Maintaining Flexible Pavements—The Long Term Pavement Performance Experiment SPS-3 5-Year Data Analysis

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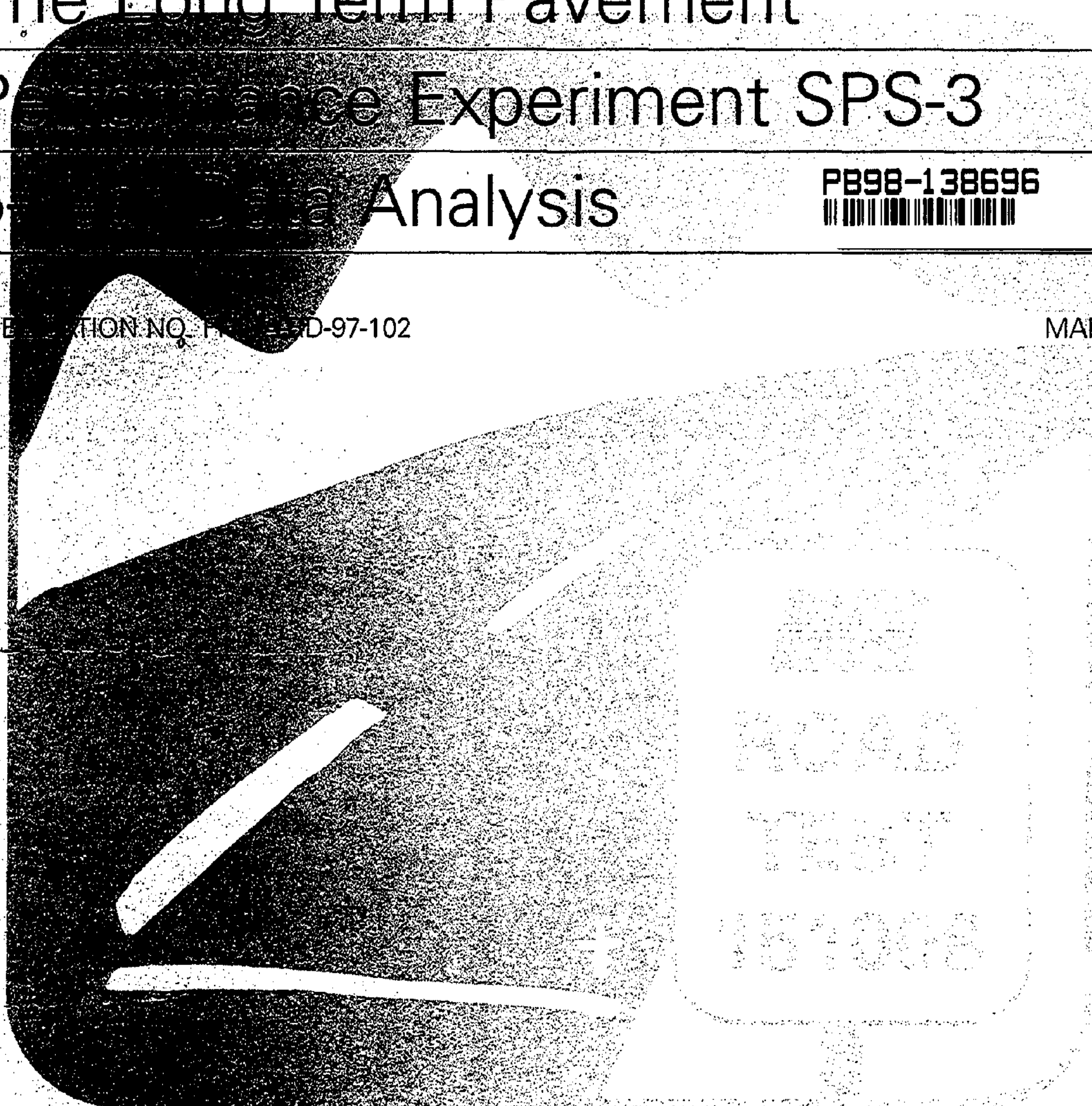

U.S. Department of Transportation
Federal Highway Administration

Research and Development
Turner-Fairbank Highway Research Center
6300 Georgetown Pike
McLean, VA 22101-2296

LTPP

FOREWORD

During the conduct of the Strategic Highway Research Program (SHRP) on highway operations, flexible and rigid pavement preventive maintenance treatments were placed on pavements in the United States and Canada. The placement and performance monitoring of these Specific Pavement Studies (SPS-3 and SPS-4) has been conducted under the SHRP and Federal Highway Administration (FHWA) Long-Term Pavement Performance Program (LTPP).

Field performance reviews of the preventive maintenance treatments have also been conducted by Expert Task Groups (ETG) organized by the Pavement Division of the FHWA. The ETG performance surveys conducted after 5 years of service, along with the assessment of available surface monitoring data from the LTPP data base, are evaluated in order to provide performance information and guidance to public agencies utilizing preventive maintenance techniques.

This report is prepared for the FHWA-sponsored study titled "Pavement Maintenance Effectiveness on SHRP Experimental Pavement Sections" and conducted for the Long-Term Pavement Performance and Pavement Divisions of the FHWA.

Charles J. Nemmers, P.E.
Director
Office of Engineering Research and Development

NOTICE

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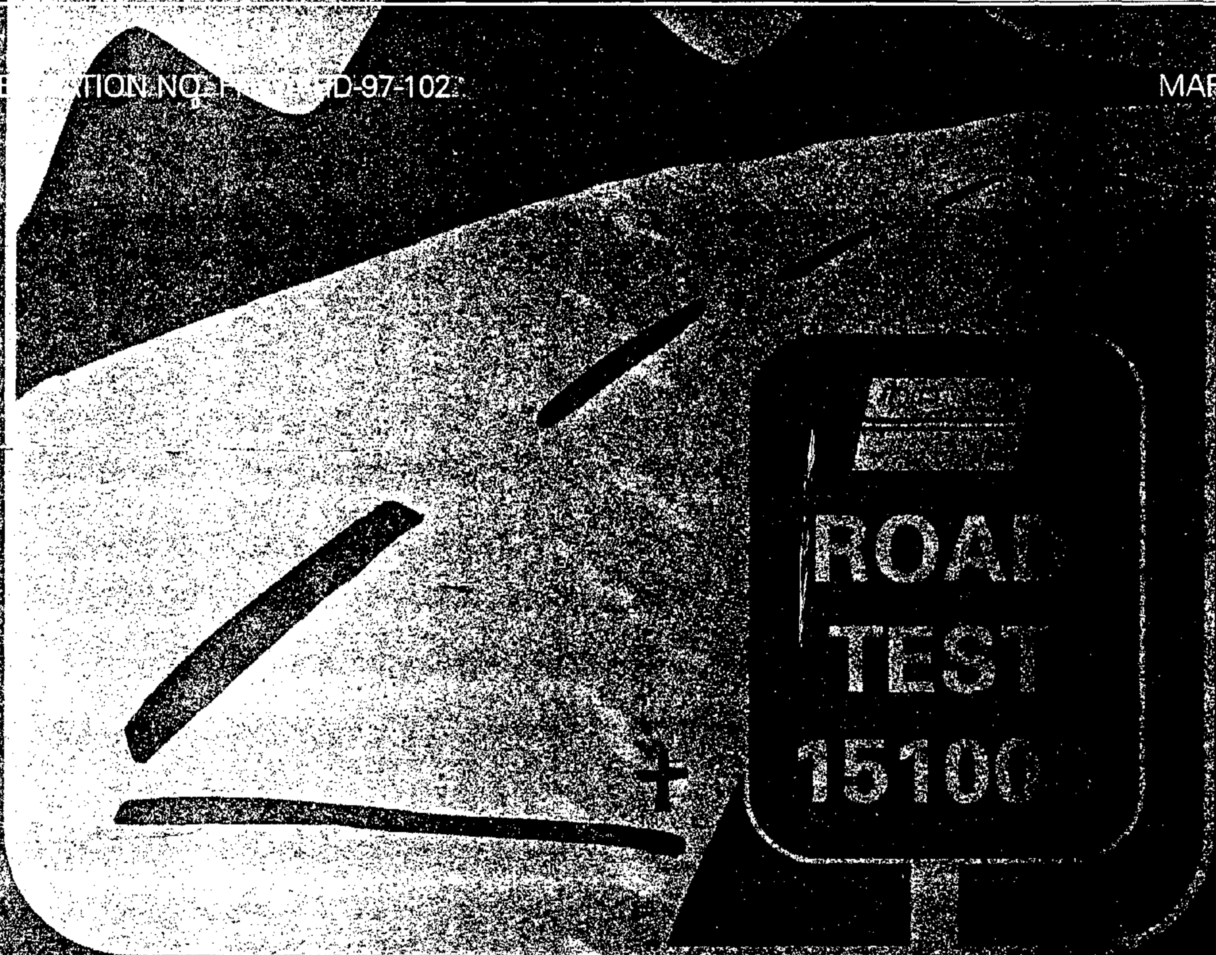

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Technical Report Documentation Page

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16. Abstract The Strategic Highway Research Program developed and coordinated construction of test sections for flexible pavement maintenance throughout the United States and Canada. Test sites included specific test sections for evaluation of the performance of crack sealing, slurry seals, chip seals, and thin hot-mix overlays as maintenance treatments. Each site also included an untreated control section.

This report discusses the project background and analysis of monitoring data collected over a 5-year period by the Long Term Pavement Performance project at SPS-3 sites throughout the United States and Canada. The analysis considers three important characteristics of the maintenance treatments: treatment performance, timing of application, and cost-effectiveness. In addition to data analysis results, the report conclusions include information from "Pavement Treatment Effectiveness, 1995 SPS-3 and SPS-4 Site Evaluations, National Report," May 1997.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
NOTE: Volumes greater than 1000 l shall be shown in m^3.				
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9 or (F-32)/1.8	Celcius temperature	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.71	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celcius temperature	1.8C + 32	Fahrenheit temperature	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
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.

(Revised September 1993)

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INTRODUCTION

Pavement maintenance operations can be conveniently grouped into two categories, corrective and preventive. Corrective pavement maintenance operations, including patching, are performed to restore distressed areas to an acceptable condition. Preventive maintenance operations are applied to pavement surfaces to prevent the development of damage or to reduce the rate of damage developed.[1] Preventive maintenance operations are intended to preserve rather than improve the structural capacity of the pavement.[2] Preventive maintenance operations for flexible pavements are the subject of this report.

Several preventive maintenance operations are available for treatment of asphalt-surfaced pavements. Typical asphalt pavement preventive maintenance treatments include thin hot-mix overlays, slurry seals, chip seals, fog seals, and crack sealing. The selection of an appropriate preventive maintenance treatment is generally made based on the experience of the maintenance supervisor or engineer with responsibility for a region of the roadways within a public agency. This decision is often made without documentation, which clearly defines the appropriate treatment, when the treatment should be applied during the life of the roadway, and the life expectancy of the treatment.

Since billions of dollars are expended for pavement reconstruction, rehabilitation, and maintenance, and since the optimization of the selection of the treatment type could result in substantial savings, a portion of the Strategic Highway Research Program (SHRP) was devoted to the study of preventive pavement maintenance activities for both asphalt and portland cement concrete surfaced roadways.[3] This preventive maintenance program was performed as part of the project H-101, "Pavement Maintenance Effectiveness," and the Long-Term Pavement Performance (LTPP) study. These studies were responsible for placing preventive pavement maintenance treatments on pavement sections throughout the United States and Canada beginning in 1990.

The performance of these sections (after 5 years of service) has been recently evaluated in the field by regional expert task groups assembled by the Federal Highway Administration (FHWA). The results of these surveys are summarized in this report, along with analysis of the LTPP monitoring data for the test sections. This report is intended to provide early performance information and guidance to the public agencies utilizing preventive pavement maintenance techniques.

BACKGROUND

SHRP and LTPP

This report is based on SHRP and LTPP research efforts. Background information on SHRP and LTPP is provided to add context to this study.

SHRP Program History

SHRP was created to support highly focused technical advances in highway research which would improve the way highway systems are operated and maintained. Initiated in 1987, the program provided funding over a 5-year period in four specific areas of research: Long-Term Pavement Performance, Concrete and Structures, Highway Operations and Asphalt Materials.[4]

LTPP Program History

Unlike the other program areas, the LTPP program was originally envisioned as continuing for 20 years, with the objective of collecting a full cycle of pavement performance data. Since the first 5 years of research, which were funded under SHRP, the LTPP program has continued under the oversight of the FHWA.

The LTPP program was developed to evaluate the long-term performance of pavements consisting of various material and layer compositions. Originally established as a 20-year project, LTPP has necessarily outlived the SHRP program funded under the Intermodal Surface Transportation Efficiency Act (ISTEA). Under the guidance of FHWA, the primary emphasis to date has been on data collection activities. Data analysis efforts have begun more recently.[5]

The Specific Pavement Studies (SPS) relating to maintenance activities (SPS-3 and SPS-4) were developed under the Highway Operations field and continued under the LTPP program. These two experiments were designed to evaluate the effectiveness of standard preventive pavement maintenance activities for asphalt (SPS-3) and portland cement concrete (SPS-4) surfaced pavements. A prior field review was conducted nationally in 1993 and even earlier in the Western region.[6] This report specifically addresses the SPS-3 experimental findings.

Study Objectives

Preventive pavement maintenance treatments selected for study under SHRP contract H-101 were placed under the LTPP Program as the specific pavement study SPS-3 for flexible pavements.

The purpose of the research experiment was identified as follows:

- To define the most effective timing for the application of various treatments.
- To evaluate the effectiveness of treatments in prolonging the life of the pavement.
- To share information and experience among highway agencies and industry.[7]

Preventive Pavement Maintenance Treatments

The flexible pavement preventive maintenance treatments studied included:

- Crack sealing.
- Slurry seal.
- Chip seal.
- Thin hot-mix asphalt overlay.

These preventive pavement maintenance treatments were selected to represent the most commonly used techniques, and the techniques most likely to be cost-effective. It intentionally did not include evaluation of more recently developed maintenance treatments such as microsurfacing. Individual agencies incorporated these types of treatments as supplemental study sites.

Concepts of Preventive Maintenance

As the demands on limited highway agency budgets continue to increase, it becomes more important to make the best use of available funds. Although traditional maintenance practices have focused on corrective maintenance activities, this approach no longer serves the needs of today's pavement agencies in terms of the level of pavement condition expected by the traveling public or in terms of managing highway agency budgets. Preventive maintenance offers a way for agencies to work smarter.

Preventive maintenance is most simply described by the adage once used by the automotive industry for an engine oil filter advertising campaign: "pay me now or pay me later." This adage applies to the automotive industry, as well as to the highway industry. This notion of performing maintenance before serious problems occur, as applied to pavements, not only increases the expected performance period, but it also saves money in the long-term cost of a highway facility. By using preventive maintenance practices, a higher level of service is retained, and a smaller investment in maintenance is made earlier — before extensive change to the highway occurs (paying now). The highway does not have to reach a minimal service level before funds are invested in maintenance activities (paying later).

As agencies have developed and implemented pavement management systems, it has become evident that the monetary requirements for retaining the condition of the vast, but aging highway network within the United States are huge and growing. As demands on tax funds are sought for other uses, the portion devoted to highways becomes difficult to maintain, even without considering an increase in highway needs. These two factors make the highway agencies' task of providing safe, effective highways at a reasonable cost more difficult than ever.

Figure 1 illustrates an example of the preventive maintenance concept. Assuming a fixed initial investment in a section of pavement, both the long-term condition level and the total investment in preserving the pavement benefit from a preventive maintenance strategy, rather

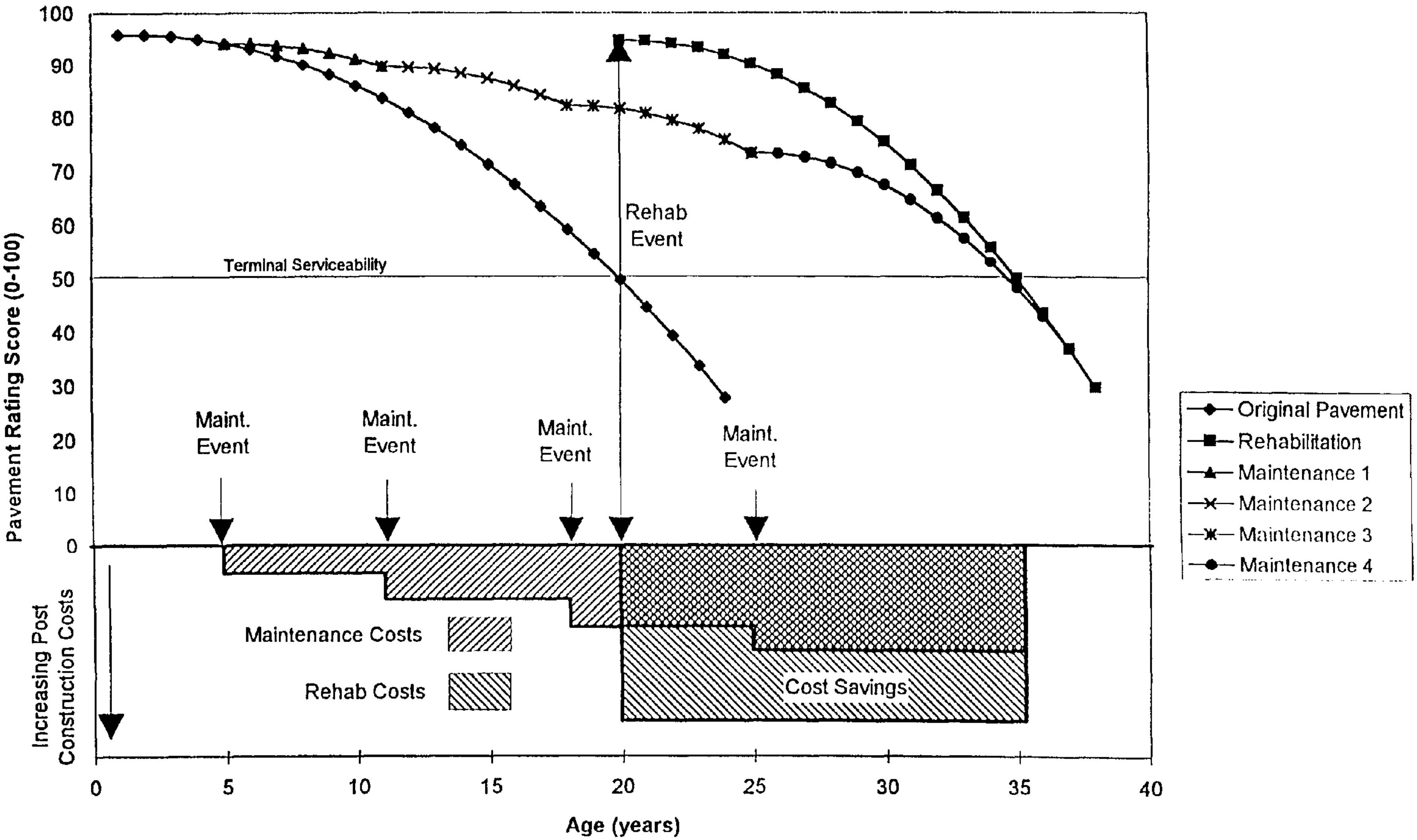

Figure 1. Performance curves and relative costs illustrating the preventive maintenance concept.

than a corrective approach. In the example, a better pavement condition is maintained by the early application of the preventive maintenance treatment, than by waiting to perform corrective maintenance or rehabilitation. At the same time, the cumulative investment in that section of pavement is lower over the total pavement life. Highway agencies, by using pavement management systems, provide the opportunity to capture the actual local performance and cost data needed to quantify the benefits of preventive maintenance.

Agencies are cautious in deciding to adopt a preventive maintenance strategy, since this strategy does not result in more available funding or immediately lessen needs for those funds. But over time it will enable an agency to "do more with less." In the short term, however, limited maintenance funds will be applied to pavements in better condition, while reports for some pavements in poorer condition are postponed. The public may perceive that scarce funding is not being wisely utilized. Unless a proactive approach is taken by highway agencies to educate the general public of the benefits of converting to a preventive maintenance strategy, significant criticism may be encountered. The automotive industry has achieved some degree of success in selling the "pay me now or pay me later" concept; why not the highway industry? The agencies and the public want highway conditions to improve and to maintain demands on available highway funds.

One of the primary objectives of this study has been to investigate the validity of the preventive maintenance theory. The section which discusses the relative benefit found in applying the SHRP maintenance treatments, while pavements are still in relatively good condition, illustrates the practicality of adopting a preventive maintenance strategy. While some transition period may be needed for agencies to complete the conversion to a preventive maintenance strategy, the message that it is in our collective best interest to do so is clear.

Purpose of Maintenance Treatments

Maintenance treatments are used for several reasons. Two primary reasons for using maintenance treatments are to seal cracks in the pavement and to arrest oxidation aging. Sealing cracks keeps moisture out of the pavement base and subgrade layers, thereby maintaining uniform support and load-carrying capacity. Arresting oxidation aging avoids embrittlement of the asphalt surface and the progressive development of further cracking. Other reasons include the enhancement of pavement friction, lane delineation, and correction of rutting in the case of thin overlay treatments and special applications of slurry seals.

This report will assess the success of the various treatments studied in the SPS-3 experiment in accomplishing these objectives.

Field Experiment for Flexible Pavements

Experiment Design

The field experiment was designed in 1987 by the Texas Transportation Institute to evaluate the effectiveness of the various preventive maintenance treatments.[1] The main variables in the experiment design for asphalt pavements were climate (wet-no freeze, wet-freeze, dry-no freeze, dry-freeze), subgrade type (fine and coarse grained), traffic volume (low and high), pavement condition (good, fair and poor), and structural capacity (adequate and inadequate). A total of 96 test sites were desired for the asphalt pavement preventive maintenance study. A total of 81 SPS-3 sites, consisting of 486 test sections, were actually placed in the United States and Canada in 1990 and 1991 (figure 2).

Placement of Sections

The logistical effort required to construct this experiment across the many participating States and provinces was quite extensive. Regional Expert Task Groups assembled to develop specifications for site construction. They also assisted in coordinating the construction process.

A construction contract was developed in each region to accomplish the actual construction. These contracts were administered by the Federal Highway Administration Eastern Federal Lands Highway Division for the Southern and North Atlantic regions, Central Federal Lands Highway Division for the North Central region, and Western Federal Lands Highway Division for the Western region. A single construction contractor was selected for site construction in each region.

To reduce construction and material variability on the flexible pavement sections, the same materials placement crews and placement supervision were used throughout each of the four LTPP regions of the United States and Canada for the slurry seals and chip seals. The crack sealing material and crews were also the same in each of the regions; however, the crack sealing installation procedure differed. Construction specifications are provided in appendixes A through D. Also, since each agency provided the thin overlays, a different hot-mix asphalt and placement crew were used for the thin overlay sections at each site. The test sites were placed in 1990 and 1991.

The project study team attempted to incorporate material properties from the actual construction materials used in constructing the SPS-3 sections. After diligent effort, it was concluded that this effort could not be included as an element of this report. The materials information exist at the regional offices. It consists of a large volume of paper data collection forms, much of which has been archived, and is not readily obtainable. Therefore, we have included available information on the materials used, and a sample of the SHRP field data collection forms in appendixes E and F. These provide an indication of the types of data which should be available by contacting LTPP regional contracting offices.

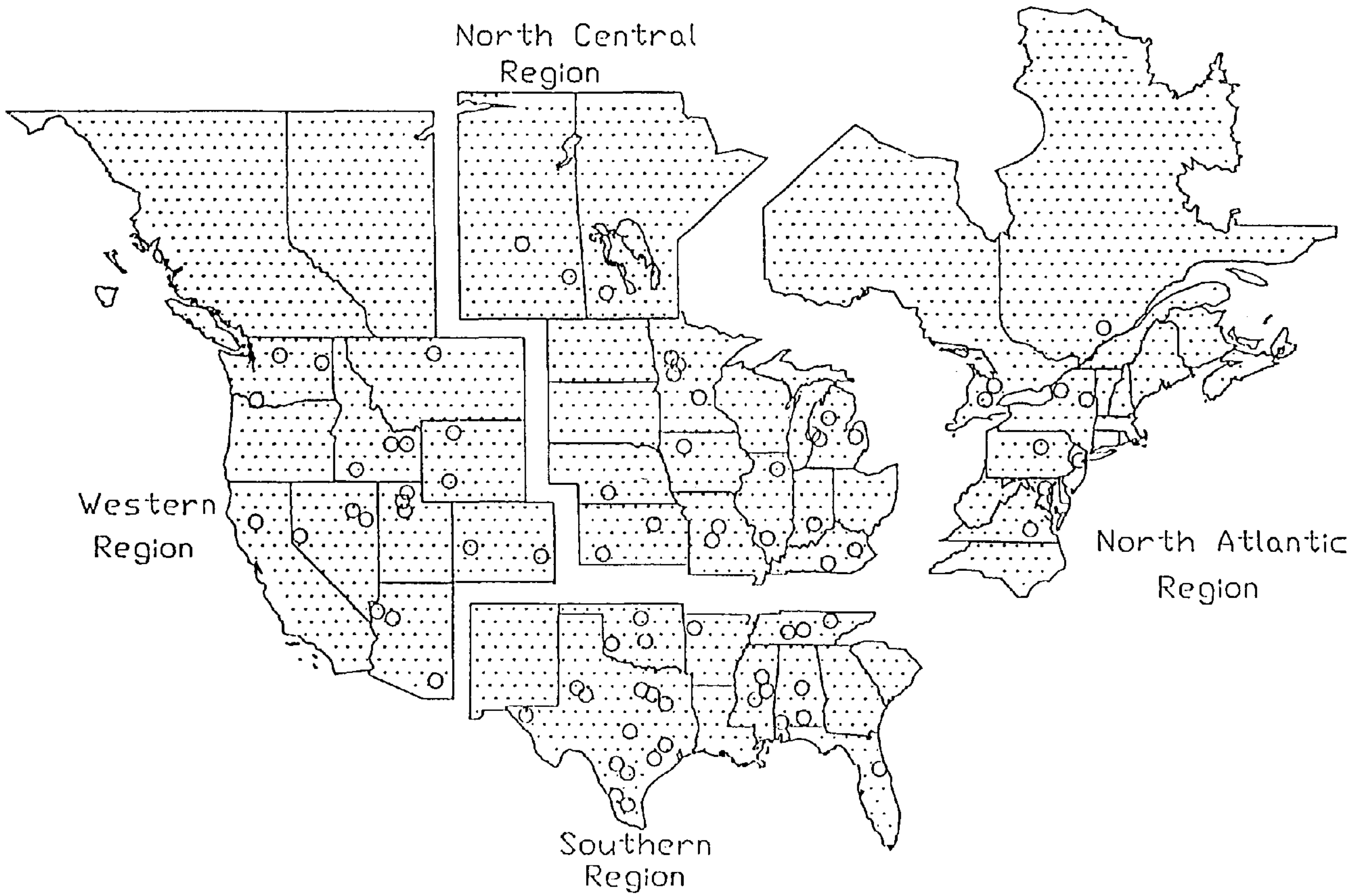

Figure 2. SPS-3 sites placed in the United States and Canada in 1990 and 1991.

State Supplemental Studies

Since the experiment did not vary binder type, aggregate type or design quantities (except by region), and since other types of preventive maintenance treatments were not included, several agencies placed "supplemental" sections to study some of these variables. State supplemental sections included such treatment variations as rubber modified chip seals and thin overlays. These special State studies located adjacent to the standard sites reviewed in the field are included in the SPS-3 LTPP evaluation presented in this report.

Status of Test Sections

As of the 1996 construction season, 100 SPS-3 sections have gone out of service since the original construction. A detailed description of these sections, along with the reason the sections were lost to the experiment, is provided in "Pavement Treatment Effectiveness," 1995, SPS-3 and SPS-4 Site Evaluations, National Report.[8] Problems, including treatment failure during construction, the development of excessive distress, and safety concerns, have resulted in a number of sections no longer being available to the experiment. Section performance evaluated in this report is based on both the 58 SPS-3 sites reviewed in the field during the summer and fall of 1995 by the regional ETGs and data available in the LTPP data base. The site data from the regional tours, found in appendix G, represent only those sections which are still active, and which were evaluated in the field.

A list of those sections which have gone out of service can be found in the trip report, also included in appendix G.

SPS-3 Data Analysis

The performance of each of the SPS-3 sites has been evaluated under the LTPP Program and by an Expert Task Group (ETG) for each LTPP region as previously discussed. The LTPP Program evaluated the condition of the pavement before the preventive maintenance treatment was applied and at regular intervals, after the treatment was applied. The evaluation tools used as part of the LTPP effort include the following:

- Manual distress surveys using the SHRP distress identification manual.
- Distress surveys conducted from film logs taken by the PASCO device.
- Deflection using the Falling Weight Deflectometer.
- Ride quality or longitudinal profile using the K.J. Law type profilometer.
- Rut depth using PASCO data and the Dipstick.
- Friction number as collected and submitted to LTPP by individual agencies.

The frequency of these measurements is typically on a biennial basis. The information from the LTPP data files has been analyzed under contract to the FHWA.

Report Organization

The products of this study are organized into several independent components: this main report which documents findings, conclusions, and recommendations; stand-alone appendixes containing additional supporting documentation; and a CD-ROM data base containing all data related to the projects, as well as some analysis data.

The products of this study must clearly communicate to the pavement community the benefits of preventive maintenance, the selection of alternative maintenance strategies, and effective application practices. A large quantity of highly variable data was evaluated in the course of this project. This project is among the first to deal intensively with data supplied from the SHRP/LTPP data base and the efforts used here to draw conclusions from this data source may be of use to others dealing with this process. The final report, therefore, will consist of several stand-alone documents:

- SPS-3 Final Report, Results and Conclusions: This document will clearly summarize the findings of the both the field evaluation tours and the LTPP performance data analysis. The report includes some appendixes in full, and indicates the contents and format of the remaining appendixes.

- Stand-Alone Appendixes: The appendixes contain analyses that are crucial as supporting and backup documentation, but are of limited interest to agency maintenance practitioners.

- CD-ROM - A Microsoft Access™ data base containing tables of data used in the analysis and original files from the LTPP data base. A macro has also been developed within this data base that can be used to plot some types of performance data from individual sites. Operating procedures are provided on the CD, and briefly described in appendix H. The CD-ROM also includes spreadsheet tables of data used in the analyses of this report.

EXPERT TASK GROUP FIELD REVIEWS

The first phase of the study was to conduct four ETG field evaluations of the test sections. The Expert Task Groups are composed of highway agency practitioners, industry representatives and academics representatives, and are organized on a LTPP regional basis to perform SPS-3 and SPS-4 site evaluations. The Western region ETG conducted site reviews in 1991 and 1992. All four LTPP regions conducted evaluations in 1993. A summary report from the 1993 site reviews is available.(7)

The four LTPP regions conducted site reviews again in 1995. The results of these reviews, together with an analysis of the data collected during the tours and supporting the conclusions below, were presented in a national report which is included in its entirety as appendix G.

TOUR CONCLUSIONS

Information from the ETG reviews indicated that the ***crack seal*** treatment performed best when a wide, shallow reservoir was prepared and filled with sealant. The treatment seemed to improve pavement performance when compared with adjacent untreated control pavement test sections. The crack seal treatment was observed to provide the most benefit when applied to pavements still in good condition.

When compared with the control sections, the ***slurry seal*** treatment was observed to have performed best in the no freeze climatic zones (the southeast and southwest). The slurry seal was also seen to provide the most benefit when applied to pavements in good condition (those with little initial distress). The greatest benefit from the slurry seal treatment was observed in the dry-no freeze climate, where it was observed to provide benefit to pavements at all condition levels.

When compared with the control sections, the ***chip seal*** treatment was observed to have performed well in all four climatic regions. The benefit received from placement of the chip seal was evident across all levels of pavement condition, except in the freeze climates, where it did not contribute significant benefit to poor pavement sections.

The ***thin overlay*** treated sections were observed to be performing well, improving the condition of the test section pavements relative to the control sections. The benefit received from the thin overlay treatment was evident in all four climatic regions, and at all levels of pavement condition.

The overall performance of State supplemental sections was not very different from that of the standard SHRP treatment sections. In any specific treatment category, about as many supplemental sites performed better than the adjacent standard treatment as performed the same or worse. No dramatic differences in performance exist in most cases. Individual sites should be evaluated on their own merit. In this manner, agencies can identify those supplemental sections they believe are worthy of further investment.

SUMMARY OF INDIVIDUAL DISTRESS RATINGS BASED ON ETG REVIEWS

The ETG groups also completed a field data sheet rating the treatment sections in terms of certain individual distress types (appendix G). These performance ratings were collected in hopes of providing more in depth information about the performance or failure mechanisms of the maintenance treatments. Certain trends were evident even though there was a mixture of ratings. The detailed distresses monitored include longitudinal, transverse, and fatigue cracking, along with bleeding, raveling, and snow plow damage. The ratings for each section can also be found in appendix G.

Analysis of this data reveals that after 5 years of field performance, the ETGs observed the treatments to have reduced the presence of cracking. The best performance in this respect is observed for the thin overlay and chip seal sections. The crack seal treatment does not show significant improvement with respect to cracking distress, except in the North Atlantic and North Central Region where the wide shallow routed sealant reservoir was used. The Southern region did not route cracks at all, but used an overband design. The interpretation of crack sealed section data is unclear since neither the manual nor the LTPP PASCO distress survey distinguishes between sealed and unsealed cracks. (Sealed cracks are recorded as low severity.)

With respect to the other distress types--bleeding, raveling, and snow plow damage--more disparity in the ETG ratings was found. Each treatment was observed to affect these distresses differently. The crack seal treatment was observed to have a positive effect on only pavement raveling. The exclusion of water from pavement cracks seems to have retarded the surface raveling process. Microcracking resulting from the presence of water in cracks has been reduced by sealing the cracks. Snow plow damage and bleeding were not affected. The slurry seal treatment indicated some improvement in the presence of raveling, with no real change relative to the other two distresses. The chip seal treatment was visually rated as having more occurrences of all three types of distress than the control sections. This likely resulted from the different appearance of a chip seal surface from a hot-mix asphalt surface. The ETG observations indicated that the chip seal treatment did improve the raveling condition in about one-third of the sections. The thin overlay treatment improved the pavement condition with respect to all three of these distresses. The greatest improvement was in reducing raveling, and the least in reducing snow plow damage.

LTPP DATA BASE ANALYSIS

REGRESSION MODELS OF TREATMENT PERFORMANCE

An attempt was made to model treatment performance using multiple regression techniques. Factors from the original experiment matrix (figure 3), were used in an attempt to evaluate their contribution to treatment performance. Modifications were made to some of the original criteria such as traffic and initial condition. Initial condition was based on pavement rating score (PRS), as described in appendix I, and traffic was evaluated at three levels instead of the original two. These factors or independent variables were:

- Age (years).
- Original pavement condition level (good, fair, and poor).
- Traffic level (high, medium, low).
- Pavement structural adequacy (structural number ratio either greater than or less than one).[1]
- Climatic zone.
- Subgrade type (fine versus coarse).

Although age was not a direct component of the original experimental matrix, it was included as an independent variable in the regression analysis to allow for an evaluation of the performance of the treatment over time.

Dependent variables used in the regression analysis were:

- Pavement rating score (PRS).
- Total longitudinal cracking.
- Total transverse cracking.
- Total fatigue cracking.
- Pavement rutting.
- Pavement profile.
- Pavement friction.

Construction and material quality were not included in the regression analysis, since they were not factors in the experiment design. An attempt was made to eliminate variability from these sources by limiting contractor and material sources.

Although based on highly variable data which affects significance levels, very good relationships were developed using the data resulting from the PRS concept. It was hoped that these results could be approached using multiple regression techniques. The analysis approach was

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[1]Structure number ratio is defined as the actual structural number of the test section divided by structural number requirements to carry the section traffic volume.

Cell Number — 18 — 991001 — SHRP ID

CONDITION	SN RATIO	DRY							
	MOISTURE	DRY							
	TEMPERATURE	FREEZE				NO-FREEZE			
	SUBGRADE	FINE		COARSE		FINE		COARSE	
	TRAFFIC	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH
G	≤1	49: 201010 311030	55	61: 491006	67	73: 403749 489005	79: 481122 482172	85	91
G	>1	50: 161020 831801	56: 81053	62: 161010	68: 531008	74: 61253	80	86: 483769 481094	92: 41021
F	≤1	51: 82008	57	63	69	75: 404087	81: 483865	87	93: 483739
F	>1	52	58	64	70	76	82	88	94
P	≤1	53: 321021 567775	59: 322027 906405 901802	65: 491004	71	77	83	89	95
P	>1	54: 201005 301001	60	66: 481017 531501 561007	72: 161021 327000	78: 41036	84	90: 41017	96: 41016 481183

Cell Number — 18 — 991001 — SHRP ID

CONDITION	SN RATIO	WET							
	MOISTURE	WET							
	TEMPERATURE	FREEZE				NO-FREEZE			
	SUBGRADE	FINE		COARSE		FINE		COARSE	
	TRAFFIC	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH
G	≤1	1: 171003 211034 361644	7: 171002 871620	13	19	25: 483559	31: 53071 481050	37: 281802 14155	43: 14125
G	>1	2: 421597	8	14: 211010 241634 261001	20: 511023	26	32	38: 473075 481169	44: 11019
F	≤1	3: 261010 291002	9: 181028 196150	15: 361643	21	27: 401015 483579	33: 471023	39	45
F	>1	4: 261012	10: 891021	16	22: 261013	28	34	40	46: 129054
P	≤1	5: 291005	11	17: 271016	23: 871622	29: 473101	35: 404088 481069	41	47: 123997 124154
P	>1	6: 276251	12: 421605	18: 271019	24: 271028	30	36	42: 531801	48

Figure 3. Experimental design for treatments applied to flexible pavements.

to create models at different data levels. It was expected that the models would improve at each succeeding level. The first level was to develop models for each treatment using all of the six independent variables above. The next attempt was to narrow the focus to each treatment by environmental zone, and then each treatment by environmental zone and initial condition.

A series of regression models was developed to identify the significance of the various factors on the performance of the maintenance treatment sections. These regressions were based on the dependent and independent variables discussed above. Table 1 shows the dummy variable codes used to represent the different levels of some of the variables, as required by the analysis technique. The dummy variables used were non-zero integers ranked from the worst or most severe case, to the best, or least severe case. For example, the initial condition levels of poor, fair, and good are represented by 1, 2, and 3, respectively, with poor initial condition being the most severe case. Using this approach, each component of the model would theoretically generate a positively sloped curve.

Although the analysis did not result in the development of reliable models, some important and consistent trends emerged. Tables 2 through 6 show some of the statistics from the multiple regression and ANOVA analysis for the thin overlay treatment. The figures show the F-ratio and P-value statistics for each independent variable in the models created for the different dependent variables. The R-squared statistic for each model is also shown. The P-value indicates whether a variable is a significant contributor to the model at a certain confidence level. A P-value greater than 0.1, for example, indicates that a variable is not significant at a 90 percent confidence level. The F-ratio is a variance measure that also indicates whether a variable is contributing to the model. In this analysis, an F-ratio less than 4.0 means that a variable is not significant and the model can be simplified, or improved, by removing that variable. The R-squared statistic, of course, indicates how much of the variation in the data is explained by the model. Table 7 demonstrates the final models developed.

The tables demonstrate the strongest trends revealed by the multiple regression analysis. As can be seen, environmental zone, age and initial condition are the most consistent significant contributors to the various models. The combining index, PRS, also consistently shows the highest or next highest R-squared value among the dependent variables. These trends are consistent with those obtained from the PRS analysis.

The independent variable, age, deserves some attention, because it embodies and combines three of the other variables: traffic, structural adequacy, and subgrade type. The inconsistency in the significance of these variables is attributable to their representation as two and three level variables.

Results of the regression analysis are discussed throughout this report in the individual sections appropriate to the variable.

Table 1. Independent variables and dummy codes used in multiple regression analysis.

Treatment Type (Trt)	
Control	1
Crack	2
Slurry	3
Chip	4
Thin Overlay	5
Environmental Zone	
Wet-Freeze	1
Dry-Freeze	2
Wet-No Freeze	3
Dry-No Freeze	4
Age Range (Age)	
0 - 0.7 years	5
0.7 - 1.4 years	4
1.4 - 2.5 years	3
2.5 - 4.5 years	2
4.5 years - present	1
Initial or Pretreatment Condition (IC)	
Poor	1
Fair	2
Good	3
Traffic Level (Traf)	
High	1
Medium	2
Low	3
Structural Adequacy (SA)	
< = 1	1
> 1	2
Subgrade (SG)	
Fine	1
Coarse	2

Table 2. Multiple regression analysis for crack seal treatment.

Independent Variables	Pavement Rating Score F-Ratio	Pavement Rating Score P-Value	Total Longitudinal Cracking F-Ratio	Total Longitudinal Cracking P-Value	Total Transverse Cracking F-Ratio	Total Transverse Cracking P-Value	Total Fatigue Cracking F-Ratio	Total Fatigue Cracking P-Value
Environmental Zone	15.80	0.02	14.12	0.00	20.75	0.00	0.35	0.34
Age	83.83	0.00	0.01	0.74	1.74	0.12	18.29	0.00
Initial Condition	58.66	0.00	4.79	0.09	24.94	0.00	22.91	0.00
Traffic Level	1.80	0.30	9.24	0.00	0.29	0.59	1.07	0.27
Structural Adequacy	1.90	0.26	11.07	0.00	0.22	0.97	0.86	0.38
Subgrade Type	0.09	0.77	0.03	0.86	1.15	0.28	15.86	0.00
R^2 for Model (%)	31.47		9.96		12.15		14.32	

	IRI Roughness F-Ratio	IRI Roughness P-Value	Friction Number F-Ratio	Friction Number P-Value	Rutting F-Ratio	Rutting P-Value
Environmental Zone	0.89	0.58	19.69	0.00	0.60	0.14
Age	4.29	0.03	0.39	0.33	0.95	0.48
Initial Condition	29.80	0.00	13.25	0.00	2.03	0.20
Traffic Level	2.37	0.21	1.24	0.33	8.39	0.00
Structural Adequacy	0.82	0.45	1.51	0.99	0.07	0.56
Subgrade Type	0.11	0.74	3.88	0.05	0.62	0.43
R^2 for Model (%)	10.99		22.70		6.54	

Table 3. Multiple regression analysis for slurry seal treatment.

Independent Variables	Pavement Rating Score F-Ratio	Pavement Rating Score P-Value	Total Longitudinal Cracking F-Ratio	Total Longitudinal Cracking P-Value	Total Transverse Cracking F-Ratio	Total Transverse Cracking P-Value	Total Fatigue Cracking F-Ratio	Total Fatigue Cracking P-Value
Environmental Zone	50.00	0.00	23.38	0.00	27.70	0.00	0.33	0.71
Age	98.05	0.00	6.99	0.00	8.72	0.00	38.40	0.00
Initial Condition	43.10	0.00	15.50	0.00	30.74	0.00	12.86	0.00
Traffic Level	0.86	0.39	0.47	0.42	5.64	0.00	0.09	0.89
Structural Adequacy	.20	0.97	0.29	0.51	6.77	0.00	1.47	0.60
Subgrade Type	0.60	0.44	0.16	0.69	1.32	0.25	1.46	0.23
R^2 for Model (%)	36.05		12.03		19.08		13.74	

	IRI Roughness F-Ratio	IRI Roughness P-Value	Friction Number F-Ratio	Friction Number P-Value	Rutting F-Ratio	Rutting P-Value
Environmental Zone	0.08	0.22	75.00	0.00	0.00	0.82
Age	10.60	0.00	2.96	0.09	0.12	0.80
Initial Condition	41.97	0.00	10.18	0.01	2.95	0.11
Traffic Level	4.01	0.11	9.60	0.00	1.85	0.14
Structural Adequacy	1.92	0.34	0.01	0.05	0.10	0.48
Subgrade Type	1.08	0.30	12.19	0.00	0.99	0.32
R^2 for Model (%)	16.01		42.13		3.25	

Table 4. Multiple regression analysis for chip seal treatment.

Independent Variables	Pavement Rating Score		Total Longitudinal Cracking		Total Transverse Cracking		Total Fatigue Cracking	
	F-Ratio	P-Value	F-Ratio	P-Value	F-Ratio	P-Value	F-Ratio	P-Value
Environmental Zone	13.07	0.07	27.03	0.00	25.66	0.00	5.53	0.00
Age	39.95	0.00	19.78	0.00	3.05	0.08	4.96	0.04
Initial Condition	37.12	0.00	12.65	0.00	9.60	0.00	12.27	0.00
Traffic Level	2.38	0.49	0.03	0.45	6.08	0.00	0.86	0.79
Structural Adequacy	2.57	0.00	2.41	0.02	2.25	0.04	4.44	0.02
Subgrade Type	18.85	0.00	5.18	0.02	2.69	0.10	0.91	0.34
R^2 for Model (%)	25.49		16.76		12.90		8.00	

	IRI Roughness		Friction Number		Rutting	
	F-Ratio	P-Value	F-Ratio	P-Value	F-Ratio	P-Value
Environmental Zone	0.09	0.84	33.82	0.00	0.09	0.59
Age	7.70	0.00	35.65	0.00	0.25	0.74
Initial Condition	28.02	0.00	7.42	0.03	2.70	0.13
Traffic Level	1.70	0.20	16.58	0.00	11.89	0.00
Structural Adequacy	0.01	0.87	1.22	0.30	0.90	0.76
Subgrade Type	0.03	0.87	10.67	0.00	1.74	0.19
R^2 for Model (%)	10.93		42.08		9.12	

Table 5. Multiple regression analysis for thin overlay treatment.

Independent Variables	Pavement Rating Score		Total Longitudinal Cracking		Total Transverse Cracking		Total Fatigue Cracking	
	F-Ratio	P-Value	F-Ratio	P-Value	F-Ratio	P-Value	F-Ratio	P-Value
Environmental Zone	14.43	0.00	24.94	0.00	17.13	0.01	1.96	0.05
Age	123.19	0.00	58.94	0.00	11.86	0.00	8.70	0.00
Initial Condition	13.31	0.00	1.78	0.17	39.40	0.00	3.53	0.03
Traffic Level	0.33	0.85	0.13	0.84	1.75	0.22	0.24	0.46
Structural Adequacy	4.64	0.56	0.81	0.77	0.38	0.90	1.12	0.15
Subgrade Type	9.99	0.00	1.42	0.23	2.51	0.11	1.16	0.28
R^2 for Model (%)	33.04		21.68		18.67		4.99	

	IRI Roughness		Friction Number		Rutting	
	F-Ratio	P-Value	F-Ratio	P-Value	F-Ratio	P-Value
Environmental Zone	2.57	0.06	1.66	0.71	0.23	0.64
Age	6.43	0.01	1.58	0.52	0.54	0.49
Initial Condition	6.48	0.01	9.05	0.00	0.01	0.93
Traffic Level	0.01	0.80	1.18	0.30	0.00	0.98
Structural Adequacy	0.23	0.73	1.02	0.36	0.00	0.68
Subgrade Type	0.15	0.70	11.56	0.00	1.03	0.31
R^2 for Model (%)	4.98		15.23		1.01	

Table 6. Multiple regression analysis for control section.

Independent Variables	Pavement Rating Score F-Ratio	Pavement Rating Score P-Value	Total Longitudinal Cracking F-Ratio	Total Longitudinal Cracking P-Value	Total Transverse Cracking F-Ratio	Total Transverse Cracking P-Value	Total Fatigue Cracking F-Ratio	Total Fatigue Cracking P-Value
Environmental Zone	22.95	0.00	11.98	0.00	27.13	0.00	0.33	0.46
Age	53.44	0.00	0.95	0.20	2.03	0.14	17.49	0.00
Initial Condition	88.75	0.00	6.58	0.02	52.16	0.00	55.01	0.00
Traffic Level	4.11	0.05	1.20	0.11	0.38	0.25	0.37	0.52
Structural Adequacy	0.39	0.99	12.09	0.04	4.26	0.01	0.08	0.72
Subgrade Type	1.52	0.22	5.48	0.02	2.46	0.12	1.81	0.18
R^2 for Model (%)	31.80		9.42		19.37		16.95	

	IRI Roughness F-Ratio	IRI Roughness P-Value	Friction Number F-Ratio	Friction Number P-Value	Rutting F-Ratio	Rutting P-Value
Environmental Zone	0.20	0.50	12.57	0.00	1.58	0.16
Age	9.68	0.00	0.22	0.58	1.18	0.83
Initial Condition	21.74	0.00	16.64	0.00	2.42	0.16
Traffic Level	0.60	0.42	3.18	0.22	5.07	0.03
Structural Adequacy	0.44	0.31	1.91	0.98	0.00	0.54
Subgrade Type	1.40	0.24	5.14	0.03	1.61	0.21
R^2 for Model (%)	13.40		25.98		8.23	

Table 7. Regression models.

Model	Dependent Variable	=	Final Model (Form:C+a(Trt)+b(EZ)+c(Age)+d(IC)+e(Traf)+f(SA)+g(SG))	R^2	Standard Error of Estimate	n	Factors Removed from Model
All Data	Pavement Rating Score (PRS)	=	15.1033+4.12(Trt)+2.39(EZ)+5.91(Age)+10.21(IC)-2.41(SA)+4.10(SG)	32.45	18.68	1747	Traffic
	Longitudinal Cracking	=	246.06-14.86(Trt)-15.38(EZ)-8.36(Age)-18.25(IC)-6.40(Traf)-15.42(SG)	12.46	88.27	1751	Structural Adequacy
	Transverse Cracking	=	108.46-5.13(Trt)-6.62(EZ)-3.34(Age)-17.86(IC)+4.18(Traf)+7.90(SA)-6.78(SG)	16.17	40.79	1751	None
	Fatigue Cracking	=	98.94-7.86(Trt)+3.58(EZ)-8.89(Age)-19.93(IC)+9.59(SG)	12.14	58.77	1751	Traffic, Structure
	IRI	=	150.77-3.16(Trt)-4.74(Age)-13.98(IC)	10.19	36.52	1486	Subgrade, Structure, Traffic, Environment
	Friction	=	34.47+0.81(Trt)-1.07(EZ)+0.70(Age)+3.93(IC)+1.45(Traf)-3.73(SG)	12.83	8.98	724	Structure
	Rutting	=	13.89-0.85(Trt)-0.65(IC)-0.85(Traf)	10.15	4.11	866	Structure, Age Range, Environment, Subgrade
Thin Overlay	Pavement Rating Score (PRS)	=	43.3476+1.88071(EZ)+6.137(Age)+4.37(IC)+6.122(SG)	33.53	14.4	324	Traffic, Structure
Slurry Seal	Pavement Rating Score (PRS)	=	23.426+4.42829(EZ)+6.92985(Age)+9.43464(IC)	36.11	18.1	348	Structure, Traffic, Subgrade
Crack Seal	Pavement Rating Score (PRS)	=	26.7872+6.54727(Age)+11.23(IC)	30.58	18.08	359	Subgrade, Traffic, Structure, Environment
Control	Pavement Rating Score (PRS)	=	-1.48418+3.09(EZ)+5.89(Age)+15.8(IC)+3.317(Traf)	31.36	21.9	373	Structure, Subgrade
Chip Seal	Pavement Rating Score (PRS)	=	45.26+4.37(Age)+9.79(IC)-9.21(SA)+10.43(SG)	24.78	18.17	339	Traffic, Environment
Dry-Freeze	Pavement Rating Score (PRS)	=	-2.90+2.67(Trt)+8.14(Age)+11.38(IC)+9.96(SA)	36.52	19.43	414	Subgrade, Traffic
Dry-No Freeze	Pavement Rating Score (PRS)	=	28.19+3.15(Trt)+4.35(Age)+14.64(IC)-11.34(SA)+6.30(SG)	41.23	16.44	295	Traffic
Wet-Freeze	Pavement Rating Score (PRS)	=	-12.83+5.18(Trt)+7.99(Age)+9.54(IC)+4.57(Traf)+10.96(SG)	39.63	18.93	546	Structure
Wet-No Freeze	Pavement Rating Score (PRS)	=	43.51+4.57(Trt)+2.81(Age)+9.15(IC)+2.93(Traf)-6.13(SG)	33.44	14.58	489	Structure

DISTRESS ANALYSIS

Distress was viewed as the most critical aspect of the performance analysis of the preventive maintenance treatments. If carrying or distributing load is the primary function of a pavement, the secondary function is protecting the underlying layers from the infiltration of water and erosion. Cracking is the inevitable phenomenon by which this secondary function is undermined. It is the function of a maintenance treatment to offset the detrimental effects of cracking by sealing the crack itself, as well as the pavement surface. This prevents or decreases the infiltration of water and incompressibles into the cracks and subsequent loss of supporting material out of the crack. Maintenance treatments also reduce the rate of future cracking by slowing the pavement aging process. Untended cracks are a major contributor to pavement deterioration and consume significant amounts of a pavement's performance life.

Distress Background

The distress data evaluated in this portion of the study were obtained from the Regional Information Management Systems (RIMS) of the four LTPP regions. This data has been collected on General Pavement Studies (GPS) sections since 1988 and in fact, the GPS data were reviewed as a basis for selecting sites for the SPS-3 experiment.

It must be noted that there are several significant sources of differences in the distress data that explain some of the data variability. Among these are:

- Rater variability.
- PASCO versus manual methods.
- Weather and time of day effects.
- Seasonal effects.

Although distress criteria are clearly defined, subjective evaluation of distress data results in rater variability. The distress data used in this analysis is particularly subject to this because two different methods of distress data collection were used: manual and PASCO. The manual procedures were still under development at the beginning of this project and were not finalized until 1993. Consequently, the majority of initial distress data was gathered by the automated procedure.

Weather and time of day influence rater variability. Data collection activities varied from morning to evening on clear and overcast days. These factors influence the raters ability to perceive different types of cracks.

Seasonal effects can influence the extent, severity, and number of cracks that appear in pavement. Depending on the climate, some types of cracks heal themselves during the heat of summer. Conversely, cracks may increase in width and number during the winter. No control over which season the distress evaluations were made was possible, so subsequent ratings at one site may have varied from winter and summer. As a result, it is possible the data could reflect distress actually present in the field, yet show significantly different amounts of cracking from one data collection round to another.

Distress Initial Condition

One component of the initial experiment design was to evaluate the effect of maintenance treatments on pavements of varying initial condition and to determine the most appropriate treatment timing. Four initial pavement condition categories were identified, excellent, good, fair, and poor. The criteria for these categories is shown in table 8. No excellent sections were included in the study since they did not warrant maintenance.

The SHRP regional contractors (RCOCs) were asked to provide candidate sites that met the initial condition criteria in table 1. This was done by reviewing distress data from already established GPS sites. After a site was selected for inclusion, RCOC staff laid out individual test sections at the site. They were often accompanied by agency personnel who laid out State supplemental test sections as well.

A SHRP experimental pavement section requires 30.5m of pavement. The actual test sections of 15.25m are bounded on each end by transition and sampling areas. If the associated GPS section was used as the control, a minimum of approximately 1,600 m was required for the placement of all the core treatments. In practice, this length was generally closer to 3 to 5km. As a result of this and other constraints on section layout, maintaining uniform distress consistency among all the sections was very difficult unless the sites were in very good or very poor condition. Consequently, not all sections within a site have the same initial condition rating even though they are from the same overall section of pavement.

Figures 4 and 5 show the variation and consistency in initial condition found between treatments at two different sites. As identified in figure 6, the trends shown are a combination of both manually and PASCO collected data. Figure 4 shows transverse cracking versus age for site 26A300 in Michigan. The transverse cracking data is presented in meters, and all severity levels are included. Data in the negative age zone were collected prior to the treatment application. Zero age represents the time of maintenance treatment application. Note that the amount of transverse cracking for all treatments is nearly the same prior to the treatment application, ranging from 15 to 18 m of transverse cracking. Figure 5, from 36B300 in New York, however, shows a wide variation in initial condition between the different treatments at a single site. Applying the original initial condition criteria to this data results in the slurry and thin overlay treatments being classified as "good," the crack seal and chip seal treatments being classified as "fair," and the control section being classified as "poor," based only on the transverse cracking.

In some cases, no pretreatment distress evaluation data were available. In those cases, the initial condition of all of the sections were based on the control and crack seal initial conditions.

Table 8. Criteria for condition evaluation.

POOR (P)

Distress	Severity Level		
	Low	Medium	High
Fatigue Cracking	> 30 m^2	> 10 m^2	> 5 m^2
Longitudinal Cracking	> 300 m	> 40 m	> 20 m
Transverse Cracking	> 40 m	> 20 m	> 10 m
Patching	> 30 m^2	> 10 m^2	> 5 m^2
Bleeding	> 500 m^2	> 250 m^2	> 125 m^2

FAIR (F)

Distress	Severity Level		
	Low	Medium	High
Fatigue Cracking	15 - 30 m^2	5 - 10 m^2	2.5 - 5 m^2
Longitudinal Cracking	150 - 300 m	20 - 40 m	10 - 20 m
Transverse Cracking	20 - 40 m	10 - 20 m	5 - 10 m
Patching	15 - 30 m^2	5 - 10 m^2	2.5 - 5 m^2
Bleeding	250 - 500 m^2	125 - 250 m^2	50 - 125 m^2

GOOD (G)

Distress	Severity Level		
	Low	Medium	High
Fatigue Cracking	<15 m^2	<5 m^2	<2.5 m^2
Longitudinal Cracking	<150 m	<20 m	<10 m
Transverse Cracking	<20 m	<10 m	<5 m
Patching	<15 m^2	<5 m^2	<2.5 m^2
Bleeding	<250 m^2	<125 m^2	<50 m^2

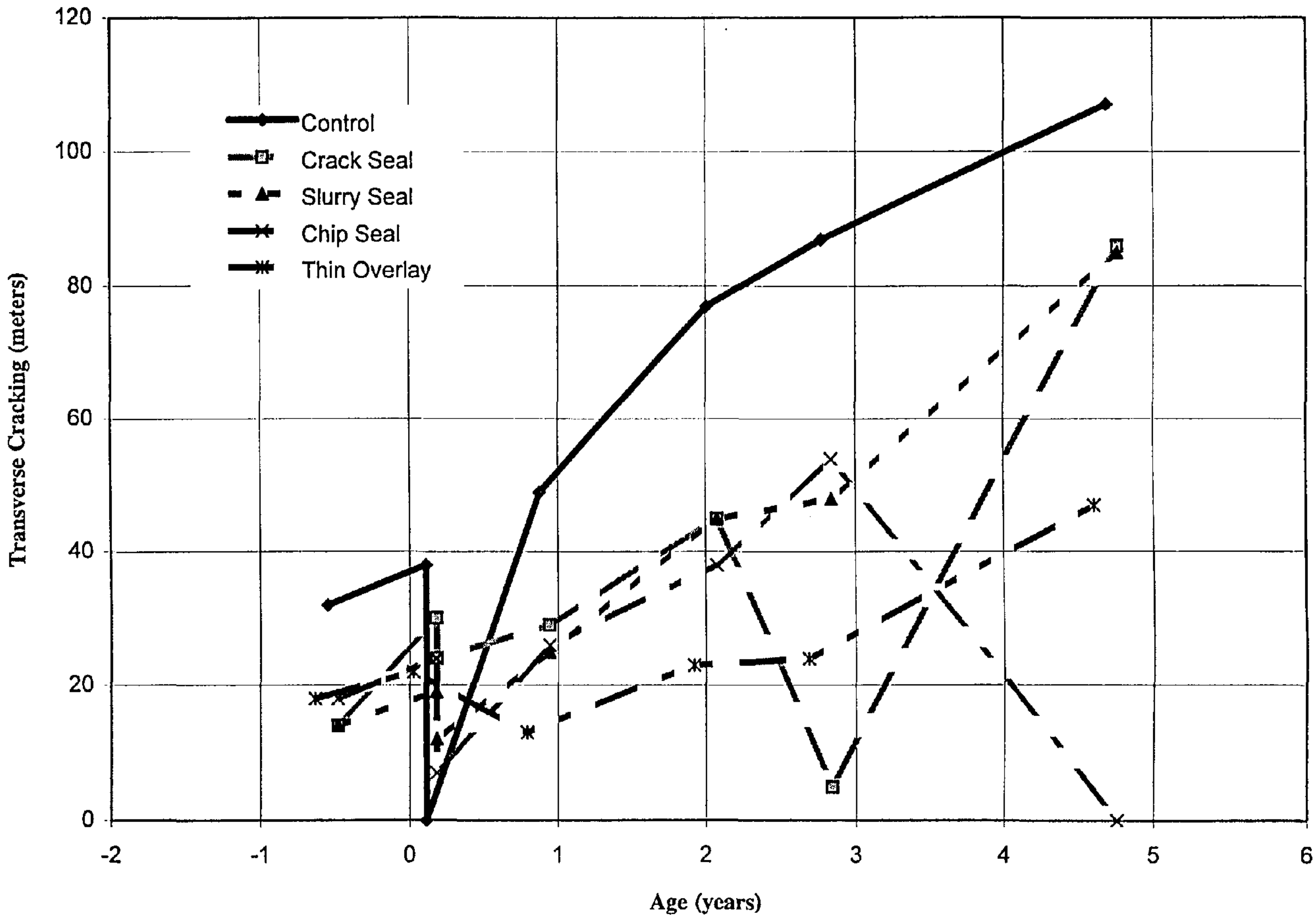


Figure 4. Total transverse cracking vs. age for Michigan site 26A300, showing uniform initial condition of treatment sections.

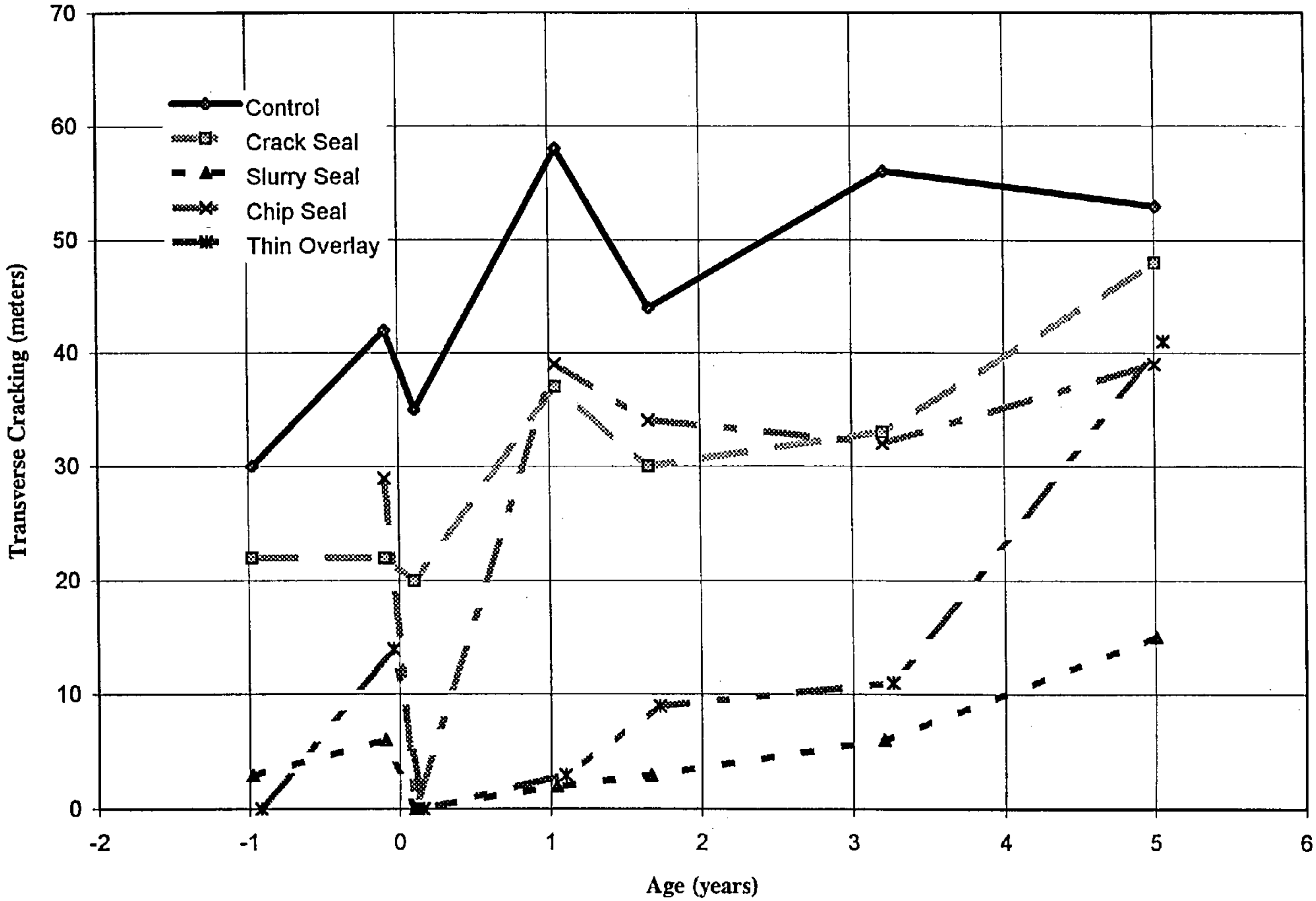


Figure 5. Transverse cracking vs. age for New York site 36B300, showing large variations in initial condition of treatment sections.

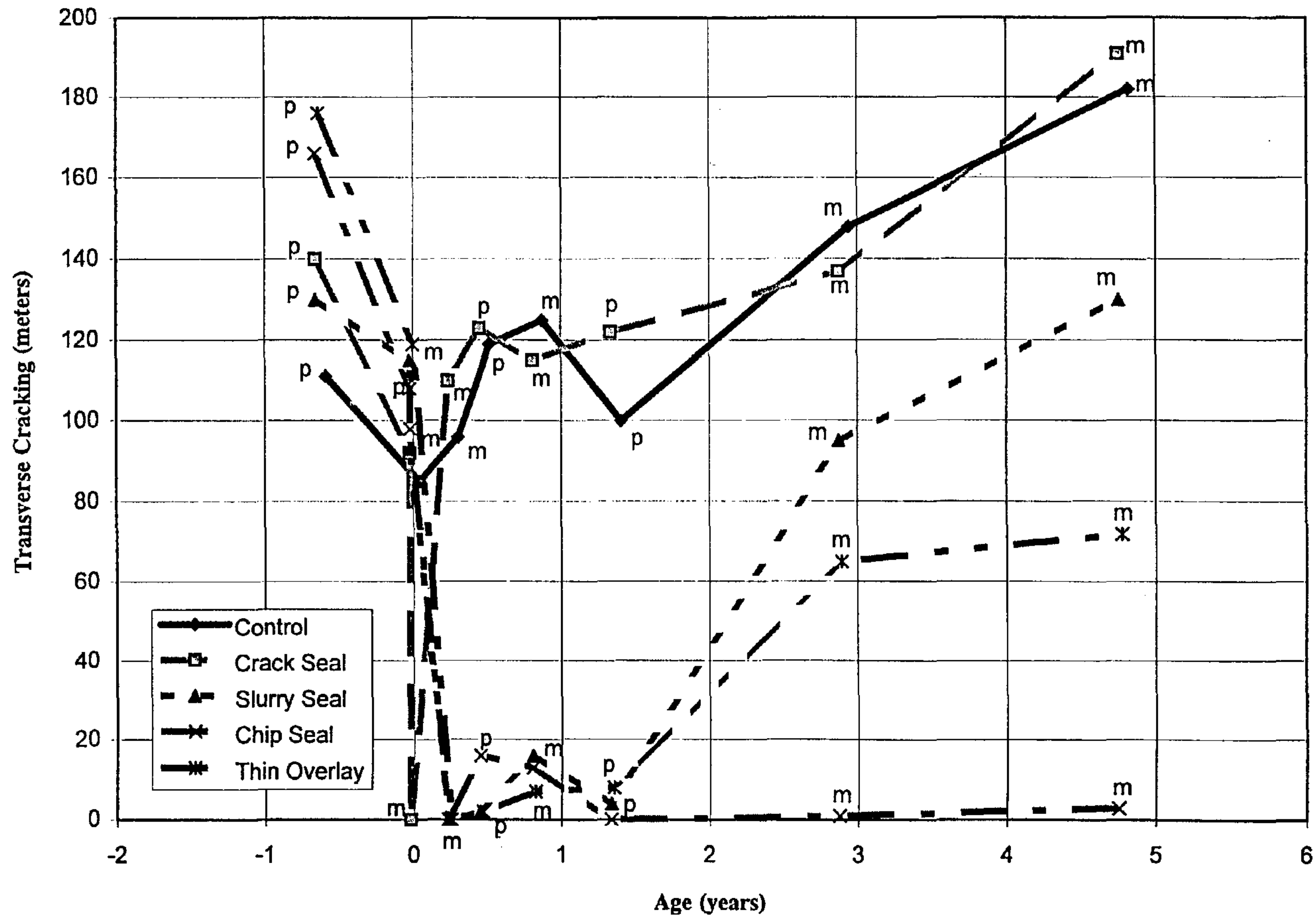


Figure 6. Transverse cracking vs. age for Texas site 48B300, identifying manual and PASCO data points.

Types of Data Collection

Both manual and PASCO distress data continue to be collected, but PASCO data has not been entered into the RIMS data base since 1992. As a result of concerns with the uniformity in the analysis of the PASCO data, this type of data interpretation is still being evaluated. Since the majority of the initial or pretreatment data available in the RIMS was collected by PASCO, and the initial condition information was critical to the goals of this study, the results of the two methods had to be combined. This was done by combining data from the two separate data bases used for the manual and automated data.

Table 9 shows the distress data types stored under each of the different methods as it is recorded in the RIMS data base. Note sealed cracks are not differentiated from unsealed cracks in the PASCO data method. In analyzing the distress for this study, transverse, longitudinal, and fatigue cracking, as well as potholes and patching combined, were the distresses most consistent with the original condition criteria. Those categories marked by an asterisk were combined to obtain more complete performance dates.

Appendix J contains plots of longitudinal, transverse, and fatigue cracking for each section in the study. A review of these plots reveals significant variation in the ratings from point to point and distress by distress. Figure 6 shows the transverse cracking versus treatment age for section 48B300 in Texas. Both manual and PASCO data are shown, with the manual data points by a "m" and the PASCO data points indicated by a "P." Note that only manual data appears after year two. This plot is typical in that there is as much consistency between consecutive data points collected by the two different methods, as there is between consecutive points done by the same method. In other words, individual rater variability appears to overwhelm the variation between data collection methods.

PRS Analysis

The distress data for the SPS-3 sites was evaluated using a Pavement Rating Score (PRS). This method indexes the distress data and helps reduce variation in the data. The necessity of using the PRS approach was the result of the high variability in the distress data. Variability in this data is the result of seasonal (temperature) changes in distress severity, variability between individual distress rates, and potential variability between PASCO and manually collected distress data.

The PRS method is based on a 0 to 100 scale and uses deduct values which are assigned to individual distresses and severity levels. A pavement with no distresses present would have a PRS score of 100; the value decreases with increasing distress. The development of the deduct values used for this analysis is described in appendix I. The deduct values used are shown in table 10.

As an example of how the PRS score reduces distress data variability, figure 7 shows fatigue, transverse and longitudinal cracking versus age in the chip seal and control sections for site 49B300 in Utah. As can be seen from the figures, there is significant variation in the amount

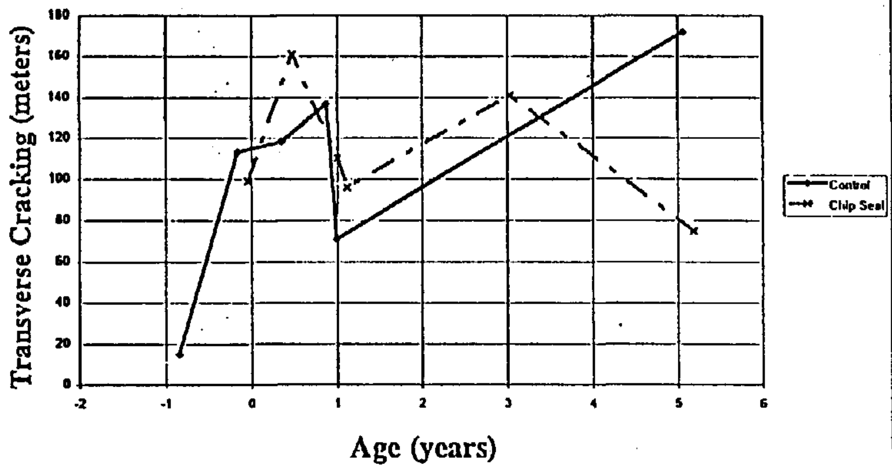
Table 9. Distress data stored in LTPP data base for both manual and PASCO data collections methods.
(asterisks show data combined for analysis)

MON_DIS_AC_REV	Revised distress survey information for pavements with AC surfaces. File Ext - M10.			
• SHRP_ID	• STATE_CODE	CONSTRUCTION_NO	• SURVEY_DATE	SURVEYOR1
SURVEYOR2	PHOTO_VIDEO	BEFORE_TEMP	AFTER_TEMP	• GATOR_CRACK_A_L
• GATOR_CRACK_A_M	• GATOR_CRACK_A_H	BLK_CRACK_A_L	BLK_CRACK_A_M	BLK_CRACK_A_H
EDGE_CRACK_L_L	EDGE_CRACK_L_M	EDGE_CRACK_L_H	• LONG_CRACK_WP_L_L	• LONG_CRACK_WP_L_M
• LONG_CRACK_WP_L_H	LONG_CRACK_WP_SEAL_L_L	LONG_CRACK_WP_SEAL_L_M	LONG_CRACK_WP_SEAL_L_H	• LONG_CRACK_NWP_L_L
• LONG_CRACK_NWP_L_M	• LONG_CRACK_NWP_L_H	LONG_CRACK_NWP_SEAL_L_L	LONG_CRACK_NWP_SEAL_L_M	LONG_CRACK_NWP_SEAL_L_H
REFL_CRACK_TRANS_NO_L	REFL_CRACK_TRANS_NO_M	REFL_CRACK_TRANS_NO_H	REFL_CRACK-TRANS_L_L	REFL_CRACK_TRANS_L_M
REFL_CRACK_TRANS_L_H	REFL_CRACK_TRANS_SEAL_L_L	REFL_CRACK_TRANS_SEAL_L_M	REFL_CRACK_TRANS_SEAL_L_H	REFL_CRACK_LONG_L_L
REFL_CRACK_LONG_L_M	REFL_CRACK_LONG_L_H	REFL_CRACK_LONG_SEAL_L_L	REFL_CRACK_LONG_SEAL_L_M	REFL_CRACK_LONG_SEAL_L_H
TRANS_CRACK_NO_L	TRANS_CRACK_NO_M	TRANS_CRACK_NO_H	• TRANS_CRACK_L_L	• TRANS_CRACK_L_M
• TRANS_CRACK_L_H	TRANS_CRACK_SEAL_L_L	TRANS_CRACK_SEAL_L_M	TRANS_CRACK_SEAL_L_H	PATCH_NO_L
POTHOLES_NO_L	POTHOLES_NO_M	• PATCH_A_L	• PATCH_A_M	• PATCH_A_H
• POTHOLES_A_H	SHOVING_NO	POTHOLES_NO_H	• POTHOLES_A_L	• POTHOLES_A_M
BLEEDING_A_H	POLISH_AGG_A	SHOVING_A	BLEEDING_A_L	BLEEDING_A_M
PUMPING_NO	PUMPING_L	RAVELING_A_L	RAVELING_A_M	RAVELING_A_H
		DIM_VERSION	OTHER	RECORD_STATUS

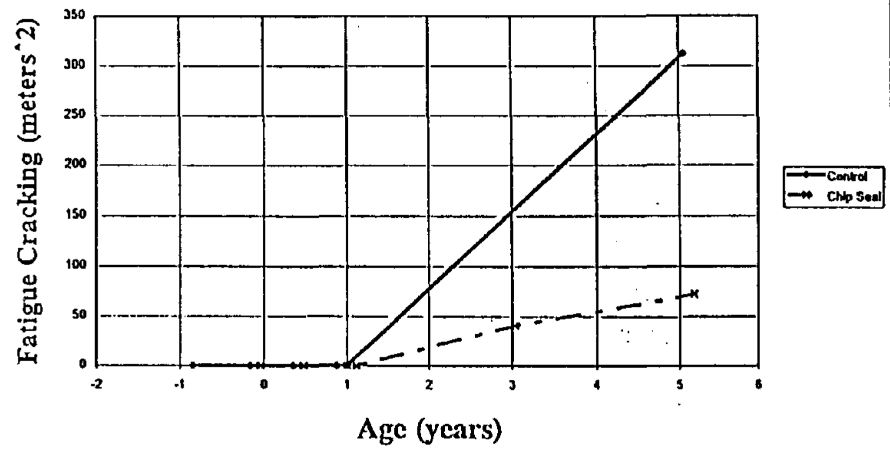
MON_DIS_PADIAS_AC	Distress survey information for pavements with AC surfaces. File Ext - M15.			
• SHRP_ID	• STATE_CODE	CONSTRUCTION_NO	• SURVEY_DATE	IMS_LOAD_DATE
FMA_MAGNIFICATION	• GATOR-CRACK_SF_L	• GATOR_CRACK_SF_M	• GATOR_CRACK_SF_H	• GATOR_CRACK_SF_U
BLK_CRACK_SF_L	BLK_CRACK_SF_M	BLK_CRACK_SF_H	BLK_CRACK-SF_U	EDGE_CRACK_LF_L
EDGE_CRACK_LF_M	EDGE_CRACK-LF_H	EDGE_CRACK_LF_U	• LONG_CRACK_LF_L	• LONG_CRACK_LF_M
• LONG_CRACK_LF_H	• LONG_CRACK_LF_U	LONG_REFL_CRACK-NO_L	LONG_REFL_CRACK_NO_M	LONG_REFL_CRACK_NO_H
LONG_REFL_CRACK_NO_U	LONG_REFL_CRACK_LF_L	LONG_REFL_CRACK_LF_M	LONG_REFL_CRACK_LF_H	LONG_REFL_CRACK_LF_U
TRANS_REFL_CRACK_NO_L	TRANS_REFL_CRACK_NO_M	TRANS_REFL_CRACK_NO_H	TRANS_REFL_CRACK_NO_U	TRANS_REFL_CRACK_LF_L
TRANS_REFL_CRACK_LF_M	TRANS_REFL_CRACK_LF_H	TRANS_REFL_CRACK_LF_U	TRANS_CRACK_NO_L	TRANS_CRACK_NO_M
TRANS_CRACK_NO_H	TRANS_CRACK_NO_U	• TRANS_CRACK_LF_L	• TRANS_CRACK_LF_M	• TRAN_CRACK_LF_H
• TRANS_CRACK_LF_U	• PATCH_SF_L	• PATCH_SF_M	• PATCH_SF_H	• PATCH_SF_U
PATCH_NO_L	PATCH_NO_M	PATCH_NO_H	PATCH_NO_U	POTHOLES_NO
• POTHOLES_SF	SHOVING_SF	SHOVING_NO	BLEEDING_SF_L	BLEEDING_SF_M
BLEEDING_SF_H	BLEEDING_SF_U	POLISH_AGG_SF	RAVELING_SF_L	RAVELING_SF_M
RAVELING_SF_H	RAVELING_SF_U	LANE_SHOULDER_DROP_LF	LANE_SHOULDER_SEP_LF_L	LANE_SHOULDER_SEP_LF_M
LANE_SHOULDER_SEP_LF_H	LANE_SHOULDER_SEP_LF_U	WATER_BLEED_PUMP_LF_L	WATER_BLEED_PUMP_LF_M	WATER_BLEED_PUMP_LF_H
WATER_BLEED_PUMP_LF_U	WATER_BLEED_PUMP_NO_L	WATER_BLEED_PUMP_NO_M	WATER_BLEED_PUMP_NO_H	WATER_BLEED_PUMP_NO_U
OTHER	ANALYSIS_DATE	ANALYST_NAME	REMARK1	REMARK2
REMARK3	RECORD_STATUS			

Table 10. PRS condition evaluation and deduct values for SPS-3 sites.

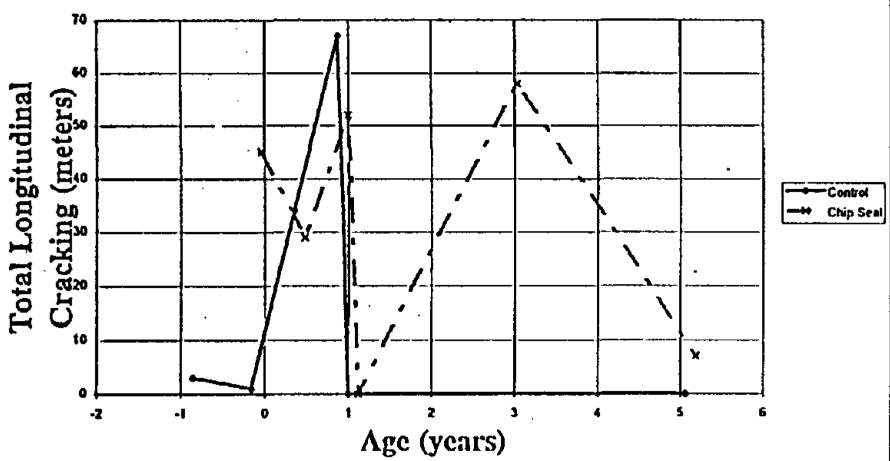
Distress	Low Severity		Medium Severity		High Severity	
	Extent	D.V.	Extent	D.V.	Extent	D.V.
Fatigue Cracking (m^2)	< 15 15 - 30 730	5 10 15	< 5 5 - 10 > 10	10 15 20	< 2.5 2.5 - 5 >5	15 20 25
Longitudinal Cracking (m)	< 150 150 - 300 > 300	15 10 15	< 20 20 - 40 > 40	10 15 20	< 10 10 - 20 > 20	15 20 25
Transverse Cracking (m)	< 20 20 - 40 > 40	3 4 5	< 10 10 - 20 > 20	5 7 10	< 5 5 - 10 > 10	10 12 15
Patching (m^2)	< 15 15 - 30 > 30	2 5 7	< 5 5 - 10 > 10	5 7 10	< 2.5 2.5 - 5 > 5	7 10 15



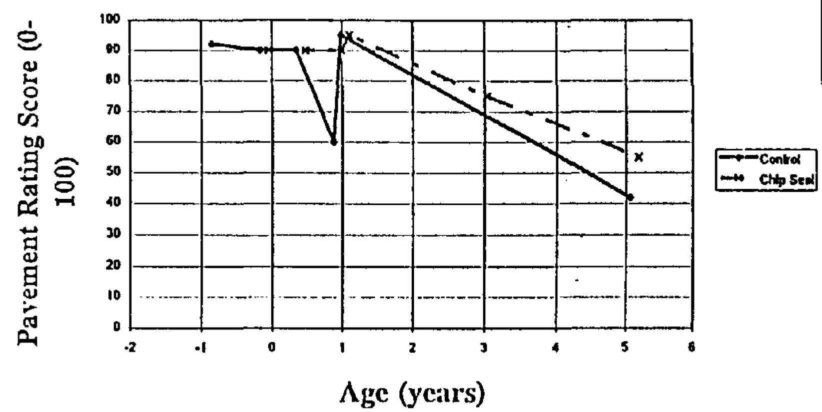
a. Transverse cracking vs. age.



c. Fatigue cracking vs. age.



b. Total longitudinal cracking vs. age.



d. Pavement Rating Score (PRS) vs. age.

Figure 7. Example of how PRS reduces data variability for Utah site 49B300.

of cracking prior to the treatment application (in the negative age range). The transverse cracking just prior to the treatment application ranges from approximately 65 to 150 m of cracking in each treatment section. Figure 7 shows PRS versus age for the same site. As can be seen from the figure, the treated section's initial condition is very uniform in terms of PRS.

PRS Initial Condition

A separate report discussing the development of the Pavement Rating Score (PRS) methodology is contained in appendix I. Figure 8 shows the age range distribution of all the data base data for the SPS-3 sites in terms of PRS. Each data point on this figure represents one evaluation for a treatment test section. Triangles represent PASCO data and squares represent manual survey data. When evaluating the distress performance data based on initial condition, it was necessary to develop new criteria in order to apply PRS ranges that would define "good," "fair," and "poor" initial conditions. In the above examples for site 49B300, the sections would have been classified as "poor" under the original transverse cracking criteria and "good" under the longitudinal cracking criteria. The transverse would govern and the site would have been rated poor. The PRS methodology applies weight to both types of distresses, and is therefore more comprehensive and sensitive to the influence of several different distress types.

PRS ranges of 100 to 86, 85 to 70, and 69 and below were selected to represent good, fair, and poor initial conditions, respectively. These ranges were determined from the chart shown in figure 8. This significantly altered the distribution of sections in terms of initial condition. The comparison below shows this change by site, based on the initial condition of the control sections.

	PRS	Original Experiment
Good	51	36
Fair	20	16
Poor	10	29

It should be noted that while this is a useful concept in evaluating LTPP distress data, the threshold values of good, fair, and poor pavement condition levels are specific to the SPS-3 experiment, and may not be universally applicable to other studies.

Environmental Zone

The PRS approach to the distress data analysis supported the development of a distress-based performance curve for each test section at each location. By combining test section data into climatic regions, as identified by the LTPP program, and subclimatic regions, as defined for the SHRP asphalt binder specifications, better analysis trends could be developed, representing the performance of the treatments in specific climatic areas.

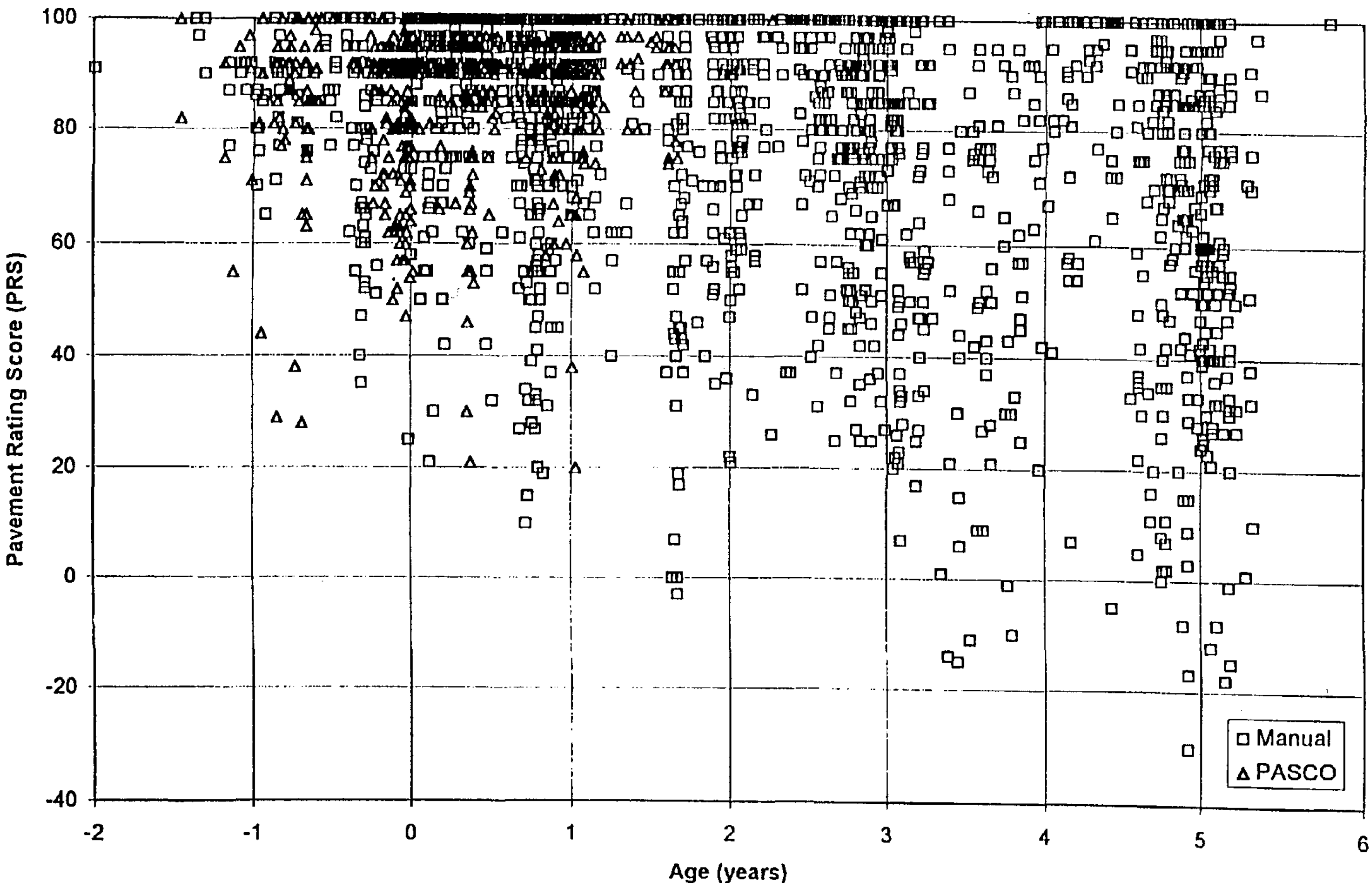


Figure 8. PRS vs. age showing distribution and range of all data.

The LTPP program identifies four climatic regions; wet-freeze, dry-freeze, wet-no freeze, and dry-no freeze. These zones are shown in figure 9. There are nine environmental zones associated with the SHRP Superpave asphalt pavement design procedure. These are shown in figure 10.

Treatment Timing

One of the primary goals of the SHRP maintenance treatment study is to determine the optimum time in the life of pavements to apply a treatment. While many pavement and maintenance engineers believe that the early application of maintenance treatments is advantageous, this study provides data supporting that concept.

The distress data collection efforts on the SPS-3 experiment are clustered into six broad groups over the 5 to 6 years the treatments have now been in service. Figure 7 shows all the distress evaluations performed on each SPS-3 section since each treatment was placed. As can be seen, there was a large amount of activity prior to the construction of the treatments from which the initial condition is obtained. Immediately after construction, from 0 to 0.7 years, there was another round of testing. Other intervals are from 0.7 to 1.4 years, 1.4 to 2.5 years, 2.5 to 4.5 years, and from 4.5 years to the present.

Figures 11 through 14 show post-construction performance curves for all treatments by environmental zone. The PRS scores were averaged over the above indicated evaluation periods and plotted. ***As can be seen from these figures, the treatments placed on pavements in good initial condition have outperformed the initially fair and poor sections in the dry-freeze and dry-no freeze zones over time. In the wet-freeze zone, this trend is less obvious, but still exists. The performance of treatments on pavements of all initial conditions continues to be strong in the wet-no freeze zone. The benefit to pavement condition level of applying treatments earlier in a pavement's life is clearly indicated.***

Figure 12c indicates a peculiar trend for the dry-freeze climate thin overlay. This unusual trend represents data from only two sites, which have sizable disparity in distress level, and thus provides no significant conclusions.

A comparison of test section performance within each climate, by initial pavement condition level, indicates the relative loss in performance level. The example in figure 15 utilizes data from the dry-freeze climate, zone III-C. The figure shows that the loss in test section performance level for good condition pavements is less than half that experienced by the fair and poor condition sections.

Table 11 provides data from this comparison for the three "pure" climates, I-A, II-C, and III-C, and for the dry-no freeze climate at large. Sufficient data is not available to further refine the analysis for this climate.

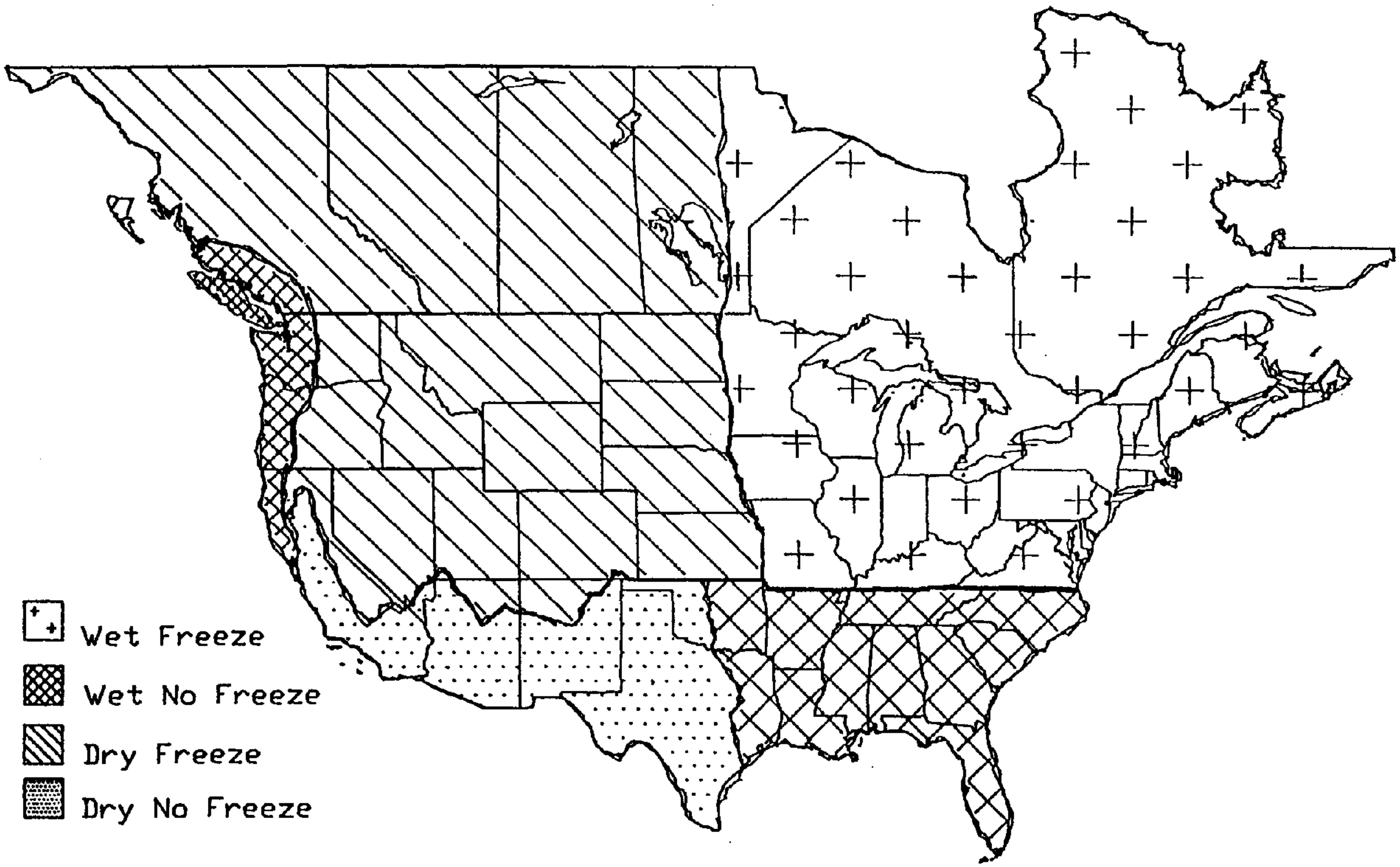


Figure 9. SHRP/LTPP environmental zones.

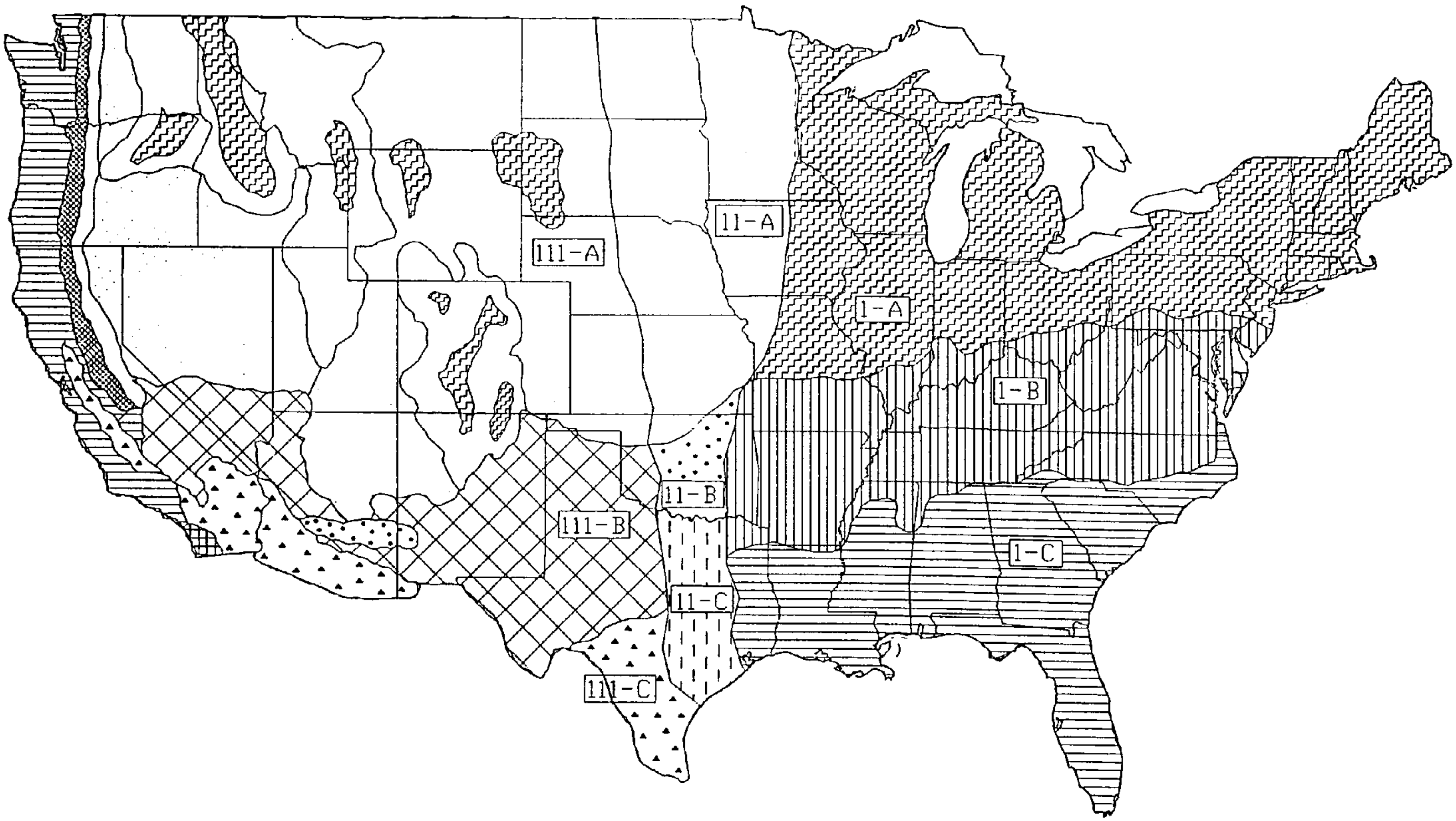
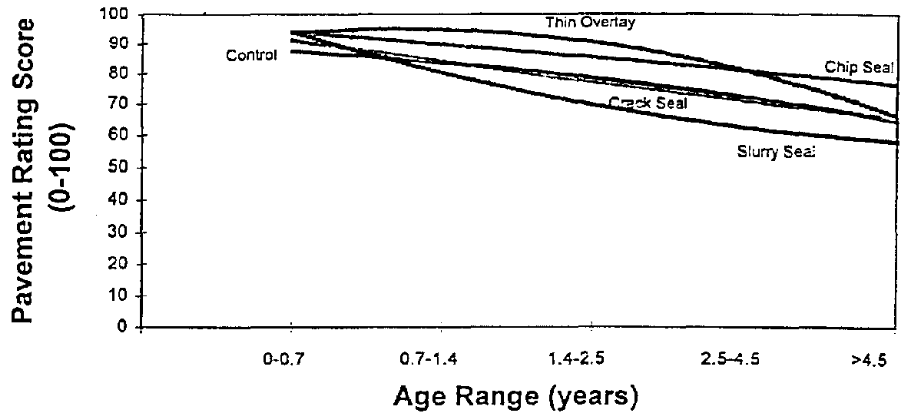
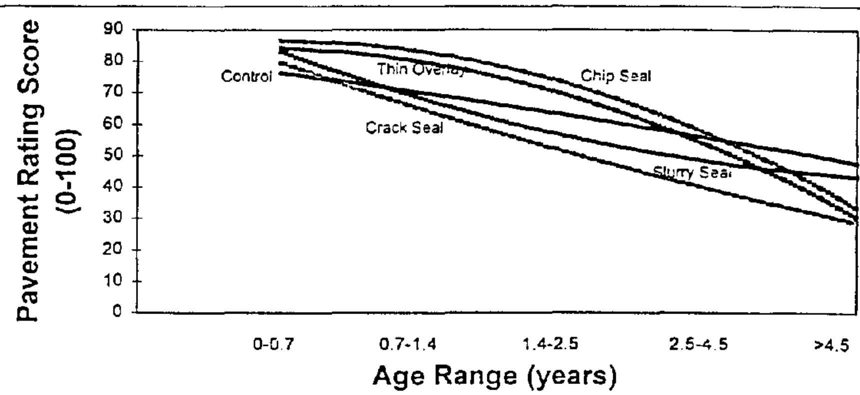


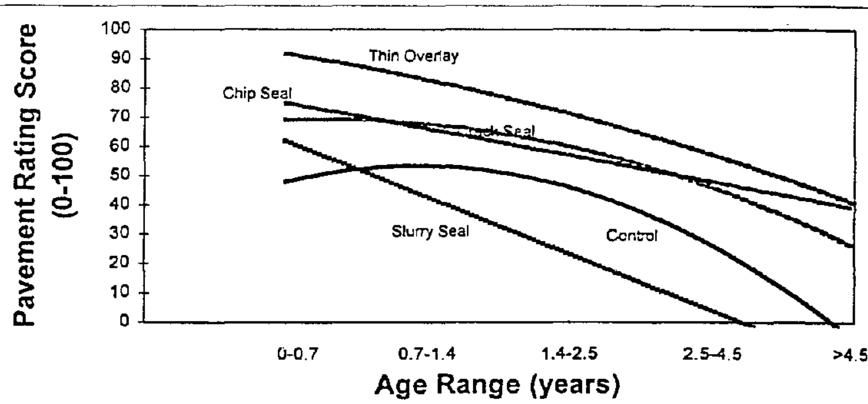
Figure 10. Superpave environmental zones.



a. Good initial condition.

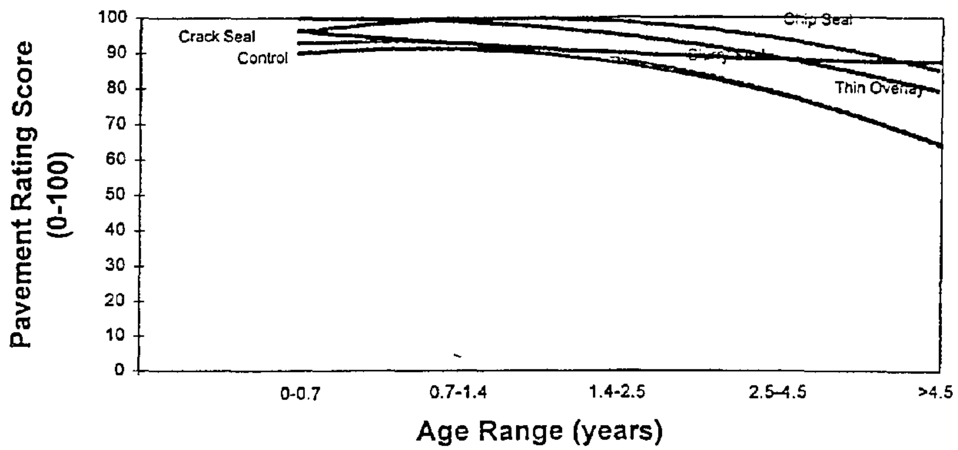


b. Fair initial condition.

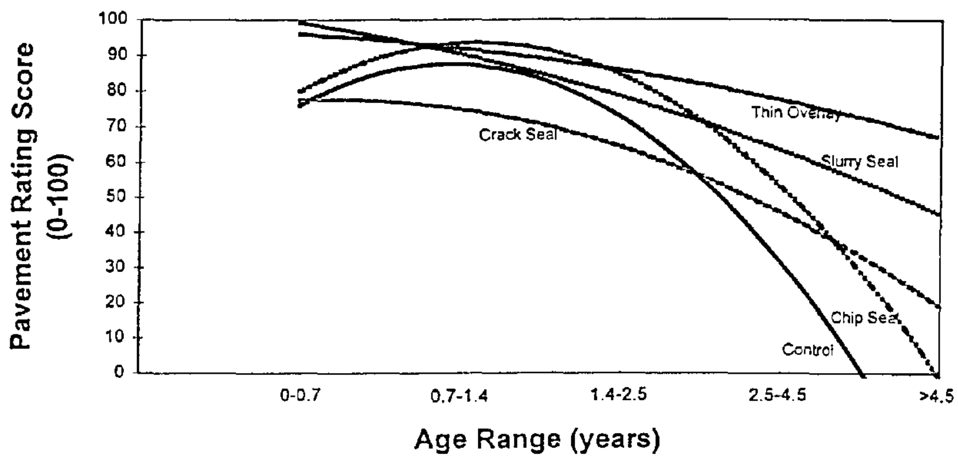


c. Poor initial condition.

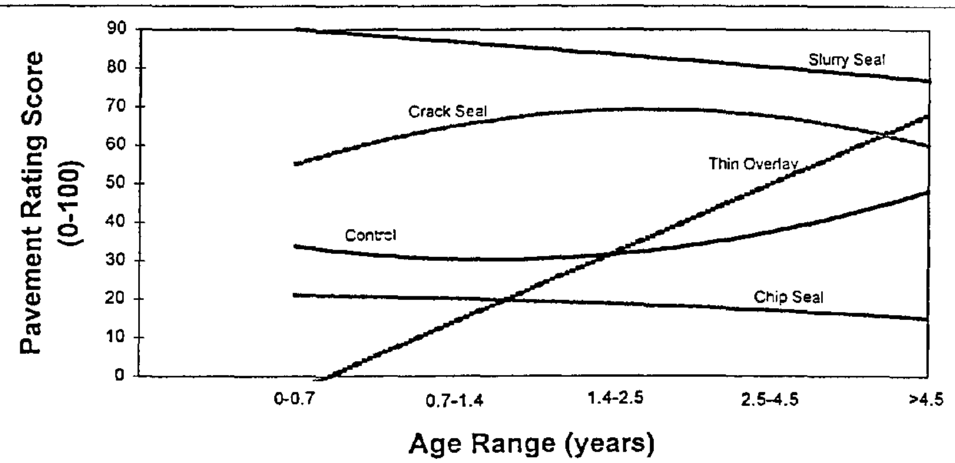
Figure 11. Pavement rating score (PRS) vs. age range by treatment type and initial condition for the dry-freeze environmental zone, post-construction data only.



a. Good initial condition.

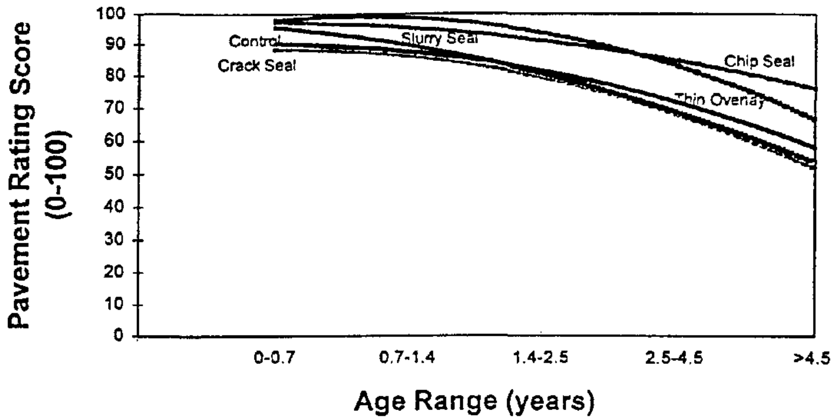


b. Fair initial condition.

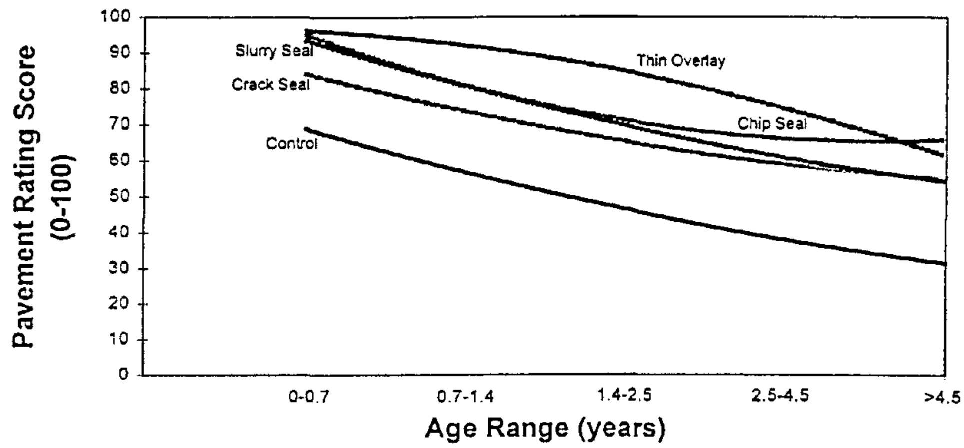


c. Poor initial condition.

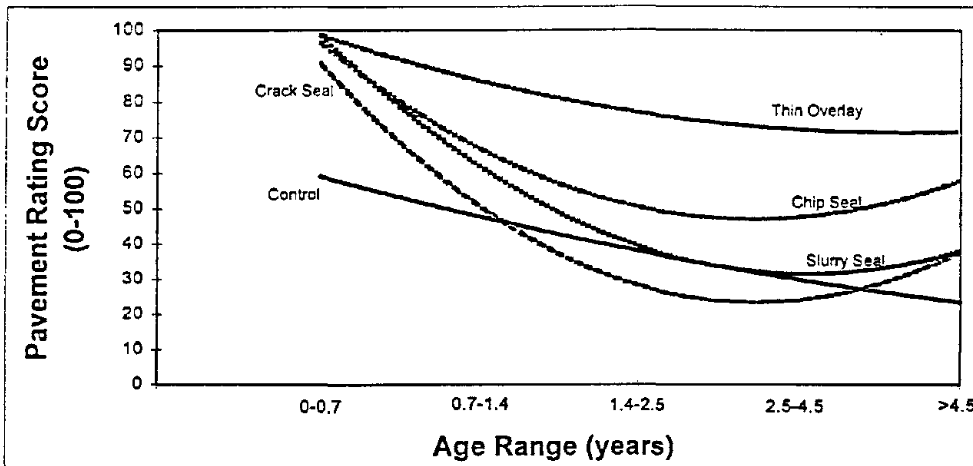
Figure 12. Pavement rating score (PRS) vs. age range by treatment type and initial condition for the dry-no freeze environmental zone, post-construction data only.



a. Good initial condition.

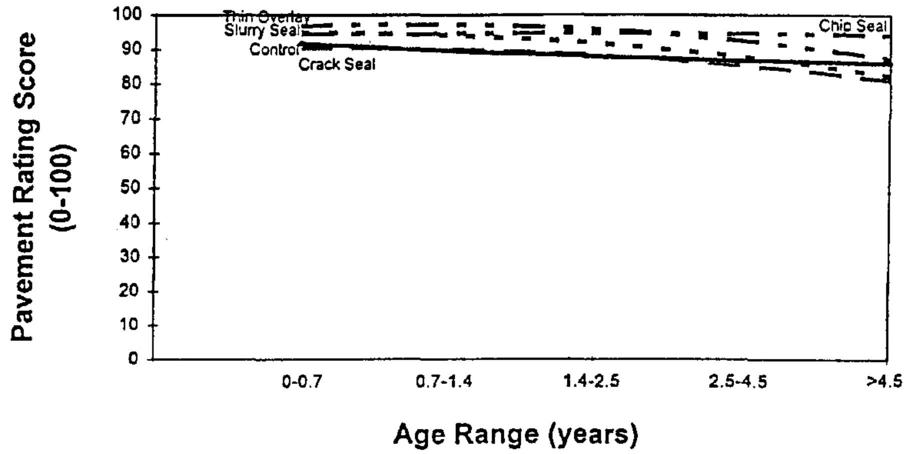


b. Fair initial condition.

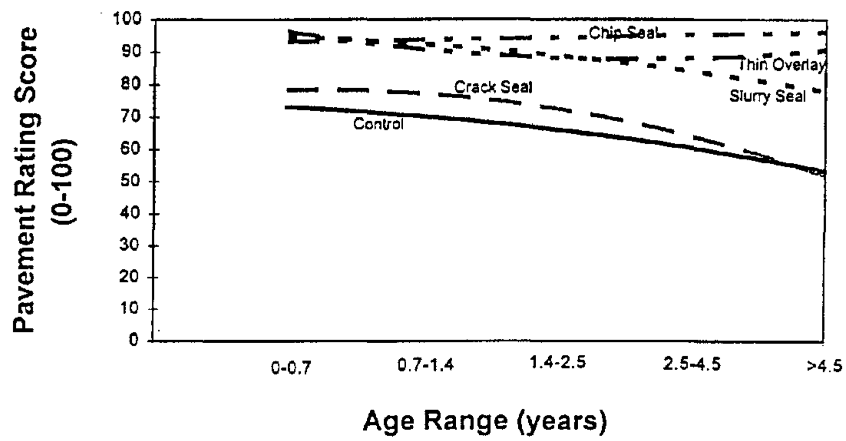


c. Poor initial condition.

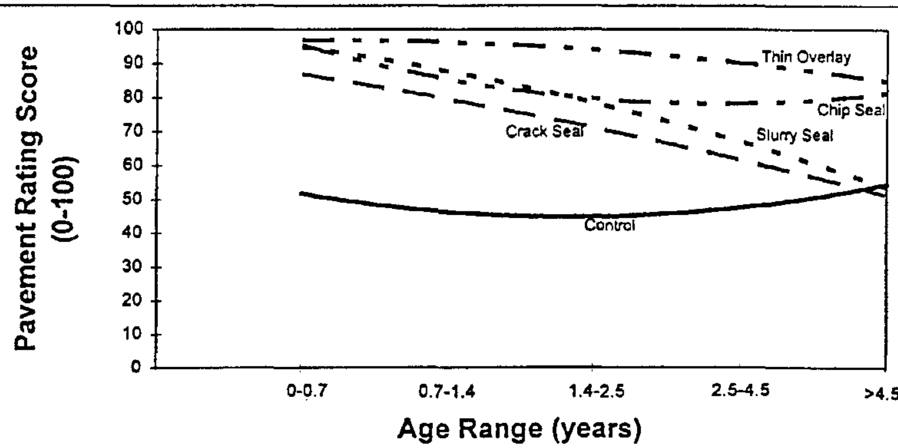
Figure 13. Pavement rating score (PRS) vs. age range by treatment type and initial condition for the wet-freeze environmental zone, post-construction data only.



a. Good initial condition.



b. Fair initial condition.



c. Poor initial condition.

Figure 14. Pavement rating score (PRS) vs. age range by treatment type and initial condition for the wet-no freeze environmental zone, post-construction data only.

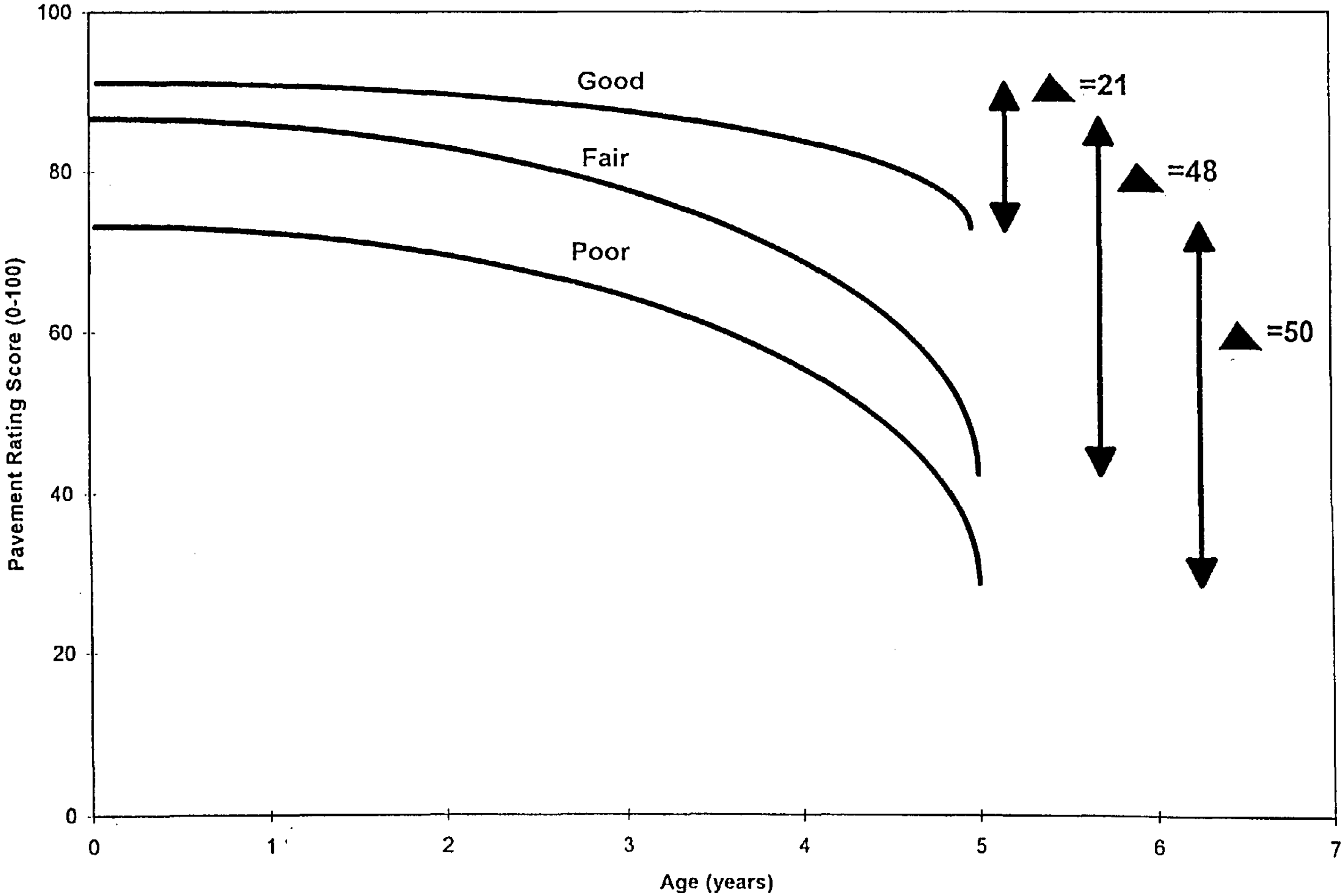


Figure 15. Delta PRS for maintenance treatments by initial condition in the dry-freeze zone.

Table 11. Treatment performance by climatic region (after application).

Climatic Region	Control	Crack Seal	Slurry Seal	Chip Seal	Thin Overlay
1-A (wet-freeze) PRS/Yr	8.5	5.2	13.6	8.7	8.9
Age at TSI (yrs)	3-4	5	4	6-7	7
Goodness of Fit (R^2)	0.93	0.73	0.90	0.90	0.77
1-C (wet-no freeze) PRS/Yr	6.4	7.2	1.8	0.2	0.5
Age at TSI (yrs)	9	7	> 12	> 12	> 12
Goodness of Fit (R^2)	0.73	0.85	0.79	0.19	0.37
111-A (dry-freeze) PRS/Yr	6.3	5.9	4.1	3.0	9.2
Age at TSI (yrs)	6-7	6	5	11	6-7
Goodness of Fit (R^2)	0.94	0.61	0.98	0.61	0.93
Dry-No Freeze PRS/Yr	8.4	3.7	3.7	18.7	5.1
Age at TSI (yrs)	6	9-12	< 12	7	> 12
Goodness of Fit (R^2)	0.95	0.82	0.80	0.95	0.86

Note: TSI of 50 on PRS scale.

PRS Analysis Results

The assessment of data taken as a whole did not reveal any significant performance trends, or provide meaningful statistical assessments. By beginning with individual site performance trends and grouping project sites into the subclimatic and climatic regions, it was found that the trends and the statistical significance associated with them became much stronger. The performance trends provided in appendix I represent individual site information, and the groupings of these data as discussed.

One significant trend can be observed throughout most of the data for the climatic regions. That is the benefit obtained when the treatments were applied to pavements in good condition exceeded the benefit of treatments applied to pavements in fair or poor condition. In other words, earlier application of the treatments result in greater benefit, as measured by the rate of pavement deterioration. This enhancement to pavement performance varies with treatment type and climate.

Data scatter contributes to inexplicable conclusions in certain situations, particularly where a limited amount of data is available to represent certain combinations of conditions. An example of this is the assessment of the slurry seal and thin overlay treatments in the dry-no freeze climate for fair condition pavements. The current condition of the designated fair pavements is better than the current condition of the designated good pavements in that situation. This trend, however, is based on data from only one fair condition site.

Similarly, the poor pavements outperformed the average of the good pavements in all cases in the dry-freeze region. However, only one poor site is represented in the data base, so this cannot be considered as a representative trend.

The benefit of applying the treatments from good to fair to poor condition is assessed by expressing the average change in PRS over the 5-year evaluation period as a ratio of the higher condition level divided by the average change in PRS of the lower condition level. For example, the change in PRS for good condition pavements is divided by the change in PRS of the fair condition pavements. This typically results in a decimal value less than one. The difference between the ratio value and one is considered to be the percent of increased benefit. For example:

$$Benefit=\frac{\Delta\ Good\ Section\ PRS}{\Delta\ Poor\ Section\ PRS \text{ or } \Delta\ Fair\ Section\ PRS}$$

The results of this analysis are provided in table 12. The following conclusions were drawn from this exercise.

Crack Seal. The crack seal treatment provided better performance in the wet-no freeze regions than in the other regions. Compared with fair condition pavements, however, the benefit of early application is clear in all climates. The wet-no freeze climate has a benefit

Table 12. Ratio of change in PRS values.

Treatment	SHRP No.	Dry-Freeze	Dry-No Freeze	Wet-No Freeze	Wet-Freeze
Thin Overlay	310	.37 better than F poor better than G	worse than F & P (1.5 - 2.2 times)	> 1 worse than F .42 better than P	.4 better than F & P
Slurry Seal	320	.15 better than F poor better than G	worse than F & P (1.8 - 1.2 times)	.52 better than F .69 better than P	.5 better than F & P
Crack Seal	330	.23 better than F poor better than G	.13 better than F (1.2 better than poor) limited data	.85 better than F .76 better than P 1(F)	.35 better than F .45 better than P
Chip Seal	350	.57 better than F poor better than G	.85 better than F .5 better than P	half as good as F .74 better than P	.74 better than F .8 better than P

ratio of 0.15, or benefit of 0.85. For the freeze climates, this benefit is from 0.23-0.35. For the wet-no freeze climate, the benefit is only 0.13, since the crack seal treatment performed well at all pavement condition levels.

When compared with poor condition pavements, the benefits are 0.45 for the wet-freeze climate, 0.76 for the wet-no freeze climate, and 1.2 for the dry-no freeze climate. The poor pavements in the dry-freeze region were represented by only one site, which outperformed the average of the good sites.

Slurry Seal. In the wet climates, the slurry seal pavements in good condition, resulted in half the deterioration of the fair pavements, or two times the benefit. The same is true when compared with the poor pavements in the wet-freeze region. Only one site in poor condition is included in the wet-no freeze region data set.

In the dry-freeze climate, the benefit of good pavements compared with fair pavements is 0.85. The comparison with poor pavements in the dry-freeze region, and the fair, and poor pavements in the dry-no freeze region are represented by a single site in each case and the resulting trends are not considered to be representative. However, the magnitude of change in pavement condition at all levels of initial pavement condition is minimal.

Chip Seal. The good condition chip seal sections were found to provide benefit varying from 0.5 to 0.85, when compared with the fair condition sections in all climates. The benefit is greatest in the dry-no freeze and wet-freeze climates.

When the good condition pavements are compared with the poor condition sites, the same trends are observed. In this case, the wet-freeze and wet-no freeze climates show the most benefit. No data was available for the chip seal treatments on poor pavements in the dry-freeze climate.

Thin Overlay. In the freeze regions, the good pavements provide a 0.4 benefit, as compared with the fair pavements, and the poor pavements in the wet-freeze climate. A single poor site in the dry-no freeze climate has evidenced no change in performance over the a 5-year evaluation period.

The fair condition pavements in both good and fair condition in the wet-no freeze climate have shown little change in condition over the 5 years of evaluation. Slightly greater change is evident in the performance of the poor sections, resulting in a 0.42 benefit.

In the dry-no freeze climate, both the fair and poor condition pavements are represented by a single section, and reasonable trends cannot be identified. However, the change in pavement conditions at all levels of original pavement condition is minimal.

RUTTING DATA

The rutting data used for this analysis was provided by PASCO data collection activities. This data is collected by a transverse rut bar on the PASCO data collection vehicle. Data is collected as a transverse profile image of the pavement section. This data is then digitized and stored in the LTPP data base. The information analyzed was provided directly to the project team by PASCO USA, since they were able to provide a more complete set of data than was resident in the LTPP data base. Manually collected transverse profile data is resident in the LTPP data base, but does not represent as complete a set of information as the PASCO data. To simplify the evaluation, only the PASCO information was used.

Rutting information was treated as a dependent variable in the regression analysis. The significance of rutting on the performance of the various maintenance treatments is summarized in tables 2 through 7. Rutting was not found to be a very significant factor on the performance of any of the treatments.

Two primary questions can be asked relative to the rutting distress data. First, what is the initial effect of the individual treatments on rutting? Second, what is the long-term effect of the individual treatments on rutting? The first question can be addressed by comparing rut depths immediately before and after treatment. The second is answered by reviewing the long-term effect of the treatment in mitigating further development of rutting, as compared with the development which occurs over the same period of time in the control sections.

In answer to these queries, the following observations can be made. In general, little change in rut depth was identified as a result of the treatment applications. As expected, the crack seal treatment had no effect on removing rutting. The slurry seal and chip seal had only a minimal effect, which relates to the thickness of the treatment, but does not significantly affect deeper ruts. Only the thin overlay was found to result in a significant reduction in rutting following treatment application.

The second question is addressed by comparing the change in rut depth of the various test sections after 5 years of performance with the rut depth immediately after treatment. The crack seal treatment was found to result in similar performance as the control sections when this comparison was made, the conclusion being that the crack seal treatment did not reduce rutting. The slurry seal resulted in slightly less rutting than the control sections and the chip seal in slightly more. The thin overlay also developed rutting at about the same rate as the control sections. These trends describe the test sections in general, and are not specific to any individual location. Rutting data are provided as a part of appendix K.

Greater rutting was found to be present in the outer wheelpath at a majority of the sections. The distribution of the maximum rut between the left (inside) and right (outside) wheelpaths was 46 percent inside wheel path and 54 percent outside wheelpath. No correlation was found between the reduction in friction characteristic and the development in rutting.

Accelerated rutting was identified at certain Arizona sites treated with chip seals or slurry seals. The placement of tight seals on the surface appears to have accelerated stripping of the pavements at these sections. Similar activity has been suspected, but not verified, at a number of chip seal and slurry seal sites in other States and climates as well. The application of seals to pavements produces a relatively impermeable membrane in the pavement structures. This relatively impermeable membrane stops or slows down the movement of water (solid or vapor) from the subgrade and base course through the hot-mix asphalt. The amount of water moving from the natural soil and base course through the hot-mix asphalt to the atmosphere is largely controlled by the level of the water table, the nature of the natural soil and base course, and the temperature. Substantial quantities of water move through pavements during the spring and early summer months.

The application of a seal to the pavement surface traps moisture in the hot-mix asphalt and other layers. With the placement of the seal, the water content in the hot-mix asphalt may be higher and remain in the pavement over a longer period of time than the pavement ever experienced in its previous history. High temperatures and high traffic accelerate the effect of the moisture on the hot-mix asphalt. Moderately susceptible hot-mix asphalt, while not stripping in pavement without seals, can strip in a few weeks with the placement of seals in the spring or summer months. The sudden and extensive pavement failures resulting from the phenomena are expensive to repair. Recommendations for evaluating the stripping potential of pavements are included in appendix G.

PROFILE DATA

Profile data has been collected for the LTPP program by a fleet of four K.J. Law type profilometers. A minimum of five consecutive data collection runs are made at each site. A criterion for maximum variability assures that the data is uniform. For this study, the data has been reduced by averaging the results of the five runs.

Profile data, in the form of International Roughness Index (IRI) data was included as a dependent variable in the regression analysis. It was not found to influence the performance of the treatment test sections significantly. The results of this analysis are provided in tables 2 through 7. The complete analysis is provided in appendix L.

Similar questions apply to profile data as those which were addressed in the section on pavement rutting. What is the effect of the treatment on pavement roughness? What is the long-term effect of the treatment on roughness? The first issue can be addressed by comparing performance data immediately before and after treatment. The second comparison looks at the change in pavement roughness over the 5 years of performance compared with the change in roughness of the control sections.

Each of the treatments can be expected to improve the ride quality of the pavement upon application. The extent of improvement depends on the treatment type and the original condition of the pavement. For example, the improvement in roughness measurement in any pavement will be minimal for those pavement sections already in good condition. As the pavement condition gets worse, the impact of treatment application can be seen more readily. However, the continued performance of the pavement resulting from the application of the treatment can be expected to be shorter for pavements in worse initial condition.

With regard to the pavement roughness comparison before and after treatment, the following conclusions can be drawn:

- Thin overlays significantly improved pavement smoothness immediately after treatment.

- Chip seals and slurry seals improved pavement smoothness slightly after treatment.

- The crack seal treatment did not significantly affect pavement smoothness. The comparison of pavement roughness data immediately after treatment with that after 5 years indicated little change, implying that the treatment has helped to preserve the condition of the pavement section.

- Relative to the control sections, pavement smoothness was improved by all treatments over the 5-year evaluation period.

A general observation relating to profile data is that pavement roughness appears to have a strong correlation with distress only in the extreme wet-freeze environment. In other regions, the development of distress does not correlate well with the propagation of pavement roughness. Apparently, without the combination of moisture and freeze-thaw cycles, continued deterioration of pavement distress evolves sufficiently slowly that the development of roughness lags significantly in time, resulting in a poor correlation between the two measures of performance. Fatigue cracking is frequently observed to exist for some time without resulting in excessive roughness in climates other than wet-freeze.

Once again the crack seal sections must be looked at differently from the other treatment sections. The crack seal treatment does little to improve initial roughness, and in some cases may actually cause a decrease in ride quality. The benefit of crack sealing can only be evidenced by improvement in pavement performance over the life of the treatment. The evaluation of this trend in the SPS-3 site data is difficult to identify, since new cracks were not kept sealed at most of the sites in the experiment, as originally requested. Other sections designated as crack seal sections contained no visible cracking.

FRICTION DATA

The pavement friction data stored in the LTPP data base has been collected by the individual agencies. Each agency collects this information with their own equipment. The majority of this equipment is the K. J. Law type, meeting ASTM E-274. Several other devices have also been used by agencies.

Friction data available for the SPS-3 sites were evaluated to identify the effect of the maintenance treatments on pavement friction characteristics. It must be recognized that the long-term friction quality of any pavement surface is a function of the hardness of the coarse aggregate used in the pavement surface mix, along with mix characteristics and void content. The collection of friction data for the LTPP data base is strictly voluntary on the part of the agencies, and for this reason, a full set of data is not available. However, a large amount of data is available, and is provided in appendix M. The data does not address the issue of microtexture versus macrotexture.

As with pavement profile and rutting data, friction was included in the regression analysis as a dependent variable (tables 2 through 7). Once again, friction was not found to significantly influence the performance of the maintenance treatments in maintaining pavement condition.

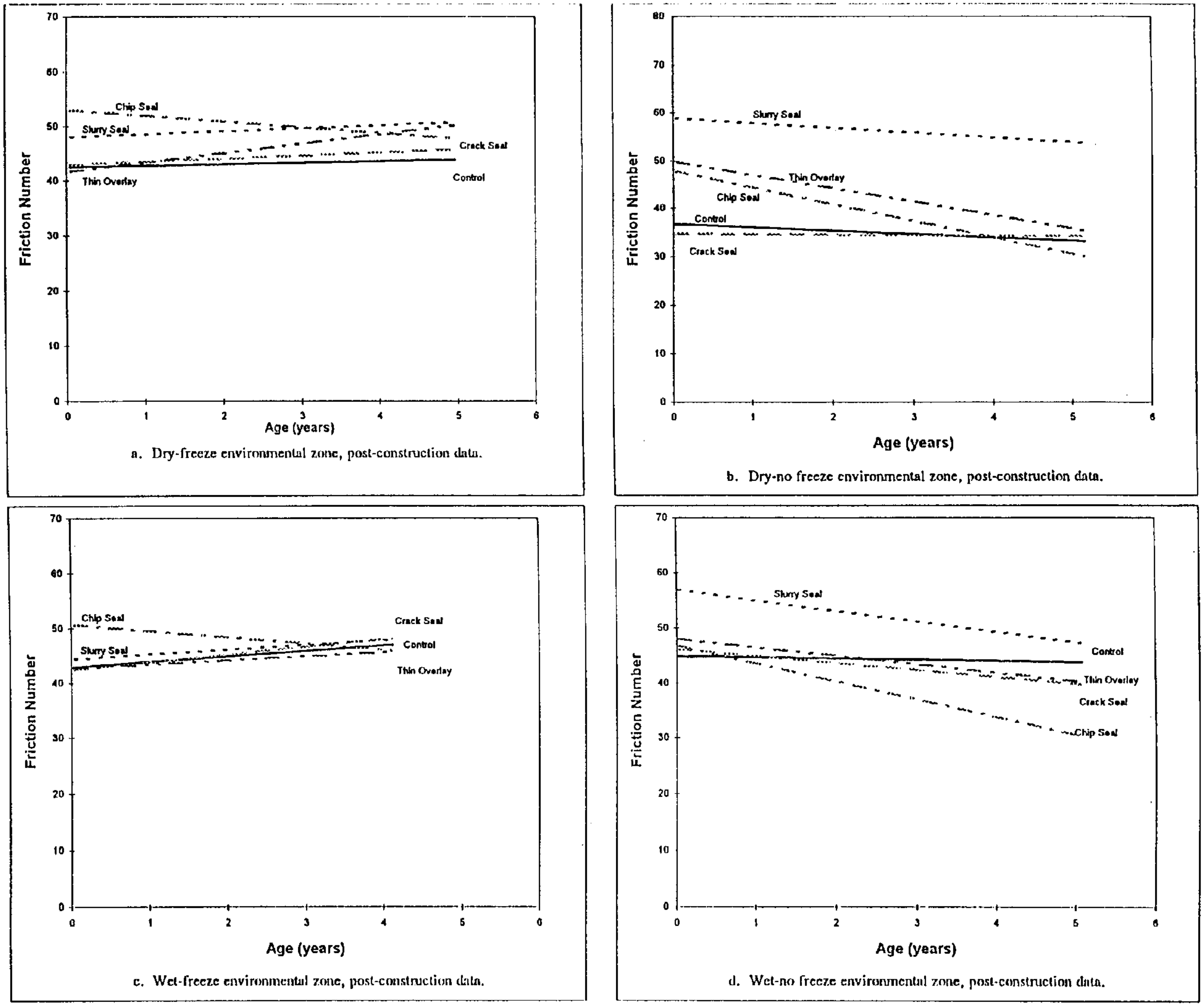
Again, the two questions to be addressed are: "What is the effect of applying a treatment on pavement friction?" and "What is the effect on the longer term friction quality of the pavement relative to the control?"

Since the aggregates for the original pavements and the hot-mix overlays were randomly selected by the individual States, it is difficult to make comparisons for these surfaces across state lines. Within LTPP regions, the aggregates used for the chip seal and slurry seal sections were consistent. In addition, the specifications for these materials were similar for all four LTPP regions.

When the data is reviewed on the basis of climatic region, some general observations are forthcoming. Most noticeable among these is that the friction quality provided by the slurry seals (large Type II or Type III gradation) stands out throughout almost all the sections as retaining a very high friction value. Relationships between original pavement surfaces and thin overlays show very parallel curves in figure 16. In most cases, an improvement in friction is observed following the application of any of the treatments, but in isolated cases, this does not occur.

Overall, the friction quality of nearly all the sections is quite good regardless of the treatment type. The crack seal treatment understandably has virtually no effect on pavement friction quality. The chip seal treatment improves friction, unless there is a problem with the performance of the treatment due to aggregate loss or embedment.

These trends can be seen in the composite curves from each of the four major climatic regions as shown in figure 16. As expected, the level of friction quality slightly decreases over time for all the treatments and control sections. A distinct exception is noted in the freeze climates, where gradual increases in friction are seen over time. This is attributed to the oxidizing effect of the climate in combination with the relatively low volume of traffic at most of these sites. Traffic action is not sufficient to knead the pavement and minimize the effect of pavement aging, as measured by friction values. In addition, freeze climate pavements experience more surface roughening from studded tires and snow chains.



a. Dry-freeze environmental zone, post-construction data.

b. Dry-no freeze environmental zone, post-construction data.

c. Wet-freeze environmental zone, post-construction data.

d. Wet-no freeze environmental zone, post-construction data.

Figure 16. Friction vs. age for different climatic regions, post-construction data.

TRAFFIC DATA

Traffic data was extracted from LTPP program traffic information. It is composed of two distinct types of data, weigh-in-motion (WIM) monitoring data and agency estimated data. For purposes of this study, the primary concern is the magnitude of traffic, and not the precision of the traffic measurement procedures. Therefore, monitoring data has been combined with the agency traffic estimates to obtain a complete listing of average daily traffic (ADT) for each test section. The objective is to identify whether the traffic volume is high or low in order to assess the impact of traffic volume on the performance of the maintenance test sections. The surface wear of traffic is related to the volume of vehicles. The magnitude of traffic loads is important to pavement structural capacity, which is not expected to be affected by the presence of maintenance treatments.

In order to meet this objective, traffic data was compiled for all the sites from the LTPP traffic data base. Two sources of data are included in the data base, data generated for on site WIM equipment and agency estimated data. WIM data is comprised of at least two different types of data collection equipment, piezo and bending plate. A number of manufacturers are represented in the data base, along with various means and level of equipment calibration. Agency estimates are developed for a site for any years for which WIM data is not available. Each agency uses its own techniques to develop these estimates.

In addition, LTPP traffic procedures result in a calculation of equivalent single-axle loads (ESALs), and sometimes in an estimate of average daily traffic (ADT). All of these various data types and formats were combined to arrive at the classification of traffic data for this study. Where ADT data was not provided in the data base, an appropriate traffic level category was assigned by relating ESAL data to that for other sites which had both data form represented. This results in an imprecise, but necessary correlation procedure for placing all the sites into a traffic level category. The result is that traffic data used in this study is not considered to be of very high quality. Detailed information is provided in appendix N.

Having compiled a list of ADT for the test lane only, the traffic data was grouped into three levels: high, medium, and low. The range of lane ADT values varies from 81 vehicles per day to over 11,320. The division of lane ADT into the high, medium, and low groupings were established as:

- Low - less than 1000 lane ADT
- Medium - 1000-3000 lane ADT
- High - greater than 3000 lane ADT

This definition was developed by looking at a frequency distribution of the data for all the test sites.

Traffic was included in the regression analysis as an independent variable. The results of the regression analysis demonstrated that the level of traffic variable was not significant to treatment performance. This is shown in tables 2 through 7.

Further analysis of the effect of traffic was carried out by comparing the PRS performance level of the various treatments over time. The change in pavement condition, expressed as PRS, for each test section was computed. The average of these changes was subsequently computed for all the sections, by treatment type, in each environmental region.

The evaluation of test section performance with respect to these three levels of traffic volume is provided in table 13. The summary of the results provides few well-defined trends. For the chip seal and slurry seal treatments, the change in condition (PRS value) between treatment application and the 5-year evaluation, increases with increased level of traffic. It can also be noted that for certain treatments in specific climates, little variation occurs with the change in traffic level. This observation applies to the thin overlay in the wet-freeze environment. It also applies to the slurry seal and chip seal in both no freeze climates. It also is true for the chip seal in the dry-freeze climate.

An exercise to correlate traffic, as originally identified in the experiment design as low and high, with pavement performance was also carried out. This activity was not found to improve the strength of the relationship between traffic and performance.

It is reasonable to expect that consideration of the structural adequacy of these sections would influence the pavement performance as related to traffic. This analysis included looking at the pavement sections within each environmental region, by original pavement condition, grouped by adequate and inadequate structural capacity. Sixty-five percent of the sections evaluated were originally in good condition, 24 percent in fair original condition, and only 11 percent in poor condition originally.

PAVEMENT STRUCTURAL ADEQUACY

The experiment originally designated each test site as being structurally adequate or inadequate. The experiment design evaluated these criteria on the basis of a structure number ratio which consists of the existing structural capacity divided by the required structural capacity and calculated in accordance with the AASHTO Guide for the Design of Pavement Structures.[9] The structure number ratio represents this as a number greater than, less than, or equal to one. This assessment activity identifies the effect of pavement structural adequacy on the performance of the treated test sections.

A review of the impact of structural capacity on the performance of the sections carried out during the regression analysis revealed no significant effect. That is the pavements with inadequate pavement structure performed as well, or as poorly, as those with adequate structure. No significance is attached to the effect the treatments had on extending pavement performance.

Further evaluation using the change in pavement condition represented as PRS was carried out. A comparison was made of the change in pavement section performance over the performance monitoring period between the structurally adequate and inadequate sections. Correlation to

Table 13. Effect of traffic level on average of change in PRS.

Traffic	Wet-Freeze					Wet-No Freeze					Dry-Freeze					Dry-No Freeze				
	310	320	330	340	350	310	320	330	340	350	310	320	330	340	350	310	320	330	340	350
H	32	69	43	43	61	0	29	13	30	4	91	61	65	36	25	9	13		13	8
M	38	41	4	28	15	12	21	20	7	5	16	31	23	29	26	5	12	8	15	2
L	26	28	23	9	28	3	25	44	8	0	43	42	30	34	27	18	11	13	18	11

310 - Thin Overlay
320 - Slurry Seal
330 - Crack Seal
340 - Control
350 - Chip Seal

the change in PRS value for the pavement section in good, fair, and poor original condition were considered for each of the four environmental regions. Once again, no significant trends could be identified. Several instances were found where the deterioration of the structurally adequate sections was greater than the deterioration of the structurally inadequate sections in the same original condition. This analysis was severely limited for fair and poor sections, which included very few sections in several matrix cells.

The distribution of sections between the structurally adequate and structurally inadequate categories for the good and fair original pavement condition sections is nearly even. There are slightly more in the low structure category in each case. In the originally poor condition category, however, three-fourths of the sections were in the inadequate group. The information is contained in appendix O.

Any relationship between structural capacity and traffic level appears to be purely random. Since the three traffic levels analyzed were different from the original two classifications used in the experiment design, other groupings of the traffic levels were considered as well. The low and medium levels were combined, or the medium and high levels. In either case, the relationship with structural capacity did not improve. It was evident that there were fewer sections in fair and poor original condition with structural adequacy, than in good condition. However, there were also more good condition pavements.

DEFLECTION DATA

Deflection data is collected for the LTPP program by a fleet of eight Dynatest Falling Weight Deflectometers (FWD). Four devices were used until 1994, at which time four more were added to the fleet. These are operated from the LTPP regional contractor offices.

Deflection data was collected at the SPS-3 sites at least every other year. Therefore, a relatively good set of data exists in terms of the number of data collection incidences. However, this data was collected randomly at all times of year (depending on the climate of the particular region) with no correction for seasonal variability available.

Several approaches were taken to the review of pavement deflection data. The basis of most of the analysis was the review of raw deflection data normalized to a 4082-kg load. Questions asked were: Did placement of the treatment have any impact on the pavement deflections immediately before and after treatment? Did the treatments have any impact on the deflections over the 5 years of performance? To determine these impacts, deflection magnitudes were compared both before and after treatment, and immediately after treatment and after 5 years. In neither case was a dominant trend found. The variability of the data, presumably resulting from unaccounted seasonal variation, was great enough to obliterate any trend which may exist.

Performance trends were looked for by reviewing both pavement layer and subgrade deflection data. No appreciable change was observed in the subgrade data. The expected change in deflection before versus after placement of the thin overlay could not even be identified. Site deflection data for the SPS-3 sites is provided in appendix P. It identified changes in deflection both before and after treatment, and over time.

Backcalculation analyses were conducted on the data from selected sites in Arizona. The subgrade modulus values computed failed to show any difference in subgrade properties over time. This analysis approach was not successful in identifying any benefit from the maintenance treatments. The difference in any performance indications in the data was obscured by the lack of sensitivity in the analysis tools. As a result of the large volume of data points, deflection data was not included in the regression analysis.

ASPHALT BINDER PROPERTIES

A series of cores were taken prior to the construction of the SPS-3 maintenance treatments for the purpose of monitoring the effect of the treatments on the properties of the asphalt binder. Testing was performed on extracted asphalt materials. Test results were reported for incorporation into the LTPP data base for:

- Asphalt content.
- Vacuum capillary asphalt viscosity at 60 degrees C and 300 mm Hg.
- Asphalt penetration at 25 degrees C (0.1 mm).

The results are included in appendix Q.

Only samples from the North Atlantic and Southern regions were available for this assessment. This investigation was conducted on samples for sites in the Southern region, since it is believed that the hotter climate in that region would tend to accelerate changes in asphalt properties, providing a greater opportunity of noting these anticipated changes.

Samples were again taken after the treatments were placed in 1993. Testing of these samples was not accomplished until the summer of 1996. Fewer samples were taken the second time. While asphalt test results were reported for both ends of many test sections initially, samples from either end of the sections had to be combined for the second round of testing to obtain sufficient material to perform the test. Since variability can be observed in the results from either end of the test section at some of the sites, combining material from either end could influence the results.

The literature suggests that hardening of asphalt binders is greatest during the first 4 years of the life of a hot-mix asphalt pavement. The benefits of using seals to prevent oxidative hardening are more likely if the seals are placed within the first 2 years after placement of the hot-mix asphalt. The data available in this project indicates that almost all of the test sections were 4 or more years of age when the preventive maintenance treatments were placed.

Table 14 summarizes the individual SPS-3 test sections relative to changes of asphalt binder properties with time and relative difference in asphalt binder properties between sealed and

Table 14. Relative change in asphalt binder properties.

Test Section	**Relative Change in Asphalt Binder Properties with Time**	**Relative Difference in Asphalt Binder Properties between Sealed and Non-sealed Treatments**
Alabama B	softer	softer
Florida B	softer	softer
Oklahoma A	mixed	softer
Texas D	softer	harder
Texas F	mixed	softer
Texas K	softer	no difference

non-sealed treatment sections. The data indicate that the asphalt binder softened with time in four of the six sections. Mixed results were obtained in the other two sections. A change in asphalt recovery method from the Abson to the Rotavapor method is probably largely responsible for this unexpected result.

Examining table 14, the expected results of softer asphalt binders in sealed sections as compared to non-sealed sections was evident on four of the projects. In one section, the asphalt binder was harder in the sealed section and in one section no difference was noted.

The data does not support the expected hardening trends found in the literature. The probable reasons for not obtaining the expected trends probably are related to the use of different recovery test methods, sample storage, variability of test methods, and an insufficient number of replicate samples.

Upon reviewing the results of the asphalt tests, it was determined that expected trends in changes of the test result properties could not be identified. Correlation of the results from the initial and second rounds of testing were disappointing. The fact that initial changes in asphalt penetration and viscosity expected in the years following pavement placement had already occurred when the SPS-3 study of these pavements began is a factor in not seeing further change in these values. This situation can be expected to exist for the normal application of maintenance treatments. The asphalt properties have probably reached a stabilized value after 4 to 5 years, and will show little subsequent change. However, the erratic nature of the data gave the study team cause for concern.

Investigation into the similarities and differences in testing procedures, equipment, and lab circumstances, revealed that there may have been an unanticipated effect from the distillation procedures used in the extraction process. While the first round of testing used a multi-sample heating mantle, the second round used a roto-vacuum system. Observations from the laboratory provide suspicion that the asphalt samples were oxidized in the heating mantles during the first round of testing. If this was indeed the case, it is difficult to continue the evaluation of the effect of the treatments on the properties of the asphalt.

Western Technologies used the Abson Recovery method of extracting asphalt material from the samples from the first round of data samples. It seems that there was a strong possibility that some of the asphalt samples experienced hardening during this process. This would have influenced the results of subsequent penetration and viscosity testing to result in the irrational trends mentioned above.

For the second round of testing, the Rotavapor process was used to extract the asphalt samples. This process is far less likely to result in hardening of the asphalt. Thus, trends in penetration and viscosity data indicating softening of the asphalt over time appear to have been the result of hardening the asphalt samples during the first round of testing, and not in the second round of testing.

Unfortunately, since the problem with the testing seems to have occurred during the first round of testing, there is no initial data point with which to make future comparisons. As a result of the limited anticipated remaining life of the maintenance treatment test sections, there appears to be little use in attempting to compare any future testing to the second round results.

In summary, no significance could be determined from the results of the testing. Further, it is unlikely that further sampling of these sections will provide a meaningful contribution to understanding the performance of the four maintenance treatments included in the SPS-3 experiment.

It is the recommendation of the research team that all further sampling and testing associated with determining asphalt binder properties for the SPS-3 experiment be terminated. A more extensive testing program and tighter control of the testing and analysis is needed if reasonable results are to be obtained from a study of this type.

PERFORMANCE SUMMARY

In order to quantify the effectiveness of the maintenance treatments in various climates, an exercise was performed to capture information which provides insight into treatment performance. The objective of this exercise was to develop a series of treatment performance curves reflecting expectations for the treatments in various climates. The climates selected were selected on the basis of previous work which indicated that climatic effects were quite significant on treatment performance, and that a change in PRS value over time reflected a decrease in pavement condition level. Subsequently, comparisons of performance could be made on the basis of the treatment performance curves developed.

The first step in this exercise was to develop the treatment performance curves for each treatment. Information available consisted of a treatment performance curve based on the change in PRS value over time, for each of the three initial pavement condition levels, good, fair, and poor. The constraint was that the condition evaluation for each pavement condition included no more than 5 years of performance data. Realistically, the data available covered 4 years on the average.

Conceptually, if the performance curves for the three pavement condition levels could be linked together into a single treatment performance curve, it would describe treatment performance over a longer period than the 4 to 5 years of data available. In some cases, this technique could be expected to provide a performance trend describing the expected performance life of a treatment.

The concept discussed in the previous paragraph was accomplished by beginning with the good condition pavement performance data from the time of treatment and progressing chronologically through the data available. Performance data from recent data collection for the fair and poor pavement sections was added chronologically to the initial data from the good pavement sections. Data points from the fair and poor treatment sections soon after treatment were intentionally not used, since they reflected the "masking" effect of the treatments on pavement performance. Later, when the initial condition of the pavement sections began to be apparent, the data points were successfully used to develop a performance curve which generally describes the long-term performance of the treatments. Polynomial forms were fitted to the data to find those which seemed to best describe the composite performance of the treatments across all three levels of pavement condition, represented now as pavement age. Figure 17 is an example that demonstrates the component parts and the composite curve.

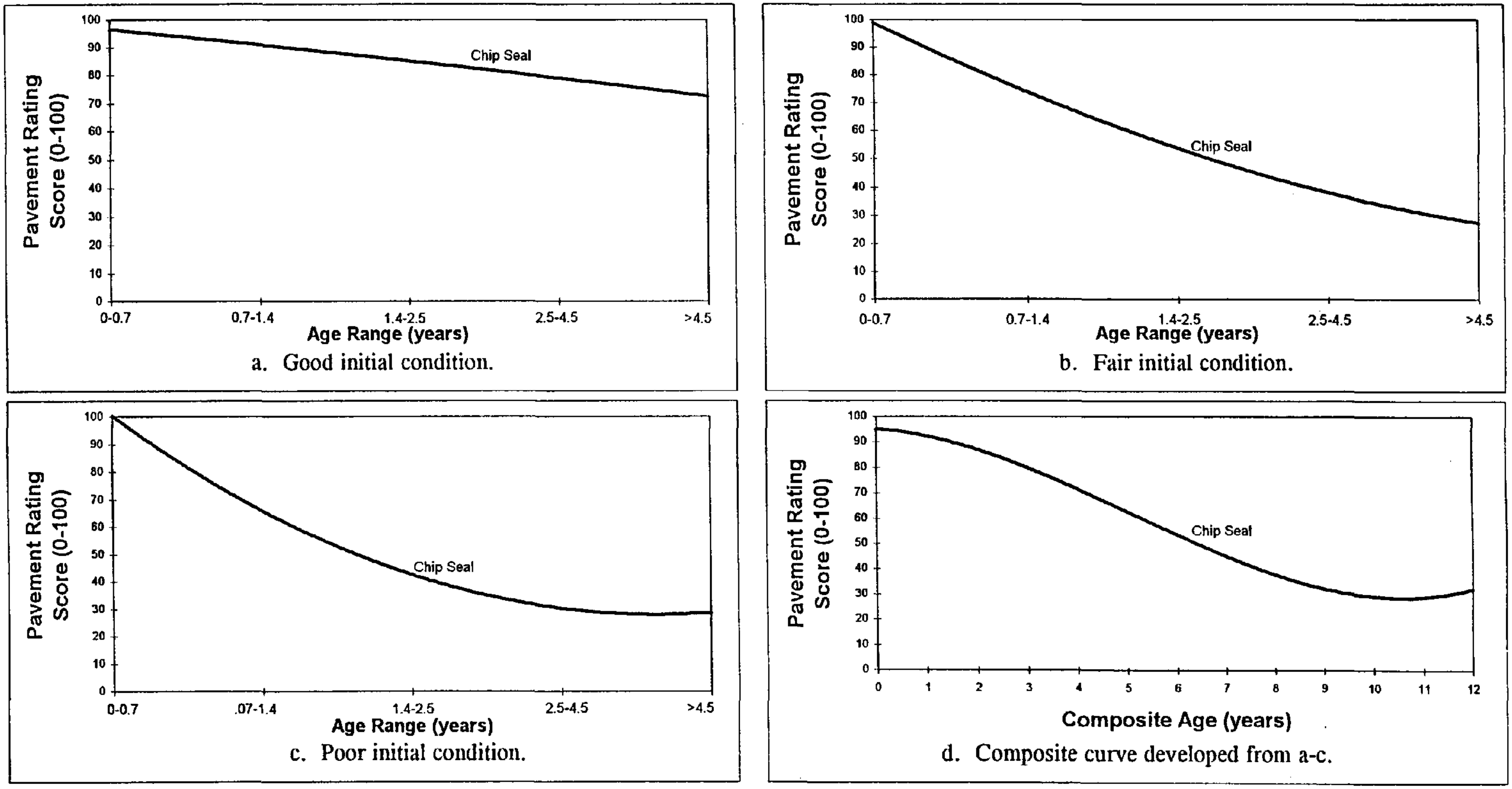
This analysis, admittedly, is not a rigorous technique. However, it provides a means of representing and quantifying treatment performance when the variability and frequency of data defy more rigid analysis techniques. These representations also correlate well with observations and conclusion previously derived from the study, and with the study team's experience and engineering judgment regarding the performance of the maintenance treatments.

The climatic regions used in this exercise represent three Superpave microclimates. They are the pure wet-freeze, wet-no freeze, and dry-freeze climates. Sufficient sites were not available in the dry-no freeze climate to develop the Superpave "pure" climate, so all data from the dry-no freeze climate were used.

A summary of this analysis is provided in table 15. The information presented in the table includes an indication of the deterioration rate of each treatment, in each climate. This is provided as an average change in PRS per year. The average PRS change is developed from the essentially linear portion of the performance curve, and ignores the tails which represent performance before and after most of the deterioration has occurred. These "representative deterioration" rates can be compared across climates and treatments.

A goodness-of-fit category reflecting the accuracy with which the model curve represents the data is provided as an R-squared value. Two specifically low R-squared values are present in the table for chip seal and thin overlay treatments in the wet-no freeze climate. The R-squared value for the chip seal is low only due to the wide range of data described, and not because of a poor fit to the performance trend. The thin overlays in this climate have performed in an outstanding manner for all initial pavement condition levels, and although the data essentially describes linear performance, the R-squared value for the polynomial curve provided indicates an even better fit to the data than a linear model.

Finally, the "age at terminal serviceability index" provides an indication of how long after application a specific treatment can be expected to perform in a given climate. This information, taken from the composite treatment performance curves, correlates reasonably well with the ETG estimates. This age is based on the time after application the composite performance curve reaches a terminal serviceability level of 50 on the PRS scale. This level of 50 is based on the expectation of the study team of a PRS distress level which would precipitate maintenance activity. It is not predicated on the level of distress appropriate for preventive maintenance action discussed earlier in the report. The PRS value of TSI at 50 also represents a reasonable approximation of a TSI of 2.5 used by many highway agencies on the 5-point TSI scale.



a. Good initial condition.
b. Fair initial condition.
c. Poor initial condition.
d. Composite curve developed from a-c.

Figure 17. Composite performance curve development for the chip seal treatment in Superpave zone IA.

Table 15. Treatment performance summary.

Climatic Region		Control	Crack Seal	Slurry Seal	Chip Seal	Thin Overlay
Dry-No Freeze	PRS/Yr.	8.4	3.7	3.7	18.7	5.1
	Age at TSI (yrs)	6	9-10	> 12	7	> 12
	Goodness of Fit (R^2)	0.95	0.82	0.80	0.95	0.86
Dry-Freeze	PRS/Yr.	6.3	5.9	4.1	3.0	9.2
	Age at TSI (yrs)	6-7	6	5	11	6-7
	Goodness of Fit (R^2)	0.94	0.61	0.98	0.61	0.93
Wet-No Freeze	PRS/Yr.	6.4	7.2	1.8	0.2	0.5
	Age at TSI (yrs)	9	7	> 12	> 12	> 12
	Goodness of Fit (R^2)	0.73	0.85	0.79	0.19	0.37
Wet-Freeze	PRS/Yr.	8.5	5.2	13.7	8.7	8.9
	Age at TSI (yrs)	3-4	5	4	6-7	7
	Goodness of Fit (R^2)	0.93	0.73	0.90	0.90	0.77

These three pieces of information taken together provide a useful key to the performance a maintenance engineer can expect from the treatments in his area. How long the treatments last, how quickly the deterioration occurs, and the reliability of the estimate is quantified in the table.

As indicated earlier, the climates represented were isolated to provide "pure" trends, with the exception of the dry-no freeze data. Insufficient data was available from the study to reasonably characterize other, fringe climates. Any agency which does not fall within these "pure" climates can interpolate treatment performance from the climates they border, or collect sufficient data in their own area to perform a similar analysis.

LIFE-CYCLE COST ANALYSIS

Although the Expert Task Group field review of the SPS-3 test sites provided insight into the benefits of placing the maintenance treatments, only the application of sound life-cycle cost analysis techniques can effectively address the cost-effectiveness of the treatments. Even though the consensus of the ETGs was that thin overlays continue to perform best after 5 years, this observation cannot conclude that they are the most cost-effective treatment.

Two input factors are critical to performing a realistic cost analysis. The first is good treatment cost data. A request was sent to all the highway agencies for normal average costs for the SPS-3 treatments. Experimental costs, such as those actually incurred in carrying out the specialized SPS-3 construction contracts, are not reflective of costs associated with normal construction. The use of realistic costs is essential to the agencies in evaluating the practicality of investing in a given treatment within their jurisdiction.

Likewise, good estimates of treatment performance are required. A comparison between performance life estimates resulting from the TSI PRS value of 50 (table 15) and the ETG estimates (table 16) was favorable. Considering the methods used, the comparison of model and ETG estimates is generally good. The most notable difference applied to the slurry seal treatment. The slurry seal models in the no freeze regions have not reached the TSI value yet, while those in wet-freeze climates came down quickly. The ETG estimates also represent a wider climatic distribution of sites, except in the dry-no freeze data. Therefore, the performance life estimates provided by the Expert Task Groups in the field was used in the following life cycle cost estimate.

As an example of a method for evaluating cost-effectiveness, the results of these data have been combined to provide a table of values for each climatic region which brackets the extremes of both performance and cost expectations (table 17). That is, minimum performance life and maximum costs are used, along with maximum performance life and minimum costs. Inordinately high treatment costs have not been used. The performance life identified for the States selected on the basis of costs were then used to calculate an annual high and low cost for each treatment in each climatic region. This information was then expressed, for each climatic region, in terms of a ratio of equivalent costs based on the chip seal treatment. The chip seal was selected as a reference value because of its widespread suitability and use.

As an example, the average annual unit cost of any treatment is divided by the average annual cost of the chip seal to produce the chip seal ratio.

$$\textit{Chip Seal Ratio} = \frac{\textit{Average annual unit cost of thin overlay}}{\textit{Average annual unit cost of chip seal}}$$

Table 16. Average expected performance from ETG estimates (years).

		North Atlantic Region	North Central Region	Southern Region	Western Region
Crack Seal	Good	6	6	8	6
	Poor	10	8	8	6
Slurry Seal	Good	10	10	9	7
	Poor	8	7	8	7
Chip Seal	Good	10	9	10	9
	Poor	8	7	12	6
Thin Overlay	Good	8	8	11	10
	Poor	10(1)	7	10	8

Table 17. Chip seal costs, dry-freeze climatic zone.

	High Cost ($/yd²)	**Minimum Performance (Years)**	**Average Cost ($/yd²/Year)**
Wyoming	1.51	7	0.21
	Low Cost ($/yd²)	**Maximum (Years)**	**Average Cost ($/yd²/Year)**
South Dakota	0.34	9	0.04

The project study team has also provided estimates of costs for the treatments assuming that the treatment is in widespread usage in the given area. The calculated ratios derived from the study team cost estimates generally fall within the range of the other computed ratio values. This information is summarized in table 18 by climatic region.

CRACK SEAL

Using the averages computed, the crack seal treatment appears to be very cost-effective, as compared with the chip seal treatment. Although there is variation in the equivalency ratio from one climatic region to another, the range of these values is quite tight, and the ratio values quite low. This is further confirmed by the cost ratio computed using values estimated by the project study team.

SLURRY SEAL

The slurry seal treatment is observed to be competitive with the chip seal in the wet regions. In the dry regions, the performance ratio varies from 2.5 to over 10 times the chip seal cost. This data results from costs obtained from California and New Mexico.

The computations based on the study team's estimated cost for the slurry seal treatment once routine use has been established in an area indicates approximate equivalence in cost-effectiveness with the chip seal.

Performance observations from Arizona would significantly reduce the cost ratio of the slurry seal in that climatic region.

CHIP SEAL

Other treatment types are compared to the cost-effectiveness of the chip seals. For this reason, the chip seal ratio values in table 18 show the cost ratio for the chip seal is always 1.

THIN OVERLAY

In the wet-freeze region, the thin overlay compares reasonably well with the chip seal treatment. It appears that cost-effective performance can be met on the low end of the cost range.

The ratios for equivalent cost-effectiveness for the thin overlay in the dry regions vary from two to six times that of the chip seal treatment.

The estimate developed by the project team indicates that the thin overlay can be as cost-effective as the chip seal, in conditions where the performance life of the overlay is good.

Table 18. Cost ratio to chip seal treatment by environmental zone.

	Environmental Zone				
Treatment Type	**Dry-Freeze (Low-High)**	**Dry-No Freeze (Low-High)**	**Wet-Freeze (Low-High)**	**Wet-No Freeze (Low-High)**	**By Team Estimate**
Crack Seal	0.1 - 0.2	0.2 - 0.5	0.1 - 0.3	0.2 - 0.4	0.3 - 0.6
Slurry Seal	2.5 - 12.6	2.7 - 5.8	0.75 - 3.2	1.1 - 2.0	0.7 - 1.7
Chip Seal	1	1	1	1	1
Thin Overlay	2.1 - 4.6	4.8 - 5.8	1.3 - 2.1	1.6 - 7.0	1 - 2.8

As indicated, these trends are based on selected cost information provided by the agencies. Certainly the average cost of any treatment decreases with increased usage and increased quantity. It is not possible to evaluate the basis for the costs reported by the agencies to ensure that they represent realistic production costs of the treatments. The range of costs are intended to provide some insight into the levels of costs which agencies have experienced, and the impact these cost ranges can have on the issue of treatment cost-effectiveness. This information is provided entirely to provide agencies in various parts of continental North America an indication of what they can expect from a given treatment in their own area.

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

SUMMARY

The SHRP SPS-3 experiment provided an opportunity to evaluate the performance of four preventive maintenance treatments. The objectives were to evaluate the effectiveness of the treatments in preserving pavement condition level, determine the optimum application timing for the treatments in terms of pavement distress, and to provide an opportunity for highway agencies to share information about maintenance treatments.

The study of these test sections has been successful in meeting these objectives. Although a majority of the treatment test sections have not reached the end of their performance lives, strong evidence has been collected to support the positive contribution of the maintenance treatments in preserving pavement condition. Continuation of the experiment evaluation will allow for the SPS-3 evaluation to be closed out as the test sections reach the end of their performance lives. To accomplish this, only the identified distress data is needed. Specifically, transverse longitudinal and fatigue cracking, along with pothole patching, were the distress types most identified with changes in pavement performance. Profile data proved useful only when correlated well with the presence of distress in the wet-freeze climate.

The question of when to apply the maintenance treatments to receive the most return on the highway funds investment is an old and difficult one. The SPS-3 study has provided trends after 5 performance years which suggest that:

- The application of all the maintenance treatments has been beneficial to the performance of the test pavements.

- The maintenance treatments have been effective in improving the performance of pavements at all levels of condition: good, fair, and poor.

- The greatest benefit to pavement performance is received when the maintenance treatment is applied using a preventive concept, before extensive distress occurs.

- The issue of cost-effectiveness of the treatments is highly dependent upon the local performance of the individual treatments and the local cost of their application.

- All the treatments evaluated proved to be cost-effective when environmental conditions, in combination with costs resulting from frequent use, resulted in adequate performance life.

Summary observations for the specific maintenance treatments were as follows:

- Crack Sealing
  - -- Most effective on pavements in good condition
  - -- Regional shape factor differences significant to performance
  - -- Wide shallow reservoir (38.1mm by 9.5mm) used in North Central and North Atlantic performed very well
  - -- 25.4-mm x 25.4-mm reservoir used in Western Region exhibited adhesion failure

- Slurry Seals
  - -- Improved pavement performance relative to control
  - -- Performed best in no-freeze climates
  - -- Performed well on sections with little cracking
  - -- Moisture sensitivity was observed on certain sections

- Chip Seals
  - -- Performed well across all environmental zones
  - -- Performed very well in wet no-freeze environment
  - -- Benefited the performance of pavements in poor condition
  - -- Quality and characteristics of aggregate important to success
  - -- Emulsified asphalts require proper handling
  - -- Good construction control is necessary for successful application and performance (SHRP Specifications)
  - -- Moisture sensitivity was observed on certain sections

- Thin Overlays
  - -- Performing well
  - -- Improve ride quality
  - -- Reduce rutting
  - -- Reduce severity of reflective cracking

The SPS-3 experiment objective of disseminating information among agencies about pavement maintenance has been met in several ways already. These include:

- Experiences among the ETG members, and observations were captured from the experiment section performance. Many ETG members witnessed successful performance of treatments not normally used by their agency.

- A better understanding of the maintenance treatments was gained throughout the highway industry.

- Improved specifications were developed by the ETGs and used in construction of the experiment sections.

- Information about accelerated pavement damage in the form of stripping and rutting resulted from placing slurry and chip seals on pavements with stripping potential was shared among highway agencies.

CONCLUSIONS

The major conclusions from the field evaluation trips and the evaluation of the LTPP data are found to support each other. Other conclusions encompass construction and materials specification, performance data, and cost trends. All these conclusions are stated below:

- The use of the SHRP SPS-3 materials and construction specifications enhanced the performance of the maintenance treatments studied.

- The use of these maintenance treatments results in extended pavement performance, except where accelerated rutting resulted from the placement of slurry seals and chip seals.

- Early application of the treatments, in a preventive maintenance strategy, provides the best preservation of pavement performance levels.

- Climatic factors had the greatest effect on the performance of the pavement test sections

- Under appropriate environmental conditions and cost levels, all four treatments can be cost-effective.

- Traffic did not appear to significantly affect the performance of the maintenance treatments. Very high-volume, as well as low-volume, sites are evidencing good treatment performance.

- Pavement structural adequacy did not appear to have an effect on maintenance treatment performance.

- Deflection, profile, rut, and friction data collected to date did not contribute significantly to the evaluation of treatment performance.

- The pavement rating score concept developed during the project is a useful tool for evaluating LTPP data.

RECOMMENDATIONS

Several strong recommendations can be made from the results of this study. They address materials, construction, and use of the four maintenance treatments:

- Agencies should strongly consider adoption of the SHRP specifications for materials and construction.

- Based on the effects of climate on the performance of the treatments, and local use, which influences costs, agencies should consider use of each treatment for conditions found favorable:

  -- Crack seal treatment for preserving pavements that are otherwise in acceptable condition. The wide, shallow seal design performed best.

  -- Slurry seal treatment for preserving pavements with minimal cracking, but requiring surface protection. Slurry seals worked best in warmer climates.

  -- Chip seal treatment for pavements in any condition, except poor condition pavements in a wet-freeze climate. Performance is most cost-effective when placed on pavement in better condition.

  -- Thin overlays for pavements in any condition, when the cost is warranted. Performance is more cost-effective when placed on better condition pavements.

  -- Pavement stripping potential should be evaluated prior to placing slurry seals or chip seals, to avoid accelerated stripping damage.

- Evaluation of the SPS-3 test sections should continue until the test sections reach the end of their performance lives. It is recommended that future evaluations be conducted on the basis of environmental regions, rather that the LTPP geographical regions. This will allow projections made in this report to be replaced with actual performance information. Based on the data evaluated in this report, it appears that pavement distress is developing more quickly in the freeze environments than the no freeze environments. A reasonable recommendation for continued evaluation of the SPS-3 sites is to conduct another review of the freeze environment sites in 2 to 3 years. This also facilitates the logistics of the reviews and aids in providing strong consistency and quality control of the evaluation process. Only distress data is needed to complete the performance evaluations. This can be accomplished by the evaluation of LTPP distress information. Site inspections to identify special problems can be accomplished by a smaller, more cost-effective analysis team.

  A longer evaluation interval seems prudent for the no freeze sites. Much of the data in these regions has not shown any significant change in distress, or performance level. More time is necessary to determine when significant deterioration will begin, and to develop meaningful performance trends.

Review of continued distress data will provide an indication of the appropriate timing to close out the study of the sections.

- The results of this evaluation indicate that not all the monitoring data collected has yet contributed meaningfully to the study. The study team recommends that:

  -- Distress data be carefully collected at 2-year intervals, and will serve as the primary tool for future evaluations. Improved methods of recording distress, such as 35-mm detail photographs or video logging could be valuable.

  -- Profile data has correlated well with distress only in the wet-freeze environment. Continued profile data collection may facilitate the development of distress-roughness relationships for the various climatic regions.

  -- Friction data may produce some conclusions with a longer data collection period for the chip and slurry seal treatments where consistent aggregates were used. Continued collection of this data at a longer interval, such as 4 years could prove useful in defining the suitability of the treatments as a friction enhancement measure.

- The construction of additional test sections including additional treatments would serve the maintenance community well. Additional sections should include several of the treatments in common use by highway agencies now, and perhaps some which appear to be promising.

APPENDIX A
MATERIALS AND CONSTRUCTION SPECIFICATIONS FOR THE NORTH ATLANTIC REGION

The enclosed sections contain the specifications for materials and construction of the SPS-3 flexible maintenance treatments. The materials and construction specifications are grouped by LTPP region. Appendix A contains the entire set of specifications for the North Atlantic region. The entire specification document for any region is available in SHRP Document H-350.

These specifications were developed by regional Expert Task Groups and contain many features frequently not used in agency construction specifications for these treatments. The use of these specifications is likely a contributing factor to the overall good performance of the various maintenance treatments studied.

PART 400 - ASPHALT PAVEMENTS AND SURFACE TREATMENTS

Section 407.--CHIP SEAL

Description

407.01 This work consists of furnishing all materials, equipment, and labor for constructing the asphalt chip seal surface treatment areas. The treatment areas shall be constructed on the existing pavement in accordance with these specifications and in conformance with details and at the locations shown in the site descriptions. There is one treatment area for chip sealing at each project site and the demonstration site.

Equipment

407.02 The equipment used by the Contractor shall include but to be limited to the following:

(a) Power broom. A motorized power broom, center mount only, shall be used for removing loose material from the surface to be treated and for removing loose aggregate after work is completed.

(b) Rollers. A sufficient number of self-propelled, pneumatic-tired rollers shall be used for rolling aggregates after spreading such that the entire lane width of the treatment area is covered in one pass of the rollers. Each pneumatic-tired roller shall have a compacting width of not less than 60 inches and a minimum ground contact pressure of 80 pounds per square inch. If 60 inch wide rollers were used, then the Contractor would be required to have 3 rollers to roll the 13 foot wide test sections.

(c) Asphalt distributor. A pressure distributor shall be used for applying the asphalt material. It shall be designed and operated to distribute the asphalt material in a uniform spray at the specified rate without atomization. It shall be equipped with a bitumeter having a dial registering feet of travel per minute. The dial shall be visible to the operator in order to maintain the constant speed required for the application at the specified rate. The pump shall be equipped with a tachometer having a dial registering gallons (or liters) per minute passing through the nozzles. The dial shall be readily visible to the operator. The distributor shall be provided with a full circulatory system that includes the spray bar. The distributor shall be provided with heaters that can be used to bring the asphalt material to spray application temperature. Means shall be provided for accurately indicating the temperature of the asphalt material at all times. The thermometer well shall not be in contact with the heating tube. The normal width of application of the spray bar shall be 13 feet with provision for greater or lesser width when necessary. A hose and spray nozzle attachment shall be provided for applying asphalt material to patches and areas inaccessible to the spray bar. The spray bar height, nozzle angle, and pump pressure will be calibrated weekly or as required by the Engineer. The calibration shall be performed in accordance with TAI Manual Series No. 19(MS-29), 2nd Edition. The allowable deviation shall be not more than 10 percent in the longitudinal and transverse directions. The longitudinal and transverse spread rates shall be checked using ASTM D2995.

(d) Aggregate spreader. The aggregate spreader shall be a self-propelled mechanical spreader with an operational scalper screen capable of uniformly distributing aggregate at the prescribed rate. The aggregate spreader will be checked weekly or as required by the Engineer. The calibration shall be performed in accordance with TAI Manual Series No. 19(MS-19), 2nd Edition. The allowable deviation in the amount of aggregate spread shall not be more than 10 percent (by weight) in the longitudinal or transverse directions.

(e) Hauling Equipment. Trucks used for hauling aggregate shall have a cover of canvas or other suitable material of such size as to protect the aggregate from weather. Truck bed shall be covered and securely fastened when delivering aggregate to the project sites.

(f) Auxiliary Equipment. Shovels and other equipment shall be used as necessary to perform the work. Cleaning equipment including but not limited to power brooms, air compressors, water flushing equipment, and hand brooms shall be adequate for surface preparation.

Materials

407.03 Asphalt. The base asphalt to be emulsified shall be an AC-10, meeting the requirements of AASHTO M226, Table 2. The emulsified asphalt shall conform to Subsection 702.03 for either emulsified asphalt grade CRS-2, RS-2, or HFRS-2.

Acceptance sampling, point of acceptance, and test methods are specified in Subsection 106.06.

407.04 Mineral Aggregates. Aggregates shall meet the requirements of Subsection 703.13(a).

Acceptance sampling, point of acceptance, and test methods are specified in Subsection 106.06.

407.05 Water. All water shall be potable and compatible with the chip seal. Compatibility must be ensured by the Contractor.

407.06 Mix Design. The chip seal surface treatment shall be designed in accordance with TAI design method found in Manual Series No. 19 (MS-19), 2nd Edition. The Contractor shall have the design of the chip seal prepared by qualified personnel, approved by the Engineer, experienced in asphalt surface treatment design.

The chip seal surface treatment design shall be based on traffic of over 2,000 vehicles per day and assume a slightly pocked, porous oxidized surface.

Application rate for the emulsified asphalt binder shall be from 0.25 and 0.40 gallons per square yard. The final application rate shall be determined after the source of materials is known.

Spread rate for the aggregate, based on weight of dry aggregate, shall be from 18 to 25 pounds per square yard. The final application rate shall be determined after the source of materials is known.

The design of the surface treatment shall be submitted to the Engineer for approval 15 working days prior to any work being accomplished. The design will include the following information:

(a) Aggregate gradation.
(b) Bulk specific gravity of aggregate.
(c) Loose unit weight of aggregate.
(d) Emulsified asphalt rate of application and type.
(e) Aggregate rate of application.

In addition to the above data, the Contractor is to submit with the design of the surface treatment a sample of the aggregate and the emulsion for use to the Engineer for verifying test results. The design may be verified by the Government.

Construction Requirements

407.07 Weather Limitations. The chip seal surface treatment shall be placed only when the surface to be treated is dry or slightly damp, when the temperature of the road surface and the air temperature are 60 degrees F and rising, and when the weather is not foggy or rainy.

407.08 Preparation of Surface, General. All roadway surfaces to be treated shall be cleaned by the Contractor. The Contractor shall sweep the pavement with a motorized power broom to remove all loose material. All depressions not reached by the power broom will be cleaned by the Contractor using hand brooming. The Contractor shall ensure that the outer edges of the pavement to be treated including the 1 foot of the shoulder width, if a paved shoulder exists, are thoroughly cleaned. Work will not continue until the surface is approved by the Engineer.

407.09 Temporary Centerline Markings. Prior to the placement of the chip seal surface treatment, temporary centerline markings meeting the requirements of Section 635 shall be installed by the Contractor.

407.10 Application of Emulsified Asphalt Binder. The rate of application for the emulsified asphalt binder shall be at the rate determined by the surface treatment design. See Subsection 407.06. The Engineer will make adjustments to the rate of application if necessary. Application of the emulsified asphalt binder shall be made uniformly at this rate with the pressure distributor, one full lane width at a time (including shoulder). Further adjustments in the rate of application shall be made by the Engineer, if needed, during the course of the work. The emulsified asphalt binder shall be applied at a temperature between 125 and 185 degrees F. The final spray temperature will be specified by the Engineer.

Before beginning application, building paper shall be spread over the surface, from the beginning point back and from the endpoint forward, for a sufficient distance for the spray bar to be at full force when the surface to be treated is reached. The spray bar shall be shut off instantaneously at the endpoint to ensure a straight line and the full application of binder up to the endpoint. After the asphalt is applied, the building paper shall be removed and disposed of properly. A hand spray shall be used to apply asphalt binder where necessary to touch up all spots missed by the distributor.

407.11 Application of Mineral Aggregates. After the asphalt binder has been spread evenly over the roadway surface, aggregates of the type specified shall be evenly applied to the roadway surface by self propelled spreader equipment. The aggregate shall be distributed uniformly by a spreader within 1 minute of the emulsified asphalt application.

All aggregate shall be watered down before placement, but not immediately before, to provide aggregates that are uniformly damp as approved by the Engineer at the time of placement on the roadway.

The aggregate shall be spread in one operation in such a manner that an 8 inch strip of the emulsified asphalt is left exposed along the longitudinal joint to form a lap for succeeding applications of the emulsified asphalt. If necessary, thin or bare spots in the spread of aggregates shall be corrected by hand spreading or other methods subject to the approval of the Engineer.

The aggregate shall be spread at the rate determined by the surface treatment design. See Subsection 407.06. The Engineer will make adjustments to the rate of application if necessary.

The aggregate shall be rolled following spreading. A maximum time of 3 minutes will be allowed between the spreading of the aggregate and completion of the initial rolling of that aggregate. The rollers shall proceed in a longitudinal direction at a speed less than or equal to 5 miles per hour. The rollers shall make three complete coverages of the aggregate with the final pass in the direction of traffic.

Immediately prior to opening to traffic, the surface of the roadway shall be swept, at the direction of the Engineer, with a power broom at adequate pressure to remove loose aggregate.

Trucks hauling aggregate shall be operated in a manner that shall not damage the roadway or the freshly applied surface.

Method of Measurement and Basis of Payment

407.12 All materials and work required by this Section will be measured and paid for in accordance with Section 410.

Section 408.--SLURRY SEAL

Description

408.01 This work consists of furnishing all materials, equipment, and labor for constructing the asphalt slurry seal treatment areas. The treatment areas shall be constructed on existing pavement in accordance with these specifications and in conformance with details and at the locations shown on the plans. There is one treatment area for slurry sealing at each project site and the demonstration site.

Equipment

408.02 The equipment used by the Contractor shall include but not be limited to the following:

(a) Slurry Seal Mixer. The slurry seal mixing machine shall be a continuous flow mixing unit with calibrated controls capable of delivering accurately predetermined proportions of aggregate, water, and asphalt emulsion to the mixing chamber and of discharging the thoroughly mixed product on a continuous basis. Each machine shall be equipped with metering devices, easily readable, that will accurately measure all raw materials prior to entering the pugmill. Each machine shall have an automated system capable of automatically sequencing in all raw materials to ensure constant slurry mixture. This mixing chamber shall be capable of thoroughly blending all ingredients together. No violent mixing will be permitted. The aggregate shall be pre-wetted in the pugmill immediately prior to mixing with the emulsion.

The mixer shall be equipped with an approved fines feeder having an accurate metering device or other approved means to introduce a predetermined quantity of mineral filler into the mixer at the time and location that the aggregate is introduced into the mixing machine. The fines feeder shall be used whenever mineral filler is a part of the aggregate blend.

The mixing machine shall be equipped with a water pressure system and a fog-type spray bar adequate for complete fogging of the surface immediately ahead of the spreading equipment. Rate of fog application shall be 0.03 to 0.06 gallon of water per square yard.

The mixer shall be capable of mixing all materials at preset proportions regardless of the engine speed without changing the mixing machine settings.

The machine shall be capable of a minimum speed of 60 feet per minute and shall not exceed 130 feet per minute while in operation. The mixing machine shall have sufficient storage capacity to properly mix and apply a minimum of 7 tons of slurry seal.

Approved means of measuring all materials used in each slurry seal batch shall be provided, properly calibrated, and made accessible to the Engineer by the Contractor. The slurry seal mixer shall be checked weekly or as required by the Engineer. The calibration of the slurry seal mixer shall be performed in accordance with ISSA Performance Guidelines A105. The Engineer may use the recorders and measuring facilities of the slurry seal unit to determine application rates, asphalt emulsion content and mineral filler content of individual loads.

(b) Spreading Equipment. Attached to the mixing machine shall be a mechanical type single squeegee distributor equipped with flexible material in contact with the surface to prevent loss of slurry and adjustable to assure a uniform spread of varying grades and crowns. It shall be steerable and adjustable in width with a flexible strike-off.

The box shall not cause grooving of the slurry by any of its parts. It shall be kept clean, and build-up of material on the spreader will not be permitted. The type drag, burlap, or other textile will be approved by the Engineer and it shall be cleaned or changed as frequently as needed or as designated by the Engineer. The drag shall be wetted at the beginning of each application.

(c) Hauling Equipment. Trucks used for hauling aggregate shall have a cover of canvas or other suitable material of such size as to protect the aggregate from weather. Truck beds shall be covered and securely fastened when delivering aggregate to the project sites.

(d) Auxiliary Equipment. Hand squeegees, shovels, and other equipment shall be used as necessary to perform the work. Cleaning equipment including but not limited to power brooms, air compressors, water flushing equipment, and hand brooms shall be adequate for surface preparation.

Materials

408.03 Asphalt. The emulsified asphalt shall be quick-set emulsified asphalt confirming to Subsection 702.03, Table 702-1.

Acceptance sampling and point of acceptance are specified in subsection 106.06.

408.04 Mineral Aggregates. Aggregate shall meet the requirements of subsection 703.13(b).

Point of acceptance is specified in subsection 106.06.

408.05 Mineral Filler. Mineral filler shall meet the requirements of subsection 703.11.

Acceptance of mineral filler is specified in Subsection 106.06.

408.06 Water. All water shall be potable and compatible with the slurry seal. Compatibility must be ensured by the Contractor.

408.07 Mix Design. The slurry mixture shall be designed in accordance with requirements of ASTM D 3910, as applicable. The Contractor shall have a mix design prepared by one of the following laboratories:

Alpha Labs P.O. Box 74 Alpha, OH 45301 (513) 298-6647 Contact: Ben Benedict	ScanRoad, Inc. P.O. Box 7677 Waco, TX 76714 (817) 772-7677 Contact: Tony Ng
Asphalt Technologies 9890 B Elder Creek Road Sacramento, CA 95829 (916) 381-8033 Contact: Jim Stevens	Valley Slurry Seal Lab P.O. Box 1620 W. Sacramento, CA 95691 (916) 373-1500 Contact: Jim Harriman
Koch Materials 1194 Zinns Quarry Road Reading, PA 17404 (717) 843-0975 Contact: Ron Kohlar	Sahuaro Labs P.O. Box 6536 Phoenix, AZ 85005 (602) 252-3061 Contact: Mike Doyle

The mix design shall be based upon the requirement that the treated area will be opened to traffic within 2 hours after placement of the slurry seal mixture.

Residual asphalt content, percent weight of dry aggregate, shall be from 7.5 to 13.5 percent as determined by AASHTO T 59.

Application rate of slurry mixture, based on weight of dry aggregate, shall be from 15 to 25 pounds per square yard.

The mix design will be submitted to the Engineer for approval 15 working days before work begins. The mix design will include the following information:

(a) Aggregate gradation.

(b) Mineral filler to be used if needed, percentage by weight of aggregate.

(c) Emulsified asphalt percentage and type.

(d) Sand equivalent of aggregate.

(e) Setting time (40 minutes maximum).

(f) Water resistance test results; pass or fail.

(g) Results of Wet Track Abrasion Test (max. loss of 75 grams per square foot).

In addition to the above data, the Contractor is to submit with the mix design a sample of the aggregate, the emulsified asphalt, and the mineral filler, for use to the Engineer for verifying test results.

After the design mix has been established, the mixture supplied to the project shall conform thereto within the following tolerances:

Passing U.S. No. 4 and larger sieves	±7%
Passing U.S. No. 8 to U.S. No. 100 sieve	±4%
Passing U.S. No. 200 sieve	±2%
Residual Asphalt (by extraction)	±0.4%
Mineral filler (portland cement)	±0.5%

The Engineer may adjust the emulsified asphalt content during construction to account for the amount of asphalt absorbed by the pavement.

Construction Requirements

408.08 Weather Limitations. Slurry seal shall be applied only when the surface to be treated is dry or slightly damp, when the temperature of the road surface and the air temperature are 60°F and rising, and when the weather is not foggy or rainy.

408.09 Preparation of Surface, General. All roadway surfaces to be treated shall be cleaned by the Contractor. The Contractor shall sweep the pavement with a motorized power broom to remove all loose material. All depressions not reached by the power broom will be cleaned by the Contractor using hand brooming. The Contractor shall ensure that the outer edges of the pavement to be treated, including the 1 foot of the shoulder width if a paved shoulder exists, are thoroughly cleaned.

408.10 Temporary Centerline Markings. After placement of the slurry seal surface treatment, temporary centerline marking meeting the requirements of Section 635 shall be installed by the contractor.

408.11 Application of Slurry Seal. The surface shall be fogged with water immediately preceding the spreader. The slurry seal mixture shall be of the desired consistency as it leaves the mixer. The mixture furnished shall conform to the established design mix. The total mixing time shall not exceed 4 minutes. A sufficient amount of slurry seal mixture shall be carried in all parts of the spreader such that complete coverage of the base surface is effected.

In areas not accessible to the slurry mixer, the slurry seal mixture shall be hand worked with approved squeegees.

Treated areas will be allowed to cure until such time as the Engineer permits these treated areas to be opened to traffic.

The following will not be permitted:

(a) Lumping, balling, or unmixed aggregate.

(b) Segregation of the emulsified asphalt and aggregate fines from the coarse aggregate. If the coarse aggregate settles to the bottom of the slurry seal mix, the slurry seal mix shall be removed from the base surface.

(c) Excessive breaking of the emulsified asphalt in the spreader box.

(d) Streaks or other unsightly appearances. The shoulder line shall be uniform and straight.

(e) Excessive build-up of slurry seal mix on longitudinal or transverse joints.

(f) If oversize materials are encountered, final screening prior to placement will be required.

Method of Measurement and Basis of Payment

408.12 All materials and work required by this Section will be measured and paid for in accordance with Section 410.

Section 409.--CRACK SEALING

Description

409.01 This work consists of furnishing all materials, equipment, and labor for sealing cracks in the existing pavement in the treatment areas. Crack sealing shall be in accordance with these specifications and in conformance with details and at the locations shown on the plans. There is one treatment area for crack sealing at each project site and the demonstration site.

Equipment

409.02 The equipment used by the Contractor shall include but not be limited to the following:

(a) Hot-Compressed Air-Lance (HCA). The hot-compressed air-lance shall provide clean, oil-free compressed air at a volume of 100 cubic feet per minute at a pressure of 120 pounds per square inch and at a temperature of 2000 degree F.

(b) Application Wand. The crack sealant applicator wand shall be attached to a heated hose, attached to a heated sealant chamber. Temperature controls shall be capable of maintaining the temperature of the sealant within manufacturer's tolerances.

(c) Heating Kettle. The equipment for heating the sealant materials shall be constructed as an indirect heating type double boiler using oil or other heat transfer medium and shall be capable of constant agitation. Additionally, the heating equipment shall be capable of controlling the sealant material temperature within the manufacturer's recommended temperature range and shall be equipped with a calibrated thermometer capable of ±5°F accuracy from 200°F to 600°F. This thermometer shall be located such that the Engineer may safely check the temperature of the sealant material.

(d) Router. A hand controlled mechanical router specifically designed for routing cracks in pavements. The router shall have the ability to rout random cracks to the cross section specified at a minimum rate of 1,000 linear feet per hour.

Materials

409.03 The crack sealant shall conform to the requirements of Subsection 705.01.

Acceptance of crack sealant is specified in Subsection 106.06.

Construction Requirements

409.04 Preparation of Crack. The pavement area to be treated shall be clean and dry with no standing or flowing water on the surface.

All cracks greater than 12 inches in length, and greater than 1/8 inch width shall be sealed.

Cracks less than 1/8 inch in width shall be routed to 1 ½ inch wide and 3/8 inch deep. Sides of the routed cracks shall be vertical. The router shall be guided so that the crack lies entirely within the routed channel. The bits used to rout the cracks must be kept sharp and replaced when dull. All cracks shall be thoroughly cleaned of all foreign material.

All cracks shall be blown clean and dry using the HCA lance. Care shall be exercised to keep the HCA lance moving at a pace that will avoid burning the surrounding pavement.

409.05 Sealing the Crack. For each crack, the crack sealant shall be placed and finished within 2 minutes after heating with the HCA lance. Each crack shall be slightly overfilled.

409.06 Acceptance. Following the application of the crack sealant and before opening the roadway to traffic, the job will be visually inspected by the Engineer for area exhibiting adhesion failure, damage to the sealant from construction equipment or personnel, missed cracks, foreign objects in the sealant, or other problems which will accelerate failure or indicate the job is not acceptable. Portions of the job identified by the Engineer that do not meet these acceptable criteria will be prepared and resealed until satisfactory to the Engineer.

Method of Measurement and Basis of Payment

409.07 All materials and work required by this Section will be measured and paid for in accordance with Section 410.

Section 410.--ASPHALT SURFACE TREATMENTS

Description

410.01 This work shall consist of furnishing all materials, equipment, tools, and labor for the construction of the treatment areas for chip seals, slurry seals, and crack sealing at each project site and the demonstration site.

This work shall include that described in the following Sections:

Section 311	-	Stockpiled Aggregates
Section 407	-	Chip Seal
Section 408	-	Slurry Seal
Section 409	-	Crack Sealing
Section 635	-	Temporary Traffic Control

410.02 Project sites and the demonstration site will be measured by the each completed and accepted.

Surplus materials produced for anticipated sites added or for sites deleted from the contract and that are not used in the work will not be measured for payment but will be considered a subsidiary obligation of the Contractor.

410.03 The accepted quantities determined as provided above, will be paid for at the contract price per each for the pay item listed below and shown in the bid schedule, which price and payment will be full compensation for the work prescribed in this section.

Payment will be made under:

Pay Item	Pay Unit
410(18) Project Site	Each
410(19) Demonstration Site	Each

PART 700 MATERIALS

Section 702. -- BITUMINOUS MATERIALS

702.01 and 702.02 Reserved.

702.03 Emulsified Asphalts.

(a) The emulsified asphalts for chip sealing shall be cationic, grade CRS-2, and conform to the AASHTO M 208 Table 1. The base asphalt to be emulsified shall conform to AASHTO M 226, Table 2 for an AC-10.

The sieve test specified under AASHTO M 208 is not required.

(b) Emulsified asphalts for slurry sealing shall conform to the requirement of Table 702-1 below:

Table 702-1
Quick-Set Emulsified Asphalts

Property	Specification	AASHTO Test Method
Viscosity, 77°F, Saybolt Furol, sec	20 - 100	T 59
Residue by Distillation, %	57 min.	T 59
Sieve Test	0.10 max.	T 59
Tests on Residue from Distillation		
Penetration, 77°F, 100g, 5 sec	40 - 110	T 49
Solubility in Trichloroethylene, %	97.5 min.	T 44
Ductility, 77°F, cm	40 min.	T 51

702.04 Acceptance Procedures for Asphalts.

(a) General Acceptance Procedures. Acceptance of asphalt is subject to the following:

(1) Laboratory Tests. The supplier shall test all material intended for shipment to the Government.

(2) Examination of Shipping Container. Before loading, the supplier shall examine the shipping container and shall remove all remnants of previous cargos that might contaminate the material to be loaded.

(3) Delivery Ticket. The Contractor shall furnish with each shipment two copies of the delivery ticket. The delivery ticket shall contain the following information:

Consignees
Project No.
Grade
Net gallons
Net weight
Type and amount of antistripping agent
Identification No. (truck, car, tank, etc.)
Destination
Date
Loading temperature
Specific gravity at 60°F

(4) Test Results and Certification. The Contractor, or authorized supplier, shall deliver to the Engineer the applicable test results obtained from (1) above and a certification signed by an authorized supplier to cover the quality and quantity of material and the condition of container for each shipment. The certification shall be essentially in the following form and may be stamped, written, or printed on the delivery ticket:

> "This is to certify that this shipment of __________ tons/gallons of __________ asphalt meets all contract specifications and the shipping container was clean and free from contaminating material when loaded."
>
> Supplier:
> Signed:

Failure to sign the certification will be cause to withhold use of the material until it can be sampled and tested for compliance.

(5) Acceptance Sampling Procedures. Samples of asphalt materials shall be taken by the Engineer in accordance AASHTO T40, from the shipping containers at the point of delivery. Samples shall be taken of each separate tank at the time of discharge into distributors or other conveyances on the project.

(b) Alternate Acceptance Procedures. Asphalt will be accepted by certification under (a) (1) through (a) (4). Quality control reviews may be conducted by the Government or an authorized representative at the point of production to determine the reliability of the supplier's certifications.

If the certifications are not reliable, acceptance by certification will be discontinued and the contents of each shipping container will be sampled at the point of delivery in accordance with (a) (5), and tested for compliance prior to incorporation in the work. This procedure will be followed until the supplier's quality control and testing procedures are such that material meeting contract specifications is being consistently produced.

(c) Requirements for Asphalt Containing Antistripping Additives. In addition to either (a) or (b), the Contractor or authorized supplier shall furnish the Engineer on delivery of the initial shipment of fortified asphalt to the project and with subsequent shipments when ordered by the Engineer, a 1 quart sealed sample of the asphalt taken at time of loading at the refinery and prior to introduction of the additive, along with a separate 1 pint sample of the antistripping additive.

(d) Nonspecification Asphalt. Asphalt not conforming to the specifications will either be rejected or accepted in accordance with the following:

- The Engineer will evaluate the qualities of the nonconforming material and determine whether the deficiencies are such as to require complete removal of the material, or if in the interest of the Government, the nonconforming material may be accepted at a reduced price and permitted to be used or to remain in the completed work.

- All rejected asphalt shall be immediately removed from the work, including all portions of the work in which such rejected asphalt has been incorporated, and shall be replaced with specification material at no additional cost to the Government.

- When the nonconforming asphalt is permitted to remain in the work, the Engineer will determine the quantity of material represented and an appropriate adjustment in contract price based on engineering judgment.

Section 703. -- AGGREGATES

703.01 through 703.10 Reserved

701.11 Filler. Filler material for asphaltic mixtures shall meet the requirements of AASHTO M 17.

703.12 Reserved

703.13 Aggregate for Chip Seals and Slurry Seals. Aggregates shall meet the following requirements for grading and quality:

(a) Aggregates for Chip Seal. Aggregate shall be hard, durable particles or fragments of crushed stone or crushed gravel. Aggregates shall conform to the grading requirements in Table 703-1 below.

Table 703-1
Grading Requirements for Chip Seal Aggregate
(Percentage by Weight Passing U.S. Standard Sieves,
AASHTO T 27 and T 11)

Sieve Designation	Percent Passing
½" square	100
3/8" square	40 - 70
¼" square	0 - 15
U.S. No. 10	0 - 15
U.S. No. 200	0 - 1.0

Not less than 75 percent by weight of the aggregate shall be particles having at least one fractured face. The fracture requirement shall apply to material retained on each sieve size No. 10 and above if the sieve retains more than 5 percent of the total sample.

The portion of aggregate retained on the 3/8 inch sieve shall not contain more than 15 percent of particles by weight that are flat or elongated or both, when tested in accordance with ASTM D 4791 using a dimensional ratio of 1 : 5.

The aggregate shall have a minimum polish value of 32 as determined by AASHTO T 279.

The aggregate shall pass the static stripping test as determined by AASHTO T 182.

The aggregate shall show a durability factor not less than 35 (coarse and fine aggregate) as determined by AASHTO T210.

Coarse aggregate shall have a percent of wear of not more than 30 at 500 revolutions as determined by AASHTO T 96.

The finished product shall be clean, uniform in quality, and free from wood, bark, roots, and other deleterious materials.

(b) Aggregates for Slurry Seal. Aggregate shall consist of manufactured sand or crusher fines, or other approved mineral aggregate or combination thereof. Aggregates shall conform to the grading requirements in Table 703-2 below.

Table 703-2
Grading Requirements for Slurry Seal Aggregate
(Percentage by Weight Passing U.S. Standard Sieves,
AASHTO T 27 and T 11)

Sieve Designation	Percent Passing
5/16" square	99 - 100
U.S. No. 4	70 - 90
U.S. No. 8	45 - 70
U.S. No. 16	28 - 50
U.S. No. 30	19 - 34
U.S. No. 50	12 - 25
U.S. No. 100	7 - 18
U.S. No. 200	5 - 15

Smooth, textured sand of less than 1.25 percent water absorption shall not exceed 50 percent of the total combined aggregate as determined by the AASHTO T 84.

The aggregate shall have a minimum sand equivalent of 55 as determined by AASHTO T 176, alternate Method No. 2.

The finished product shall be clean, uniform in quality, and free from wood, bark, roots and other deleterious materials.

The aggregate shall show a durability factor not less than 35 as determined by AASHTO T 210.

Material used in the production of the aggregate shall have a percent of wear of not more than 35 at 500 revolutions as determined by AASHTO T 96.

APPENDIX B
MATERIALS AND CONSTRUCTION SPECIFICATIONS FOR THE NORTH CENTRAL REGION

The enclosed sections contain the specifications for materials and construction of the SPS-3 flexible maintenance treatments. The materials and construction specifications are grouped by LTPP region. Appendix B contains the entire set of specifications for the North Central region. The entire specification document for any region is available in SHRP Document H-350.

These specifications were developed by regional Expert Task Groups and contain many features frequently not used in agency construction specifications for these treatments. The use of these specifications is likely a contributing factor to the overall good performance of the various maintenance treatments studied.

Section 407.--CHIP SEAL
(ADDED SECTION)

Description

407.01 This work consists of furnishing all materials, equipment, and labor for constructing the asphalt chip seal surface treatment areas. The treatment areas shall be constructed on the existing pavement in accordance with these specifications and in conformance with details and at the locations shown in the site descriptions. There is one treatment area for chip sealing at each project site and the demonstration site.

Equipment

407.02 The equipment used by the Contractor shall include but to be limited to the following:

(a) Power broom. A motorized power broom, center mount only, shall be used for removing loose material from the surface to be treated and for removing loose aggregate after work is completed.

(b) Asphalt distributor. A pressure distributor shall be used for applying the asphalt material. It shall be designed and operated to distribute the asphalt material in a uniform spray at the specified rate without atomization. It shall be equipped with a bitumeter having a dial registering feet of travel per minute. The dial shall be visible to the operator in order to maintain the constant speed required for the application at the specified rate. The pump shall be equipped with a tachometer having a dial registering gallons (or liters) per minute passing through the nozzles. The dial shall be readily visible to the operator. The distributor shall be provided with a full circulatory system that includes the spray bar. The distributor shall be provided with heaters that can be used to bring the asphalt material to spray application temperature. Means shall be provided for accurately indicating the temperature of the asphalt material at all times. The thermometer well shall not be in contact with the heating tube. The normal width of application of the spray bar shall be 13 feet with provision for greater or lesser width when necessary. A hose and spray nozzle attachment shall be provided for applying asphalt material to patches and areas inaccessible to the spray bar. The spray bar height, nozzle angle, and pump pressure will be calibrated weekly or as required by the Engineer. The calibration shall be performed in accordance with the Asphalt Institute Manual calibration Series No. 19, 2nd Edition. The allowable deviation shall be not more than 10 percent in the longitudinal and transverse directions. The longitudinal and transverse spread rates shall be checked using ASTM D2995.

(c) Aggregate Spreader. The aggregate spreader shall be a self-propelled mechanical spreader capable of uniformly distributing aggregate at the prescribed rate. The aggregate spreader shall be checked weekly or as required by the Engineer. The calibration of the aggregate spreader shall be performed in accordance with the Asphalt Institute Manual Series No. 19, 2nd Edition. The allowable deviation in the amount of aggregate spread shall not be more than 10 percent (by weight) in the longitudinal or transverse directions.

(d) Rollers. A sufficient number of self-propelled pneumatic-tired rollers shall be used for rolling aggregates after spreading such that the entire lane width of the treatment area is covered in one pass of the rollers. Each pneumatic-tired roller shall have a total compacting width of not less than 60 inches and shall have a minimum ground contact pressure of 80 pounds per square inch.

(e) Hauling Equipment. Vehicles used for hauling aggregate shall have a cover of canvas or other suitable material of such size as to protect the aggregate from weather. Aggregates shall be covered during delivery to the project sites.

(f) Auxiliary Equipment. Air compressors, water flushing equipment, hand brooms, shovels, and other equipment shall be used as necessary to perform the work.

Materials

407.03 Asphalt. Asphalt shall conform to the requirements of Subsection 702.03, Emulsified Asphalts and shall be obtained from a source selected by the Contractor that will assure compatibility with the aggregate selected.

Acceptance sampling and point of acceptance are specified in Subsection 106.06.

407.04 Aggregates. Aggregates shall meet the requirements of Subsection 703.13, Table 703-1.

Point of acceptance is specified in Subsection 106.06.

407.05 Water. All water shall be potable and compatible with the chip seal. Compatibility must be ensured by the Contractor.

407.06 Mix Design. The chip seal coat shall be designed in accordance with the Asphalt Institute design method found in their Manual Series No. 19, 2nd Edition. The Contractor shall have the design of the chip seal prepared by qualified personnel experience in asphalt surface treatment design.

The surface treatment design shall be based on traffic of over 2,000 vehicles per day and assume a slightly picked, porous oxidized surface.

Application rate for the emulsified asphalt shall be from 0.25 and 0.45 gallons per square yard. The final application rate shall be determined after the source of materials is know.

Spread rate for the aggregate, based on weight of dry aggregate, shall be from 20 to 40 pounds per square year. The final application rate shall be determined after the source of materials is known.

The design of the surface treatment shall be submitted to the Engineer for approval 21 days prior to any work being accomplished. The design will include the following information:

(a) Aggregate gradation.
(b) Bulk specific gravity of aggregate.
(c) Loose unit weight of aggregate.
(d) Asphalt rate of application and type.
(e) Aggregate rate of application.

In addition to the above data, the Contractor shall submit with the design of the surface treatment a sample of the aggregate and the emulsion for use by the Engineer for verifying test results. The design may be verified by the Government.

After the design mix has been established, the mixture supplied to the project shall conform to the following tolerances:

Passing U.S. No. 4 and larger sieves	±7%
Passing U.S. No. 8 to U.S. No. 100 sieve	±4%
Passing U.S. No. 200 sieve	±2%
Residual Asphalt (by extraction)	±0.4%

Construction Requirements

407.07 Weather Limitations. The chip seal surface treatment shall be placed only when the surface to be treated is dry or slightly damp, when the temperature of the road surface and the air temperature are 60 degrees F and rising, and when the weather is not foggy or rainy.

407.08 Preparation of Surface, General. All roadway surfaces to be treated shall be cleaned by the Contractor. The Contractor shall sweep the pavement with a motorized power broom to remove all loose material. All depressions not reached by the power broom will be cleaned by the Contractor using hand brooming. The Contractor shall ensure that the outer edges of the pavement to be treated including the 1 foot of the shoulder width, if a paved shoulder exists, are thoroughly cleaned. Work will not continue until the surface is approved by the Engineer.

407.09 Temporary Centerline Markings. Prior to the placement of the chip seal surface treatment, temporary centerline markings meeting the requirements of Section 640 shall be installed by the Contractor.

407.10 Application of Emulsified Asphalt. Emulsified asphalt shall not be placed on any wet surface or when weather conditions will otherwise prevent its proper handling or finishing. Application of emulsified asphalt shall be made only when the surface is dry as determined by the Engineer.

The rate of application for the emulsified asphalt binder shall be at the rate determined by the surface treatment design. See Subsection 407.06. The Engineer will make adjustments to the rate of application if necessary. Application of the emulsified asphalt binder shall be made uniformly at this rate with the pressure distributor, one full lane width at a time (including shoulder). Further adjustments in the rate of application shall be made by the Engineer, if needed, during the course of the work. The emulsified asphalt binder shall be applied at a temperature between 125 and 185 degrees F. The final spray temperature will be specified by the Engineer.

Before beginning application, building paper shall be spread over the surface, from the beginning point back and from the endpoint forward, for a sufficient distance for the spray bar to be at full force when the surface to be treated is reached. The spray bar shall be shut off instantaneously at the endpoint to ensure a straight line and the full application of binder up to the endpoint. After the asphalt is applied, the building paper shall be removed and disposed of properly.

407.11 Application of Aggregates. Immediately after the emulsified asphalt has been spread evenly over the roadway surface, aggregates of the type specified shall be evenly applied to the roadway surface by self-propelled spreader equipment. The aggregate shall be distributed uniformly by a spreader within 1 minute of the emulsified asphalt application.

All aggregate shall be moistened prior to placement to provide aggregates that are uniformly damp at the time of placement on the roadway.

The aggregate shall be spread in one operation in such a manner that an 8 inch strip of emulsified asphalt is left exposed along the longitudinal center joint to form a lap for succeeding applications of asphalt. If necessary, thin or bare spots in the spread of aggregates shall be corrected by hand spreading or other method subject to the approval of the Engineer.

The aggregate shall be spread at the rate determined by the surface treatment design. See Subsection 407.06. The Engineer will made adjustments to the rate of application if necessary.

The aggregate shall be rolled following spreading. A maximum time of 3 minutes will be allowed between the spreading of the aggregate and completion of the initial rolling of that aggregate. The rollers shall proceed in a longitudinal direction at a speed less than or equal to 5 miles per hour. The rollers shall make three complete coverages of the aggregate with the final pass being in the direction of traffic.

At the direction of the Engineer, prior to opening to traffic, the surface of the roadway shall be swept with a power broom at adequate pressure to remove loose aggregate.

The operation of vehicles hauling aggregate shall be so regulated that no damage as determined by the Engineer will result to the roadway or the freshly applied surface.

Method of Measurement

407.12 Asphalt will be measured by the ton. The quantity to be measured will be the number of tons indicated in the bid schedule or authorized by the Engineer.

Chip sealing will be measured by the each for the actual number of test sections completed and accepted.

Basis of Payment

407.13 The accepted quantities, determined as provided above, will be paid for the contract price per unit of measurement, respectively, for each of the particular pay items listed below and shown in the bid schedule.

The quantity of asphalt shown in the bid schedule is more than sufficient to construct the treated areas. Loss of material due to the Contractor's method of operations or rejection of material by the Engineer due to contamination or other reasons will not be cause for payment of increased quantity above that shown on the bid schedule. All excess asphalt remaining after satisfying the needs of the contract shall become the property of the Contractor.

Payment for Pay Item 407 (1) Asphalt for Chip Seal, will be made to the Contractor upon presentation of proof of purchase (paid invoice) for the quantity shown in the bid schedule, or authorized by the Engineer.

The unit contract price per each for "Chip sealing" shall be full payment to complete the work as specified, including all costs for labor, tools, equipment, materials, and transportation. This includes but is not limited to the following:

(a) Water necessary for brooming the surface.
(b) Calibration of equipment.
(c) Furnishing and placing temporary raised pavement markers.
(d) Water necessary for wetting the aggregate.
(e) Placement of the materials on the roadway.
(f) Brooming after placement is complete.

The cost of preparing and furnishing the chip seal mix design shall be incidental to the work required under other items of the contract. No direct payment will be made for such work.

Payment will be made under:

Pay Item	Pay Unit
407(1) Asphalt for chip seal	Ton
407(2) Chip sealing per site	Each

Section 408.--SLURRY SEAL
(ADDED SECTION)

Description

408.01 This work consists of furnishing and transporting all materials, equipment, and labor for constructing conventional asphalt slurry seal treatment areas. The treatment areas shall be constructed on the existing pavement in accordance with these specifications and in conformance with details and at the locations shown on the plans. There is one treatment area for slurry sealing at each project site.

Equipment

408.02 The equipment used by the Contractor shall include but not be limited to the following:

(a) Slurry Seal Mixer. The slurry seal mixing machine shall be a continuous flow mixing unit with calibrated controls capable of delivering accurately predetermined proportions of aggregate, water, and asphalt emulsion to the mixing chamber and of discharging the thoroughly mixed product on a continuous basis. Each machine shall be equipped with metering devices, easily readable, that will accurately measure all raw materials prior to entering the pugmill. Each machine shall have an automated system capable of automatically sequencing in all raw materials to ensure constant slurry mixture. This mixing chamber shall be capable of thoroughly blending all ingredients together. No violent mixing will be permitted. The aggregate shall be pre-wetted in the pugmill immediately prior to mixing with the emulsion.

The mixer shall be equipped with an approved fines feeder having an accurate metering device or other approved means to introduce a predetermined quantity of mineral filler into the mixer at the time and location that the aggregate is introduced into the mixing machine. The fines feeder shall be used whenever mineral filler is a part of the aggregate blend.

The mixing machine shall be equipped with a water pressure system and a fog-type spray bar adequate for complete fogging of the surface immediately ahead of the spreading equipment. Rate of fog application shall be 0.03 to 0.06 gallon of water per square yard.

The mixer shall be capable of mixing all materials at preset proportions regardless of the engine speed without changing the mixing machine settings.

The machine shall be capable of a minimum speed of 60 feet per minute and shall not exceed 180 feet per minute while in operation. The mixing machine shall have sufficient storage capacity to properly mix and apply a minimum of 7 tons of slurry seal.

Approved means of measuring all materials used in each slurry seal batch shall be provided and made accessible to the Engineer by the Contractor. The slurry seal mixer shall be checked weekly or as required by the Engineer. The calibration of the slurry seal mixer shall be performed in accordance with the Asphalt Institute Manual Series No. 19, 2nd Edition. The Engineer may use the recorders and measuring facilities of the slurry seal unit to determine application rates, asphalt emulsion content and mineral filler content of individual loads.

(b) Spreading Equipment. Attached to the mixing machine shall be a mechanical type single squeegee distributor equipped with flexible material in contact with the surface to prevent loss of slurry and adjustable to ensure a uniform spread of varying grades and crowns. It shall be steerable and adjustable in width with a flexible strike-off.

The box shall not cause grooving of the slurry by any of its parts. It shall be kept clean, and build-up of material on the spreader will not be permitted. The type drag, burlap, or other textile will be approved by the Engineer and it shall be cleaned or changed as frequently as needed or as designated by the Engineer. The drag shall be wetted at the beginning of each application.

(c) Hauling Equipment. Vehicles used for hauling aggregate shall have a cover of canvas or other suitable material of such size as to protect the aggregate from weather. Aggregate shall be covered during delivery to the project sites.

(d) Auxiliary Equipment. Hand squeegees, shovels, and other equipment shall be used as necessary to perform the work. Cleaning equipment including but not limited to power brooms, air compressors, water flushing equipment, and hand brooms shall be adequate for surface preparation.

Materials

408.03 Asphalt. Asphalt shall conform to the requirements of Subsection 702.03, Emulsified Asphalts and shall be obtained from a source selected by the Contractor that will ensure compatibility with the aggregate selected.

Acceptance sampling and point of acceptance are specified in Subsection 106.06.

408.04 Aggregates. Aggregate shall meet the requirements of Subsection 703.13, Table 703-2.

Point of acceptance is specified in Subsection 106.06.

408.05 Mineral Filler. Mineral filler shall meet the requirements of Subsection 703.11. Mineral filler shall be obtained from a source selected by the Contractor in accordance with the requirements of Subsection 106.01.

Acceptance of mineral filler is specified in Subsection 106.06.

408.06 Water. All water shall be potable and compatible with the slurry seal. Compatibility must be ensured by the Contractor.

408.07 Mix Design. The slurry mixture shall be designed in accordance with requirements of ASTM D 3910, as applicable. The Contractor shall have a mix design prepared by one of the following laboratories:

Alpha Labs
P.O. Box 74
Alpha, OH 45301
(513) 298-6647
Contact: Ben Benedict

ScanRoad, Inc.
P.O. Box 7677
Waco, TX 76714
(817) 772-7677
Contact: Tony Ng

Asphalt Technologies
9890 B Elder Creek Road
Sacramento, CA 95829
(916) 381-8033
Contact: Jim Stevens

Valley Slurry Seal Lab
P.O. Box 1620
W. Sacramento, CA 95691
(916) 373-1500
Contact: Jim Harriman

Koch Materials
1194 Zinns Quarry Road
Reading, PA 17404
(717) 843-0975
Contact: Ron Kohlar

Sahuaro Labs
P.O. Box 6536
Phoenix, AZ 85005
(602) 252-3061
Contact: Mike Doyle

The mix design shall be based upon the requirement that the treated area will be opened to traffic within 2 hours after placement of the slurry seal mixture.

Application rate of slurry mixture, based on weight of dry aggregate, shall be from 15 to 25 pounds per square yard.

The mix design will be submitted to the Engineer for approval 15 working days before work begins. The mix design will include the following information:

(a) Aggregate gradation.

(b) Mineral filler to be used if needed, percentage by weight of aggregate.

(c) Asphalt percentage and type.

(d) Sand equivalent of aggregate.

(e) Setting time (40 minutes maximum).

(f) Water resistance test results; pass or fail.

(g) Results of Wet Track Abrasion Test (max. loss of 75 grams per sq ft).

In addition to the above data, the Contractor is to submit with the mix design a sample of the aggregate, the emulsified asphalt, and the mineral filler, for use to the Engineer for verifying test results.

After the design mix has been established, the mixture supplied to the project shall conform thereto within the following tolerances:

Passing U.S. No. 4 and larger sieves	±7%
Passing U.S. No. 8 to U.S. No. 100 sieve	±4%
Passing U.S. No. 200 sieve	±2%
Residual Asphalt (by extraction)	±0.4%
Accelerator (portland cement)	±0.2

The Engineer may adjust the asphalt emulsion percentage during construction if necessary.

Construction Requirements

408.08 Weather Limitations. Slurry seal shall be applied only when the surface to be treated is dry or slightly damp, when the temperature of the road surface and the air temperature are 60°F and rising, and when the weather is not foggy or rainy.

408.09 Preparation of Surface, General. All roadway surfaces to be treated shall be cleaned by the Contractor. The Contractor shall sweep the pavement with a motorized power broom to remove all loose material. All depressions not reached by the power broom will be cleaned by the Contractor using hand brooming. The Contractor shall ensure that the outer edges of the pavement to be treated, including the 1 foot to the shoulder width, are thoroughly cleaned. Work will not continue until the surface is approved by the Engineer.

408.10 Temporary Centerline Markings. Following the placement and curing of the slurry seal surface treatment, temporary centerline marking meeting the requirements of Section 640 shall be installed by the Contractor.

408.11 Application of Slurry Seal. The surface shall be fogged with water immediately preceding the spreader. The slurry seal mixture shall be of the desired consistency as it leaves the mixer. The mixture furnished shall conform to the established design mix. The total mixing time shall not exceed 4 minutes. A sufficient amount of slurry seal mixture shall be carried in all parts of the spreader such that complete coverage of the surface is effected.

Treated areas will be allowed to cure until such time as the Engineer permits these treated areas to be opened to traffic.

The following will not be permitted:

(a) Lumping, balling, or unmixed materials.

(b) Segregation of the emulsion and aggregate fines from the coarse aggregate. If the coarse aggregate settles to the bottom of the slurry seal mix, the slurry seal mix shall be removed from the surface.

(c) Excessive breaking of the emulsion in the spreader box.

(d) Streaks or other unsightly appearances. The shoulder line should be uniform and straight.

(e) Excessive build-up of slurry seal mix on longitudinal or transverse joints.

Method of Measurement

408.12 Asphalt will be measured by the ton. The quantity to be measured will be the number of tons shown in the bid schedule or authorized by the Engineer.

Slurry sealing will be measured by the each for the actual number of test sections completed and accepted.

Basis of Payment

408.13 The accepted quantities, determined as provided above, will be paid for at the contract price per unit of measurement, respectively, for each of the particular pay items listed below and shown in the bid schedule.

The quantity of asphalt shown in the bid schedule is more than sufficient to construct the treated areas. Loss of material due to the Contractor's method of operations or rejection of material by the Engineer due to contamination or other reasons will not be cause for payment of increased quantity above that shown in the bid schedule.

All excess asphalt remaining after satisfying the needs of the contract shall become the property of the Contractor.

Payment for Pay Item 408(1), Asphalt for Slurry Seal, will be made to the Contractor upon presentation of proof of purchase (paid invoice) for the quantity shown in the bid schedule, or authorized by the Engineer.

The unit contract price per each for "Slurry sealing" shall be full payment to complete the work as specified, including all costs for labor, tools, equipment, materials, and transportation. This includes but is not limited to the following:

(a) Water necessary for brooming the base surface.
(b) Calibration of equipment.
(c) Furnishing and placing temporary raised pavement markers.
(d) Placement of the materials on the roadway.
(e) Protecting the slurry seal throughout the curing period.

The cost of preparing and furnishing the slurry seal mix design shall be incidental to the work required under other items of the contract. No direct payment will be made for such work.

When mineral filler is required by the mix design, no direct payment will be made for furnishing and incorporating the mineral filler into the work. The cost of such work shall be incidental to the work required under other items of the contract.

Payment will be made under:

Pay Item	Pay Unit
408(1) Asphalt for slurry seal	Ton
408(2) Slurrry sealing per site	Each

Section 409.--CRACK SEALING (ADDED SECTION)

Description

409.01 This work consists of furnishing and transporting all materials, equipment, and labor for sealing cracks in the existing pavement in the treatment areas. Crack sealing shall be in accordance with these specifications and in conformance with details and at the locations shown on the plans. There is one treatment area for crack sealing at each project site.

Equipment

409.02 The equipment used by the Contractor shall include but not be limited to the following:

(a) Hot-Compressed Air-Lance (HCA). The hot-compressed air-lance shall provide clean, oil-free compressed air at a volume of 100 cubic feet per minute at a pressure of 120 pounds per square inch and at a temperature of 2000 degrees F.

(b) Application Wand and Sealant Heating Equipment. The crack sealant applicator wand shall be attached to a heated hose, attached to a heated sealant chamber. Temperature controls shall be capable of maintaining the temperature of the sealant within manufacturer's tolerances.

(c) Router. A hand controlled mechanical router specifically designed for routing cracks in pavements. The router shall have the ability to rout random cracks to the cross section specified at a minimum rate of 1,000 linear feet per hour.

(d) Squeegee. A hand held squeegee shall be used to ensure that the crack is filled flush to the existing surface. The squeegee shall be of the size and shape to ensure that a three inch band is centered on the finished sealed crack.

Materials

409.03 The crack sealant shall be a polymer modified rubber asphalt and shall conform to the requirements of ASTM Designation D 3405 when tested in accordance with ASTM Designation D 3407. Crack sealant shall be obtained from a source selected by the Contractor in accordance with the requirements of Subsection 106.01. Crack sealant material shall be furnished from one production lot.

Acceptance of crack sealant is specified in Subsection 106.06.

409.04 Preparation of Surface, General. The pavement area to be treated shall be clean and dry with no standing or flowing water on the surface.

409.05 Cracks to be Treated. All cracks greater than 12 inches in length, and greater than 1/8 inch width shall be treated.

409.06 Preparation of Crack. Cracks shall be routed to 1 ½ inches wide and ⅜ inch deep. Sides of the routed cracks shall be vertical. The bits used to rout the cracks must be kept sharp and replaced when dull. All cracks shall be thoroughly cleaned of all foreign material.

409.07 Cleaning the Crack. All cracks shall be blown clean and dry using the HCA lance. Care shall be exercised to keep the HCA lance moving at a pace that will avoid burning the surrounding pavement.

409.08 Sealing the Crack. For each crack, the crack sealant shall be placed and finished within 5 minutes after heating with the HCA lance. Each crack shall be filled flush to the existing surface so that the finished sealed crack is approximately 3 inches wide and entered on the existing crack.

409.09 Acceptance of Crack Sealing. Following the application of the crack sealant and prior to the Government opening the roadway to traffic, the job will be visually inspected by the Engineer for areas exhibiting adhesion failure, damage to the sealant from construction equipment or personnel, missed cracks, foreign objects in the sealant, or other problems which will accelerate failure or indicate the job is not acceptable. Portions of the job identified by the Engineer that do not meet these criteria will be prepared and resealed until satisfactory to the Engineer.

Method of Measurement

409.10 Crack sealant will be measured in pounds determined by the count of containers and partial containers actually used and the weight of each.

Crack sealing will be measured by the each for the actual number of test sections completed and accepted.

Basis of Payment

409.11 The accepted quantities, determined as provided above, will be paid for at the contract price per unit of measurement, respectively, for each of the particular pay items listed below and shown in the bid schedule.

The unit contract price per pound for "Crack sealant for sealing" shall be full payment for all costs associated with furnishing the sealant to the project site.

The quantity of crack sealant shown in the bid schedule is more than sufficient to construct the treatment areas. Upon completion of all work it is expected that all excess, unused crack sealant material will be returned to the supplier. Payment will be made only for that quantity of material actually incorporated in the work.

The unit contract price per each for "Crack sealing per site" shall be full payment to complete the work as specified, including all costs for labor, tools, equipment, materials, and transportation. This includes but is not limited to the following:

(a) Brooming the base surface.
(b) Routing.
(c) Cleaning and drying the cracks.
(d) Placement of materials.

Payment will be made under:

	Pay Item	Pay Unit
409(1)	Crack sealant for sealing	Pound
409(2)	Crack sealing per site	Each

Section 702.--BITUMINOUS MATERIALS

702.03 Emulsified Asphalt. Delete the text of this subsection and substitute the following:

(a) Emulsified asphalts for chip sealing shall conform to the following:

Emulsified Asphalt, Grade CRS-2 complying with AASHTO M 208, Table 1. The base asphalt to be emulsified shall be an AC 5 meeting the requirements of AASHTO M 226, Table 2.

(b) Emulsified Asphalt for slurry seal shall conform to the following:

Emulsified Asphalt, Grade CSS-1h complying with AASHTO M 208, Table 1 or Grade SS-1h complying with AASHTO M 140, Table 1. The cement mixing test is waived.

(c) Material for crack sealant shall conform to ASTM D 3405.

Section 703. -- AGGREGATES

703.13 Aggregate for Seal Coats, Cover Coats, and Surface Treatments. Delete the text under this subsection and substitute the following:

Aggregates shall meet the following requirements for grading and quality:

(a) Aggregates for Chip Seal. Aggregate shall be hard, durable particles or fragments of crushed stone or crushed gravel. Aggregates shall conform to the grading requirements in Table 703-1 below.

Table 703-1
Grading Requirements for Chip Seal Aggregate
(Percentage by Weight Passing U.S. Standard Sieves,
AASHTO T 27 and T 11)

Sieve Designation	Percent Passing
½" square	100
3/8" square	40 - 70
No. 4	0 - 15
No. 8	0 - 5
No. 200	0 - 1.0

Not less than 75 percent by weight of the aggregate shall be particles having at least one fractured face. The fracture requirement shall apply to material retained on each sieve size No. 10 and above if the sieve retains more than 5 percent of the total sample.

The aggregate shall have a maximum flakiness index of 15 as determined by CFLHD DFT 508.

The aggregate shall have a minimum polish value of 32 as determined by AASHTO T 279.

The aggregate shall pass the static stripping test as determined by AASHTO T 182.

The aggregate shall show a durability factor not less than 35 (coarse and fine aggregate) as determined by AASHTO T 210.

Coarse aggregate shall have a percent of wear of not more than 30 at 500 revolutions as determined by AASHTO T 96.

The finished product shall be clean, uniform in quality, and free from wood, bark, roots, and other deleterious materials.

(b) Aggregates for Slurry Seal. Aggregate shall consist of manufactured sand or crusher fines, or other approved mineral aggregate or combination thereof. Aggregates shall conform to the grading requirements in Table 703-2 below.

Table 703-2
Grading Requirements for Slurry Seal Aggregate
(Percentage by Weight Passing U.S. Standard Sieves,
AASHTO T 27 and T 11)

Sieve Designation	Percent Passing
5/16"	100
No. 4	70 - 90
No. 8	45 - 70
No. 16	28 - 50
No. 30	19 - 34
No. 50	12 - 25
No. 100	7 - 18
No. 200	5 - 15

Smooth, textured sand of less than 1.25 percent water absorption as determined by AASHTO T 84 shall not exceed 50 percent of the total combined aggregate.

The aggregate shall have a minimum sand equivalent of 55 as determined by AASHTO T 176, Alternate Method No. 2.

The finished product shall be clean, uniform in quality, and free from wood, bark, roots, and other deleterious materials.

The aggregate shall show a durability factor not less than 35 as determined by AASHTO T 210.

Material used in the production of the aggregate shall have a percent of wear of not more than 25 at 500 revolutions as determined by AASHTO T 96.

APPENDIX C
MATERIALS AND CONSTRUCTION SPECIFICATIONS FOR THE SOUTHERN REGION

The enclosed sections contain the specifications for materials and construction of the SPS-3 flexible maintenance treatments. The materials and construction specifications are grouped by LTPP region. Appendix C contains the entire set of specifications for the Southern region. The entire specification document for any region is available in SHRP Document H-350.

These specifications were developed by regional Expert Task Groups and contain many features frequently not used in agency construction specifications for these treatments. The use of these specifications is likely a contributing factor to the overall good performance of the various maintenance treatments studied.

PART 400 - ASPHALT PAVEMENTS AND SURFACE TREATMENTS

Section 407.--CHIP SEAL

Description

407.01 This work consists of furnishing all materials, equipment, and labor for constructing the asphalt chip seal surface treatment areas. The treatment areas shall be constructed on the existing pavement in accordance with these specifications and in conformance with details and at the locations shown in the site descriptions. There is one treatment area for chip sealing at each project site and the demonstration site.

Equipment

407.02 The equipment used by the Contractor shall include but not be limited to the following:

(a) Power broom. A motorized power broom, center mount only, shall be used for removing loose material from the surface to be treated and for removing loose aggregate after work is completed.

(b) Rollers. A sufficient number of self-propelled, pneumatic-tired rollers shall be used for rolling aggregates after spreading such that the entire lane width of the treatment area is covered in one pass of the rollers. Each pneumatic-tired roller shall have a compacting width of not less than 60 inches and a minimum ground contact pressure of 80 pounds per square inch. If 60 inch wide rollers were used, then the contractor would be required to have 3 rollers to roll the 13 foot wide test sections.

(c) Asphalt distributor. A pressure distributor shall be used for applying the asphalt material. It shall be designed and operated to distribute the asphalt material in a uniform spray at the specified rate without atomization. It shall be equipped with a bitumeter having a dial registering feet of travel per minute. The dial shall be visible to the operator in order to maintain the constant speed required for the application at the specified rate. The pump shall be equipped with a tachometer having a dial registering gallons (or liters) per minute passing through the nozzles. The dial shall be readily visible to the operator. The distributor shall be provided with a full circulatory system that includes the spray bar. The distributor shall be provided with heaters that can be used to bring the asphalt material to spray application temperature. Means shall be provided for accurately indicating the temperature of the asphalt material at all times. The thermometer well shall not be in contact with the heating tube. The normal width of application of the spray bar shall be 13 feet with provision for greater or lesser width when necessary. A hose and spray nozzle attachment shall be provided for applying asphalt material to patches and areas inaccessible to the spray bar. The spray bar height, nozzle angle, and pump pressure will be calibrated weekly or as required by the Engineer. The calibration shall be performed in accordance with TAI Manual Series No. 19 (MS-29), 2nd Edition. The allowable deviation shall be not more than 10 percent in the longitudinal and transverse directions. The longitudinal and transverse spread rates shall be checked using ASTM D 2995.

(d) Aggregate spreader. The aggregate spreader shall be a self-propelled mechanical spreader with an operational scalper screen capable of uniformly distributing aggregate at the prescribed rate. The aggregate spreader will be checked weekly or as required by the Engineer. The calibration shall be performed in accordance with TAI Manual Series No. 19 (MS-19), 2nd Edition. The allowable deviation in the amount of aggregate spread shall not be more than 10 percent (by weight) in the longitudinal or transverse directions.

(e) Hauling Equipment. Trucks used for hauling aggregate shall have a cover of canvas or other suitable material of such size as to protect the aggregate from weather. Truck bed shall be covered ans securely fastened when delivering aggregate to the project sites.

(f) Auxiliary Equipment. Shovels and other equipment shall be used as necessary to perform the work. Cleaning equipment including but not limited to power brooms, air compressors, water flushing equipment, and hand brooms shall be adequate for surface preparation.

Materials

407.03 Asphalt. The base asphalt to be emulsified shall be an AC-10, meeting the requirements of AASHTO M226, Table 2. The emulsified asphalt shall conform to Subsection 702.03 for either emulsified asphalt grade CRS-2.

Acceptance sampling, point of acceptance, and test methods are specified in Subsection 106.06.

407.04 Mineral Aggregates. Aggregates shall meet the requirements of Subsection 703.13(a).

Acceptance sampling, point of acceptance, and test methods are specified in Subsection 106.06.

407.05 Water. All water shall be potable and compatible with the chip seal. Compatibility must be ensured by the Contractor.

407.06 Mix Design. The chip seal surface treatment shall be designed in accordance with TAI design method found in Manual Series No. 19 (MS-19), 2nd Edition. The contractor shall have the design of the chip seal prepared by qualified personnel, approved by the Engineer, experienced in asphalt surface treatment design.

The chip seal surface treatment design shall be based on traffic of over 2,000 vehicles per day and assume a slightly pocked, porous oxidized surface.

Application rate for the emulsified asphalt binder shall be from 0.25 and 0.40 gallons per square yard. The final application rate shall be determined after the source of materials is known.

Spread rate for the aggregate, based on weight of dry aggregate, shall be from 18 to 25 pounds per square yard. The final application rate shall be determined after the source of materials is known.

The design of the surface treatment shall be submitted to the Engineer for approval 15 working days prior to any work being accomplished. The design will include the following information:

(a) Aggregate gradation
(b) Bulk specific gravity of aggregate
(c) Loose unit weight of aggregate
(d) Emulsified asphalt rate of application and type
(e) Aggregate rate of application

In addition to the above data, the contractor is to submit with the design of the surface treatment a sample of the aggregate and the emulsion for use to the Engineer for verifying test results. The design may be verified by the government.

Construction Requirements

407.07 Weather Limitations. The chip seal surface treatment shall be placed only when the surface to be treated is dry or slightly damp, when the temperature of the road surface and the air temperature are 60 degrees F and rising, and when the weather is not foggy or rainy.

407.08 Preparation of Surface, General. All roadway surfaces to be treated shall be cleaned by the Contractor. The Contractor shall sweep the pavement with a motorized power broom to remove all loose material. All depressions not reached by the power broom will be cleaned by the Contractor using hand brooming. The Contractor shall ensure that the outer edges of the pavement to be treated including the 1 foot of the shoulder width, if a paved shoulder exists, are thoroughly cleaned. Work will not continue until the surface is approved by the Engineer.

407.09 Temporary Centerline Markings. Prior to the placement of the chip seal surface treatment, temporary centerline markings meeting the requirements of Section 635 shall be installed by the contractor.

407.10 Application of Emulsified Asphalt Binder. The rate of application for the emulsified asphalt binder shall be at the rate determined by the surface treatment design. See Subsection 407.06. The Engineer will make adjustments to the rate of application if necessary. Application of the emulsified asphalt binder shall be made uniformly at this rate with the pressure distributor, one full lane width at a time (including shoulder). Further adjustments in the rate of application shall be made by the Engineer, if needed, during the course of the work. The emulsified asphalt binder shall be applied at a temperature between 125 and 185 degrees F. The final spray temperature will be specified by the Engineer.

Before beginning application, building paper shall be spread over the surface, from the beginning point back and from the endpoint forward, for a sufficient distance for the spray bar to be at full force when the surface to be treated is reached. The spray bar shall be shut off instantaneously at the endpoint to ensure a straight line and the full application of binder up to the endpoint. After the asphalt is applied, the building paper shall be removed and disposed of properly. A hand spray shall be used to apply asphalt binder where necessary to touch up all spots missed by the distributor.

407.11 Application of Mineral Aggregates. After the asphalt binder has been spread evenly over the roadway surface, aggregates of the type specified shall be evenly applied to the roadway surface by self propelled spreader equipment. The aggregate shall be distributed uniformly by a spreader within 1 minute of the emulsified asphalt application.

All aggregate shall be watered down before placement, but not immediately before, to provide aggregates that are uniformly damp as approved by the Engineer at the time of placement on the roadway.

The aggregate shall be spread in one operation in such a manner that an 8 inch strip of the emulsified asphalt is left exposed along the longitudinal joint to form a lap for succeeding applications of the emulsified asphalt. If necessary, thin or bare spots in the spread of aggregates shall be corrected by hand spreading or other methods subject to the approval of the Engineer.

The aggregate shall be spread at the rate determined by the surface treatment design. See Subsection 407.06. The Engineer will make adjustments to the rate of application if necessary.

The aggregate shall be rolled following spreading. A maximum time of 3 minutes will be allowed between the spreading of the aggregate and completion of the initial rolling of that aggregate. The rollers shall proceed in a longitudinal direction at a speed less than or equal to 5 miles per hour. The rollers shall make three complete coverages of the aggregate with the final pass in the direction of traffic.

Immediately prior to opening to traffic, the surface of the roadway shall be swept, at the direction of the Engineer, with a power broom at adequate pressure to remove loose aggregate.

Trucks hauling aggregate shall be operated in a manner that shall not damage the roadway or the freshly applied surface.

Method of Measurement and Basis of Payment

407.12 All materials and work required by this Section will be measured and paid for in accordance with Section 410.

Section 408.--SLURRY SEAL

Description

408.01 This work consists of furnishing all materials, equipment, and labor for constructing the asphalt slurry seal treatment areas. The treatment areas shall be constructed on existing pavement in accordance with these specifications and in conformance with details and at the locations shown on the plans. There is one treatment area for slurry sealing at each project site and the demonstration site.

Equipment

408.02 The equipment used by the Contractor shall include but not be limited to the following:

(a) Slurry Seal Mixer. The slurry seal mixing machine shall be a continuous flow mixing unit with calibrated controls capable of delivering accurately predetermined proportions of aggregate, water, and asphalt emulsion to the mixing chamber and of discharging the thoroughly mixed product on a continuous basis. Each machine shall be equipped with metering devices, easily readable, that will accurately measure all raw materials prior to entering the pugmill. Each machine shall have an automated system capable of automatically sequencing in all raw materials to insure constant slurry mixture. This mixing chamber shall be capable of thoroughly blending all ingredients together. No violent mixing will be permitted. The aggregate shall be pre-wetted in the pugmill immediately prior to mixing with the emulsion.

The mixer shall be equipped with an approved fines feeder having an accurate metering device or other approved means to introduce a predetermined quantity of mineral filler into the mixer at the time and location that the aggregate is introduced into the mixing machine. The fines feeder shall be used whenever mineral filler is a part of the aggregate blend.

The mixing machine shall be equipped with a water pressure system and a fog-type spray bar adequate for complete fogging of the surface immediately ahead of the spreading equipment. Rate of fog application shall be 0.03 to 0.06 gallon of water per square yard.

The mixer shall be capable of mixing all materials at preset proportions regardless of the engine speed without changing the mixing machine settings.

The machine shall be capable of a minimum speed of 60 feet per minute and shall not exceed 130 feet per minute while in operation. The mixing machine shall have sufficient storage capacity to properly mix and apply a minimum of 7 tons of slurry seal.

Approved means of measuring all materials used in each slurry seal batch shall be provided, properly calibrated, and made accessible to the Engineer by the Contractor. The slurry seal mixer shall be checked weekly or as required by the Engineer. The calibration of the slurry seal mixer shall be performed in accordance with ISSA Performance Guidelines A105. The Engineer may use the recorders and measuring facilities of the slurry seal unit to determine application rates, asphalt emulsion content and mineral filler content of individual loads.

(b) Spreading Equipment. Attached to the mixing machine shall be a mechanical type single squeegee distributor equipped with flexible material in contact with the surface to prevent loss of slurry and adjustable to assure a uniform spread of varying grades and crowns. It shall be steerable and adjustable in width with a flexible strike-off.

The box shall not cause grooving of the slurry by any of its parts. It shall be kept clean, and build-up of material on the spreader will not be permitted. The type drag, burlap, or other textile will be approved by the Engineer and it shall be cleaned or changed as frequently as needed or as designated by the Engineer. The drag shall be wetted at the beginning of each application.

(c) Hauling Equipment. Trucks used for hauling aggregate shall have a cover of canvas or other suitable material of such size as to protect the aggregate from weather. Truck beds shall be covered and securely fastened when delivering aggregate to the project sites.

(d) Auxiliary Equipment. Hand squeegees, shovels, and other equipment shall be used as necessary to perform the work. Cleaning equipment including but not limited to power brooms, air compressors, water flushing equipment, and hand brooms shall be adequate for surface preparation.

Materials

408.03 Asphalt. The emulsified asphalt shall be quick-set emulsified asphalt confirming to Subsection 702.03, Table 702-1.

Acceptance sampling and point of acceptance are specified in subsection 106.06.

408.04 Mineral Aggregates. Aggregate shall meet the requirements of subsection 703.13(b).

Point of acceptance is specified in subsection 106.06.

408.05 Mineral Filler. Mineral filler shall meet the requirements of subsection 703.11.

Acceptance of mineral filler is specified in Subsection 106.06.

408.06 Water. All water shall be potable and compatible with the slurry seal. Compatibility must be ensured by the Contractor.

408.07 Mix Design. The slurry mixture shall be designed in accordance with requirements of ASTM D 3910, as applicable. The Contractor shall have a mix design prepared by one of the following laboratories:

Alpha Labs P.O. Box 74 Alpha, OH 45301 (513) 298-6647 Contact: Ben Benedict	ScanRoad, Inc. P.O. Box 7677 Waco, TX 76714 (817) 772-7677 Contact: Tony Ng
Asphalt Technologies 9890 B Elder Creek Road Sacramento, CA 95829 (916) 381-8033 Contact: Jim Stevens	Valley Slurry Seal Lab P.O. Box 1620 W. Sacramento, CA 95691 (916) 373-1500 Contact: Jim Harriman
Koch Materials 1194 Zinns Quarry Road Reading, PA 17404 (717) 843-0975 Contact: Ron Kohlar	Sahuaro Labs P.O. Box 6536 Phoenix, AZ 85005 (602) 252-3061 Contact: Mike Doyle

The mix design shall be based upon the requirement that the treated area will be opened to traffic within 2 hours after placement of the slurry seal mixture.

Residual asphalt content, percent weight of dry aggregate, shall be from 7.5 to 13.5 percent as determined by AASHTO T 59.

Application rate of slurry mixture, based on weight of dry aggregate, shall be from 15 to 25 pounds per square yard.

The mix design will be submitted to the Engineer for approval 15 working days before work begins. The mix design will include the following information:

(a) Aggregate gradation.

(b) Mineral filler to be used if needed, percentage by weight of aggregate.

(c) Emulsified asphalt percentage and type.

(d) Sand equivalent of aggregate.

(e) Setting time (40 minutes maximum).

(f) Water resistance test results; pass or fail.

(g) Results of Wet Track Abrasion Test (max. loss of 75 grams per square foot).

In addition to the above data, the Contractor is to submit with the mix design a sample of the aggregate, the emulsified asphalt, and the mineral filler, for use to the Engineer for verifying test results.

After the design mix has been established, the mixture supplied to the project shall conform thereto within the following tolerances:

Passing U.S. No. 4 and larger sieves	±7%
Passing U.S. No. 8 to U.S. No. 100 sieve	±4%
Passing U.S. No. 200 sieve	±2%
Residual Asphalt (by extraction)	±0.4%
Mineral filler (portland cement)	±0.5%

The Engineer may adjust the emulsified asphalt content during construction to account for the amount of asphalt absorbed by the pavement.

Construction Requirements

408.08 Weather Limitations. Slurry seal shall be applied only when the surface to be treated is dry or slightly damp, when the temperature of the road surface and the air temperature are 60°F and rising, and when the weather is not foggy or rainy.

408.09 Preparation of Surface, General. All roadway surfaces to be treated shall be cleaned by the Contractor. The Contractor shall sweep the pavement with a motorized power broom to remove all loose material. All depressions not reached by the power broom will be cleaned by the Contractor using hand brooming. The Contractor shall ensure that the outer edges of the pavement to be treated, including the 1 foot of the shoulder width if a paved shoulder exists, are thoroughly cleaned.

408.10 Temporary Centerline Markings. After placement of the slurry seal surface treatment, temporary centerline marking meeting the requirements of Section 635 shall be installed by the contractor.

408.11 Application of Slurry Seal. The surface shall be fogged with water immediately preceding the spreader. The slurry seal mixture shall be of the desired consistency as it leaves the mixer. The mixture furnished shall conform to the established design mix. The total mixing time shall not exceed 4 minutes. A sufficient amount of slurry seal mixture shall be carried in all parts of the spreader such that complete coverage of the base surface is effected.

In areas not accessible to the slurry mixer, the slurry seal mixture shall be hand worked with approved squeegees.

Treated areas will be allowed to cure until such time as the Engineer permits these treated areas to be opened to traffic.

The following will not be permitted:

(a) Lumping, balling, or unmixed aggregate.

(b) Segregation of the emulsified asphalt and aggregate fines from the coarse aggregate. If the coarse aggregate settles to the bottom of the slurry seal mix, the slurry seal mix shall be removed from the base surface.

(c) Excessive breaking of the emulsified asphalt in the spreader box.

(d) Streaks or other unsightly appearances. The shoulder line shall be uniform and straight.

(e) Excessive build-up of slurry seal mix on longitudinal or transverse joints.

(f) If oversize materials are encountered, final screening prior to placement will be required.

Method of Measurement and Basis of Payment

408.12 All materials and work required by this Section will be measured and paid for in accordance with Section 410.

Section 409.--CRACK SEALING

Description

409.01 This work consists of furnishing all materials, equipment, and labor for sealing cracks in the existing pavement in the treatment areas. Crack sealing shall be in accordance with these specifications and in conformance with details and at the locations shown on the plans. There is one treatment area for crack sealing at each project site and the demonstration site.

Equipment

409.02 The equipment used by the Contractor shall include but not be limited to the following:

(a) Hot-Compressed Air-Lance (HCA). The hot-compressed air-lance shall provide clean, oil-free compressed air at a volume of 100 cubic feet per minute at a pressure of 120 pounds per square inch and at a temperature of 2000 degrees F.

(b) Application Wand. The crack sealant applicator wand shall be attached to a heated hose, attached to a heated sealant chamber. Temperature controls shall be capable of maintaining the temperature of the sealant within manufacturer's tolerances.

(c) Heating Kettle. The equipment for heating the sealant materials shall be constructed as an indirect heating type double boiler using oil or other heat transfer medium and shall be capable of constant agitation. Additionally, the heating equipment shall be capable of controlling the sealant material temperature within the manufacturer's recommended temperature range and shall be equipped with a calibrated thermometer capable of $\pm 5^\circ$F accuracy from 200°F to 600°F. This thermometer shall be located such that the Engineer may safely check the temperature of the sealant material.

(d) Router. A hand controlled mechanical router specifically designed for routing cracks in pavements. The router shall have the ability to rout random cracks to the cross section specified at a minimum rate of 1,000 linear feet per hour.

Materials

409.03 The crack sealant shall conform to the requirements of Subsection 705.01.

Acceptance of crack sealant is specified in Subsection 106.06.

Construction Requirements

409.04 Preparation of Crack. The pavement area to be treated shall be clean and dry with no standing or flowing water on the surface.

All cracks greater than 12 inches in length, and greater than 1/8 inch width shall be sealed.

Cracks less than 1/8 inch in width shall be routed to 1 ½ inch wide and 3/8 inch deep. Sides of the routed cracks shall be vertical. The router shall be guided so that the crack lies entirely within the routed channel. The bits used to rout the cracks must be kept sharp and replaced when dull. All cracks shall be thoroughly cleaned of all foreign material.

All cracks shall be blown clean and dry using the HCA lance. Care shall be exercised to keep the HCA lance moving at a pace that will avoid burning the surrounding pavement.

409.05 Sealing the Crack. For each crack, the crack sealant shall be placed and finished within 2 minutes after heating with the HCA lance. Each crack shall be slightly overfilled.

409.06 Acceptance. Following the application of the crack sealant and before opening the roadway to traffic, the job will be visually inspected by the Engineer for area exhibiting adhesion failure, damage to the sealant from construction equipment or personnel, missed cracks, foreign objects in the sealant, or other problems which will accelerate failure or indicate the job is not acceptable. Portions of the job identified by the Engineer that do not meet these acceptable criteria will be prepared and resealed until satisfactory to the Engineer.

Method of Measurement and Basis of Payment

409.07 All materials and work required by this Section will be measured and paid for in accordance with Section 410.

Section 410.--ASPHALT SURFACE TREATMENTS

Description

410.01 This work shall consist of furnishing all materials, equipment, tools, and labor for the construction of the treatment areas for chip seals, slurry seals, and crack sealing at each project site and the demonstration site.

This work shall include that described in the following Sections:

Section 311	-	Stockpiled Aggregates
Section 407	-	Chip Seal
Section 408	-	Slurry Seal
Section 409	-	Crack Sealing
Section 635	-	Temporary Traffic Control

410.02 Project sites and the demonstration site will be measured by the each completed and accepted.

Surplus materials produced for anticipated sites added or for sites deleted from the contract and that are not used in the work will not be measured for payment but will be considered a subsidiary obligation of the Contractor.

410.03 The accepted quantities determined as provided above, will be paid for at the contract price per each for the pay item listed below and shown in the bid schedule, which price and payment will be full compensation for the work prescribed in this section.

Payment will be made under:

Pay Item	Pay Unit
410(18) Project Site--	Each
410(19) Demonstration Site---	Each

PART 700 MATERIALS

Section 702. -- BITUMINOUS MATERIALS

702.01 and 702.02 Reserved.

702.03 Emulsified Asphalts.

(a) The emulsified asphalts for chip sealing shall be one of the following: grade CRS-2 conforming to AASHTO M 208, Table 1, grade RS-2 conforming to AASHTO M140, Table 1, or grade HFRS-2 conforming to ASTM D 977, Table 1. The base asphalt to be emulsified shall conform to AASHTO M 226, Table 2 for an AC-10.

The sieve test specified under AASHTO M 208 is not required.

(b) Emulsified asphalts for slurry sealing shall conform to the requirement of Table 702-1 below:

Table 702-1
Quick-Set Emulsified Asphalts

Property	Specification	AASHTO Test Method
Viscosity, 77°F, Saybolt Furol, sec	20 - 100	T 59
Residue by Distillation, %	57 min.	T 59
Sieve Test	0.10 max.	T 59
Tests on Residue from Distillation		
Penetration, 77°F, 100g, 5 sec	40 - 110	T 49
Solubility in Trichloroethylene, %	97.5 min.	T 44
Ductility, 77°F, cm	40 min.	T 51

702.04 Acceptance Procedures for Asphalts.

(a) General Acceptance Procedures. Acceptance of asphalt is subject to the following:

(1) Laboratory Tests. The supplier shall test all material intended for shipment to the Government.

(2) Examination of Shipping Container. Before loading, the supplier shall examine the shipping container and shall remove all remnants of previous cargos that might contaminate the material to be loaded.

(3) Delivery Ticket. The Contractor shall furnish with each shipment two copies of the delivery ticket. The delivery ticket shall contain the following information:

Consignees
Project No.
Grade
Net gallons
Net weight
Type and amount of antistripping agent
Identification No. (truck, car, tank, etc.)
Destination
Date
Loading temperature
Specific gravity at 60°F

(4) Test Results and Certification. The Contractor, or authorized supplier, shall deliver to the Engineer the applicable test results obtained from (1) above and a certification signed by an authorized supplier to cover the quality and quantity of material and the condition of container for each shipment. The certification shall be essentially in the following form and may be stamped, written, or printed on the delivery ticket:

"This is to certify that this shipment of __________ tons/gallons of __________ asphalt meets all contract specifications and the shipping container was clean and free from contaminating material when loaded."

Supplier:
Signed:

Failure to sign the certification will be cause to withhold use of the material until it can be sampled and tested for compliance.

(5) Acceptance Sampling Procedures. Samples of asphalt materials shall be taken by the Engineer in accordance AASHTO T40, from the shipping containers at the point of delivery. Samples shall be taken of each separate tank at the time of discharge into distributors or other conveyances on the project.

(b) Alternate Acceptance Procedures. Asphalt will be accepted by certification under (a) (1) through (a) (4). Quality control reviews may be conducted by the Government or an authorized representative at the point of production to determine the reliability of the supplier's certifications.

If the certifications are not reliable, acceptance by certification will be discontinued and the contents of each shipping container will be sampled at the point of delivery in accordance with (a) (5), and tested for compliance prior to incorporation in the work. This procedure will be followed until the supplier's quality control and testing procedures are such that material meeting contract specifications is being consistently produced.

(c) Requirements for Asphalt Containing Antistripping Additives. In addition to either (a) or (b), the Contractor or authorized supplier shall furnish the Engineer on delivery of the initial shipment of fortified asphalt to the project and with subsequent shipments when ordered by the Engineer, a 1 quart sealed sample of the asphalt taken at time of loading at the refinery and prior to introduction of the additive, along with a separate 1 pint sample of the antistripping additive.

(d) Nonspecification Asphalt. Asphalt not conforming to the specifications will either be rejected or accepted in accordance with the following:

* The Engineer will evaluate the qualities of the nonconforming material and determine whether the deficiencies are such as to require complete removal of the material, or if in the interest of the Government, the nonconforming material may be accepted at a reduced price and permitted to be used or to remain in the completed work.

* All rejected asphalt shall be immediately removed from the work, including all portions of the work in which such rejected asphalt has been incorporated, and shall be replaced with specification material at no additional cost to the Government.

* When the nonconforming asphalt is permitted to remain in the work, the Engineer will determine the quantity of material represented and an appropriate adjustment in contract price based on engineering judgment.

Section 703. -- AGGREGATES

703.01 through 703.10 Reserved

701.11 Filler. Filler material for asphaltic mixtures shall meet the requirements of AASHTO M 17.

703.12 Reserved

703.13 Aggregate for Chip Seals and Slurry Seals. Aggregates shall meet the following requirements for grading and quality:

(a) Aggregates for Chip Seal. Aggregate shall be hard, durable particles or fragments of crushed stone or crushed gravel. Aggregates shall conform to the grading requirements in Table 703-1 below.

Table 703-1
Grading Requirements for Chip Seal Aggregate
(Percentage by Weight Passing U.S. Standard Sieves,
AASHTO T 27 and T 11)

Sieve Designation	Percent Passing
½" square	100
3/8" square	40 - 70
¼" square	0 - 15
U.S. No. 10	0 - 15
U.S. No. 200	0 - 1.0

Not less than 75 percent by weight of the aggregate shall be particles having at least one fractured face. The fracture requirement shall apply to material retained on each sieve size No. 10 and above if the sieve retains more than 5 percent of the total sample.

The portion of aggregate retained on the 3/8 inch sieve shall not contain more than 15 percent of particles by weight that are flat or elongated or both, when tested in accordance with ASTM D 4791 using a dimensional ratio of 1:5.

The aggregate shall have a minimum polish value of 32 as determined by AASHTO T 279.

The aggregate shall pass the static stripping test as determined by AASHTO T 182.

The aggregate shall show a durability factor not less than 35 (coarse and fine aggregate) as determined by AASHTO T210.

Coarse aggregate shall have a percent of wear of not more than 30 at 500 revolutions as determined by AASHTO T 96.

The finished product shall be clean, uniform in quality, and free from wood, bark, roots, and other deleterious materials.

(b) Aggregates for Slurry Seal. Aggregate shall consist of manufactured sand or crusher fines, or other approved mineral aggregate or combination thereof. Aggregates shall conform to the grading requirements in Table 703-2 below.

Table 703-2
Grading Requirements for Slurry Seal Aggregate
(Percentage by Weight Passing U.S. Standard Sieves,
AASHTO T 27 and T 11)

Sieve Designation	Percent Passing
5/16" square	99 - 100
U.S. No. 4	70 - 90
U.S. No. 8	45 - 70
U.S. No. 16	28 - 50
U.S. No. 30	19 - 34
U.S. No. 50	12 - 25
U.S. No. 100	7 - 18
U.S. No. 200	5 - 15

Smooth, textured sand of less than 1.25 percent water absorption shall not exceed 50 percent of the total combined aggregate as determined by the AASHTO T 84.

The aggregate shall have a minimum sand equivalent of 55 as determined by AASHTO T 176, alternate Method No. 2.

The finished product shall be clean, uniform in quality, and free from wood, bark, roots and other deleterious materials.

The aggregate shall show a durability factor not less than 35 as determined by AASHTO T 210.

Material used in the production of the aggregate shall have a percent of wear of not more than 35 at 500 revolutions as determined by AASHTO T 96.

APPENDIX D
MATERIALS AND CONSTRUCTION SPECIFICATIONS FOR THE WESTERN REGION

The enclosed sections contain the specifications for materials and construction of the SPS-3 flexible maintenance treatments. The materials and construction specifications are grouped by LTPP region. Appendix D contains the entire set of specifications for the Western region. The entire specification document for any region is available in SHRP Document H-350.

These specifications were developed by regional Expert Task Groups and contain many features frequently not used in agency construction specifications for these treatments. The use of these specifications is likely a contributing factor to the overall good performance of the various maintenance treatments studied.

Section 407.--CHIP SEAL
(ADDED SECTION)

Description

407.01 This work consists of furnishing all materials, equipment, and labor for constructing the asphalt chip seal surface treatment areas. The treatment areas shall be constructed on the existing pavement in accordance with these specifications and in conformance with details and at the locations shown in the site descriptions. There is one treatment area for chip sealing at each project site and the demonstration site.

Equipment

407.02 The equipment used by the Contractor shall include but not be limited to the following:

(a) Power broom. A motorized power broom, center mount only, shall be used for removing loose material from the surface to be treated and for removing loose aggregate after work is completed.

(b) Asphalt distributor. A pressure distributor shall be used for applying the asphalt material. It shall be designed and operated to distribute the asphalt material in a uniform spray at the specified rate without atomization. It shall be equipped with a bitumeter having a dial registering feet of travel per minute. The dial shall be visible to the operator in order to maintain the constant speed required for the application at the specified rate. The pump shall be equipped with a tachometer having a dial registering gallons (or liters) per minute passing through the nozzles. The dial shall be readily visible to the operator. The distributor shall be provided with a full circulatory system that includes the spray bar. The distributor shall be provided with heaters that can be used to bring the asphalt material to spray application temperature. Means shall be provided for accurately indicating the temperature of the asphalt material at all times. The thermometer well shall not be in contact with the heating tube. The normal width of application of the spray bar shall be 13 feet with provision for greater or lesser width when necessary. A hose and spray nozzle attachment shall be provided for applying asphalt material to patches and areas inaccessible to the spray bar. The spray bar height, nozzle angle, and pump pressure will be calibrated weekly or as required by the Engineer. The calibration shall be performed in accordance with the Asphalt Institute Manual Series No. 19, 2nd Edition. The allowable deviation shall be not more than 10 percent in the longitudinal and transverse directions. The longitudinal and transverse spread rates shall be checked using ASTM Test Method D 2995.

(c) Aggregate Spreader. The aggregate spreader shall be a self-propelled mechanical spreader capable of uniformly distributing aggregate at the prescribed rate. The aggregate spreader shall be checked weekly or as required by the Engineer. The calibration of the aggregate spreader shall be performed in accordance with the Asphalt Institute Manual Series No. 19, 2nd Edition. The allowable deviation in the amount of aggregate spread shall not be more than 10 percent (by weight) in the longitudinal or transverse directions.

(d) Rollers. A sufficient number of self-propelled pneumatic-tired rollers shall be used for rolling aggregates after spreading such that the entire lane width of the treatment area is covered in one pass of the rollers. Each pneumatic-tired roller shall have a total compacting width of not less than 60 inches and shall have a minimum ground contact pressure of 80 pounds per square inch.

(e) Hauling Equipment. Vehicles used for hauling aggregate shall have a cover of canvas or other suitable material of such size as to protect the aggregate from weather. Aggregates shall be covered during delivery to the project sites.

(f) Auxiliary Equipment. Air compressors, water flushing equipment, hand brooms, shovels, and other equipment shall be used as necessary to perform the work.

Materials

407.03 Asphalt. Asphalt shall conform to Subsection 702.03 for emulsified asphalt, Grade CRS-2. Asphalt shall be obtained from a source selected by the Contractor in accordance with the requirements of Subsection 106.01.

Acceptance sampling and point of acceptance are specified in Subsection 106.06.

407.04. Aggregates. Aggregates shall meet the requirements of Section 311.

Point of acceptance is specified in Subsection 106.06.

407.05 Water. All water shall be potable and compatible with the chip seal. Compatibility must be ensured by the Contractor.

407.06 Mix Design. The chip seal coat shall be designed in accordance with the Asphalt Institute design method found in their Manual Series No. 19, 2nd Edition. The Contractor shall have the design of the chip seal prepared by qualified personnel experienced in asphalt surface treatment design.

The surface treatment design shall be based on traffic of over 2,000 vehicles per day and assume a slightly pocked, porous oxidized surface.

Application rate for the emulsified asphalt shall be from 0.25 and 0.40 gallon per square yard. The final application rate shall be determined after the source of materials is known.

Spread rate for the aggregate, based on weight of dry aggregate, shall be from 18 to 25 pounds per square yard. The final application rate shall be determined after the source of materials is known.

The design of the surface treatment shall be submitted to the Engineer for approval 5 days prior to any work being accomplished. The design will include the following information:

(a) Aggregate gradation.
(b) Bulk specific of aggregate.
(c) Loose unit weight of aggregate.
(d) Emulsified asphalt rate of application and type.
(e) Aggregate rate of application.

In addition to the above data, the Contractor is to submit with the design of the surface treatment a sample of the aggregate and the emulsion for use to the Engineer for verifying test results. The design may be verified by the Government.

Construction Requirements

407.07 Weather Limitations. The chip seal surface treatment shall be placed only when the surface to be treated is dry or slightly damp, when the temperature of the road surface and the air temperature are 60 degrees F and rising, and when the weather is not foggy or rainy.

407.08 Preparation of Surface, General. All roadway surfaces to be treated shall be cleaned by the Contractor. The Contractor shall sweep the pavement with a motorized power broom to remove all loose material. All depressions not reached by the power broom will be cleaned by the Contractor using hand brooming. The Contractor shall ensure that the outer edges of the pavement to be treated including the 1 foot of the shoulder width, if a paved shoulder exists, are thoroughly cleaned. Work will not continue until the surface is approved by the Engineer.

407.09 Temporary Centerline Markings. Prior to the placement of the chip seal surface treatment, temporary centerline markings meeting the requirements of Section 640 shall be installed by the Contractor.

407.10 Application of Emulsified Asphalt. Emulsified asphalt shall not be placed on any wet surface or when weather conditions will otherwise prevent its proper handling or finishing. Application of emulsified asphalt shall be made only when the surface is dry as determined by the Engineer.

The rate of application for the emulsified asphalt shall be at the rate determined by the surface treatment design. See Subsection 407.06. The Engineer will make adjustments to the rate of application if necessary. Application of the emulsified asphalt shall be made uniformly at this rate with the pressure distributor, one full lane width at a time (including shoulder). Further adjustments in the rate of applications shall be made by the Engineer, if needed, during the course of the work. The emulsified asphalt shall be applied at a temperature between 140 and 185 degrees F. The final spray temperature will be specified by the Engineer.

Before beginning application, building paper shall be spread over the surface, from the beginning point back and from the endpoint forward, for a sufficient distance for the spray bar to be a full force when the surface to be treated is reached. The spray bar shall be shut off instantaneously at the endpoint to ensure a straight line and the full application of asphalt up to the endpoint. After the emulsified asphalt is applied, the building paper shall be removed and disposed of properly.

407.11 Application of Aggregates. After the emulsified asphalt has been spread evenly over the roadway surface, aggregates of the type specified shall be evenly applied to the roadway surface by spreader equipment. The aggregate shall be distributed uniformly by a spreader within 1 minute of the emulsified asphalt application.

All aggregate shall be watered down to provide aggregates that are uniformly damp at the time of placement on the roadway.

The aggregate shall be spread in one operation in such a manner that an 8 inch strip of emulsified asphalt is left exposed along the longitudinal center joint to form a lap for succeeding applications of asphalt. If necessary, thin or bare spots in the spread of aggregates shall be corrected by hand spreading or other methods subject to the approval of the Engineer.

The aggregate shall be spread at the rate determined by the surface treatment design. See Subsection 407.06. The Engineer will make adjustments to the rate of application if necessary.

The aggregate shall be rolled following spreading. A maximum time of 3 minutes will be allowed between the spreading of the aggregate and completion of the initial rolling of that aggregate. The rollers shall proceed in a longitudinal direction at a speed less than or equal to 5 miles per hour. The rollers shall make three complete coverages of the aggregate with the final pass being in the direction of traffic.

Prior to opening to traffic, the surface of the roadway shall be swept with a power broom at adequate pressure to remove loose aggregate.

The operation of vehicles hauling aggregate shall be so regulated that no damage as determined by the Engineer will result to the roadway or the freshly applied surface.

Method of Measurement

407.12 Aggregate will be measured by the cubic yard in the hauling vehicle at the point of delivery. The quantity to be measured will be the number of cubic yards placed on the chip seal treatment area or as authorized by the Engineer.

Asphalt will be measured by the ton. The quantity to be measured will be the number of tons placed on the chip seal treatment area or as authorized by the Engineer.

Chip sealing will be measured by the each for the actual number of test sections completed and accepted.

Basis of Payment

407.13 The accepted quantities, determined as provided above, will be paid for at the contract price per unit of measurement, respectively, for each of the particular pay items listed below and shown in the bid schedule.

The unit contract prices per cubic yard for "Aggregate for chip seal" and per ton for "Asphalt for chip seal" shall be full payment for all costs for labor, tools, equipment, and materials necessary for furnishing these items at the project site.

The unit contract price per each for "Chip sealing" shall be full payment to complete the work as specified, including all costs for labor, tools, equipment, and materials. This includes but is not limited to the following:

(a) Water necessary for brooming the surface.
(b) Calibration of equipment.
(c) Furnishing and placing temporary raised pavement markers.

(d) Water necessary for wetting the aggregate.
(e) Placement of the materials on the roadway.
(f) Brooming after placement is complete.

The cost of preparing and furnishing the chip seal mix design shall be incidental to the work required under other items of the contract. No direct payment will be made for such work.

Payment will be made under:

Pay Item	Pay Unit
407(1) Aggregate for chip seal from stockpile	Cubic yard
407(2) Asphalt for chip seal	Ton
407(3) Chip sealing per site	Each

Section 408.--SLURRY SEAL
(ADDED SECTION)

Description

408.01 This work consists of furnishing and transporting all materials, equipment, and labor for constructing conventional asphalt slurry seal treatment areas. The treatment areas shall be constructed on the existing pavement in accordance with these specifications and in conformance with details and at the locations shown on the plans. There is one treatment area for slurry sealing at each project site.

Equipment

408.02 The equipment used by the Contractor shall include but not be limited to the following:

(a) Slurry Seal Mixer. The slurry seal mixing machine shall be a continuous flow mixing unit with calibrated controls capable of delivering accurately predetermined proportions of aggregate, water, and asphalt emulsion to the mixing chamber and of discharging the thoroughly mixed product on a continuous basis. Each machine shall be equipped with metering devices, easily readable, that will accurately measure all raw materials prior to entering the pugmill. Each machine shall have an automated system capable of automatically sequencing in all raw materials to ensure constant slurry mixture. This mixing chamber shall be capable of thoroughly blending all ingredients together. No violent mixing will be permitted. The aggregate shall be pre-wetted in the pugmill immediately prior to mixing with the emulsion.

The mixer shall be equipped with an approved fines feeder having an accurate metering device or other approved means to introduce a predetermined quantity of mineral filler into the mixer at the time and location that the aggregate is introduced into the mixing machine. The fines feeder shall be used whenever mineral filler is a part of the aggregate blend.

The mixing machine shall be equipped with a water pressure system and a fog-type spray bar adequate for complete fogging of the surface immediately ahead of the spreading equipment. Rate of fog application shall be 0.03 to 0.06 gallon of water per square yard.

The mixer shall be capable of mixing all materials at preset proportions regardless of the engine speed without changing the mixing machine settings.

The machine shall be capable of a minimum speed of 60 feet per minute and shall not exceed 180 feet per minute while in operation. The mixing machine shall have sufficient storage capacity to properly mix and apply a minimum of 7 tons of slurry seal.

Approved means of measuring all materials used in each slurry seal batch shall be provided and made accessible to the Engineer by the Contractor. The slurry seal mixer shall be checked weekly or as required by the Engineer. The calibration of the slurry seal mixer shall be performed in accordance with the Asphalt Institute Manual Series No. 19, 2nd Edition. The Engineer may use the recorders and measuring facilities of the slurry seal unit to determine application rates, asphalt emulsion content, and mineral filler content of individual loads.

(b) Spreading Equipment. Attached to the mixing machine shall be a mechanical type single squeegee distributor equipped with flexible material in contact with the surface to prevent loss of slurry and adjustable to ensure a uniform spread of varying grades and crowns. It shall be steerable and adjustable in width with a flexible strike-off.

The box shall not cause grooving of the slurry by any of its parts. It shall be kept clean, and build-up of material on the spreader will not be permitted. The type drag, burlap, or other textile will be approved by the Engineer and it shall be cleaned or changed as frequently as needed or as designated by the Engineer. The drag shall be wetted at the beginning of each application.

(c) Hauling Equipment. Vehicles used for hauling aggregate shall have a cover of canvas or other suitable material of such size as to protect the aggregate from weather. Aggregate shall be covered during delivery to the project sites.

(d) Auxiliary Equipment. Hand squeegees, shovels, and other equipment shall be used as necessary to perform the work. Cleaning equipment including but not limited to power brooms, air compressors, water flushing equipment, and hand brooms shall be adequate for surface preparation.

Materials

408.03 Asphalt. Asphalt shall be quick-set emulsified asphalt conforming to Subsection 702.03, Table 702-1. Asphalt shall be obtained form a source selected by the Contractor in accordance with the requirements of Subsection 106.01.

Acceptance sampling and point of acceptance are specified in Subsection 106.06.

408.04 Aggregates. Aggregate shall meet the requirements of Section 311.

Point of acceptance is specified in Subsection 106.06.

408.05 Mineral Filler. Mineral filler shall meet the requirements of Subsection 703.11. Mineral filler shall be obtained from a source selected by the Contractor in accordance with the requirements of Subsection 106.01.

Acceptance of mineral filler is specified in Subsection 106.06.

408.06 Water. All water shall be potable and compatible with the slurry seal. Compatibility must be ensured by the Contractor.

408.07 Mix Design. The slurry mixture shall be designed in accordance with requirements of ASTM D 3910, as applicable. The Contractor shall have a mix design prepared by one of the following laboratories:

Alpha Labs P.O. Box 74 Alpha, OH 45301 (513) 298-6647 Contact: Ben Benedict	ScanRoad, Inc. P.O. Box 7677 Waco, TX 76714 (817) 772-7677 Contact: Tony Ng
Asphalt Technologies 9890 B Elder Creek Road Sacramento, CA 95829 (916) 381-8033 Contact: Jim Stevens	Valley Slurry Seal Lab P.O. Box 1620 W. Sacramento, CA 95691 (916) 373-1500 Contact: Jim Harriman
Koch Materials 1194 Zinns Quarry Road Reading, PA 17404 (717) 843-0975 Contact: Ron Kohlar	Sahuaro Labs P.O. Box 6536 Phoenix, AZ 85005 (602) 252-3061 Contact: Mike Doyle

The mix design shall be based upon the requirement that the treated area will be opened to traffic within 2 hours after placement of the slurry seal mixture.

Residual asphalt content, percent weight of dry aggregate, shall be from 7.5 to 13.5 percent as determined by AASHTO T 59.

Application rate of slurry mixture, based on weight of dry aggregate, shall be from 15 to 20 pounds per square yard.

The mix design will be submitted to the Engineer for approval 5 days prior to any work being accomplished. The mix design will include the following information:

(a) Aggregate gradation.

(b) Mineral filler to be used if needed, percentage by weight of aggregate.

(c) Asphalt percentage and type.

(d) Sand equivalent of aggregate.

(e) Setting time (40 minutes maximum).

(f) Water resistance test results; pass or fail.

(g) Results of Wet Track Abrasion Test (max. loss of 75 grams per square foot).

In addition to the above data, the Contractor is to submit with the mix design a sample of the aggregate, the emulsified asphalt, and the mineral filler, for use to the Engineer for verifying test results.

After the design mix has been established, the mixture supplied to the project shall conform thereto within the following tolerances:

Passing U.S. No. 4 and larger sieves	±7%
Passing U.S. No. 8 to U.S. No. 100 sieve	±4%
Passing U.S. No. 200 sieve	±2%
Residual Asphalt (by extraction)	±0.4%
Accelerator (portland cement)	±0.2

The Engineer may adjust the asphalt emulsion during construction to account for the amount of asphalt absorbed by the pavement.

408.08 Weather Limitations. Slurry seal shall be applied only when the surface to be treated is dry or slightly damp, when the temperature of the road surface and the air temperature are 60°F and rising, and when the weather is not foggy or rainy.

408.09 Preparation of Surface, General. All roadway surfaces to be treated shall be cleaned by the Contractor. The Contractor shall sweep the pavement with a motorized power broom to remove all loose material. All depressions not reached by the power broom will be cleaned by the Contractor using hand brooming. The Contractor shall ensure that the outer edges of the pavement to be treated, including the 1 foot of the shoulder width, are thoroughly cleaned. Work will not continue until the surface is approved by the Engineer.

408.10 Temporary Centerline Markings. Prior to the placement of the slurry seal surface treatment, temporary centerline marking meeting the requirements of Section 640 shall be installed by the Contractor.

408.11 Application of Slurry Seal. The surface shall be fogged with water immediately preceding the spreader. The slurry seal mixture shall be of the desired consistency as it leaves the mixer. The mixture furnished shall conform to the established design mix. The total mixing time shall not exceed 4 minutes. A sufficient amount of slurry seal mixture shall be carried in all parts of the spreader such that complete coverage of the surface is effected.

Treated areas will be allowed to cure until such time as the Engineer permits these treated areas to be opened to traffic.

The following will not be permitted:

(a) Lumping, balling, or unmixed materials.

(b) Segregation of the emulsion and aggregate fines from the coarse aggregate. If the coarse aggregate settles to the bottom of the slurry seal mix, the slurry seal mix shall be removed from the surface.

(c) Excessive breaking of the emulsion in the spreader box.

(d) Streaks or other unsightly appearances. The shoulder line should be uniform and straight.

(e) Excessive build-up of slurry seal mix on longitudinal or transverse joints.

Method of Measurement

408.12 Aggregate will be measured by the cubic yard in the hauling vehicle at the point of delivery. The quantity to be measured will be the number of cubic yards added to the slurry seal mixture or as authorized by the Engineer.

Asphalt will be measured by the ton. The quantity to be measured will be the number of tons added to the slurry seal mixture or as authorized by the Engineer.

Slurry sealing will be measured by the each for the actual number of test sections completed and accepted.

Basis of Payment

408.13 The accepted quantities, determined as provided above, will be paid for at the contract price per unit of measurement, respectively, for each of the particular pay items listed below and shown in the bid schedule.

The unit contract prices per cubic year for "Aggregate for slurry seal from stockpile" and per ton for "Asphalt for slurry seal" shall be full payment for all costs for labor, tools, equipment, and materials necessary for furnishing these items at the project site.

The unit contract price per each for "Slurry sealing" shall be full payment to complete the work as specified, including all costs for labor, tools, equipment, and materials. This includes but is not limited to the following:

(a) Water necessary for brooming the base surface.
(b) Calibration of equipment.
(c) Furnishing and placing temporary raised pavement markers.
(d) Placement of the materials on the roadway.
(e) Protecting the slurry seal throughout the curing period.

The cost of preparing and furnishing the slurry seal mix design shall be incidental to the work required under other items of the contract. No direct payment will be made for such work.

When mineral filler is required by the mix design, no direct payment will be made for furnishing and incorporating the mineral filler into the work. The cost of such work shall be incidental to the work required under other items of the contract.

Payment will be made under:

Pay Item	Pay Unit
408(1) Aggregate for slurry seal from stockpile	Cubic yard
408(2) Asphalt for slurry seal	Ton
408(3) Slurry sealing per site	Each

Section 409.--CRACK SEALING
(ADDED SECTION)

Description

409.01 This work consists of furnishing all materials, equipment, and labor for sealing cracks in the existing pavement in the treatment areas. Crack sealing shall be in accordance with these specifications and in conformance with details and at the locations shown on the plans. There is one treatment area for crack sealing at each project site and the demonstration site.

Equipment

409.02 The equipment used by the Contractor shall include but not be limited to the following:

(a) Hot-Compressed Air-Lance (HCA). The hot-compressed air-lance shall provide clean, oil-free compressed air at a volume of 100 cubic feet per minute at a pressure of 120 pounds per square inch and at a temperature of 2000 degrees F.

(b) Application Wand. The crack sealant applicator wand shall be attached to a heated hose, attached to a heated sealant chamber. Temperature controls shall be capable of maintaining the temperature of the sealant within manufacturer's tolerances.

(c) Router. A hand controlled mechanical router specifically designed for routing cracks in pavements. The router shall have the ability to rout random cracks to the cross section specified at a minimum rate of 1,000 linear feet per hour.

409.03 The crack sealant shall be a polymer modified rubber asphalt and shall conform to the requirements of ASTM Designation D 3405 when tested in accordance with ASTM Designation D 3407. Crack sealant shall be obtained from a source selected by the Contractor in accordance with the requirements of Subsection 106.01. Crack sealant material shall be furnished from one production lot.

Acceptance of crack sealant is specified in Subsection 106.06.

409.04 Preparation of Surface, General. The pavement area to be treated shall be clean and dry with no standing or flowing water on the surface.

409.05 Cracks to be Treated. All cracks greater than 12 inches in length, and greater than 1/8 inch width shall be treated.

409.06 Preparation of Cracks. Cracks less than 3/4 inch in width shall be routed to 3/4 inch wide and 1 inch deep. Sides of the routed cracks shall be vertical. The bits used to rout the cracks must be kept sharp and replaced when dull. All cracks larger than 3/4 inch shall be thoroughly cleaned of all foreign material.

409.07 Cleaning the Crack. All cracks shall be blown clean and dry using the HCA lance. Care shall be exercised to keep the HCA lance moving at a pace that will avoid burning the surrounding pavement.

409.08 Sealing the Crack. For each crack, the crack sealant shall be placed and finished within 5 minutes after heating with the HCA lance. Each crack shall be filled to within ¼ inch of the existing surface.

409.09 Acceptance of Crack Sealing. Following the application of the crack sealant and prior to the Government opening the roadway to traffic, the job will be visually inspected by the Engineer for areas exhibiting adhesion failure, damage to the sealant from construction equipment or personnel, missed cracks, foreign objects in the sealant, or other problems which will accelerate failure or indicate the job is not acceptable. Portions of the job identified by the Engineer that do not meet these criteria will be prepared and resealed until satisfactory to the Engineer.

Method of Measurement

409.10 Crack sealant will be measured in pounds determined by the count of containers and partial containers actually used and the weight of each.

Crack sealing will be measured by the each for the actual number of test sections completed and accepted.

Basis of Payment

409.11 The accepted quantities, determined as provided above, will be paid for at the contract price per unit of measurement, respectively, for each of the particular pay items listed below and show in the bid schedule.

The unit contract price per pound for "Crack sealant for sealing" shall be full payment for all costs for labor, tools, equipment, and materials necessary for furnishing the sealant to the project site.

The unit contract price per each for "Crack sealing per site" shall be full payment to complete the work as specified, including all costs for labor, tools, equipment, and materials. This includes but is not limited to the following:

(a) Brooming the base surface.
(b) Routing.
(c) Cleaning and drying the cracks.
(d) Placement of materials.

Payment will be made under:

Pay Item	Pay Unit
409(1) Crack sealant for sealing	Pound
409(2) Crack sealing per site	Each

Section 702. -- BITUMINOUS MATERIALS

702.03 Emulsified Asphalts. Delete the text of this subsection and substitute the following:

(a) Emulsified asphalts for chip sealing shall conform to the following:

Emulsified Asphalt (Cationic) AASHTO M 208

Emulsified asphalt, Grade CRS-2, shall conform to AASHTO M 208, Table 1, except the viscosity, Saybolt Furol at 122 degrees F, shall be at least 150s and not more than 300s; and the percent of oil distillate, by volume of emulsion, shall be at least 1.5, but no greater than 3.0. The base asphalt to be emulsified shall be an AC 10 meeting the requirements of AASHTO M 226, Table 2.

The sieve test specified under AASHTO M 208 is not required.

(b) Emulsified asphalts for slurry sealing shall conform to the requirement of Table 702-1 below:

Table 702-1
Quick-Set Emulsified Asphalts

Property	Specification	AASHTO Test Method
Viscosity, 77°F, Saybolt Furol, sec	20 - 100	T 59
Residue by Distillation, %	57 min.	T 59
Sieve Test	0.10 max.	T 59
Tests on Residue from Distillation		
Penetration, 77°F, 100g, 5 sec	40 - 110	T 49
Solubility in Trichloroethylene, %	97.5 min.	T 44
Ductility, 77°F, cm	40 min.	T 51

(c) The crack sealant shall be a polymer modified rubber asphalt and shall conform to the requirements of ASTM Designation D 3405 when tested in accordance with ASTM Designation D 3407.

702.04 Acceptance Procedures for Asphalts. (5) Acceptance Sampling Procedures. Delete the text of this paragraph and substitute the following:

Samples of asphaltic materials shall be taken by the Engineer in accordance with AASHTO T 40, form the shipping containers at the point of delivery. Sample shall be taken of each separate tank at the time of discharge into distributors or other conveyances on the project.

(Revised by Amendment No. 1)

Section 703.--AGGREGATES

703.13 Aggregate for Seal Coats, Cover Coats, and Surface Treatments. Delete the text under this subsection and substitute the following:

Aggregates shall meet the following requirements for grading and quality:

(a) Aggregates for Chip Seal. Aggregate shall be hard, durable particles or fragments of crushed stone or crushed gravel. Aggregates shall conform to the grading requirements in Table 703-1 below.

Table 703-1
Grading Requirements for Chip Seal Aggregate
(Percentage by Weight Passing U.S. Standard Sieves, AASHTO T 27 and T 11)

Sieve Designation	Percent Passing
½"	100
3/8"	90 - 100
¼" square	50 - 75
No. 10	0 - 10
U.S. No. 200	0 - 1.0

Not less than 75 percent by weight of the aggregate shall be particles having at least one fractured face. The fracture requirement shall apply to material retained on each sieve size No. 10 and above if the sieve retains more than 5 percent of the total sample.

The aggregate shall have a maximum flakiness index of 15 as determined by CFLHD DFT 508.

The aggregate shall have a minimum polish value of 32 as determined by AASHTO T 279.

The aggregate shall show a durability factor not less than 35 (coarse and fine aggregate) as determined by AASHTO T 210.

Coarse aggregate shall have a percent of wear of not more than 25 at 500 revolutions as determined by AASHTO T 96.

The finished product shall be clean, uniform in quality, and free from wood, bark, roots, and other deleterious materials.

(b) Aggregates for Slurry Seal. Aggregate shall consist of manufactured sand or crusher fines, or other approved mineral aggregate or combination thereof. Aggregates shall conform to the requirements in Table 703-2 below for grading.

Table 703-2
Grading Requirements for Slurry Seal Aggregate
(Percentage by Weight Passing U.S. Standard Sieves,
AASHTO T 27 and T 11)

Sieve Designation	Percent Passing
5/16"	100
No. 4	70 - 90
No. 8	45 - 70
No. 16	28 - 50
No. 30	19 - 34
No. 50	12 - 25
No. 100	7 - 18
No. 200	5 - 15

Smooth, textured sand of less than 1.25 percent water absorption shall not exceed 50 percent of the total combined aggregate as determined by the AASHTO T 84.

The aggregate shall have a minimum sand equivalent of 55 as determined by AASHTO T 176, alternate Method No. 2.

The finished product shall be clean, uniform in quality, and free from wood, bark, roots and other deleterious materials.

The aggregate shall show a durability factor not less than 35 as determined by AASHTO T 210.

Material used in the production of the aggregate shall have a percent of wear of not more than 35 at 500 revolutions as determined by AASHTO T 96.

APPENDIX E
MATERIAL PROPERTIES

Chip seal asphalt binders varied from region to region. Table 19 indicates the asphalt materials used for chip seals in each region, along with the available information about these materials. The four regions also used different aggregates for chip seals. Table 20 contains the available information about these materials. Table 21 presents several aggregate specification requirements, as applied in each of the LTPP regions, which are often not used in chip seal aggregate specifications. These enhanced aggregate requirements contributed to the good chip seal performance results observed in the SPS-3 test sections.

Slurry seal asphalt binders also varied from region to region. Table 22 contains the available information about the types of asphalt materials used for slurry seals in each region, and information about them. Different aggregates were also used in each of the four regions for slurry seals. Information about the aggregates and the associated material properties are given in table 23.

All of the regions specified the same type of crack sealant, and in fact all used the same product, Crafco Roadsaver 221. Each LTPP region used a different crack seal application and reservoir specification, as presented in appendix A.

Table 19. Asphalt binder properties for SPS-3 chip seals.

LTPP Region	Base Asphalt	Emulsion Type	Application Range (gal/yd^2)	Target Rate	Supplier
Southern	AC-10	CRS-2	0.262 - 0.505	0.36	Ergon Asphalt Vicksburg, MS
Western	AC-20	CRS-2h	0.26 - 0.44	0.38	Sahauro Petroleum & Asphalt Phoenix, AZ
North Atlantic	AC-5	HFRS-2	0.32 - 0.35	0.32-0.35	T.D. Ponder Emulsions Ltd. - Brampton, Ontario
North Central	AC-5	CRS-2	0.299 - 0.381	--	JEBRO Sioux City, IA

Table 20. Aggregate material properties for SPS-3 chip seals.

LTPP Region	Aggregate Supplier	Aggregate Type	Application Range (lb/yd^2)	Target Spread Rate (lb/yd^2)
Southern	Capital Aggregates San Antonio, TX	Crushed Siliceous Gravel	17 -31	22
Western	Concrete Products Co. Salt Lake City, UT	Granite/Sandstone	18.5 - 23.6	19
North Atlantic	Eastern Rock Products Little Falls, NY	Dolomitic Limestone	16.9 - 26	25
North Central	Meridian Aggregate Granite Falls, MN	Crushed Granite	20.8 - 32.7	--

Table 21. Specified aggregate values for chip seals.

	North Atlantic	North Central	Southern	Western
Flakiness Index - CELHODFT508	--	15%	--	15%
Polish Value - AASHTO T279	32	32	28	32
Pass Stripping Test - AASHTO T182	--	--	--	--
Minimum Durability Factor - AASHTO T210	35	35	35	35
Maximum Coarse Aggregate % Wear - AASHTO T96 @ 500 Revolutions	30	30	30	30
Fractured Faces - Minimum of 1	75%	75%	75%	75%
Dimensional Ratio - ASTM D 4791	1:5	--	--	--

Table 22. Asphalt binder properties for SPS-3 slurry seals.

Region	Supplier	Type	Application Range*	Target Emulsion Rate*
Southern	Ergon Asphalt Emulsions Vicksburg, MS	CQS-1h	12.4 - 15.2	13.2
Western	Shahauro Petroleum & Asphalt Phoenix, AZ	CQS-h	11 - 13	.325
North Atlantic	Exxon Corp.	CSS-1h	11 - 13	12
North Central	JEBRO Sioux City, IA	AC-5 base asphalt	15.1 - 15.5	--

*Percent by weight of aggregate.

Table 23. Aggregate material properties for SPS-3 slurry seals.

LTPP Region	Aggregate Supplier	Aggregate Type	Application Range (lb/yd^2)	Target Spread Rate (lb/yd^2)	Mineral Filler
Southern	Dravo Basic Materials Columbia, TN	Arc Furnace Slab	9.4 - 26.3	16 - 18	Type I Portland Cement
Western	Concrete Products Co. Salt Lake City, UT	Granite/ Sandstone	22.4 - 26.8	22.4	Aluminum Sulfate
North Atlantic	General Crushed Stone Co.	--	16.9 - 21	20	Hydrated Lime
North Central	Meridian Aggregate Granite Falls, NM	Crushed Granite	15.7 - 21.3	--	Type I Portland Cement

APPENDIX F
MATERIAL TEST DATA

Sample material test date are included in this appendix, as presented in the field data collection forms. This information has been compiled from the four regional SPS-3 construction reports. Detailed information for individual sites of this type is available upon request from the four LTPP regional contractors.

STATE ASSIGNED ID [1 0 2 2]

STATE CODE [1 6]

SHRP SECTION ID [A 3 _ _]

SEQUENCE OF EVENTS

		DATE COMPLETED
SITE VERIFICATION		01-02-90
PROFILOMETER -	PRE-CONSTRUCTION	07-17-90
FWD -	PRE-CONSTRUCTION	07-16-90
DISTRESS SURVEY -	PRE-CONSTRUCTION	07-25-90 *
SKID DATA -	PRE-CONSTRUCTION	

CONSTRUCTION

1)	CHIP SEAL	07-30-90
2)	SLURRY SEAL	07-30-90
3)	CRACK SEAL	07-30-90
4)	THIN OVERLAY	08-13-90

POST-CONSTRUCTION MEASUREMENTS

		DATE
1)	PROFILOMETER	10-01-90
2)	FWD	
3)	DISTRESS SURVEY	10-25-90 **
4)	SKID DATA	

* PASCO
** MANUAL

Test Section

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For Data Entry

Revised June 12, 1990

Sheet 1 — *STATE ASSIGNED ID [1 0 2 2]

SPS-3 DATA — *STATE CODE [1 6]

LTPP PROGRAM — *SHRP SECTION ID [A 3 5 0]

CHIP SEAL APPLICATION DATA FOR PAVEMENTS WITH ASPHALT CONCRETE SURFACES

MEASUREMENTS TO BE TAKEN ON BOTH LANES, BUT ENTERED ONLY FOR THE LANE CONTAINING THE SPS-3 TEST SECTION

1. *DATE WORK BEGAN (MONTH/DAY/YEAR) [0 7/ 3 0/ 9 0]

   *DATE WORK WAS COMPLETED (MONTH/DAY/YEAR) [0 7/ 3 0/ 9 0]

2. *TIME WORK WAS BEGUN (Hr/Min) [0 3/ 3 3]

   *TIME OF DAY (AM = 1, PM = 2) [2]

   *TIME WORK WAS COMPLETED (Hr/Min) [0 3/ 4 0]

   *TIME OF DAY (AM = 1, PM = 2) [2]

3. *LENGTH OF TEST SECTION SEALED (Feet) [_ 7 6 0]

   *WIDTH OF TEST SECTION SEALED (Feet) [1 2.7]

4. *TYPE OF SEAL COAT [3]
   AGGREGATE SEAL............3

5. *TYPE/GRADE OF BITUMINOUS MATERIAL IN SEAL COAT
   (SEE TABLE A.16 FOR TYPE CODE) [3 5]
   DESCRIPTION OF "OTHER CEMENT" [CRS2-h]

   MANUFACTURER NAME [Sahuaro Petroleum & Asphalt]

   MANUFACTURER MATERIAL NAMES [CRS2-h]

6. *WAS APPLICATION RATE OF BITUMINOUS MATERIAL ADJUSTED AT
   JOBSITE TO CORRECT FOR SURFACE CONDITION (YES = 1, NO = 2) [1]

7. *TARGET APPLICATION RATE FOR BITUMINOUS MATERIAL (~~Gallons~~/Sq. Yd) [.3 8 0]

8. *ACTUAL APPLICATION RATE FOR BITUMINOUS MATERIAL MEASURED
   FROM DISTRIBUTOR READINGS (Gallons/Sq. Yd) [.U _ _]

9. *ACTUAL APPLICATION RATE FOR BITUMINOUS MATERIAL MEASURED
   FROM DISTRIBUTOR TANK MEASUREMENTS (Gallons/Sq. Yd) 375 gallons [.3 8 0]
   float gauge 1450 -> 1075

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Revised June 12, 19

Sheet 2	*STATE ASSIGNED ID [1 0 2 2
SPS-3 DATA	*STATE CODE [1 6
LTPP PROGRAM	*SHRP SECTION ID [A 3 5 0

CHIP SEAL APPLICATION DATA FOR PAVEMENTS WITH ASPHALT CONCRETE SURFACES (CONTINUED

MEASUREMENTS TO BE TAKEN ON BOTH LANES, BUT ENTERED ONLY FOR THE LANE CONTAINING TH SPS-3 TEST SECTION

10. *TARGET APPLICATION TEMPERATURE OF BITUMINOUS MATERIAL (°F) [1 8 0

11. *ACTUAL APPLICATION TEMPERATURE OF BITUMINOUS MATERIAL (°F) [1 8 2

12. *TYPE OF AGGREGATE USED IN SEAL COAT (SEE TABLE A.9 FOR TYPE CODE) [0 1

    DESCRIPTION OF "OTHER AGGREGATE" [Granite/Sandstone

    AGGREGATE SOURCE [Concrete Products Corp Walker Pit

13. *TARGET APPLICATION RATE FOR AGGREGATE (Pounds/Sq. Yard) [1 9 . 0

14. *ACTUAL APPLICATION RATE FOR AGGREGATE IN WHEEL PATHS (Pounds/Sq. Yard) [2 0 . 6

15. *ACTUAL APPLICATION RATE FOR AGGREGATE BETWEEN WHEEL PATHS (Pounds/Sq. Yard) [2 0 . 7

16. *INITIAL EXISTING PAVEMENT SURFACE PREPARATION (SWEEPING REQUIRED) [5

    NONE....................1 COLD MILL..................3
    SWEEP CLEAN ONLY.......2 SHOT BLAST.................4
    OTHER (SPECIFY) Already clean 5

17. *PAVEMENT CONDITIONS AT TIME SEAL COAT APPLIED
    PAVEMENT TEMPERATURE (°F) (60 °F Required) [1 0 8

    CONDITION OF SURFACE BEFORE SEALING [1
    CLEAN ....1 MOSTLY CLEAN..........2
    SOMEWHAT DIRTY....3 DIRTY.................4

    SURFACE MOISTURE CONDITION [4
    DRY .... 1 MOSTLY DRY............2
    SOMEWHAT MOIST.....3 WET...................4

18. *AMBIENT CONDITIONS AT TIME SEAL COAT APPLIED
    AIR TEMPERATURE (°F) (60 °F Required) [9 4

    RELATIVE HUMIDITY (Percent) [_ _ _

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For Data Entry

Revised June 12, 1990

Sheet 3 — *STATE ASSIGNED ID [1 0 2 2]

SPS-3 DATA — *STATE CODE [1 6]

LTPP PROGRAM — *SHRP SECTION ID [A 3 5 0]

CHIP SEAL APPLICATION DATA FOR PAVEMENT WITH ASPHALT CONCRETE SURFACES (CONTINUED)

MEASUREMENTS TO BE TAKEN ON BOTH LANES BUT ENTERED ONLY FOR THE THE LANE CONTAINING THE SPS-3 TEST SECTION

19. *SURFACE CONDITION [3]
    - BADLY OXIDIZED ....1 — NORMAL 3
    - SLIGHTLY OXIDIZED.........2 — SLIGHTLY FLUSHED.............4
    - FLUSHED....................5 — FLUSHED ONLY IN WHEEL PATHS..6
    - OTHER (SPECIFY) ______________ 7

20. *AVERAGE CRACK SEVERITY LEVEL (SEE DISTRESS IDENTIFICATION MANUAL)
    LOW = 1, MODERATE = 2, HIGH = 3 [N]

21. *PRIMARY TYPE OF CRACKS (SEE TABLE A.22 FOR TYPE CODES)
    SEE DISTRESS IDENTIFICATION MANUAL FOR DESCRIPTION [_ N]

22. *ESTIMATED PERCENT OF CRACKS SEALED [_ _ Ø]

23. *AGGREGATE CONDITION PRIOR TO USE (CLEAN OR ONLY SLIGHTLY DIRTY REQUIRED)
    CLEAN = 1 ONLY SLIGHTLY DIRTY = 2 SOMEWHAT DIRTY = 3 DIRTY = 4 [1]

    VERY DRY...........1 DRY........... 2 ONLY SLIGHTLY DAMP..3
    SOMEWHAT DAMP..... 4 SLIGHTLY WET.. 5 WET................ 6 [3]

24. *AGGREGATE MOISTURE CONTENT (PERCENT BY WEIGHT) [_ 1.Ø]

25. *ESTIMATED TIME BETWEEN APPLICATION OF BITUMINOUS MATERIAL
    AND SPREADING OF AGGREGATE MATERIAL (SECONDS) [_ 0 8]

26. *ESTIMATED TIME BETWEEN APPLICATION OF AGGREGATE MATERIAL
    AND INITIAL ROLLING (SECONDS) [_ 1 0]

27. *NUMBER OF COVERAGES PER ROLLER (THREE REQUIRED) [5]

28. *ESTIMATED TIME BETWEEN FINAL ROLLING AND BROOMING SECTION (HOURS) [_ 5.0]

29. *ESTIMATED TIME BETWEEN FINAL ROLLING AND OPENING SECTION
    TO REDUCED SPEED TRAFFIC (HOURS) [_ 3.0]

30. *MAXIMUM REDUCED SPEED ALLOWED (MPH) [35]

31. *ESTIMATED TIME BETWEEN FINAL ROLLING AND OPENING SECTION
    TO FULL SPEED TRAFFIC (HOURS) [_ 5.0]

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Sheet 4 *STATE ASSIGNED ID [1 0 2 2]

SPS-3 DATA *STATE CODE [1 6]

LTPP PROGRAM *SHRP SECTION ID [A 3 5 0]

EQUIPMENT USED IN CHIP SEAL APPLICATION

MEASUREMENTS TO BE TAKEN ON BOTH LANES BUT ENTERED ONLY FOR THE LANE CONTAINING THE SPS-3 TEST SECTION

32. *ROLLER DATA

ROLLER BRAND AND NUMBER	ROLLER DESCRIPTION	GROSS WT. (TONS)	TIRE PRES (PSI)	WIDTH (INCHES)	SPEED (MPH)
Bomag 12-A	Pneumatic-tired	9.0	85.	69.	.
Bros 2903	Pneumatic-tired	9.0	85.	69.	.
Ingram 2904	Pneumatic-tired	9.0	85.	68.	.
	Pneumatic-tired	.	.	.	.

33. *ROLLING INFORMATION (YES = 1, USUALLY = 2, SOMETIMES = 3, NEVER = 4)
ROLLER SPEED EXCEEDS 5 MPH [3]

FINAL ROLLER COVERAGES IN DIRECTION OF TRAFFIC [1]

34. *DISTRIBUTOR
BRAND Bearcat
MODEL
YEAR [1 9 8 4]

NOZZLE ANGLE (Degrees) [4 0]

SPRAY BAR HEIGHT (Inches) [1 3.0]

NOZZLE SPACING (Inches) [4.0]
NOZZLE BRAND Bearcat
MODEL #4

35. *DISTRIBUTOR DETAILS (YES = 1, USUALLY = 2, SOMETIMES = 3, NO = 4)
CLEANED BEFORE USE [1]
EQUIPPED WITH A BITUMETER THAT REGISTERS IN FT/MIN OR GAL/SY [1]
BITUMETER VISIBLE TO OPERATOR [1]
BITUMETER USED BY OPERATOR [1]
EQUIPPED WITH A TACHOMETER ON THE PUMP [1]
TACHOMETER VISIBLE TO THE OPERATOR [1]
TACHOMETER USED BY OPERATOR [1]
EQUIPPED WITH HEATERS THAT CAN BE USED TO BRING THE EMULSIFIED ASPHALT MATERIAL TO SPRAY APPLICATION TEMPERATURE [1]
THERMOMETER VISIBLE TO OPERATOR [4]
THERMOMETER WELL FREE OF CONTACT WITH THE HEATING TUBE? [1]
EQUIPPED WITH A FULL CIRCULATORY SYSTEM INCLUDING THE SPRAY BAR [1]

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Sheet 5 | *STATE ASSIGNED ID [1 0 2 2]

SPS-3 DATA | *STATE CODE [1 6]

LTPP PROGRAM | *SHRP SECTION ID [A 3 5 0]

EQUIPMENT USED IN CHIP SEAL APPLICATION (CONTINUED)

MEASUREMENTS TO BE TAKEN ON BOTH LANES BUT ENTERED ONLY FOR THE LANE CONTAINING THE SPS-3 TEST SECTION

36. *DOUBLE OR TRIPLE LAP (DOUBLE = 1, TRIPLE = 2) [1]

37. *APPLICATION OF ASPHALT (YES = 1, USUALLY = 2, SOMETIMES = 3, NO = 4, NA = 5)
    - WAS UNIFORM SPRAY APPLIED [2]
    - WAS ATOMIZATION NOTICED [4]
    - WERE ANY LOCATIONS MISSED OR DEFICIENT IN ASPHALT [4]
    - WAS A HANDSPRAYER USED TO TOUCH UP MISSED SPOTS [4]
    - WAS BUILDING PAPER USED AT THE BEGINNING OF THE TREATMENT [1]
    - WAS BUILDING PAPER USED AT THE END OF THE TREATMENT [4]
    - WAS STREAKING OF THE ASPHALT NOTICED [5]
    - WERE END NOZZLES USED TO ALLOW FOR AN OVERLAP OF EMULSIFIED ASPHALT BINDER TO THE ADJACENT LANE [1]

38. *AGGREGATE SPREADER
    - BRAND ETNYRE
    - MODEL SPK-H

39. *IS A SELF-PROPELLED MECHANICAL SPREADER USED ? (YES = 1, NO = 2) [1]

40. *SPREADING OF AGGREGATE (YES = 1, USUALLY = 2, SOMETIMES = 3, NO = 4, NA = 5)
    - IS AGGREGATE SPREAD UNIFORMLY [2]
    - IS STREAKING OF THE AGGREGATE NOTICED [4]

41. *IS A MOTORIZED POWER BROOM USED TO REMOVE LOOSE MATERIAL FROM THE SURFACE AFTER ROLLING IS COMPLETE? (YES = 1, NO = 2) [1]

42. *NUMBER OF PASSES WITH BROOM [4]

43. *ESTIMATED PERCENT OF LOOSE MATERIAL REMOVED DURING BROOMING [1]
    - NONE (<1%)...............1
    - VERY LITTLE (1 - 3%).....2
    - SOME (3 - 5%)............3
    - SUBSTANTIAL (>5%)........4

44. *ESTIMATED PERCENT OF LOOSE MATERIAL REMAINING AFTER BROOMING [1]
    - NONE (<1%)...............1
    - VERY LITTLE (1 - 3%).....2
    - SOME (3 - 5%)............3
    - SUBSTANTIAL (>5%)........4

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Sheet 6	*STATE ASSIGNED ID [1 0 2 2]
SPS-3 DATA	*STATE CODE [1 6]
LTPP PROGRAM	*SHRP SECTION ID [A 3 2 0]

SLURRY SEAL APPLICATION DATA FOR PAVEMENTS WITH ASPHALT CONCRETE SURFACES

MEASUREMENTS TO BE TAKEN ON BOTH LANES, BUT ENTERED ONLY FOR THE LANE CONTAINING THE SPS-3 TEST SECTION

1. *DATE WORK BEGAN (MONTH/DAY/YEAR) [0 7 / 3 0 / 9 0]

   *DATE WORK WAS COMPLETED (MONTH/DAY/YEAR) [0 7 / 3 0 / 9 0]

2. *TIME WORK WAS BEGUN (Hr/Min) [0 3 / 2 0]

   TIME OF DAY (AM = 1, PM = 2) [2]

   *TIME WORK WAS COMPLETED (Hr/Min) [0 3 / 2 5]

   TIME OF DAY (AM = 1, PM = 2) [2]

3. *LENGTH OF TEST SECTION SEALED (Feet) [_ 6 5 0]

   *WIDTH OF TEST SECTION SEALED (Feet) [1 3 . 0]

4. *TYPE OF SEAL COAT [2]
   SLURRY SEAL............2

5. *TYPE/GRADE OF BITUMINOUS MATERIAL IN SLURRY SEAL
   (SEE TABLE A.16 FOR TYPE CODE) [3 5]
   DESCRIPTION OF "OTHER CEMENT" [CQS]

   MANUFACTURER NAME [Sahuaro Petroleum & Asphalt]

   MANUFACTURER MATERIAL NAMES [CQS]

6. *TYPE OF AGGREGATE USED IN SLURRY SEAL
   (SEE TABLE A.9 FOR TYPE CODE) [6 1]
   DESCRIPTION OF "OTHER AGGREGATE" [Granite/Sandstone]

   AGGREGATE SOURCE [Concrete Products Co. White Hill Pit]

7. *TYPE OF MINERAL FILLER USED IN SLURRY SEAL
   (SEE TABLE A.15 FOR TYPE CODE) [2 7]
   DESCRIPTION OF "OTHER" [Aluminum Sulfate]

   MINERAL FILLER SOURCE [General Chemical Corp Morristown N.J.]

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Sheet 7 *STATE ASSIGNED ID [1 0 2 2]

SPS-3 DATA *STATE CODE [1 6]

LTPP PROGRAM *SHRP SECTION ID [A 3 2 0]

SLURRY SEAL APPLICATION DATA FOR PAVEMENTS WITH ASPHALT CONCRETE SURFACES (CONT.)

MEASUREMENTS TO BE TAKEN ON BOTH LANES, BUT ENTERED ONLY FOR THE LANE CONTAINING THE SPS-3 TEST SECTION

8. *REVOLUTION COUNT OF SLURRY SEAL MACHINE BEFORE APPLICATION [_ _ _ 0]
9. *REVOLUTION COUNT OF SLURRY SEAL MACHINE AFTER APPLICATION [_ 2 6 2]
10. *TARGET APPLICATION RATE FOR BITUMINOUS MATERIAL (Gallons/Sq. Yd) [.3 2 5]
11. *ACTUAL APPLICATION RATE FOR BITUMINOUS MATERIAL MEASURED FROM DISTRIBUTOR READINGS (Gallons/Sq. Yd) [.3 2 5]
12. *WAS APPLICATION RATE OF BITUMINOUS MATERIAL ADJUSTED AT JOBSITE TO CORRECT FOR SURFACE CONDITION (YES = 1, NO = 2) [2]
13. *TARGET APPLICATION RATE FOR AGGREGATE (Pounds/Sq. Yard) [2 2.4]
14. *ACTUAL APPLICATION RATE FOR AGGREGATE FROM DISTRIBUTOR READINGS (Pounds/Sq. Yard) [2 5.5]
15. *GATE OPENING (INCHES) [_ 5.6]
16. *TARGET APPLICATION RATE FOR MINERAL FILLER ~~(Pounds/Sq. Yard)~~ (% by wt of Agg) [0.6 0]
17. *ACTUAL APPLICATION RATE FOR MINERAL FILLER FROM DISTRIBUTOR READINGS (Pounds/Sq. Yard) [0.0 8]
18. *MINERAL FILLER SETTING [_ 6.5 0]
19. *TARGET APPLICATION RATE FOR SLURRY MIXTURE (Pounds/Sq. Yard) [2 7.4]
20. *ACTUAL APPLICATION RATE FOR SLURRY MIXTURE FROM DISTRIBUTOR READINGS (Pounds/Sq. Yard) [2 9.8]
21. *AMOUNT OF WATER ADDED (Gallons per Gallon of Emulsion) [0.6 7]

175 gals

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Sheet 8 — *STATE ASSIGNED ID [1 0 2 2]

SPS-3 DATA — *STATE CODE [1 6]

LTPP PROGRAM — *SHRP SECTION ID [A 3 2 0]

SLURRY SEAL APPLICATION DATA FOR PAVEMENTS WITH ASPHALT CONCRETE SURFACES (CONT.)

MEASUREMENTS TO BE TAKEN ON BOTH LANES, BUT ENTERED ONLY FOR THE LANE CONTAINING THE SPS-3 TEST SECTION

22. *ACTUAL TEMPERATURE OF BITUMINOUS MATERIAL PRIOR TO APPLICATION (°F) [__ __ U]

23. *ACTUAL APPLICATION TEMPERATURE OF SLURRY MATERIAL (°F) [__ __ U]

24. *INITIAL EXISTING PAVEMENT SURFACE PREPARATION (SWEEPING REQUIRED) [5]
    - NONE....................1 — COLD MILL..................3
    - SWEEP CLEAN ONLY.......2 — SHOT BLAST.................4
    - OTHER (SPECIFY) Already clean 5

25. *PAVEMENT CONDITIONS AT TIME SEAL COAT APPLIED
    - PAVEMENT TEMPERATURE (°F) (60 °F Required) [1 0 8]
    - CONDITION OF SURFACE BEFORE SEALING [U]
        - CLEAN ....1 — MOSTLY CLEAN..........2
        - SOMEWHAT DIRTY....3 — DIRTY..................4
    - SURFACE MOISTURE CONDITION [U]
        - DRY .... 1 — MOSTLY DRY............2
        - SOMEWHAT MOIST.....3 — WET....................4

26. *AMBIENT CONDITIONS AT TIME SEAL COAT APPLIED
    - AIR TEMPERATURE (°F) (60 °F Required) [__ 9 4]
    - RELATIVE HUMIDITY (Percent) [__ __ __]

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Revised June 12, 1990

Sheet 9	*STATE ASSIGNED ID [1 0 2 2]
SPS-3 DATA	*STATE CODE [1 6]
LTPP PROGRAM	*SHRP SECTION ID [4 3 2 0]

SLURRY SEAL APPLICATION DATA FOR PAVEMENT WITH ASPHALT CONCRETE SURFACES (CONTINUED)

MEASUREMENTS TO BE TAKEN ON BOTH LANES BUT ENTERED ONLY FOR THE THE LANE CONTAINING THE SPS-3 TEST SECTION

27. *SURFACE CONDITION [N]
    - BADLY OXIDIZED ....1 NORMAL 3
    - SLIGHTLY OXIDIZED..........2 SLIGHTLY FLUSHED..............4
    - FLUSHED....................5 FLUSHED ONLY IN WHEEL PATHS..6
    - OTHER (SPECIFY) ______________________ 7

28. *AVERAGE CRACK SEVERITY LEVEL (SEE DISTRESS IDENTIFICATION MANUAL)
    LOW = 1, MODERATE = 2, HIGH = 3 [N]

29. *PRIMARY TYPE OF CRACKS (SEE TABLE A.22 FOR TYPE CODES)
    SEE DISTRESS IDENTIFICATION MANUAL FOR DESCRIPTION [_ N]

30. *ESTIMATED PERCENT OF CRACKS SEALED [_ _ ~~0~~]

31. *AGGREGATE CONDITION PRIOR TO USE (CLEAN OR ONLY SLIGHTLY DIRTY REQUIRED)
    CLEAN = 1 ONLY SLIGHTLY DIRTY = 2 SOMEWHAT DIRTY = 3 DIRTY = 4 [2]

    VERY DRY...........1 DRY........... 2 ONLY SLIGHTLY DAMP..3
    SOMEWHAT DAMP..... 4 SLIGHTLY WET.. 5 WET................ 6 [3]

32. *AGGREGATE MOISTURE CONTENT (PERCENT BY WEIGHT) [_ 0 . 8]

33. *ESTIMATED TIME BETWEEN APPLICATION AND OPENING SECTION
    TO REDUCED SPEED TRAFFIC (HOURS) [_ 3 . 0]

34. *MAXIMUM REDUCED SPEED ALLOWED (MPH) [3 5]

35. *ESTIMATED TIME BETWEEN APPLICATION AND OPENING SECTION
    TO FULL SPEED TRAFFIC (HOURS) [_ 5 . 0]

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SHRP LANE
For Data Entry

Revised June 12, 1990

Sheet 10	*STATE ASSIGNED ID	[1 0 2 2]
SPS-3 DATA	*STATE CODE	[1 6]
LTPP PROGRAM	*SHRP SECTION ID	[4 3 2 0]

EQUIPMENT USED IN SLURRY SEAL APPLICATION

36. *SLURRY MIXING MACHINE
BRAND Mitchell
MODEL M-18
YEAR [1 9 8 1]

37. *SLURRY MIXING MACHINE DETAILS (YES = 1, USUALLY = 2 SOMETIMES = 3, NO = 4)

CONTINUOUS FLOW MIXING	[1]
ACCURATELY APPORTIONED MIX COMPONENTS	[1]
DISCHARGED THOROUGHLY MIXED PRODUCT CONTINUOUSLY	[1]
AGGREGATE PREWET IMMEDIATELY PRIOR TO MIXING WITH EMULSION	[1]
INGREDIENTS THOROUGHLY BLENDED IN THE MIXING CHAMBER	[1]
METERING DEVICE INTRODUCES PREDETERMINED PROPORTION OF MINERAL FILLER INTO THE MIXER	[1]
MINERAL FILLER FED AT SAME TIME AND LOCATION AS THE AGGREGATE	[1]
FINES FEEDER PROVIDED FOR MINERAL FILLER	[1]
FOG SPRAY (WATER) USED PRIOR TO SLURRY SEAL	[1]
EQUIPPED WITH A MECHANICAL TYPE SQUEEGEE DISTRIBUTOR	[1]
FLEXIBLE REAR STRIKEOFF USED	[1]
FLEXIBLE REAR STRIKEOFF KEPT IN CONTACT WITH PAVEMENT SURFACE	[1]
WORKING STEERING DEVICE ON SPREADER BOX	[4]
SPREADER BOX KEPT CLEAN AND FREE OF BUILDUP	[2]
WAS SPREADER BOX OVERLOADED	[4]
WAS SPREADER BOX EVENLY FILLED AT ALL TIMES	[2]
WAS ANY LUMPING, BALLING, OR UNMIXED AGGREGATE NOTICED	[4]
WAS SEGREGATION OF THE EMULSION AND AGGREGATE FINES FROM THE COARSE AGGREGATE NOTICED	[4]
SLURRY REMAINED WELL MIXED IN SPREADER BOX	[1]
WAS BREAKING OF EMULSION OBSERVED IN THE SPREADER BOX	[4]
BUILD-UP OF MATERIAL ALONG LONGITUDINAL AND TRANSVERSE JOINT	[4]

38. *SETTING OF SPREADER BOX WIDTH (Inches) [156

39. *TYPE OF DRAG USED (NONE = 1, BURLAP = 2, OTHER = 3) [2
OTHER (SPECIFY) ______

40. *SURFACE TEXTURE PROVIDED [3
ROUGH AND OPEN................1
SOMEWHAT ROUGH AND OPEN 2
SOMEWHAT SMOOTH AND TIGHT....3
SMOOTH AND TIGHT.............4

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By ______

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Sheet 11 *STATE ASSIGNED ID [1 0 2 2]

SPS-3 DATA NO CRACKS *STATE CODE [1 6]

LTPP PROGRAM *SHRP SECTION ID [A 3 3 0]

CRACK SEAL DATA FOR PAVEMENTS WITH ASPHALT CONCRETE SURFACES

MEASUREMENTS TO BE TAKEN ON BOTH LANES BUT ENTERED ONLY FOR THE LANE CONTAINING THE SPS-3 TEST SECTION

1. *DATE WORK BEGAN (MONTH/DAY/YEAR) [__ __/__ __/__ __]

   *DATE WORK WAS COMPLETED (MONTH/DAY/YEAR) [__ __/__ __/__ __]

2. *TIME WORK WAS BEGUN (Hr/Min) [__ __/__ __]

   TIME OF DAY (AM = 1, PM = 2) [_]

   *TIME WORK WAS COMPLETED (Hr/Min) [__ __/__ __]

   TIME OF DAY (AM = 1, PM = 2) [_]

3. *LENGTH OF TEST SECTION (Feet) [_ 6 5 0]

   *WIDTH OF TEST SECTION (Feet) [1 3 . 0]

4. *INITIAL EXISTING PAVEMENT SURFACE PREPARATION (SWEEPING REQUIRED) [5]
   NONE....................1 COLD MILL...................3
   SWEEP CLEAN ONLY.......2 SHOT BLAST..................4
   OTHER (SPECIFY) Already Clean 5

5. *AMBIENT CONDITIONS AT TIME SEAL COAT APPLIED
   AIR TEMPERATURE (°F) (60 °F Required) [__ __ __

   RELATIVE HUMIDITY (Percent) [__ __ __

6. *PAVEMENT CONDITIONS AT TIME CRACK SEAL APPLIED
   PAVEMENT TEMPERATURE (°F) (60 °F Required) [__ __ __

   CONDITION OF SURFACE BEFORE SEALING [1]
   CLEAN ....1 MOSTLY CLEAN..........2
   SOMEWHAT DIRTY....3 DIRTY.................4

   SURFACE MOISTURE CONDITION [1]
   DRY .... 1 MOSTLY DRY............2
   SOMEWHAT DAMP......3 WET...................4

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SHRP LANE
For Data Entry

Revised June 12, 1990

Sheet 12 — *STATE ASSIGNED ID [1 0 2 2]

SPS-3 DATA — *STATE CODE [1 6]

LTPP PROGRAM — *SHRP SECTION ID [A 3 3 0]

CRACK SEAL DATA FOR PAVEMENTS WITH ASPHALT CONCRETE SURFACES CONTINUED

MEASUREMENTS TO BE TAKEN ON BOTH LANES BUT ENTERED ONLY FOR THE LANE CONTAINING THE SPS-3 TEST SECTION

7. *SURFACE CONDITION [ ]
   - BADLY OXIDIZED 1
   - SLIGHTLY OXIDIZED.........2
   - FLUSHED...................5
   - NORMAL 3
   - SLIGHTLY FLUSHED.............4
   - FLUSHED ONLY IN WHEEL PATHS..6
   - OTHER (SPECIFY) ____________

8. *AVERAGE CRACK SEVERITY LEVEL (SEE DISTRESS IDENTIFICATION MANUAL) LOW = 1, MODERATE = 2, HIGH = 3 [ ]

9. *PRIMARY TYPE OF CRACKS (SEE TABLE A.22 FOR TYPE CODES) SEE DISTRESS IDENTIFICATION MANUAL FOR DESCRIPTION [_ _]

10. *ESTIMATED PERCENT OF CRACKS SEALED [_ _ _]

11. *APPROXIMATE TOTAL LENGTH OF CRACKS SEALED (FEET) [_ _ _ _]

12. *TYPE OF ASTM D3405 MATERIAL USED TO SEAL CRACKS
    - MANUFACTURER NAME Crafco
    - MANUFACTURER SEALANT NAME Roadsaver 221

13. *INFORMATION ON ROUTING (YES = 1, USUALLY = 2, SOMETIMES = 3, NEVER = 4)
    - TRANSVERSE CROACKS ROUTED [ ]
    - DIAGONAL CRACKS ROUTED [ ]
    - LONGITUDINAL CRACKS ROUTED [ ]
    - ROUTING ACCOMPLISHED IN ONE PASS [ ]

14. *DIMENSIONS OF CRACK OR ROUTED RESERVOIR (AFTER PREPARATION)
    - WIDTH (INCHES)
      - MINIMUM........[_._ _] MAXIMUM........[_._ _]
      - MEAN...........[_._ _]
    - DEPTH (INCHES)
      - MINIMUM........[_._ _] MAXIMUM........[_._ _]
      - MEAN...........[_._ _]
    - TOTAL LENGTH OF CRACKS PREPARED [_ _ _ _]

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By ________

SHRP LANE
For Data Entry

Revised June 12, 1990

Sheet 13 — *STATE ASSIGNED ID [1 0 2 2]

SPS-3 DATA — *STATE CODE [1 6]

LTPP PROGRAM — *SHRP SECTION ID [A 3 3 0]

CRACK SEAL DATA FOR PAVEMENTS WITH ASPHALT CONCRETE SURFACES (CONTINUED)

MEASUREMENTS TO BE TAKEN ON BOTH LANES BUT ENTERED ONLY FOR THE LANE CONTAINING THE SPS-3 TEST SECTION

15. *CONDITION OF CRACK JUST PRIOR TO SEALING
    (YES = 1, USUALLY = 2, SOMETIMES = 3, NEVER = 4)

    CLEAN [ ]
    DRY [ ]

    WAS HOT-AIR LANCE USED [ ]
    WAS ASPHALT AROUND CRACK CHARRED AFTER HEATING [ ]
    WAS CRACK STILL HOT FROM THE HOT-AIR LANCE WHEN SEALANT WAS PLACED [ ]

16. *MAKE AND MODEL OF SEALANT HEATING KETTLE AND APPLICATOR
    MODEL NAME Bearcat
    MODEL NUMBER BK 250

17. *MAXIMUM ALLOWABLE TEMPERATURE OF THE SEALANT (°F) [4 1 0]

18. *ACTUAL TEMPERATURE OF THE SEALANT AT THE BEGINNING OF APPLICATION (°F) [_ _ _]

19. *ACTUAL TEMPERATURE OF THE SEALANT AT THE END OF APPLICATION (°F) [_ _ _]

20. *WAS ANY SEALANT REHEATED (YES =1, NO = 2) [ ]

21. *HOW MANY TIMES WAS SEALANT REHEATED [ ]

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SHRP LANE
For Data Entry

Revised June 12, 1990

Sheet 14 — *STATE ASSIGNED ID [1 0 2 2]

SPS-3 DATA — *STATE CODE [1 6]

LTPP PROGRAM — *SHRP SECTION ID [A 3 3 0]

CRACK SEAL DATA FOR PAVEMENTS WITH ASPHALT CONCRETE SURFACES (CONTINUED)

MEASUREMENTS TO BE TAKEN ON BOTH LANES BUT ENTERED ONLY FOR THE LANE CONTAINING THE SPS-3 TEST SECTION

22. *SEALANT APPLICATION (YES = 1, USUALLY = 2, SOMETIMES = 3, NEVER = 4)

BACKFLUSHED HOSE [_]
CRACK FILLER FLUSHED [_]
SEALANT CHAMBER HEATED [_]
HOSE BETWEEN WAND AND SEALANT CHAMBER HEATED [_]
MATERIAL IN CHAMBER UNDER CONSTANT AGITATION [_]
THERMOMETER VISIBLE TO THE ENGINEER [_]
BLOTTING MATERIAL USED ON THE CRACKS [_]

DISTANCE BETWEEN APPLICATOR WAND AND SQUEEGEE (FEET) [_ _]
AVERAGE WIDTH OF COMPLETED SEALED CRACK [_._]

23. *THICKNESS OF FINISHED SEALANT [_]
CRACK OVERFILLED..........1 RECESSED 2
LEVEL WITH SURFACE........3

APPROXIMATE AVERAGE THICKNESS OF SEALANT ABOVE OR BELOW PAVEMENT SURFACE (INCHES) [.__ __]

24. *LENGTH OF TIME BETWEEN
COMPLETION OF CRACK PREPARATION AND SEALANT PLACEMENT (MINUTES) [__ __.__]

COMPLETION OF CRACK SEALANT AND OPENING TO TRAFFIC AT END WHERE SEALING BEGAN (HOURS) [__ __.__.__]

COMPLETION OF CRACK SEALANT AND OPENING TO TRAFFIC AT END WHERE SEALING ENDED (HOURS) [__ __.__.__]

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SEP 10 1992
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APPENDIX G
TRIP DATA (STAND-ALONE REPORT)

The information provided in this appendix summarizes data gathered by the Expert Task Groups during the field review of the SHRP Asphalt Pavement Sites (SPS-3). Prior to the start of the regional ETG SPS-3 and SPS-4 site tours in 1995, an inventory of site status was performed and LTPP data for each site was summarized for the tour participants. The site inventories were prepared by Nichols Consulting Engineers, with support from the LTPP regional contractors.

A thorough evaluation of this information is presented in a separate stand-alone report entitled "Pavement Treatment Effectiveness 1995 SPS-3 and SPS-4 Site Evaluations, National Review." This report is included in the CD-ROM.

APPENDIX H
SPS-3 AND SPS-4 CD-ROM DATA

A CD-ROM containing data used in the evaluation of the SPS-3 and 4 projects is available. There are two forms of data on the CD-ROM: a very large Microsoft Access™ data base that contains nearly all of the LTPP Regional Information Management System (RIMS) data base files used in the analysis and several Microsoft Excel™ files containing data on different performance parameters in a more refined form.

ACCESS™ DATABASE

The access database contained on the CD-ROM is a file named SHOWCASE.MDB. The opening Project Identification screen is shown in figure 18. The user-friendly interface allows data trend plots to be generated for a variety of data types for specific SPS-3 sites.

The information is provided in accordance with SHRP designated coding. For example, Alabama is designated as state code 01. Table 24 provides the full list of SHRP state codes. Treatment designations as defined by SHRP are:

Section Number	Maintenance Treatment
310	Thin Overlay
320	Slurry Seal
330	Crack Seal
340	Control Section (untreated)
350	Chip Seal

Once a site is selected from the screen in figure 18, the user can choose to view or print out plots from the performance data types shown in the "view data screen" in figure 19. This information can be obtained for either the basic LTPP experiment types or for state supplemental sections. Traffic and other data can be obtained by hitting the "More Data" button at the bottom of the view data screen. Please note that only SPS-3 sites and data can be accessed through these screens.

It is highly recommended that first time users read the "help text file" that can be viewed by pushing the "help" key on the Project Identification screen shown in figure 18.

For experienced Access™ users or just the adventurous type, hitting the "Database:..." button below and to the left of the Project Identification screen in figure 18 will get you into Access™

proper and allow access to the data tables shown in table 25. Most of these are the raw data files from the LTPP RIMS used in the execution of this contract. Much of the data used in the analysis of the SPS-4 data is also present here. Have fun!

EXCEL™ FILES

Also contained on the CD-ROM are several Excel™ 5.0 spreadsheet files that contain data presented in appendixes F, H, I, and J. These are distress, rutting, IRI roughness, and friction, respectively. Note that several of these files contain multiple folders.

The data is presented in such a way as to allow simple graphing and analysis by experienced Excel™ users. Also included is a file called "MASTLIST.XLS" which contains two folders of summary information on all SPS-3 sites and sections evaluated in the study.

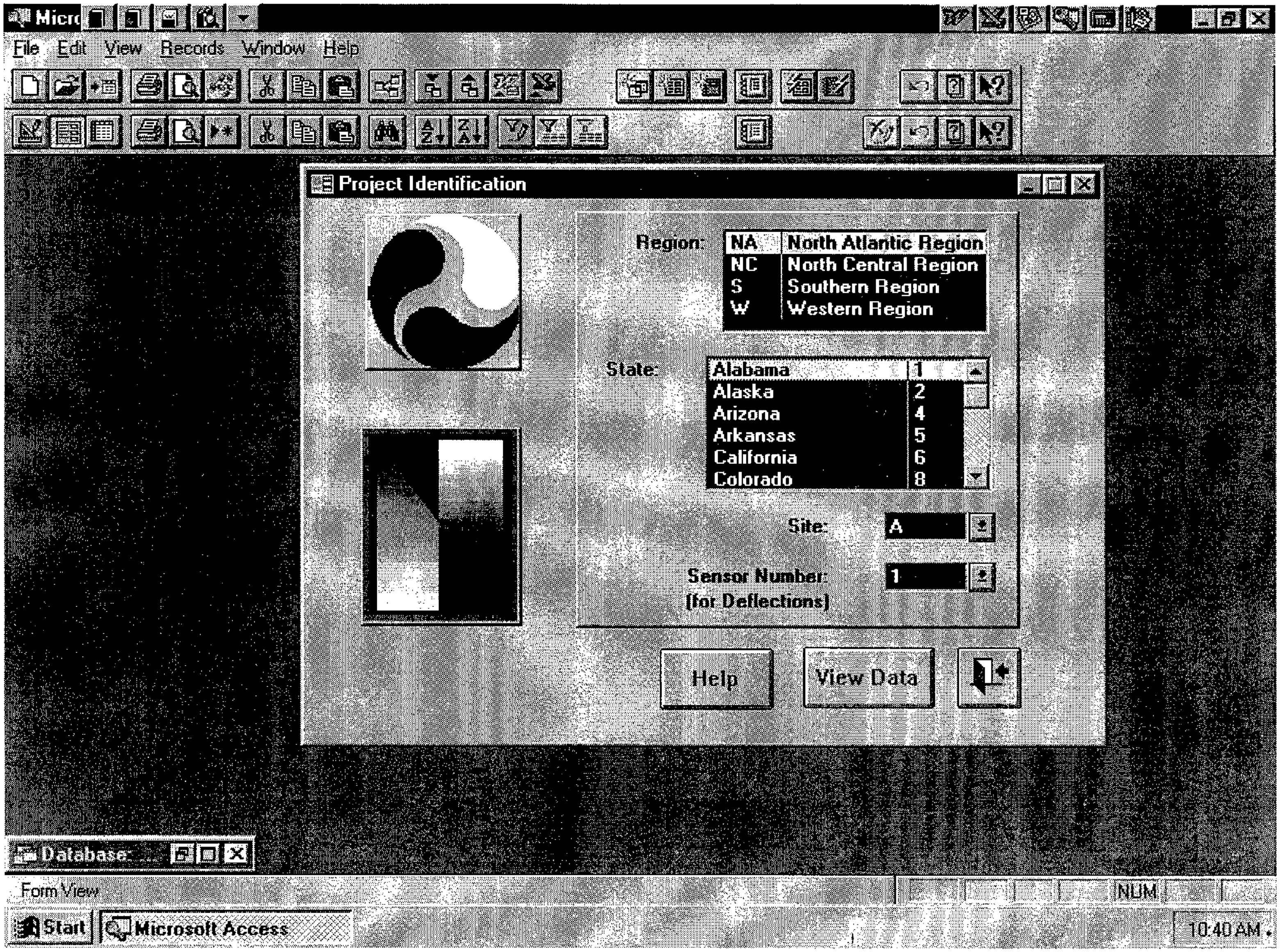

Figure 18. SHOWCASE.MDB data base "Project Identification" opening screen.

Table 24. State codes.

State	State Code
Alabama	01
Alaska	02
Arizona	04
Arkansas	05
California	06
Colorado	08
Connecticut	09
Delaware	10
District of Columbia	11
Florida	12
Georgia	13
Hawaii	15
Idaho	16
Illinois	17
Indiana	18
Iowa	19
Kansas	20
Kentucky	21
Louisiana	22
Maine	23
Maryland	24
Massachusetts	25
Michigan	26
Minnesota	27
Mississippi	28
Missouri	29
Montana	30
Nebraska	31
Nevada	32
New Hampshire	33
New Jersey	34
New Mexico	35
New York	36
North Carolina	37
North Dakota	38
Ohio	39
Oklahoma	40
Oregon	41
Pennsylvania	42
Rhode Island	44
South Carolina	45
South Dakota	46
Tennessee	47
Texas	48
Utah	49
Vermont	50
Virginia	51
Washington	53
West Virginia	54
Wisconsin	55
Wyoming	56
American Samoa	60
Guam	66
Puerto Rico	72
Virgin Islands	78
Alberta	81
British Columbia	82
Manitoba	83
New Brunswick	84
Newfoundland	85
Nova Scotia	86
Ontario	87
Prince Edward Island	88
Quebec	89
Saskatchewan	90

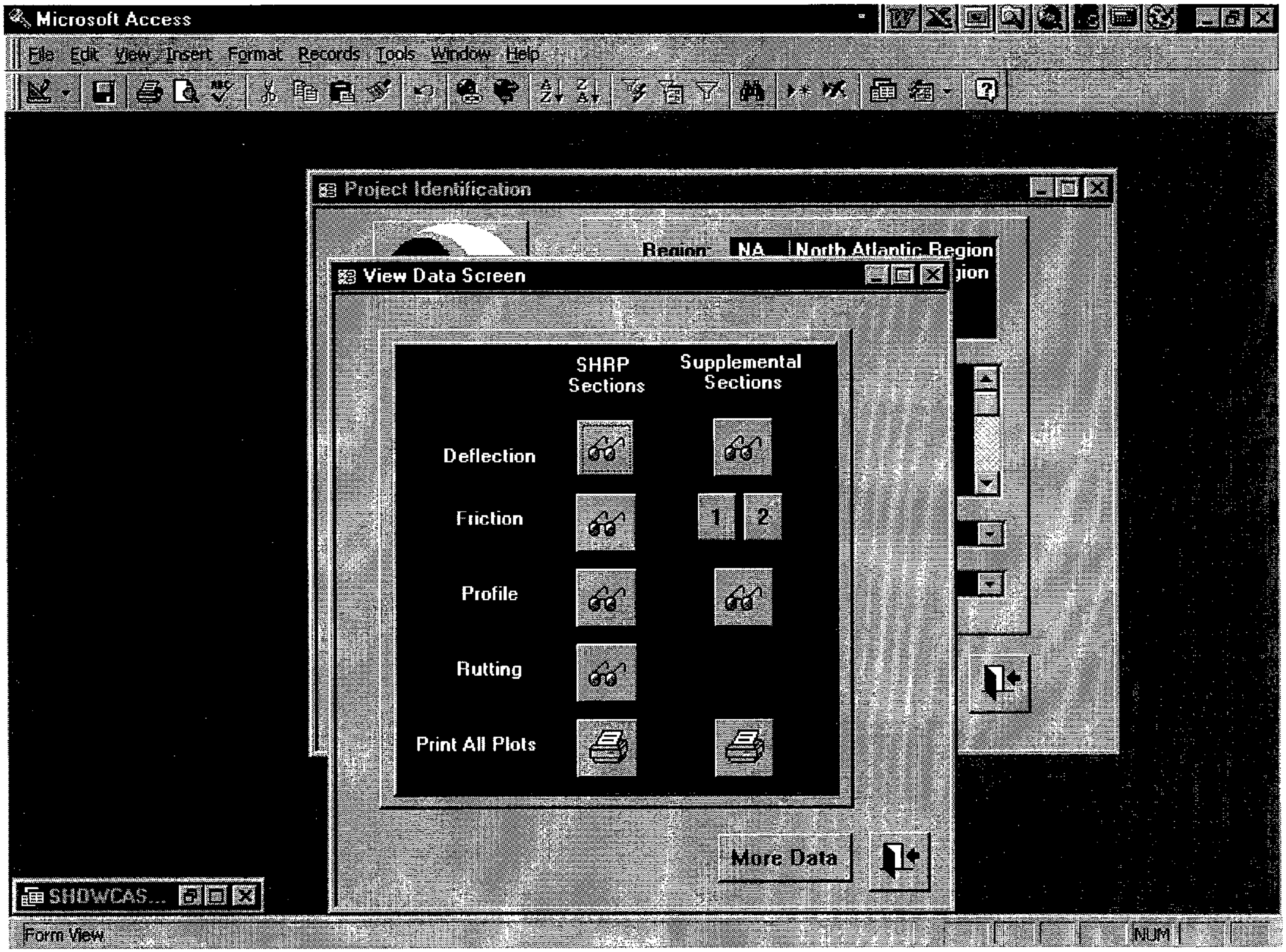

Figure 19. SHOWCASE.MDB data base "View Data Screen."

Table 25. RIMS tables needed from data extraction.

SPS-3, SPS-4 and Associated GPS Sections

EXPERIMENT_SECTION
MON_DEFL_COMMENTS
MON_DEFL_LANE_STATS
MON_DEFL_LOC_INFO
MON_DEFL_MASTER
MON_DIS_AC_REV
MON_DIS_CRCP_REV
MON_DIS_JPCC_FAULT
MON_DIS_JPCC_REV
MON_DIS_PADIAS_AC
MON_DIS_PADIAS_CRC
MON_DIS_PADIAS_JC
MON_DIS_PADIAS_MAP
MON_DROP_SEP
MON_DYNATEST_DROP_DATA
MON_FRICTION
MON_PASCO_DEV_CONFIG
MON_PROFILE_MASTER
MON_RUT_DEPTHS
MON_RUT_MASTER
MON_TEMPERATURE_DEPTHS
MON_TEMPERATURE_TEMPS
SPS3_CHIP
SPS3_CHIP_EQUIP
SPS3_CRACK
SPS3_INTERSECTIONS
SPS3_PROJECT_STATIONS
SPS3_ROLLER
SPS3_SLURRY
SPS3_SLURRY_EQUIP
SPS4_BENKELMAN_GENERAL
SPS4_BENKELMAN_MEASURE
SPS4_CONTROL_GENERAL
SPS4_CONTROL_LONG
SPS4_CONTROL_RANDOM
SPS4_CONTROL_SHOULDER
SPS4_CONTROL_TRANS
SPS4_CRACK_SEAL_GENERAL
SPS4_CRACK_SEAL_PVMT
SPS4_CRACK_SEAL_PVMT_MEAS
SPS4_CRACK_SEAL_RAND
SPS4_CRACK_SEAL_RAND_MEAS
SPS4_CRACK_SEAL_SH
SPS4_CRACK_SEAL_SH_MEAS
SPS4_DYNAFLECT_GENERAL
SPS4_DYNAFLECT_MEASURE
SPS4_EPOXY_GENERAL
SPS-4_EPOXY_MEASURE
SPS4_FWD_MEASUREMENTS
SPS4_INTERSECTIONS
SPS4_PROJECT_STATIONS
SPS4_TRANSIENT_GENERAL
SPS4_TRANSIENT_MEASURE
SPS4_UNDERSEAL_GENERAL
SPS4_UNDERSEAL_INIT_GROUT
SPS4_UNDERSEAL_PRES_GROUT
SPS4_UNDERSEAL_REGROUT

Also include the following:
*.A00 files
*.A01 files

	Ext
SPS_General	820
SPS_ID	104
SPS_ID	204
SPS_ID	804

APPENDIX I
THE DEVELOPMENT AND APPLICATION OF A PAVEMENT RATING SCORE (PRS) FOR USE WITH THE LTPP DISTRESS IDENTIFICATION MANUAL (STAND-ALONE REPORT)

The development of the PRS used in the analyses in this report is described in a separate stand-alone report.

APPENDIX J
DISTRESS DATA

Appendix J provides a tabular compilation combining PASCO and manual distress data, PRS, environmental zone, and age information. This data table is available on the CD-ROM in spreadsheet format. Table 26 illustrates the layout of this spreadsheet table. Data included in the analysis in this report are taken from this master table. Figures 20 through 24 show the distribution of individual distress and PRS data in the table.

Table 26. Sample spreadsheet data from distress table, as available on CD-ROM.

STATE_CODE	SHRP_ID	LTPP Region	ENVIRO ZONE	SUPERPAVE ZONE	LINKED_GPS_ID	CONST DATE	SURVEY_DATE	Base Date (Used for comparitive Control Age)	Age (yrs)	Low Severity Longitudinal Cracking (meters)	Medium Severity Longitudinal Cracking (meters)	High Severity Longitudinal Cracking (meters)	Total Longitudinal Cracking (m)	Low Severity Transverse Cracking (meters)	Medium Severity Transverse Cracking (meters)	High Severity Transverse Cracking (meters)	Total Transverse Cracking (m)	Low Severity Fatigue Cracking (m^2)	Medium Severity Fatigue Cracking (m^2)	High Severity Fatigue Cracking (m^2)	Total Fatigue Cracking (m^2)	Low Severity Patching (m^2)	Medium Severity Patches (m^2)	High Severity Patches (m^2)	Potholes (m^2)	Total Combined Potholes Patches (m^2)	Manual or PASCO Data	Pavement Rating Score	Current Condition	Initial Condition
1	A310	S	WNF	I-C	4125	1/7/90	6/8/90		0.416	5	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	P	95	G	G
1	A310	S	WNF	I-C	4125	1/7/90	12/11/90		0.926	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	M	100	G	G
1	A310	S	WNF	I-C	4125	1/7/90	6/21/91		1.452	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	M	100	G	G
1	A310	S	WNF	I-C	4125	1/7/90	8/24/94		4.630	38	0	0	38	0	0	0	0	7	0	0	7	0	0	0	0	0	M	90	G	G
1	A320	S	WNF	I-C	4125	8/7/90	6/8/90		-0.164	8	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	P	95	G	G
1	A320	S	WNF	I-C	4125	8/7/90	12/11/90		0.345	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	M	100	G	G
1	A320	S	WNF	I-C	4125	8/7/90	6/21/91		0.871	2	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	M	95	G	G
1	A330	S	WNF	I-C	4125	8/7/90	12/11/90		0.345	63	0	0	63	0	0	0	0	0	0	0	0	0	0	0	0	0	M	95	G	G
1	A330	S	WNF	I-C	4125	8/7/90	6/21/91		0.871	58	0	0	58	0	0	0	0	0	0	0	0	0	0	0	0	0	M	95	G	G
1	A330	S	WNF	I-C	4125	8/7/90	4/2/92		1.655	39	0	0	39	2	0	0	2	0	0	0	0	0	0	0	0	0	M	95	G	G
1	A330	S	WNF	I-C	4125	8/7/90	8/24/94		4.049	1	0	0	1	1	0	0	1	16	0	0	16	0	0	0	0	0	P	92	G	G
1	A340	S	WNF	I-C	4125	9/1/90	6/8/90	9/1/90	-0.233	6	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	M	82	F	G
1	A340	S	WNF	I-C	4125	9/1/90	2/12/91	9/1/90	0.449	5	0	0	5	1	0	0	1	3	0	0	3	0	0	0	0	0	P	95	G	G
1	A340	S	WNF	I-C	4125	9/1/90	6/21/91	9/1/90	0.803	9	0	0	9	1	0	0	1	2	0	0	2	0	0	0	0	0	P	87	G	G
1	A340	S	WNF	I-C	4125	9/1/90	4/2/92	9/1/90	1.586	16	0	0	16	2	0	0	2	0	0	0	0	0	0	0	0	0	M	87	G	G
1	A340	S	WNF	I-C	4125	9/1/90	8/24/94	9/1/90	3.981	27	12	0	39	1	0	0	1	9	0	0	9	0	0	0	0	0	P	92	G	G
1	A350	S	WNF	I-C	4125	8/7/90	6/8/90		-0.164	6	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	M	77	F	G
1	A350	S	WNF	I-C	4125	8/7/90	12/11/90		0.345	3	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	P	95	G	G
1	A350	S	WNF	I-C	4125	8/7/90	2/12/91		0.518	4	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	M	95	G	G
1	A350	S	WNF	I-C	4125	8/7/90	6/21/91		0.871	3	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	P	95	G	G
1	A350	S	WNF	I-C	4125	8/7/90	4/2/92		1.655	5	0	0	5	2	0	0	2	0	0	0	0	0	0	0	0	0	M	95	G	G
1	A350	S	WNF	I-C	4125	8/7/90	8/24/94		4.049	12	0	0	12	0	0	0	0	0	0	0	0	0	0	0	0	0	P	92	G	G
1	B310	S	WNF	I-C	1019	11/1/90	12/13/90		0.115	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	M	95	G	G
1	B310	S	WNF	I-C	1019	11/1/90	6/19/91		0.630	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	M	100	G	G
1	B310	S	WNF	I-C	1019	11/1/90	3/31/92		1.414	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	M	100	G	G
1	B310	S	WNF	I-C	1019	11/1/90	3/29/93		2.408	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	P	97	G	G
1	B310	S	WNF	I-C	1019	11/1/90	7/23/95		4.726	3	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	M	100	G	G
1	B320	S	WNF	I-C	1019	8/21/90	12/13/90		0.312	2	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	M	95	G	G
1	B320	S	WNF	I-C	1019	8/21/90	1/15/91		0.403	3	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	M	95	G	G
1	B320	S	WNF	I-C	1019	8/21/90	6/19/91		0.827	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	P	95	G	G
1	B320	S	WNF	I-C	1019	8/21/90	3/31/92		1.611	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	M	95	G	G
1	B320	S	WNF	I-C	1019	8/21/90	3/29/93		2.605	31	0	0	31	0	0	0	0	4	0	0	4	0	0	0	0	0	P	95	G	G
1	B320	S	WNF	I-C	1019	8/21/90	7/22/95		4.921	0	0	0	0	0	0	0	0	117	6	0	123	0	0	0	0	0	M	90	G	G
1	B330	S	WNF	I-C	1019	8/21/90	12/13/90		0.312	0	0	0	0	0	0	0	0	7	0	0	7	0	0	0	0	0	M	70	F	G
1	B330	S	WNF	I-C	1019	8/21/90	1/15/91		0.403	13	0	0	13	5	0	0	5	8	0	0	8	0	0	0	0	0	M	95	G	G
1	B330	S	WNF	I-C	1019	8/21/90	6/19/91		0.827	21	0	0	21	0	0	0	0	16	0	0	16	0	0	0	0	0	P	87	G	G

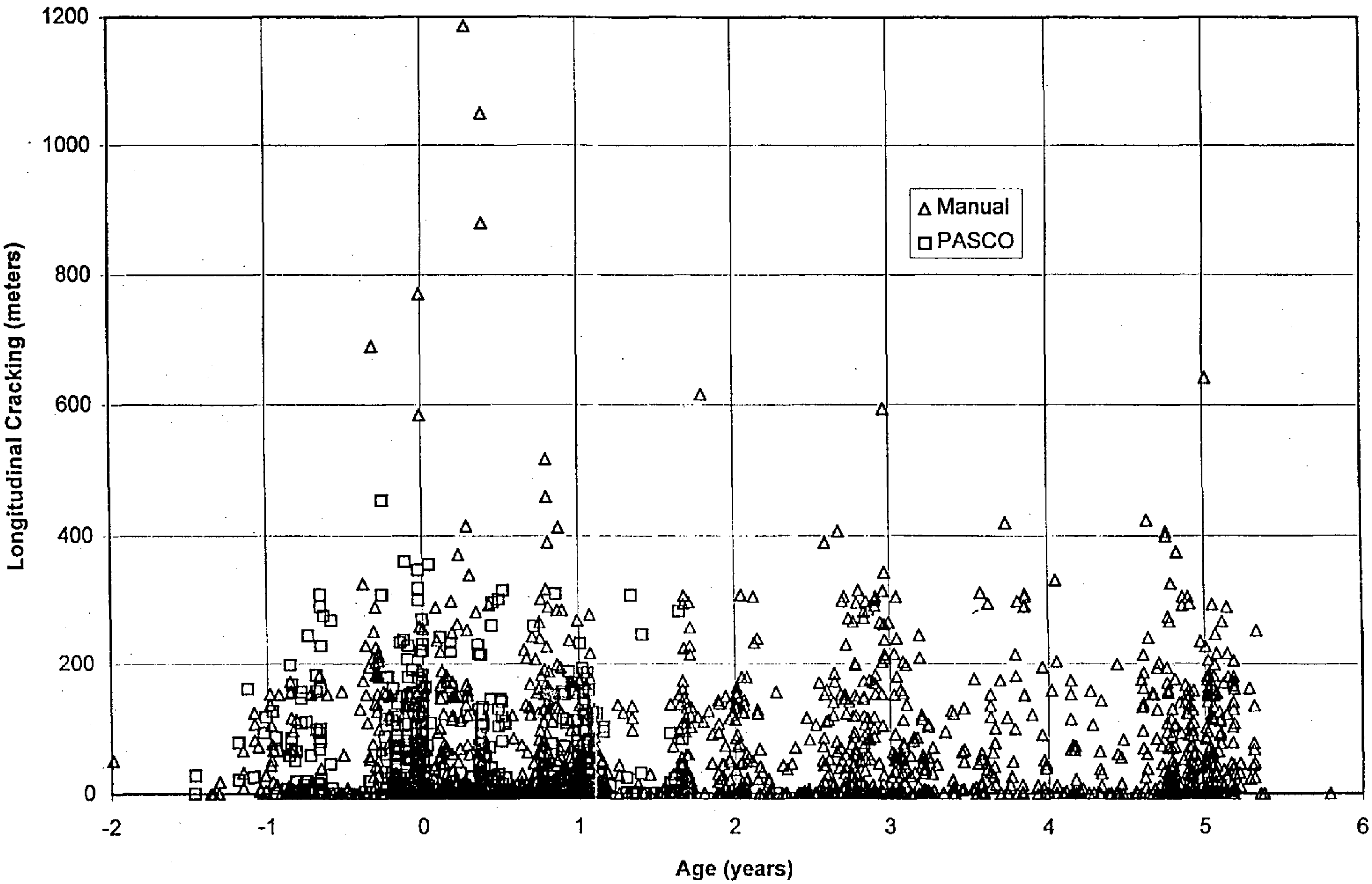

Figure 20. Longitudinal cracking vs. age showing distribution and range of all data.

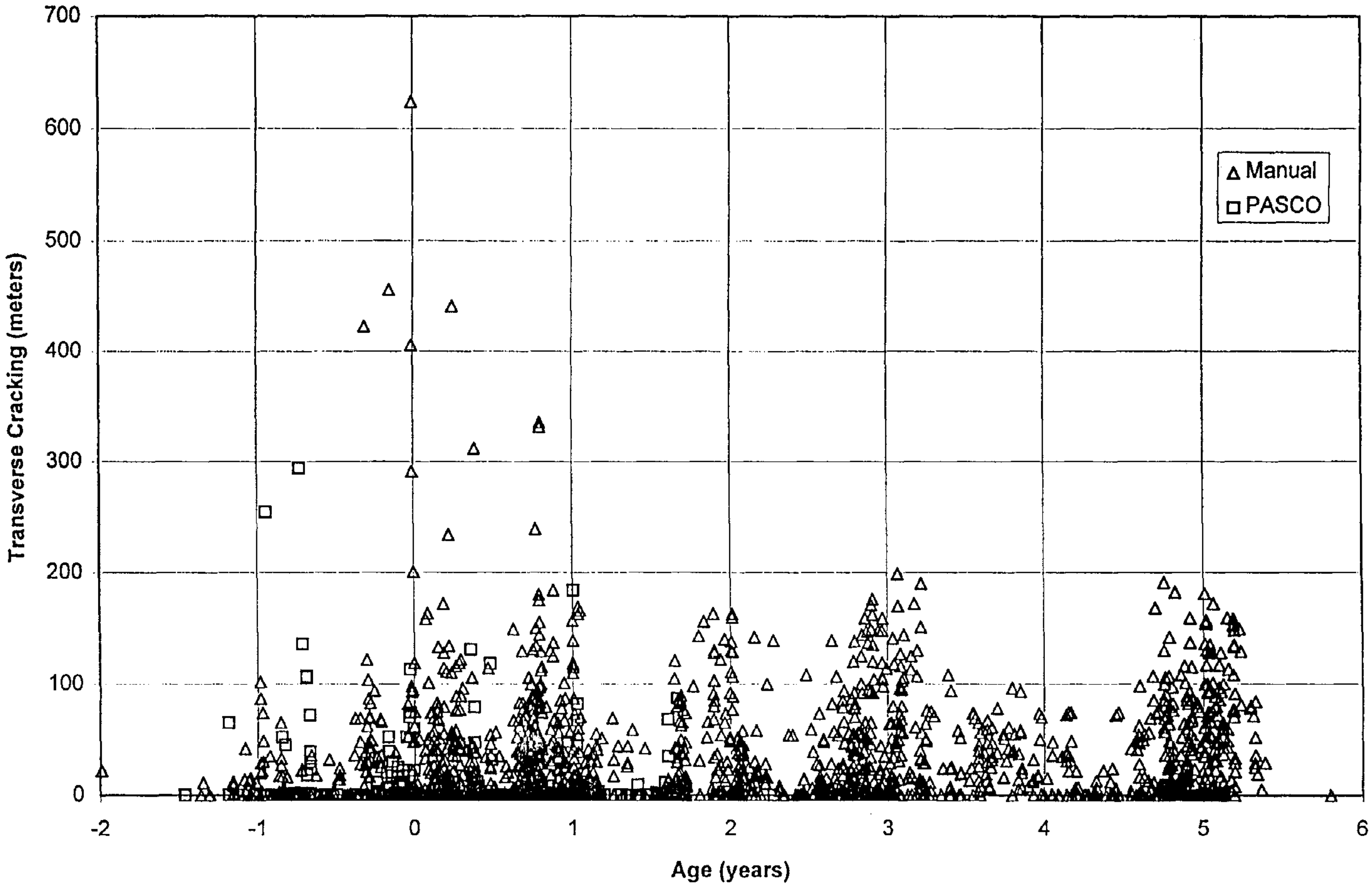

Figure 21. Transverse cracking vs. age showing distribution and range of all data.

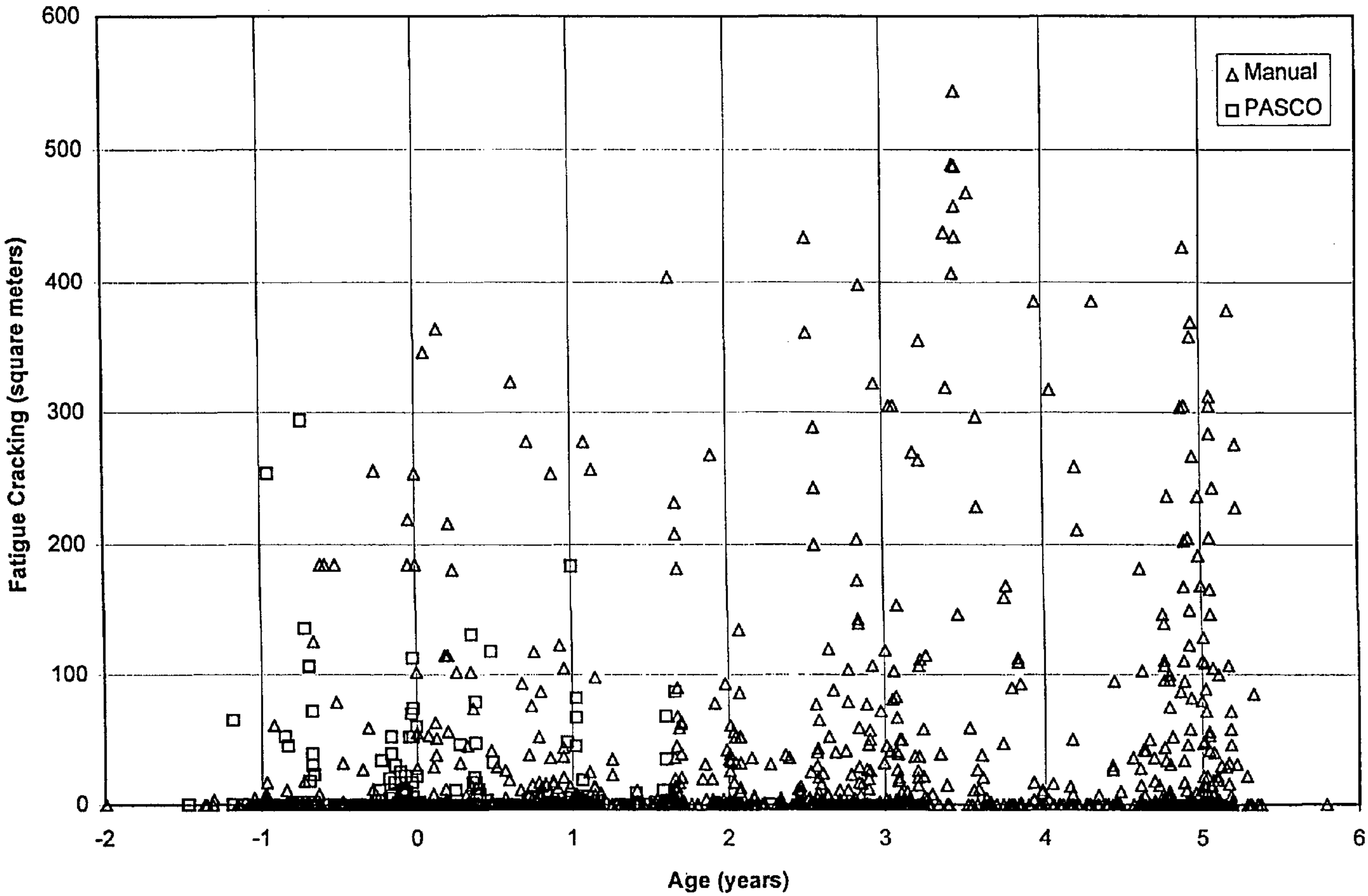

Figure 22. Fatigue cracking vs. age showing distribution and range of all data.

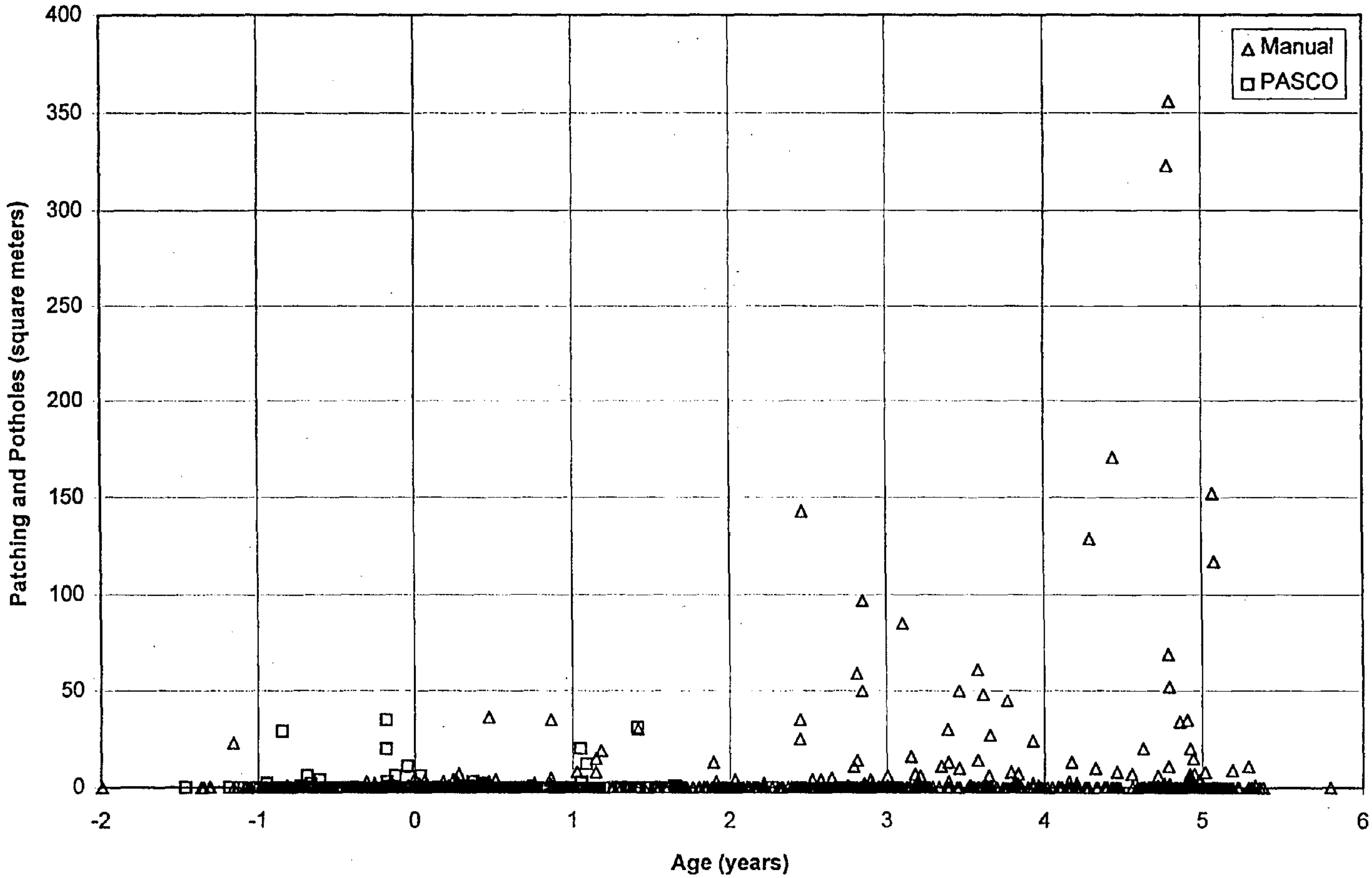

Figure 23. Patching and potholes vs. age showing distribution and range of all data.

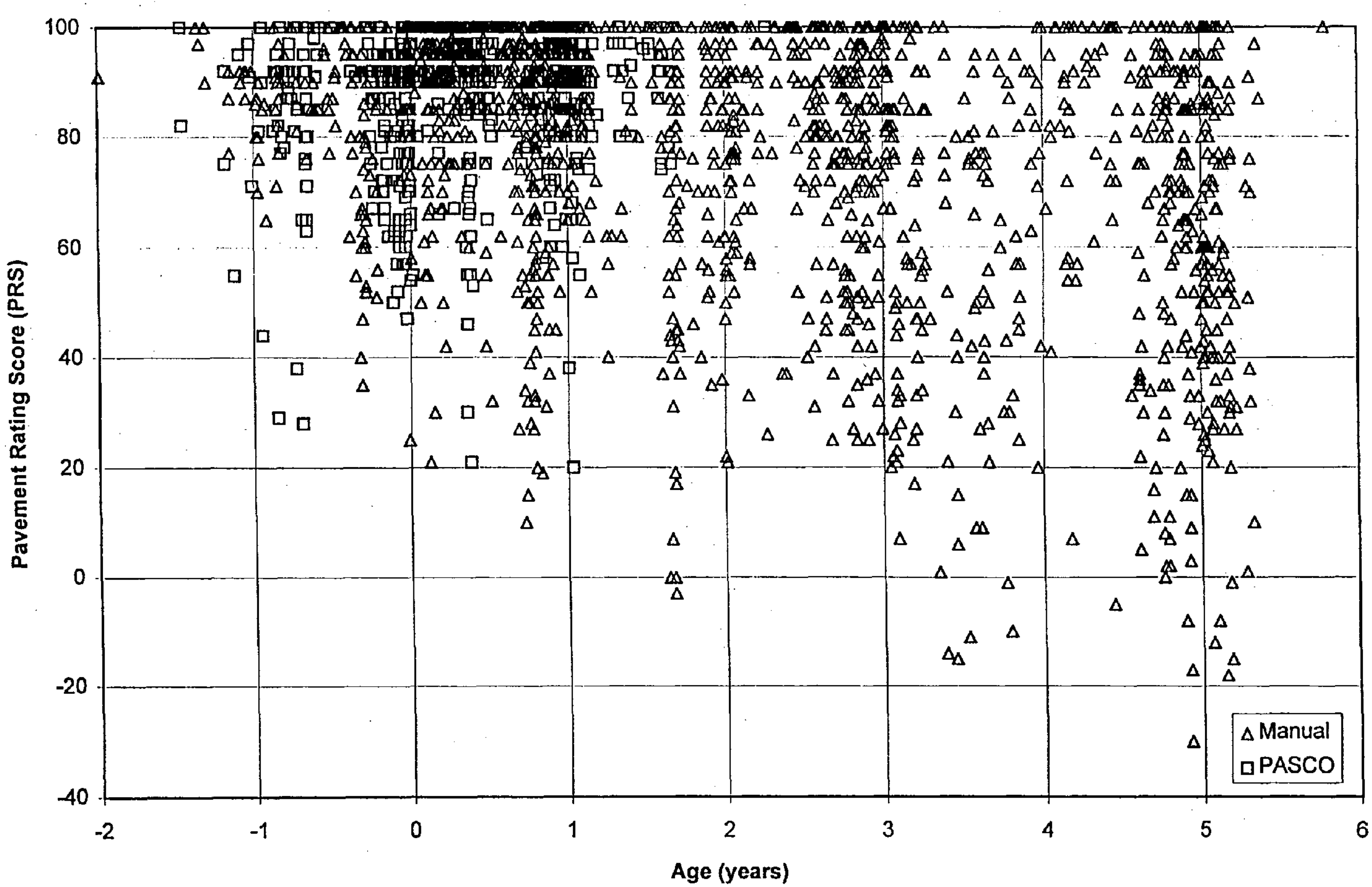

Figure 24. PRS vs. age showing distribution and range of all data.

APPENDIX K
RUTTING DATA

Appendix K provides a tabular compilation of rutting data, formatted as shown in table 27. This data table is available in its entirety in spreadsheet format on the CD-ROM. Figure 25 shows the distribution of all rutting data in the table.

Table 27. Sample rutting data from spreadsheet table, as available on CD-ROM.

STATE_CODE	SHRP_ID	LTPP Region	Environmental Zone	Super Pave Zone	Test Date	Const Date	Age (years)	Average Rutting (mm)	Initial Condition
1	A310	S	WNF	I-C	6/8/90	1/7/90	0.416	12.5	G
1	A310	S	WNF	I-C	4/2/92	1/7/90	2.236	3.5	G
1	A310	S	WNF	I-C	3/22/94	1/7/90	4.205	4.9	G
1	A320	S	WNF	I-C	6/8/90	8/7/90	-0.164	10.1	G
1	A320	S	WNF	I-C	4/2/92	8/7/90	1.655	10.4	G
1	A320	S	WNF	I-C	3/22/94	8/7/90	3.625	13.5	G
1	A330	S	WNF	I-C	6/8/90	8/7/90	-0.164	11.2	G
1	A330	S	WNF	I-C	4/2/92	8/7/90	1.655	8.5	G
1	A330	S	WNF	I-C	3/22/94	8/7/90	3.625	8.4	G
1	A340	S	WNF	I-C	6/8/90	9/1/90	-0.233	11.2	G
1	A340	S	WNF	I-C	4/2/92	9/1/90	1.586	7.8	G
1	A340	S	WNF	I-C	3/22/94	9/1/90	3.556	9.2	G
1	A350	S	WNF	I-C	6/8/90	8/7/90	-0.164	16.9	G
1	A350	S	WNF	I-C	4/2/92	8/7/90	1.655	11.5	G
1	A350	S	WNF	I-C	3/22/94	8/7/90	3.625	12.5	G
1	B310	S	WNF	I-C	4/16/90	11/1/90	-0.545	15.4	G
1	B310	S	WNF	I-C	4/16/90	11/1/90	-0.545	15.4	G
1	B310	S	WNF	I-C	3/31/92	11/1/90	1.414	6.3	G
1	B310	S	WNF	I-C	3/22/94	11/1/90	3.389	8.3	G
1	B320	S	WNF	I-C	4/16/90	8/21/90	-0.348	12.9	G
1	B320	S	WNF	I-C	4/16/90	8/21/90	-0.348	12.9	G
1	B320	S	WNF	I-C	3/31/92	8/21/90	1.611	12.4	G
1	B320	S	WNF	I-C	3/22/94	8/21/90	3.586	15.9	G
1	B330	S	WNF	I-C	4/16/90	8/21/90	-0.348	13.6	G
1	B330	S	WNF	I-C	4/16/90	8/21/90	-0.348	13.6	G
1	B330	S	WNF	I-C	3/31/92	8/21/90	1.611	14.9	G
1	B330	S	WNF	I-C	3/22/94	8/21/90	3.586	16.6	G
1	B340	S	WNF	I-C	4/16/90	9/1/90	-0.378	12.5	G
1	B340	S	WNF	I-C	4/16/90	9/1/90	-0.378	12.5	G
1	B340	S	WNF	I-C	3/31/92	9/1/90	1.581	14.1	G
1	B340	S	WNF	I-C	3/22/94	9/1/90	3.556	15	G
1	B350	S	WNF	I-C	4/16/90	8/21/90	-0.348	15.6	G
1	B350	S	WNF	I-C	4/16/90	8/21/90	-0.348	15.6	G
1	B350	S	WNF	I-C	3/22/94	8/21/90	3.586	17.5	G
1	C310	S	WNF	I-C	6/10/90	7/1/90	-0.058	6.6	G
1	C310	S	WNF	I-C	4/1/92	7/1/90	1.753	2.1	G
1	C310	S	WNF	I-C	3/17/94	7/1/90	3.712	4.7	G
1	C320	S	WNF	I-C	6/10/90	8/9/90	-0.164	7.5	G
1	C320	S	WNF	I-C	4/1/92	8/9/90	1.647	4.5	G
1	C320	S	WNF	I-C	3/17/94	8/9/90	3.605	6.5	G
1	C330	S	WNF	I-C	6/10/90	8/9/90	-0.164	9.1	G

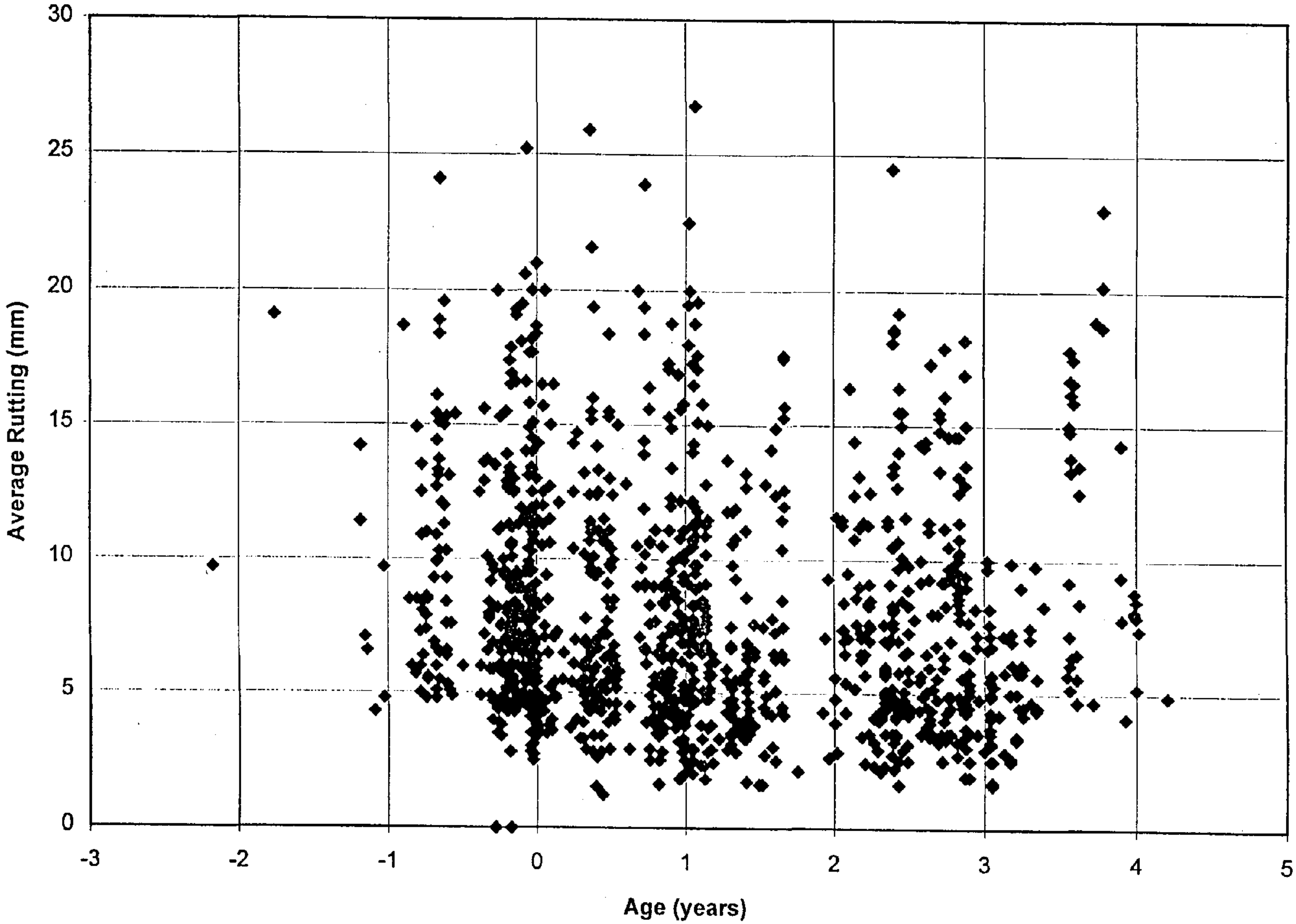

Figure 25. Rutting vs. age showing distribution and range of all data.

APPENDIX L
LONGITUDINAL PROFILE DATA

The SPS-3 longitudinal profile data are contained in a spreadsheet table on the CD-ROM. The contents of the table are demonstrated in table 28. Figure 26 shows the distribution of all IRI data in the table.

Table 28. Sample profile data from spreadsheet table, as available on CD-ROM.

STATE_CODE	SHRP_ID	LTPP Region	Environmental Zone	Superpave Zone	Test Date	Const Date	Age (years)	IRI (mm/m)	Initial Condition
1	A310	S	WNF	I-C	6/7/90	1/7/90	0.414	64.19	G
1	A310	S	WNF	I-C	12/11/90	1/7/90	0.926	84.97	G
1	A310	S	WNF	I-C	8/26/92	1/7/90	2.636	78.83	G
1	A310	S	WNF	I-C	8/24/94	1/7/90	4.630	88.92	G
1	A320	S	WNF	I-C	6/7/90	8/7/90	-0.167	57.93	G
1	A320	S	WNF	I-C	12/11/90	8/7/90	0.345	70.66	G
1	A320	S	WNF	I-C	8/26/92	8/7/90	2.055	66.67	G
1	A320	S	WNF	I-C	8/24/94	8/7/90	4.049	80.99	G
1	A330	S	WNF	I-C	6/7/90	8/7/90	-0.167	61.18	G
1	A330	S	WNF	I-C	12/11/90	8/7/90	0.345	69.14	G
1	A330	S	WNF	I-C	7/29/92	8/7/90	1.978	66.03	G
1	A330	S	WNF	I-C	8/24/94	8/7/90	4.049	69.63	G
1	A340	S	WNF	I-C	6/7/90	9/1/90	-0.236	64.62	G
1	A340	S	WNF	I-C	12/11/90	9/1/90	0.277	70.19	G
1	A340	S	WNF	I-C	7/29/92	9/1/90	1.910	66.38	G
1	A340	S	WNF	I-C	8/24/94	9/1/90	3.981	74.95	G
1	A350	S	WNF	I-C	6/7/90	8/7/90	-0.167	81.40	G
1	A350	S	WNF	I-C	12/11/90	8/7/90	0.345	86.99	G
1	A350	S	WNF	I-C	7/29/92	8/7/90	1.978	84.65	G
1	A350	S	WNF	I-C	8/23/94	8/7/90	4.047	84.05	G
1	B310	S	WNF	I-C	6/5/90	11/1/90	-0.408	52.78	G
1	B310	S	WNF	I-C	7/11/91	11/1/90	0.690	113.92	G
1	B310	S	WNF	I-C	8/21/92	11/1/90	1.805	105.76	G
1	B310	S	WNF	I-C	8/8/94	11/1/90	3.770	110.01	G
1	B320	S	WNF	I-C	6/5/90	8/21/90	-0.211	67.16	G
1	B320	S	WNF	I-C	7/11/91	8/21/90	0.888	69.35	G
1	B320	S	WNF	I-C	8/21/92	8/21/90	2.003	67.58	G
1	B320	S	WNF	I-C	8/8/94	8/21/90	3.967	74.33	G
1	B330	S	WNF	I-C	6/5/90	8/21/90	-0.211	102.73	G
1	B330	S	WNF	I-C	7/11/91	8/21/90	0.888	110.60	G
1	B330	S	WNF	I-C	8/21/92	8/21/90	2.003	107.40	G
1	B330	S	WNF	I-C	8/8/94	8/21/90	3.967	112.09	G
1	B340	S	WNF	I-C	6/5/90	9/1/90	-0.241	60.29	G
1	B340	S	WNF	I-C	7/11/91	9/1/90	0.858	65.82	G
1	B340	S	WNF	I-C	8/21/92	9/1/90	1.973	66.36	G
1	B340	S	WNF	I-C	8/8/94	9/1/90	3.937	67.48	G
1	B350	S	WNF	I-C	6/5/90	8/21/90	-0.211	101.07	G
1	B350	S	WNF	I-C	7/11/91	8/21/90	0.888	102.67	G
1	B350	S	WNF	I-C	8/21/92	8/21/90	2.003	100.35	G
1	B350	S	WNF	I-C	8/8/94	8/21/90	3.967	102.07	G
1	C310	S	WNF	I-C	6/8/90	7/1/90	-0.063	64.72	G
1	C310	S	WNF	I-C	8/25/92	7/1/90	2.153	58.05	G

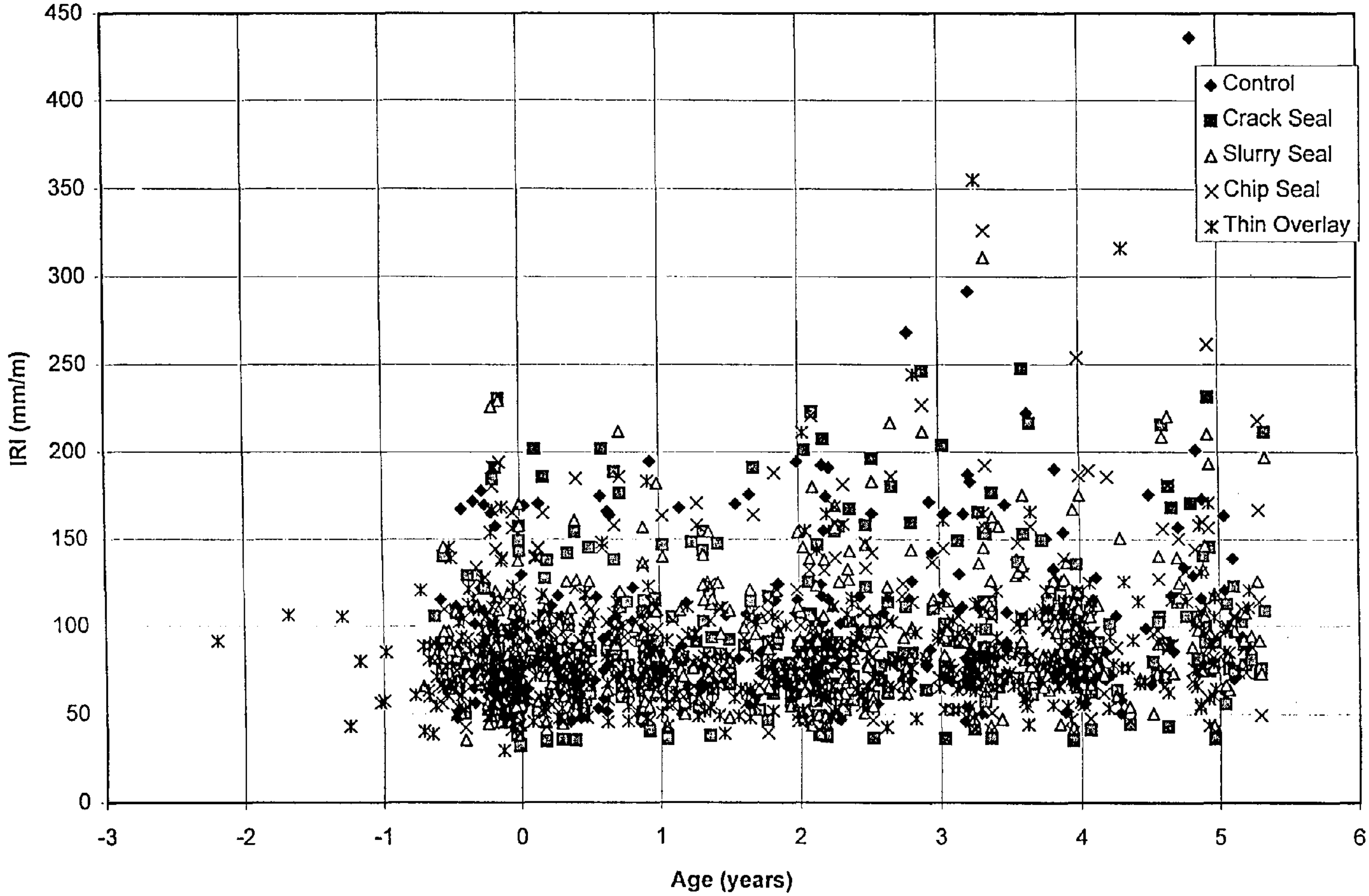

Figure 26. IRI vs. Age showing distribution and range of all data.

APPENDIX M
FRICTION DATA

Appendix M provides a tabular compilation of friction data, formatted as shown in table 29. This data is available in its entirety in spreadsheet format on the CD-ROM. Figure 27 shows the distribution of all friction data in the table.

Table 29. Sample friction data from spreadsheet table as available on CD-ROM.

STATE_CODE	SHRP_ID	LTPP Region	Environmental Zone	Superpave Zone	Test Date	Const Date	Age (years)	Friction Number	Initial Condition
1	A310	S	WNF	I-C	6/5/90	1/7/90	0.408	48	G
1	A310	S	WNF	I-C	6/15/90	1/7/90	0.436	46.5	G
1	A310	S	WNF	I-C	6/15/92	1/7/90	2.438	48	G
1	A310	S	WNF	I-C	7/22/94	1/7/90	4.540	40.5	G
1	A320	S	WNF	I-C	6/5/90	8/7/90	-0.173	48.5	G
1	A320	S	WNF	I-C	6/15/90	8/7/90	-0.145	45.5	G
1	A320	S	WNF	I-C	6/15/92	8/7/90	1.858	48.5	G
1	A320	S	WNF	I-C	7/22/94	8/7/90	3.959	44	G
1	A330	S	WNF	I-C	6/5/90	8/7/90	-0.173	51	G
1	A330	S	WNF	I-C	6/15/90	8/7/90	-0.145	46.5	G
1	A330	S	WNF	I-C	6/15/92	8/7/90	1.858	51	G
1	A330	S	WNF	I-C	7/22/94	8/7/90	3.959	44	G
1	A340	S	WNF	I-C	6/5/90	9/1/90	-0.241	53.5	G
1	A340	S	WNF	I-C	6/15/90	9/1/90	-0.214	47.5	G
1	A340	S	WNF	I-C	6/15/92	9/1/90	1.789	53.5	G
1	A340	S	WNF	I-C	7/22/94	9/1/90	3.890	43	G
1	A350	S	WNF	I-C	6/5/90	8/7/90	-0.173	33	G
1	A350	S	WNF	I-C	6/15/90	8/7/90	-0.145	45	G
1	A350	S	WNF	I-C	6/15/92	8/7/90	1.858	33	G
1	A350	S	WNF	I-C	7/22/94	8/7/90	3.959	25	G
1	B310	S	WNF	I-C	6/14/90	11/1/90	-0.384	50	G
1	B310	S	WNF	I-C	7/1/92	11/1/90	1.666	46	G
1	B310	S	WNF	I-C	7/20/94	11/1/90	3.718	47.5	G
1	B320	S	WNF	I-C	6/14/90	8/21/90	-0.186	49.5	G
1	B320	S	WNF	I-C	7/1/92	8/21/90	1.863	44.5	G
1	B320	S	WNF	I-C	7/20/94	8/21/90	3.915	45	G
1	B330	S	WNF	I-C	6/14/90	8/21/90	-0.186	49.5	G
1	B330	S	WNF	I-C	7/1/92	8/21/90	1.863	50	G
1	B330	S	WNF	I-C	7/20/94	8/21/90	3.915	45.5	G
1	B340	S	WNF	I-C	6/14/90	9/1/90	-0.216	47	G
1	B340	S	WNF	I-C	7/1/92	9/1/90	1.833	50.5	G
1	B340	S	WNF	I-C	7/20/94	9/1/90	3.885	45.5	G
1	B350	S	WNF	I-C	6/14/90	8/21/90	-0.186	49.5	G
1	B350	S	WNF	I-C	7/1/92	8/21/90	1.863	35.5	G
1	B350	S	WNF	I-C	7/20/94	8/21/90	3.915	30	G
1	C310	S	WNF	I-C	6/15/90	7/1/90	-0.044	40.5	G
1	C310	S	WNF	I-C	7/15/92	7/1/90	2.041	42	G
1	C310	S	WNF	I-C	7/14/94	7/1/90	4.038	42.5	G
1	C320	S	WNF	I-C	6/15/90	8/9/90	-0.151	42.5	G
1	C320	S	WNF	I-C	7/15/92	8/9/90	1.934	41	G
1	C320	S	WNF	I-C	7/14/94	8/9/90	3.932	43.5	G
1	C330	S	WNF	I-C	6/15/90	8/9/90	-0.151	38	G

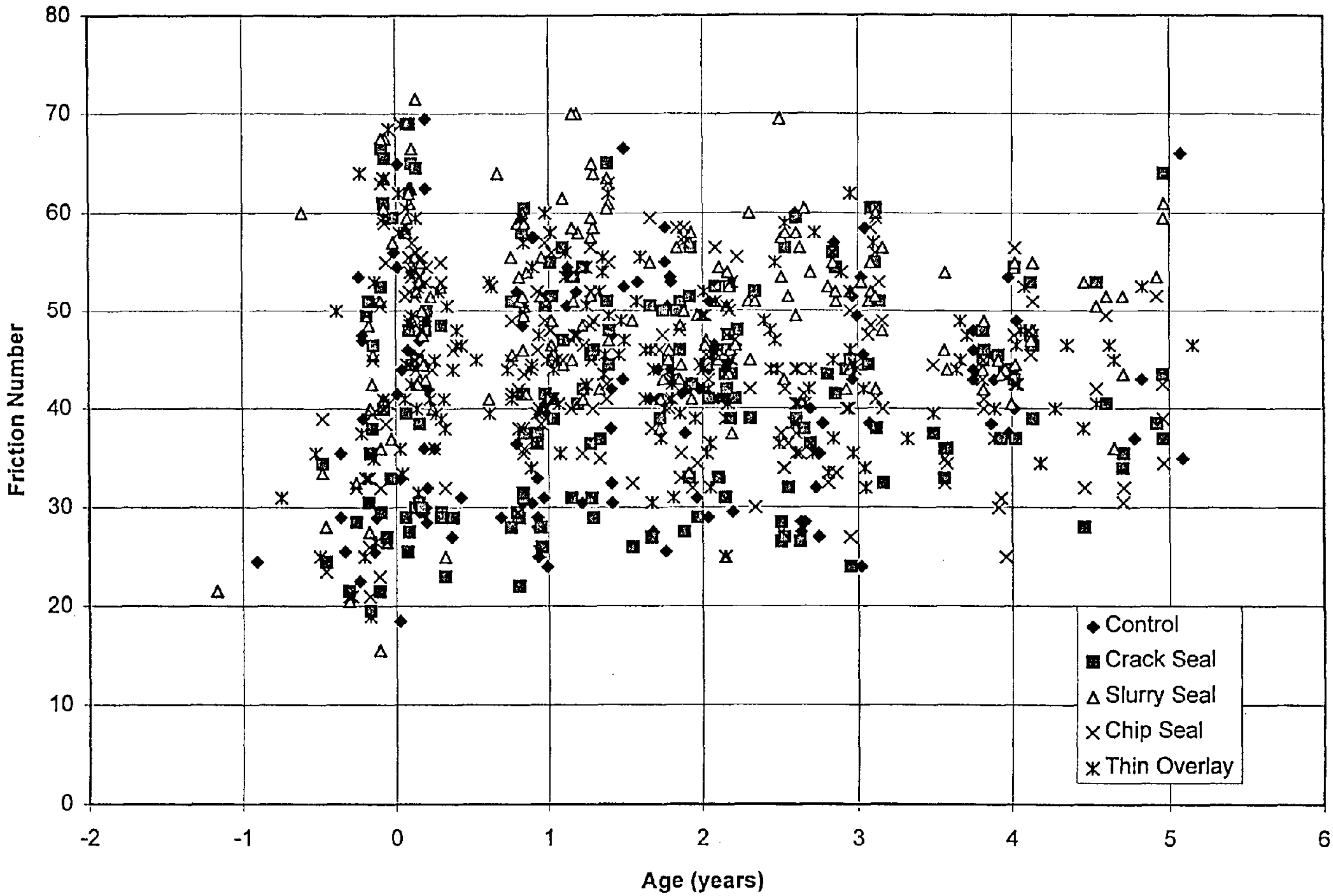

Figure 27. Friction number vs. Age showing distribution and range of all data.

APPENDIX N
TRAFFIC DATA

Available traffic data was compiled from the LTPP traffic database and other sources in the LTPP regional offices, as necessary to obtain the best possible set of data. The final list of ADT data used in the analysis is provided in table 30, and on the CD-ROM.

Table 30. ADT final list.

State	SHRP #	Type	GPS	AADT
1	B	300	1019	782
1	A	300	4125	1983
1	C	300	4155	1342
4	D	300	1016	3900
4	C	300	1017	4100
4	B	300	1021	4400
4	A	300	1036	2500
5	A	300	3071	2750
6	A	300	1253	3000
8	A	300	1053	3130
8	B	300	2008	1850
12	B	300	3997	1590
12	C	300	4154	620
12	A	300	9054	930
16		300		
16		300		
16		300		
17	A	300	1002	
17	B	300	1003	
18	A	300	1028	1030
19	A	300	6150	81
20	A	300	1005	
20	B	300	1010	
21	A	300	1010	
21	B	300	1034	
24		300	1634	
26	C	300	1001	245
26	D	300	1010	
26	B	300	1012	
26	A	300	1013	
27	A	300	1016	
27	D	300	1019	
27	C	300	1028	570
27	E	300	6251	980
28	A	300	1802	285
29	B	300	1002	390
29	C	300	5000	
29	D	300	5503	
30	A	300	1001	940
31	A	300	1030	170
32	A	300	1021	6300
32	C	300	2027	1740
32	B	300	7000	1750
36	A	300	1643	1400
36	B	300	1644	820

State	SHRP #	Type	GPS	AADT
40	B	300	1015	2805
40	A	300	4087	2464
40	C	300	4088	2780
42	B	300	1597	1450
42	A	300	1605	3232
47	C	300	1023	11320
47	B	300	3075	1460
47	A	300	3101	1280
48	H	300	1050	2900
48	B	300	1069	6200
48	A	300	1094	2300
48	J	300	1122	4300
48	G	300	1169	1300
48	E	300	1183	2100
48	D	300	2172	2200
48	I	300	3559	2800
48	F	300	3579	2200
48	N	300	3739	700
48	M	300	3749	600
48	L	300	3769	3900
48	Q	300	3865	1800
48	K	300	9005	900
49	A	300	1004	600
49	C	300	1006	1580
49	B	300	1017	650
53	A	300	1008	3400
53	B	300	1501	500
53	C	300	1801	1500
83	A	300	1801	425
87	A	300	1620	3300
87	B	300	1622	4900
89	A	300	1021	4760
56	A	300	1007	580
56	B	300	7775	190
90		300	1802	
90		300	6405	

APPENDIX O
PAVEMENT STRUCTURE

This appendix includes the information used to assess the potential effect of site-related pavement structural adequacy on treatment performance. Structural adequacy is expressed as being greater than, or less than, one. It is a ratio of the actual pavement structure to the required structure, computed in accordance with procedures contained in the AASHTO Guide for the Design of Pavement Structures. The computed structural adequacies are presented by climatic zone in tables 31 through 34.

The tables in this appendix are also on the CD-ROM.

Table 31. Structural number ratio (< 1 or > 1) for the dry-no freeze zone.

Structural Number Ratio <1		
Section	**Pavement Initial (Pretreatment) Condition***	**Traffic Level****
48D	G	M
48J	G	H
48K	G	L
48M	G	L
48N	G	L
48Q	G	M
Structural Number Ratio >1		
4A	P	M
4B	F	H
4C	F	H
4D	G	H
6A	G	H
48A	G	M
48L	G	H

* Pavement condition level - Good (G), Fair (F), Poor (P)
** Traffic Levels - High (H), Medium (M), Low (L)

Table 32. Structural number ratio (<1 or >1) for wet-freeze zone.

Structural Number Ratio <1		
Section	**Pavement Initial (Pretreatment) Condition***	**Traffic Level****
17A	G	M
17B	G	L
18A	G	M
19A	F	L
21B	G	L
26D	P	L
27A	G	M
29A	F	L
29B	G	L
36A	G	M
36B	F	L
87A	P	H
87B	P	H
Structural Number Ratio >1		
21A	G	L
24A	G	H
26A	F	M
26B	G	M
26C	G	L
27B	F	L
27C	F	L
27D	P	M
42A	G	H
51A	F	H
89A	G	H

* Pavement condition level - Good (G), Fair (F), Poor (P)

** Traffic Levels - High (H), Medium (M), Low (L)

Table 33. Structural number ratio (< 1 or > 1) for wet-no freeze zone.

Structural Number Ratio < 1		
Section	**Pavement Initial (Pretreatment) Condition***	**Traffic Level****
1A	G	M
1C	G	M
12B	F	M
12C	F	L
28A	P	L
40A	G	M
40B	F	M
40C	P	M
47A	G	M
47C	G	H
48B	F	H
48F	G	M
48H	G	M
48I	G	M
Structural Number Ratio > 1		
1B	G	L
5A	G	M
12A	G	L
47B	G	M
48E	F	M
48G	G	M
53C	F	M

* Pavement condition level - Good (G), Fair (F), Poor (P)

** Traffic Levels - High (H), Medium (M), Low (L)

Table 34. Structural number ratio (<1 or >1) for dry-freeze zone.

Structural Number Ratio <1		
Section	Pavement Initial (Pretreatment) Condition*	Traffic Level**
8B	P	M
20B	F	M
31A	G	L
32A	F	H
32C	G	M
49A	F	L
49C	G	M
56B	G	L
90A	F	Unidentified
90B	G	L
Structural Number Ratio >1		
8A	G	H
16A	G	M
16B	G	H
16C	G	M
20A	P	M
30A	G	L
32B	G	M
49B	G	L
53A	P	H
53B	F	L
56A	G	L
83A	G	L

* Pavement condition level - Good (G), Fair (F), Poor (P)
** Traffic Levels - High (H), Medium (M), Low (L)

APPENDIX P
DEFLECTION DATA

Deflection monitoring data has been collected at the SPS-3 sites throughout all the LTPP regions once every other year, on the average. Large volumes of deflection data are resident in the LTPP data base, since three repetitions are made of a seating drop and four different drop heights at 30.5 m intervals through each test section. This data is provided in the spreadsheet table or the CD-ROM.

For analysis purposes, all this data was normalized to 4,082 kg and reduced to average values at each test section. Deflection data in this form is provided in the SPS-3 data base.

APPENDIX Q
ANALYSIS OF ASPHALT BINDER PROPERTIES
(STAND-ALONE REPORT)

A full report of the materials test results has been developed by Dr. Jon Epps. This report is available as a separate stand-alone report.

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