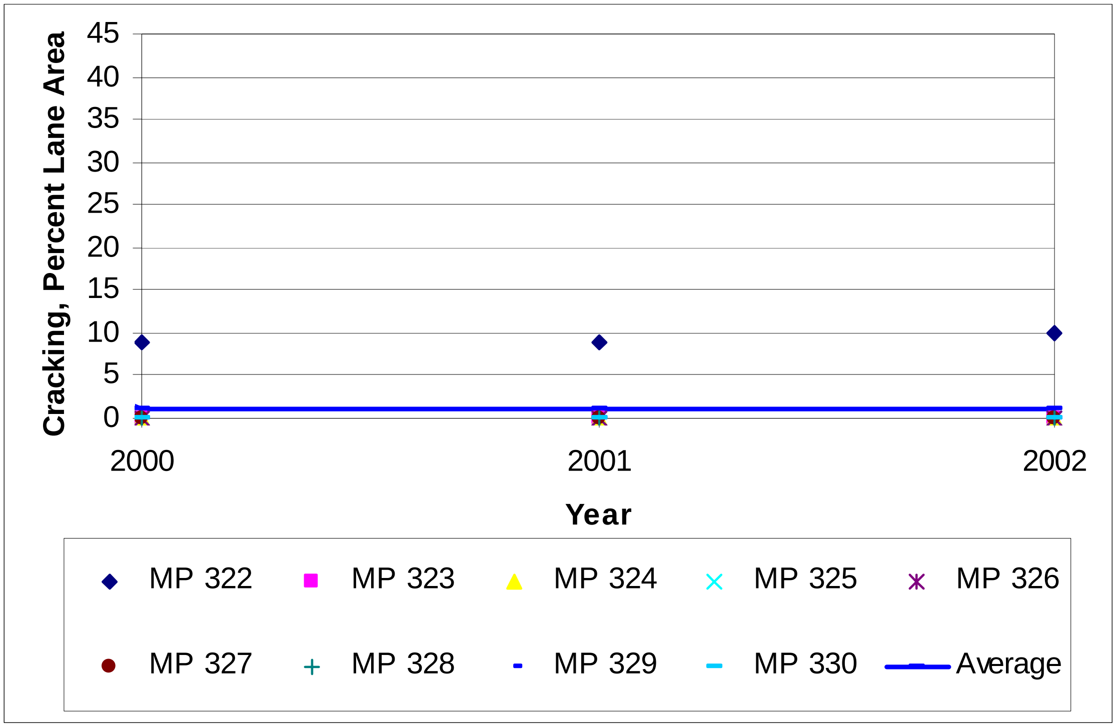

Figure 107. Cracking data for CIR Project 16—US 160 (ADOT Project No. STP-064-1(P)).

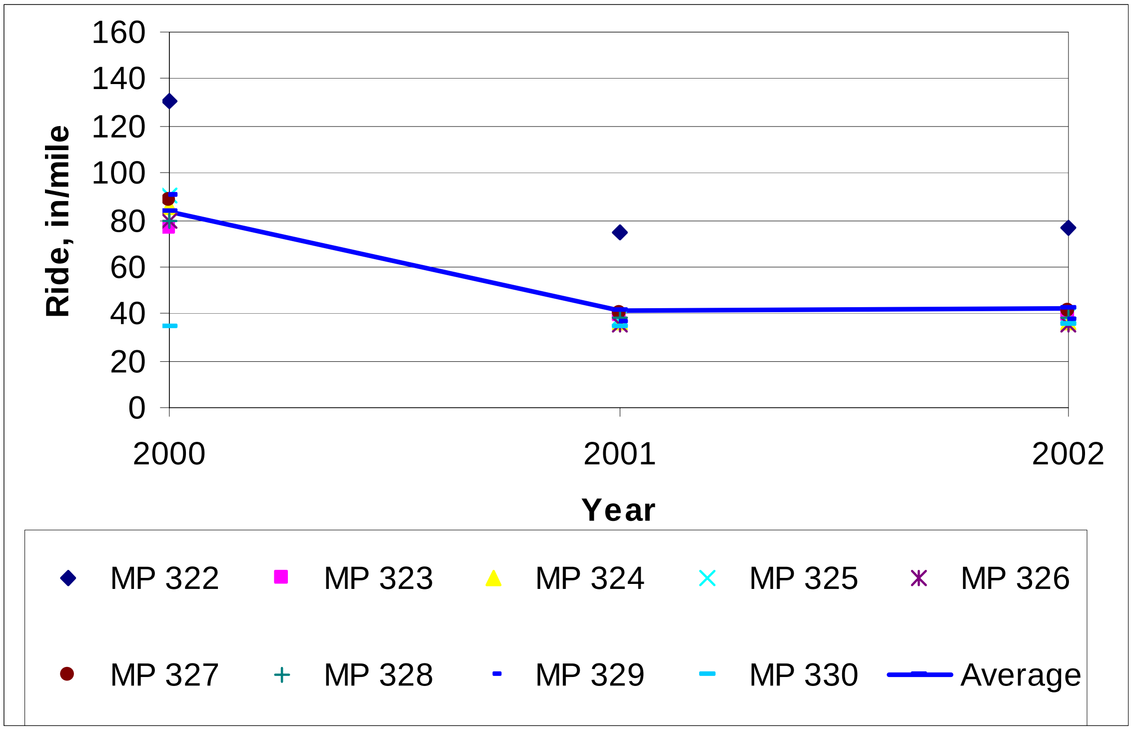

Figure 108. Ride information (Mays Ridemeter) for CIR Project 16—US 160 (ADOT Project No. STP-064-1(P)).

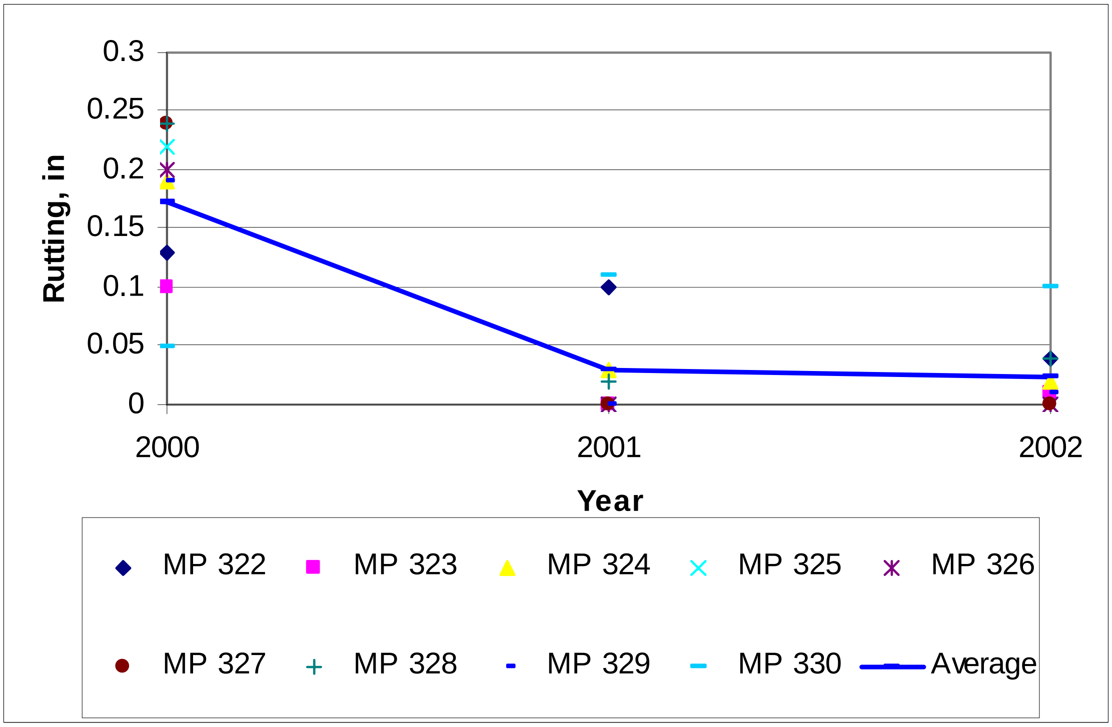

Figure 109. Rutting data for CIR Project 16—US 160 (ADOT Project No. STP-064-1(P)).

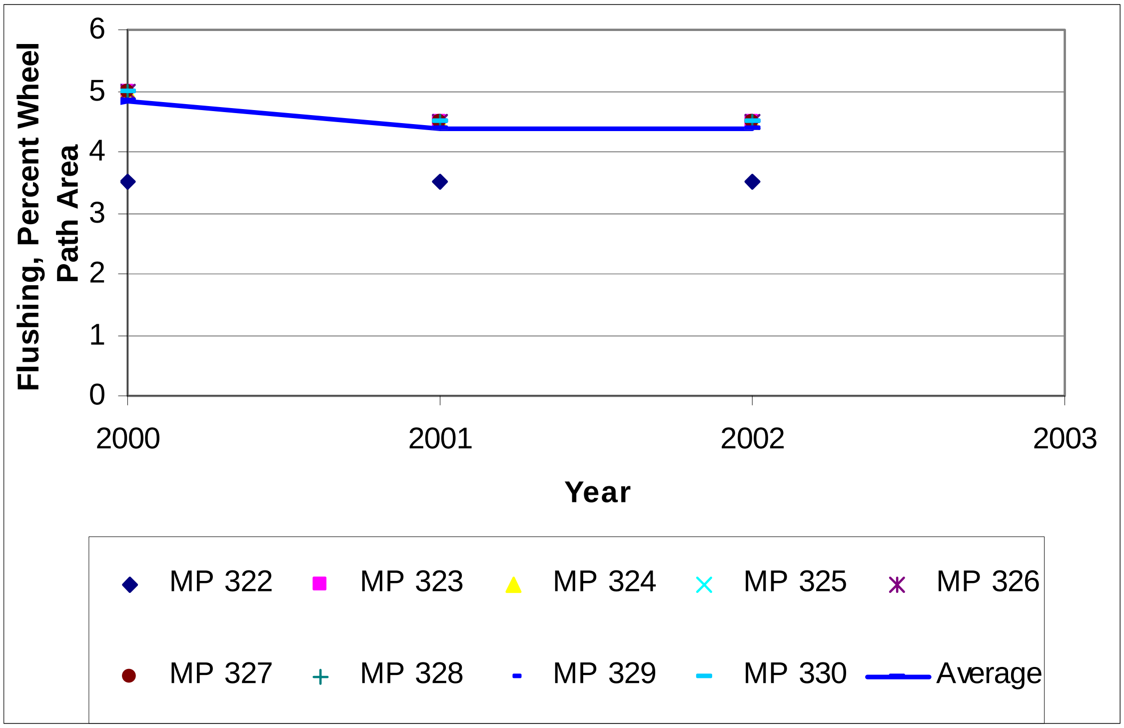

Figure 110. Flushing data for CIR Project 16—US 160 (ADOT Project No. STP-064-1(P)).

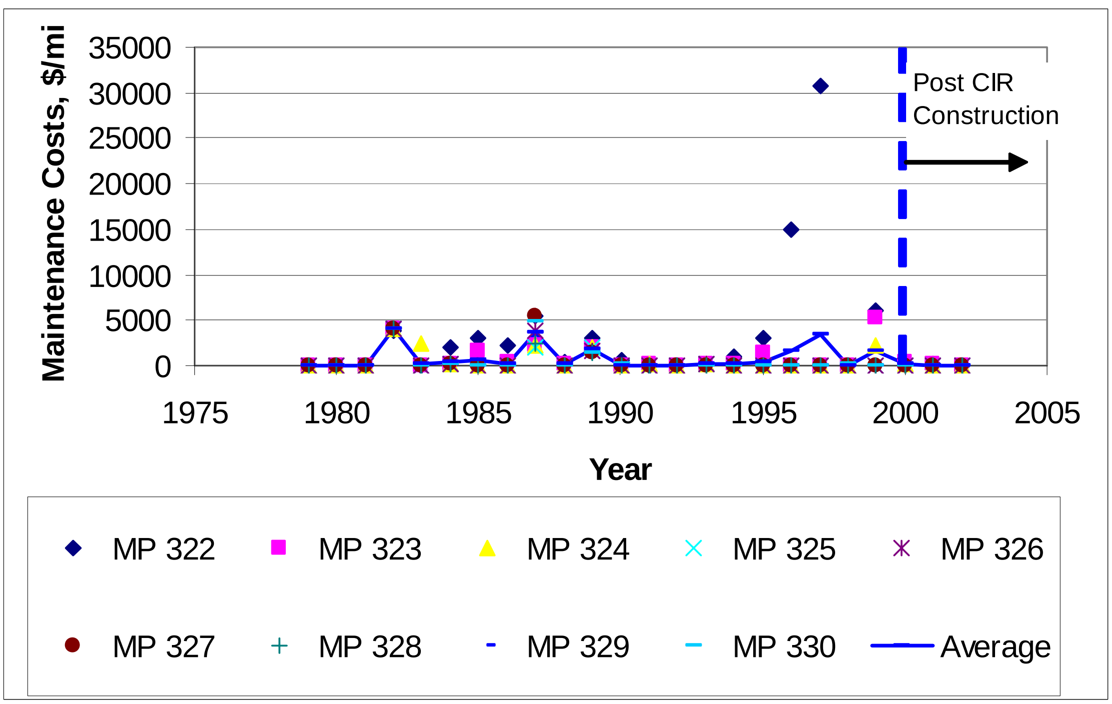

Figure 111. Maintenance costs for CIR Project 16—US 160 (ADOT Project No. STP-064-1(P)).

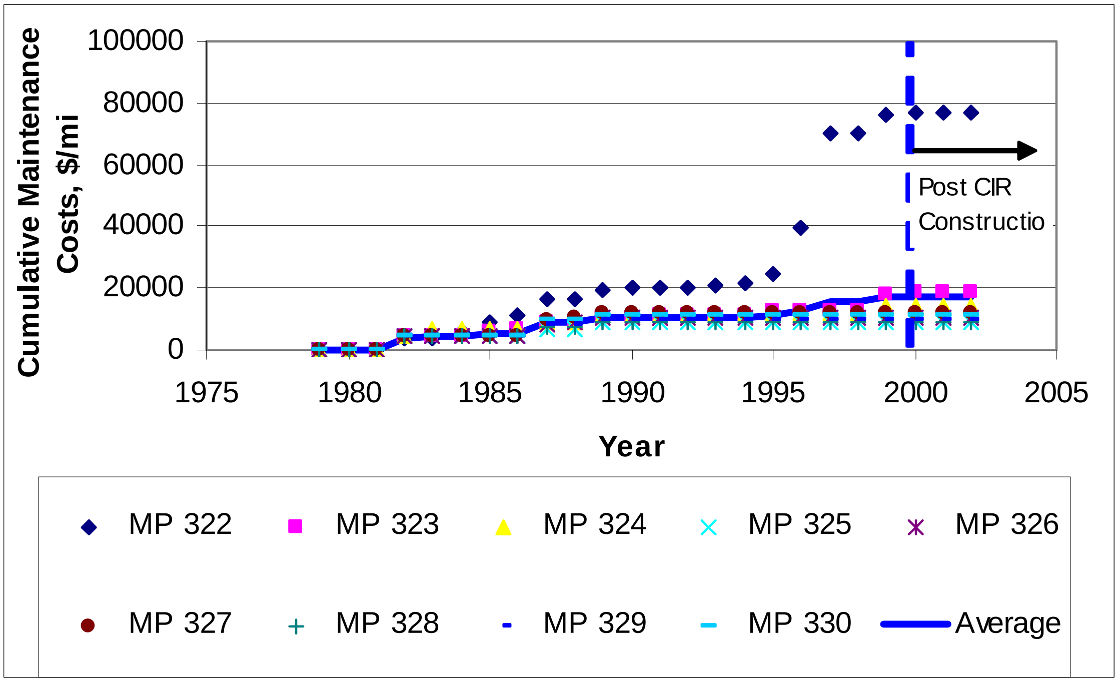

Figure 112. Cumulative maintenance costs for CIR Project 16—US 160 (ADOT Project No. STP-064-1(P)).

Summary of Performance Observations

The following observations can be made from the performance data presented:

- Figures 107, 109, and 110 show that while cracking was non-existent over the entire reporting period, both rutting and flushing did show a significant decrease in 2001 when compared to the respective quantities in the year 2000. It is possible that the performance data in 2000 were collected prior to the CIR work (could not conclusively prove it from the data); hence, the performance data from this year should not be used in evaluating the effectiveness of the CIR. The data from 2001 and 2002 show that, as expected, CIR was effective in eliminating the rutting and flushing distress.
- Figure 108 shows that the ride quality significantly improved after the CIR work, as expected, and did not change significantly in the 2 years after the work was completed (i.e., if data from only 2001 and 2002 are used for evaluation purposes).
- Figure 111 suggests a very significant drop in maintenance cost after CIR. This is in agreement with the distress, ride, and maintenance information presented in figures 107 through 110. The cumulative maintenance costs shown in figure 112 generally increase over time, reaching a sharp peak value in 1999, which is perhaps due to the routine maintenance action taken to address pavement deterioration prior to CIR. The post-CIR increases in maintenance cost are not significant.

Because of the relatively young age of this project, it was not possible to reach any definitive conclusions regarding the effectiveness of the CIR in improving pavement performance.

However, initial observations show very little distress. Further monitoring of this project will determine whether this trend will be sustained over time.

CIR PROJECT 17—US 180 EB, NAVAJO AND APACHE COUNTIES

Project Overview

This project is located on US 180 between MP 324.96 and 338.40. It was constructed in 1998 by FNF Construction under ADOT Project No. STP-051-1(17)P. The project involved CIR of the existing AC in both the eastbound and westbound lanes to a depth of 3.0 inches, followed by the placement of a 1.5 inch asphalt rubber AC overlay and a 0.5 inch asphalt rubber friction course.

Construction

No specific construction information was available on this project.

Materials

No information is available on the type of emulsion agent used for CIR.

Traffic

Figure 113 presents a plot of ADT versus time for this project, and figure 114 presents plots of AADT and percent trucks versus time. The traffic, in terms of ADT and AADT, has remained low and relatively steady. The percentage of trucks on the project is also low and unchanged since 1998.

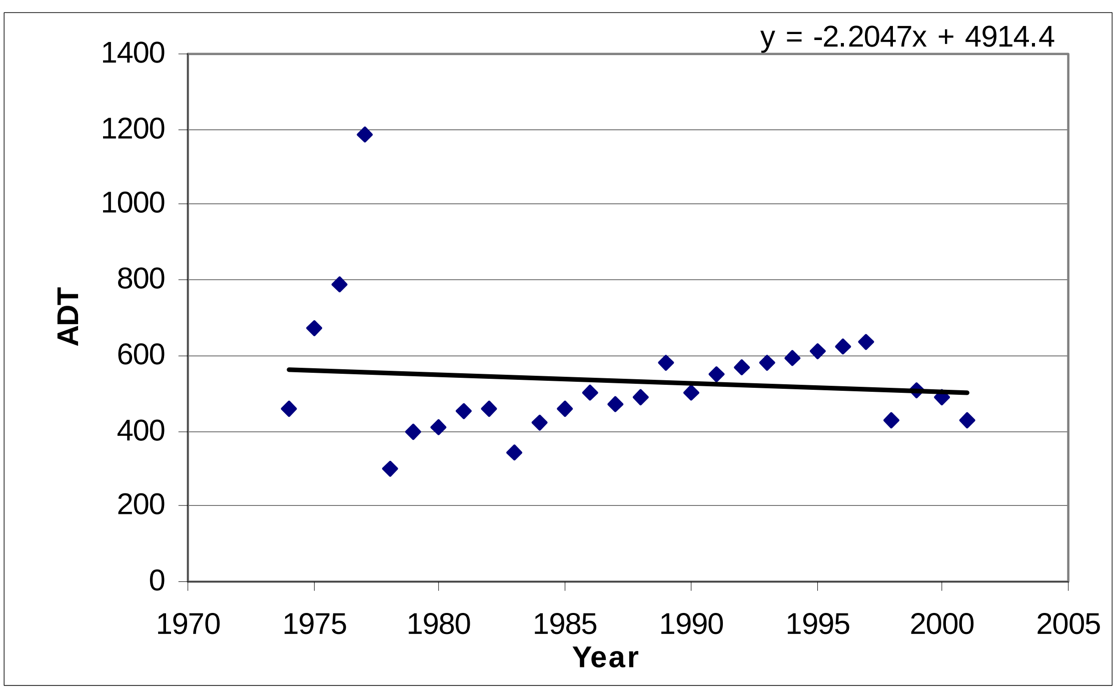

Figure 113. ADT data for CIR Project 17—US 180 EB (ADOT Project No. STP-051-1(17)P).

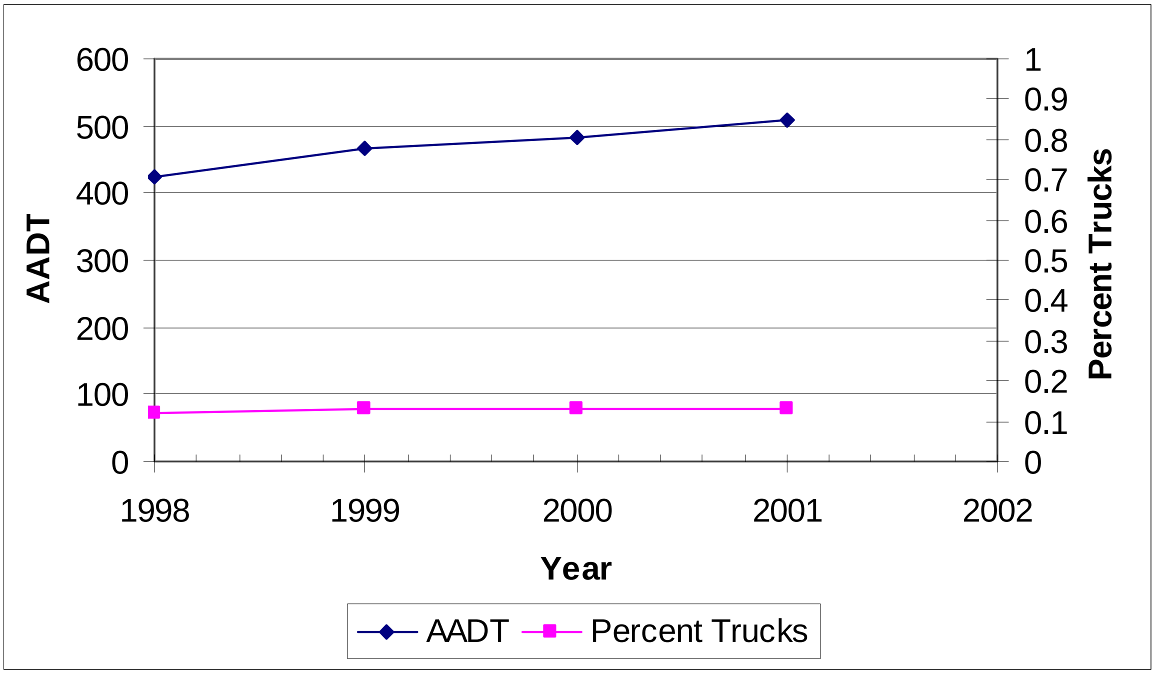

Figure 114. AADT data for CIR Project 17—US 180 EB (ADOT Project No. STP-051-1(17)P).

Pavement Performance Observations

Pavement distress data, ride quality data, and maintenance costs were extracted from the pavement management database and examined. The last condition survey on the roadway was performed in August 2002. The following is the extent of information available for each performance category considered in this report:

- Cracking – 1979 to 2002.
- Potholes – at the time of last condition survey.
- Rutting – 1989 to 2002.
- Patching – 1979 to 2002.
- Flushing – 1979 to 2002.
- Ride – 1973 to 2002.
- Maintenance costs – 1979 to 2002.

Figures 115 through 117 present the cracking, rutting, and flushing data since 1998. Pothole and patching data are not plotted since these quantities were zero over the reporting period under consideration. Figure 118 presents the ride quality data. Note that all the distress and ride data are presented on both a mile-by-mile basis and an averaged per-mile basis for the entire project (solid line). Performance-related observations are typically made using the average per-mile quantities as the basis.

Figure 119 presents the annual maintenance costs on a mile-by-mile basis as well as on an averaged per-mile basis for the entire project length. Figure 120 presents the cumulative maintenance costs on a mile-by-mile basis as well as on an averaged per-mile basis.

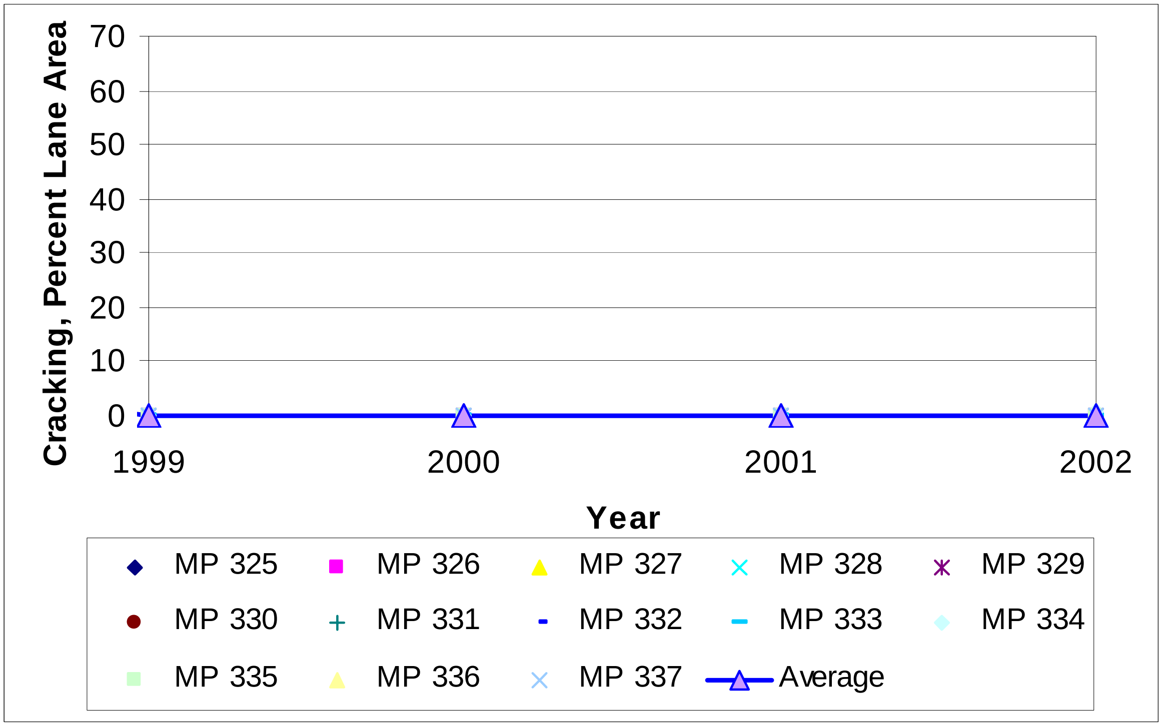

Figure 115. Cracking data for CIR Project 17—US 180 EB
(ADOT Project No. STP-051-1(17)P).

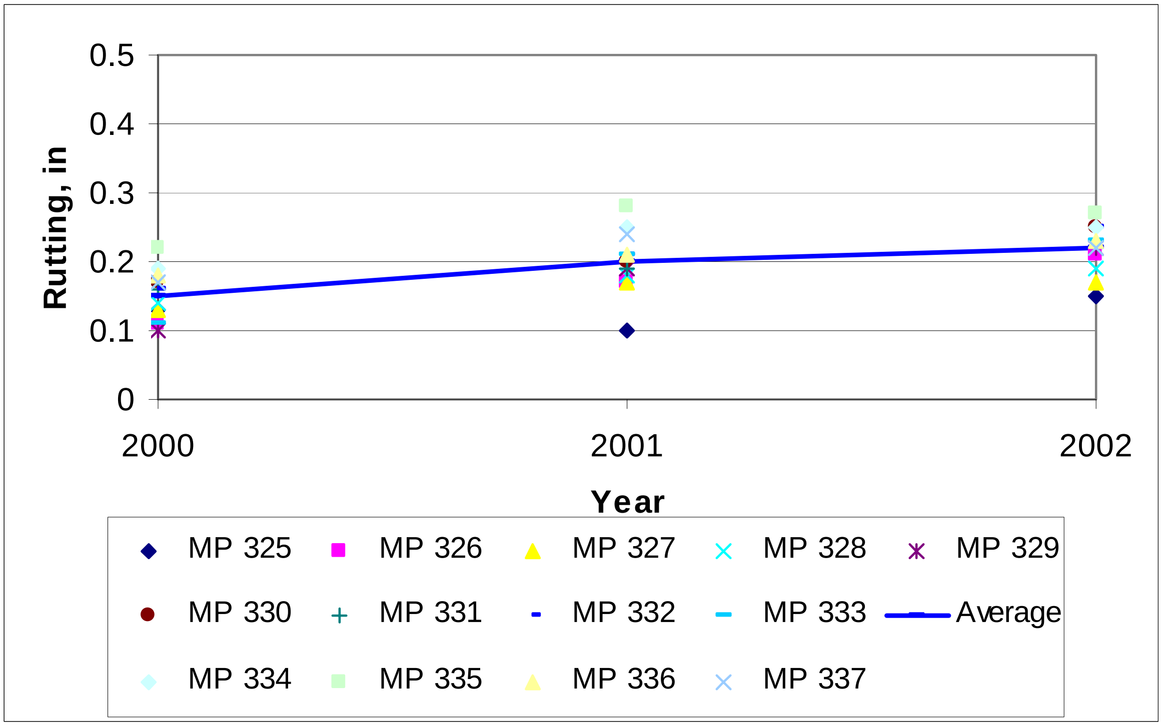

Figure 116. Rutting data for CIR Project 17—US 180 EB (ADOT Project No. STP-051-1(17)P).

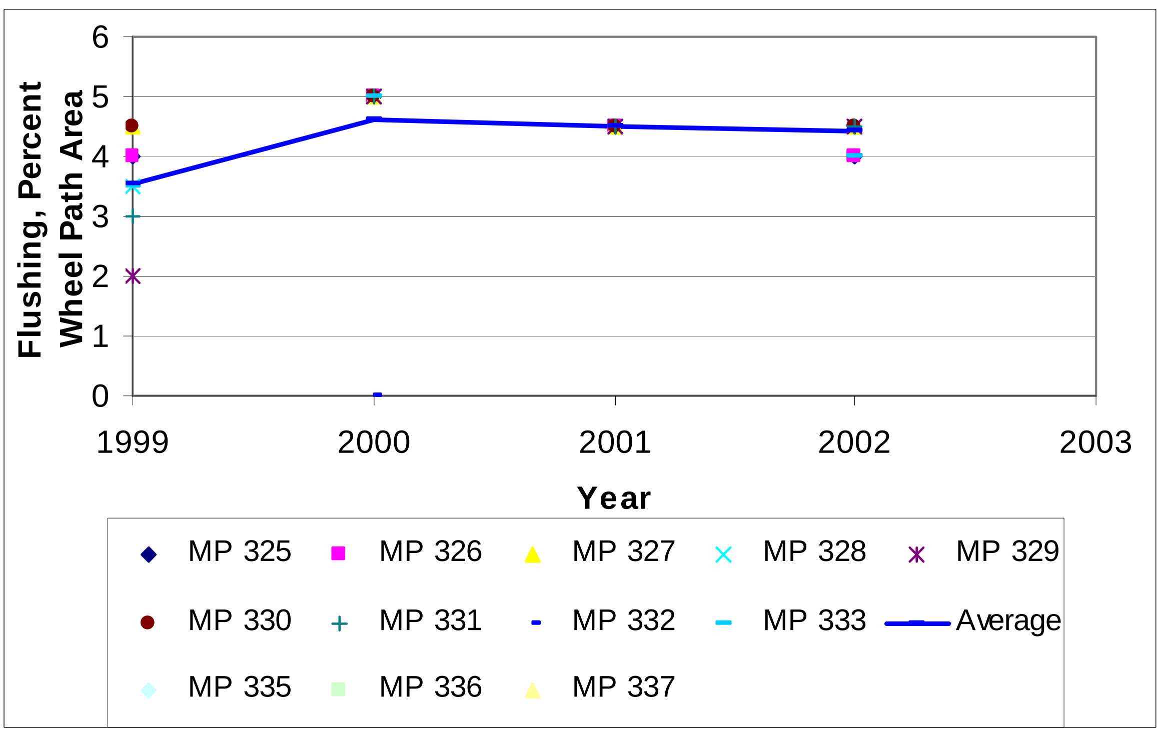

Figure 117. Flushing data for CIR Project 17—US 180 EB
(ADOT Project No. STP-051-1(17)P).

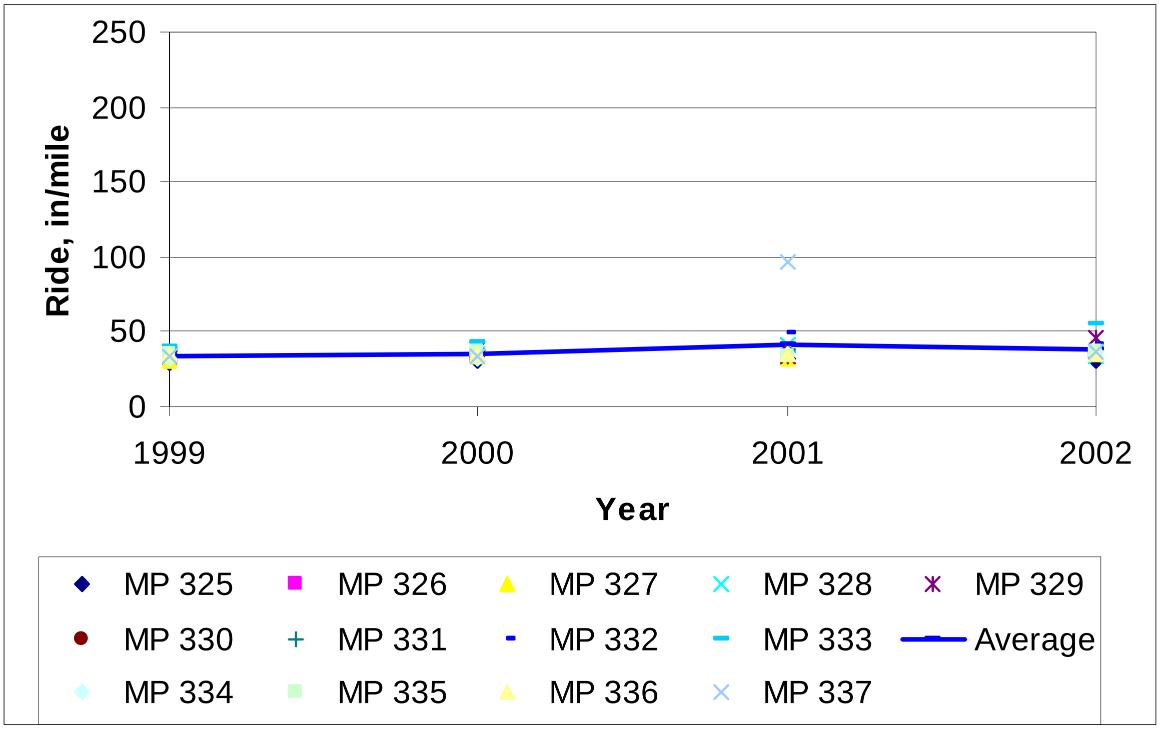

Figure 118. Ride quality information (Mays Ridemeter) for CIR Project 17—US 180 EB (ADOT Project No. STP-051-1(17)P).

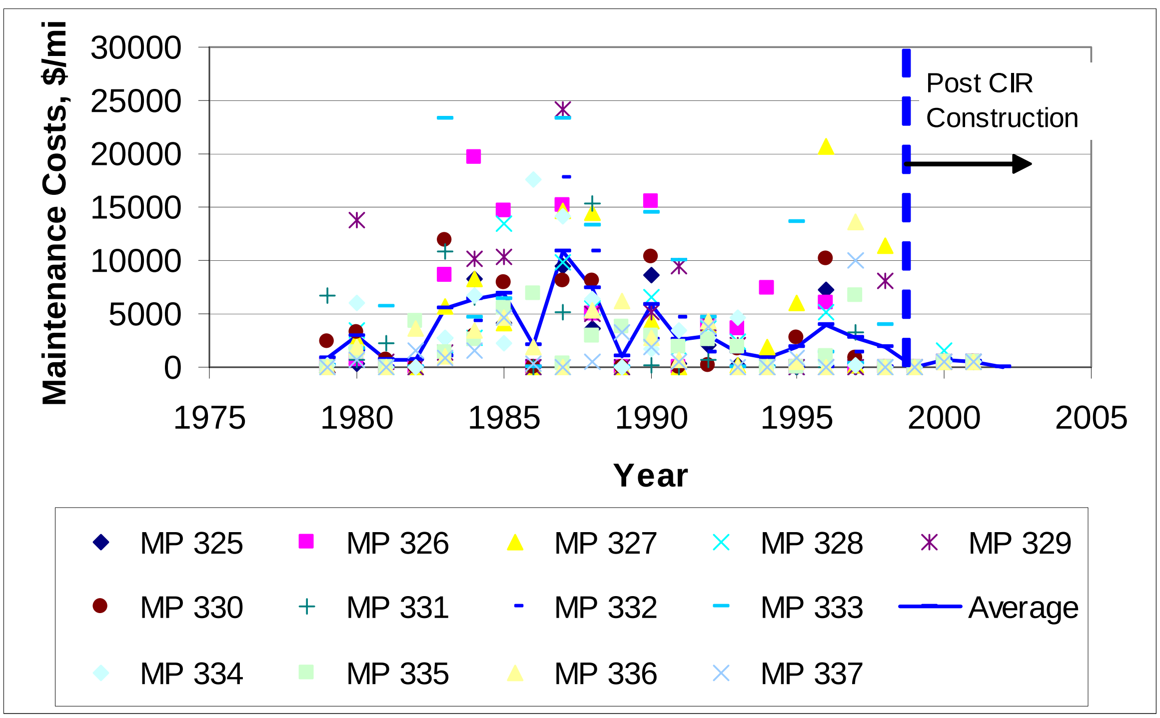

Figure 119. Maintenance costs for CIR Project 17—US 180 EB (ADOT Project No. STP-051-1(17)P).

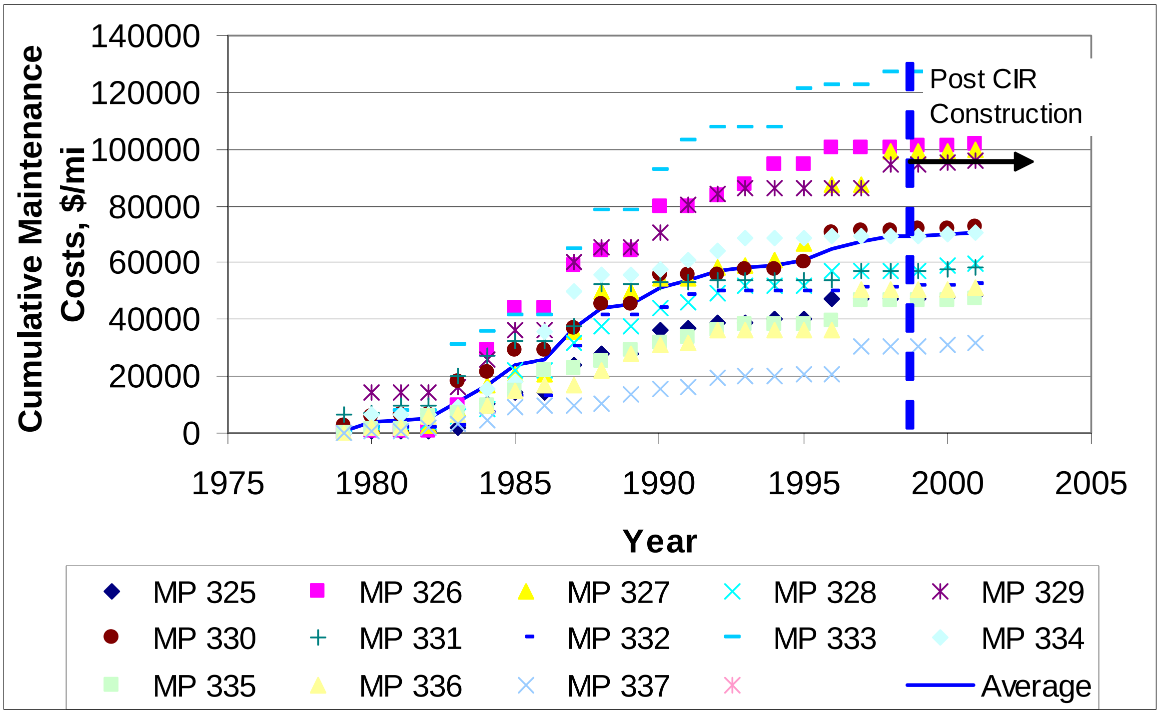

Figure 120. Cumulative maintenance costs for CIR Project 17—US 180 EB (ADOT Project No. STP-051-1(17)P).

Summary of Performance Observations

The following observations can be made from the performance data presented:

- Figure 115 shows that no cracking, of any kind, was observed over the entire reporting period.
- Figure 116 shows that rutting is low at the present time but has an increasing trend.
- Figure 117 shows that the flushing quantities remain relatively low and stable over time.
- Figure 118 shows that the ride quality is satisfactory over the entire reporting period.
- Figure 119 suggests that the mile-by-mile maintenance costs are negligible after the CIR work was done and the HMA overlay placed. Likewise, the cumulative maintenance costs, shown in figure 120, level off after 1998.

The data presented can be considered short-term (less than 5 years) and may be insufficient to predict the long-term impact of the rehabilitation activity. However, it appears that the CIR in conjunction with the conventional HMA overlay has performed satisfactorily to date.

CHAPTER 3. EXECUTIVE SUMMARY AND CONCLUSIONS

EXECUTIVE SUMMARY

The primary objective of this study was to evaluate the performance of selected CIR projects in Arizona and develop recommendations regarding CIR as a preservation technique. To achieve this objective, 17 CIR projects were evaluated, with each evaluation consisting of the following:

- Preparation of project descriptions and design and construction summaries based on ADOT records and discussions with appropriate ADOT personnel.
- Development and evaluation of pavement performance trends for each project and the specific CIR strategy employed. For the projects evaluated, the CIR strategy applied was as follows:
  - Application of CIR for the top 2 to 3 inches of an existing HMA surface layer.
  - Application of CIR for the top 2 to 3 inches of an existing HMA surface layer plus a 2- to 3-inch HMAC overlay.
- Analysis of performance trends for the selected projects and recommendations regarding CIR as a preservation technique in Arizona.

Data for evaluation and analysis for the 17 projects listed were obtained from ADOT's pavement management system, construction project history, and traffic databases. A summary of the key design and site parameters used in characterizing the projects evaluated is presented in table 2. Figures 121 through 128 present a summary of the performance history of the 15 of 17 projects that had performance data available for evaluation. The performance indicators used in the figures are cracking, rutting, ride quality, and annual maintenance cost per mile. These indicators were adopted because they are the most critical factors that affect flexible pavements performance. The ADOT criteria for assessing post-CIR performance based on these indicators were as presented in table 3. A summary of observed performance is presented in the following sections.

Table 2. Summary of the key design and site parameters of projects evaluated.

PARAMETER	RANGE
Age (post CIR)	3 to 21 years
Traffic (post CIR)	Up to 1,500 trucks/day
Depth of CIR	2 to 3 inches
HMA Overlay Thickness	2 to 3 inches

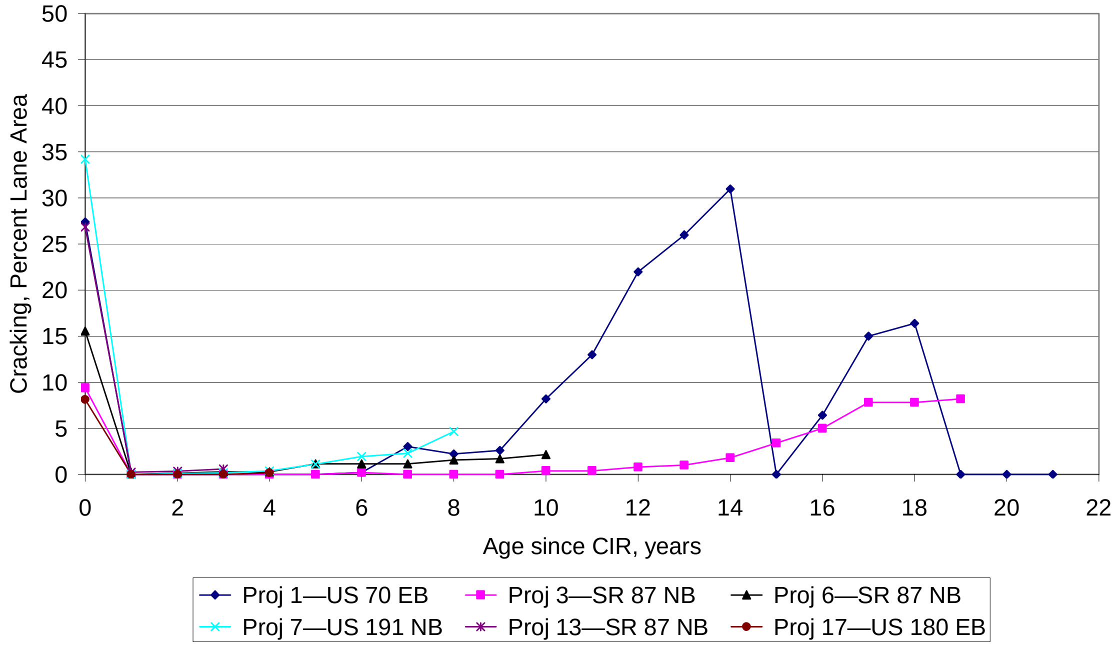

Figure 121. Plot showing cracking performance (projects with CIR only).

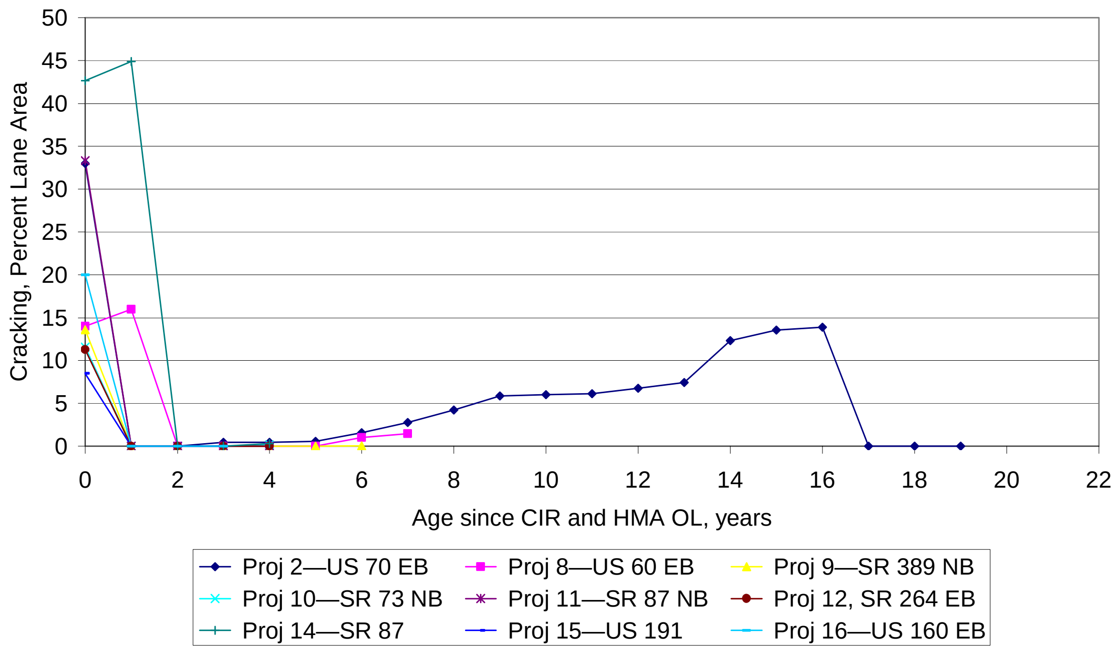

Figure 122. Plot showing cracking performance (projects with CIR and HMA overlay).

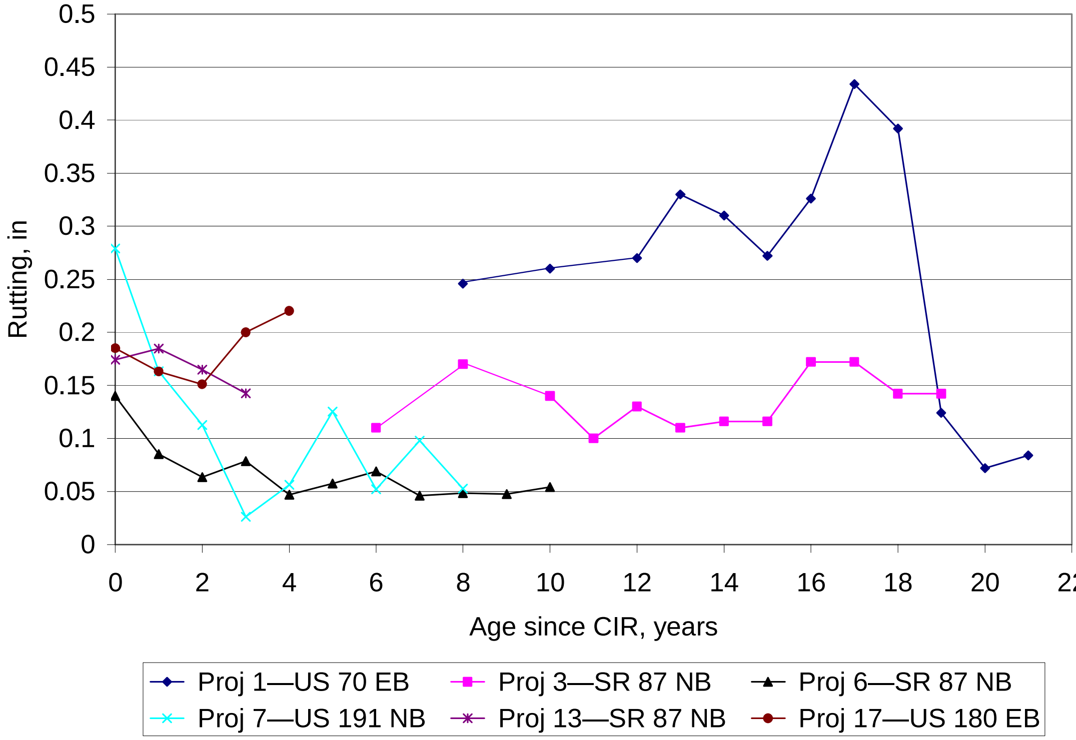

Figure 123. Plot showing rutting performance (projects with CIR only).

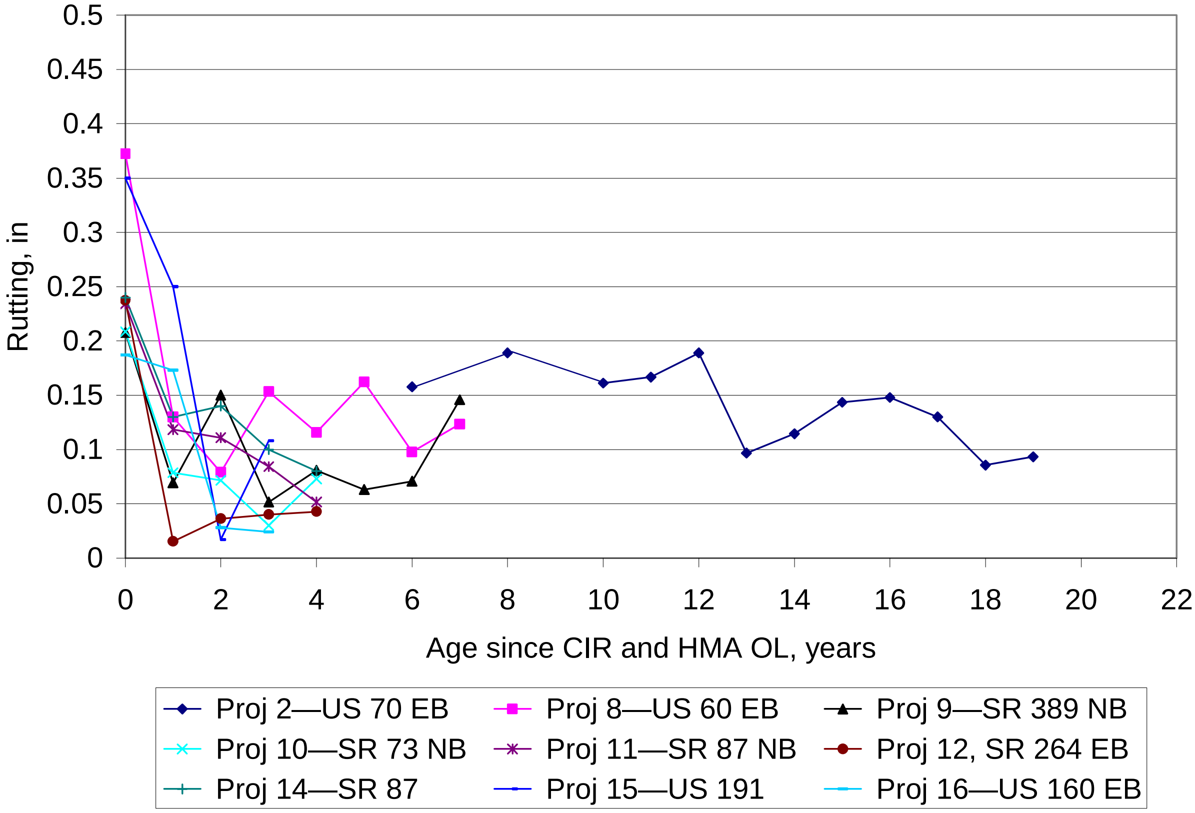

Figure 124. Plot showing rutting performance (projects with CIR and HMA overlay).

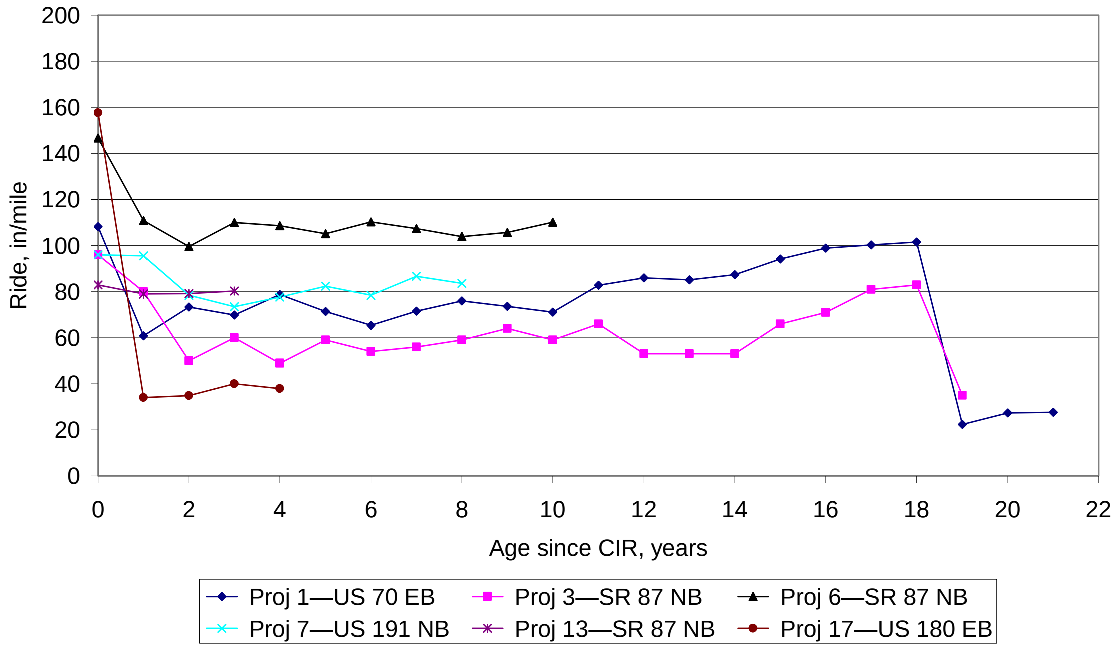

Figure 125. Plot showing ride performance (projects with CIR only).

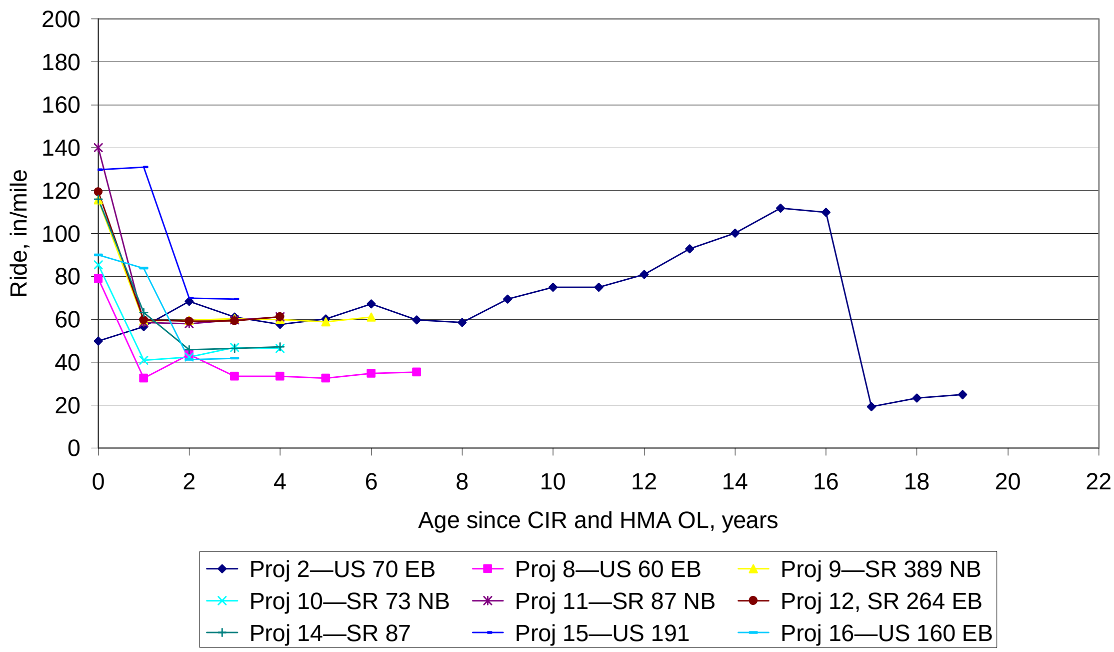

Figure 126. Plot showing ride performance (projects with CIR and HMA overlay).

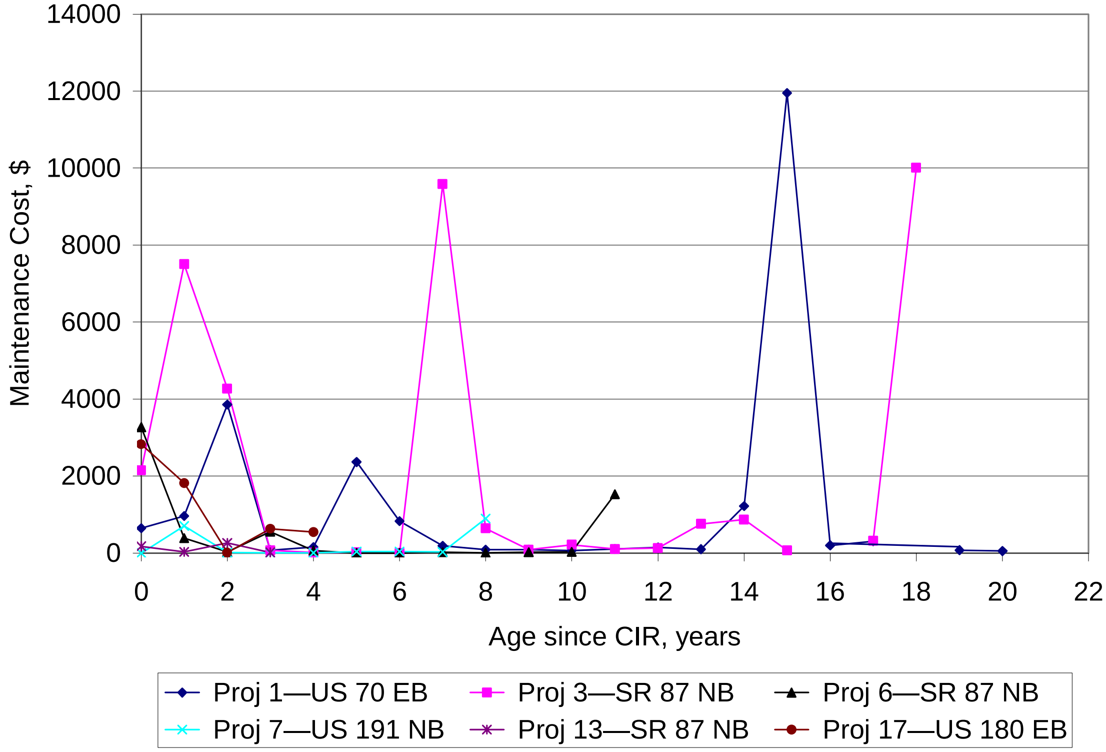

Figure 127. Plot showing maintenance cost (projects with CIR only).

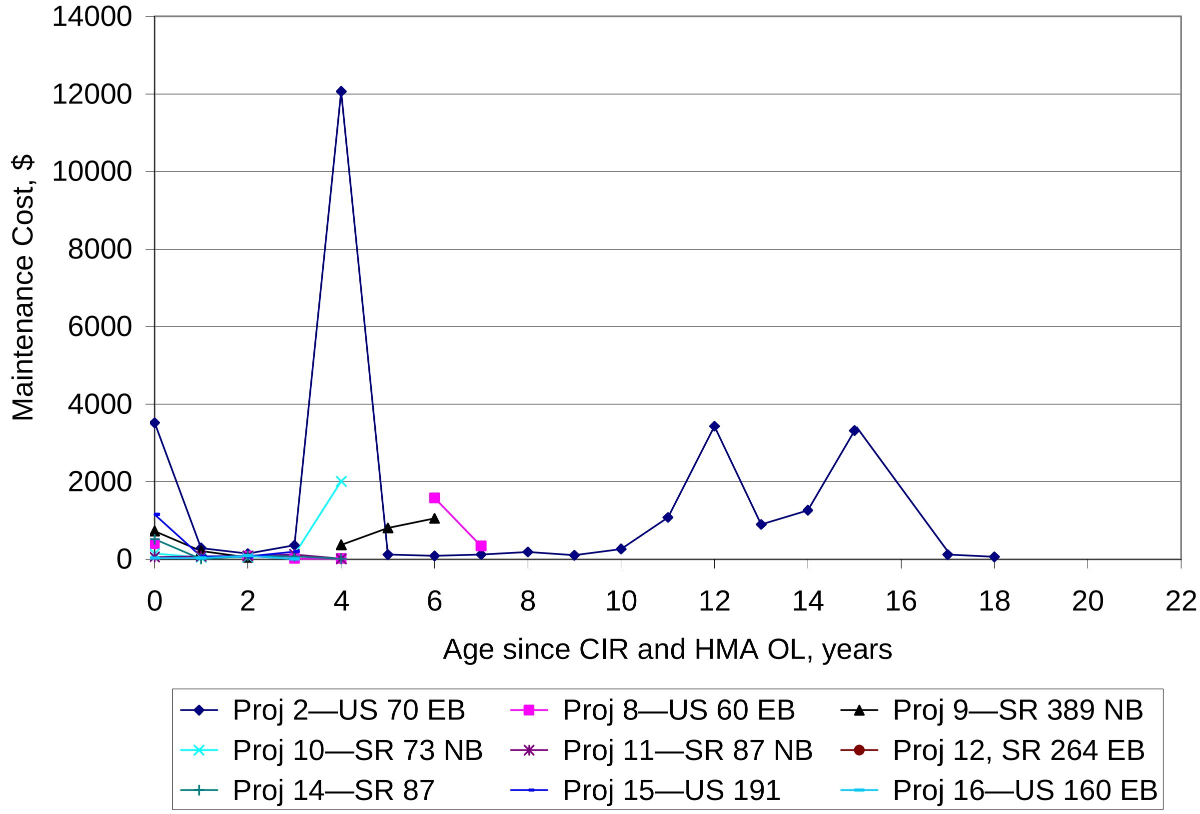

Figure 128. Plot showing maintenance cost (projects with CIR and HMA overlay).

Table 3. Criteria for assessing post-CIR performance.

PERFORMANCE INDICATOR	RANKING		
	Good	Satisfactory	Unsatisfactory
Cracking, percent	< 10	10 to 30	> 30
Rutting, in	< 0.25	0.25 to 0.5	> 0.5
Mays Ride, in/mi	< 93	93 to 143	> 143
Maintenance Cost, $/mile			> 1,000

Cracking Performance

All the projects subjected to CIR alone (typically CIR depth ranged from 2 to 3 inches) performed adequately for at least 10 years. It must be noted that the projects were, in general, subject to low to moderate levels of traffic. Only two projects had cracking data reported 10 years after CIR. Of these, one performed adequately while the other reported high levels of cracking (> 30 percent per lane area) after 13 years.

For projects subjected to both CIR and HMA overlays (typical CIR depth ranged for 2 to 3 inches, HMA overlay thickness ranged from 2 to 3 inches), cracking performance was adequate. The single project with more than 10 years of performance data experienced moderate levels of cracking 13 years after rehabilitation.

Rutting Performance

All the projects subjected to CIR alone performed adequately for at least 10 years. It must be noted that the projects were, in general, subject to low to moderate levels of traffic. Only two projects had rutting data reported 10 years after CIR. Of these, one performed adequately while the other reported moderate levels of rutting (> 0.25 inches and < 0.5 inches) after 17 years.

For projects subjected to both CIR and HMA overlays, rutting performance was adequate (< 0.25 inches) for all projects. The single project with more than 10 years of performance data experienced low levels of rutting 12 years after rehabilitation.

Ride Performance

Figure 125 shows ride performance (an indicator of overall pavement condition) for projects subjected to CIR alone. The information presented indicates adequate performance. In general, there was very little change in the levels of ride quality post-CIR. Projects more than 10 years post-CIR indicate adequate levels of performance for up to 18 years.

For projects subjected to both CIR and HMA overlays (figure 126), ride quality was adequate (Mays Ride < 93 inches/mile) for all projects 10 years post-rehabilitation. The single project with more than 10 years of performance data experienced moderate levels of ride quality 15 years after rehabilitation.

Maintenance Cost

Figure 127 shows that four of the six projects subjected to CIR alone experienced moderate levels of maintenance (cost < $1,000/mile) up to 10 years post-rehabilitation. For projects subjected to both CIR and HMA overlay (figure 128), maintenance costs were moderate for eight out of the nine projects evaluated. The information presented is reasonable, as the projects subjected to AC overlays along with CIR are expected to require less maintenance.

CONCLUSIONS

The information presented throughout this report indicates that, for HMA pavements subjected to low to moderate levels of traffic, CIR (2 to 3 inch depth) is a viable pavement preservation strategy. Typically, such pavements added 10 years of service to the existing pavement with moderate levels of distress, adequate ride quality, and reasonable maintenance activities and cost.

Combining CIR with 2- to 3-inch-thick AC overlays gives greater assurance of adequate performance and reduces the likelihood of premature failure.

In general, there were not enough performance data available to evaluate the effectiveness of CIR alone or CIR and HMA overlays after 10 years of service.

Future monitoring of the projects evaluated in this study will provide greater insight into the medium- and long-term performance of CIR, and is highly recommended.

REFERENCES

1. Muench, S.T., J.P. Mahoney, and L.M. Pierce, WSDOT *Pavement Guide Interactive*. Washington State Department of Transportation, Web Document—(http://www.asphaltwa.com/wapa_web/modules/02_pavement_types/02_recycled_hma.htm#cipr).

2. Asphalt Pavement Alliance (APA), "Recycling of Asphalt Pavement," Web Document—www.AsphaltAlliance.com.

3. American Association of State Highway and Transportation Officials (AASHTO), *Task Force 38 Report - Report on Cold Recycling of Asphalt Pavements*, AASHTO, Washington, DC, 1998.

4. Von Quintus, H.L., and J. Mallela, "Reducing Flexible Pavement Distress in Colorado Through the Use of PMA Mixtures," Final Report No. 16729.1/1, Colorado Asphalt Pavement Association (CAPA), Englewood, Colorado, 2005.

APPENDIX A. SPECIFICATION FOR HIGH-FLOAT EMULSION (HFE)

PROPERTY/TEST	TEST REQUIREMENT	
	HFE 150-P	HFE 300-P
Viscosity, Saybolt Furol, seconds @ 50°C (AASHTO T 59)	50 - 400	50 - 400
Sieve Retained on 850µm, maximum (AASHTO T 59)	0.1	0.1
Storage Stability, 1 day, % maximum (AASHTO T 59)	1	1
Residue from Distillation to 204°C, % minimum (AASHTO T 59)	65	65
Oil Distillate by Volume of Emulsion, % maximum (AASHTO T 59)	7.5	7.0
Penetration, 25°C, 100 gm, 5 sec (AASHTO T 59)	150 - 300	300+
Float Test @ 60°C, seconds, minimum (AASHTO T 50)	1,200	1,200
Ductility @ 25°C, 5 cm/min, cm/min (AASHTO T 51)	100	N/A
Tensile Stress @ 4°C, 50 cm/min, 800% elongation, kg/cm^2, minimum (ASTM D 412)	1.0	0.05

APPENDIX B. SPECIFICATION FOR CYCLOGEN® ME

PROPERTY/TEST	TEST REQUIREMENT
Viscosity @ 25°C, SFS (ASTM D 244)	15 - 85
Pumping Stability (Golden Bear (GB) method using a Roper gear pump or equivalent[1]))	Pass
Emulsion Coarseness, % by weight, maximum (Sieve test, ASTM D 244)	0.1
Sensitivity to Fines, % by weight, maximum (Cement mixing, ASTM D 244)	2.0
Particle Charge (ASTM D 244)	Positive
Concentration of Oil Phase, % by weight, minimum (ASTM D 244 modified)	60

1 Pumping stability is determined by charging 450 ml of emulsion into a one-liter beaker and circulating the emulsion through a gear pump (e.g., Roper 29 B22621) having a 6 mm inlet and outlet. The emulsion passes if there is no significant oil separation after circulating ten minutes.