Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA/VA-87/18		

4. Title and Subtitle	5. Report Date
Field Evaluation of Three Joint Sealants	June 1987
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
David Frederick Noble	VTRC 87-R18
9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
Virginia Transportation Research Council P.O. Box 3817, University Station Charlottesville, VA 22903-0817	11. Contract or Grant No. HPR 2251
12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
Virginia Department of Transportation 1221 E. Broad Street Richmond, VA 23219	Final Report 6/83 - 5/87
	14. Sponsoring Agency Code

15. Supplementary Notes

In cooperation with the U.S. Department of Transportation, Federal Highway Administration

16. Abstract

A field study was conducted to evaluate the performance of three joint sealants: (1) a compartmented (A), (2) a closed cellular (B) preformed neoprene, and (3) a two-component cold-mixed polysulfide (C). These were used in the interchanges for Interstate 64 near Charlottesville.

The condition of the sealants and joints was observed and the extent of the failures was estimated during a preliminary survey; the specific types of failure were either measured or were documented photographically during the detailed surveys.

The following conclusions were reached: 1. The neoprene sealants far out performed the polysulfide sealant. 2. The polysulfide sealant probably failed because of compression set. 3. In addition, based on observations of the condition of the slabs relative to the condition of the sealants, it was concluded that the particles in the joints caused more distress by contributing to the loss of load transfer than by causing any damage such as spalling. 4. The lack of confinement near the expansion joints and the open ends of the ramps permits one-way movement of the slabs which contributes to the loss of load transfer and the discrete functioning of the slabs so that they break up under heavy loads.

Four recommendations were made.

17. Key Words	18. Distribution Statement
Sealants, cold-poured polysulfide, preformed neoprene, load transfer, particles, cracked slabs	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	34	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

-1084

SI CONVERSION FACTORS

To Convert From	To	Multiply By
Length:		
in	cm	2.54
in	m	0.025 4
ft	m	0.304 8
yd	m	0.914 4
mi	km	1 . 609 344
Area:		
in^2	cm^2	6.451 600 E+00
ft^2	m^2	9.290 304 E-02
yd^2	m^2	8.361 274 E-01
mi^2	Hectares	2.589 988 E+02
acre (a)	Hectares	4.046 856 E-01
Volume:		
oz	m^3	2.957 353 E-05
pt	m^3	4.731 765 E-04
qt	m^3	9.463 529 E-04
gal	m^3	3.785 412 E-03
in^3	m^3	1.638 706 E-05
ft^3	m^3	2.831 685 E-02
yd^3	m^3	7.645 549 E-01
Volume per Unit Time: NOTE: $1m^3 = 1{,}000$ L		
ft^3/min	m^3/sec	4.719 474 E-04
ft^3/s	m^3/sec	2.831 685 E-02
in^3/min	m^3/sec	2.731 177 E-07
yd^3/min	m^3/sec	1.274 258 E-02
gal/min	m^3/sec	6.309 020 E-05
Mass:		
oz	kg	2.834 952 E-02
dwt	kg	1.555 174 E-03
lb	kg	4.535 924 E-01
ton (2000 lb)	kg	9.071 847 E+02
Mass per Unit Volume:		
lb/yd^2	kg/m^2	4.394 185 E+01
lb/in^3	kg/m^3	2.767 990 E+04
lb/ft^3	kg/m^3	1.601 846 E+01
lb/yd^3	kg/m^3	5.932 764 E-01
Velocity: (Includes Speed)		
ft/s	m/s	3.048 000 E-01
mi/h	m/s	4.470 400 E-01
knot	m/s	5.144 444 E-01
mi/h	km/h	1.609 344 E+00
Force Per Unit Area:		
lbf/in^2 or psi	Pa	6.894 757 E+03
lbf/ft^2	Pa	4.788 026 E+01
Viscosity:		
cSt	m^2/s	1.000 000 E-06
P	Pa·s	1.000 000 E-01

Temperature: $(°F-32)^5/9 = °C$

-1065

FINAL REPORT

FIELD EVALUATION OF THREE JOINT SEALANTS

by

David Frederick Noble
Research Scientist

(The opinions, findings, and conclusions expressed in this report are those of the author and not necessarily those of the sponsoring agencies.)

Virginia Transportation Research Council
(A Cooperative Organization Sponsored Jointly by the
Virginia Department of Transportation and
the University of Virginia)

In Cooperation with the U. S. Department of Transportation
Federal Highway Administration

Charlottesville, Virginia

June 1987
VTRC 87-R18

PAVEMENT MANAGEMENT RESEARCH ADVISORY COMMITTEE

W. R. DAVIDSON, Chairman, District Engineer, VDOT

J. M. AMOS, Resident Engineer, VDOT

J. P. BASSETT, Pavement Design Engineer, VDOT

T. R. BLACKBURN, District Materials Engineer, VDOT

DR. ROBERT CHENG, Professor of Civil Engineering, Old Dominion University

C. M. CLARKE, Assistant District Engineer, VDOT

E. L. COVINGTON, JR., Assistant District Engineer - Maintenance, VDOT

T. F. FARLEY, Assistant District Engineer - Planning and Administration, VDOT

C. L. FITCHETT, Engineering Programs Supervisor, VDOT

K. H. MCGHEE, Senior Research Scientist, VTRC

W. A. MCKAY, Highway Geologist, VDOT

A. D. NEWMAN, Pavement Management Engineer, VDOT

B. W. SUMPTER, District Engineer, VDOT

C. S. TAYLOR, JR., Programming/Systems Development Supervisor, VDOT

R. WELTON, District Engineer, FHWA

ABSTRACT

The purpose of the study reported here was to evaluate the performance of three joint sealants -- compartmented (A) and closed cellular (B) preformed neoprene, and a two-component cold-mixed polysulfide (C)-- that were used in the interchanges for Interstate 64 near Charlottesville.

The condition of the sealants and joints was observed, and the extent of the failures was estimated during a preliminary survey. The specific types of failure were then either measured or documented photographically during the warm- and cold-weather surveys.

It was concluded that:

1. The neoprene sealants far out-performed the polysulfide sealant.

2. The polysulfide sealant probably failed because of compression set.

3. The particles in the joints caused more distress by contributing to the loss of load transfer than by causing any damage such as spalling.

4. The lack of confinement near the expansion joints and the open ends of the ramps permits one-way movement of the slabs; this contributes to the loss of load transfer and the discrete functioning of the slabs so that they break up under heavy loads.

It was recommended that:

1. The Department discontinue the use of cold-mixed polysulfide material to seal contraction joints in PCC pavements.

2. The Department use preformed neoprene sealants or comparable sealants to seal joints in PCC.

   These first two recommendations have already been put into effect by the Materials Division on the basis of field tests made by the Materials Division and the conclusions of this report.

3. Expansion joints be eliminated, and the anchoring of slabs near the open ends of ramps be investigated.

FIELD EVALUATION OF THREE JOINT SEALANTS

by

David Frederick Noble
Research Scientist

INTRODUCTION

In the vicinity of Charlottesville, Virginia, the pavement on I-64 is continuously reinforced portland cement concrete (PCC). However, the pavement on the ramps of the interchanges and at a rest stop is jointed PCC slabs. On these interchanges, from Boyd's Tavern east of Charlottesville to Yancey's Mill west of town, three joint sealants -- preformed compartmented neoprene, preformed closed-cellular (spongy) neoprene, and cold mixed, two-component polysulfide -- were installed in 1970 for an evaluation of their performances.

Although sealants and the design of joints for plain PCC pavement have been the subjects of considerable research, the study reported on here was considered necessary because (1) the movement that a portland cement concrete pavement experiences is different in different geographic regions and this affects the performance of sealants (1), and (2) the sealants that were to be evaluated for this study had been in service 13 to 14 years by the time they were studied; thus, they were older than most of the other sealants that had been studied since 1974 (2, 3, 4).

PURPOSE AND SCOPE

The purpose of the study was to determine which of the three sealants was the most effective.

Because of the density and speed of the traffic and the difficulty of exercising traffic control for a moving work zone, the scope of the study was limited to observations of the condition of the sealants and pavements and to those measurements that could be made quickly by one person, such as the width of the joints, depth to sealant (when obviously out of specifications), and the magnitude of faulting (where it occurred). It was considered that for the changes in the measurements to be significant, they would have to be relatively large. Therefore, the methods of measurement were not designed to be sensitive to very small differences. The percentage of the sealant that experienced a particular failure, such as loss of adhesion or cohesion, was determined visually.

MATERIALS AND JOINT PREPARATION

The dimensions for the sealants and the sawed joints are shown in Figures 1 and 2 and Table 1.

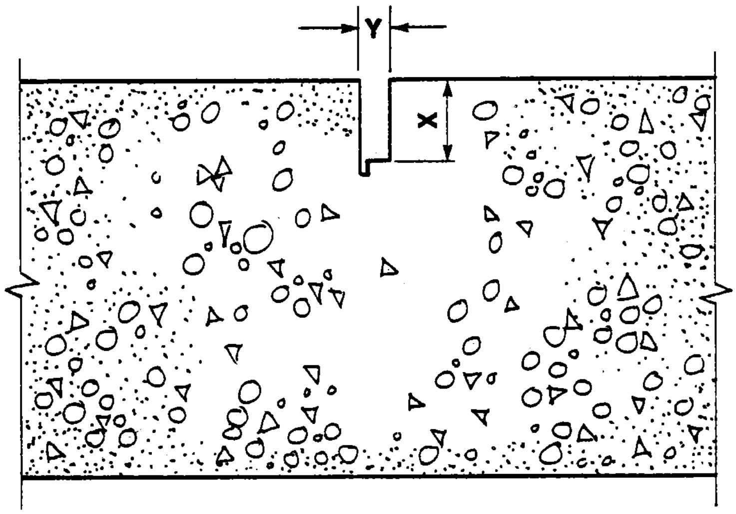


Figure 1. Shape of the sawed joint.

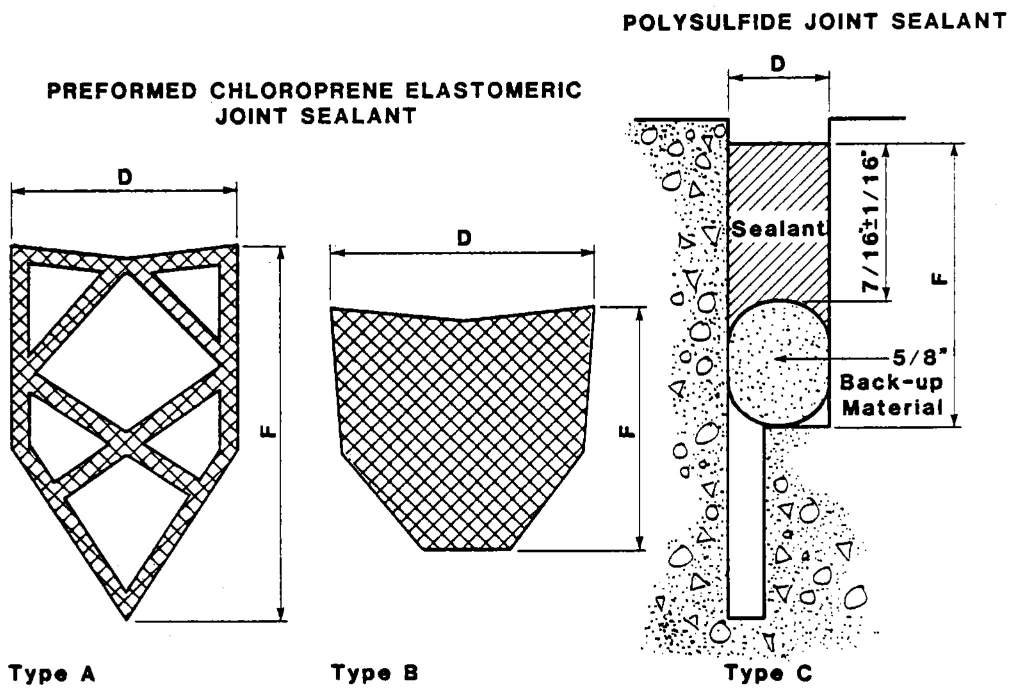


Figure 2. Shapes of the sealants.

Table 1

Dimensions to go with Figures 1 and 2 in Inches

For 20 ft. Slab Lengths (Plain)			
	Sealant Type		
Dimension	A	B	C
X	1 3/4	1 1/8	1 1/4
Y	3/8	3/8	1/2 ±1/16
D	13/16+1/16	3/4+1/16	1/2 ±1/16
F	1 3/8±1/16	21/32	(7/16±1/16)+5/8=1 to 1 1/8*

*Sealant plus back-up material

"Special Provisions D (49-69)," dated February 1, 1969, was written to describe the work to be performed, the preparation of the joints, the installation of the sealants, the various ASTM test procedures and the physical requirements that they determine, and the resistance-to-degradation tests that the materials had to meet.

In essence, the onus was placed on the manufacturer to see that the material supplied was suited to do the task of sealing the joints and that the material was installed using the optimum procedures.

Brushing or other means were to be used to loosen foreign material in the joint that could not be removed with oil-free compressed air. The preformed sealants were to be installed using an adhesive as a lubricant; a primer was to be used for the polysulfide; the preformed sealants were not to be stretched more than five percent of the length of the joint.

PROCEDURES

Field Surveys

A preliminary survey was made so that the general condition of all the sealants and concrete slabs could be assessed and a record of that assessment could be made for future reference in the planning of the detailed surveys. For the preliminary survey, each joint was inspected for (1) the percentage of adhesive loss of the sealant, (2) the percentage of cohesive loss for the sealant, (3) the presence of spalling along the edges of the joint, (4) the occurrence of faulting between the leave and approach slabs, (5) the occurrence of installation mistakes (sealant at incorrect depths and the twisting of preformed sealants), (6) the occurrence of cracking within the slabs, and (7) the percentage of sealant covered by debris.

The detailed surveys were made in both warm and cool temperatures on 332 of the 3206 joints that were included in the preliminary survey. These joints were not chosen randomly; they were chosen to represent the various types of distress and to represent the various locations of the joints: areas within the ramps (where the slabs are tied into the mainline, close to the expansion joints, or independent of the mainline), or near the open end where the ramp abuts the asphaltic concrete pavement of the intersecting primary or secondary highway.

The width of the joint was measured by laying a rule across it. The joint and rule were photographed close to the edge of the pavement and other photographs were taken when needed to document a particular type of distress elsewhere. A flash was used to provide uniformity of lighting and to show the particulate matter in some of the joints that were not sealed. If the depth to the sealant was out of specifications (usually too deep), the depth was measured with a sliding caliper rule. Where significant faulting occurred, it was measured at a distance of one foot from the edge of the pavement. Two heavy steel plates of the same thickness were aligned parallel to the joint and on opposite sides. Their purpose was to average out the roughness of the pavement finish. A combination square that was graduated to thirty-seconds of an inch was used to measure the difference in elevation between the two plates.

Analytical

Along with the evaluation of the sealants, it was thought that there would be considerable benefit in analyzing as many factors as possible that relate not only to the performance of the sealants but also to the performance of the joints.

Most of the ramps in interchanges have four areas that can be identified by location and whether that location is relatively confined or unconfined:

1. The beginning of an "on" ramp and the end of an "off" ramp (the open ends) are relatively unconfined for four or five

slabs because such ramps frequently butt against flexible pavement, which tends to give when the PCC slabs expand.

2. The slabs that are midway between the open end and the expansion joints may be thought of as relatively confined by the 10 to 15 slabs between them and the open end and between them and the expansion joints.

3. Two or three slabs each side of the expansion joints may be considered to be in a relatively unconfined state because of the space within the expansion joints, which allows one-way movement to occur during the expansion cycle.

4. The slabs adjacent to the mainline are confined because they are tied into the mainline and eventually merge with the mainline such that there is no space for one-way movement of the slabs.

For faulted and for cracked slabs the following calculations were made.

1. The percentage distribution of the faulted and the cracked slabs located within the four readily identifiable areas of a ramp was examined to determine whether there were any significant differences in the incidence of failure to be found in these areas.

2. The percentage distribution per ramp of the faulted and cracked slabs within an interchange was investigated because a concentration of failures within one or two ramps would suggest that the various characteristics of those ramps should be examined and compared with those characteristics of the other ramps.

3. The percentage of the joints and the slabs per ramp that were faulted or cracked was calculated because that would focus attention on those ramps with particularly high proportions of a specific failure.

The data for the rest stop will be handled differently from that for the other ramps because the rest stop had no open ends, it had an inordinate number of expansion joints (eight groups), the automobile and truck parking aprons were very wide (five and nine pavement widths, respectively), and the most frequently used parking areas within the aprons received much more static loading than did the ramps. The entrance ramp from the mainline to the gore area that separates the automobile and truck traffic and the exit ramp from the other gore area where the automobile and truck traffic merge will be treated as two ramps and will be compared with the other ramps on an equal basis.

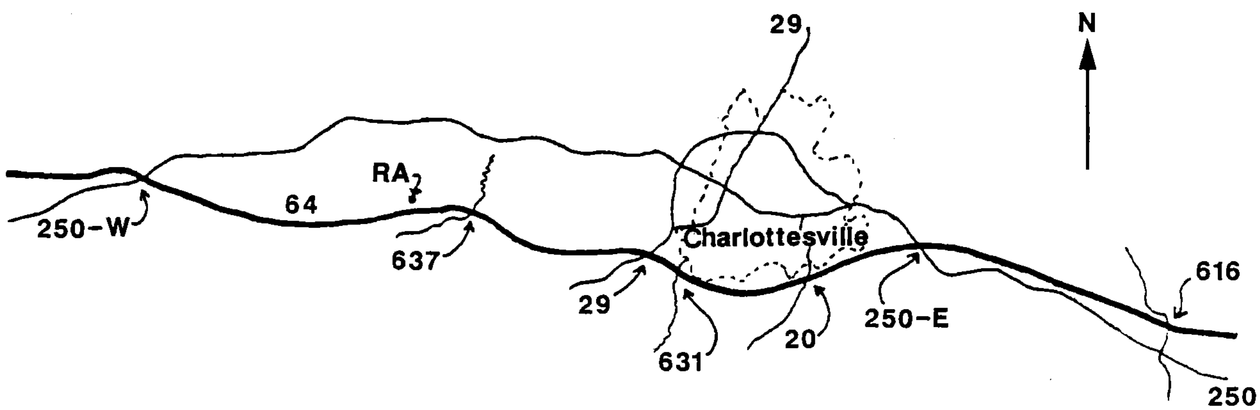
-1074

RESULTS AND DISCUSSION

To set the time frame for the discussion of the results, the activities and the times during which they occurred are listed below.

Activity	Date
Construction of ramps	summer - 1970
Preliminary survey	summer - 1983
Warm weather survey	summer - 1984
Cool weather survey	winter and spring - 1985

A sketch map that shows the location of the interchanges and a list of their type, and the type sealant used are presented in Figure 3.



Interchange	Type	Sealant Used
250-W	Diamond	Compartmented Neoprene - A
Rest Area (RA)	---	Spongy Neoprene - B
637	Diamond	Polysulfide - C
29	Partial Cloverleaf	Spongy Neoprene - B
631	Diamond	Compartmented Neoprene - A
20	Partial Cloverleaf	Compartmented Neoprene - A
250-E	Diamond	Polysulfide - C
616	Diamond	Spongy Neoprene - B

Figure 3. Sketch map of Interstate 64 near Charlottesville.

Preliminary Survey

Although the preliminary survey was done as quickly as possible and did not entail any measurements or lengthy observations, it was a good record of the number of occurrences of specific failures for the three types of sealants. Therefore, the results of the preliminary survey are presented in Table 2 as the percent of joints using a specific sealant that have experienced a given failure.

The failures enumerated in Table 2 are defined as follows:

1. Adhesive loss occurs when the sealant has separated from the side of the joint.

2. Cohesive loss occurs when a separation exists within the sealant, the tensile strength of the sealant having been exceeded.

3. Minor spalls are relatively small (2x1x¼ inches), flaky pieces of PCC that have broken off the edge of the joint. Severe spalls are much larger, and since they are caused by compressive forces, 3 to 4 inches of the slab back from the joint may be severly cracked or crushed.

4. A fault is the vertical displacement that occurs across a joint between the leave and approach slabs. Faulting is caused by the movement of support material from under the end of one slab (usually the approach slab) and the deposition of that material under the end of the other slab (usually the leave slab).

Table 2

Percentage of Joints Per Type Sealant
Experiencing a Particular Type of Failure

Type Sealant	No. of Joints	Adhesive Loss	Cohesive Loss	Spalls	Faults	Install. Mistakes	Cracks in Slab	Sealant Covered by Particles
A	1,116	9.4	0.0	35.9	22.0	8.8	38.4	5.1
B	1,232	8.1	0.0	21.7	11.4	2.8	20.6	2.3
C	858	69.5	57.7	54.9	7.6	19.3	28.0	0.0

5. Installation mistakes include incorrectly sawn joints, twisted preformed sealants, and sealants at an incorrect depth below the pavement surface.

6. A crack in the slab is any obvious discontinuity within the concrete. A severe crack is one along which movement occurs under the dynamic loading of traffic, that readily accepts the infiltration of water, that moves with the heating and cooling of the slab.

Adhesive and Cohesive Losses

The failures that reflect the performance of a sealant the most are adhesive and cohesive losses. It is obvious when looking at the adhesive loss that the polysulfide with an incidence of failure well over seven times that of either of the neoprene sealants had the poorest performance. A comparison of the cohesive failures makes for an even greater discrepancy in that the type A and B (preformed neoprene) sealants did not have any cohesive failures. All the tensile failures for the neoprene sealants were confined to adhesive failures. Thus, the performance of the type C sealant was far worse than that of the preformed neoprene sealants.

The remaining types of failure are not directly the result of the failure of the sealant. However, failed sealants contribute to the occurrence of these other failures because water and particles can then penetrate the joints.

Spalling

Severe spalling is the result of the intrusion of incompressibles into a joint (5, 6, 7, 8). Most of the spalling noted during the preliminary survey was minor and was probably caused by the saw blade at the time of cutting. A few severe spalls will be noted and illustrated in the detailed examinations of the joints.

Faulting

There are many factors that contribute to the faulting of a jointed concrete pavement. The Route 631, 29, and 250-East interchanges using type A, B, and C sealants, respectively, have the highest percent of faulting within their groups. Two of the characteristics that these interchanges share are high traffic density and heavy loads. Those two characteristics obviously contribute to the faulting.

The open end of a ramp and the area near the expansion joints are relatively unconfined; that is, the slabs near the open end can move out into the asphaltic concrete and the slabs near the expansion joints can move toward them. To the extent that such movement causes the loss of load transfer and allows the infiltration of water to the base and subbase, the potential for faulting is enhanced. That 13 out of 18 comparable ramps have 60 percent or more of their faulted joints near the open end and the expansion joints seems to support the preceding hypothesis. Of the four interchanges within which the distribution of faults can be compared, those at Routes 637, 29, and 250-E, each had a ramp with a disproportionately high incidence of faulting. All of those ramps carried heavier loads than did the other ramps, i.e., full trash trucks and dump trucks with aggregate or plant mix.

If all of the ramps are taken into account, the joints per ramp that were faulted ranged from a low of 0.0 percent to a high of 53.0 percent. These data were compared with many characteristics of the ramps, but no correlations were noted. Thus, no explanation for this variation in percentages is offered.

Installation Mistakes

The principal installation mistakes involved the twisting of and incorrect depth of the type A and B sealants, and the incorrect depth and partial lack of backing cord for the type C sealant.

Cracking

The two most obvious categories that the cracks fit into were those of nonworking and working. A nonworking crack is one that is in a relatively static state; a working crack may be said to be in a dynamic state. The principal nonworking cracks were in the area of the ramps that were adjacent to and tied to the interstate pavement. They were transverse and were usually continuations of the cracks that were in the adjacent mainline pavement. The working cracks usually occurred in that part of the ramp that was separated from the mainline of the interstate; they were transverse, longitudinal, and usually in proximity to areas where the pavement was, in effect, unconfined as it is at the open ends of the ramps and near the expansion joints. Some longitudinal cracks in the sections of the ramps that were isolated from both the mainline and the unconfined areas appeared to be nonworking, though they might become working cracks.

There are many factors that affect whether or not cracking will occur. How well the sealant prevents the intrusion of water and particles will affect the incidence of cracking. The intrusion of water provides lubrication for the movement of particles and also softens the base and subbase, and the accumulation of incompressible particles in the joint prevents the normal movement of the slab that accompanies changes in temperature. Eventually, the load transfer that occurs across the irregular surfaces of the contraction crack is lost when the slabs are forced so far apart that the meshing of the irregular surfaces which affects load transfer no longer occurs. Those areas where the slabs are less confined, such as at the open ends and near the expansion joints of the ramps, tend to support such conditions. For the 18 ramps in which the frequency of cracking within the four distinct areas of the ramps can be compared, 11 ramps had 50 percent or more of their cracked slabs close to the open end and the expansion joints. This observation becomes more important when coupled with the fact that the more severe cracking occurred within these less confined areas.

On only one ramp was the percentage of cracked slabs within its interchange much larger than the ramp's representation within the interchange's total population of slabs. The west bound (WB) off-ramp for the Route 250-E interchange had 47.7 percent of the cracked slabs and only 23.7 percent of the slabs within the interchange. The contractor made the initial joint cuts in this ramp later than he should have, and the changes that lead to shrinkage or contraction cracks were already occurring within the concrete. Thus, the initial cuts did not exercise the normal control over the locations of cracking, and many more cracks occurred than would have occurred had the sawing procedures been done earlier.

With the exception of the Route 616 interchange, the ramps had a relatively high incidence of cracking not significantly affected by the type sealant used. The very limited occurrence of cracks in the ramps within the Route 616 interchange was probably the result of the very low-density, light-load traffic that used that interchange.

Detailed Surveys

Approximately 10 percent (332) of the total number of joints, were examined in detail. After completing the detailed surveys, the extent to which the ramps were in cuts, at grade, or on embankments was quickly checked to provide information that might correlate with the analysis of the measured data.

The observations fit under four categories:

1. Joint - (1) width, (2) minor spalls, (3) intrusion by particles, (4) sawing errors, (5) extent of coverage by particles.

2. Sealant - (1) type sealant, (2) loss of adhesion, (3) loss of cohesion, (4) depth in joint, (5) installation error.

3. Concrete slabs - (1) cracking, (2) faulting, (3) severe spalling, (4) temperature of pavement surface.

4. Environment and site - (1) weather, (2) location in a cut or an embankment, (3) traffic conditions, (4) location of joints within a ramp.

Seasonal Effects

The detailed surveys were made in both warm and cold weather because it was anticipated that the widths of the joints would be significantly wider in cold weather and thus the loss of adhesion and cohesion would be easier to determine. The starting and ending dates of the surveys and the temperatures of the pavement surface are in Table 3.

To analyze the effect of temperature, the values obtained in warm weather were subtracted from the cold weather values. The widths of the joints were measured in 16ths of an inch. All of the interchanges had at least one joint that was open more when warm than when cold, thus giving a negative result. Many joints measured the same, warm or cold. Because no obvious pattern was discerned, the differences for each interchange were added algebraically. Then the averages of these sums were calculated. These results and the results from a similar analysis done on the faulting data (32nds of an inch) are presented in Table 4.

Table 3

Dates and Pavement Surface Temperatures

	Warm	Cold
Dates	8-28 to 9-21-84	3-15 to 4-9-85
Temperature range for entire period	62° to 116°F	20° to 74°F
Average daily temperature range	85° to 105°F	38° to 58°F

Table 4

Average Unit* Change Per Joint Per Interchange

	Averages							
Interchange/ Parameter	250-W	Rest Area	637	29	631	20	250-E	616
Width *1/16 in	-0.44	0.46	-0.16	0.23	0.46	-0.38	0.09	0.65
Fault *1/32 in	0.88	-0.67	1.0	1.14	0.29	1.09	1.5	0.00

That none of the values for the width approaches ±1.0 indicates that there was insufficient consistent expansion or contraction of the slabs within a given interchange to average at least a 16th of an inch of either the closing or opening of the joints.

The values for the analysis of the faulting show that five of the interchanges, with averages that ranged from 0.88 to 1.50, experienced more severe faulting during the cold weather survey. However, considering that the faulting was measured in 32nds of an inch, the magnitude of the average increase was not very great. Other than an increase in particles on top of the sealants because of the use of abrasives during winter snows, the preceding discussions seem to cover the differences that can be attributed to differences in temperature and seasons. Thus, no additional consideration will be given to the subject of the effect of temperature. In addition, it should be mentioned that the lack of sensitivity of the measurement techniques and different technicians making the measurements could easily account for those differences that were obtained.

Widths

Within the relatively confined areas of the ramps, most of the joints were as wide as they were originally cut. However, as a group, the change in the 1/2-inch joints (polysulfide) ranged from -25 to +25 percent, whereas the range for the group of 3/8-inch joints (neoprene) was from -17 to +33 percent. The change in a few joints within the unconfined areas, ranged from +50 to +200 percent. These large widths were always accompanied by failure of the sealant. There were several cases of the type A and B sealants being completely detached from the joint and either being removed from or very deeply buried within the joint. Despite its other failings, the type C sealant was usually firmly attached to at least one side of the joint and thus remained within the joint and near the surface.

Depths and Installation Mistakes

The only depths to sealant that were consistent were those of the type C sealant at the Route 637 interchange; unfortunately, they were near the surface, which was an installation mistake. There were many signs of tire-sealant contact -- such as abrasion, polishing, and stippling (possibly by studded tires) -- at that interchange.

The depths to the sealant at the rest of the interchanges were quite variable. The ranges in measured depths for the type A, B, and C sealants were 0.0 to 1.1, 0.065 to 1.5 and 0.0 to 1.2 inches, respectively.

Table 5 was prepared to allow for the easy calculation of the maximum depths possible for the sealants within the confined areas of the ramps, assuming the sealants did not experience any vertical compression and were sitting on the bottom of the wide-cut portion of the joints.

Table 5

Vertical Dimensions of Sealants and Joints in Inches
Based on Figure 1 and Table 1

Type Sealant	F Sealant	X Upper Section of Cut	Surface to Sealant	Z* Maximum Possible, Surface to Sealant
A	1 3/8 ± 1/16	1 6/8	3/16 ± 1/16	7/16 (0.44)
B	21/32	1 1/8	3/16 ± 1/16	15/32 (0.47)
C	(7/16±1/16)+5/8=1 to 1 1/8**	1 2/8	3/16 ± 1/16	2/8 (0.25)

* Z = X - F
** Sealant plus back-up material, when used.

If this maximum distance (Z) is exceeded, it would be interpreted as an installation mistake, which could have been caused by the vertical dimension of the sealant being too short, the wide-cut portion of the joint being cut too deep, or (with the type C sealant) a lack of the back-up material. Simply being deeper than the specified depth could have been caused by an installation mistake or by a loss of adhesion and subsequent settling of the sealant.

There were many locations where portions of a type A sealant were 0.45 to 0.55 inches deep and a few sites where it was 0.7 to 0.8 inches deep, see Figures 4 and 5. It would seem that some of these examples were the result of installation mistakes. Since these deep areas were usually so limited in length, it appears that the saw may have cut too deep in one location.

The depths that were measured for the type B sealant were quite variable, but they exceeded 0.47 inches only four times. However, when those four measurements range from 0.7 to 1.35 inches, it is likely that some type of installation mistake was involved.

The type C sealant at the Route 250-E interchange was either at the surface or was too deep. The depth measurements where the sealant was too deep ranged from 0.4 to 1.23 inches. The latter, of course, is very close to being as deep (1.25 inches) as the wide-cut section of the joint is supposed to be cut.

The other types of installation mistakes that were observed were twisted type A sealant (Figure 6), incorrectly sawn joints (Figure 7), and type C sealant that was too close to or at the surface at the Route 250-E interchange (Figure 8).

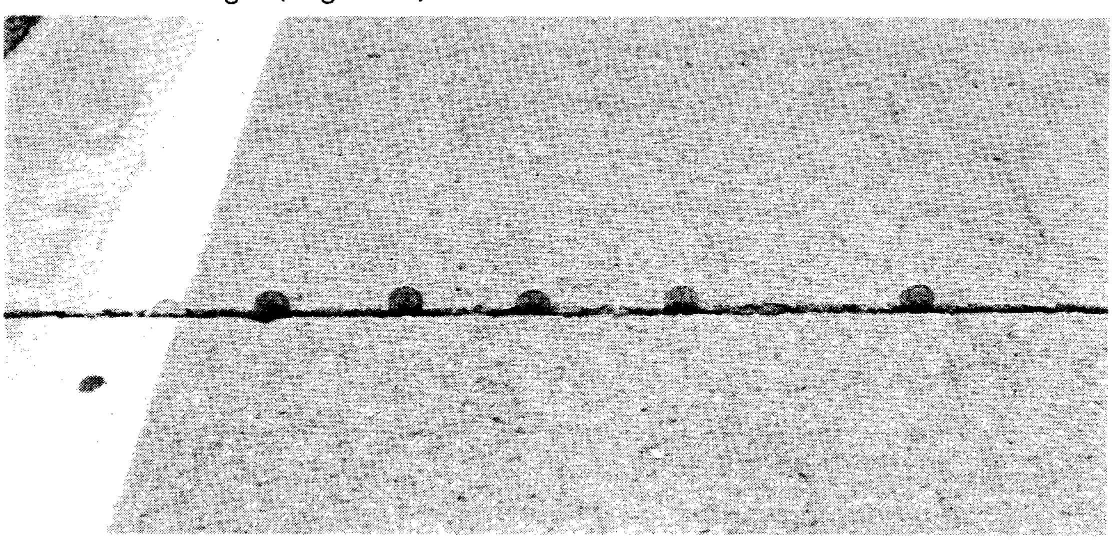


Figure 4. Type A sealant with depths of 0.45 to 0.55 inches.

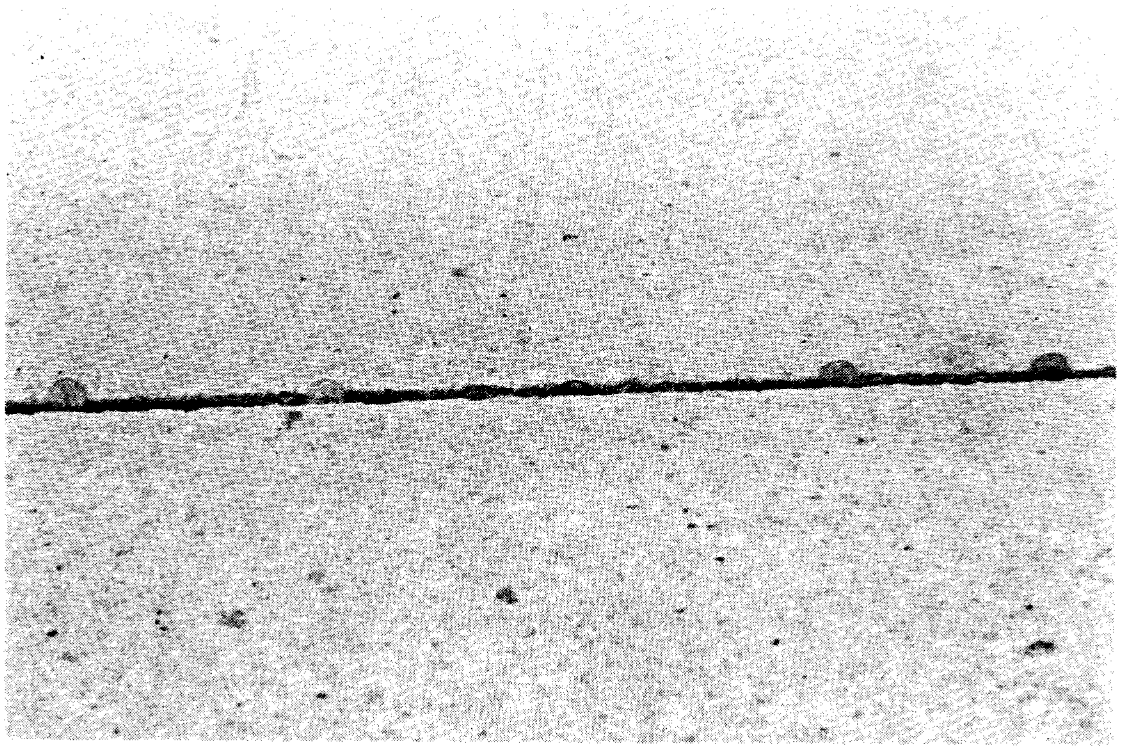


Figure 5. Type A sealant with depths of 0.7 to 0.8 inches.

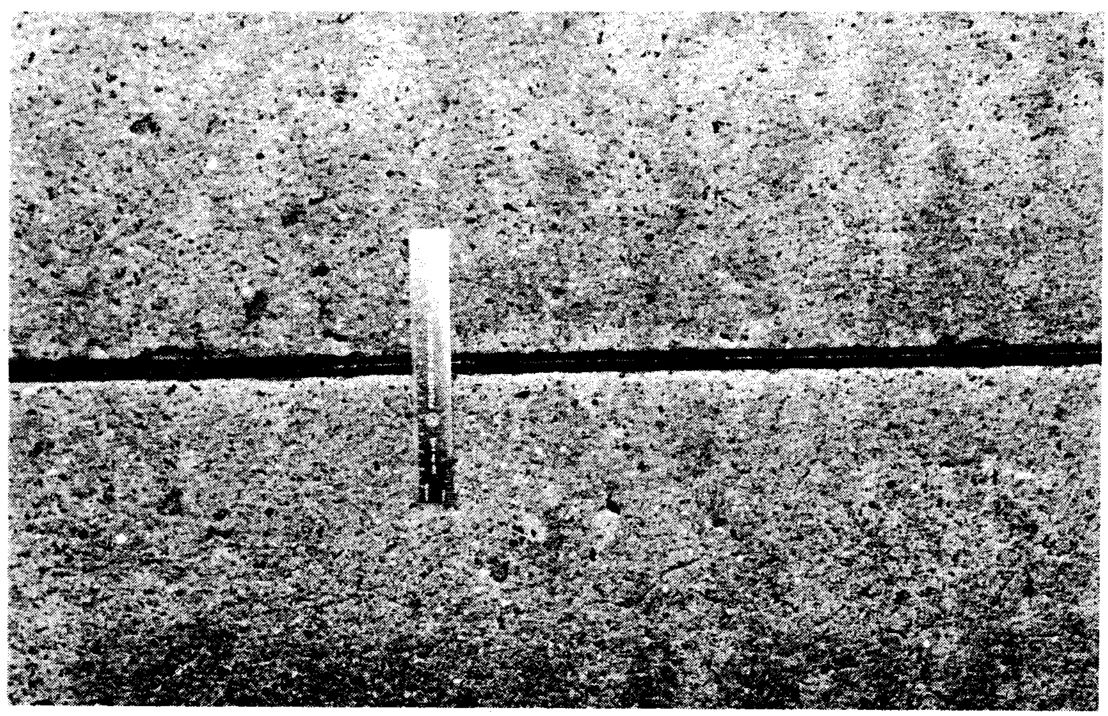


Figure 6. Type A sealant - twisted.

-1084

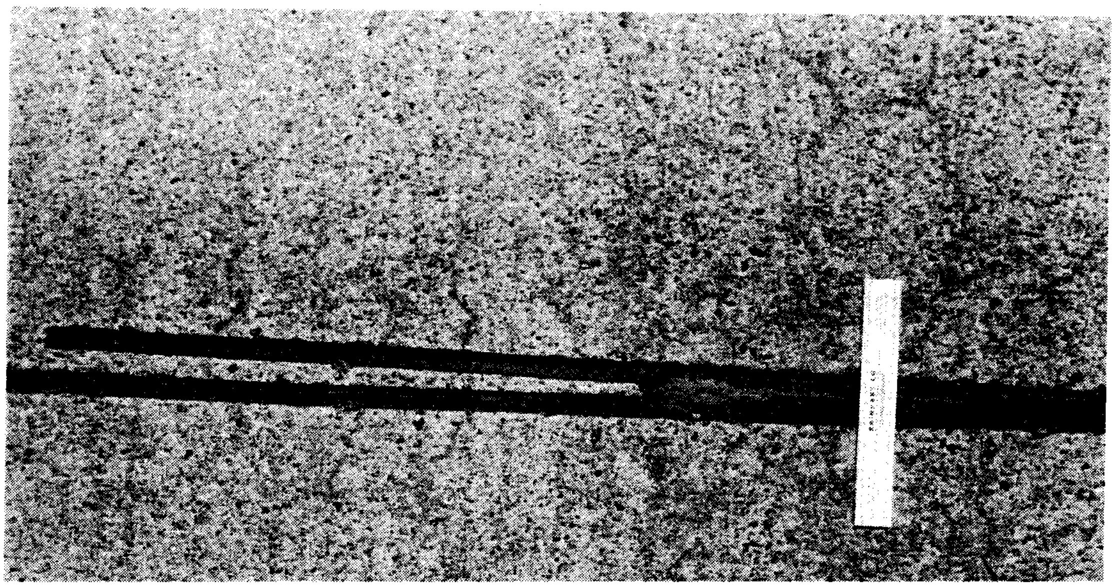


Figure 7. Incorrectly sawn joint.

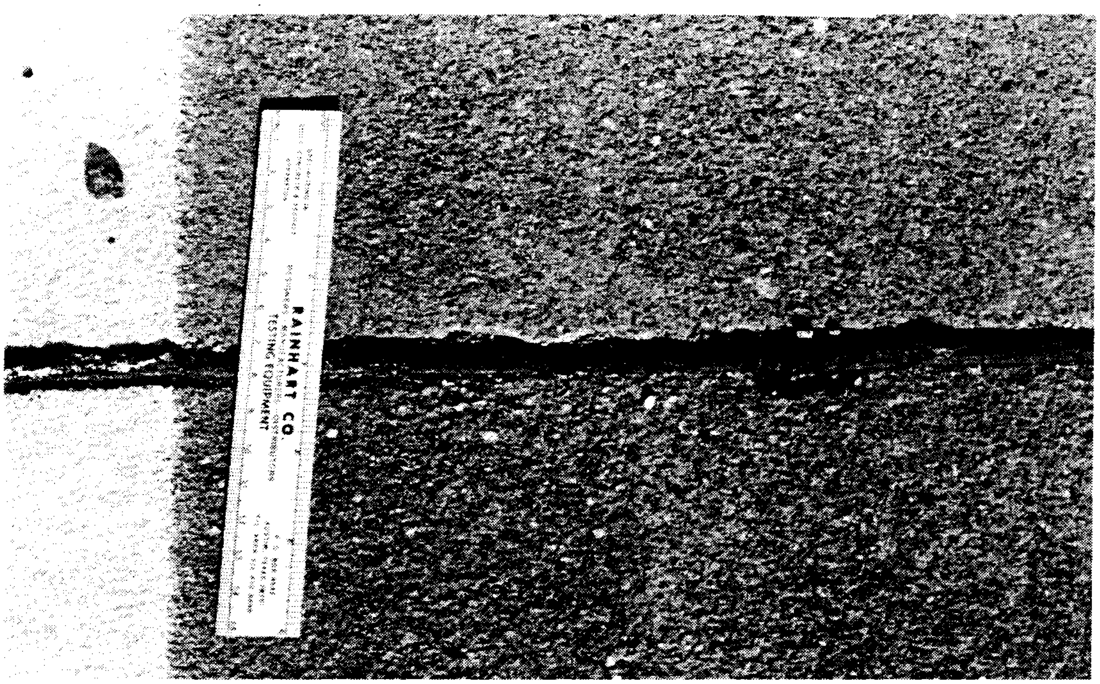


Figure 8. Type C sealant that is above pavement surface.

Faulting

All of the interchanges had some faulting of the joints, though the occurrence was much less at some than at others. There was so little faulting at the rest area and the Route 616 interchange that only one measurement was made at each of those sites. The ranges in measurements are listed in Table 6.

The detailed observations tended to confirm the conclusions drawn from the analysis of the preliminary survey, that traffic density, load, and the location of the joints in a confined or an unconfined area of the ramps affects the occurrence and severity of the faulting. The most frequent and most severe faulting occurred in the unconfined areas of the ramps. Those ramps that carried high density traffic or heavy loads also had a significant quantity of severe faulting within the confined areas of the ramps, for example, on the west bound "on" ramp from south bound Route 20, the west bound "off" ramp to north bound Route 29, and the west bound "on" ramp from Route 250-E for type A, B, and C sealants, respectively.

Adhesive and Cohesive Losses

The incidence of adhesive loss for the preformed sealants (A and B) was quite low. This type failure occurred only within the relatively unconfined areas of the ramps for those sealants. Apparently the movement in the joints within the unconfined areas had been so large that a few joints experienced total failure of the sealant, though this did not often occur. At two or three joints, the sealant was missing, and at one it was buried under 1.5 inches of particles (See Figures 9 and 10). These sealants (A and B) did not have any cohesive loss.

Table 6

Faulting in Inches

Interchange	Type Sealant	Range
250W	A	1/32 to 10/32
Rest Area	B	2/32
637	C	1/32 to 5/32
29	B	2/32 to 9/32
631	A	2/32 to 9/32
20	A	2/32 to 10/32
250E	C	2/32 to 8/32
616	B	2/32

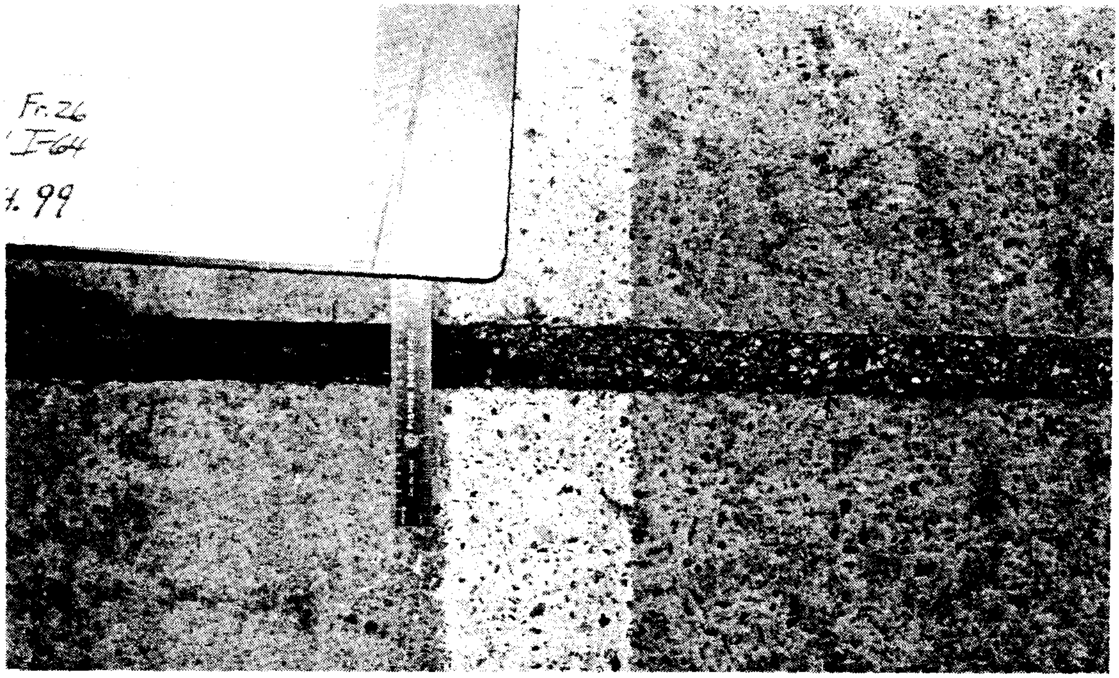


Figure 9. Type A sealant missing at Rt. 631 interchange.

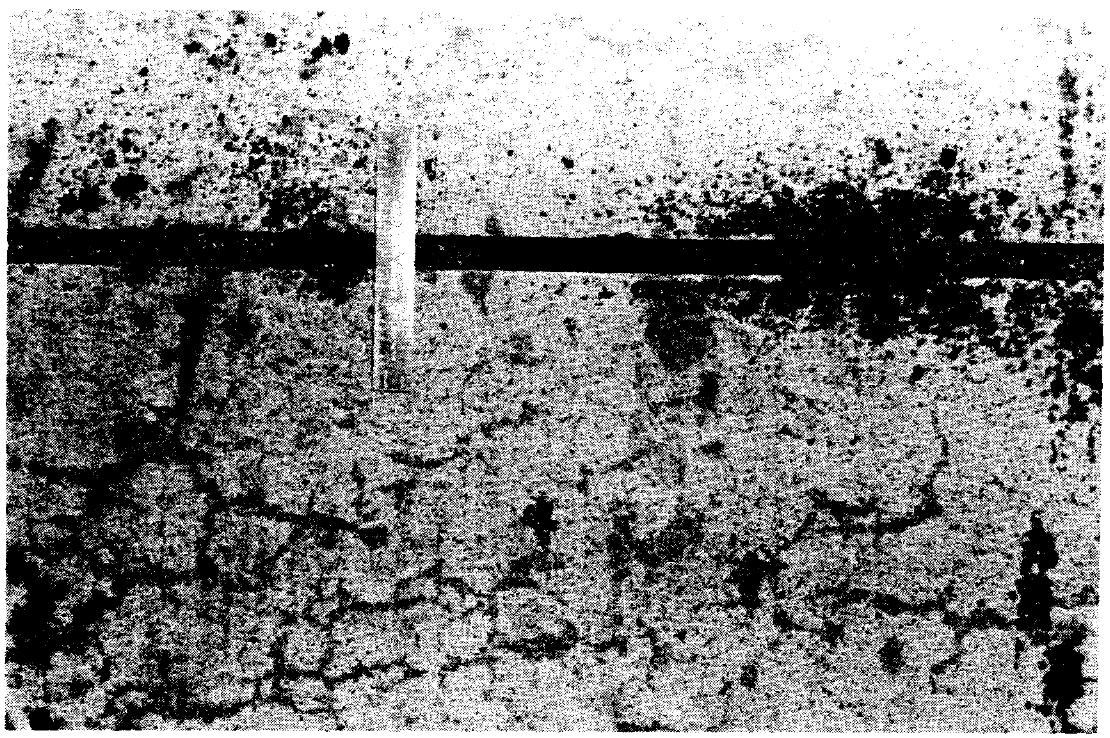


Figure 10. Type B sealant buried at rest stop.

The preformed sealants experienced failure only where extreme movement of the joints could occur, such as at the open ends of the ramps and near the expansion joints. Also, these materials appear to have greater tensile strength than the adhesives that were used to lubricate and then bond the sealants to the sides of the joints.

The incidence of adhesive and cohesive losses for the type C sealant was very high. The failures occurred in all portions of the ramps. The severest failures were located within the least confined areas of the ramps. Most of the joints were their specified width; and it can be assumed that the sealant initially filled the joint because where there was cohesive failure, the sealant was firmly fixed to both sides of the joint. Inasmuch as the gaps that were created by the adhesive and cohesive losses were easily observed, it appears that the polysulfide sealant suffered compressive set (loss of elasticity while in the compressed state) followed by loss of adhesion and cohesion (See Figure 11).

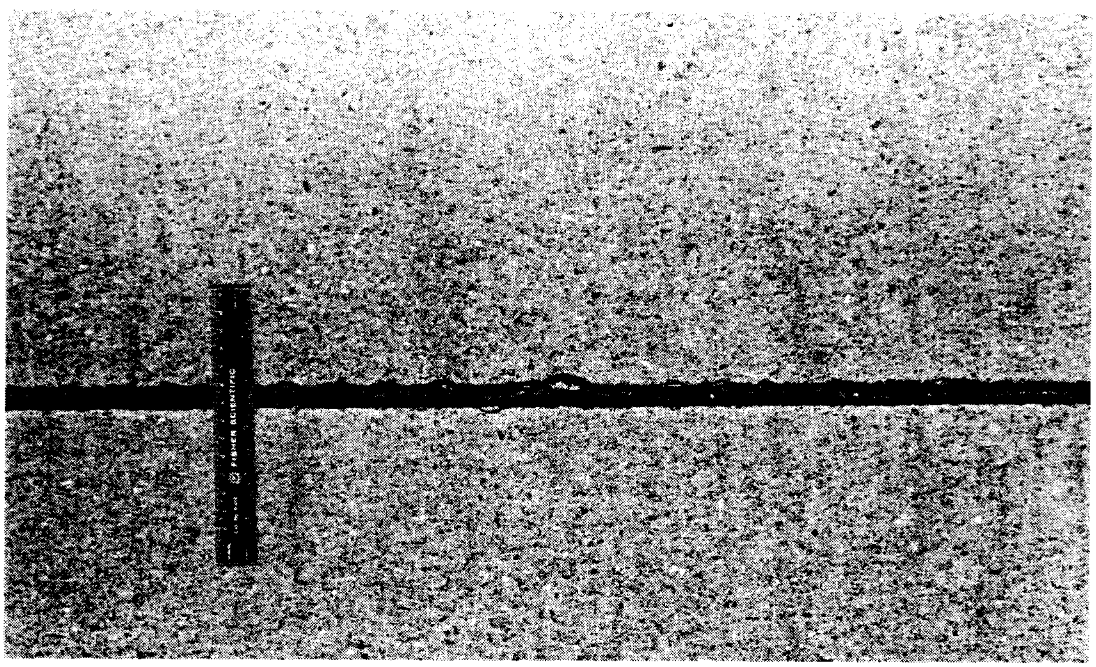


Figure 11. Cohesive and some adhesive loss for the type C sealant.

Interestingly, many of the joints with type C sealant had both adhesive and cohesive losses within the same length of sealant (Figure 12); consequently, they suffered 100 percent failure.

Particles in Joints

Wherever the integrity of the sealant was disrupted, particles were in the joint and below the sealant in varying concentrations. Other than participating as part of the mechanism by which the slabs in the unconfined areas were pushed further apart each year by the seasonally controlled contraction and expansion of the slabs, this intrusion did not seem to be responsible for any specific and widespread failure of the slabs (Figure 13).

The widest spaced joints with the greatest volumes of particles were those in the vicinity of the open ends of the ramps and the expansion joints. The particles apparently came from a variety of sources, such as deicing mixtures, adjacent terrain, trucks going to the dump, and trucks delivering aggregate (See Figure 19.)

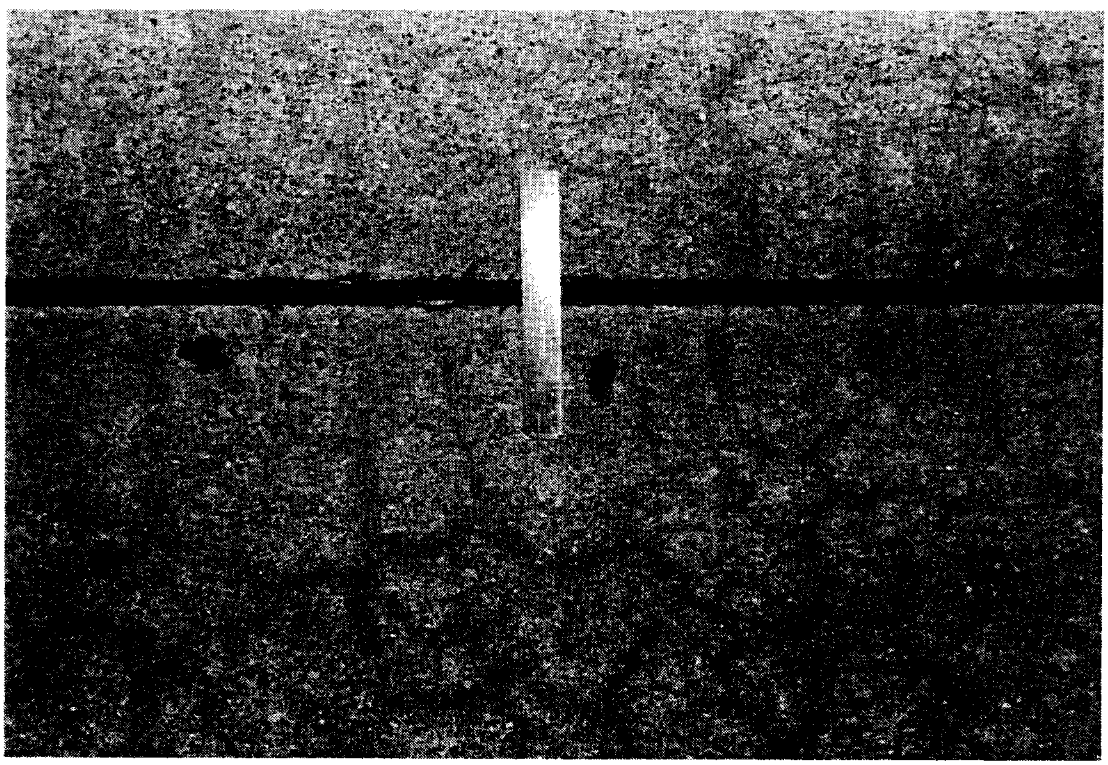


Figure 12. Overlapping failure for type C sealant.

Spalling

Minor spalling, which may have been caused by the saw blade at the time the joint was cut, was widespread, but did not have any detrimental effect on the slabs. Relatively few large spalls were observed that could disrupt the integrity of the sealants and with the intrusion of particles into the joint, eventually contribute to distress within the slab (See Figures 14 and 15).

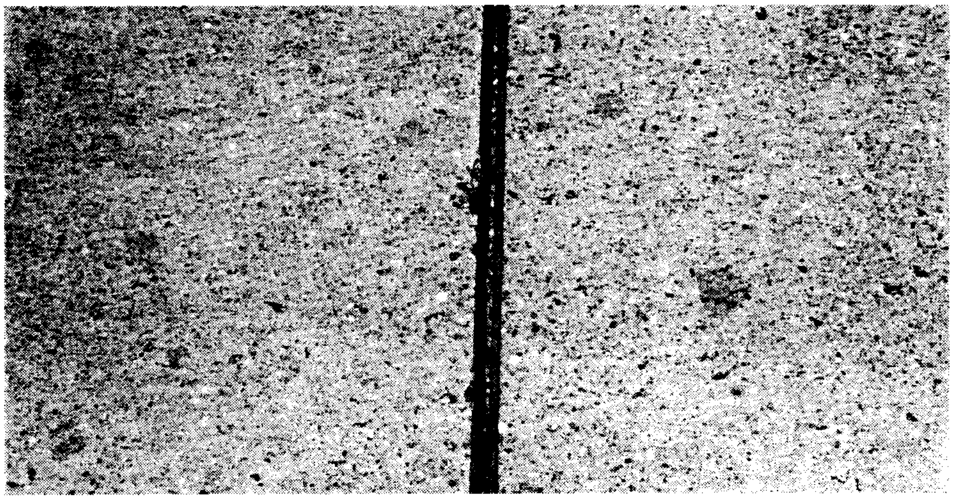


Figure 13. Large content of particles with minimal distress of slab.

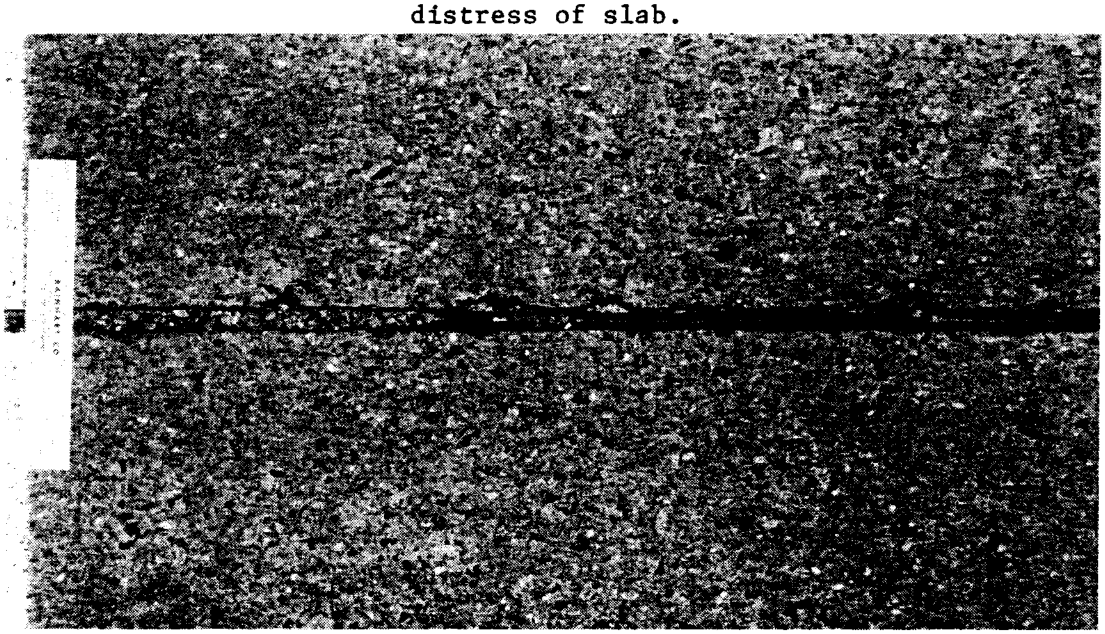


Figure 14. Small spalls.

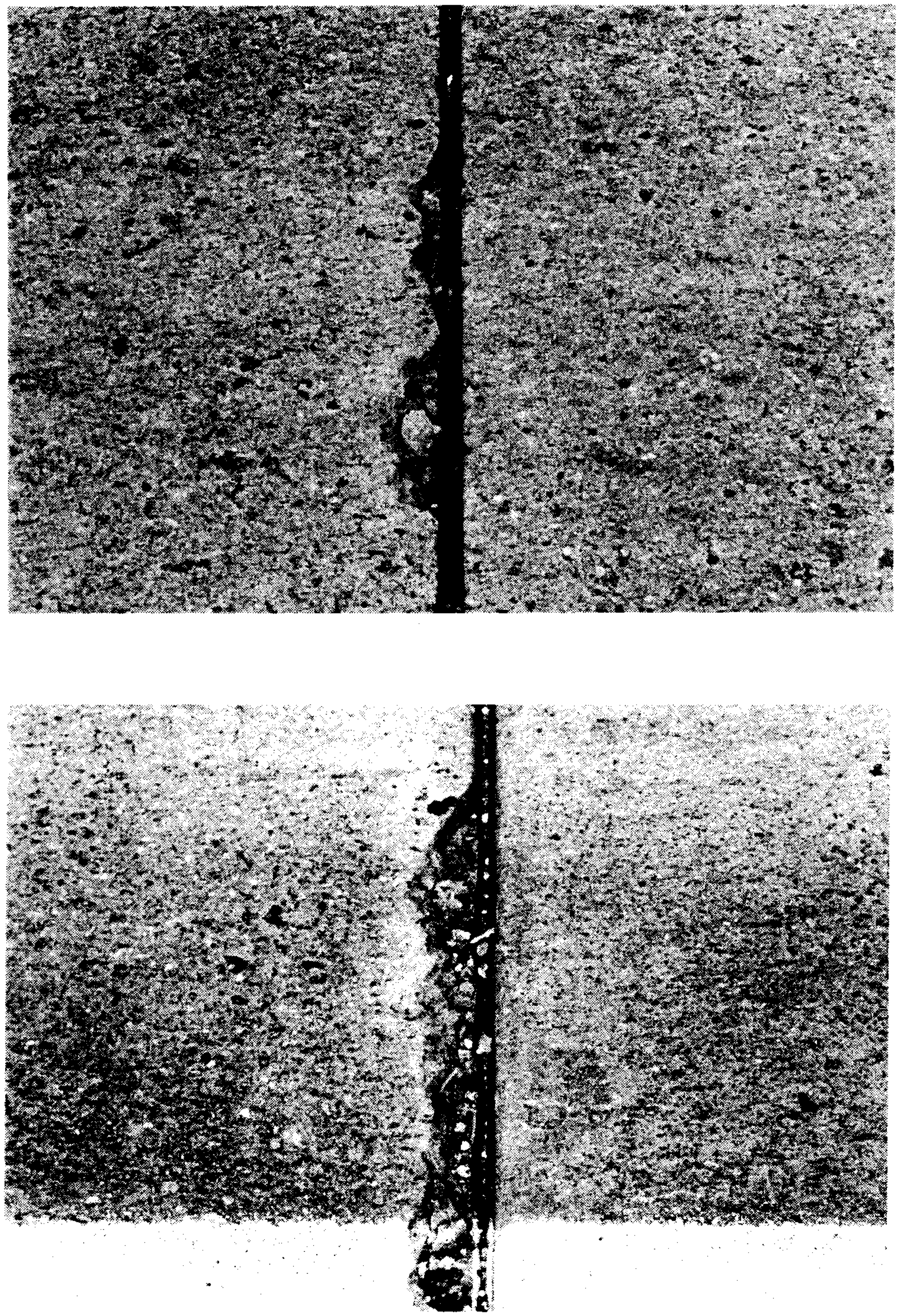


Figure 15. Large spalls.

Cracking of the Slabs

Cracking occurred at all the sites, though to a lesser degree at the lightly traveled Route 616 interchange. The severest cracking occurred close to the relatively unconfined sections of the ramps. It was hypothesized that the slabs could lose their intergranular load-transfer mechanism in the unconfined sections of the ramps because they had freedom to move either toward the open end or the expansion joints. It seems that once the slabs lost their load transfer mechanism and were functioning independently of each other, they were severely abused by the heavy traffic.

Figures 16, 17, and 18 show the type of cracking that occurred close to the open ends, expansion joints, and the confined areas. The cracks pictured in Figures 19 and 20 illustrate the significance of a slab's being relatively unconfined or confined. The Route 250-E interchange did not have expansion joints cut. Figure 19 shows the severity of the cracking and the width of joint 1 near the open end of the west bound "on" ramp. Figure 20 shows the relatively mild cracking of the slabs in the location where expansion joints would have been located; but because these slabs remained confined, they maintained their load-transfer mechanism.

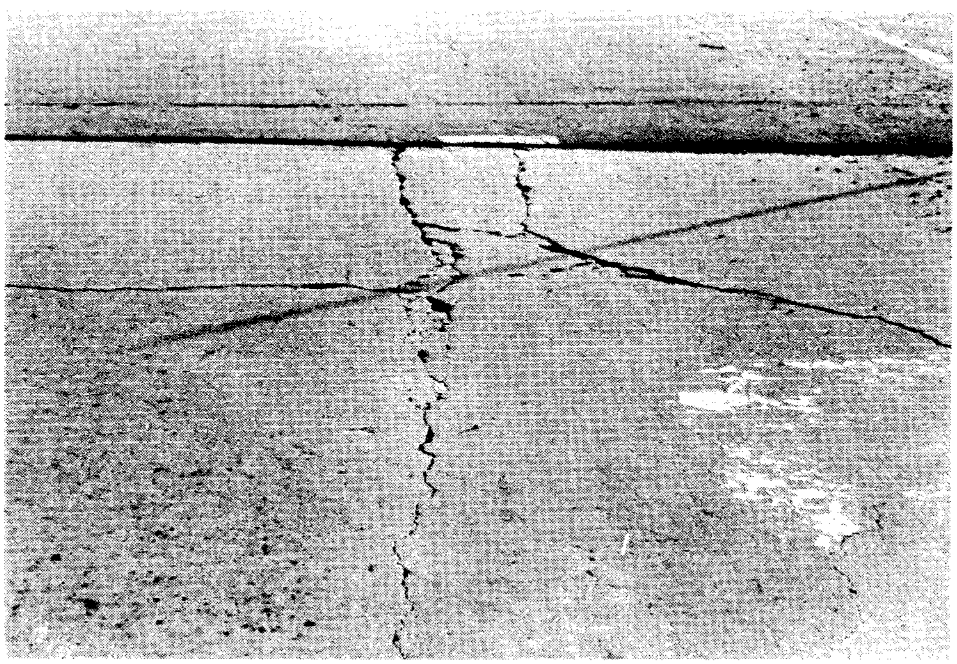


Figure 16. Severely cracked slab at open end of ramp.

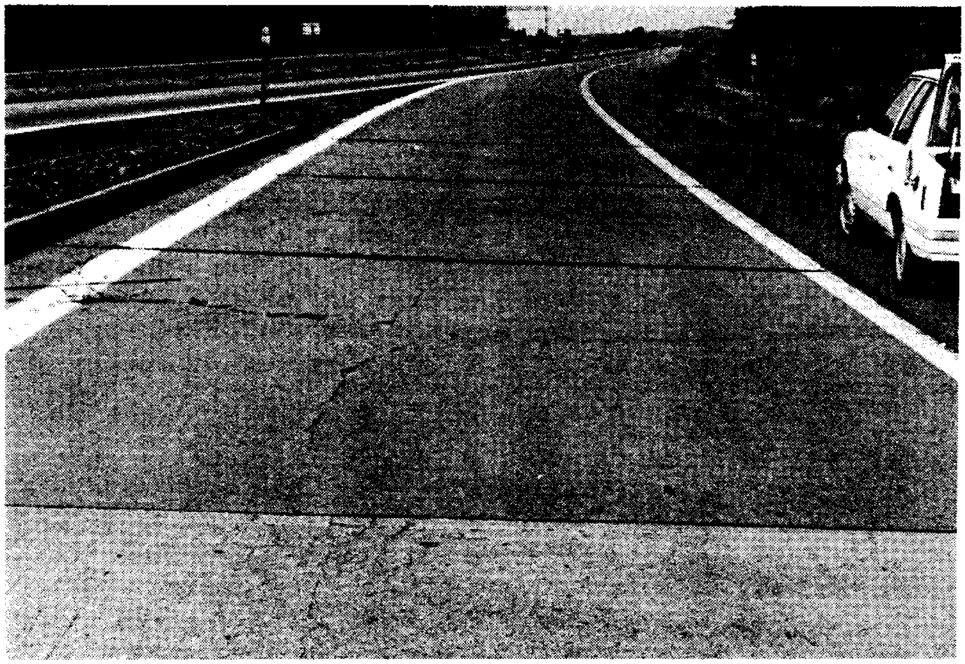


Figure 17. Severely cracked slab adjacent to expansion joints.

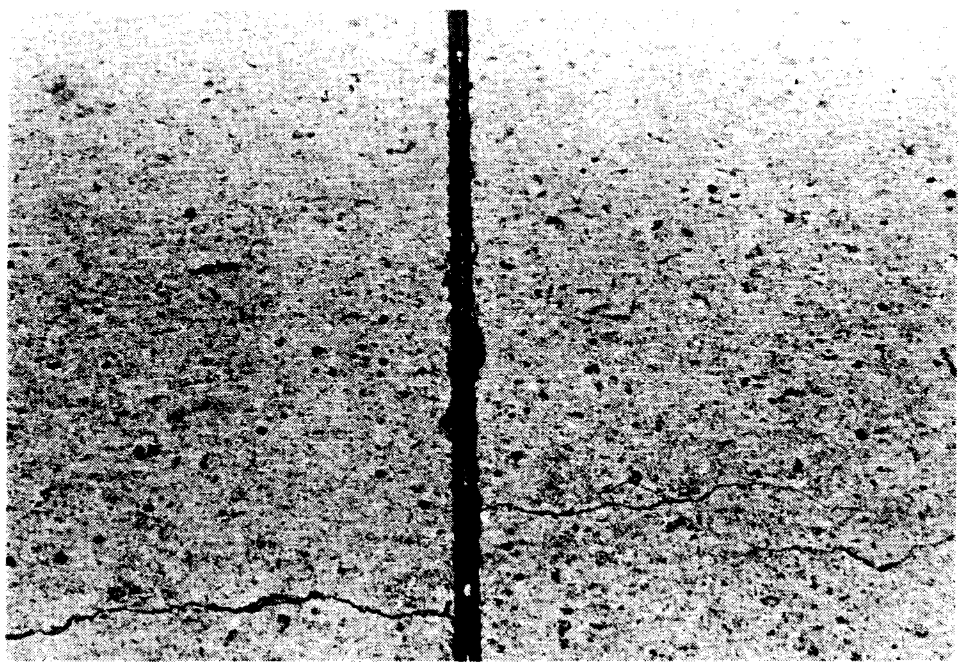


Figure 18. Cracking of slabs within a confined area.

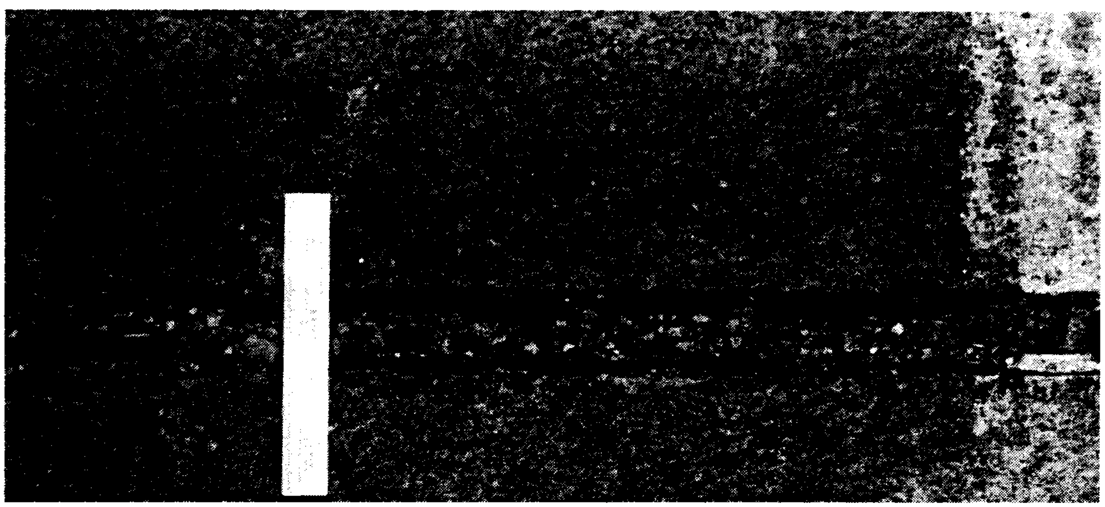


Figure 19. A - Cracking of 1st slab WBL on 250 E.
B - 1st Joint - 1/34 inches wide.

-1094

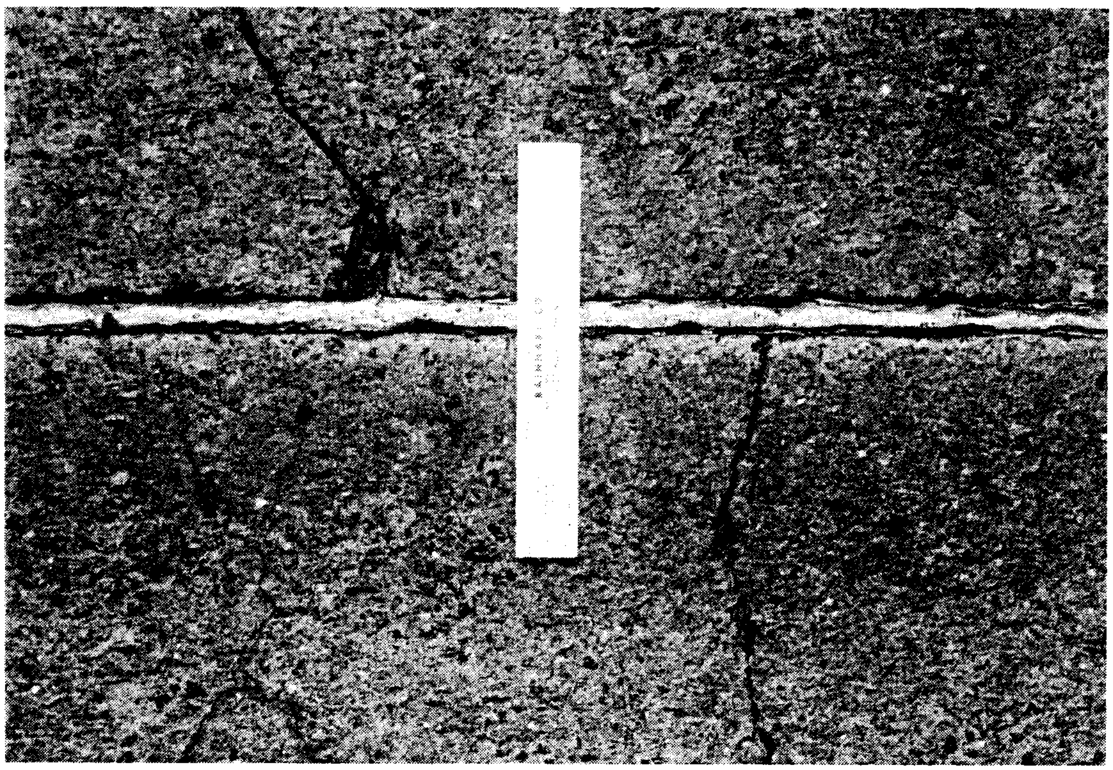


Figure 20. Mildly cracked slabs.

CONCLUSIONS

The type A and B sealants performed much better than the type C sealant; they had very low adhesive losses and no cohesive losses compared to the polysulfide sealant.

The widths of most of the joints in the Routes 637 and 250-E interchanges were within the limits of the specifications, yet quite obvious gaps were observed in the type C sealant that had initially filled the joints. Thus, the type C sealant appears to have failed because of compression set, with the subsequent loss of adhesion and cohesion when the slabs contracted.

Inasmuch as the type A and B sealants did not experience any loss of cohesion, it seems that they had much greater tensile strength than did the adhesive that was used to bond them to the sides of the joints.

The particles in the joints were more instrumental in forcing the slabs apart (resulting in the loss of the load transfer mechanism) than they were for any damage such as spalling.

The faulting between and the cracking of the slabs were frequently symptoms of failed sealants rather than failures of the slab; they occurred when the slabs were forced apart thereby losing the load transfer, and the slabs began to function independently rather than as part of a linear support system.

The loss of load transfer probably occurred because the sealants failed and particles penetrated the open joints when the weather was cool; consequently, when the slabs expanded during hot weather, there was no space to allow for the expansion. Thus the slabs moved toward those areas where they were less confined, such as the open ends of the ramps and the expansion joints.

Based on the rather limited evidence collected at the Route 250-E interchange, the absence of expansion joints contributed to the maintenance of the load transfer mechanism.

RECOMMENDATIONS

It is recommended that:

1. The Department discontinue the use of cold-mixed polysulfide material to seal contraction joints in PCC pavements.

2. The Department use preformed neoprene sealants or comparable sealants to seal joints in PCC.

   These first two recommendations have already been put into effect by the Materials Division on the basis of field tests made by the Materials Division and the conclusions of this report.

3. Because the loss of the load transfer mechanism appears to be a very important factor in the distress of concrete slabs, the Department should discontinue the cutting of expansion joints in ramps near their join with the mainline. This should be put into effect on a limited basis, and the performance of the ramps so treated should be monitored.

4. One or more slabs at the open ends of the ramps should be anchored so that the load transfer mechanism is not lost by the movement of the slabs outward against a nonconfining roadway.

ACKNOWLEDGEMENTS

This study was supported with HP&R funds, the use of which was supervised by the FHWA.

I hereby acknowledge the help of the Research Council's professional and support staffs in providing assistance in carrying out the study reported on here. In particular, I would like to thank M. O. Harris for his help with the preliminary and detailed surveys, B. A. Turner for her assistance in preparing the final report, and K. H. McGhee for his technical input relative to the design of pavements and the use of sealants.

-1098

REFERENCES

1. Minkarah, I., J. P. Cook, and J. F. McDonough, "Magnitude of Horizontal Movement in Jointed Concrete Pavements," Transportation Research Record No. 821, Transportation Research Board, Washington, D.C., pp. 61-67, 1981.

2. Thornton, J. B., "Rigid Pavement Joints and Sealants Study," Georgia Department of Transportation Research Project No. 6903, Office of Materials and Research, Atlanta, Georgia, 144 pp., 1975.

3. Bryden, James E., Wm. M. McCarty, and L. J. Cocozzo, "Maintenance Resealing of Rigid Pavement Joints," Transportation Research Record No.598, Transportation Research Board, Washington, D. C., pp. 37-44, 1976.

4. Bryden, James E., and R. A. Lorini, "Performance of Preformed Compression Sealers in Transverse Pavement Joints," Research Report 76, New York State Department of Transportation, Albany, New York, 39 pp., 1980.

5. Cook, J. P., and R. M. Lewis, "Evaluation of Pavement Joint and Crack Sealing Materials and Practices," National Cooperative Highway Research Program -- Report No. 38, Highway Research Board, Washington, D. C., 40 pp., 1967.

6. National Cooperative Highway Research Program -- Synthesis of Highway Practice -- Report No. 19, "Design, Construction, and Maintenance of PCC Pavement Joints," Highway Research Board, Washington, D. C., 40 pp., 1973.

7. Ray, G. K., "Effect of Defective Joint Seals on Pavement Performance," Transportation Research Record No. 752, Transportation Research Board, Washington, D. C., pp. 1-3, 1980.

8. National Cooperative Highway Research Program - Synthesis of Highway Practice - Report No. 56, "Joint-Related Distress in PCC Pavement - Cause, Prevention and Rehabilitation," Transportation Research Board, Washington, D.C., 36 pp., 1979.