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Structural Overlay Strategies for Jointed Concrete Pavements

Volume I, Sawing and Sealing of Joints in AC Overlays of Concrete Pavements

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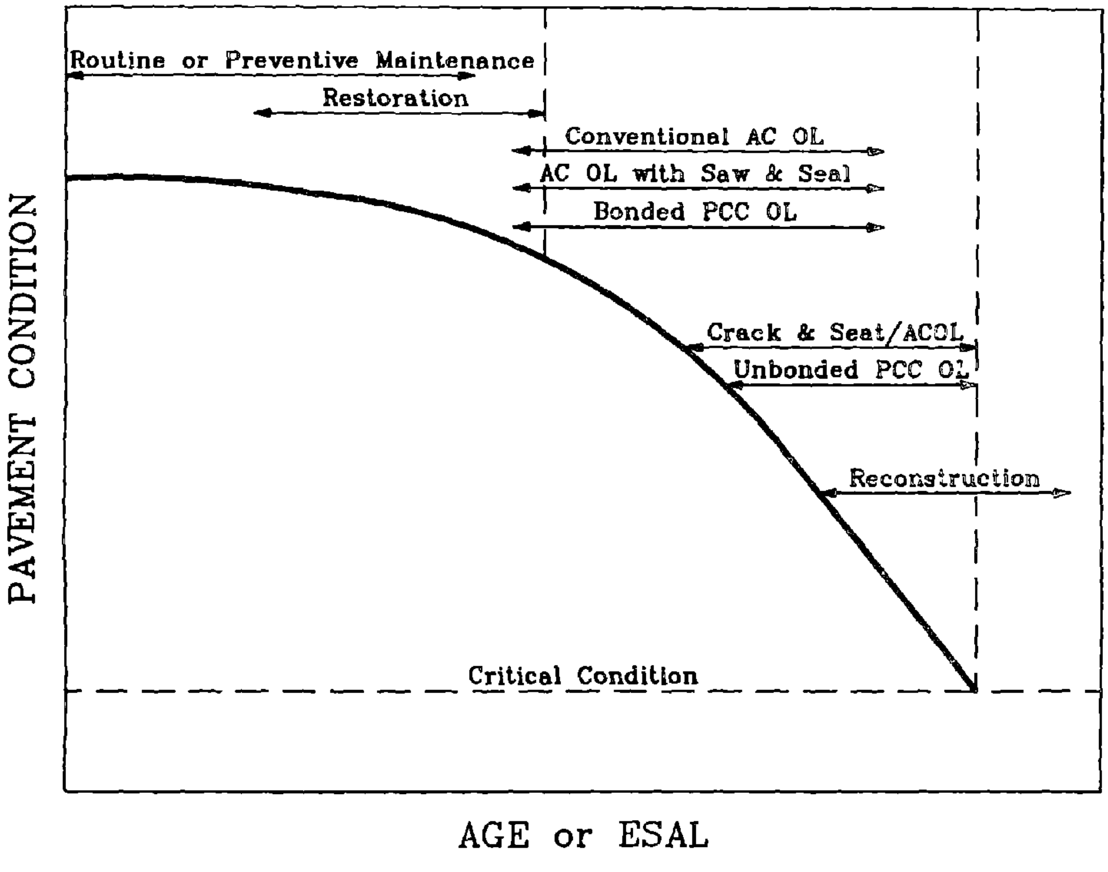

U.S. Department of Transportation
Federal Highway Administration

Research, Development, and Technology
Turner-Fairbank Highway Research Center
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FOREWORD

This report is one volume of a four volume set of interim reports documenting a major field study and evaluation of the effectiveness of three structural overlay types for jointed portland cement concrete pavements and guidelines for their use. The three overlay types are sawing and sealing joints in asphalt concrete (AC) overlays of PCC pavements, cracking and seating PCC pavements prior to AC overlay and constructing a thin bonded PCC overlay on top of the existing PCC pavement. Condition survey, deflection testing and roughness measurements were performed on a total of 60 sections. It should be noted that the small sample of projects and the unknown condition of the pavement prior to overlay limit the conclusions that can be drawn from the study. Volume V (Summary of Research Findings) and the technical summary will be given widespread distribution in the near future. These reports will be of interest to those involved in design, construction and rehabilitation of jointed concrete pavements.

Sufficient copies of this report are being distributed by FHWA memorandum to provide one copy to each FHWA Region and Division and two copies to each State highway agency. Direct distribution is being made to the division offices. Additional copies for the public are available from the National Technical Information Service (NTIS), U.S. Department of Commerce, 5285 Port Royal Road, Springfield, Virginia 22161. A small charge will be imposed for each copy ordered from NTIS.

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Director, Office of Engineering and
Highway Operations Research and Development

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16. Abstract

A major field study and evaluation has been conducted into the effectiveness of three structural overlay types for portland cement concrete (PCC) pavements. These include sawing and sealing asphalt concrete (AC) overlays of PCC pavements, cracking and seating PCC pavements prior to AC overlay, and constructing a thin bonded PCC overlay on top of the existing PCC pavement. Condition surveys, deflection testing, and roughness measurements were performed on a total of 55 sections. The performance of these sections was evaluated and the effectiveness of each overlay type analyzed. Based on the field data, guidelines were developed for the use of structural overlays. In addition, the results of this study were used to revise and enhance the EXPEAR rehabilitation advisory system.

This volume examines the effectiveness of the sawing and sealing of AC overlays of PCC pavements. Sawing and sealing is an attempt to control, not prevent, the occurrence and severity of reflective cracks from the underlying PCC slabs. Joints are sawed in the AC overlay directly above joints in the existing slab and then immediately sealed. The first part of this report examines the literature and evaluates the performance of in-service saw and seal overlays. Part II develops many of the recommendations from the research effort into guidelines for techniques and specifications for sawing and sealing operations.

This volume is first in a series. The other volumes are:

FHWA No.	Vol. No.	Short Title
FHWA-RD-89-143	II	Cracking and Seating of Concrete Slabs Prior to AC Overlay
FHWA-RD-89-144	III	Performance Evaluation and Analysis of Thin Bonded Concrete Overlays
FHWA-RD-89-145	IV	Guidelines for the Selection of Rehabilitation Alternatives
FHWA-RD-89-146	V	Summary of Research Findings
FHWA-RD-89-147	VI	Appendix A - Users Manual for the EXPEAR Computer Program

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

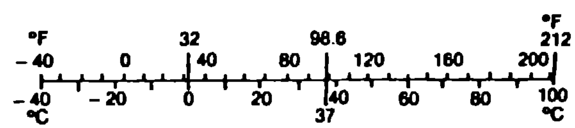
Symbol	When You Know	Multiply By	To Find	Symbol
	LENGTH			
in	inches	25.4	millimetres	mm
ft	feet	0.305	metres	m
yd	yards	0.914	metres	m
mi	miles	1.61	kilometres	km
	AREA			
in^2	square inches	645.2	millimetres squared	mm^2
ft^2	square feet	0.093	metres squared	m^2
yd^2	square yards	0.836	metres squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometres squared	km^2
	VOLUME			
fl oz	fluid ounces	29.57	millilitres	mL
gal	gallons	3.785	litres	L
ft^3	cubic feet	0.028	metres cubed	m^3
yd^3	cubic yards	0.765	metres cubed	m^3

NOTE: Volumes greater than 1000 L shall be shown in m^3.

Symbol	When You Know	Multiply By	To Find	Symbol
	MASS			
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5(F-32)/9	Celcius temperature	°C

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
	LENGTH			
mm	millimetres	0.039	inches	in
m	metres	3.28	feet	ft
m	metres	1.09	yards	yd
km	kilometres	0.621	miles	mi
	AREA			
mm^2	millimetres squared	0.0016	square inches	in^2
m^2	metres squared	10.764	square feet	ft^2
ha	hectares	2.47	acres	ac
km^2	kilometres squared	0.386	square miles	mi^2
	VOLUME			
mL	millilitres	0.034	fluid ounces	fl oz
L	litres	0.264	gallons	gal
m^3	metres cubed	35.315	cubic feet	ft^3
m^3	metres cubed	1.308	cubic yards	yd^3
	MASS			
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
	TEMPERATURE (exact)			
°C	Celcius temperature	1.8C + 32	Fahrenheit temperature	°F



* SI is the symbol for the International System of Measurement

(Revised April 1989)

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PART I

1. INTRODUCTION AND RESEARCH APPROACH

BACKGROUND

The highway pavement system in the United States represents one of the nation's most important public works investments. The system, which has nearly 4 million miles of pavement, represents a cost of more than 1 trillion dollars.[1,2] In addition, the system is used for the transportation of approximately 90 percent of the goods consumed in the country.[3] Highways not only serve an economic need, but also provide for social and military transportation requirements.

The Interstate system, arterials, and collection roads account for approximately 25 percent of the highway mileage; however, these same highways carry approximately 85 percent of the traffic.[4] Interstate highways alone carry 21 percent of the nation's traffic on only 1 percent of the highway miles.

Many of the miles of pavement on the Interstate and arterial network are composed of portland cement concrete (PCC). In most cases, these pavements have provided many years of service with relatively low maintenance costs. Today, however, these pavements are approaching the end of their design life, and many have reached their terminal serviceability level. The need to develop more dependable rehabilitation techniques for PCC pavements is becoming increasingly important.

One method used to rehabilitate PCC pavements is to place an asphaltic concrete overlay on the existing pavement. The overlays can help improve the structural capacity by reducing deflections and they can also improve serviceability by reducing the pavement roughness. Although an overlay can improve the pavement performance, it can create some maintenance problems. Generally, maintenance problems result from reflection cracking at the location of joints and cracks in the underlying slab. The reflective cracks can occur within a short time following the overlay.

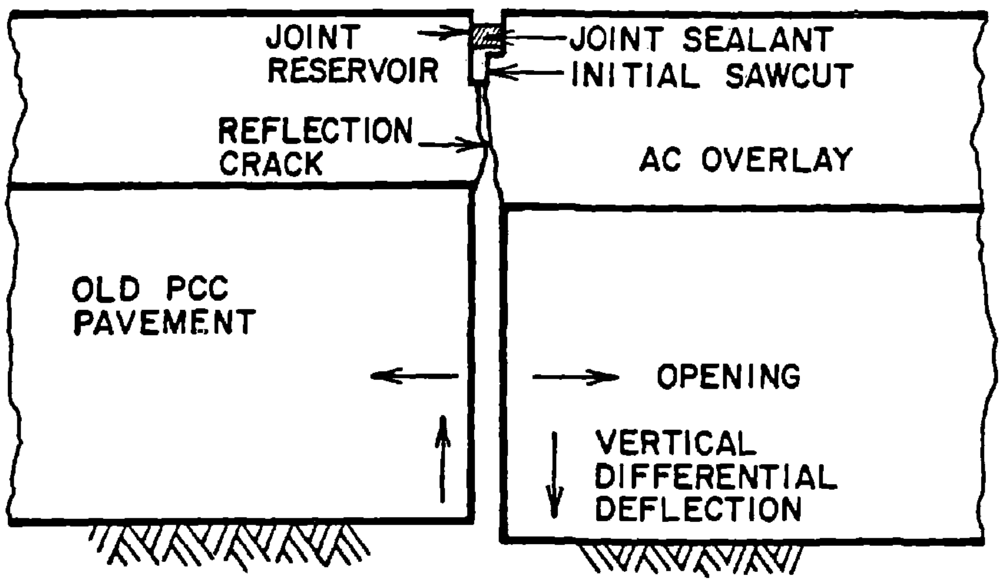
Numerous techniques and treatments have been tried to prevent or minimize the reflection cracking problem. Some of the treatments include the use of fabrics, stress-relieving interlayers, crack-arresting interlayers, and cracking and seating. The results of these treatments vary considerably. It appears, however, that it is almost impossible to stop reflection cracking.

Because this is the case, some agencies have decided to control the problem rather than eliminate it. One method is to saw a joint in the overlay above all existing transverse joints immediately after overlay, as illustrated in the schematic in figure 1. The joints are sealed and subsequently maintained as typical pavement joints. The purpose of this report is to document the effectiveness of the "sawing and sealing" method of reflective crack control.

PROBLEM STATEMENT AND RESEARCH OBJECTIVES

The sawing and sealing of joints, in the asphalt concrete overlay directly above the joints in the underlying PCC slab, is believed to control the occurrence and severity of reflective cracks; thus, it will prolong the life of the overlay. This type of overlay treatment has been constructed for more than 30 years by some State highway agencies. Several States, particularly in the northeastern United States, have developed procedures for the design and construction of the sawing and sealing rehabilitation technique. There has been, however, little or no evaluation or documentation of the field performance of sawing and sealing on either a regional or nationwide basis. It was felt that an in-depth evaluation of sawing and sealing could provide information to determine expected performance life of the technique. This information can assist the highway engineer with the design of PCC pavement rehabilitation projects.

The research discussed in this report was part of a major Federal Highway Administration (FHWA) project titled "Performance/Rehabilitation of Rigid Pavements." The overall objective of the study was summarized as the improvement of initial design procedures and the improvement of overlay design procedures through consideration of existing analytical techniques



NOTE: The sawed joint should be within 1 inch of the underlying PCC joint to prevent secondary cracking.

Figure 1. Schematic illustrating the saw and seal method of reflective crack control.[27]

and field performance observations. The research was divided into two distinct phases. The sawing and sealing research effort was a task under Phase II.

A report titled "Rigid Pavement Structural Overlay Summary Report" was prepared under Phase I.[5] The Summary Report provided the details that were used to develop a work plan for the sawing and sealing project. The research objective for the sawing and sealing, included in the study list of objectives for Phase II, was to:

> Develop improved design and construction procedures for the following overlay techniques: thin bonded PCC overlays, crack and seat and overlay, and sawing and sealing joints in AC overlays over existing PCC joints.

The specific objectives for the sawing and sealing task were to:

1. Evaluate the performance of inservice saw and seal overlay projects.
2. Determine the life extension/cost effectiveness provided by this procedure.
3. Verify existing recommended design and construction procedures.
4. Evaluate the impact of drainage on the performance of saw and seal sections.
5. Develop improved design and construction procedures as appropriate.

SCOPE OF THE STUDY

As mentioned, several States in the Northeast have used sawing and sealing of asphalt overlays for many years. Consequently, there are numerous highway sections that have sawing and sealing treatments. Recognizing that the inclusion of an unlimited number of sawed and sealed overlays was beyond the resources of this project, the scope was limited to the evaluation of fifteen overlays that included a wide range of design variables. Furthermore, the test sections were restricted to overlays of jointed reinforced concrete pavement.

RESEARCH APPROACH

The research objectives were accomplished primarily by evaluating the performance of inservice saw and seal overlay projects in several locations in the United States. In the course of this evaluation, an extensive database was developed that contained information regarding measured field performance, original pavement and rehabilitation design, traffic, and environmental data. The following procedures were used to obtain the above-mentioned data elements:

- Field condition surveys were conducted on each pavement section to determine the performance of the overlay.
- The original pavement design and overlay designs were determined from as-built plans and specifications.
- Historical traffic volumes and classifications were obtained from the State highway agencies for each project.
- Environmental data were taken from documentation of the monthly normals of temperature, precipitation, and heating and cooling degree days from the National Oceanic and Atmospheric Administration.

The data were assembled in a database created by the RBASE program.[6] Engineering analysis of the data was done to determine the performance of the saw and seal projects.

2. THE REFLECTION CRACKING PROBLEM

BACKGROUND

Reflection cracking in an asphalt concrete overlay has always been a perplexing problem for highway engineers. This problem is becoming increasingly important because of the shift from new highway construction to rehabilitation of the existing highway system. The need for more pavement overlays increases the amount of reflection cracking of pavements around the country.

Perhaps the best definition of this type of pavement distress was given by Treybig et al. when they defined it as:

> ...Fractures in an overlay or surface that are a result of, and reflect, the crack or joint pattern in the underlying layer, and may be either environmental or traffic induced.[7]

Treybig et al. goes on to state that:

> ...It is imperative that such cracking be prevented or controlled in order to provide a smooth riding surface, maintain the structural integrity of the overlay, and prevent the intrusion of water into the pavement system.[7]

Attempts to prevent the occurrence of these reflective cracks have been reported in the literature as far back as 1932.[8] Since that time, most of the advancement in the state of the art for reflective crack prevention has come primarily from the experience gained from trial and error experiments on inservice pavements. Only in the last 10 to 15 years have theoretical studies of reflection cracking been conducted. While these studies have not succeeded in developing a method that successfully prevents reflection cracking, they have provided a better understanding of the mechanisms that cause an overlay to fail in this manner. A discussion of these mechanisms is presented in the following section.

FAILURE MECHANISMS

An important step in developing a method to control reflection cracking is to develop an understanding of the mechanisms that cause such failures. Pavement researchers generally agree that the primary mechanisms leading to the development of reflection cracks in an asphalt concrete overlay are the horizontal and differential vertical movements at joints and cracks in the existing pavement with horizontal movements being considered more critical.[7,9-12] Smith et al. stated that these damaging horizontal movements are caused by three factors: traffic loadings, seasonal temperature changes, and daily temperature cycles.[11]

Traffic loadings are responsible for differential vertical movements that occur at underlying joints with poor load transfer and at working cracks. Jayawickrama et al. have stated that three stress pulses occur as a moving wheel load travels across an underlying joint or crack as illustrated in figure 2.[13,14] According to Jayawickrama et al.:[13]

> As the wheel load approaches the crack, the shear stress in the overlay above the crack will reach a maximum illustrated as point A.... When the wheel is directly above the crack, the maximum bending stress will occur as illustrated by point B.... As the wheel load crosses the crack, a second maximum shear stress in the reverse direction will occur as illustrated by point C....

These stress pulses induce cracking in two distinct modes: opening (Mode I) and shearing (Mode II). These two stress modes are illustrated in figure 3.

Seasonal temperature changes and daily temperature cycles cause expansion, contraction, and curling in the existing slabs and overlay. The actual amount of movement is controlled by the temperature change, thermal coefficient of expansion of the pavement materials, the joint or crack spacing, and the amount of friction between the slab and base layer and also between the overlay and the PCC slab.[14]

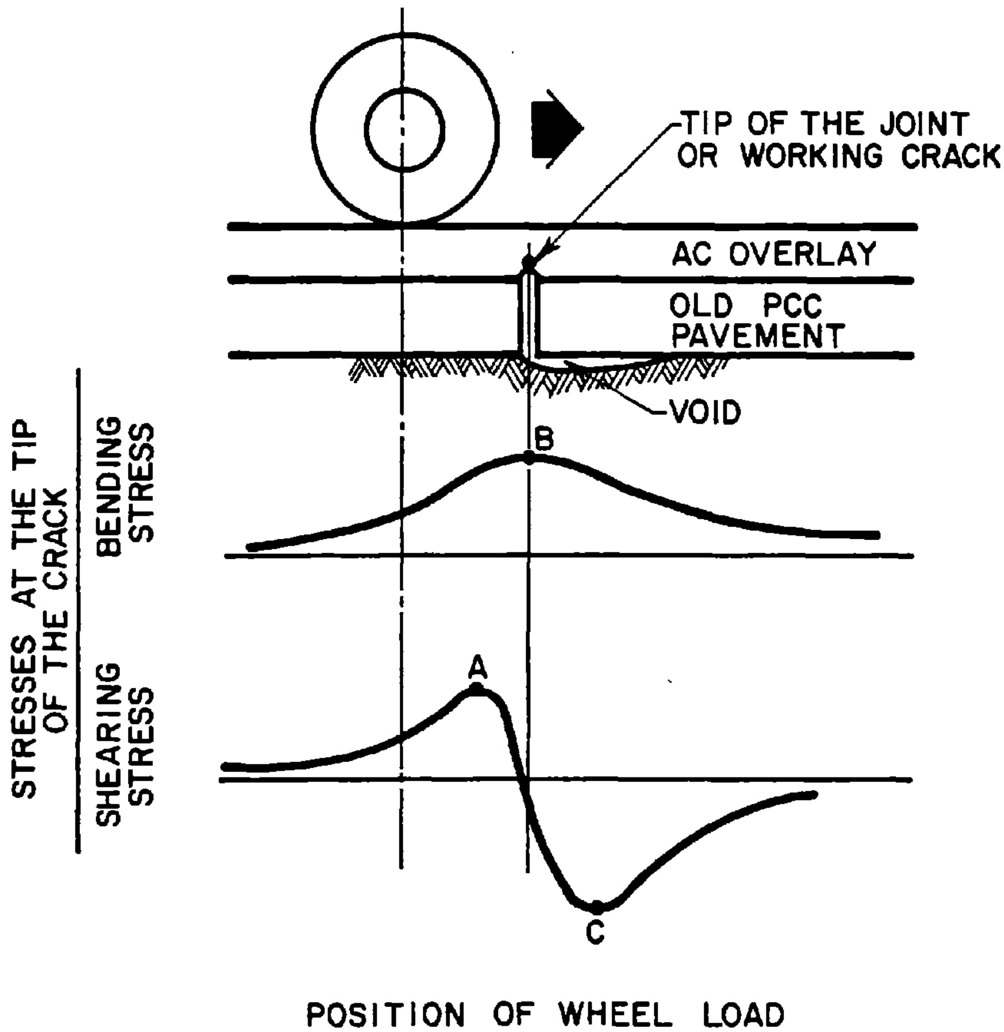


Figure 2. Shearing and bending stresses in an asphalt concrete overlay resulting from a moving traffic load.[13]

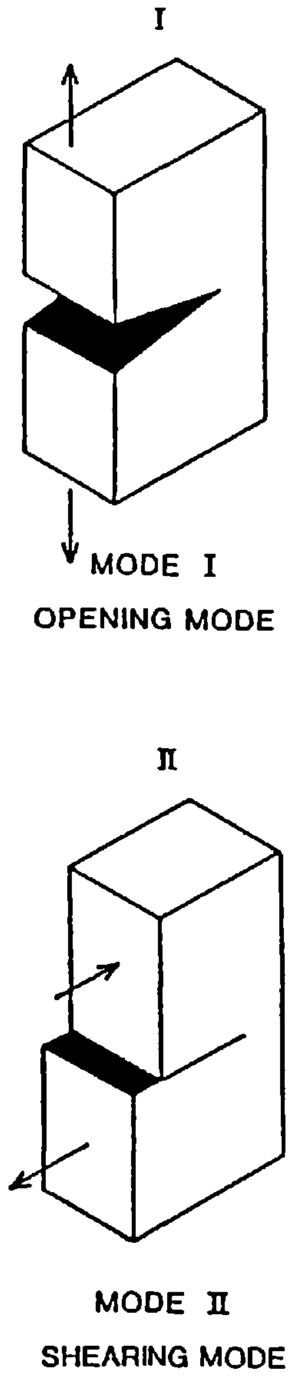


Figure 3. Two distinct modes of crack propagation in an asphalt concrete overlay.[13]

The seasonal lowering of temperatures causes the existing PCC pavement to contract, which results in horizontal movements at the joints and cracks. As a result of this movement, the overlay is subjected to tensile stress concentrations in the opening mode as shown in figure 4. In addition, the overlay itself reacts to the lower temperatures, resulting in a further tensile stress as shown in figure 5.

Daily temperature cycles also cause a tensile stress in the overlay. When a PCC pavement is subjected to a temperature gradient through its depth, it will tend to warp or curl. If the top of the slab is warmer than the bottom, the curling will be concave downward. If, however, the top of the slab is cooler than the bottom, the corners and joints of the slab will tend to curl upward as shown in figure 6. This upward curling produces an opening at the joints, causing an increase in the tensile stress in the overlay.

REVIEW OF SAW AND SEAL DESIGN PROCEDURES

The concept of sawing and sealing joints in an asphalt concrete overlay as a method of controlling the location and severity of reflective cracks seems to have first been recommended in 1954 by Bone et al.[15] As a potential solution to the reflection cracking problem, they suggested to:

> Accept the cracks and develop adequate means for maintaining them. To avoid the difficulty of filling narrow and crooked cracks, it has been suggested that grooves be sawed in the resurfacing over joints in the concrete and that these sawcuts be filled with elastic material.

However, this suggestion apparently was not followed with any experimental work until several years had passed. Since this early reference to the sawing and sealing technique, most of the literature pertaining to this technique has been limited to performance reviews of full-scale experiments on inservice pavements. In this section, the experiences of the States that have reported such results are reviewed.

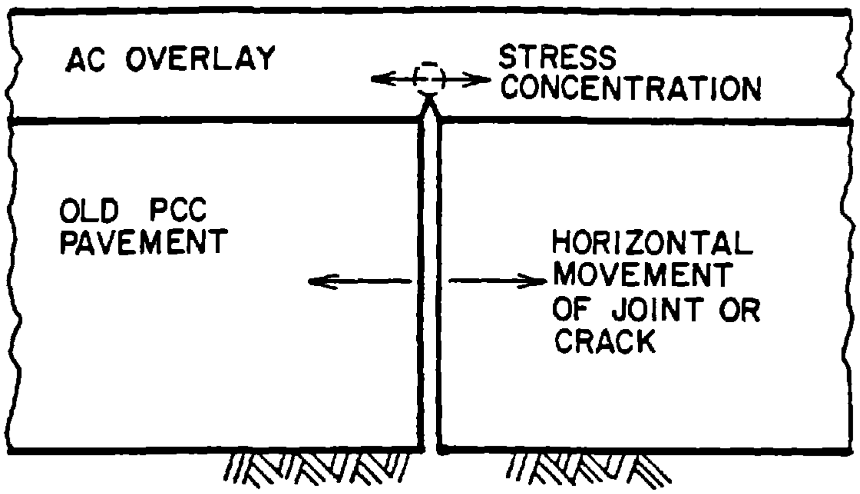


Figure 4. Stress concentrations in an AC overlay resulting from thermally induced movements of the PCC slab.[26]

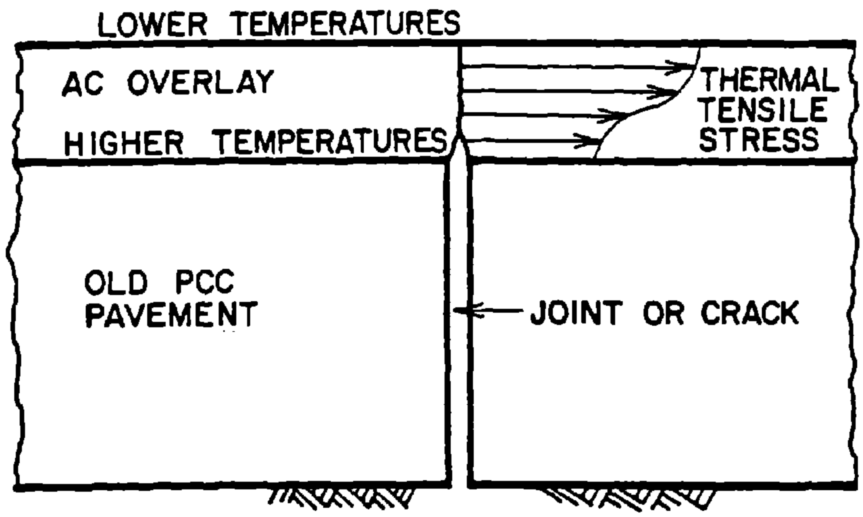


Figure 5. Thermal tensile stress in an AC overlay producing a crack above the joint or crack.[26]

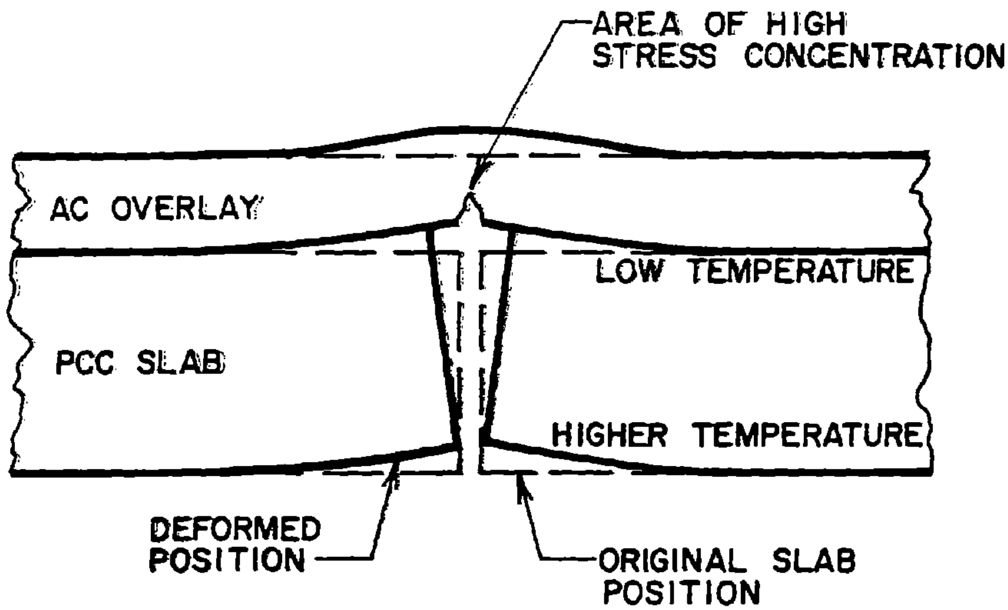


Figure 6. Stress concentrations in an AC overlay resulting from thermal curling of the pavement slab.

Massachusetts

The earliest reported study of the sawing and sealing technique was described by Tons.[16,17] To reduce the adverse effects of reflection cracking, this study investigated grooving the existing cracks in the AC overlay before adding the sealer, as opposed to constructing a "Band Aid" type crack seal. This involved routing the cracks to make them wider and more uniform, which simplified the application of the sealer. The result was improved sealer performance, which led to the concept of building uniform discontinuities into the asphalt concrete overlay by means of the saw and seal procedure. The concept was tried on two separate Massachusetts pavements. The results from both study sections showed that the procedure improved overlay condition and performance.

Connecticut

Wilson reported on Connecticut's first experience with sawed joints in an AC overlay.[18] This study was to determine whether sawing and sealing joints in the overlay would extend the maintenance-free life of the overlay enough to justify the additional construction cost. In 1958 researchers sawed joints in the overlay on two sections of highway: U.S. Route 7 in Norwalk, and U.S. Route 1 in East Haven.

On U.S. 7, the existing pavement constructed in 1926 consisted of 20-ft wide, 8-in thick reinforced concrete pavement on a variable-depth gravel subbase. The slabs were 40 ft long by 10 ft wide, with 1/2-in expansion joints. No load transfer devices were used. In 1958, the pavement was overlaid with 1 1/2 in of AC. Joints 3/8-in wide and 1 3/4-in deep were sawed into the overlay using a diamond saw. There was, however, a 3-month delay in constructing the joints. The material used to seal the joints was a hot rubber asphalt compound applied with a combination melter and applicator.

On U.S. 1, the existing pavement constructed in 1942 consisted of a 75-ft, 9-in long reinforced PCC slabs. Intermediate 1/4-in dummy joints were spaced at 25 ft 3 in. Load transfer devices at expansion joints and longitudinal tie bars were used. This pavement was also overlaid in 1958 with 2 1/2 in of AC. Joints identical to those on U.S. 7 were sawed into the overlay after a 4-month delay.

Wilson stated that the sawed joints on these two projects performed well, but adhesion failure of the sealer was a problem on some of the joints.[18] The amount of adhesion failure and reflection cracking observed on these two projects after a 3-year period is listed in table 1. It should be noted that an adhesion failure of the sealant was considered to be a reflection crack failure. Consequently, as the slab expanded and contracted, the sealant material opened and closed. This is the reason for the increase and decrease in reflection cracking shown in table 1. The results for the control section were not tabulated because 100 percent of the joints had reflected through the overlay.

In 1960, a third experimental project was undertaken to determine "the depth of cut required to ensure that the controlled crack would occur over the joint in the original pavement, and the effect of various joint shapes on the performance of the sealer."[18] The five different joint configurations illustrated in figure 7 were constructed on three seperate pavement sections. However, because of delays exceeding 3 months in sawing the joints in the overlay, reflection cracks developed in all three sections, diminishing the usefulness of the results of this study. Based on this limited experience, both as to the extent and age (3 years or less) of the experimental projects, Wilson concluded that:

- Crack control joints are anticipated to provide from 5 to 10 years of maintenance-free service.
- The 3/8-in wide by 1/2-in deep joint shape is considered adequate to control crack formation in a 2 1/2-in overlay.
- Further experimentation is needed to determine the required curing period for the overlay material to achieve the most efficient sawing operation at various seasons of the year.
- Relative efficiency of abrasive disks and diamond saws in forming crack control joints remains to be evaluated.
- A need for experimentation with other sealers is indicated.

Table 1. Observed reflection cracks and adhesive failures in Connecticut saw and seal study.

Date of Inspection	Project 1 - U.S. 7		Project 2 - U.S. 1	
	Reflection Crack[1] (ft)	Adhesive Failure[2] (ft)	Reflection Crack[1] (ft)	Adhesive Failure[2] (ft)
Oct. 1958	216	-	No obs.	No obs.
Dec. 16, 1958	223	Slight	No obs.	No obs.
Feb. 3, 5, 1960	-	-	65	359
Mar. 11, 1960	55	28	-	-
June 11, 19, 1960	41	17	-	-
July 6, 8, 1960	-	-	66	117
Mar. 13, 1961	58	1172	-	-
Mar. 16, 1961	-	-	52	743
Aug. 17, 22, 1961	4	813	-	-
Aug. 16, 1961	-	-	60	403

[1]Over transverse joint.
[2]Any failure 1/4 in or more in depth.

NOTE: 100 percent of the control section joints reflected through.

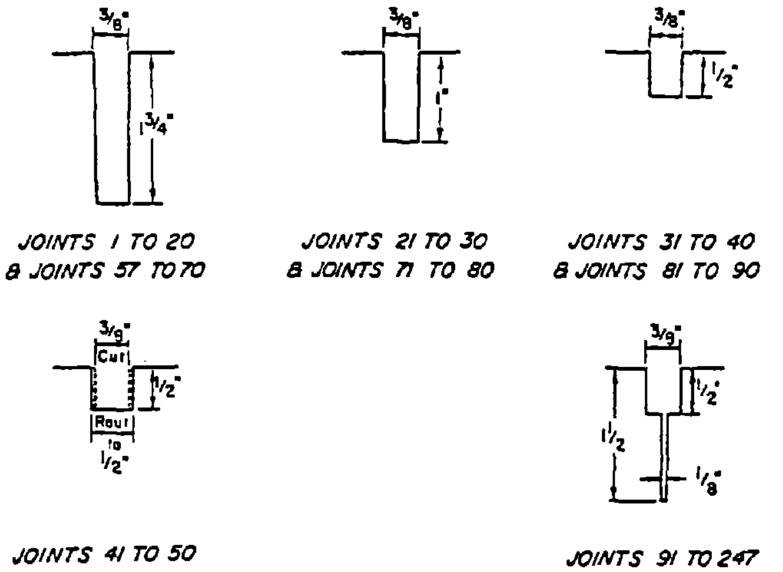


Figure 7. Experimental joint shapes used in the Connecticut saw and seal study.

Since these early studies, Connecticut has refined and adopted the saw and seal method as a routine design procedure to control reflection cracking. Today, Connecticut's standard joint configuration consists of a 1/2-in deep by 3/8-in wide reservoir filled with a hot-poured rubber sealant conforming to the requirements of AASHTO M 173.[19]

New York

After testing such methods as bond breakers, reinforcing mesh, and fabrics for controlling reflection cracking, and obtaining poor or inconsistent results, the New York Department of Transportation decided to investigate the sawing and sealing of joints in asphalt concrete overlays. Noonan and McCullagh and Vyce have reported on the construction of two experimental sections of roadway.[20-21] The first was located on I-684 in Westchester County, and the second on Route 30 in Fulton County.

On the I-684 study, joints 1/2-in wide by 5/8-in deep were sawed over each transverse joint and sealed with a hot-poured material. However, the sawing and sealing was not completed within the specified time, and the joints were not properly cleaned and referenced prior to overlay. Noonan and McCullagh stated:[20]

> ...for more than 25 percent of the southbound joints and 75 percent of the northbound, sawcuts were 6 in to 30 ft away from the underlying concrete. Although this eliminated any meaningful evaluation of the sawed-joint concept in these areas, it did provide the opportunity to estimate the amount of error that can be tolerated with this procedure. Misaligning the sawcut by as little as 3 in destroys its effectiveness, as indicated by 45 occurrences of cracking that distance from the joints. However, the remaining 174 (properly located) sawed and sealed joints appear to be controlling reflection cracking after six years.

Because of the construction problems with I-684 joints, New York State research personnel decided to use their own maintenance forces on the Route 30 project. The pavement on this project was an existing overlay on PCC, with reflection cracking throughout. A section of 77 consecutive transverse joints was selected for the study. Sawed and sealed joints similar to those on I-684 were constructed over 43 of the existing joints, with the remainder left for control purposes. After construction, it was determined that most of the saw cuts were accurately located. The performance of the overlay was monitored for 2 years. The occurrence of reflection cracking observed on this project after 1 and 2 years of service is summarized in table 2. Concerning the performance of this overlay Vyce concluded that "...the effectiveness of the sawing and sealing on this project is apparent in both the percentage of total joint length cracked and in the number of joints with 100 percent cracking or no cracking."[21]

In addition to these two projects, New York researchers constructed a third experimental project on a pavement with 100-ft slab lengths. The joint details were similar to the two projects previously described. On the performance of this overlay Vyce states:[21]

> After the initial winter, the sealer had pulled loose from the joint face in a number of locations, but the joints themselves remained in good condition--not breaking or shoving despite this lack of lateral support. The sealer failures were due to their insufficient width in relation to slab length and related horizontal movement which required elongations greater than the material's capacity.
>
> As a result, the joint configuration for future work was changed to adapt sealer width to slab length. Specified joint widths currently vary from 1/2 in for slabs less than 50 ft long to 1 in for slab lengths greater than 87 ft and depths from 5/8 to 7/8 in. An additional requirement was added to ensure that the crack forms between the sawcut and concrete joints on thicker overlays. This calls for an additional sawcut 1/8 in wide and 2 in deep in overlays greater than 3 in, exclusive of any truing and leveling.

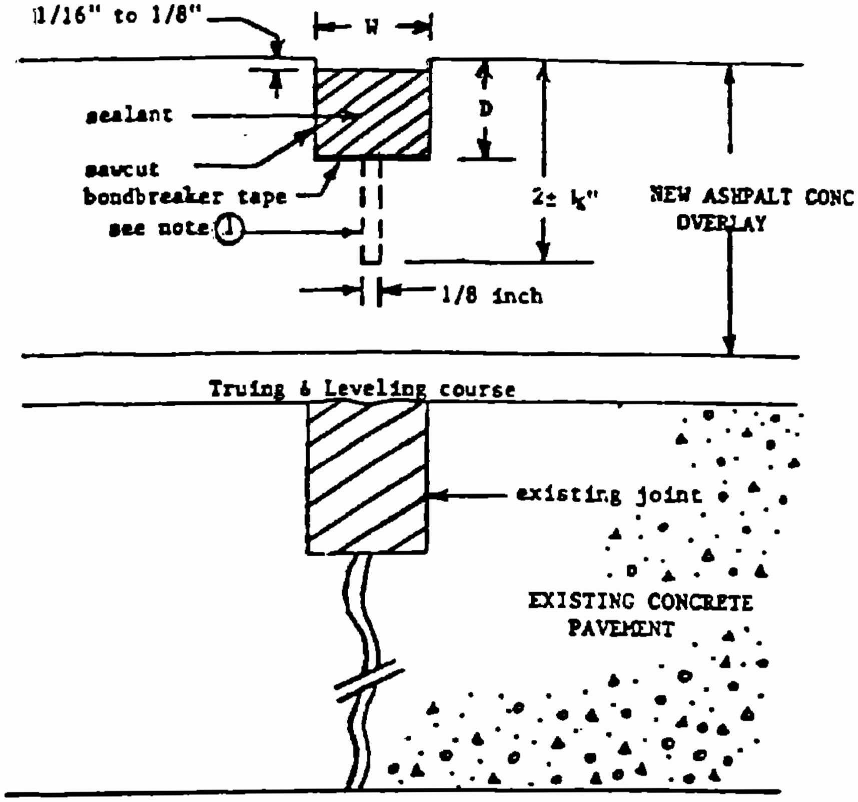
Based on the results of these studies, New York now saws and seals transverse joints on all new asphaltic concrete overlays of JCP.[22] Details of New York's current design are provided in figure 8.

Maine

Standley has described a research study undertaken in Maine to evaluate the effectiveness of three techniques in preventing reflection cracking of AC overlays of PCC.[23] These three methods included Petromat fabrics, rubber-asphalt interlayers, and sawed and sealed joints above the underlying PCC joints.

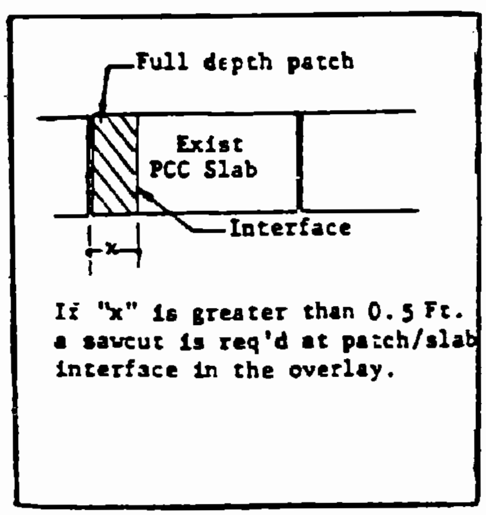
Table 2. Reflection cracking on Route 30 saw and seal overlay in New York.

Time In Service	Number of Joints: Total	No Cracking	100% Cracking	% with Cracking	% of Total Transverse Joint Length With Cracking
1 Year					
Control	34	4	22	88	78
Sawed	43	15	2	67	21
Total	77	19	24	75	46
2 Years					
Control	34	4	23	88	79
Sawed	43	13	2	70	22
Total	77	17	25	78	47



PROFILE VIEW

PLAN VIEW



SAW CUT DIMENSIONS

SLAB LENGTH	W	D
50 Ft or less	1/2 in	5/8 in
51 to 62 Ft	5/8 in	5/8 in
63 to 75 Ft	3/4 in	5/8 in
76 to 87 Ft	7/8 in	3/4 in
88 to 100 Ft	1 in	7/8 in

NOTE I

When the total overlay thickness is greater than 3 in and the T & L course is in excess of 1 1/2 in, a 1/8-in wide saw cut shall be included in the joint geometrics to a depth of 2 ± 1/2 in.

Figure 8. New York State DOT details for saw cutting transverse joints in asphalt concrete overlays.

The saw and seal section was constructed on an 850-ft long section of I-95, about 1/2 mile north of Falmouth. Using a two-step procedure, joints were sawed in the bituminous overlay above the joints in the old concrete. First a 1/8-in wide by 2 1/2-in deep joint was cut. Then another cut 1/2-in wide by 1/2-in deep was made with two, 1/4-in blades bolted together. These joints were then sealed with rubberized joint sealer conforming to Federal Specification Rubber-Asphalt Sealer SS-S-1401B. Joint performance was monitored for 3 1/2 years after construction. Figures 9 and 10 show the performance observed on both the control and saw and seal sections. It should be noted that in figure 10, reflection cracking at sawed joints in the overlay over the underlying transverse joint was measured as the amount of crack (adhesion failure) observed between the sealer in the sawed reservoir and the adjacent AC pavement. In figure 10, it can be observed that the percentage of reflected transverse joint cracks increases during the winter months. This is due to adhesion failure of the sealant material. During the warmer months, the slabs expand and thus close the adhesion failure. Based upon these results and observations of the other study sections Standley concluded:[23]

> ...the methods evaluated do not effectively retard the reflection of transverse or longitudinal joints in PCC pavement through the bituminous overlay. The "best" method used with the bituminous overlay on top of PCC pavement appears to be that of locating and sawing with subsequent sealing joints in the overlay over all of the individual joints in the concrete pavement. It was effective in that no jagged or raveled edges have appeared in these joints in this section.
>
> The 60 ft long concrete slabs on this project are subject to more expansion and contraction than the more normal 20 to 40 ft slabs. It is therefore recommended that if joints are to be sawed and then sealed in bituminous overlays over PCC that any slabs longer than 40 ft be sawn into two or more slabs prior to any overlay. The 20 to 40 ft joint spacing is regarded as adequate for a 1/2 in wide sawn joint. If there are eroded or spalled areas or poor joint areas in the existing concrete pavement, these all should be repaired prior to placing the overlay.

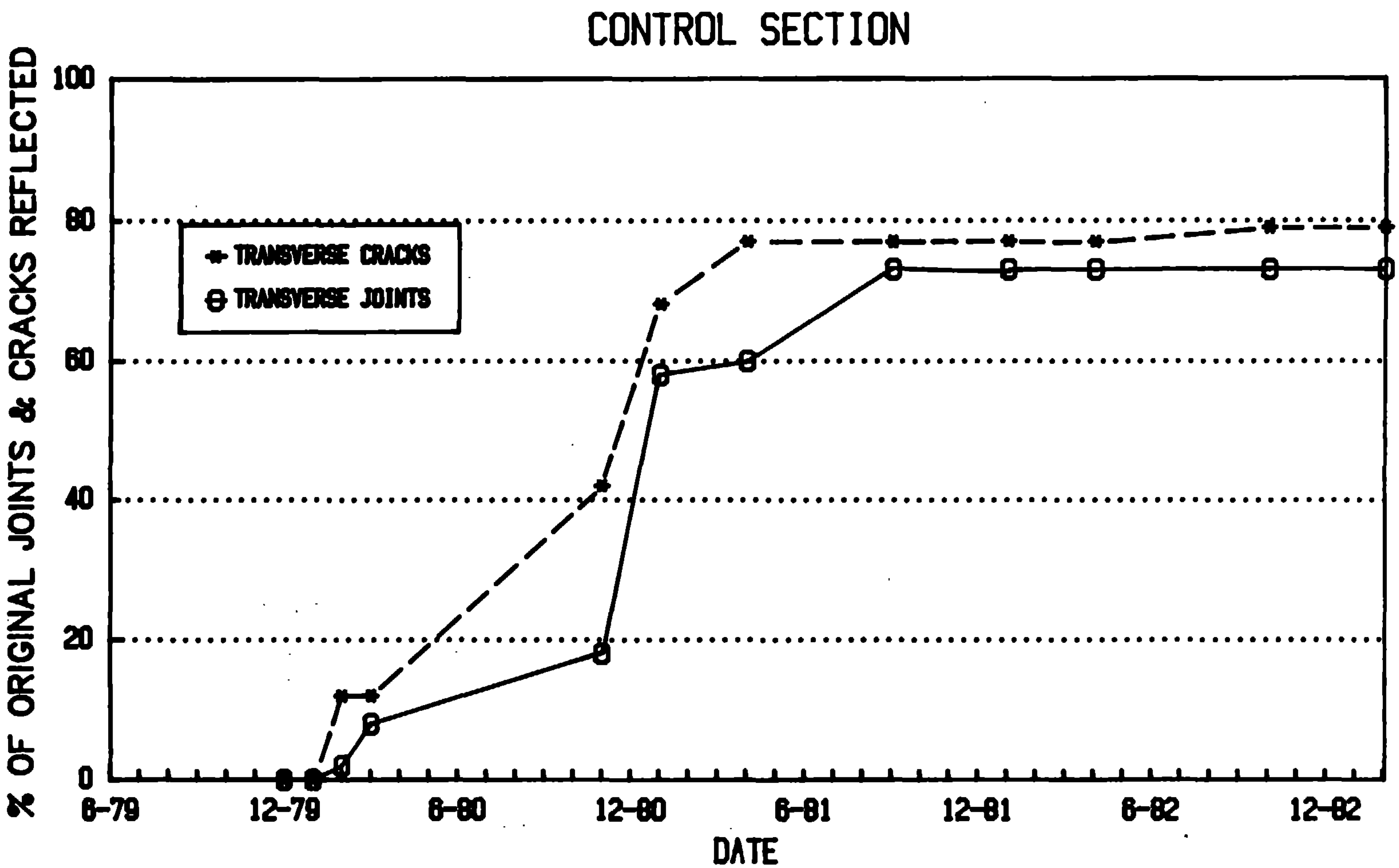


Figure 9. Reflection cracking in control section of Maine study.[23]

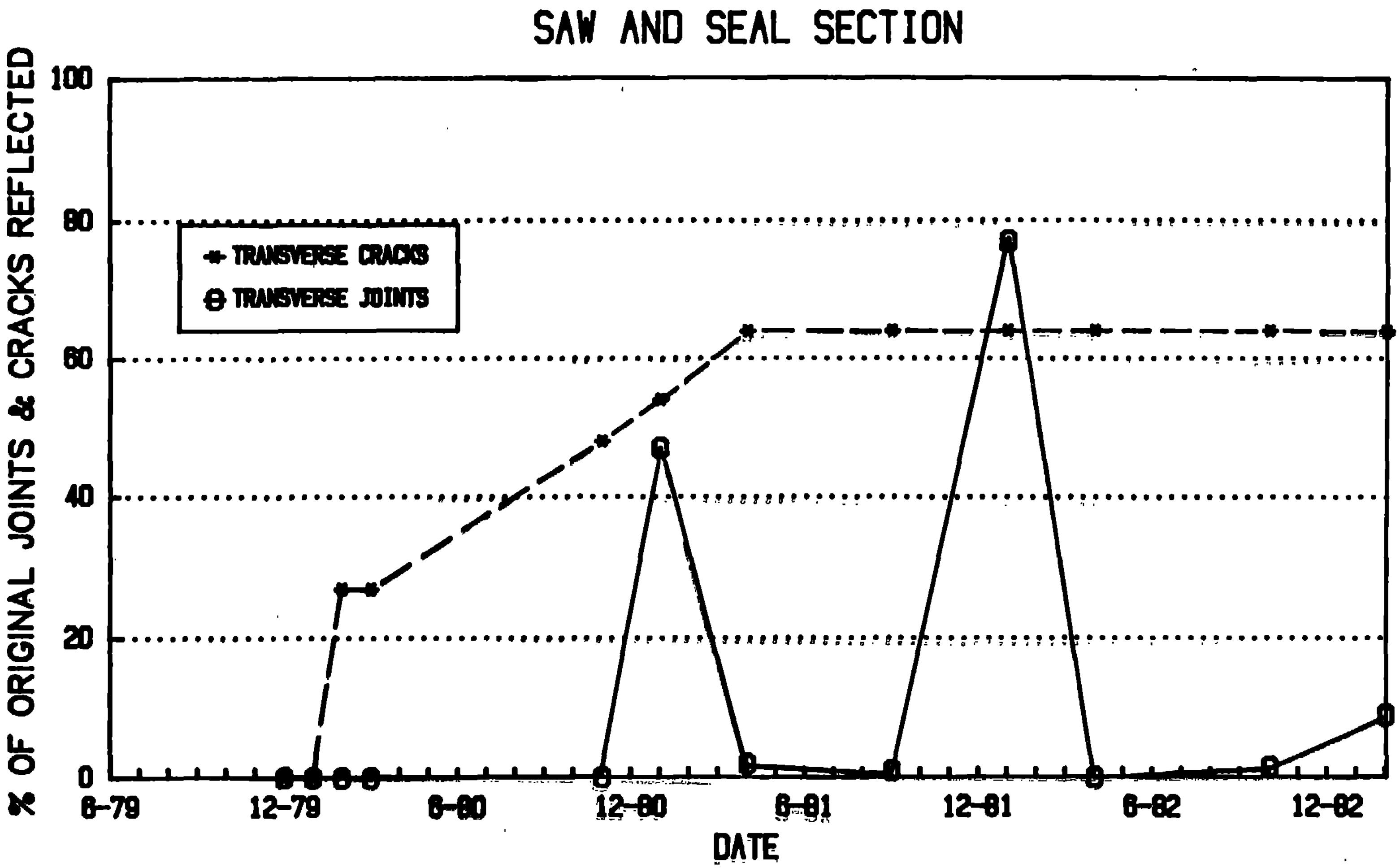


Figure 10. Reflection cracking in saw and seal section of Maine study.[23]

Pennsylvania

Pennsylvania has been sawing and sealing joints in asphalt concrete overlays for several years. Unfortunately, no reports have been published on the effectiveness of the procedure in controlling reflection cracking. Pennsylvania's construction specifications are based almost entirely upon New York's research in this area. There are, however, two differences worth noting.[24] The first is that Pennsylvania does not vary the size of the sealant reservoir with the slab length. All cuts are sawed to a width of 1/2 in and a depth of 1 in. The second difference is that no details are provided on the method the contractor should use to locate the existing joints on the overlay. The method appears to be left to the discretion of the contractor or field engineer.

Ohio

Miller et al. recently reported design and performance data from a saw and seal project in Ohio.[25] The project was a 3.4-mi, six-lane divided highway located on I-70 in Franklin County. The original pavement consisted of 9 in of dowel-mesh PCC, built in 1968. The transverse joint spacing was 60 ft. In 1985, two eastbound sections were rehabilitated with overlays containing sawed and sealed joints. The first section used joint sealer as specified in AASHTO M 173. The second section used joint sealer as specified in ASTM D 3405. The saw cuts on both sections were made to a depth of 1 in and a width of 1/2 in.

A field survey conducted 6 months after construction revealed that the sections with sawed joints had very little reflection cracking. Minimal problems occurred in locating the existing joint: only five joints were observed with a sawed cut and reflective crack that did not match.

SUMMARY OF LITERATURE REVIEW

Based upon the literature review, a number of findings can be drawn concerning past and current saw and seal design practices:

- Most of the States that have reported experience with saw and seal AC overlays are in the northeastern part of the country. Connecticut, New York, New Jersey, Pennsylvania, Massachusetts, Ohio, and Maine have had the most experience.

- Several States have prepared specifications and standards for the saw and seal overlay procedure.

- States that have implemented or experimented with sawing and sealing have had "marginal to good" results with the technique. (See table 3.)

- A critical step in the construction process is properly locating the saw cut above the existing joint. Unless a precise match of the saw cut and existing joint is made, the asphaltic concrete overlay will crack at the joint location.

- As with any AC overlay of PCC, the effectiveness of sawing and sealing depends greatly on the condition of the underlying pavement. To obtain the full benefit from sawing and sealing, only concrete pavements with relatively good joints and no surface deterioration (other than wear) should be selected. Joints wider than 3 in make it difficult to control reflective cracks. Concrete pavements with numerous full-depth and surface patches, misaligned slabs, and midslab cracking are not candidates for this techinque.

- The overall experience with saw and seal overlays is extremely limited. Information concerning measured field performance, traffic, existing pavement condition, and characterization of the existing pavement in terms of joint width, load transfer efficiency, crack spacing, joint and crack opening under known temperature changes, and load deflection is generally lacking.

Table 3. States using the saw and seal procedure and the effectiveness of the method.

State	Marginal	Good
Arizona		X
Connecticut		X
Louisiana	X	
Maine		X
Massachusetts		X
Michigan	X	
New Jersey		X
New York		X
North Carolina*		
Ohio		X
Pennsylvania		X
Rhode Island		X

*Recently constructed--no data available.

3. DATA COLLECTION PROCEDURES

Five categories of data were used in the analysis and the development of improved design and construction procedures: measured field performance, original PCC pavement design factors, overlay design factors, traffic, and environmental data. These data were obtained from pavement condition surveys, State highway agency as-built plans and special provisions, and other agency records. In general, the procedures specified in the Strategic Highway Research Program's (SHRP) "Data Collection Guide for the Long-Term Pavement Performance Studies" were used.[28] This chapter describes the pavement sections selected for the study, the procedures used in collecting data, and the types of data obtained.

SELECTION OF STUDY SECTIONS

Pavement sections suitable for study were identified by several methods. An extensive literature search identified experimental projects, research projects, and other pavement sections for which performance data had been reported in published studies. A computer search of the Transportation Research Information Services (TRIS) on-line computer files was conducted by the FHWA; in addition, a manual search of the card catalogues, HRIS abstracts, etc., of the library of the Pennsylvania Transportation Institute was conducted. Publications from major transportation organizations such as the Transportation Research Board, FHWA, National Cooperative Highway Research Program, etc., were reviewed. Also, the results of a recent FHWA inquiry to the States concerning sawing and sealing were reviewed to identify potential study sections.

The results of these searches were rather disappointing. Only a few saw and seal studies had been reported in detail in the literature. Furthermore, many of the pavement sections for which performance data had been reported were so old that they were no longer in service. Because a sufficient number of pavement sections were not identified using these methods, it was decided to make direct contact with the States using the saw and seal procedure. Written and telephone inquiries were made to a total of nine States asking their assistance in identifying suitable pavement sections.

Using these methods, a group of candidate saw and seal projects was identified. From this group the actual study sections were selected using several criteria. The first criterion was to have study sections located in each of the four major environmental zones of the country. This was found to be impossible because most of the saw and seal overlays identified were located in the northeastern U.S., a wet/freeze zone. While one saw and seal overlay was identified in Arizona, a State in the dry/freeze zone, and North Carolina, a State in the wet/nonfreeze zone, these overlays had been in service less than 1 year at the time of the field surveys. Because it was believed that no discernable performance trends would be observed on these pavements, they were not selected for the study. Other States, such as Georgia, Virginia, and Louisiana, have tried sawing and sealing but have not documented the performance of these projects.

The second criterion was to select pavement sections for which past field performance, original PCC pavement and overlay design details, and historical traffic volumes could be obtained from the appropriate State agency.

Finally, special consideration was given to sawed and sealed overlays that had an adjacent control section available for comparison. Using these criteria, 10 projects with a total of 15 overlays were identified and selected for inclusion in the study. Table 4 lists the 15 selected pavement sections.

Two of the more important design variables considered when selecting the sections were the overlay age and thickness. The age of the selected overlays varied from 2 to 10 years, while the thickness of the selected overlays ranged from 2 in to 4 1/2 in. The distribution of the overlays by age and thickness is illustrated in figures 11 and 12, respectively.

The original PCC pavement and rehabilitation designs were determined from as-built plans, specifications, and special provisions. These were

Table 4. Pavement sections selected for inclusion in the study.

Project No.	Route	Location	Lane
1	I-91	Meridian, CT	NB
2	I-84	New Britain, CT	EB
3(A)	I-95	Falmouth, ME (control)	NB
3(B)	I-95	Falmouth, ME	NB
4(A)	US-22	Somerville, NJ	WB
4(B)	US-22	Somerville, NJ (control)	WB
5(A)	I-80	W. Paterson, NJ (control)	EB
5(B)	I-80	W. Paterson, NJ	EB
6(A)	Route 5	Caledonia, NY (control)	EB&WB
6(B)	Route 5	Caledonia, NY	EB&WB
7	I-81	Syracuse, NY	NB
8	I-87	Albany, NY	SB
9(A)*	I-70	Columbus, OH	EB
9(B)	I-70	Columbus, OH	EB
10	US-22	Huntingdon, PA	EB&WB

*Sections A and B due to different sealant materials.

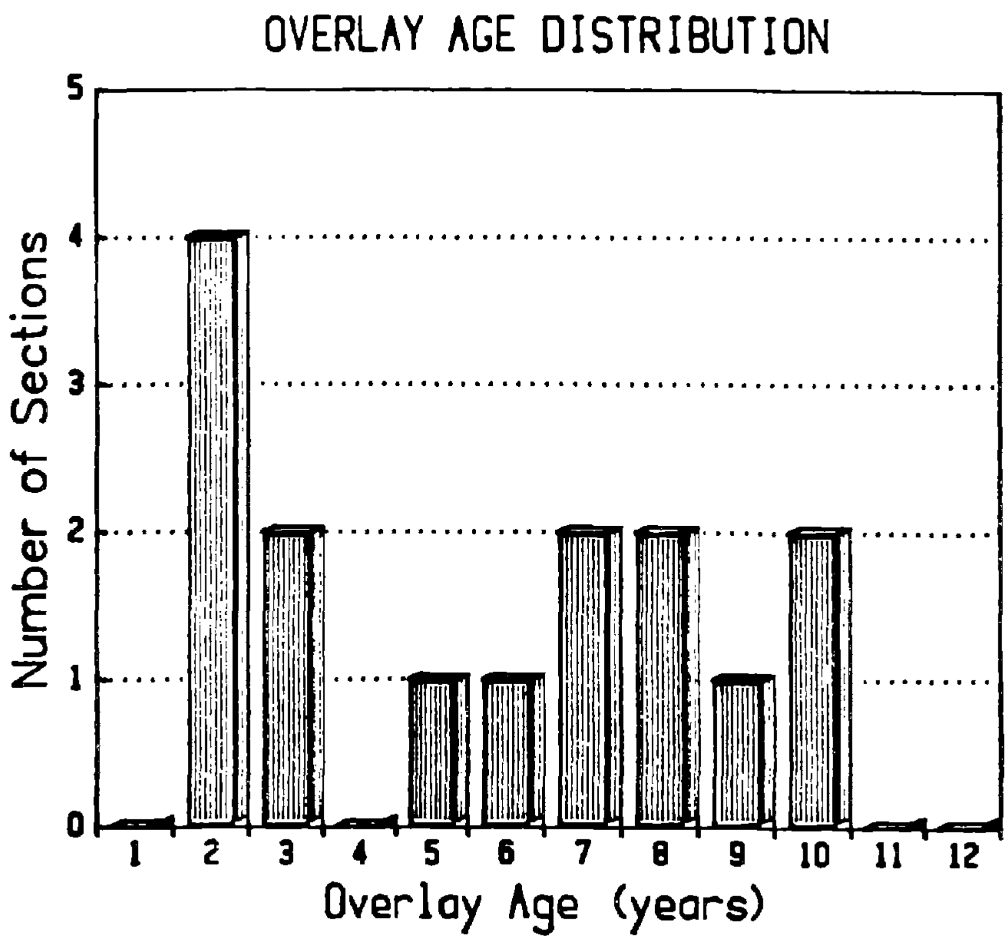


Figure 11. Age distribution of study sections.

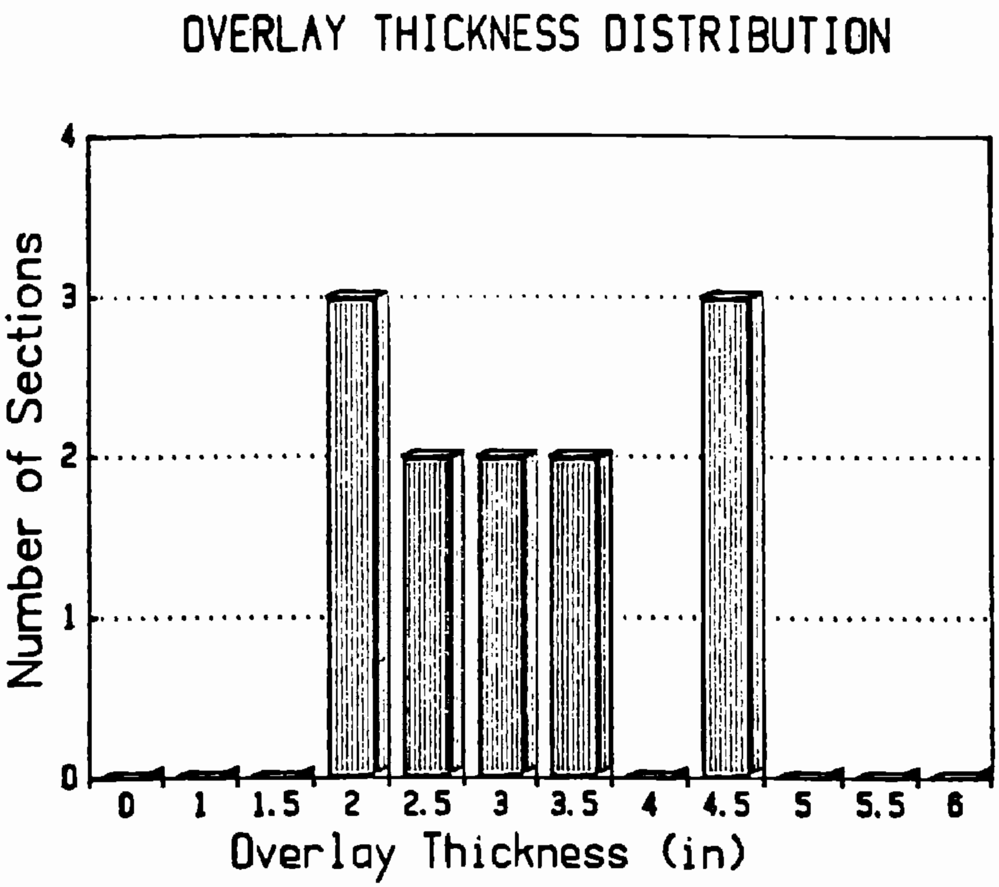


Figure 12. Overlay thickness distribution of the study sections.

obtained from the appropriate State agency for each study section. The original PCC pavement and rehabilitation design variables obtained during the study are summarized in tables 5 and 6, respectively.

FIELD DATA COLLECTION

Three categories of field data were collected: pavement distress, roughness, and deflections. These data collection efforts are described in the following sections.

Pavement Distress

A thorough condition survey was conducted on each pavement section during July and August 1987. The procedures used were those specified under the SHRP Long-Term Pavement Performance (LTPP) program. SHRP's standard "Distress Identification Manual for the LTPP Studies" was used as a guide to identify the types, severities, and quantities of the various distress.[29] Table 7 contains a summary of the types of distress data collected during the field surveys.

Roughness

The roughness of each pavement section was determined using a May's Ride Meter--an electromechanical device that continuously logs the pavement surface by recording the magnitude, direction, and summation of rear axle to body excursions of its parent automobile together with synchronized distance increments.[30] This is accomplished by a photocell sensing system that drives a stepping motor for pen and chart movements on a paper tape recorder. By measuring the amount of chart movement per unit of road length traveled, a roughness index, in inches per mile, was computed for each study section.

In addition to the roughness measurements, the survey crew rode each of the pavement sections to give a subjective present serviceability rating (PSR).

Table 5. Original PCC pavement design variables.

IDENTIFICATION AND LOCATION DATA

- Project ID
- Date of Data Collection
- Highway Number
- Direction of Survey
- Test Section Location (beginning and ending mile markers or stations)
- Date Constructed

GEOMETRIC AND SHOULDER DATA

- Number of Through Lanes (one direction)
- Lane Width
- Lanes Included in Study Section
- Outside Shoulder Width
- Inside Shoulder Width
- Shoulder Surface Type
- Shoulder Base Type
- Shoulder Surface Thickness
- Shoulder Base Thickness

PCC PAVEMENT JOINT DATA

- Average Contraction Joint Spacing
- Skewness of Transverse Joints
- Transverse Contraction Joint Load Transfer System
- Type of Longitudinal Joint

Table 6. Rehabilitation design variables.

- Date of Construction of AC overlay
- Thickness of AC overlay
- Sawed Joint Data
  - Method used to locate underlying joints
  - Width of reservoir
  - Depth of reservoir
  - Type of sealant
  - Depth of saw cut (if any)

Table 7. Pavement distress data collected during the field surveys.

GENERAL

Date of Distress Survey
Lane Number
Number of Transverse Joints in the Study Section

AC OVERLAY DISTRESS

Alligator cracking
Bleeding
Block cracking
Crack between lane and shoulder
Longitudinal cracking
Longitudinal sawed joint condition (if sawed)
Mean lane shoulder dropoff
Mean rut depth inner wheel path
Mean rut depth outer wheel path
Missawed joints
Patch deterioration
Potholes
Pumping and water bleeding
Raveling/weathering
Reflection cracking above longitudinal joint
Transverse cracking
Transverse joint reflection cracking
Transverse reflection cracking at patch
Transverse sawed joint condition

Deflections

Pavement deflections were measured on each saw and seal study section to determine the joint load transfer efficiency and the stiffness of the pavement layers and foundation. Deflections were not measured on the control sections in an effort to reduce data collection costs. The deflections were measured using a Falling Weight Deflectometer (FWD) at three load levels: 9,000, 13,000, and 17,000 lb. The following locations were tested within each study section:

- Slab corners on both the approach and leave sides of the transverse joint (for load transfer efficiency).
- Slab centers (for determination of layer stiffnesses).

The testing pattern used on each of the sawed and sealed study sections is illustrated in figure 13.

TRAFFIC DATA

Traffic volumes, including percentage of truck traffic, were collected from the appropriate State highway agency for each study section. Requests were made to the State agencies for volumes from the time the pavement was opened to traffic to the date of survey. However, in some instances traffic counts were unavailable for each year the overlay experienced traffic.

ENVIRONMENTAL DATA

Environmental data were taken from documentation of monthly temperatures and precipitation published by the National Oceanic and Atmospheric Administration. The nearest weather station was assumed to be representative of the environmental conditions at each study section. In addition, the U.S Army Corps of Engineers freezing index contour map was used to determine the mean freezing indices of the study sections.[32] Table 8 summarizes the environmental data elements that were collected.

Table 8. Environmental data elements collected in the study.

TEMPERATURE

- Average Monthly Temperature
- Average Maximum Daily Temperature by Month
- Average Minimum Daily Temperature by Month
- Freezing Index
- Average Number of Annual Air Freeze-Thaw Cycles
- Elevation Above Sea Level
- Two Year in Ten Average Maximum Temperature
- Two Year in Ten Average Minimum Temperature

PRECIPITATION

- Average Monthly Precipitation
- Average Annual Number of Days of Precipitation
- Thornthwaite Moisture Index
- Two Year in Ten Average Maximum Precipitation
- Two Year in Ten Average Minimum Precipitation

GENERAL

- General Type of Environment (Zone)

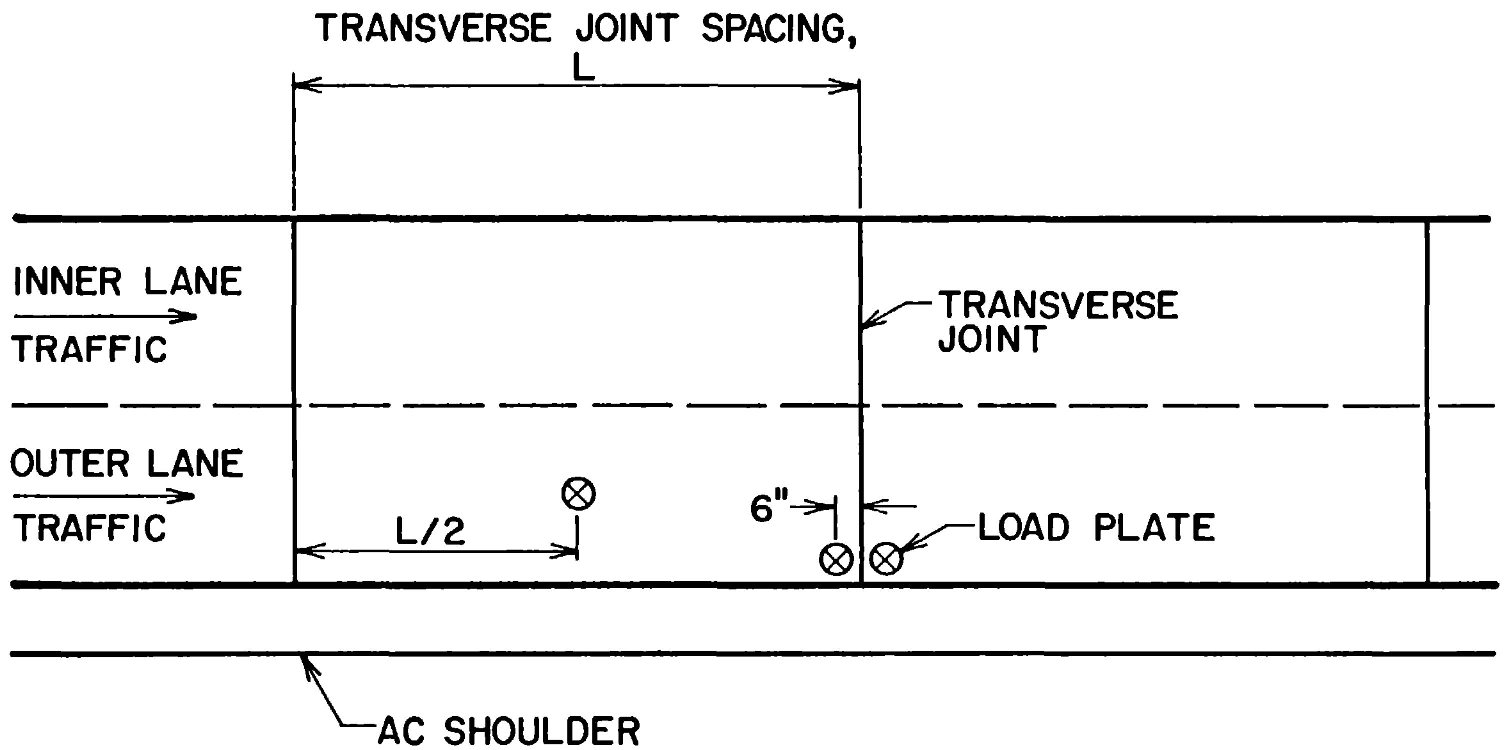


Figure 13. FWD test pattern used on each saw and seal study section.

DATABASE DESCRIPTION

The raw data obtained from the aforementioned sources were in several formats, such as field distress forms, construction plans, research reports, etc. After reduction, these data elements were entered into a database that resides on a hard storage disk of an IBM personal computer. The PC software used to manage the database was RBASE System V, which allowed for efficient data entry, retrieval, and management. The data elements can be easily exported in several forms, including ASCII delimited text files.

DATABASE SUMMARY

The data elements that were collected for the saw and seal sections are presented in tables 9 through 14. Many of the data fields represent the raw data; however, several of the fields are the results of data analysis. For example, the 18-kip ESALs were calculated based upon ADT, growth rates, and truck factors. Data elements that were not available are listed as N/A.

Table 9. General and environmental data.

PROJECT LOCATION	PROJECT NUMBER	PROJECT SECTION ID	YEAR OVERLAY PLACED	STARTING MILE MARKER	ENDING MILE MARKER	DIRECTION	FUNCT. CLASS	LENGTH	THORNTHWAITE MOISTURE INDEX	CORPS OF ENGINEERS FREEZING INDEX
I-91 Meridian, CT	1	CT 1	1978	21.7	21.9	NB	1	1057	70	250
I-84 New Britain, CT	2	CT 4	1982	58.77	58.97	EB	1	1058	70	250
I-95 Falmouth, ME (control)	3(A)	ME 1-1	1979	55.87	56.05	NB	11	950	80	800
I-95 Falmouth, ME	3(B)	ME1-2	1979	56.06	56.22	NB	11	850	80	800
US-22 Somerville, NJ	4(A)	NJ 4-1	1977	N/A	N/A	WB	14	610	60	90
US-22 Somerville, NJ (control)	4(B)	NJ 4-2	1977	N/A	N/A	WB	14	1000	60	90
I-80 W. Paterson, NJ (control)	5(A)	NJ 5-1	1985	54.4	54.48	EB	11	416	65	110
I-80 W. Paterson, NJ	5(B)	NJ 5-2	1985	55.54	55.75	EB	11	1092	65	110
Route 5 Caledonia, NY (control)	6(A)	NY 3-1	1980	106.48	106.27	EB	6	1090	50	500
Route 5 Caledonia, NY	6(B)	NY 3-2	1980	103.9	104.1	EB	6	1052	50	500
I-81 Syracuse, NY	7	NY 4	1984	303.24	303.44	NB	11	1094	60	700
I-87 Albany, NY	8	NY 5	1984	206.43	206.62	SB	11	1000	60	800
I-70 Columbus, OH	9(A)	OH 3-1	1985	87.54	87.74	EB	11	1065	50	100
I-70 Columbus, OH	9(B)	OH 3-2	1985	87.34	87.54	EB	11	1048	50	100
US-22 Huntingdon, PA	10	PA 2	1981	N/A	N/A	EB&WB	6	1113	60	250

Table 10. Performance data.

PROJECT NUMBER	PROJECT SECTION ID	LANE NUMBER	AVG PSR	MAY'S ROUGH IN/MI	AVG RUT DEPTH IN	TRANSVERSE JOINT REFLECTION CRACKING LIN FT/MI	MISSAWED JOINTS/ MILE*	LONGITUDINAL JOINT REFLECTION CRACKING LIN FT/MI	CRACK BETWEEN LANE AND SHOULDER LIN FT/MI	PATCH DETERIORATION SQ FT/MI	LONGITUDINAL CRACKING LIN FT/MI	ALLIGATOR CRACKING SQ FT/MI	TRANSVERSE CRACKING LIN FT/MI	BLEEDING SQ FT/MI	TRANSVERSE REFLECTION CRACK AT JOINT PATCH
1	CT 1	1	3.6	78	0.20	499	45	4591	3662	240	-	60	260	-	-
		2			0.22	579	45	4810	-	520	-	60	-	-	-
		3			0.13	140	10	-	4810	-	-	-	-	-	-
2	CT 4	1	4.2	40	0.12	329	25	1687	1607	10	-	-	70	-	-
		2			N/A	309	25	2949	-	10	-	-	-	-	-
		3			0.11	539	45	-	1552	-	-	-	60	-	-
3(A)	ME 1-1	1	3.8	55	0.11	800	-	5280	5280	-	-	-	333	-	-
		2			0.10	934	-	-	-	-	-	-	267	-	-
3(B)	ME1-2	1	4.2	38	0.08	-	-	5280	5280	-	31	-	304	-	-
		2			0.08	-	-	-	-	-	-	-	75	-	-
4(A)	NJ 4-1	1	3.8	58	0.30	286	26	4960	-	-	242	684	104	-	-
		2			0.19	-	-	-	-	-	35	874	-	-	-
4(B)	NJ 4-2	1	4	59	0.28	422	-	5248	1943	-	306	-	-	-	-
		2			0.15	1262	-	-	-	-	-	-	-	-	-
5(A)	NJ 5-1	1	4	116	0.10	1066	-	2399	4963	-	-	-	-	-	-
		2			0.16	1066	-	5280	-	-	-	-	-	-	-
5(B)	NJ 5-2	1	3.6	69	0.08	513	44	-	1644	-	-	-	29	-	-
		2			0.08	290	39	1968	-	-	-	-	10	-	-
6(A)	NY 3-1	1	3.4	83	0.12	693	58	4844	26	-	-	-	-	97	-
		2			0.17	693	58	-	-	-	-	-	-	-	-
6(B)	NY 3-2	1	3.2	102	0.15	120	15	1165	-	-	-	146	25	50	-
		2			0.14	120	10	-	-	-	-	50	55	85	-
7	NY 4	1	4.2	50	0.08	-	-	-	-	-	-	-	-	-	116
		2			N/A	-	-	-	-	-	-	-	-	-	116
		3			N/A	-	-	-	-	-	-	-	-	-	116
8	NY 5	1	4.2	60	0.15	95	11	5280	5280	-	-	-	16	-	-
		2			N/A	74	11	5280	-	-	-	21	-	-	-
		3			0.10	-	-	-	-	-	-	-	-	449	-
9(A)	OH 3-1	1	4.1	60	0.10	-	-	5280	-	-	-	-	40	-	-
9(B)	OH 3-2	1	4.4	38	0.11	-	-	126	-	-	-	-	-	-	-
10	PA 2	1	3.6	90	0.63	-	-	-	-	-	-	-	57	417	-
		2			0.63	5	-	-	-	-	-	-	85	-	-

Table 11. Traffic data.[31]

PROJECT NUMBER	PROJECT SECTION ID	YEAR OVERLAY PLACED	1987 ESTIMATE: ADT, thous.	1987 ESTIMATE: % Trucks	OUTER LANE (1): 1987 ESAL from ADT, % Trucks	OUTER LANE (1): Estimated ESAL's to Date	INNER LANE (2): 1987 ESAL from ADT, % Trucks	INNER LANE (2): Estimated ESAL's to Date
1	CT 1	1978	57.0	0.07	436905	4842965	109226	1154987
2	CT 4	1982	105.2	0.10	1535920	10260570	383980	2383800
3(A)	ME 1-1	1979	30.6	0.10	462170	3654518	51352	419281
3(B)	ME 1-2	1979	30.6	0.10	462170	3654518	51352	419281
4(A)	NJ 4-1	1977	60.9	0.16	2399653	25231898	266628	2860313
4(B)	NJ 4-2	1977	60.9	0.16	2399653	25231898	266628	2860313
5(A)	NJ 5-1	1985	119.7	0.17	4178602	12268772	1392867	4129520
5(B)	NJ 5-2	1985	119.7	0.17	4178602	12268772	1392867	4129520
6(A)	NY 3-1	1980	7.4	0.15	242105	1074456	N/A	N/A
6(B)	NY 3-2	1980	7.4	0.15	242105	1074456	N/A	N/A
7	NY 4	1984	43.5	0.08	685908	2576397	171477	643006
8	NY 5	1984	59.7	0.10	1177475	4362020	294369	1088645
9(A)	OH 3-1	1985	34.5	0.24	1543917	4572445	385979	1143111
9(B)	OH 3-2	1985	34.5	0.24	1543917	4572445	385979	1143111
10	PA 2	1981	10.0	0.10	164250	636645	N/A	N/A

Table 12. Pavement transverse joint data.

PROJECT NUMBER	PROJECT SECTION ID	AC OVERLAY THICKNESS DESIGN (IN)	AC OVERLAY THICKNESS FIELD (IN)	ORIGINAL PCC PVMT THICKNESS (IN)	JOINT SPACING (FT)	SKEWED JOINTS, Y/N	OVERLAY JOINT SHAPE FACTOR	OVERLAY JOINT SEALANT TYPE	OVERLAY JOINT SEALANT CONDITION
1	CT 1	2.75	3.0	9.0	40.0	N	0.75	AASHTO M 173	EXCELLENT
2	CT 4	3.0	3.5	9.0	40.0	N	0.75	AASHTO M 173	EXCELLENT
3(A)	ME 1-1	4.5	N/A	8.0	60.0	N	N/A	N/A	N/A
3(B)	ME1-2	4.5	3.5	8.0	60.0	N	1.00	SS-S-1401B	EXCELLENT
4(A)	NJ 4-1	2.0	4.0	9.0	78.0	N	0.75	ASTM D-1190	GOOD
4(B)	NJ 4-2	2.0	N/A	9.0	78.0	N	N/A	N/A	N/A
5(A)	NJ 5-1	2.0	N/A	9.0	78.0	N	N/A	N/A	N/A
5(B)	NJ 5-2	2.0	2.5	9.0	78.0	N	0.60	ASTM D-1190	GOOD
6(A)	NY 3-1	2.5	N/A	9.0	90.0	N	N/A	N/A	N/A
6(B)	NY 3-2	2.5	5.0	9.0	90.0	N	0.80	ASTM D-3405	EXCELLENT
7	NY 4	3.5	4.0	9.0	43.0	N	0.80	ASTM D-3405	EXCELLENT
8	NY 5	4.5	4.2	9.0	61.0	N	1.00	ASTM D-3405	GOOD
9(A)	OH 3-1	3.0	N/A	9.0	15.0	Y	0.50	ASTM D-3405	EXCELLENT
9(B)	OH 3-2	3.0	N/A	9.0	15.0	Y	0.50	AASHTO M 173	EXCELLENT
10	PA 2	3.5	4.0	9.0	62.0	N	0.80	ASTM D-3405	GOOD

Table 13. Drainage and shoulder information.

PROJECT NUMBER	PROJECT SECTION ID	SUB-DRAINAGE Y/N	DEPTH OF DITCH, FT	OUTER LANE: AVERAGE TRANS. SLOPE, %	OUTER LANE: AVERAGE LONGIT. SLOPE, %	OUTER SHOULDER: SURFACE TYPE	OUTER SHOULDER: WIDTH, FT	INNER SHOULDER: SURFACE TYPE	INNER SHOULDER: WIDTH, FT	SHOULDER JOINT SEAL DAMAGE N/L/M/H	OVERALL DRAINAGE EVALUATION
1	CT 1	N	3	1.04	1.04	AC	10.0	AC	2.0	N/A	GOOD
2	CT 4	Y	3	1.56	1.04	AC	8.0	AC	4.0	N/A	GOOD
3(A)	ME 1-1	N	7	2.08	1.04	AC	10.5	AC	4.0	N	GOOD
3(B)	ME1-2	N	6	2.08	1.04	AC	10.0	AC	4.0	N	GOOD
4(A)	NJ 4-1	N	N/A	2.60	0.52	AC	10.0	AC	2.5	N	GOOD
4(B)	NJ 4-2	N	N/A	3.12	0.52	AC	10.0	AC	2.0	N/A	GOOD
5(A)	NJ 5-1	N	N/A	1.56	2.08	AC	12.0	AC	8.0	N	GOOD
5(B)	NJ 5-2	N	N/A	1.04	1.04	AC	12.0	AC	10.0	N	GOOD
6(A)	NY 3-1	N	5	1.56	0.52	AC	8.0	N/A	N/A	N	GOOD
6(B)	NY 3-2	N	3	2.08	0.00	AC	8.0	AC	8.0	N	GOOD
7	NY 4	N	5	2.08	0.52	AC	10.0	AC	3.0	N	GOOD
8	NY 5	N	6	1.04	1.04	AC	10.0	AC	4.0	L	GOOD
9(A)	OH 3-1	N	4	2.08	2.08	AC	10.0	AC	5.0	N/A	GOOD
9(B)	OH 3-2	N	4	2.08	2.08	AC	10.0	AC	5.0	N/A	GOOD
10	PA 2	Y	2	2.60	2.60	AC	10.0	AC	10.0	N/A	GOOD

Table 14. Deflection data--outer lane.

PROJECT NUMBER	PROJECT SECTION ID	DEFLECTIONS (All values in mils): MID-SLAB HIGH	LOW	AVG.	LOADED CORNER	UNLOADED CORNER	ADJUSTED LOAD TRANSFER EFFICIENCY (PERCENT)
1	CT 1	4.40	2.80	3.67	5.21	3.78	107.35
2	CT 4	4.50	2.70	3.60	6.33	5.14	103.21
3(A)	ME 1-1	N/A	N/A	N/A	N/A	N/A	N/A
3(B)	ME1-2	5.10	4.40	4.65	14.23	9.17	84.64
4(A)	NJ 4-1	3.80	2.40	2.88	6.40	3.67	85.25
4(B)	NJ 4-2	N/A	N/A	N/A	N/A	N/A	N/A
5(A)	NJ 5-1	N/A	N/A	N/A	N/A	N/A	N/A
5(B)	NJ 5-2	4.80	3.90	4.34	5.97	4.20	91.32
6(A)	NY 3-1	N/A	N/A	N/A	N/A	N/A	N/A
6(B)	NY 3-2	6.30	2.80	4.58	10.43	5.58	78.65
7	NY 4	4.20	2.80	3.24	7.65	6.04	96.64
8	NY 5	5.00	3.00	3.68	9.28	5.79	93.23
9(A)	OH 3-1	1.90	1.20	1.36	2.32	1.87	99.78
9(B)	OH 3-2	1.90	1.10	1.57	2.75	2.39	108.29
10	PA 2	2.50	1.50	1.96	5.22	3.33	79.55

4. FIELD PERFORMANCE AND EVALUATION

OVERVIEW OF PERFORMANCE

Pavement performance can be evaluated using criteria from several categories. These categories include functional, and structural characteristics, safety, and appearance.[33] In this study, it was decided to evaluate the field performance of the pavement sections based on functional and structural characteristics.

Functional performance can be described as the ability of a pavement to provide a serviceable surface in terms of the quality of the ride experienced by the roadway user.[33] This serviceability can be evaluated either subjectively or by using physical measurements correlated with subjective evaluations. Research has shown that the primary factor affecting the serviceability, and hence the functional performance of a pavement, is the surface roughness of a pavement.[34] In this study the functional performance of the study sections was determined using longitudinal roughness measurements. The results of this testing are presented in "Pavement Roughness," found later in this chapter.

Structural performance refers to the ability of a pavement to maintain its structural integrity without experiencing distress.[34] In this study the structural performance of the study sections was determined using the nondestructive deflection testing methods described in chapter 3. These test results and the occurrences of distress, observed in the field, are summarized in "Sawed and Sealed Overlay Distress," found later in this chapter.

The evaluation of safety primarily involves the measurement of skid resistance but can be expanded to include other factors such as hydroplaning, icing potential, and severe surface distortion, such as rutting.[35] While such considerations are certainly of paramount importance when evaluating a pavement, the inclusion of such factors (with the exception of surface distortion) was considered beyond the scope of this study.

The evaluation of a pavement's appearance is rather self explanatory and is not as important a consideration as the first three factors. It was not considered when evaluating the performance of the study sections.

PAVEMENT ROUGHNESS

Pavement roughness is a phenomenon that manifests itself at the surface of the pavement structure. It has been defined as "...the longitudinal deviations of a pavement surface from a true planar surface with characteristic dimensions that affect vehicle dynamics, ride quality, and dynamic pavement loads."[36] There are three main components of pavement roughness: longitudinal variations, transverse variations, and horizontal variations of the pavement alignment.[35] Longitudinal variations have been shown to be the major cause of undesirable vehicle forces.[37] Transverse variations, or the roll component transmitted to the vehicle, is the second major cause of roughness. The least offensive is the horizontal curvature of a roadway which, if poorly designed, can impart undesirable yaw forces to a vehicle.

The longitudinal roughness of each pavement section was measured with a May's ride meter as described earlier. The roughness measurements obtained on each of the 15 study sections are listed in table 15. It can be seen that there was a wide variation in the amount of surface roughness; from a low of 38 in/mi to a high of 116 in/mi. The two study sections with the least amount of roughness, 38 in/mi, were the overlays with sawed and sealed joints on I-95 in Falmouth, Maine, and I-70 in Columbus, Ohio. The study section found to have the most roughness, 116 in/mi, was the control section on I-80 in West Paterson, New Jersey. The average roughness for the saw and seal and control sections was found to be 60 and 78 in/mi, respectively.

There were four projects that had control sections available to compare how the roughness of an AC overlay with sawed joints compared to an adjacent overlay without such joints. The roughness measurements taken on these eight overlays are depicted in figure 14. Three of the four sawed and sealed overlays exhibited from 10 to 41 percent less roughness than the

Table 15. Mays meter roughness measurements.

Project	Section ID	Roughness (in/mi)
1	CT 1	78
2	CT 4	40
3(A)*	ME 1-1	55
3(B)	ME 1-2	38
4(A)	NJ 4-1	54
4(B)*	NJ 4-2	60.5
5(A)*	NJ 5-1	116.5
5(B)	NJ 5-2	69
6(A)*	NY 3-1	80
6(B)	NY 3-2	98
7	NY 4	50
8	NY 5	60
9(A)	OH 3-1	60
9(B)	OH 3-2	38
10	PA 2	90

*Control sections

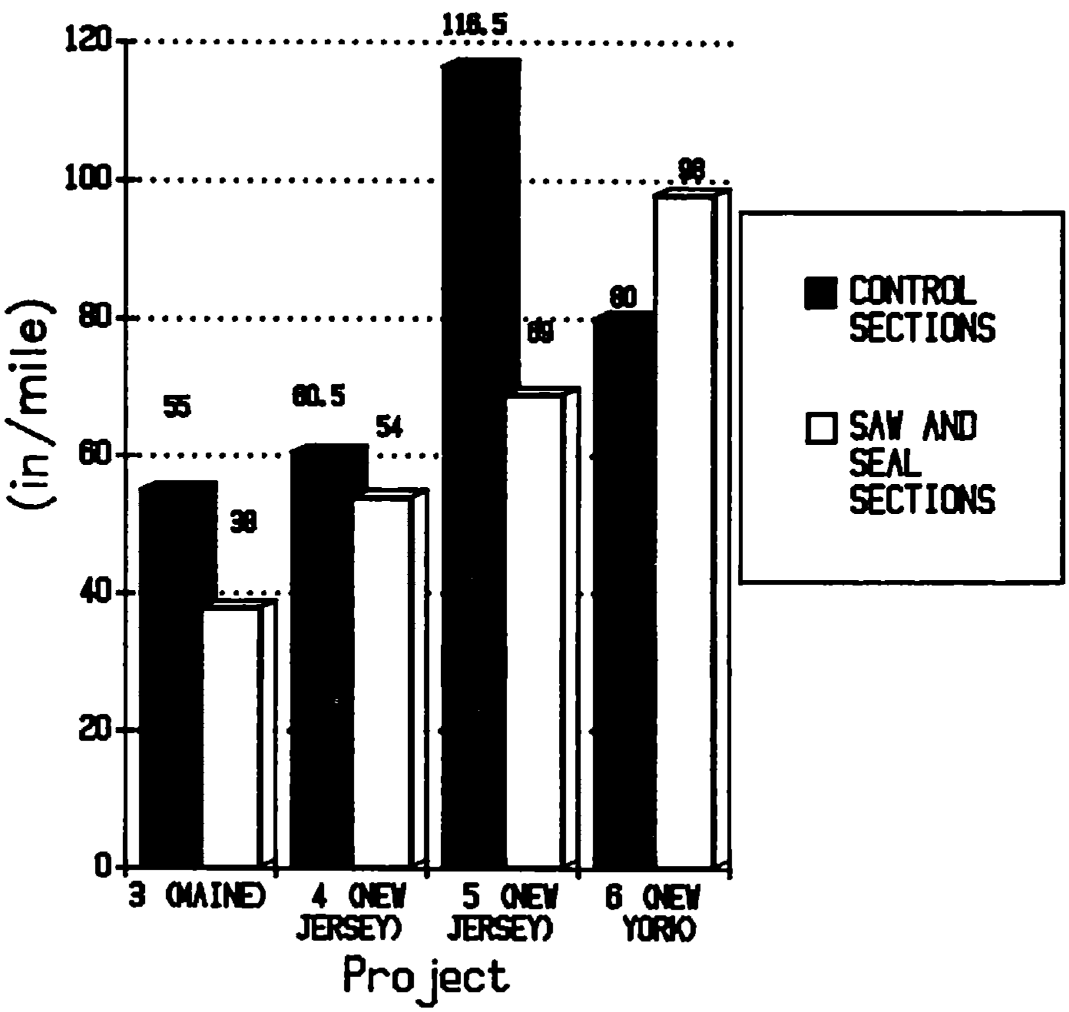


Figure 14. Comparison of roughness measurements taken on the four saw and seal overlays with control sections.

control sections. The one sawed and sealed overlay with more roughness than its adjacent control section was the overlay built on Route 5 near Caledonia, New York, in 1980. The probable cause of this overlay's poor performance was the substandard design of the overlay joint configuration. Conversations with NYDOT personnel have indicated that the joint reservoir width of 5/8 in used in this overlay was too narrow to accommodate the temperature induced horizontal movements experienced by the 90-ft long PCC slabs.[38] The large slab movement resulted in an adhesion failure of the joint sealant, which led to severe spalling and eventual failure of the joints in the AC overlay.

If the roughness measured on the sawed and sealed and adjacent control sections is compared, it is found that, on the average, the sawed and sealed overlays exhibited 20.3 percent less roughness than the control sections. Since roughness is usually considered as one of the primary indicators of pavement performance, it can be said that sawing and sealing will help extend the life of the overlay. It is difficult, however, to determine the approximate number of additional years of service that are due to the sawing and sealing technique. An average of 20 percent difference in roughness (control versus saw and seal) does not directly translate to a 20 percent increase in pavement life. Pavement life is a function of the magnitude in the change in roughness and the rate of change for each particular performance curve. It can be pointed out, though, that from a subjective evaluation, the saw and seal sections performed better than the control sections. This implies that the saw and seal section should provide a better level of serviceability for a longer period of time. Because there were only four control test sections, it is difficult to draw conclusive results about extended pavement life.

The roughness of each study section was plotted against overlay thickness to determine the effects of this variable on performance. The graph is shown in figure 15. Figure 15 shows that an inverse relationship exists between design overlay thickness and roughness. As would be expected, pavement roughness decreased as overlay thickness increased. This was found to be true for both the sawed and sealed and control sections, although the trend is less pronounced for the sawed and sealed overlays.

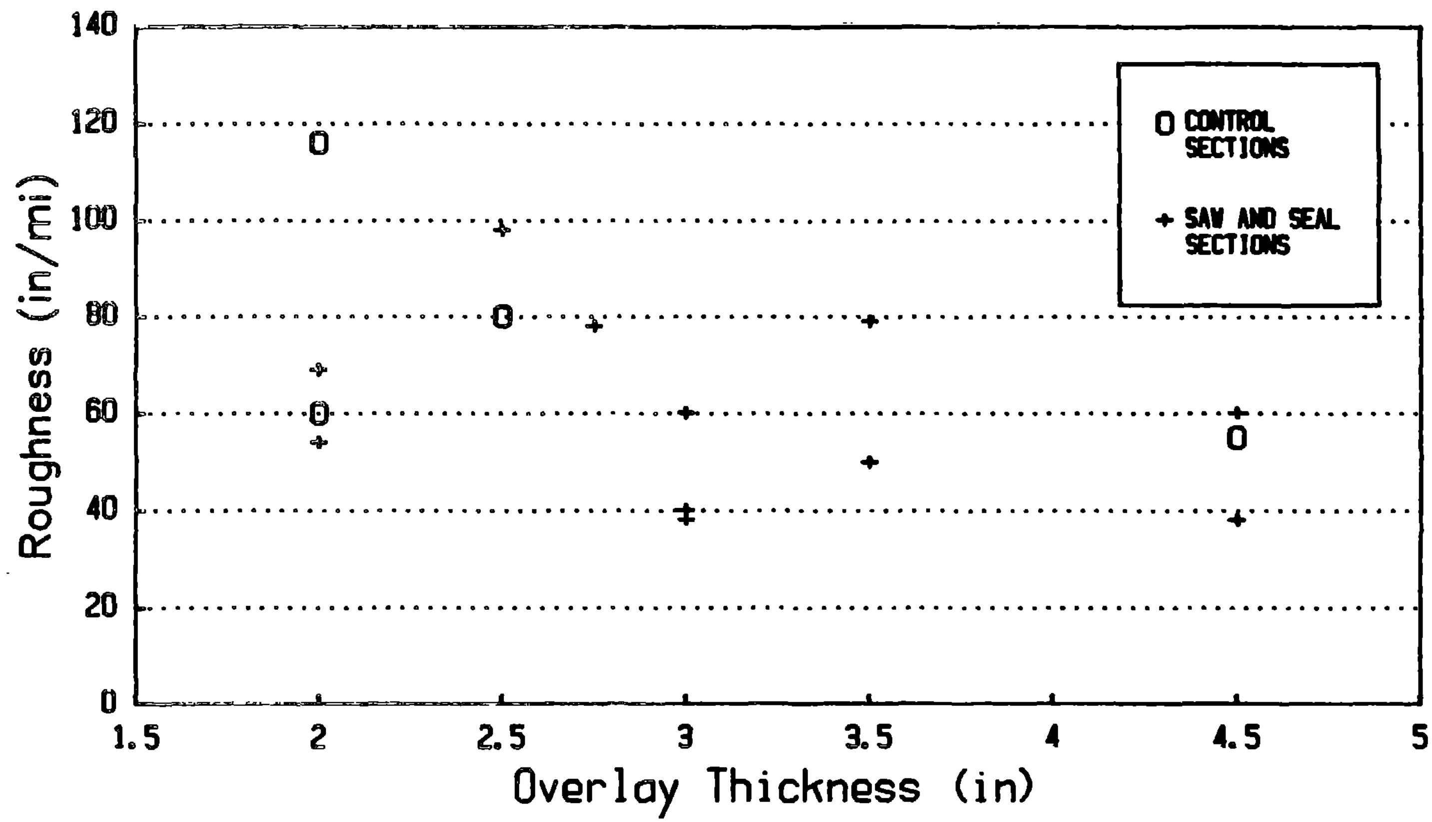


Figure 15. Pavement roughness versus AC overlay thickness.

The data point for the New Jersey control section is very high with respect to the other sections. This is the result of high traffic (12,000,000 18-kip ESALs) and a thin overlay of 2.0 in.

The roughness data were then plotted against the actual field overlay thickness normalized for traffic. Figure 16 shows the roughness versus the normalized thickness divided by ESALs. Included in the figure are both control sections and saw and seal sections. From figure 16 it can be seen that there is a slight increase in roughness as the thickness increases with decreasing traffic. This is contrary to experience, which implies that a thicker overlay will reduce roughness. Since there is a limited amount of data points, no significant conclusions can be drawn from this figure.

SAWED AND SEALED OVERLAY DISTRESS

The primary goal when designing a pavement is to design and construct a structure able to support the estimated axle loads expected during its design life and to withstand the adverse effects of the environment. These traffic loadings and environmental effects cause stresses, strains, and deflections in the pavement system. It is the accumulation of these permanent strains and the repeated application of stress which can cause the limiting strains of the material involved to be exceeded, and causes pavement distress in the form of fracture or permanent deformation. This distress represents a materials failure but not necessarily a failure of the total pavement structure. Failure of the pavement structure occurs only when the accumulation of distress results in a lowering of the pavement's serviceability below a minimum acceptable level.

Hudson et al. have identified the most important distresses that affect the performance of an AC-overlaid PCC pavement.[39] Two of the more important were found to be reflection cracking and rutting. The occurrences of reflection cracking observed during the field surveys is discussed in the following sections.

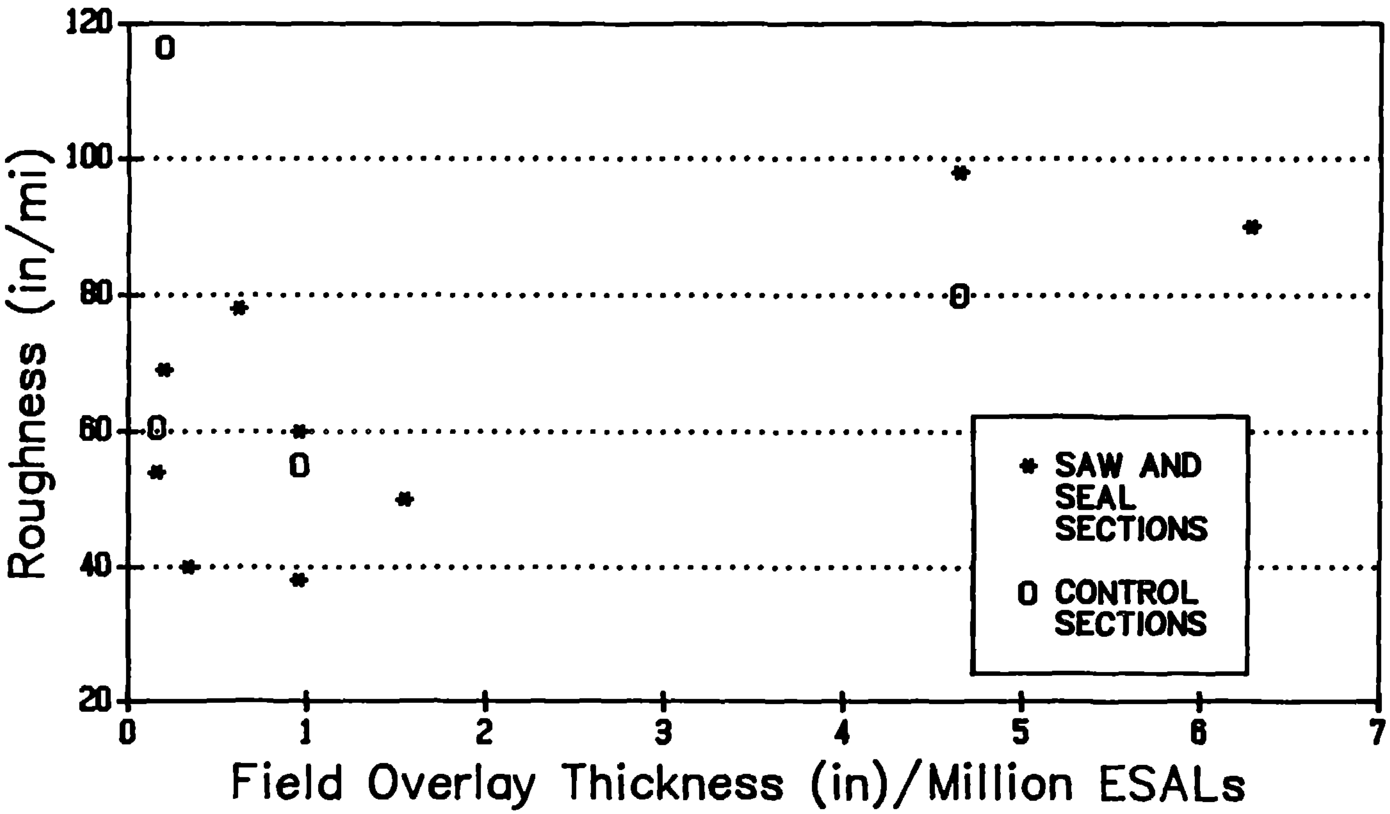


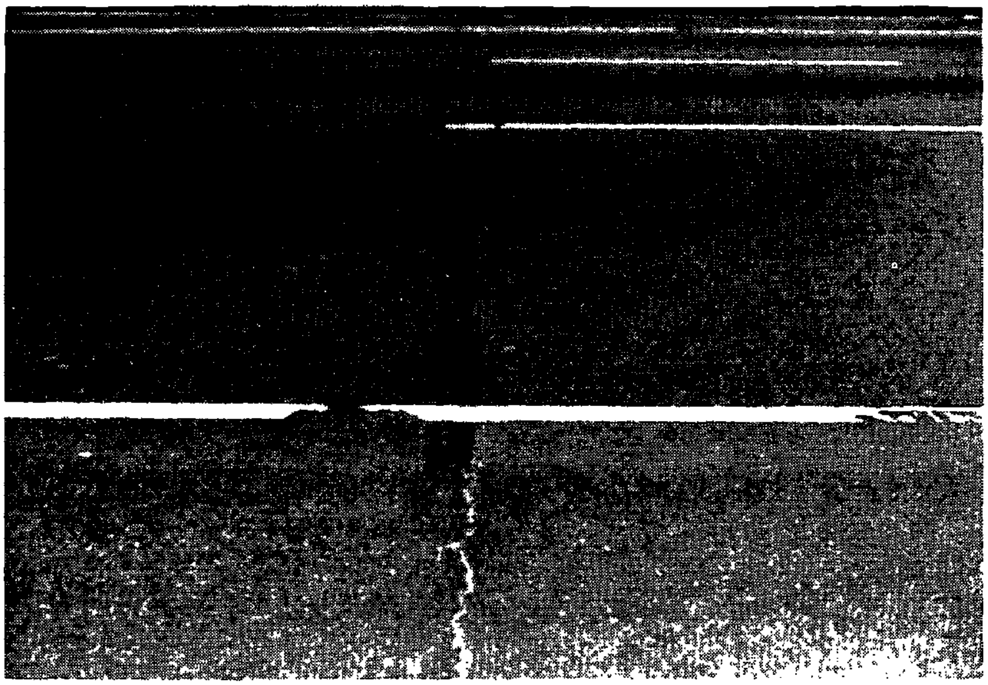
Figure 16. Pavement roughness versus overlay thickness divided by traffic since overlay.

Transverse Joint Reflection Cracking

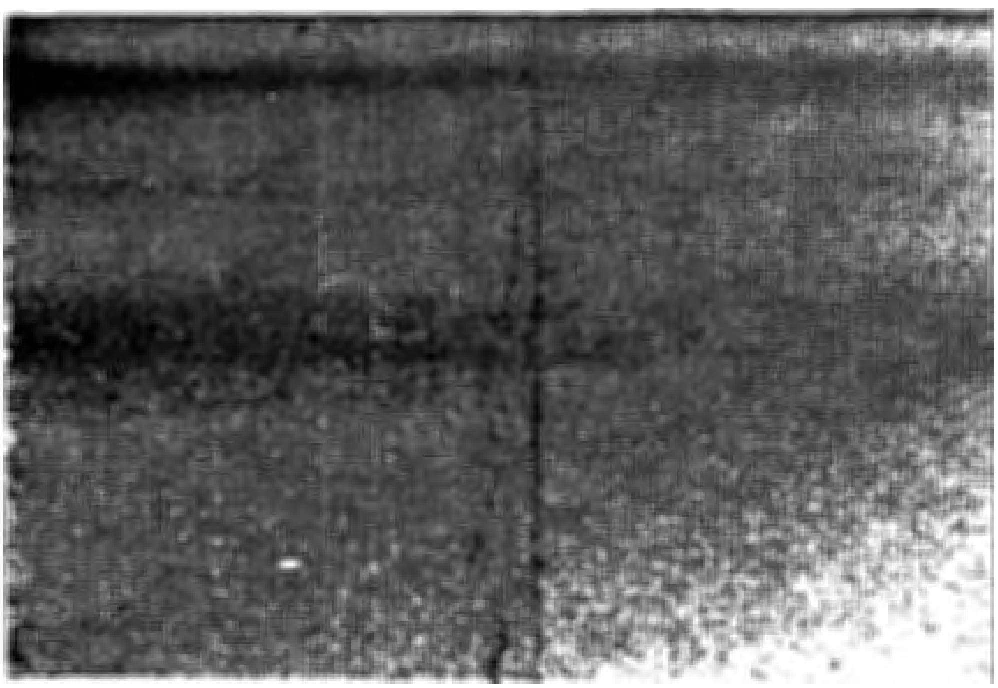
Joint reflection cracks are a common distress manifestation for AC overlays of PCC, the causes of which were discussed in detail in chapter 2. After these cracks have developed and the stress is relieved in the overlay, it is possible that little further deterioration will occur. However, where heavy traffic loads, substantial differential vertical movements, or asphalt hardening are present, the AC near the initial crack can break down and progressively deteriorate beyond a small, narrow crack. Spalling can result, which significantly widens the crack (see the photos in figures 21 to 24), resulting in an overlay that, in a short period of time, can have a worse riding surface than the original pavement before it was rehabilitated.[21]

The construction of a joint in the AC overlay is supposed to alleviate these problems. However, during the field surveys it became apparent that a related problem existed. This was the appearance of secondary cracking adjacent to and paralleling the sawed joint. This type of distress appeared on many of the joints in the sawed and sealed overlays. The cause of this secondary cracking is not known for certain. It can be the result of a tear due to low tensile strength because of poor mix design or other thermal type cracking. In most cases, especially for cracks appearing several inches from the joint, they can probably be attributed to the improper location of the sawed joints above the underlying joints in the PCC. Secondary cracks as close as 1 in from the saw joint were observed. This implies that it is crtical to locate the saw cut directly above the joint. A saw cut more than 1 in away can result in secondary cracking. An example of secondary cracking is shown in the photos in figure 17. It should be noted that asphaltic concrete and PCC concrete have different mechanical properties especially with regard to elastic modulus.

Another hypothesis that seems plausible is the one put forth by Darter and Barenburg to explain secondary cracking in somewhat similar rehabilitation technique--bonded concrete overlays.[40] They suggest that this cracking initiates before the saw cut is made and propagates to the



(a)



(b)

Figure 17. Secondary cracking on (a) I-84, New Britain, CT and (b) I-80, West Paterson, NJ.

surface at random angles. If the crack growth is not too great in the wrong direction at the time the saw cut is made, the crack will supposedly redirect its path to meet the saw cut. However, if the sawing operation is delayed for too long, a secondary crack may develop as illustrated in figure 18. Therefore, it is important to saw the asphaltic concrete as soon as possible after the overlay has been placed. If traffic is placed on the overlay, or if there is a significant change in ambient temperature, the asphaltic concrete may experience secondary cracking.

It has also been suggested that this cracking can be caused by badly spalled joints in the existing PCC pavement.[40] Supposedly, if the spall is not repaired prior to overlay, replacing the spalled concrete may cause a secondary crack to develop at a location other than a point directly over the existing joint.

While these theories were first put forth to explain secondary cracking in PCC concrete overlays, it seems reasonable to expect that these same mechanisms may cause secondary cracking in AC overlays of PCC.

Because core samples were not taken at the location of reflective cracks, it is not known whether these cracks occurred due to secondary cracking or because the joints were missawed. For this reason, in the remainder of this report it shall be understood that when reflection cracking of sawed and sealed overlays is mentioned, it refers to either missawed joints or secondary cracking.

The amount of transverse joint reflection cracking observed on each study section during the field surveys is illustrated in figure 19. It can be seen that there was a wide variation in the amount of reflection cracking present on the overlays. Six of the sawed and sealed overlays had experienced low and medium severity transverse reflection cracking of from 4 to 46 percent of the transverse joints. The five remaining sawed and sealed overlays were totally free of any transverse reflection cracking. The only overlay with high severity cracking was the sawed and sealed overlay on Route 5 in Caledonia, New York, which had experienced high severity cracking on approximately 12 percent of its joints.

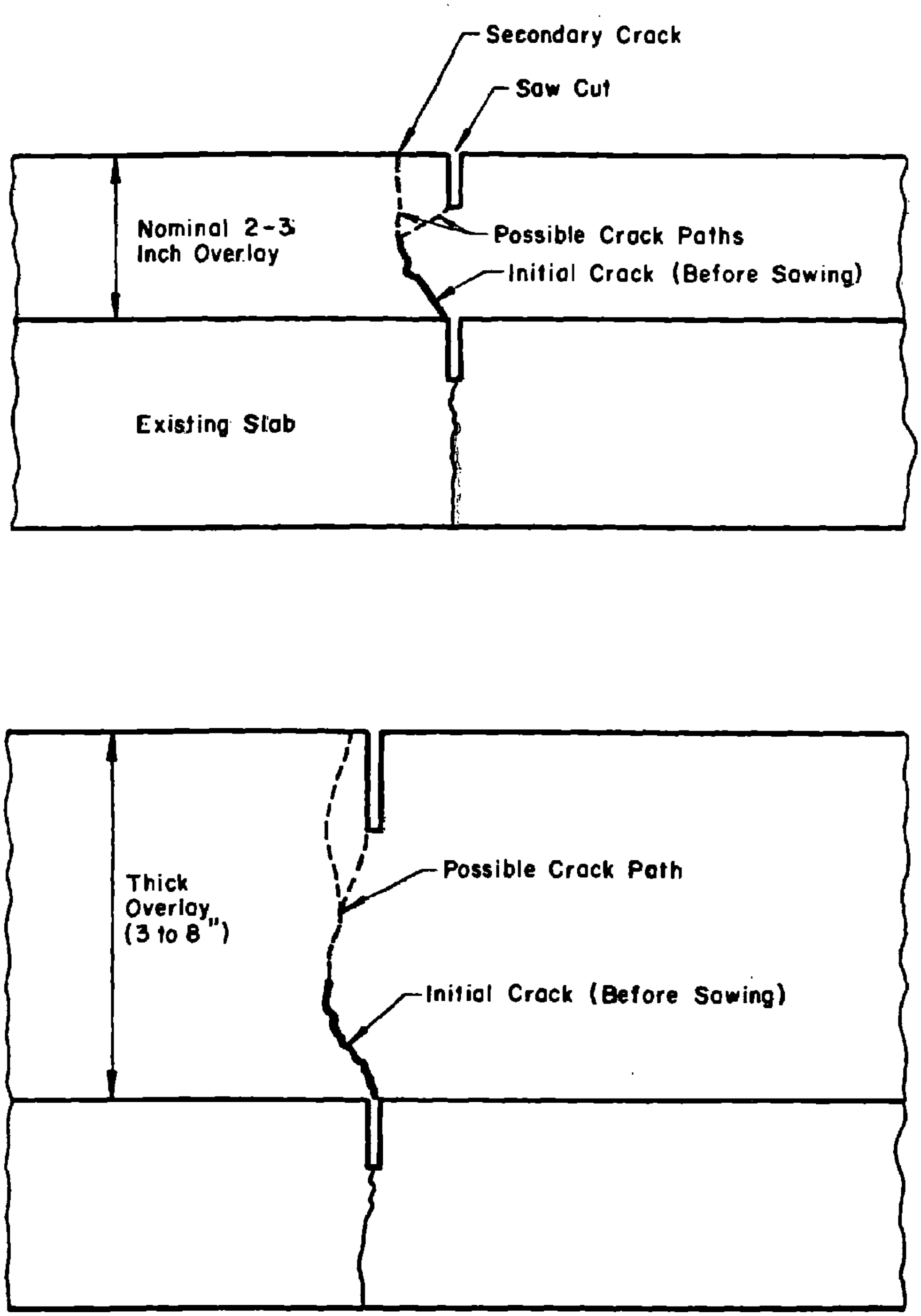


Figure 18. Possible causes of secondary cracking in nominal and thick overlays.

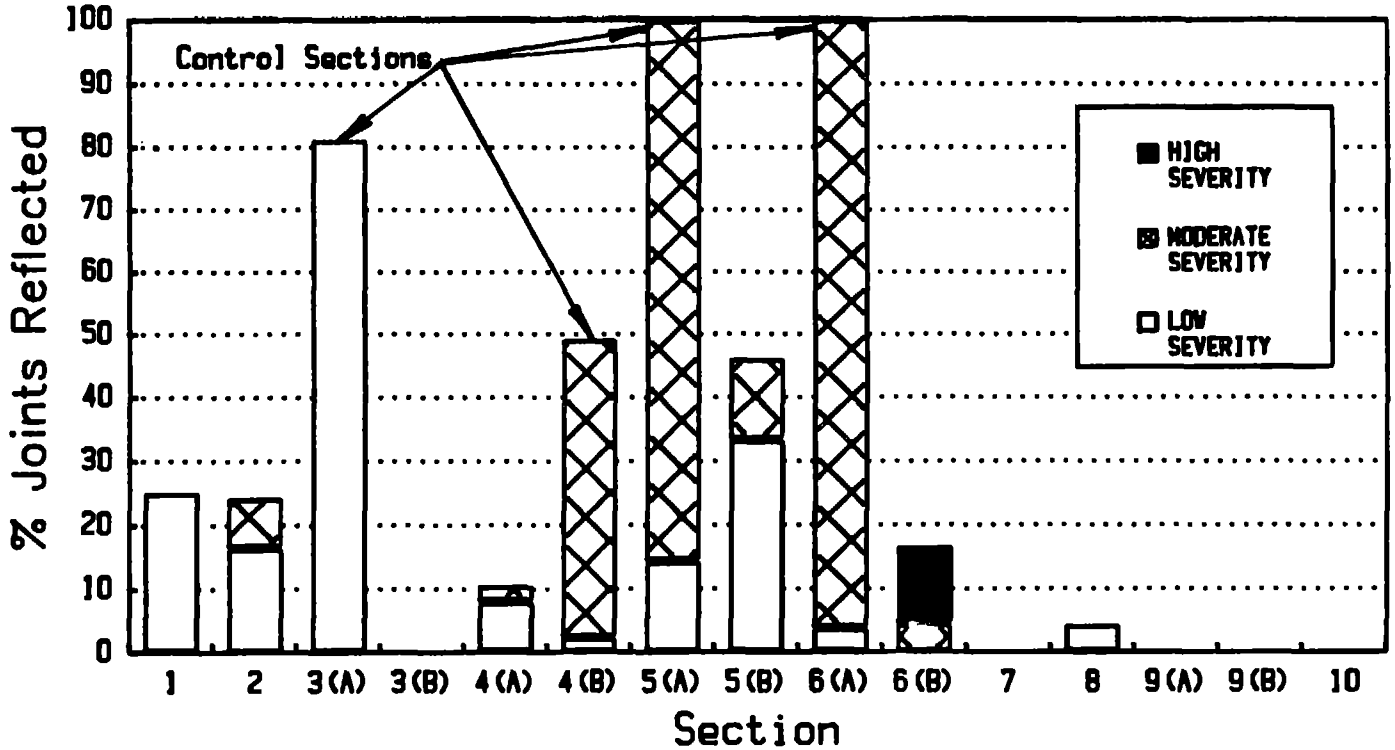


Figure 19. Distribution of transverse joint reflection cracking on the 15 pavement sections.

The amount of transverse reflection cracking measured on the four sawed and sealed overlays is compared with the amount measured on their control sections in figure 20. It can be seen that all of the control sections experienced more reflection cracking than the pavement sections with sawed and sealed joints. One hundred percent of the underlying joints had reflected through on two of the control sections, while the remaining two control sections experienced transverse reflection cracking on 81 and 49 percent of their joints. The percentage of transverse reflection cracking on the sawed and sealed overlays varied between 0 and 46.1 percent. The average percentage of transverse joints that had reflected through the control overlays was 83 percent, while on the sawed and sealed overlays this figure was 18 percent. Using this comparison it can be said that the sawed and sealed overlays experienced approximately 65 percent less transverse reflection cracking than the control sections.

The condition of the sawed and sealed and control overlays at the location of the underlying joints in the PCC slab is compared pictorially in figures 21 to 24. It can be seen in the photos that the control sections had developed transverse cracks with severe spalling. The saw and seal joints were in excellent condition and did not show any signs of spalling or raveling. In a subjective comparison, the photos show that the saw and seal sections are performing much better than the control sections.

Variables such as age, joint spacing normalized by thickness, field thickness, and roughness were plotted against transverse reflection cracking to determine what, if any, trends were present. These plots are shown in figures 25 through 28, respectively. The plot of transverse reflection cracking versus age shows that more cracking occurred in the control sections than on the sawed and sealed overlays, as was discussed previously. The amount of reflection cracking observed on the sawed and sealed overlays remained rather constant with age. This could suggest that if reflection cracking is to occur on a sawed and sealed overlay due to missawed joints or secondary cracking, it will occur shortly after the overlay is constructed and remain relatively constant throughout its life.

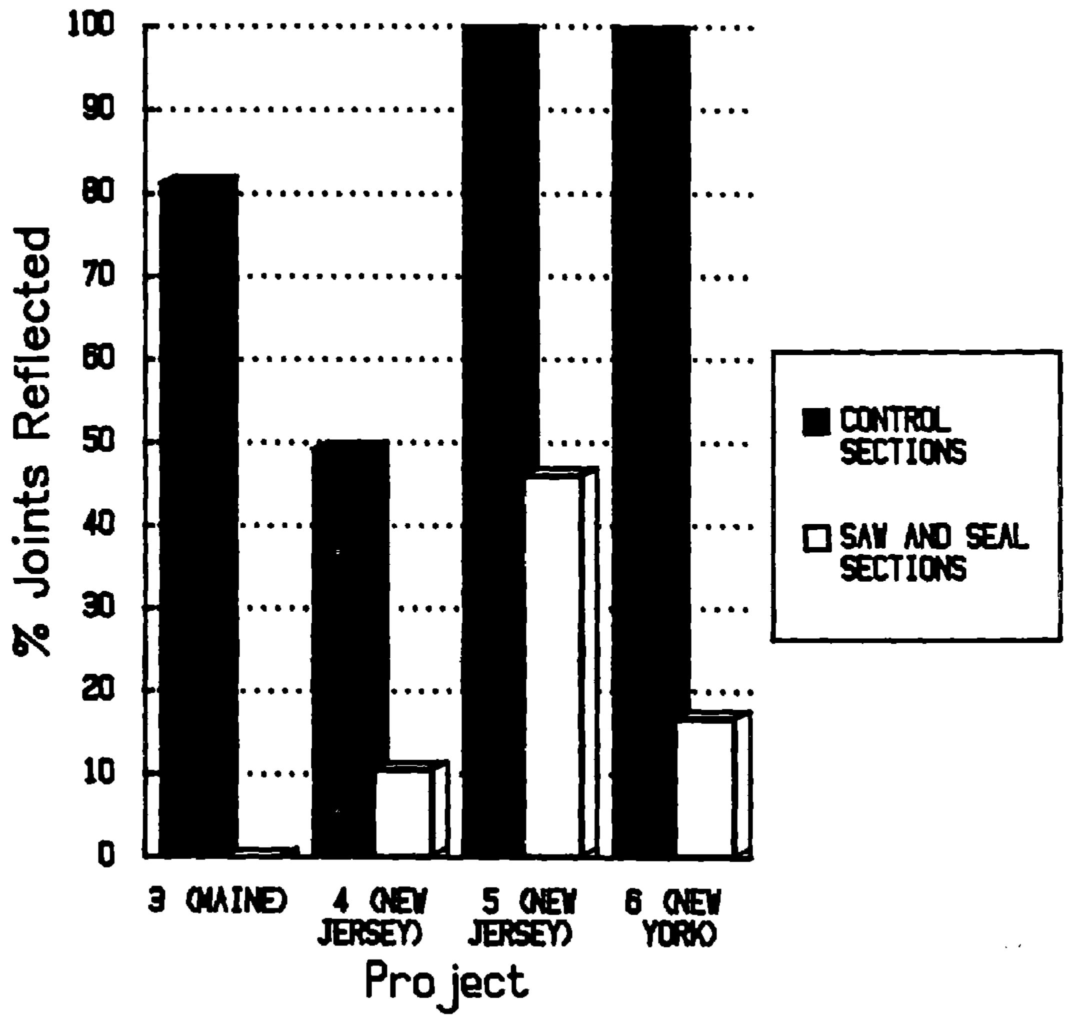
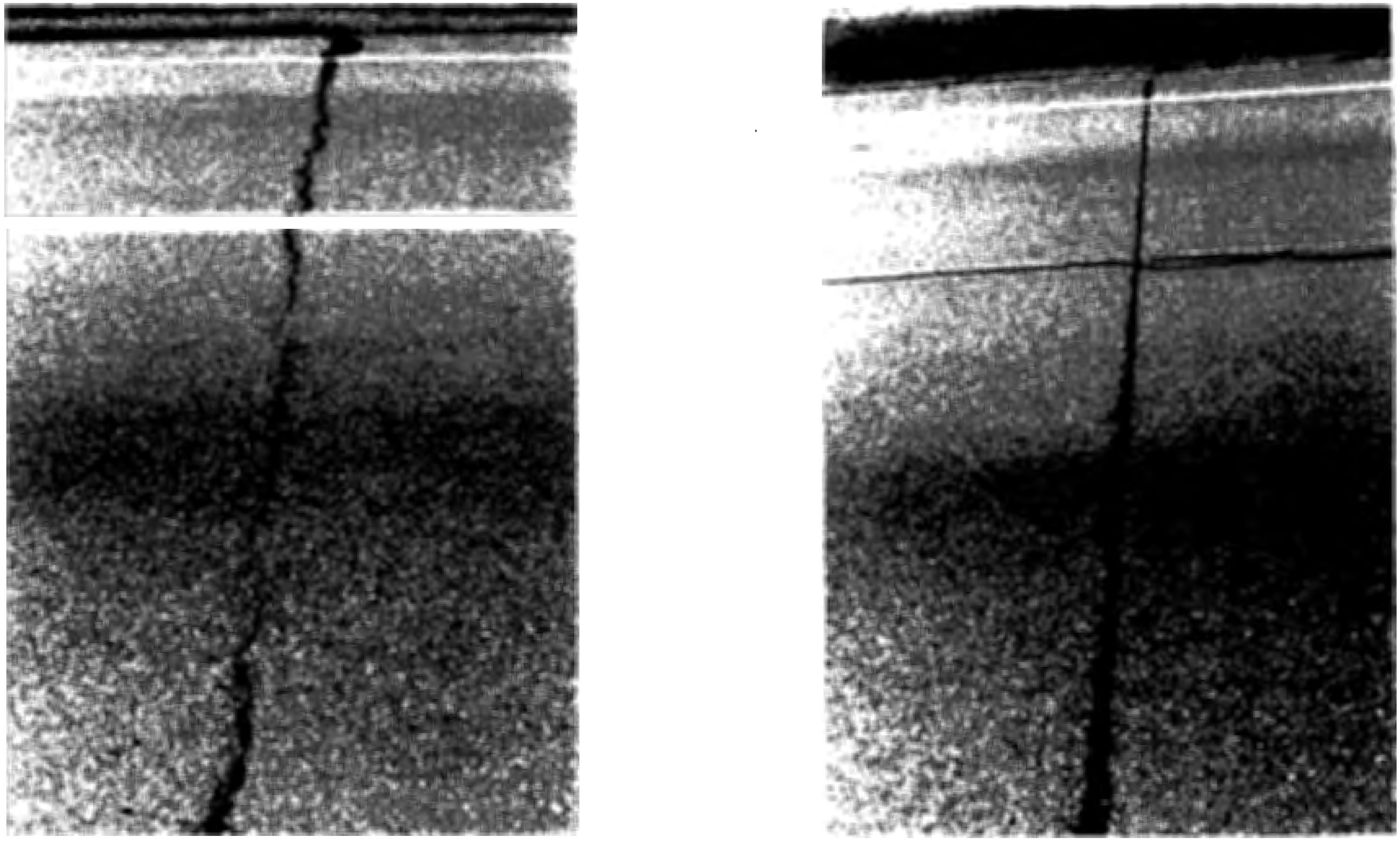
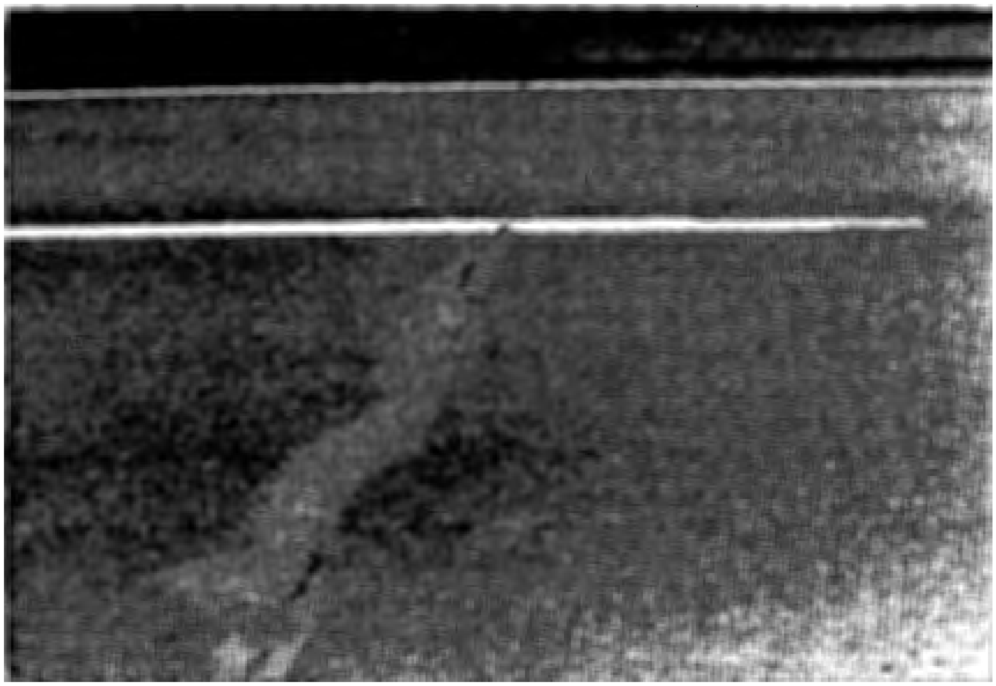


Figure 20. Comparison of transverse joint reflection cracking observed on the four saw and seal overlays with control sections.

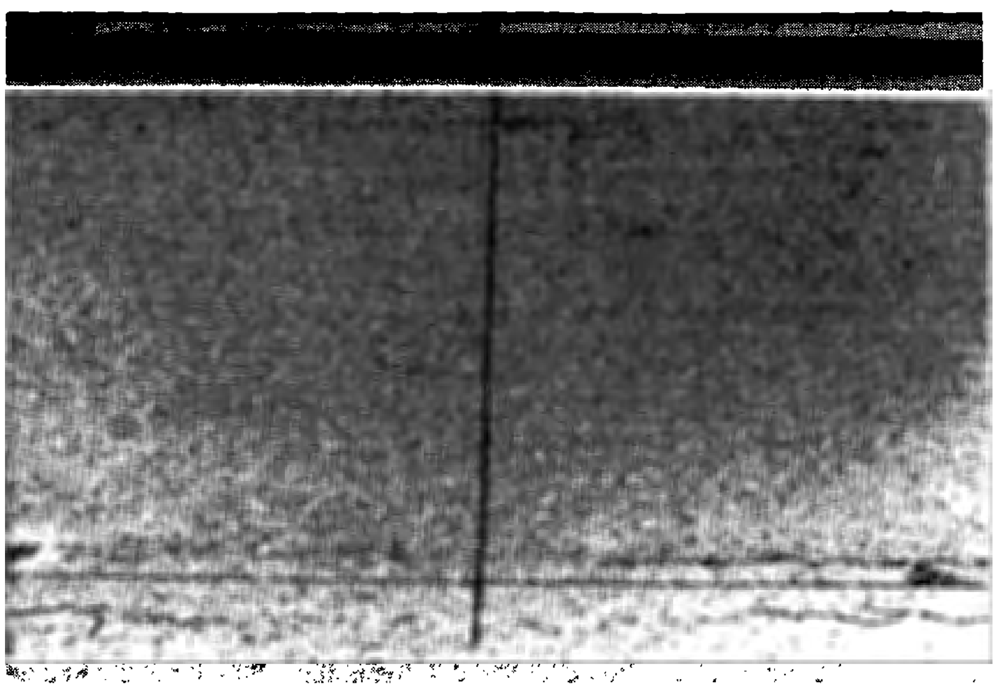


(a) (b)

Figure 21. Overlay condition of (a) control section, and (b) saw and seal section on I-95, Falmouth, ME.

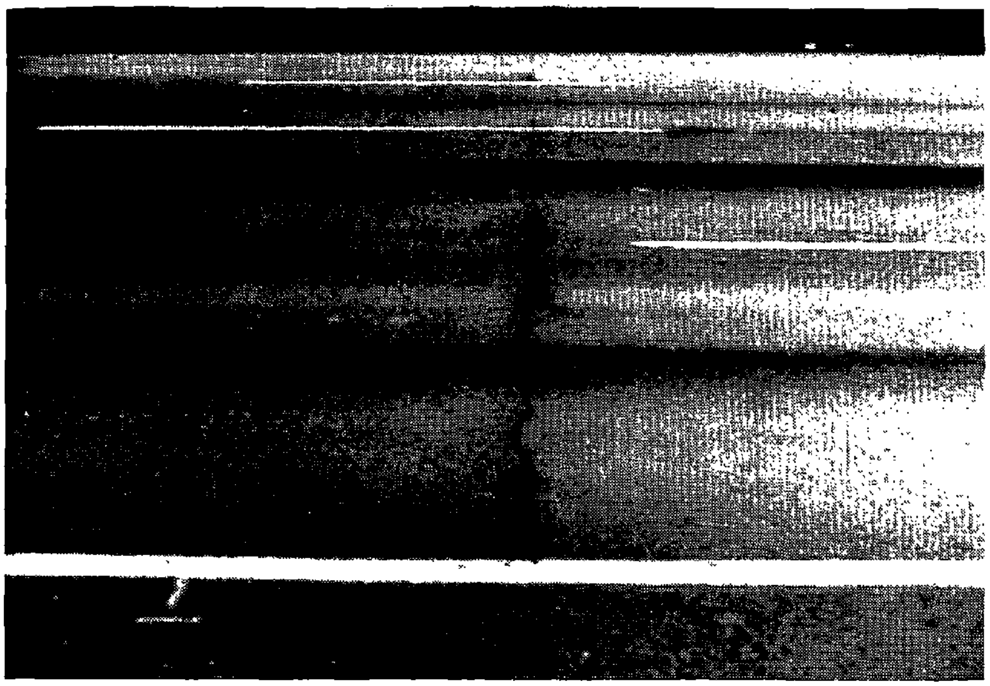


(a)

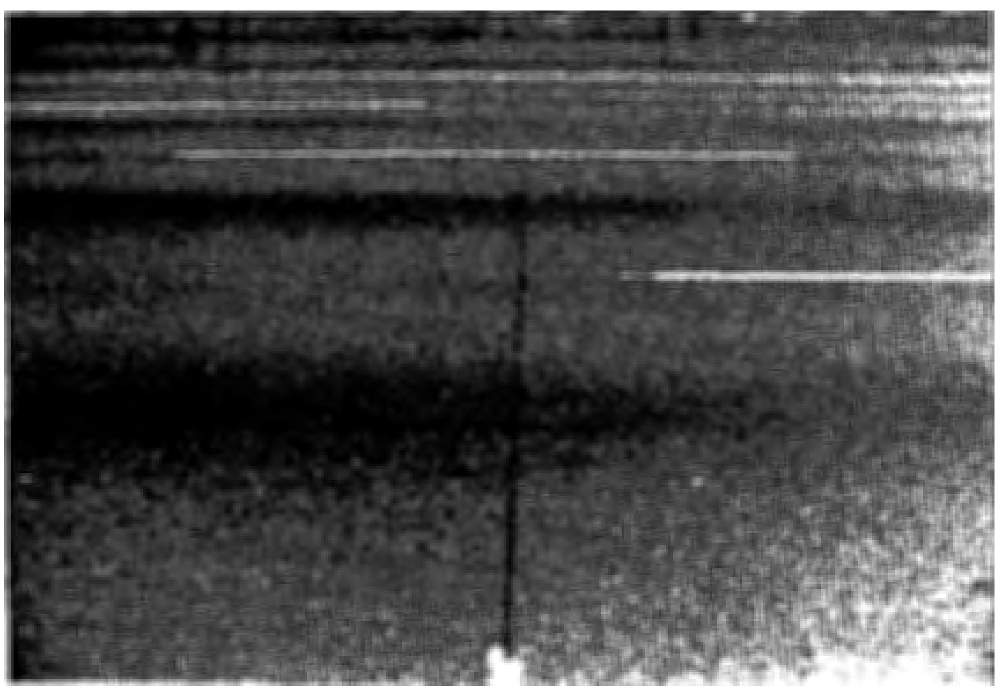


(b)

Figure 22. Overlay condition of (a) control section, and (b) saw and seal section on US-22, Somerville, NJ.

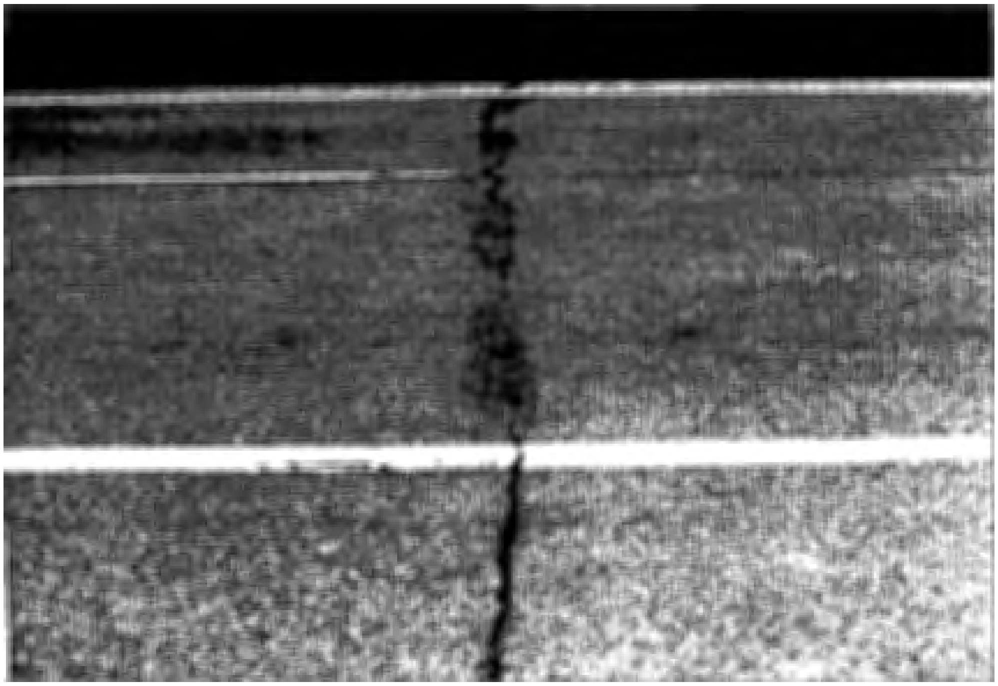


(a)

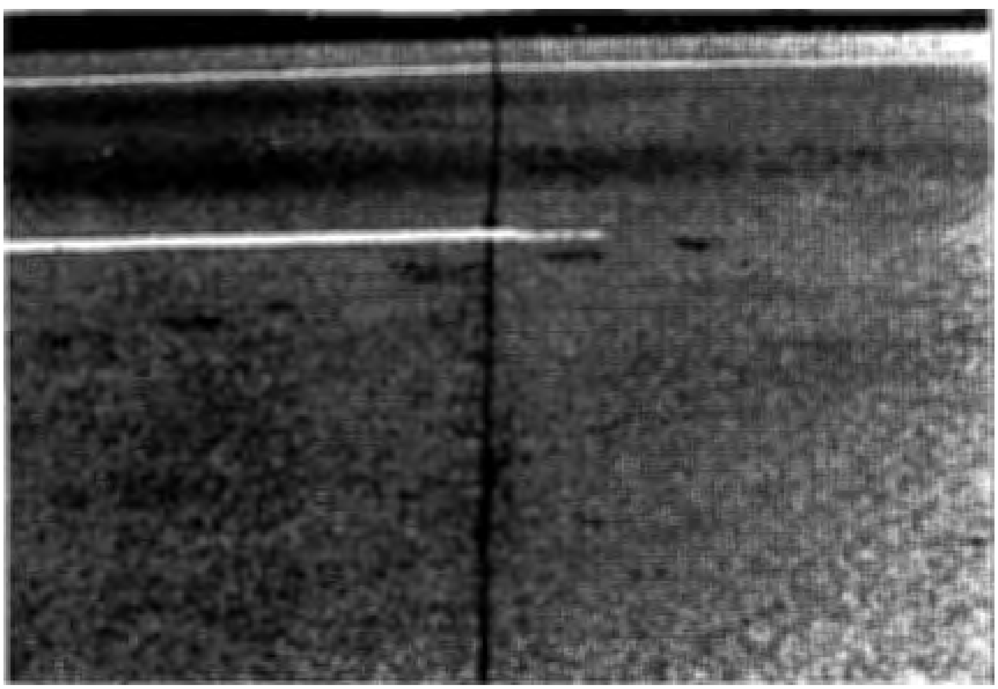


(b)

Figure 23. Overlay condition of (a) control section, and (b) saw and seal section on I-80, West Paterson, NJ.



(a)



(b)

Figure 24. Overlay condition of (a) control section, and (b) saw and seal section on Route 5, Caledonia, NY.

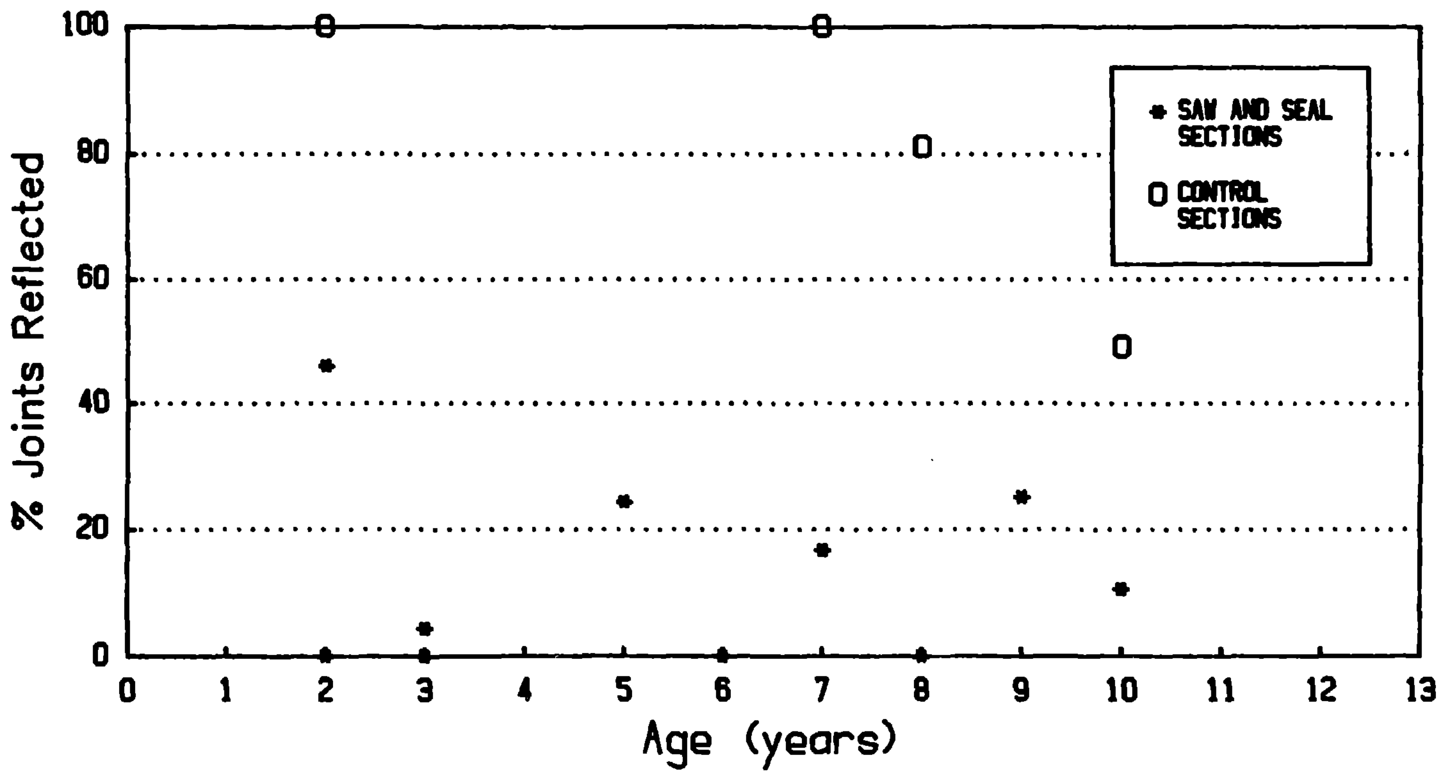


Figure 25. Percentage of transverse joints reflected versus overlay age.

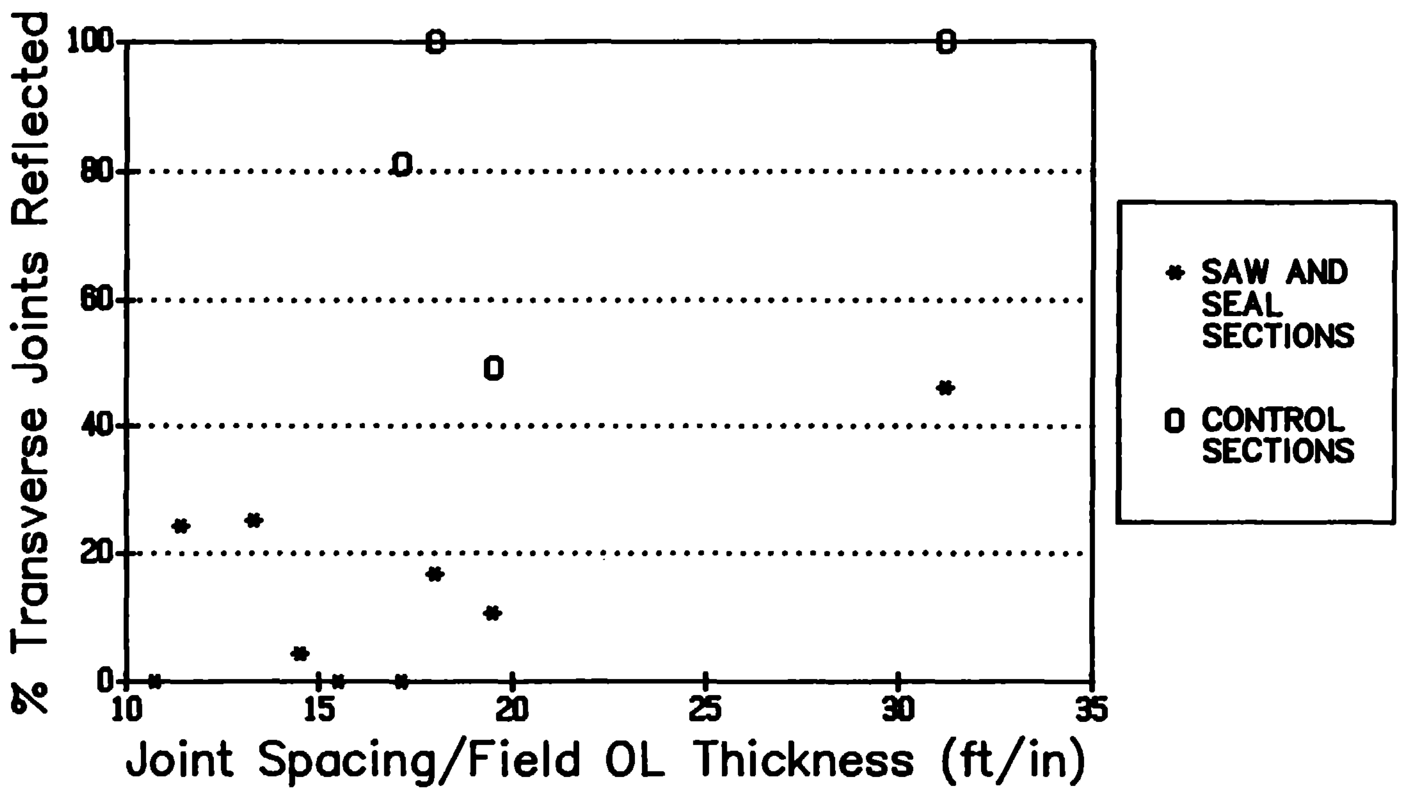


Figure 26. Percentage of transverse joints reflected versus joint spacing divided by overlay thickness.

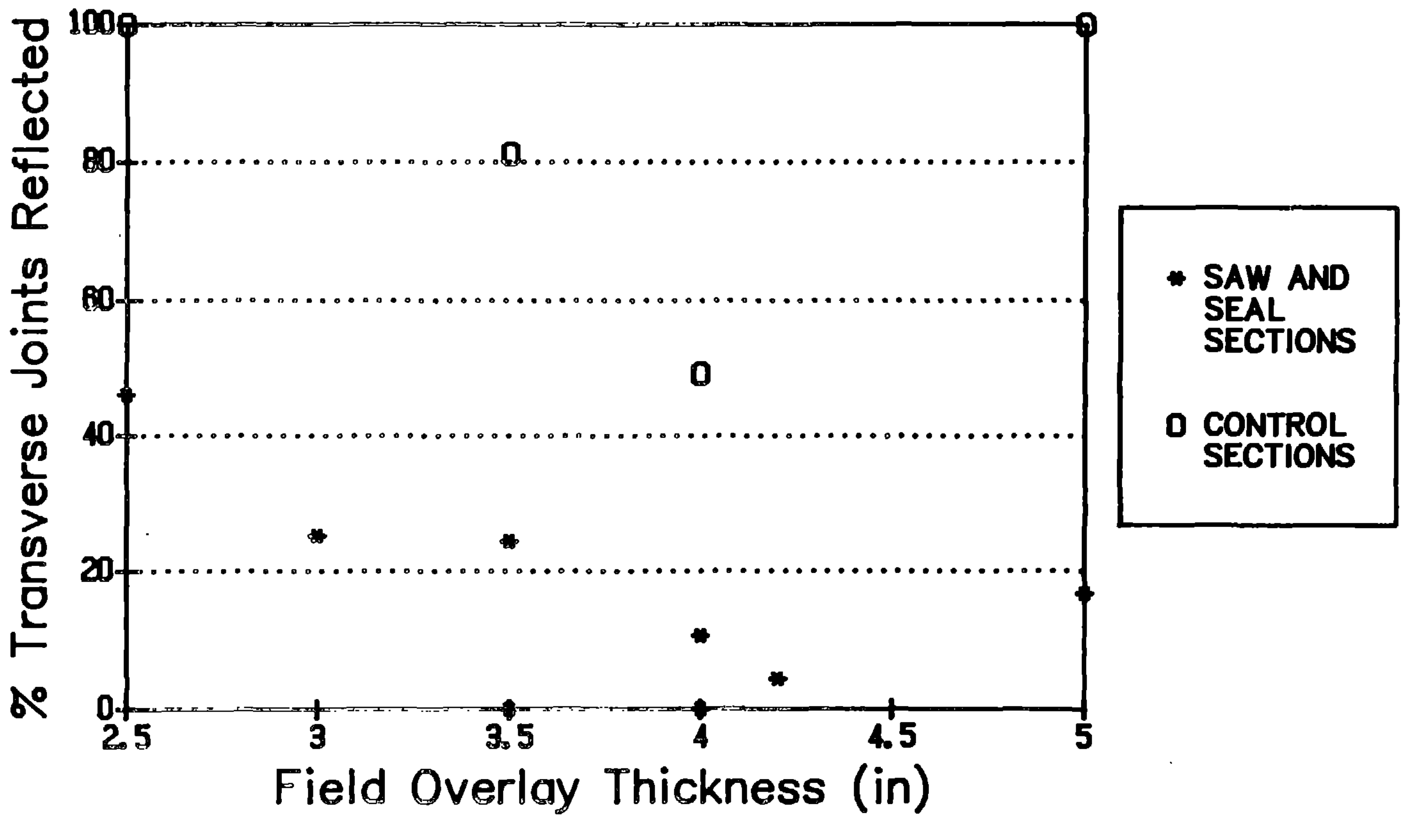


Figure 27. Percentage of transverse joints reflected versus overlay thickness.

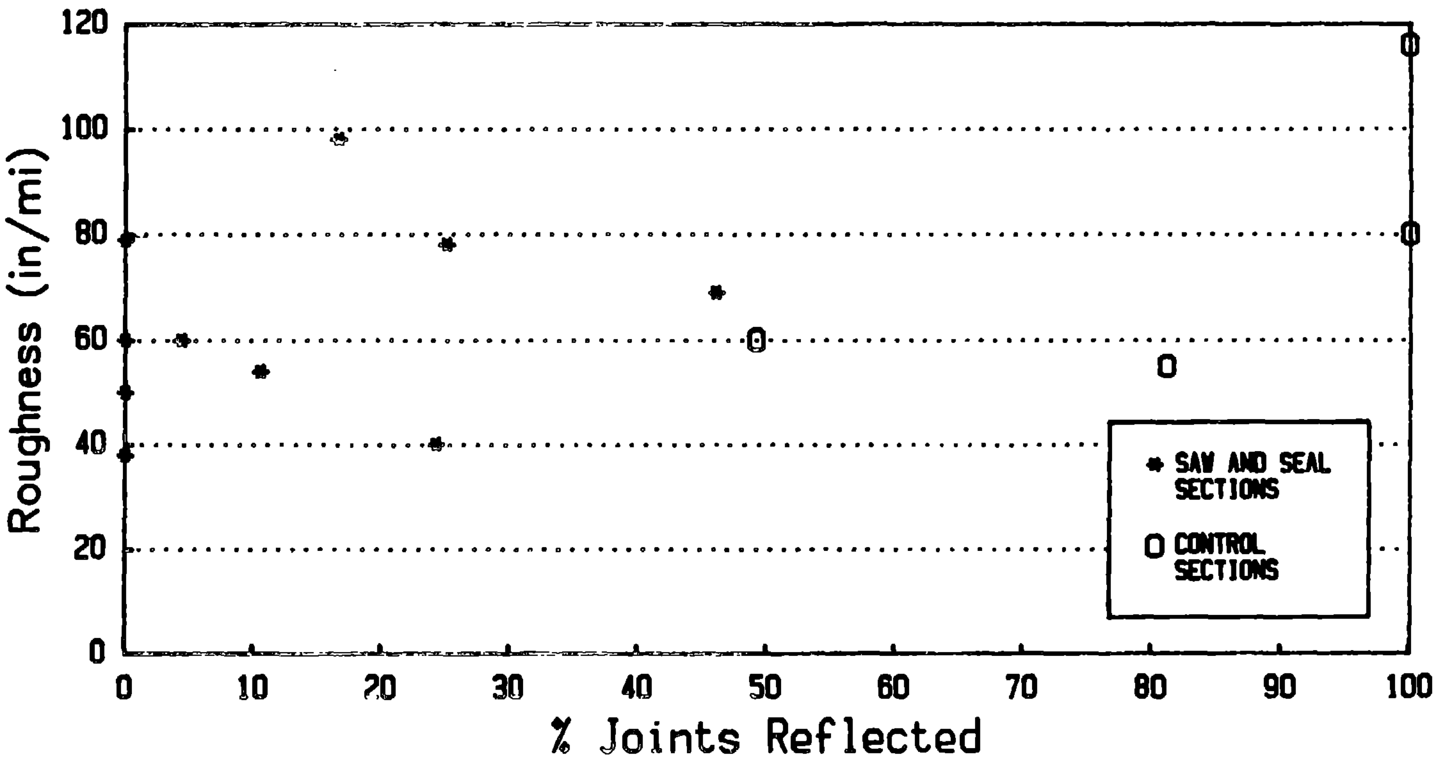


Figure 28. Pavement roughness versus transverse joint reflection cracking.

Figure 26 shows the plot of reflected cracking versus joint spacing normalized by thickness. According to the plot, 0 to 30 percent reflection cracking takes place on saw and seal sections; 45 to 100 percent on control sections. It appears that neither joint spacing nor overlay thickness has an effect on reflected cracking.

A similar trend is seen in figure 27, which shows reflected joints versus overlay thickness. The saw and seal section had less reflection cracking than the control section, and it does not appear that thickness has any effect on the amount of cracking on the saw and seal sections.

The plot of roughness versus reflected joints is shown in figure 28. This plot shows that the saw and seal sections had a slight increase in roughness as the number of reflection joints increased. The same trend occurred for the control sections except at a higher degree of roughness.

Longitudinal Joint Reflection Cracking

Longitudinal joint reflection cracking occurs in the AC overlay above the longitudinal joint between lanes in the underlaying PCC pavement. This type of distress is caused mainly by movement of the underlying PCC slab caused by thermal and moisture changes, although traffic loadings may cause a breakdown of the AC at the initial crack, resulting in spalling.[41]

The amount of longitudinal joint reflection cracking observed on each study section is illustrated in figure 29. As was the case with transverse reflection cracking, there was a wide variation in the amount of reflection cracking present on the overlays. Eight of the sawed and sealed overlays experienced low to high severity reflection cracking of from 9 to 100 percent of the longitudinal joints. The three remaining sawed and sealed overlays were totally free of any transverse reflection cracking.

Projects 4(A) and 5(B) were the only two overlays that had sawed and sealed joints constructed over the longitudinal joints. These overlays were on I-80 in West Paterson, N.J., and on U.S. 22 in Somerville, N.J. These

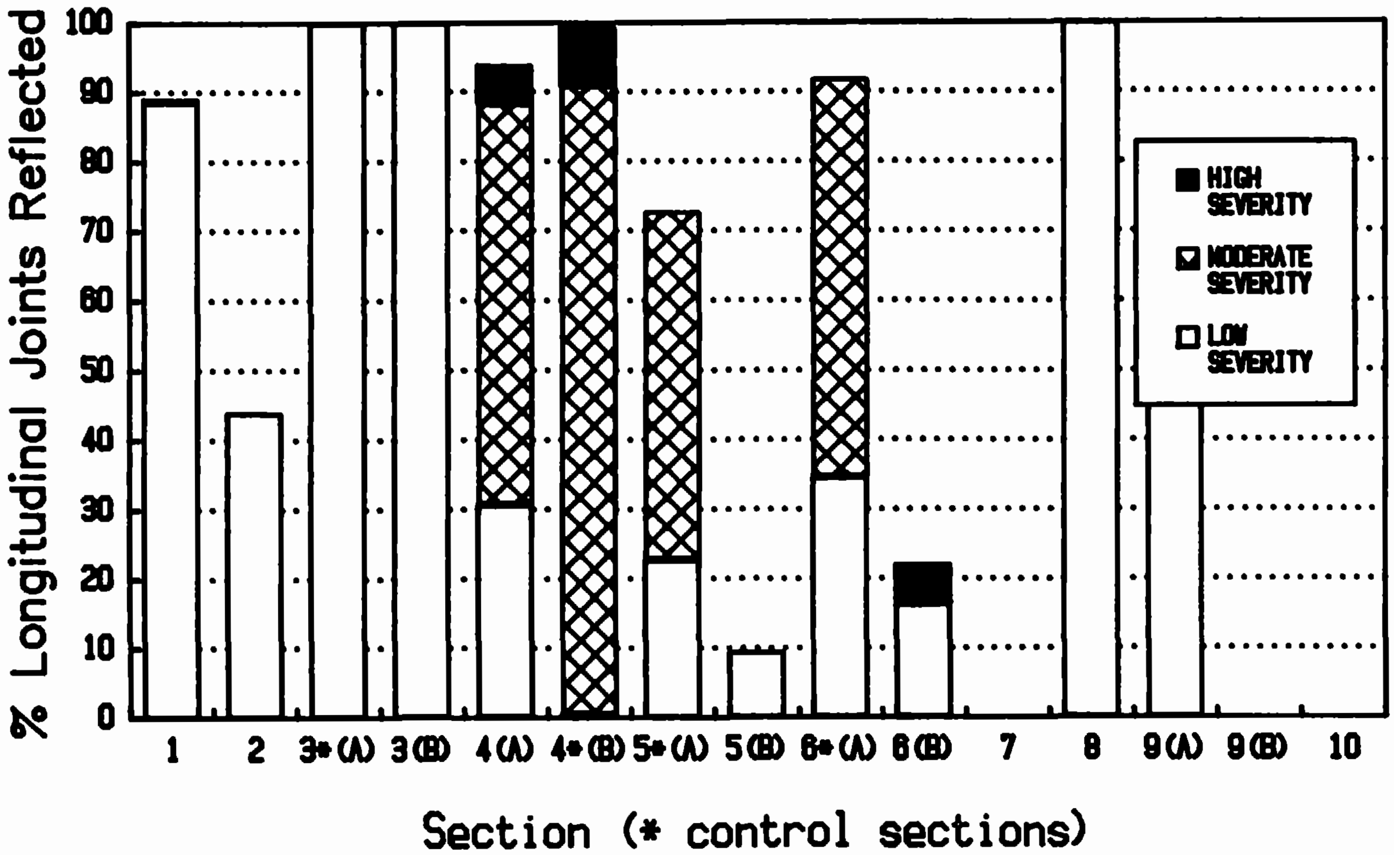


Figure 29. Distribution of longitudinal joint reflection cracking on the 15 pavement sections.

efforts resulted in a reduction in longitudinal reflection cracking of approximately 5 percent on U.S. 22 and 63 percent on I-80.

DEFLECTION MEASUREMENTS

Nondestructive testing of the 11 saw and seal overlays was conducted using a falling weight deflectometer (FWD) as described previously. The deflection measurements obtained on the 11 sawed and sealed overlays are summarized in table 16. It can be seen that there was a wide variation in the measured midslab deflections; from a low of 1.10 mils to a high of 6.30 mils. Transverse joint load transfer efficiency varied from 78.6 percent to 108.3 percent (adjusted). This level of load transfer implies good to excellent load transfer.

The roughness of each study section was plotted against average load transfer efficiency as shown in figure 30. As expected, the roughness of the sawed and sealed overlays increased sharply as load transfer decreased.

The plots of load transverse versus transverse and longitudinal reflection cracking shown in figures 31 and 32 did not reveal any noticeable trends. Corner deflection profiles were plotted for the sawed and sealed overlays. These are presented in the appendix.

Table 16. Summary of falling weight deflectometer measurements.

Project Number	Section ID	Original PCC Pav't Thickness (in.)	Joint Spacing (ft.)	Deflection (mils) Midslab High	Midslab Low	Midslab Avg.	Leave Slab Avg.	Approach Slab Avg.	Load Transfer Efficiency (%)
1	CT 1	9.0	40.0	4.40	2.80	3.67	5.21	3.78	107.35
2	CT 4	9.0	40.0	4.50	2.70	3.60	6.33	5.14	103.21
3(A)	ME 1-1	8.0	60.0	-	-	-	-	-	-
3(B)	ME 1-2	8.0	60.0	5.10	4.40	4.65	14.23	9.17	84.64
4(A)	NJ 4-1	9.0	78.0	3.80	2.40	2.88	6.40	3.67	85.25
4(B)	NJ 4-2	9.0	78.0	-	-	-	-	-	-
5(A)	NJ 5-1	9.0	78.0	-	-	-	-	-	-
5(B)	NJ 5-2	9.0	78.0	4.80	3.90	4.34	5.97	4.20	91.32
6(A)	NY 3-1	9.0	90.0	-	-	-	-	-	-
6(B)	NY 3-2	9.0	90.0	6.30	2.80	4.58	10.43	5.58	78.65
7	NY 4	9.0	43.0	4.20	2.80	3.24	7.65	6.04	96.64
8	NY 5	9.0	61.0	5.00	3.00	3.68	9.28	5.79	93.23
9(A)	OH 3-1	9.0	15.0	1.90	1.20	1.36	2.32	1.87	99.78
9(B)	OH 3-2	9.0	15.0	1.90	1.10	1.57	2.75	2.39	108.29
10	PA 2	9.0	62.0	2.50	1.50	1.96	5.22	3.33	79.55

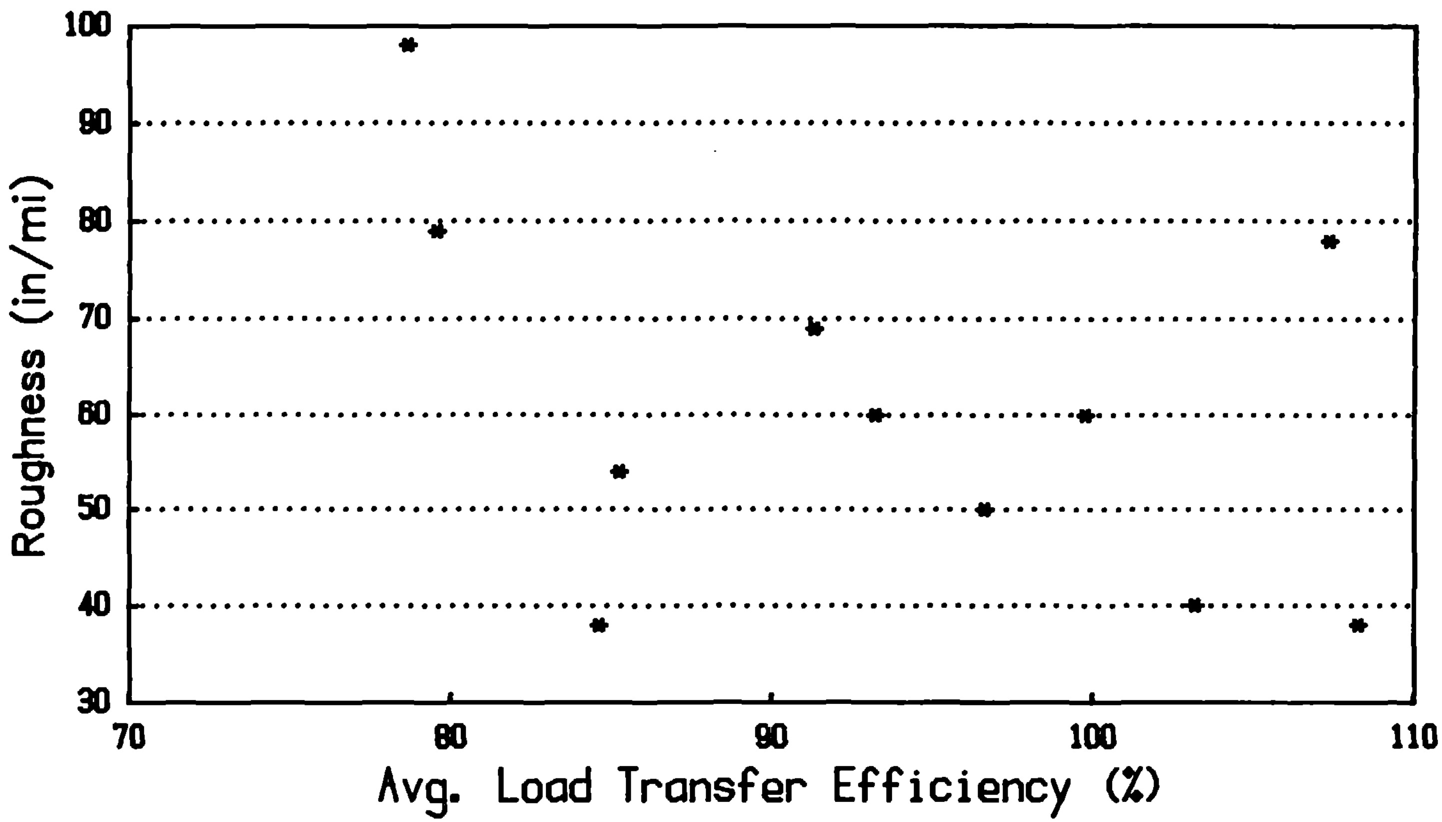


Figure 30. Pavement roughness versus average load transfer efficiency.

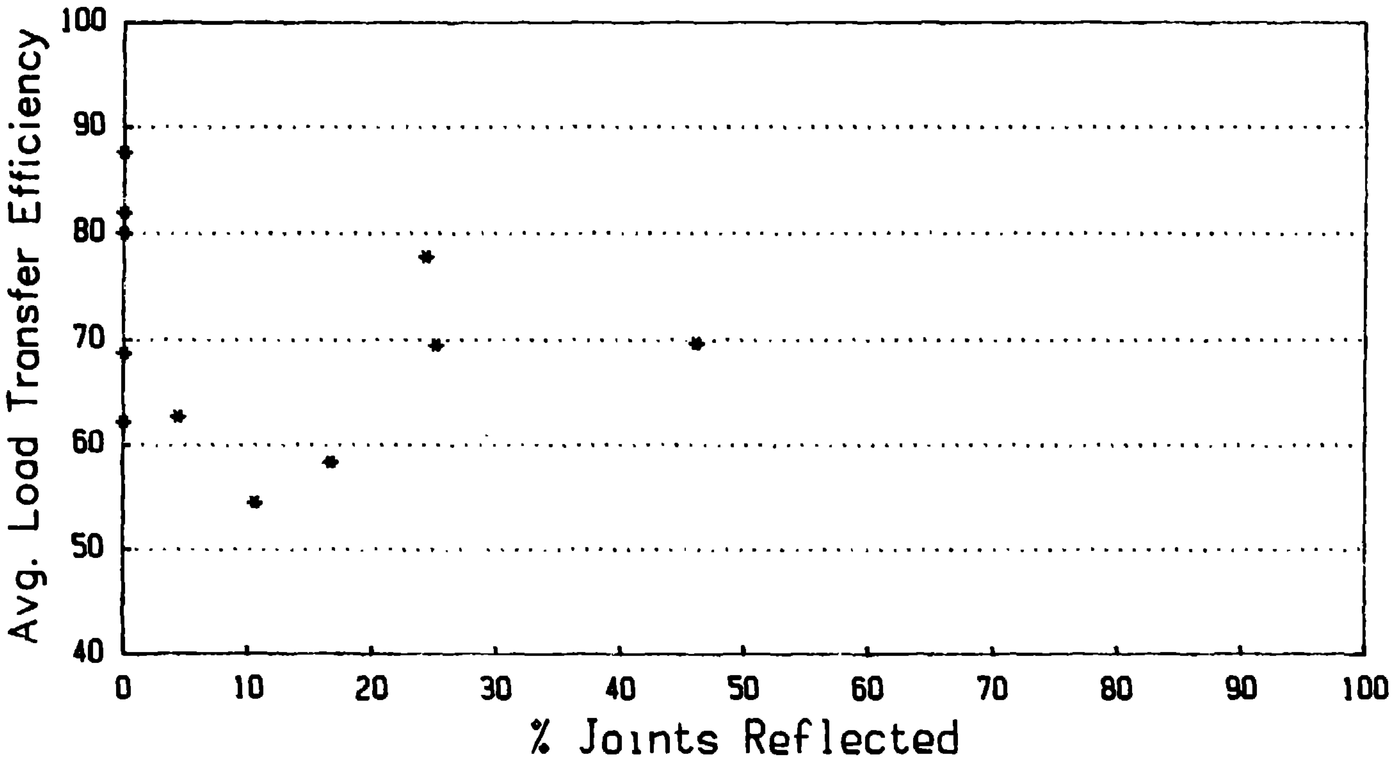


Figure 31. Average load transfer efficiency versus transverse joint reflection cracking.

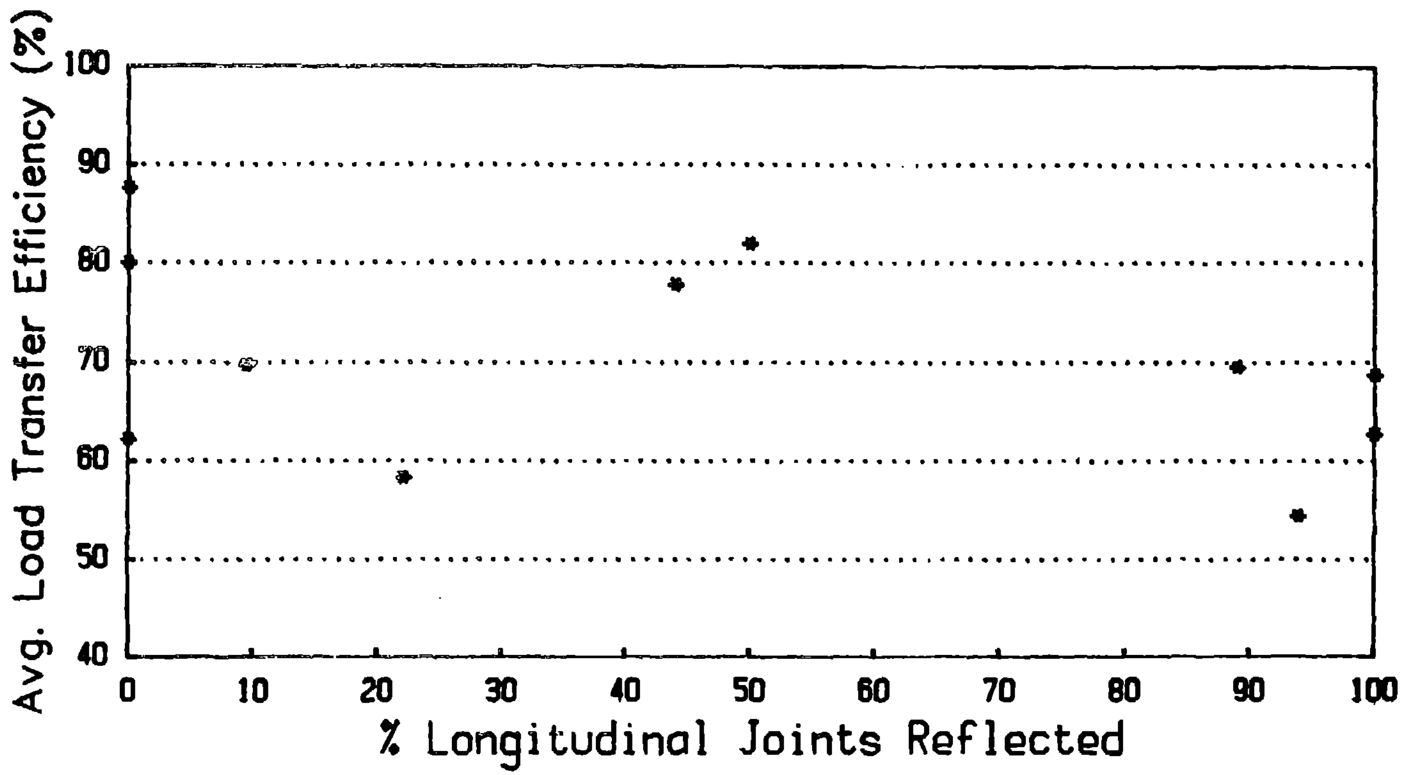


Figure 32. Average load transfer efficiency versus longitudinal reflection cracking.

5. SUMMARY AND CONCLUSIONS

SUMMARY

One of the most common methods used to rehabilitate PCC pavements is to place an AC overlay on the existing pavement. These overlays often deteriorate rapidly due to the problems associated with joint reflection cracking. Numerous techniques have been tried over the years in attempts to reduce the adverse effects of these cracks, with widely varying results. Because of the difficulties encountered in trying to eliminate reflection cracking, some agencies have instead decided to control the problem rather than eliminate it. One method of control is to saw a joint above the existing transverse joints immediately after overlay. The joints are sealed and subsequently maintained as typical pavement joints. The purpose of this study was to evaluate the performance, determine the cost effectiveness, and verify and/or develop improved design and construction guidelines for sawed and sealed overlays.

The above objectives were accomplished primarily by evaluating the performance of sawed and sealed overlays that had been in service for up to 10 years. Field condition surveys, roughness measurements, deflection measurements, traffic, environmental, and other data were obtained. Using these data elements, a detailed analysis was performed to document and evaluate the performance of the sawed and sealed overlays.

Using information from past research studies, existing design procedures, and field performance results from this study, design and construction guidelines and guide specifications were developed to assist the pavement engineer with the design of this rehabilitation technique.

CONCLUSIONS

Based upon work conducted during this study and reported herein, the following conclusions were drawn:

- A total of 12 States were found either to have experimented with or to be using saw and seal AC overlays as a routine rehabilitation procedure. Most of these States are in the northeastern part of the country. Connecticut, New York, New Jersey, and Pennsylvania seem to have had the most experience. Several States have prepared specifications and standards for the saw and seal overlay procedure. States that have documented their experiments with sawing and sealing have reported marginal to good results with the technique.

- The overall documented experience with saw and seal overlay is extremely limited. Information concerning measured field performance, traffic, existing pavement condition, and characterization of the existing pavement in terms of joint width, load transfer efficiency, crack spacing, joint and crack opening under known temperature changes, and load deflection is generally lacking.

- An important step in the construction process is properly locating the saw cut above the existing joint. Secondary reflective cracking can occur unless a precise match of saw cut and existing joint is made (within 1.0 in).

- Saw and seal sections with thick overlays (5.0 in) performed better (roughness and reflective cracking) than sections with thin overlays (2.5 in).

- If properly constructed, sawed and sealed joints in an AC overlay of jointed PCC can reduce the adverse effects of reflection cracking. For the pavement sections examined in this study (control versus saw and seal), pavement roughness was reduced by 20 percent and transverse reflection cracking was reduced by 64 percent. Sawing and sealing joints in asphalt concrete overlays on PCC pavements can extend the pavement life.

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PART II. SAWING AND SEALING JOINTS IN ASPHALT CONCRETE OVERLAYS ON PORTLAND CEMENT CONCRETE PAVEMENTS

PART A. DESIGN AND CONSTRUCTION GUIDELINES

INTRODUCTION

These guidelines provide information for engineers, technicians and contractors involved with the design and construction of asphalt concrete (AC) overlays on portland cement concrete pavements. In particular, the guidelines discuss the sawing and sealing of joints in the AC overlay directly over joints in existing pavement. These guidelines will also be useful to personnel resealing joints as part of a maintenance program.

NEED FOR SAWING AND SEALING

An accepted rehabilitation strategy for portland cement concrete pavements is to overlay the pavement with an asphalt concrete material. The overlay will provide a new, smooth riding surface with good skid characteristics. Thicker overlays will also provide an increase in the structural capacity of the pavement. Highway engineers often select an AC overlay because the work can be done in a reasonable amount of time and initial capital costs are usually less than portland cement concrete overlays and concrete pavement restoration (CPR).

However, there is a perplexing problem with AC overlays on PCC pavements--the phenomenon of reflection cracking. Reflection cracking is the propagation of cracks and joints in existing PCC pavement through the new overlay. Movement of the existing pavement causes reflective cracks in the overlay. Movement can be caused by temperature change, moisture content change, traffic loadings, and a combination of these conditions. The movements are usually classified as horizontal or vertical. Traffic loading and poor load transfer efficiency cause vertical movements; temperature changes create horizontal movements. Movement of the PCC slab causes stress to concentrate above the existing joint or crack, and whenever the stress exceeds the limiting strength of the material, a crack will propagate.

The major concern with reflection cracking is that it will lead to rapid deterioration of the overlay. Reflection cracking allows moisture into the pavement system and causes a loss of support from the subgrade and base layers. The crack can also deteriorate and spall, creating a maintenance problem. Excessive spalling can lead to potholes or peeling of the AC surface.

A significant amount of research has been done to solve the reflection cracking problem. All highway engineers are looking for a solution because of the large number of miles of pavement overlaid each year. Typically, these overlays will fail because of reflection cracking or other types of deterioration caused by cracking. Each load passing over the pavement, or each change in temperature, creates additional damage. The crack will continue to propagate.

Currently, there are two basic approaches to the solution of the reflection cracking problem. The first tries to mitigate the propagation of cracks in the AC overlay. Some of the treatments include:

- Fabrics.
- Stress-relieving interlayers.
- Crack-arresting interlayers.
- Pre-overlay repair.
- Crack and seat.

In one way or another, all of these treatments are designed to stop or reduce the rate of crack propagation. For example, fabrics act as a reinforcement layer in the AC overlay. The fabric provides physical restraint to the opening of cracks. However, excessive movement will still cause reflection cracking.

Stress-relieving interlayers dissipate the stresses from joint movement within the interlayer. Rubberized asphalt chip seals are an example of a stress-relieving interlayer. Crack-arresting interlayers are comprised of aggregate graded to create large voids designed to stop crack propagation.

Pre-overlay repair includes all treatments that reduce the movement of PCC slabs. Treatments such as full-depth patching, subsealing, and re-establishment of load transfer will reduce pavement movement.

The second approach to the reflection cracking problem is to let the cracking occur, but control it. This approach assumes that reflection cracking is inevitable; however, with proper construction techniques the severity of cracking is minimal and good performance can be achieved. Sawing and sealing joints in asphalt concrete overlays on PCC pavements is the only treatment that effectively reduces the severity of reflection cracking. Other approaches, such as very thick overlays, will defer the cracking; however, a trade-off exists with increased overlay costs versus delay of cracking.

The sawing and sealing of joints in asphalt overlays eliminates or reduces the severity of spalling at the reflective crack. Without the sawing and sealing, the reflective crack usually spalls and deteriorates to the point where a rough ride results from rapid breakdown of the pavement.

EFFECTIVENESS

Many States in the northeastern United States have used the technique of sawing and sealing joints in asphalt concrete overlays. Connecticut, New York, Pennsylvania, New Jersey, Massachusetts, and Maine routinely use the treatment. In all, 13 States have tried sawing and sealing of joints. In the States using the technique the longest (Connecticut and New York), it has been recognized that the treatment is cost effective, leading to an extended pavement life with better performance. Results from the FHWA project "Performance/Rehabilitation of Rigid Pavements" (FHWA-RD-88-204) showed that the sawing and sealing of joints in asphalt concrete overlays reduced the roughness of the pavement (compared to control section) by 20 percent.

The performance of sawing and sealing of joints in asphalt concrete overlays depends upon other interactive parameters. Construction quality control, mix design, environmental factors, and others will have an influence on pavement performance. There are, however, several other rehabilitation work requirements which should be performed before the placement of the overlay and subsequent sawing and sealing of the joints.

WORK PRIOR TO OVERLAY

As with any overlay on a PCC pavement, there is a need to rehabilitate the concrete pavement before placing the overlay. The type and amount of work depends upon existing conditions of the pavement, traffic loading, environment, subgrade, and other factors. In general, the following rehabilitation techniques should be considered:

- Full-depth slab repair.
- Partial-depth slab repair.
- Slab stabilization.
- Joint and crack resealing.
- Shoulder repair.
- Drainage improvements.

Each overlay project is unique. Consequently, the work prior to overlay must be tailored to improve the existing condition. It should be kept in mind that rehabilitation treatments that reduce slab movements will provide better overlay performance. Full-depth slab repair, slab stabilization, and drainage improvements give the longest life to the overlay system.

The "Pavement Rehabilitation Manual," FHWA Publication ED-88-025, and the "Field Inspection Guide for Restoration of Jointed Concrete Pavements" should be consulted as guides.

DESIGN AND CONSTRUCTION

The design of a sawing and sealing asphalt concrete overlay project requires an evaluation of the entire overlay design process: structural evaluation, analysis of existing conditions, selection of sealant material, joint reservoir dimension and CPR treatments.

Overlay Design and Existing Conditions

The decision to specify the sawing and sealing of asphalt concrete overlays should not be the most important criterion in the rehabilitation selection process. To select the rehabilitation strategy, the transportation agency should proceed with the usual pavement management system approach, which includes data collection of pavement attributes, structural analysis, and life cycle costing. If the decision is made that the most cost effective solution is to place an asphalt concrete overlay on the PCC pavement, then the agency should consider the sawing and sealing technique. Results of the FHWA "Performance/Rehabilitation of Rigid Pavements" study showed that sawing and sealing reduced pavement roughness by 20 percent and it reduced reflection cracking by greater than 60 percent.

The sawing and sealing of cracks in an asphalt concrete overlay is not as effective a treatment for extremely poor PCC pavement conditions. The existing PCC pavement must be repaired with CPR technique to ensure that the overlay will perform adequately. If the PCC pavement is not repaired prior to overlay, the overlay will fail from other conditions besides reflection cracking deterioration.

The specifications for a sawing and sealing project are similar to those for crack sealing of flexible pavements and the sealing of joints in concrete pavements. A few minor differences occur with sawing and sealing. The FHWA Guide Specification for "Crack Sealing of Flexible Pavements" and NCHRP Report No. 281, "Joint Repair Methods for Portland Cement Concrete Pavements," provide excellent information and guidelines concerning the sealing of joints and cracks.

Selection of Sealant Materials

The sealant selected should meet the requirements the agency uses for sealant materials in asphalt concrete cracks. The sealant must be able to withstand expected horizontal and vertical movements, particularly if the existing joints have poor load transfer efficiency. The sealant material must also be able to withstand the effects of ultraviolet light, moisture, temperature extremes, etc.

States using the sawing and sealing technique have only used hot-poured, elastomeric-type materials. No agencies have used low modulus silicone or preformed compression seals; consequently, their performance is not known.

Joint Reservoir Dimensions

The performance of sealants in joints has been shown to be a function of the shape and dimensions of the joint reservoir. The sealant shape factor is known as the ratio of depth, D, to width, w. It has been shown that a D/w ratio of 1 provides for lower stresses and strains on the sealant material.

All agencies using the saw and sealing technique have used shape factors from 0.5 to 1.00 with the majority at 0.8. Dimensions vary depending on the different experience of each state. For example, Pennsylvania uses a D = 1/2 in and w = 1 in, while New Jersey uses a D = 1/2 in and w = 5/8 in (for overlays up to 3 1/2 in thick). New Jersey will use a D = 3/8 in and w = 5/8 in for overlays thicker than 4 in. The State of New York selects the reservoir dimension based upon the existing PCC slab length. The New York dimensions are:

Slab Length, ft	D in	w in
<50	5/8	1/2
51-62	5/8	5/8
63-75	5/8	3/4
76-87	3/4	7/8
88-100	7/8	1

Several agencies require that a 1/8-in wide by 2-in deep (or one-third the overlay thickness, whichever is greater) saw cut be included in the joint if the total overlay thickness is greater than 4 in.

A backer rod or bond breaker is recommended to provide the desired shape factor and prevent three-sided adhesion. The backer rod should be used to maintain a D/w ratio of 1. The backer rod is needed if the w dimension exceeds the D dimension by at least the diameter of the backer rod. Bond breaker tape can be used (in lieu of a back rod) in the bottom of the reservoir if the reservoir has the correct D/w ratio.

The surface of the sealant, after cooling, should not be greater than 1/8 in $\pm$ 1/16 in below the asphalt concrete surface.

Location of Saw Cut and Sawing Operation

It is very important that the sawcut in the asphalt concrete overlay be directly above the existing PCC pavement joint. If the saw cut is mismatched, a reflective crack will occur above the existing joint. The reflective crack can occur with a mismatch of 1 in or more. The location of the existing joint can be marked by extending a string line over the joint and placing stakes, steel pins, etc., where they will not be disturbed during paving. After paving is completed, the joint can be marked with a chalk line or other suitable marking.

Full-depth PCC repair should have saw cuts in the overlay directly above the patch/slab interface. Also, any working crack (a crack that has vertical or horizontal movement) should have a saw cut placed directly above it. Existing transverse joints, offset by more than 1 in, should have separate saw cuts terminating at the longitudinal joint. Saw cuts should extend for the full width of the pavement and extend into the shoulder to a distance of 3 ft beyond the edge of the PCC pavement.

The saw cut can be made as soon as the asphalt concrete overlay has cooled to a level where the mix is stable. The saw cut should be made before the pavement is opened to traffic and/or before the pavement undergoes temperature extremes. A significant change in temperature can cause the asphalt mat to begin to crack due to PCC slab movement. If the pavement receives traffic prior to sawing, cracking can begin due to vertical slab movement.

Proper sawing techniques are essential to provide the correct sealant reservoir at the exact location of the PCC joint. Accurate operation of forward speed, vertical pressure, etc., must be maintained during the cutting. The joints can be sawed with either a wet or dry procedure. If sawed dry, the joints should be cleaned thoroughly with a stream of air to remove any dirt or deleterious material which can hinder sealant adhesion. Wet sawed joints should be thoroughly cleaned with water to remove the sawing slurry. If sawed wet, the joints must have sufficient time to dry before the sealant is applied. Wet slurry material or dry dust should be removed from the pavement surface. Research has shown that dirty joint faces do not allow for good sealant adhesion.

The joints should be sealed as soon as possible after they are sawed. If the overlay is opened to traffic before the joints are sealed, it is possible that the traffic will knead together the sawed joints. If this should occur, the joints must be resawed when the sealing operation resumes.

Joint Sealing

Before placing the sealant material, the joints should be cleaned with a stream of air to remove dirt or dust. Wet sawed joints must be given sufficient time to dry before placement of the sealant material.

The sealant material should be placed according to the manufacturer's suggestion. Regardless of that suggestion, material should not be placed when the air temperature is less than 50 °F. The material should be poured within the paving temperature range, and an effort should be made to maintain the temperature during the entire process. When heating is required, it should be done with equipment that heats indirectly. This is usually done with a double boiler. Positive temperature control and mechanical agitation should be provided.

A single batch of material can be maintained for up to 4 h at the pouring temperature. The material should be heated only once.

The application wand should be heated or insulated to maintain the pouring temperature. Pour pots should not be used because a constant temperature cannot be guaranteed.

When cooled, the top of the sealant material should be just below the surface of the asphalt concrete. Pouring excess material over the joint should not be allowed. The overlay should not be opened to traffic until the material has become tack free.

Regular checks should be made to ensure that the correct temperature is being maintained and that the pumps are continuously circulating the heated sealant through the hoses to the applicator and back to the kettle. It is very important to ensure that the material is not overheated or heated for an extended period of time (greater than 4 h).

INSPECTION AND QUALITY CONTROL

Before starting work, the project engineer, inspectors, and the contractor, should meet and review the specification and construction procedures. Since environmental conditions will change during the project, everyone should be aware of the temperature limitations of the sealant material. Continued observation of the saw and sealing operation is required because all operations will probably occur simultaneously.

The guide specification accompanying these Design and Construction Guidelines are recommended as an initial framework for the Specifications. They must be revised to reflect the experience, standards, and procedures of the transportation agency and the design engineer.

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PART B. GUIDE SPECIFICATIONS

GENERAL

The following guide specifications are recommended for use only after revision to reflect local agency policy and standards.

DESCRIPTION OF WORK

The work shall consist of marking, sawing, cleaning, and sealing of joints in asphalt concrete overlays on portland cement concrete pavements. The location of the joints shall be directly over the existing joints and cracks as shown on the plans and/or directed by the engineer.

STANDARD SPECIFICATIONS

The standard specifications applicable to the work on this project are as published in the current edition of (Local, State, Federal, Military) "Standard Specifications."

SUBMITTALS

Materials

Sealant materials, backer rod, and a bond breaker shall be inspected and approved by the agency or engineer prior to their incorporation into the work. The contractor shall provide advance notice to the agency to permit testing and approval of materials before placing orders. All samples and the collection of samples will be forwarded without charge to the agency.

Unless otherwise designated, all tests will be done in accordance with the most recently cited standard methods of ASTM or AASHTO--those current on the date of advertisement for bids, or with other testing methods approved by the agency and/or engineer. All materials are subject to inspection, testing, or rejection at any time. Any work done with unacceptable materials without approval will not be paid for. The unacceptable materials will be removed and replaced with accepted materials at the contractor's expense.

The joint sealant material shall be packaged in a container marked with the manufacturer's name, batch and lot number, paving temperatures, and safe heating temperature.

The bond breaker and/or backer rod shall consist of a material designated for use with the hot-poured sealant. Regular masking tape is a suitable bond breaker. The width of the tape should be equal to but not less than 1/8 in narrower than the width of the sawed cut.

Equipment

A list of equipment to be used shall be submitted to the agency and/or engineer for approval prior to use on the project.

Manufacturer's Recommendations

Copies of the manufacturer's installation procedures which are applicable to the material and equipment shall be submitted to the agency and/or engineer at the time the materials are submitted for approval.

MATERIALS

Joint Sealant

The sealant shall meet the requirements of one of the following specifications:

- ASTM D3405-78 Standard Specification for Joint Sealants, Hot-Poured, for Concrete and Asphalt Pavements.

- ASTM D3406-85 Standard Specifications for Joint Sealant, Hot-Applied, Elastomeric-Type, for Portland Cement Concrete Pavements.

Backer Rod and/or Bond Breaker

The backer rod and/or bond breaker shall consist of a material designated for use with hot-poured sealant.

Regular masking tape is a suitable bond breaker. The width of the tape shall be equal to but not less than 1/8 in narrower than the width of the saw cut. The backer rod shall be a solid, round, heat-resistant polyurethane foam with a density of 2 to 4 lb/ft^3.

EQUIPMENT

General

The contractor shall furnish all necessary equipment and accessories to saw, clean, and seal the joints. All machines, tools, and other equipment shall be maintained in proper working condition at all times. The use of all machines and tools shall be subject to the approval of the agency and/or engineer.

Joint Sawing Equipment

A self-propelled power saw capable of providing a straight cut of uniform depth and width shall be used. Diamond saw blades with either single or gang blade arrangement shall be used.

Joint Cleaning Equipment

A portable air compressor capable of blowing out dust, water, and other material from the joint shall be used. The compressor shall be equipped with a device to remove any oil or water from the air line.

Sandblasting equipment shall be capable of removing any dirt or other foreign material after the sawing process. Equipment shall include air compressor, hose, and nozzles of the proper size. The nozzle should align with the saw cut and be kept approximately 1 in above the pavement.

High-pressure water jets shall include a compressor, water pumps, hose, water jets, and controls. Adjustable nozzles shall be available to control the water pressure.

A self-propelled vacuum sweeper capable of removing dust, dirt, water, and other materials from the pavement surface shall be available.

Joint Sealing Equipment

Hot-poured sealant shall be installed with equipment capable of heating and extruding the sealant material in one operation. The heating kettle shall be a double-wall unit with an oil medium in the outer space for heat transfer purposes. There shall be positive temperature control for both the heating oil and sealant material. The equipment shall have a power-driven mechanical agitator and circulating pump. The circulating system shall allow for the circulation of sealant through the delivery hose and return to the kettle when not sealing a joint. The sealing wand, shall be insulated for the entire length. The nozzle tip shall be equipped with a metal crossbar to ensure that the sealant is fed into the joint, and it is level and below the pavement surface.

CONSTRUCTION METHODS

Marking Joints

All joints, working cracks, full-depth patch edges, and any other discontinuities that can reflect through the overlay shall be marked for future location reference. Metal pins, large nails, wooden stakes, etc., shall be placed on the side of the paved portion of the traveled way to mark the alignment of the existing crack. To mark the location of pins, string line shall be stretched taut over the existing joint.

After the overlay has been placed and has cooled to a level where the mat is stable, a chalk line shall be stretched between the marker pins to locate the existing joint and mark the overlay for the saw cutting operations. Other suitable marking procedures will be permitted with the approval of the agency and/or engineer.

Sawing Joints

Saw cutting shall be done only after the asphalt concrete overlay has had sufficient time to cool. Saw cuts shall be made in a straight line to the dimension specified on the plans and/or specifications. The saw cuts shall be directly over the existing joints, cracks, and discontinuities. Either dry or wet saw cutting will be allowed.

If the total depth of overlay exceeds 4 in, a 1/8-in wide by 2-in (or 1/3 of the total overlay thickness, whichever is greater) saw cut shall be made. The joint sealant reservoir can then be sawed directly above the initial cut. The saw cuts shall extend the full width of the pavement and shall extend into the shoulder (if the shoulder is asphalt concrete) to a distance of 3 ft unless otherwise directed on the plans or by the agency and/or engineer. Existing transverse joints that are offset at the longitudinal joint by more than 1 in shall require separately sawed cuts terminating at the longitudinal joint.

Traffic shall not be permitted on the overlay unless the joints have been sealed. If traffic is allowed to knead or damage the saw cut, the joints shall be resawed prior to the sealing operation. The entire sawing and sealing operation shall be completed within 7 days after the placement of the final wearing cover.

Cleaning of Joints

Dry-sawed joints shall be cleaned with a stream of air sufficient to remove all dirt, dust, and deleterious matter that can adhere to the joint face. Wet-sawed joints shall be cleaned with a water blast immediately after the sawing to remove all sawing slurry and other deleterious matter. Wet-cleaned joints shall be blown with air to help dry the joints prior to sealing.

All dust, dirt, and sawing slurry shall be swept or vacuumed for the pavement surface in the immediate joint area.

The contractor shall provide protective screening if the cleaning operations are capable of causing damage to or interference with traffic in adjacent lanes.

Joint Sealing

Immediately after the cleaning process (dry), or immediately after the joint has dried from a wet cleaning, the joint should be sealed. Prior to placing the sealant, the bond breaker tape or backer rod shall be placed at the proper location of the joint reservoir. If a backer rod is used, it shall be inserted with a steel wheel device which places the backer rod at the specified depth.

The joints shall be sealed when the sealant material is at the recommended pouring temperature. The sealant should not be placed if the air temperature is less than 50 °F. The reservoir shall be sealed with material to a level 1/8 in ± 1/16 in below the pavement surface. Sealant material shall not be spread over the pavement surface. Sand shall not be spread on the sealed joints to allow early opening to traffic. The sealant shall be tack free prior to opening to traffic.

MEASUREMENT AND PAYMENT

Measurement

This work shall be measured by the number of linear feet of joints properly sawed and sealed.

Basis of Payment

The unit price bid per linear foot shall include the cost of all labor, equipment, and materials necessary to complete the work as specified.

APPENDIX

Figures 33 through 43 are plots of the corner deflections measured during the FWD testing on the 11 test sections (control sections) not included).

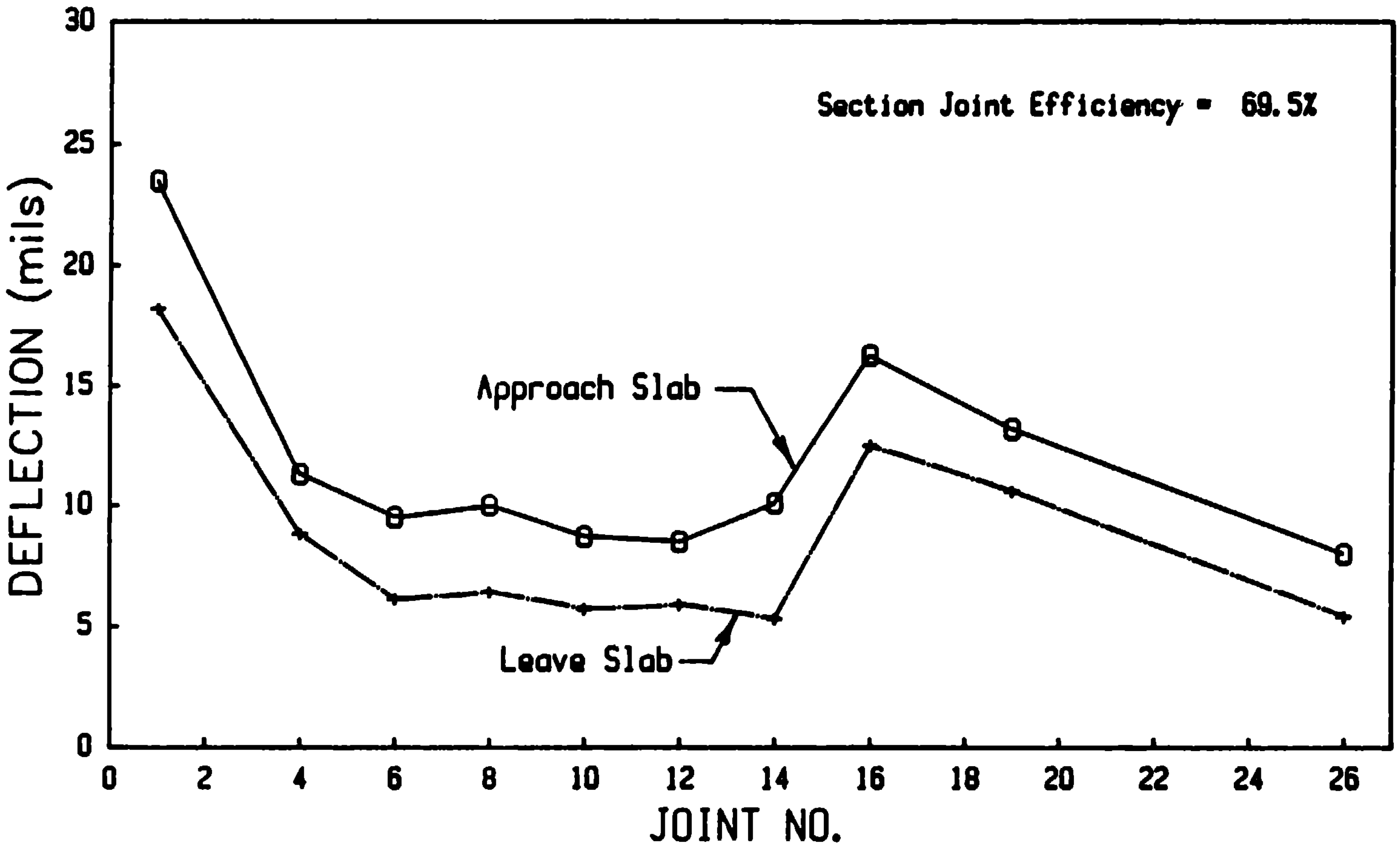

Figure 33. Corner deflection profile for I-91, Meridian, CT.

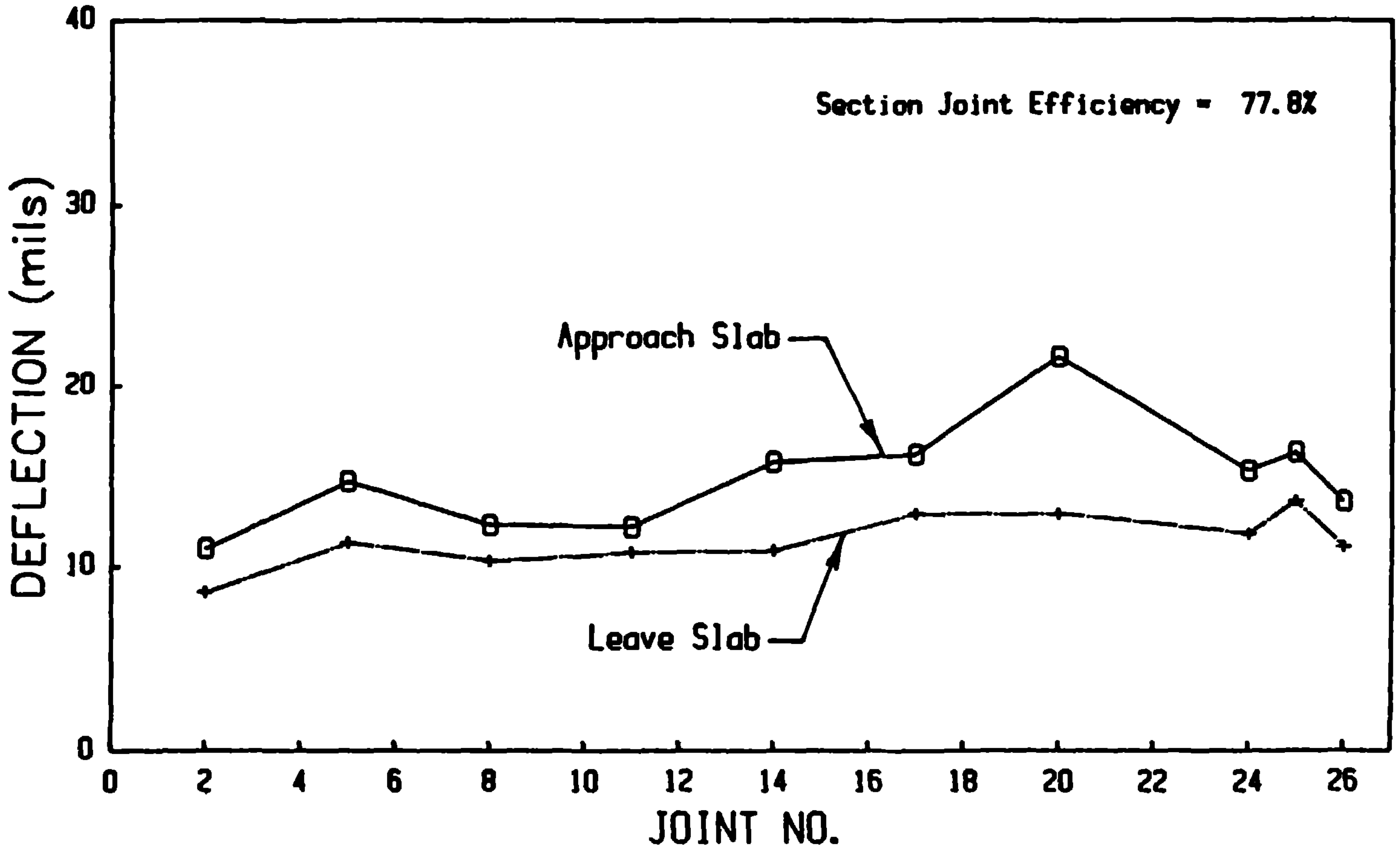

Figure 34. Corner deflection profile for I-84, New Britain, CT.

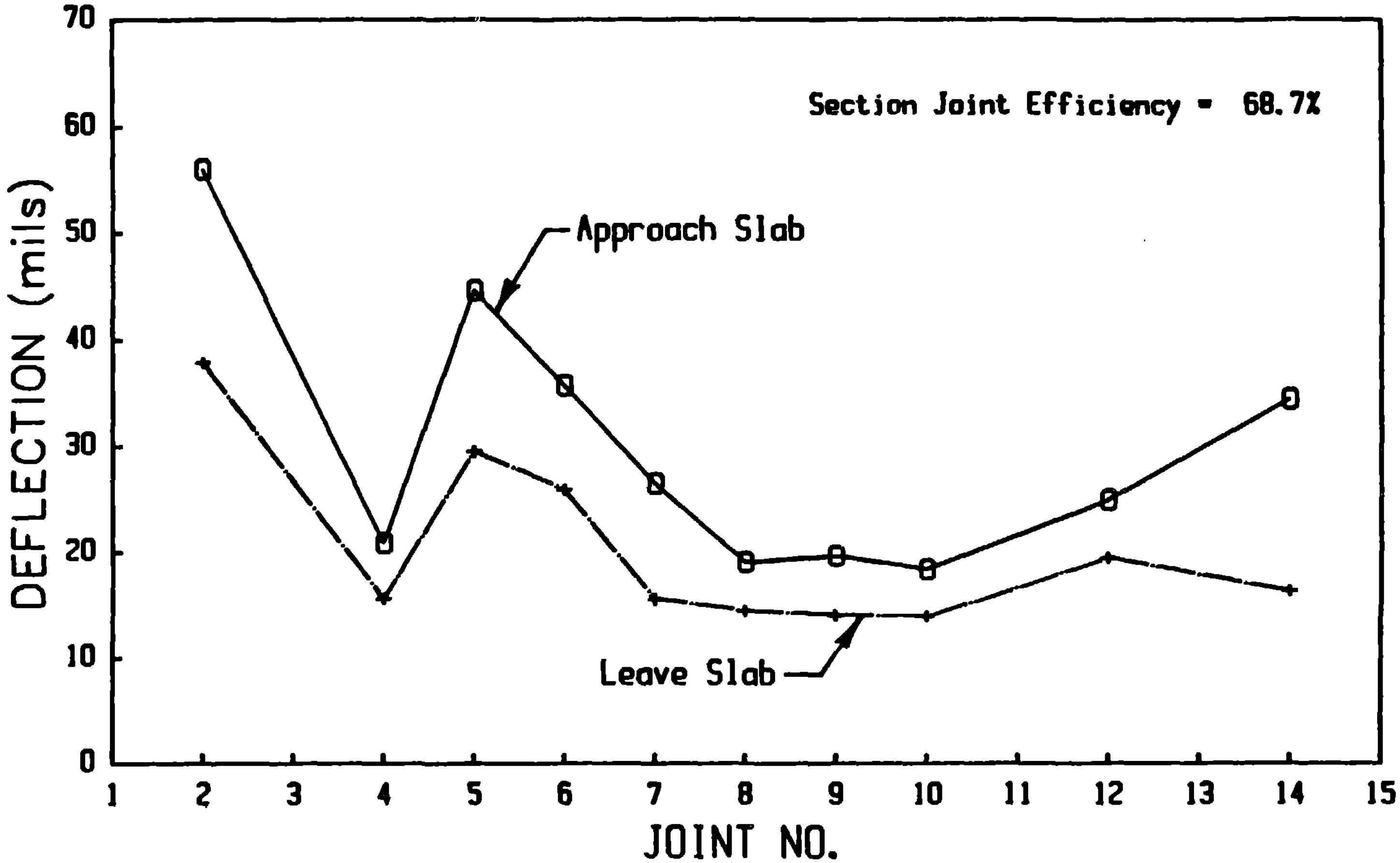

Figure 35. Corner deflection profile for I-95, Falmouth, ME.

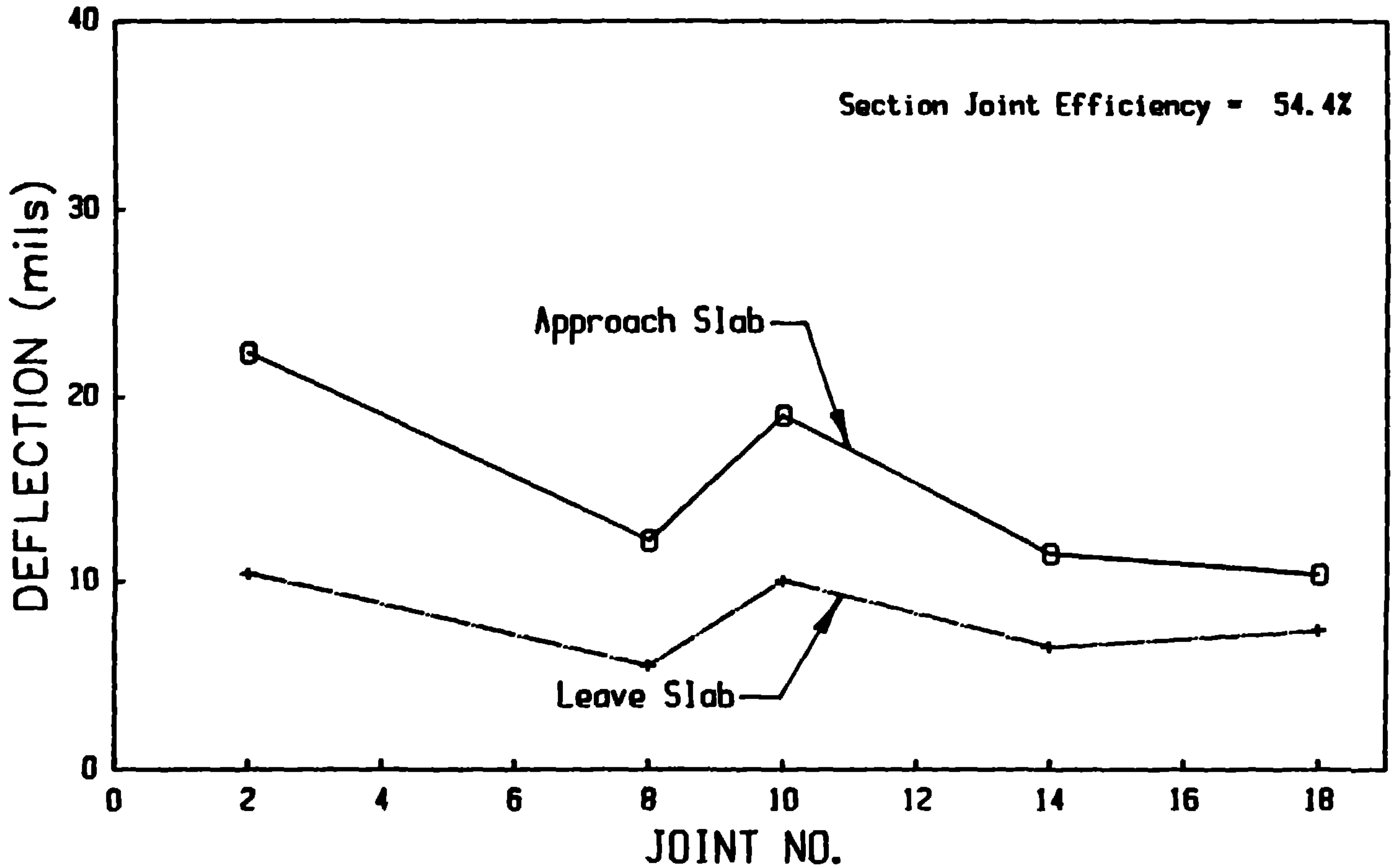

Figure 36. Corner deflection profile for US 22, Somerville, NJ.

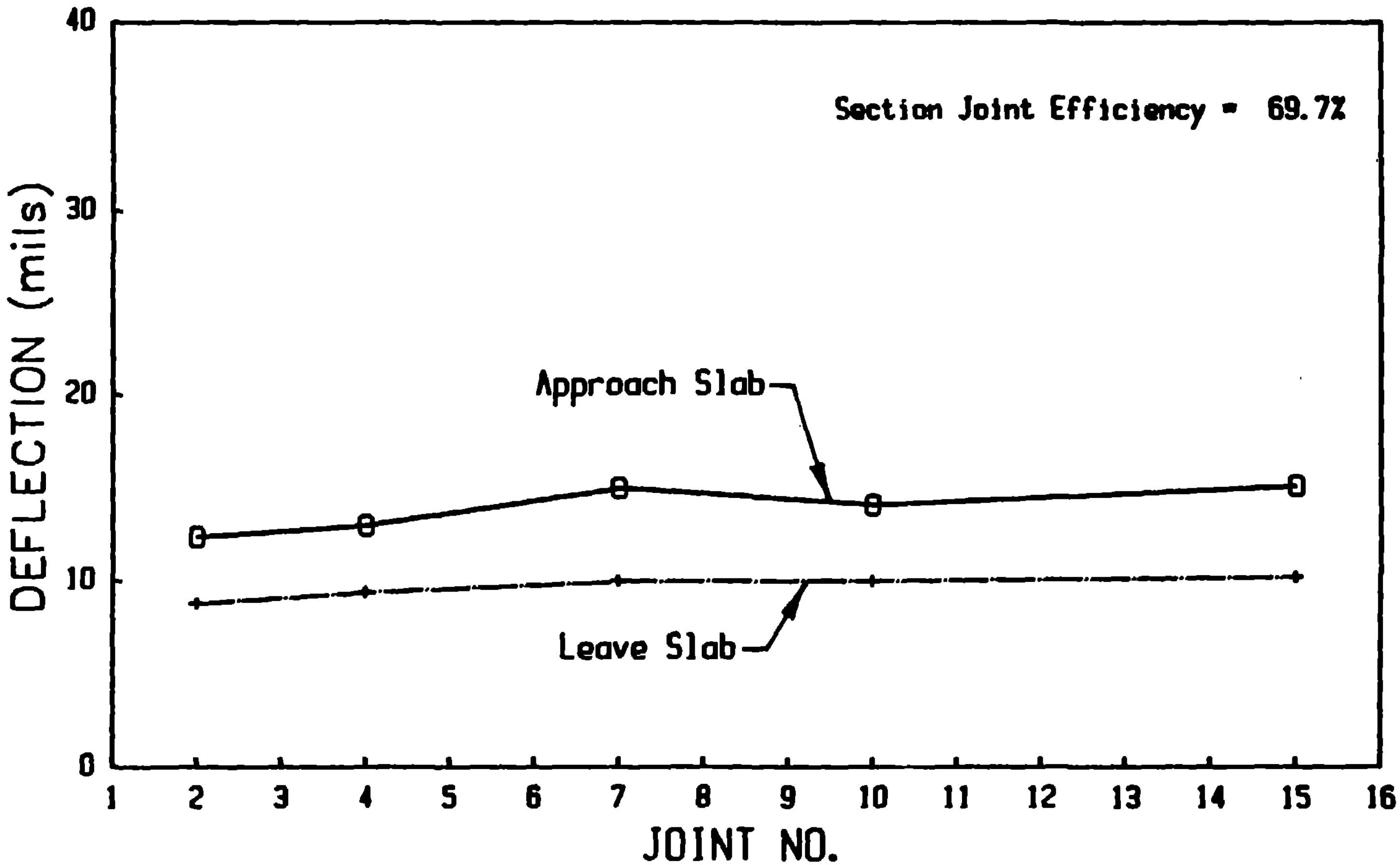

Figure 37. Corner deflection profile for I-80, West Paterson, NJ.

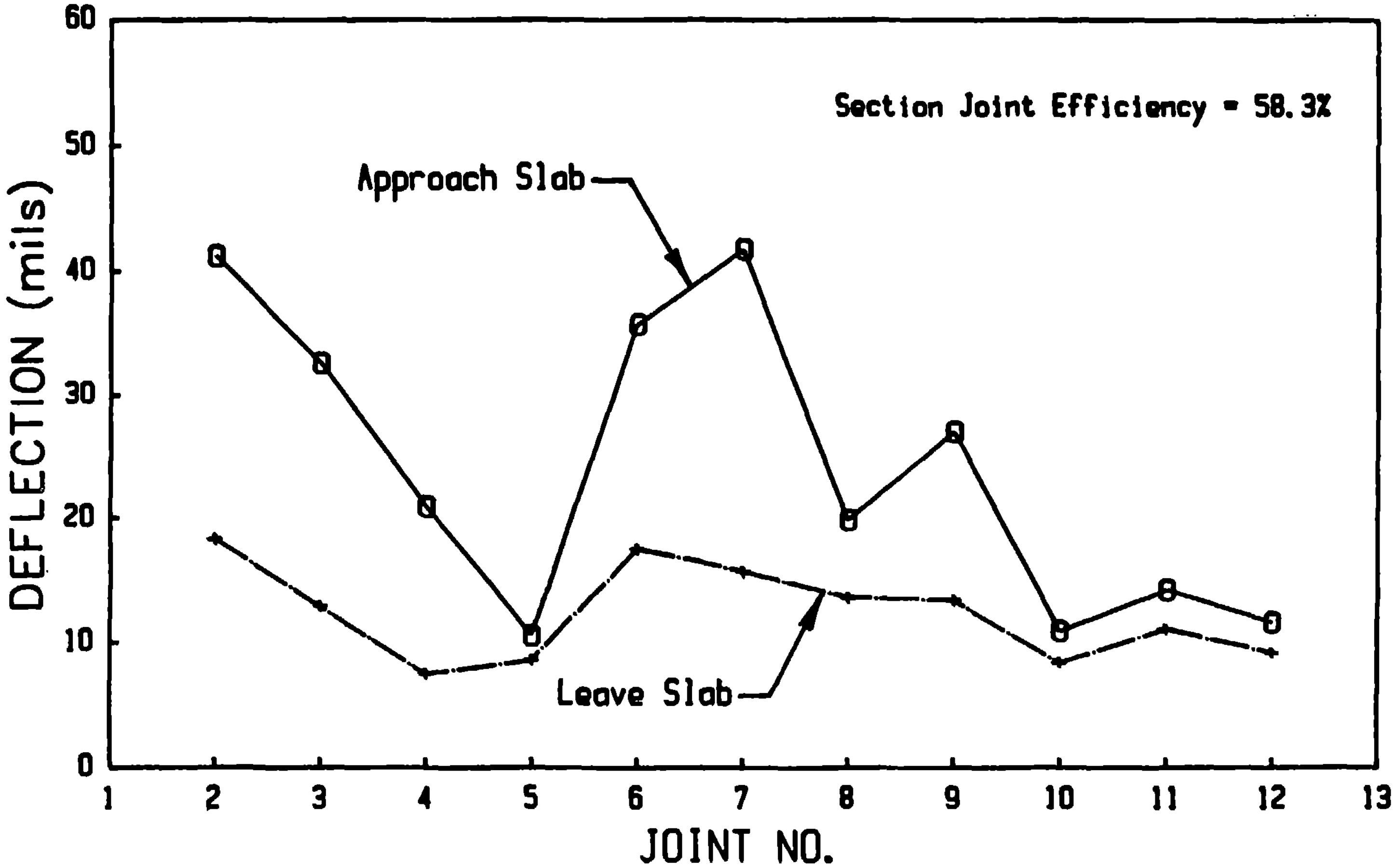

Figure 38. Corner deflection profile for Route 5, Caledonia, NY.

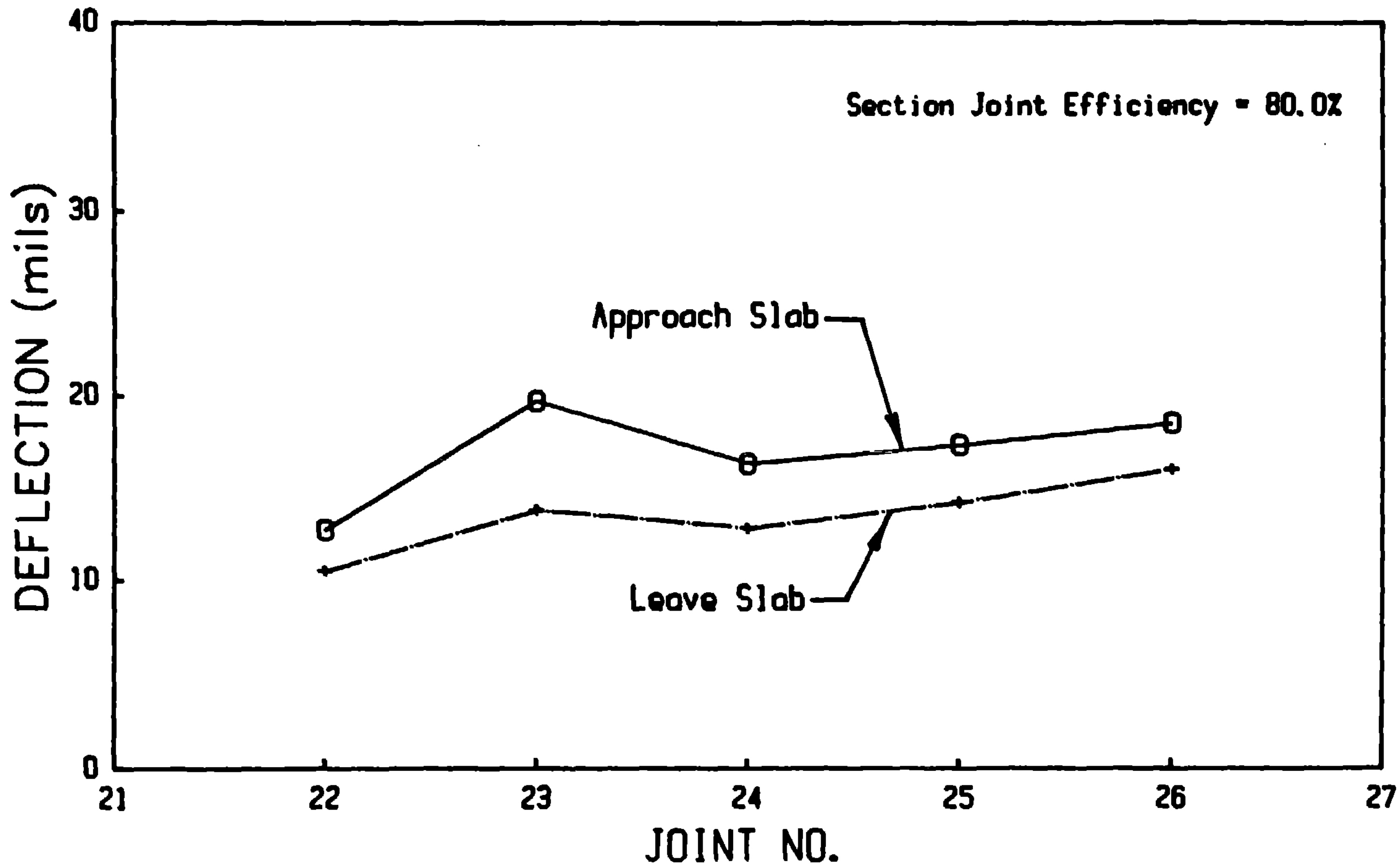

Figure 39. Corner deflection profile for I-81, Syracuse, NY.

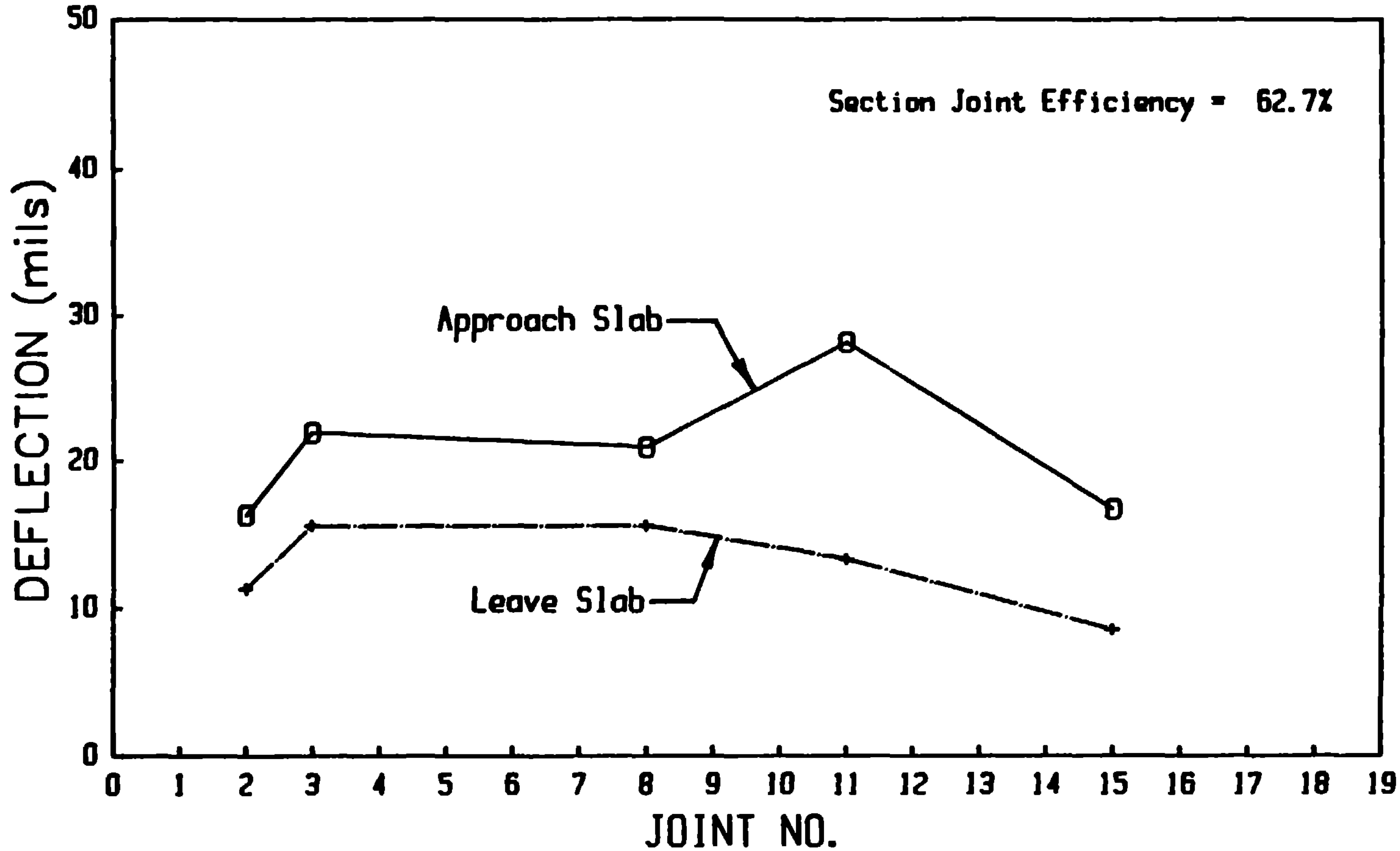

Figure 40. Corner deflection profile for I-87, Albany, NY.

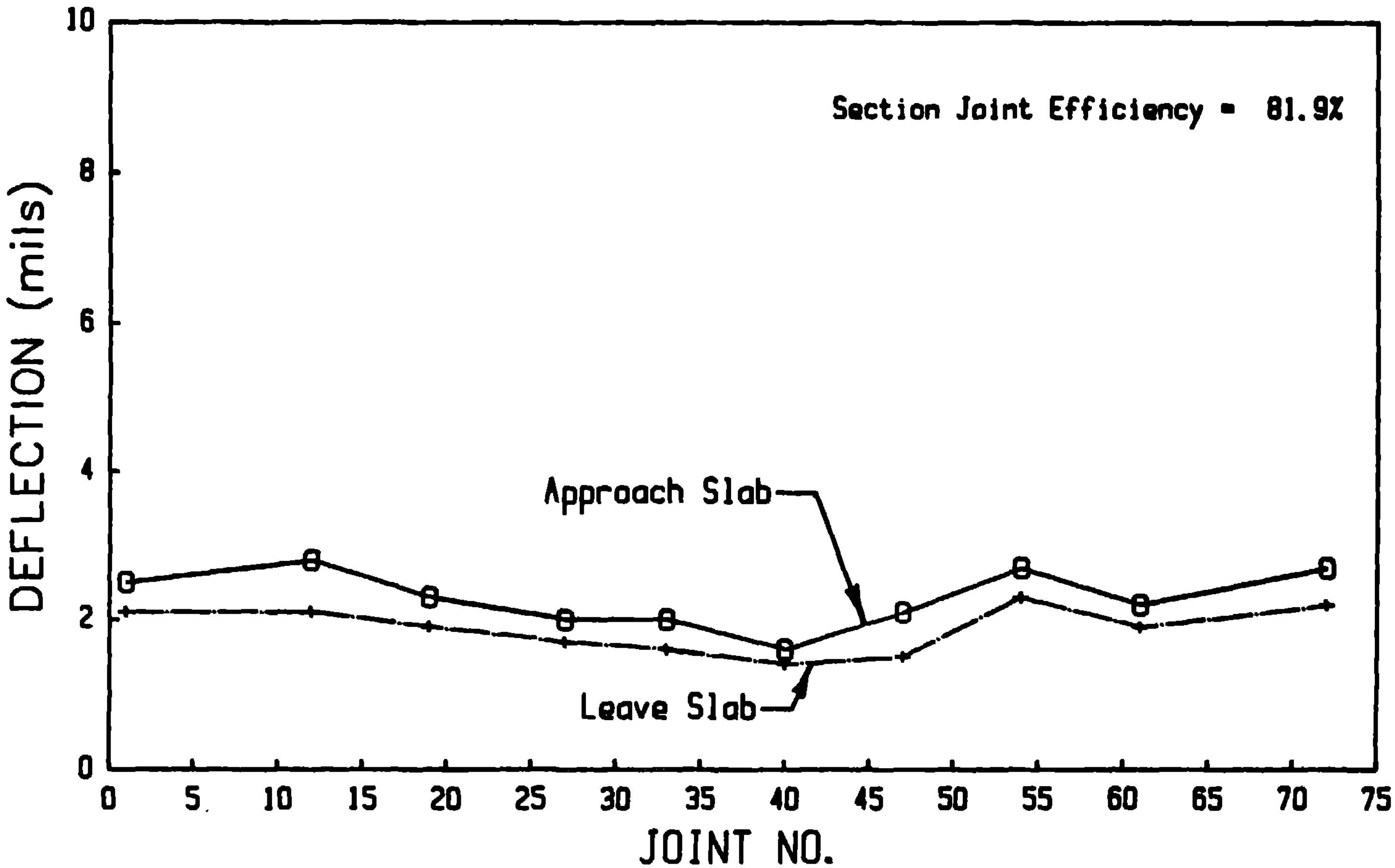

Figure 41. Corner deflection profile for I-70, Columbus, OH.
(Sealant ASTM P-3405)

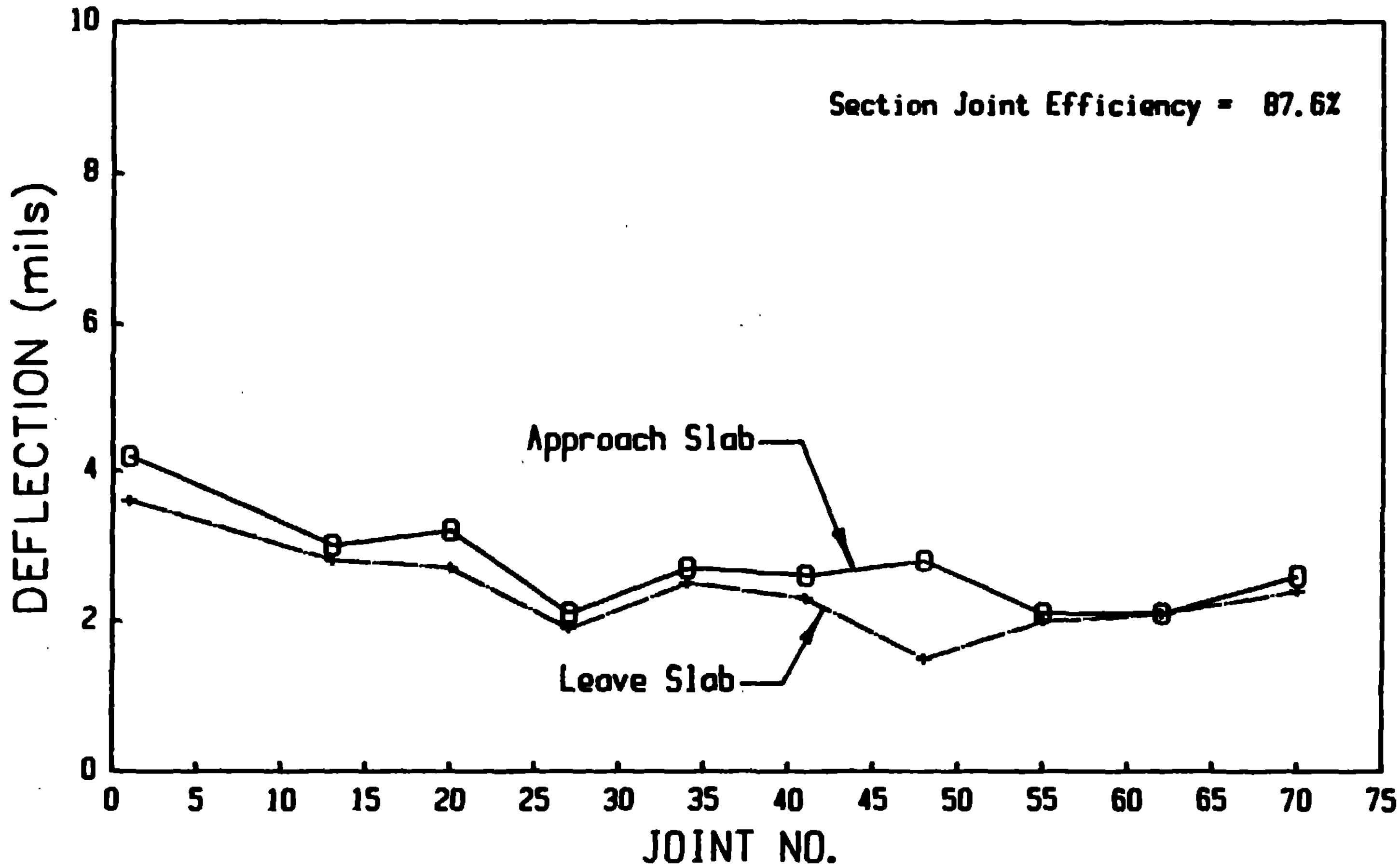

Figure 42. Corner deflection profile for I-70, Columbus, OH.
(Sealant AASHTO M 173)

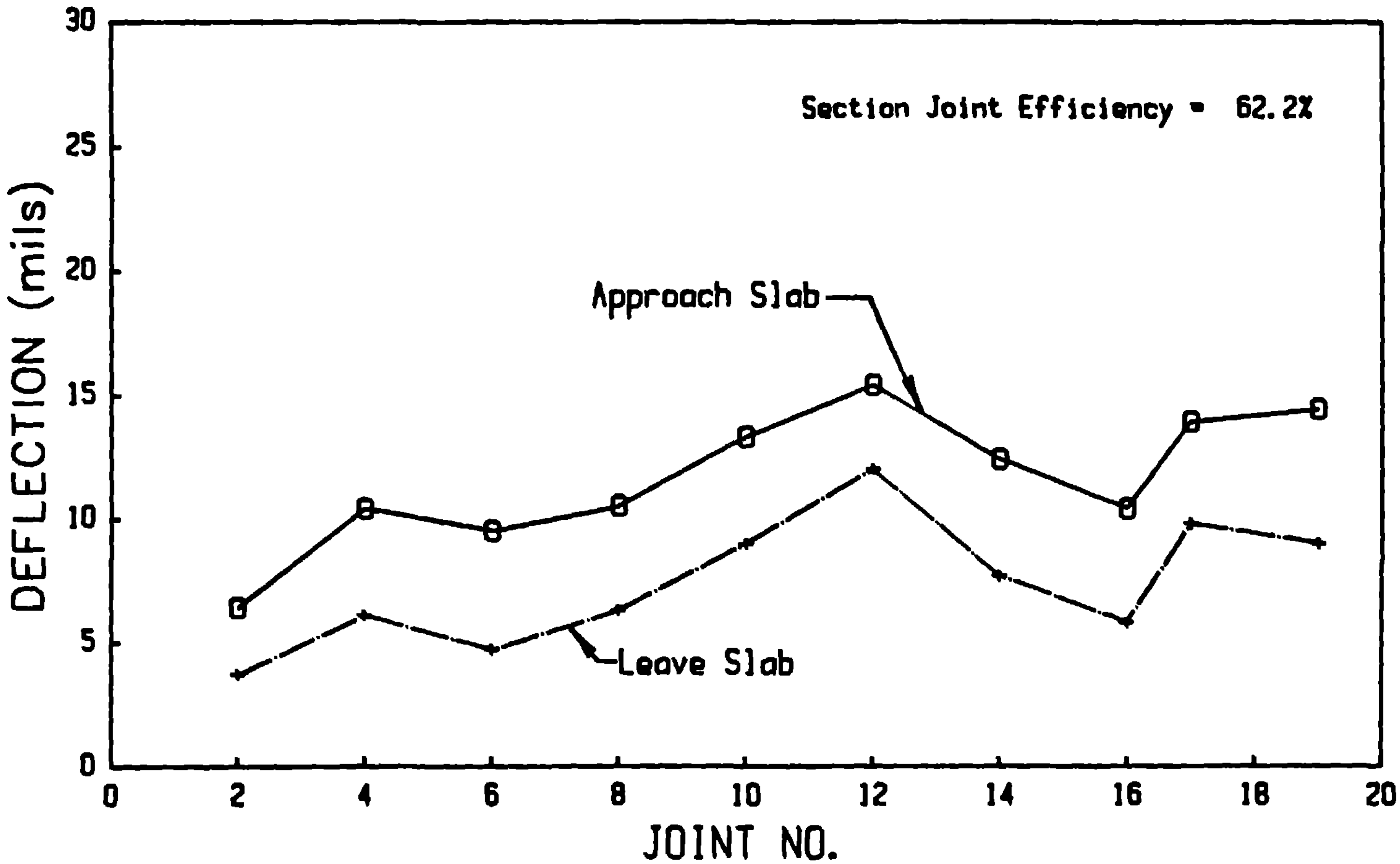

Figure 43. Corner deflection profile for US 22, Huntingdon, PA.