1839

STATE DEMONSTRATION PROJECT: LOOP DETECTORS

by

E. D. Arnold, Jr.
Research Scientist

G. L. Munn
Electrical Engineer

and

R. E. Steele
Materials Engineer

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

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

Charlottesville, Virginia

January 1985
VHTRC 85-R21

-1840

TRAFFIC RESEARCH ADVISORY COMMITTEE

-1841

ABSTRACT

The Virginia Department of Highways and Transportation frequently utilizes induction loops in its vehicle detector systems. Although not documented, there have been many instances of loop failure; therefore, the practices and materials used by the Department in installing loop detectors were investigated. Two field tests were initially undertaken -- the encasement of the loop wires by PVC conduit and vinyl tubing and the performance of different types of loop sealants. Also, laboratory tests were undertaken to further evaluate the performance of loop sealants, to determine the type and quantity of sand to add to epoxy sealants, and to derive the expansion factor of the resulting mixture. Finally, a third field test was undertaken to evaluate several of the laboratory findings.

This report provides the status of the first two demonstrations and documents the findings and conclusions of the laboratory tests and the third field test. Several recommendations concerning the expansion factor, the current sealant specifications, and the required width of saw cut are made.

-1842

STATE DEMONSTRATION PROJECT: LOOP DETECTORS

by

E. D. Arnold, Jr.
Research Scientist

G. L. Munn
Electrical Engineer

and

R. E. Steele
Materials Engineer

INTRODUCTION

A common type of vehicle detector system utilized by the Department is the induction loop detector. Typically, the system is installed in conjunction with a traffic signal system or an isolated signal where vehicle detection is needed for actuation. Loop detectors are also being used for volume counting.

The installation of loop detectors, while not excessively difficult or complicated, does require that attention be given to following established procedures. Otherwise, the detector system may fail prematurely. While the incidence of failure has not been documented in Virginia, the replacement of loops is not a rare event. As more loops are installed, it is anticipated that failures and the need for replacement will become more common.

Accordingly, a research project was initiated in the fall of 1981 to investigate the current practices and materials used by the Department in the installation of loop detectors. Two field tests were conducted -- an investigation of the feasibility and value of encasing the loop wires in PVC conduit or vinyl tubing and of the performance of various loop sealants. An Installation Report was prepared which documented the installation of the two field demonstrations and the initial findings and recommendations.(1)

---

1. Arnold, E. D., Jr., and G. L. Munn, "Installation Report, State Demonstration Project--Loop Detectors," VHTRC 83-R15, Virginia Highway and Transportation Research Council, Charlottesville, Virginia, October 1982.

-1844

Also, laboratory tests were undertaken at the Research Council and at the Materials Division which had direct bearing on the project. The former tests were performed to evaluate loop sealants, whereas the latter tests were conducted in response to recommendations in the Installation Report regarding the type and quantity of sand to be added to epoxy systems and the resulting expansion.

Finally, a third demonstration was undertaken to evaluate in field application several of the findings of the laboratory tests at the Materials Division.

PURPOSE AND SCOPE

Accordingly, the purpose of this report is to describe the activities associated with the loop detector demonstration project that have been conducted since the initial Installation Report. Specifically, documentation of the following is contained in this report.

1. Status of the first two demonstrations

2. Descriptions, findings, and conclusions of the laboratory tests conducted at the Research Council and the Materials Division

3. Description of the third demonstration

Several recommendations based on the aforementioned activities are also presented.

STATUS OF DEMONSTRATIONS 1 AND 2

The test loops at the first two demonstration sites were inspected several times after their installation. None of the loops had failed; however, noticeable deterioration had occurred in several instances. Further, recent repair work at both sites has negated all or part of the demonstrations. Following is a brief description of the demonstrations and their status. It should again be noted that an Installation Report describes in detail these first two demonstrations.(1)

Demonstration 1 -- Encasement

The purpose of the first demonstration was to test the feasibility of encasing the standard loop wire (12 gauge, Type XHHW, 600 volt) in 1/4" plastic tubing and in 1/2" rigid PVC conduit prior to installing it in the pavement. In November 1981, two 3-turn, 7' x 8' loops utilizing the above encasements were installed and wired in series with two loops installed without encasement in a left-turn lane having an exclusive signal phase at an intersection in Richmond. This installation was a replacement for an 8' x 40' loop which had apparently failed because of extreme pavement distortion resulting from a slight decline and a large number of heavy trucks approaching the signal. It was hypothesized that the encased loops would better withstand the adverse conditions at the site than the non-encased loops and, accordingly, would not fail as quickly. Since the loops were wired in series, a failure in a single loop could be detected.

The severe distortion of the pavement at the site necessitated repair. Accordingly, on September 13, 1984, the surface was removed with a heater plane and the section was repaved. In the process, the test loops were ripped out, thus cancelling further evaluation of the site.

At that point, the test loops had been through three winters and three summers and, as indicated previously, had not yet failed. All loops, however, had begun to deform as the pavement continued to buckle under the adverse traffic and geometric conditions. Significant displacements in the saw cuts had occurred, particularly across the lane. In fact, a failure appeared imminent. Figure 1 shows an example of this displacement. The saw cuts have been highlighted with chalk.

Figure 1. Loop distortion at site of Demonstration #1.

Demonstration 2 -- Sealants

The purpose of the second demonstration was to field test different types of loop sealants. In March 1982, nine field-test loops utilizing six types of sealants were installed in Richmond. The sealants were Bondo P-606, Sealex, E-Bond 1260, Gold Label Flex, MagnoLoop I, and 3M. Each sealant was evaluated in terms of ease of mixing, typical quantity mixed, ease of application, pot life, cure time, and clean-up.

At this point, all test loops have been through two winters and three summers and, as indicated previously, are functioning properly. The Sealex is still very flexible and seems to be bonding well with the sides of the saw cut. No debris has become embedded in the sealant. The 3M sealant seems to be hardening, debris has become embedded in it at spots, and it seems to be pulling out of the slot at spots. The other four sealants, all of which are relatively hard and rigid, are performing satisfactorily with few signs of deterioration.

Unfortunately, field forces inadvertently covered two of the loops and part of a third loop with a crack sealer. It cannot be determined why these particular loops were covered and, accordingly, a valid comparison of these loops with the other test loops is not possible.

Conclusions from Demonstrations 1 and 2

Since the test loops at the first demonstration site were ripped out during the maintenance work, no final conclusions regarding encapsulation of the wire by PVC conduit or vinyl tubing can be made. After almost 3 years, the test loops using both nonencapsulated and encapsulated wire were all functioning properly; therefore, there is no evidence to suggest that encapsulating the wire improves performance. Unfortunately, 3 years of evaluation is too short a period to conclude that encapsulation is not warranted.

Since all test loops at the second demonstration site are still functioning, it is impossible to draw final conclusions regarding the sealants being tested. Periodic monitoring of the site will be maintained.

LABORATORY TESTING

Personnel at both the Research Council and the Materials Division of the Department of Highways and Transportation have conducted laboratory tests pertinent to the demonstration project. All tests were devised to address questions concerning the type and use of loop sealants. None of the evaluations utilized standardized or ASTM-type testing procedures; therefore, the results must be used only to draw conclusions concerning relative performance. In other words, the tests do not necessarily measure field performance. This section of the report describes the laboratory testing.

Tests at the Research Council

Laboratory testing at the Research Council was undertaken with the primary purpose of evaluating different types of loop sealants. It was not intended to evaluate individual brands but rather to compare the performance of the hard, rigid sealant to the soft, pliable sealant. A secondary purpose was to evaluate a 1/4" slot width versus a 3/8" slot width for the loop wire. Current Department standards require a 3/8" slot for the twisted lead-in wire and a 3/8" or 1/4" slot for the remainder of the loop.

A total of 45 asphaltic test beams measuring 3-1/4" x 3-1/2" x 15" and 24 concrete test beams with dimensions of 3" x 4" x 16" were made. Both the asphalt and the concrete mixtures were typical of those used in Virginia pavements. Saw cuts which were either 1/4" or 3/8" wide were then made along the length of the beams. Two saw cuts were made in 21 of the beams. As required in the Department's standards, the slots were generally 3" deep in the asphaltic beams and 2" deep in the concrete beams. The depth of cut for the asphaltic beams tested in fatigue was only 1" because the beam had to be cut down in cross section in order to fit it into the fatigue testing machine. Three strands or two twisted strands of the Department's standard loop wire (12 gauge, Type XHHW, 600 volt) were then placed in each slot. The ends of the beams were plugged with duct seal compound, and the slots were then filled with one of six loop sealants used in Demonstration 2. These operations were carried out inside a large garage with the doors open for ventilation. Examples of the completed test beams are shown in Figure 2.

-1848

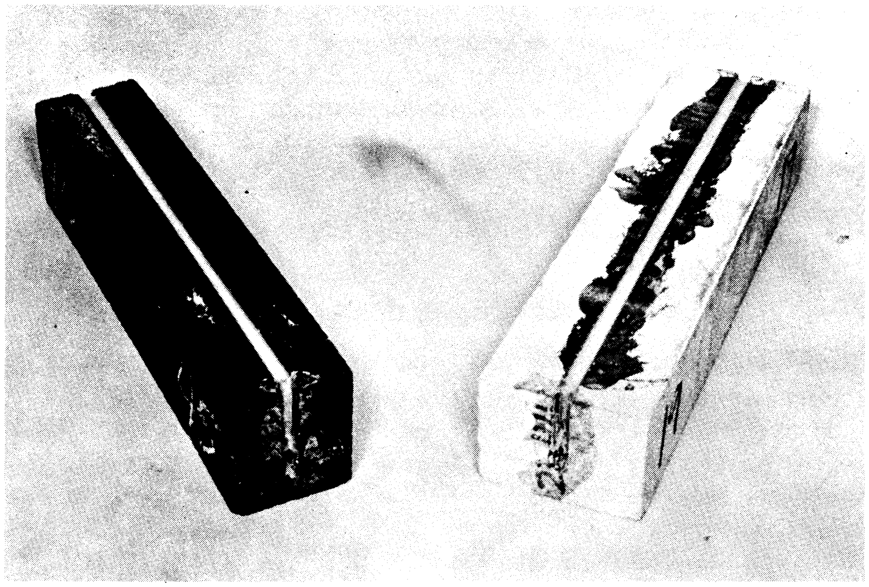

Figure 2. Laboratory test beams.

Three measures of performance were evaluated--the adequacy of encapsulation of the loop wires by the sealant, the effects of freeze/thaw cycling, and the effects of repeated bending or fatiguing of the test beams. It is noted that the fatigue test was performed on asphaltic beams only. Table 1 summarizes the testing procedure. The next sections describe the tests and results.

Table 1

Summary of Testing Procedures

Test, Material, Slot Width, Loop Wire Configuration	Number of Test Slots					
	MagnoLoop	E-Bond	Bondo	Sealex	Gold Label	3M
Encapsulation-Concrete						
1/4" slot, 3 strands	1	1	1	1	1	1
3/8" slot, 3 strands	1	1	1	1	1	1
3/8" slot, twisted	1	1	1	1	1	1
Encapsulation-Asphalt						
1/4" slot, 3 strands	1	1	1	1	1	1
3/8" slot, 3 strands	1	1	1	1	1	1
3/8" slot, twisted	1	1	1	1	1	1
Freeze/Thaw-Concrete						
1/4" slot, 3 strands	1	1	1	1	1	1
3/8" slot, 3 strands	2	2	2	2	2	2
Freeze/Thaw-Asphalt						
1/4" slot, 3 strands	1	1	1	1	1	1
3/8" slot, 3 strands	2	2	2	2	2	2
Fatigue-Asphalt						
1/4" slot, 3 strands	1	1	1	1	1	1
3/8" slot, 3 strands	2	2	2	2	2	2

Encapsulation Test

It is generally agreed that the loop sealant should completely encapsulate the loop wires in order to keep moisture out and physically protect the wire. In order to evaluate the adequacy of encapsulation, the designated test beams were sawed into quarters across their width and depth. Examples of cross sections are shown in Figures 3 and 4. Accordingly, three cut cross sections for each of the 36 test slots were available for evaluation, which resulted in 108 observations. The adequacy of encapsulation for each cross section was subjectively rated as being either satisfactory or not satisfactory. A rating of "not satisfactory," which was given if a cavity or void was observed in the cross section, was recorded for 15 of the 108 observations. See Figure 5. The failed cross sections are categorized in Table 2.

-1850

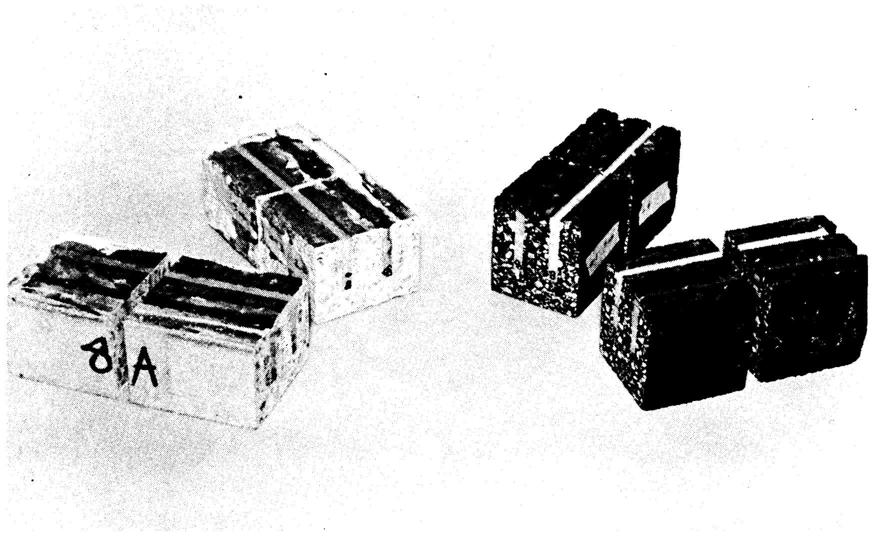

Figure 3. Beams sawed in cross section.

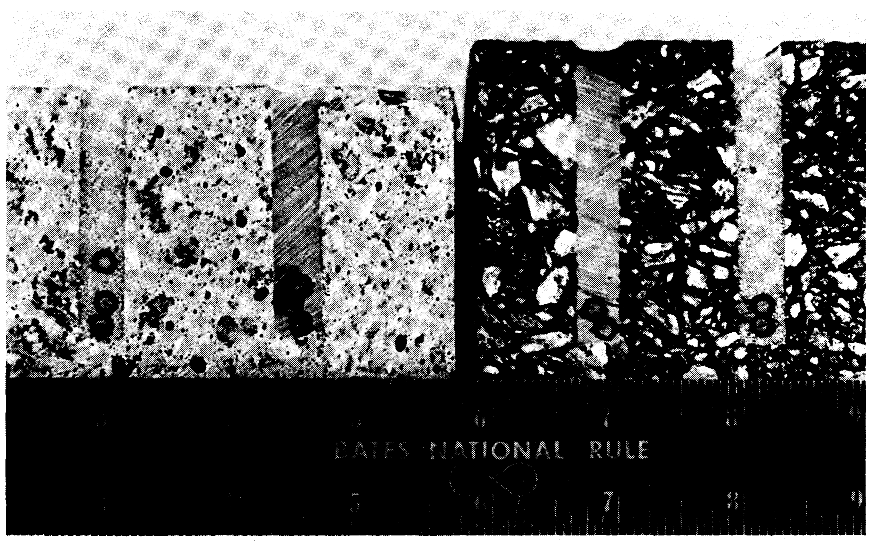

Figure 4. Close-up of beam cross section.

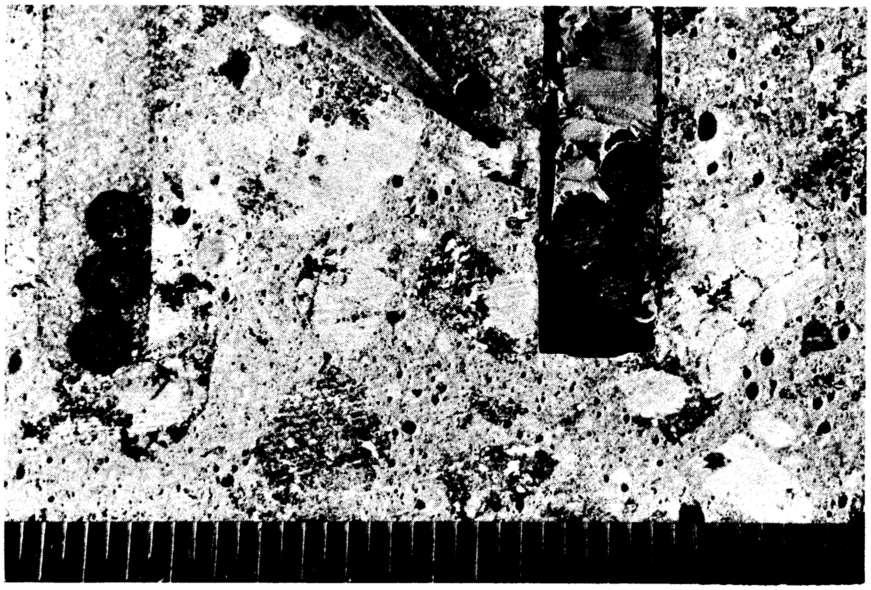

Figure 5. Example of cavity or void and of sealant pulling away from side.

Table 2

Failures in the Encapsulation Test

Material, Slot Width, Loop Wire Configuration	No. Failures for 3 Observations					
	Magnoloop	E-Bond	Bondo	Sealex	Gold Label	3M
Concrete						
1/4" slot, 3 strands	0	1	1	0	1	2
3/8" slot, 3 strands	0	1	2	0	0	2
3/8" slot, twisted	1	0	0	0	0	0
Asphalt						
1/4" slot, 3 strands	1	0	0	0	0	3
3/8" slot, 3 strands	0	0	0	0	0	0
3/8" slot, twisted	0	0	0	0	0	0

An analysis of Table 2 shows that for 3M, in 7 out of 18, or 39%, of the observations, the performance was rated not satisfactory. The 3M sealant reacted adversely with both asphalt and concrete; it appeared to have dissolved the asphalt around the saw cut and to be pulling away from the sides of the saw cut in the concrete beams. See Figures 5 and 6. The other soft, pliable sealant, Sealex, experienced no failures, and the hard, rigid sealants, as represented by the other four sealants tested, experienced minimal failures scattered throughout the samples. Accordingly, with the possible exception of 3M, the adequacy of encapsulation is not dependent on the type of sealant.

There was a higher percentage of failures in the 1/4" slots (25%) than in the 3/8" slots (8%). Also, in 19% of the observations the 3-strand loop was rated not satisfactory; whereas, in only 3% was the twisted loop wire not satisfactory. The 3 separate wires do not stack neatly and this tends to prevent the sealant from flowing uniformly around them. The problem is compounded in the 1/4" slot. Accordingly, encapsulation is better in a 3/8" slot than in a 1/4" slot.

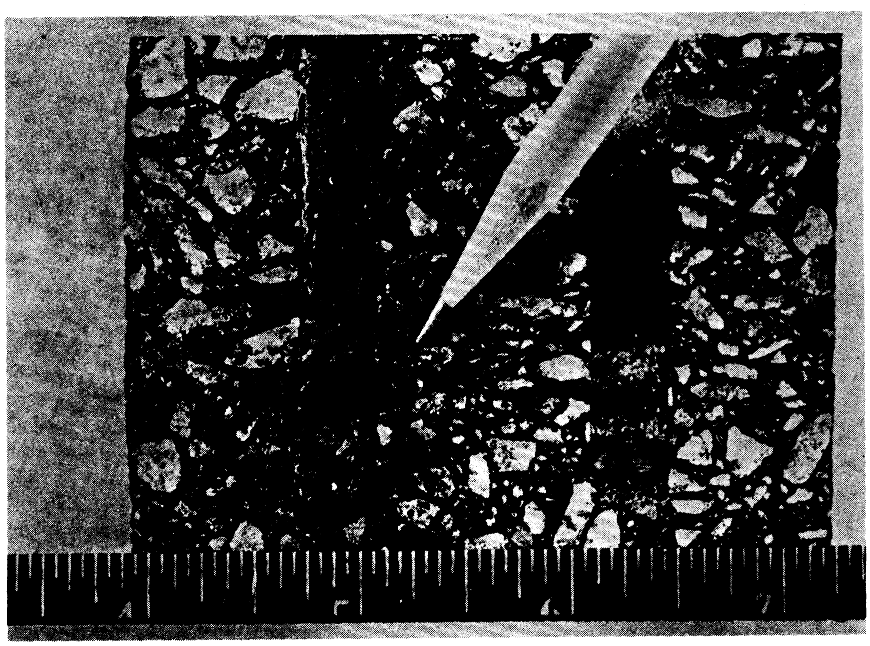

Figure 6. Example of sealant pulling away from side.

1853

Freeze/Thaw Test

To evaluate the effects of freezing and thawing, both concrete and asphalt beams were subjected to a freeze/thaw test. The dry beams were inserted in metal containers and placed in a freeze/thaw chamber that cycled the temperature between approximately 0°F and 40°F eight times a day. Water was pumped into the chamber to facilitate thawing; however, the watertight containers kept the beams dry. The main purpose of the test was to determine whether the different expansion and contraction characteristics of the sealant and concrete or asphalt affected the bond between the two materials along the sides of the saw cut. The beams were periodically removed from the containers and visually inspected for cracks in the sealant, separation of the sealant from the sides of the saw cut, and other deterioration. With the exception of the test beams using 3M sealant, there was minimal deterioration of the sealant after approximately 340 cycles. The 3M sealant had split and was pulling away from the sides of the saw cut in both the asphalt and the concrete test beams.

The beams were then subjected to more severe testing; that is, the metal containers were filled with water such that freezing occurred with the beams saturated. Since the beams were saturated, de-bonding between the sealant and sides of the saw cut became more apparent than before, as the pressure created by the expansion of the freezing water caused rapid deterioration of the beam. The beams were subjected to approximately 160 more cycles of freezing and thawing. The problems with the 3M sealant mentioned previously became much more severe; in fact, two of the asphalt test beams split in two along the sealant/saw cut interface. The other soft, pliable sealant, Sealex, also experienced a similar problem; that is, it pulled away from the sides of the saw cut in both asphalt and concrete test beams. No problems occurred with the test beams using the hard, rigid sealants. No differences in the performance of the sealant in the two widths of saw cuts, in concrete, and in asphalt were detected. Figure 7 shows examples of beam deterioration at the interface.

Thus, the results indicate that hard, rigid sealants perform better than soft, pliable sealants in laboratory simulation of freezing and thawing. The width of saw cut does not seem to affect performance. Likewise, sealant performance in asphalt and concrete does not seem to differ. Although the testing was patterned after a formal ASTM test procedure, it should be reemphasized that there is no absolute correlation between the lab test and field performance. In other words, the differences in performance between the soft and rigid sealants may not occur in the field or, more likely, may occur after such a time period that it becomes irrelevant compared to the life of the pavement.

.1854

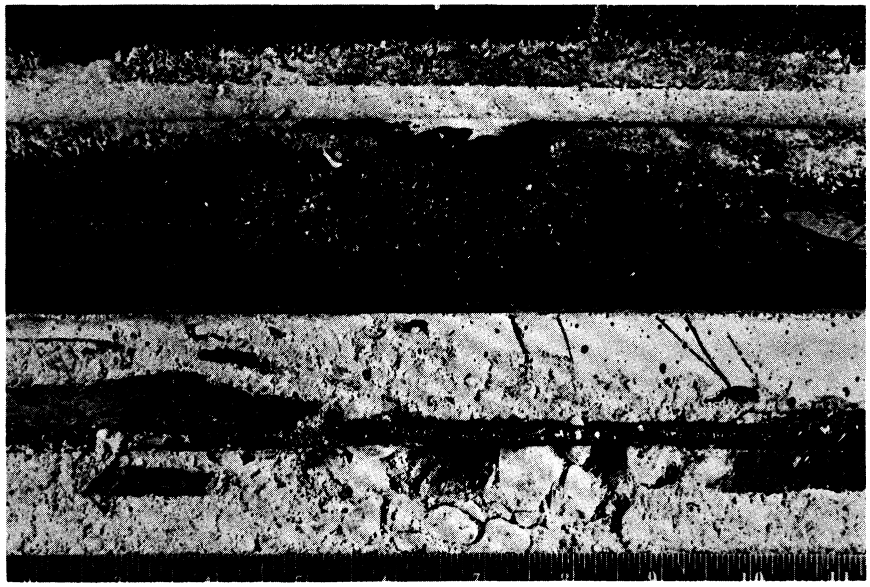

Figure 7. Deterioration at beam/sealant interface.

Fatigue Test

Asphalt beams were tested in fatigue, i.e., subjected to repeated loading which flexed the beam, using a closed loop hydraulic testing system. Ideally, the test simulated traffic loading in the field, and the purpose was to evaluate the performance of loop sealants under accelerated traffic conditions. It was anticipated that the sealant would crack or separate from the sides of the saw cut under fatigue testing.

Specifically, the beam was simply supported on both ends and subjected to a repeating or cycling load in the middle which deflected it. The procedure was to subject each beam to a constant strain, as measured by deflection at the midpoint, until such time that the load required to cause that deflection was reduced to approximately 60% of the initial load. In other words, an initial load was required to deflect the beam the preestablished amount. As the beam weakened due to the repeated bending, the load required to cause the constant deflection would lessen. When that load reached approximately 60% of the initial load, the beam was said to have failed, and the number of cycles or repetitions of loading was recorded. At that point the beams were removed from the machine and visually inspected. In some instances, the beam was put back in the machine and tested to 20,000 cycles. Thus, there was at least one beam for every sealant that was loaded for a constant number of cycles. Beams were loaded with the saw cut facing down such that the sealant would be loaded in tension.

The results of the test are given in Table 3. Neither of the two soft, pliable sealants cracked nor separated from the sides of the saw cut, even when tested to 20,000 cycles. Each of the hard, rigid sealants cracked in at least one test beam. None of the sealants shattered or broke out of the saw cut; rather, they simply cracked cleanly across the width of the saw cut.

On the other hand, the number of load cycles needed to cause the beam to fail was considerably lower for the soft sealants than for the hard sealants. This fact suggests that the hard sealants did not weaken the test beam and, in fact, may have even strengthened it. Considered another way, the beams were weakened considerably by the slot cut approximately one-half through the beam, and the hard sealants reinforced the beam whereas the soft sealants provided little or no reinforcement.

Table 3

Results of Fatigue Test

Sealant	Slot Width	Cycles to Failure	Cracks in Sealant at Failure?
MagnoLoop	3/8"	30,000 (1)	No
	3/8"	30,900	No
	1/4"	3,100	Yes-large
E-Bond	3/8"	11,200	Yes-large
	3/8"	8,100	No (large at 20,000 cycles)
	1/4"	2,600	Yes-large
Bondo	3/8"	18,000	No
	3/8"	12,400	No
	1/4"	5,600	Yes-slight (large at 20,000 cycles)
Sealex	3/8"	1,700	No
	3/8"	4,500	No
	1/4"	1,100	No
Gold Label	3/8"	5,300	Yes-slight (large at 20,000 cycles)
	3/8"	7,000	No (slight at 20,000 cycles)
	1/4"	9,400	No (large at 20,000 cycles)
3M	3/8"	3,300	No
	3/8"	4,000	No
	1/4"	2,000	No

(1) Strain approximately 18% less than for other beams.

-1856

For three of the four hard sealants, the number of cycles to failure was considerably less for those beams having a 1/4" saw cut. Cracking of the sealant was also predominant in the 1/4" slots. These results are consistent with the theory that the hard sealants tend to reinforce the beam; that is, more sealant results in stronger beams.

Thus, the results of the fatigue test suggest that the hard, rigid sealants are more susceptible to cracking than the soft, pliable sealants. However, the former seem to maintain the strength of the pavement better than the latter once slots have been sawed in the roadway. The 3/8" slots, which contain more sealant, perform better than the 1/4" slots. Again, it is important to note that results from testing a small beam in the laboratory do not necessarily parallel field experience. Of particular note in this test is the fact that the saw cuts are a much greater part of a test beam than they are of a roadway surface.

Tests at the Materials Division

Laboratory tests at the Materials Division were conducted to address the recommendations contained in the Installation Report for this project.(1) These recommendations are as follows:

1. The award of the contract for the loop sealant used by the Department is based on the lowest cost per gallon of sealant. In order to account for the increased coverage expected by the addition of sand to the epoxy systems, the quantity of polyester sealant requested in the inquiry is increased by 66%. The derivation of the 66% factor is suspect and, although suppliers are required to confirm that factor on the bid, the Department should investigate its validity.

2. In the case of epoxy sealants, the type and quantity of sand added seemed to affect the performance of the sealant. The Department should undertake an investigation to determine the appropriate type and quantity of sand to be added to epoxy sealants.

To evaluate the validity of the 66% expansion factor, several combinations of filler and epoxy were mixed. All were proportioned according to the Department's specifications; that is, 1 part filler to 1 part epoxy. Specifically, 100 cc of filler were added to 100 cc of the epoxy sealant (50 cc part A, 50 cc part B) and mixed in a paper cup. Six sand fillers were mixed with a single epoxy and all resulted in a mix of approximately 160 cc, or a 60% expansion factor. The consistent factors suggest that the expansion is independent of the type of sand filler; therefore, other types of epoxy sealants were tried. Using the above procedure, three other epoxy sealants were mixed with sand and

1857

each resulted in a mix of approximately 160 cc. Thus, the expansion factor for a 1:1 mix ratio of epoxy to sand should be 60% rather than 66%.

The above procedure also resulted in findings regarding the type and quantity of sand. The sands used were a standard graded silica sand (ASTM C109), a play sand, a mortar sand, and three gradations of blasting sands. Gradations for all the sands are shown in Table 4. The coarser sands settled out of the mixture very rapidly, which created difficulties when pouring the sealant into the loop slots.

It was also noted in the above mixtures that varying amounts of clear resin were showing at the top of the hardened samples, even for the finest sand. Therefore, in order to obtain better utilization of the epoxy, more than 1 part sand should be added to "fill" the system. Samples using three epoxies were made with 1-1/2 parts of sand, or 150 cc, and the excess resin was eliminated in the resulting mixtures. For all three samples, the volume of the filled system was 195 cc, which indicates a 95% expansion factor for mixes of 1-1/2 parts sand to 1 part epoxy.

From a practical standpoint, however, it is important to consider the effect of the additional sand on the workability of the sealant system. To evaluate workability, saw cuts were made in a 15" square concrete block and various mix ratios of sand and epoxy were used to simulate the installation of a loop. The slots were 1/4" wide, 2-1/2" deep, and first filled with four strands of loop wire. The fine blasting sand #1 and a single epoxy were used to test epoxy to sand mix ratios of 1/2:1, 1:1, 1-1/4:1, and 1-1/2:1. Due to increased stiffness,

Table 4

Sand Gradations

				Cumulative Percent Retained		
Screen	C-109	Play	Mortar	Blasting #1	Blasting #2	Blasting #3
+8		0.4	0.7			
+16	2.0	10.6	6.0			1.0
+30	30.0	49.3	25.6	0.7	48.8	88.5
+50	75.0	84.9	67.7	66.8	97.4	99.5
+100	98.0	98.3	87.2	96.8	100.0	100.0
+200		99.9	95.8	99.6		

-1858

the mixtures were more difficult to pour as the sand loading was increased; however, all mixtures readily flowed into the slots.

To further evaluate workability, the concrete block was sawed in cross section in order to check encapsulation of the wires. Cavities or voids were observed in slots using all four sand loadings, with no apparent relationships being discernible.

Thus, the above laboratory tests indicate that for those systems tested a fine sand at a mix ratio of 1-1/2 parts sand to 1 part epoxy provides the best system for an epoxy loop sealant.

To try to remedy the encapsulation problems being found, several mixes using 1 part of the coarse blasting sand, #3, and 1 part each of four epoxies were made and poured into slots as before. It was hypothesized that the coarse particles contained in blasting sand #3 would allow the epoxy to drain through the sand and thus achieve more complete encapsulation. Two mixing procedures were also tried. First, the epoxy was added and then the sand swept into the slot. Second, the sand was placed in the slot and then the epoxy poured. No significant improvement in encapsulation was detected using the coarse sand or the second mixing procedure. Large voids were consistently observed in the cross sections in which sand was added first. Complete encapsulation occurred when the epoxy was poured first; however, very little sand mixed with the epoxy to absorb the heat of reaction of parts A and B.

Next, using the fine blasting sand #1 and a single epoxy, mixes were made with 1:1 and 1-1/2:1 sand to epoxy ratios and poured into 5/16" and 3/8" wide slots. The amount of sand did not seem to affect encapsulation; however, the best encapsulation occurred in the 3/8" slot.

Thus, it appears that the positioning of the wires in the slot is the primary factor governing encapsulation. As the slot width increases, the location of the wires becomes less critical as there is more room for the sealant to flow around them.

Conclusions from the Laboratory Testing

The following are general conclusions derived from the results of the previously described laboratory testing at both the Research Council and the Materials Division. It should again be emphasized that the results in the laboratory are not necessarily indicative of field performance, and that decisions based on any of the conclusions should be thoroughly reviewed in light of field experience, engineering judgement, or both.

1859

1. Encapsulation of the loop wires by the sealant is dependent upon the position of the wires in the saw cut. That is, the wires may be positioned so as to block the uniform flow of sealant around them. Neither the type of sealant nor the type and quantity of sand seem to affect encapsulation. Examples of incomplete encapsulation could be found with all combinations of sealant and sand. On the other hand, the factors which affect the positioning of the wires also affect encapsulation. As the number of turns in the loop, or the number of lengths of wire stacked on top of each other, increase, the voids or cavities become larger. This fact was noted when comparing results of the tests by the Research Council with those by the Materials Division. Twisted, 3-turn, and 4-turn loops were simulated in the various tests. Also, better encapsulation is achieved as the width of the slot is increased. The position of the wires is less critical in a wide slot as sealant is more apt to flow down and around the wires.

   It is unknown how field installation of loop wire, which consists of continuous wrapping until the desired number of turns is obtained, affects the positioning of the wire in the saw cut. Laboratory simulation consisted of the stacking of individual lengths of wire to obtain the number of turns desired.

2. Freezing and thawing causes more problems in loops using a soft, pliable sealant than in loops using a hard, rigid sealant. The soft sealants tend to split and de-bond from the sides of the saw cut. Cavities created at the interface or in the sealant can collect water, and the resulting pressures from the formation of ice could cause deterioration of the pavement. The presence of water could also create a short in the electrical system. Neither the width of saw cut nor the type of pavement seem to affect performance of the sealant in freezing and thawing conditions.

   It is unknown how long it takes for the difference in performance of the soft and hard sealants to be reflected in field conditions. The freeze-thaw test utilized was very severe and may, in fact, not be indicative of field performance.

3. Hard, rigid sealants are more susceptible to cracking under repeated loading than are the soft, pliable sealants. On the other hand, hard sealants seem to maintain the strength of the pavement, whereas soft sealants seem to provide no reinforcement for the pavement. The 3/8" slots exhibit better performance than the 1/4" slots.

1860

It is unknown how much field loading is needed to duplicate the above laboratory results. Further, the differences in the reinforcing characteristics of the soft and hard sealants may well be irrelevant when considered in the context of a 3/8" or 1/4" saw cut located within the broad expanse of pavement at a typical loop site.

4. For an epoxy loop sealant system using a sand to epoxy ratio of 1:1, an expansion factor of 60% can be expected. For example, if a gallon of sand is added to a gallon of epoxy, the resulting mixture of sealant will measure 1.60 gallons. If the sand to epoxy ratio is 1-1/2:1, an expansion factor of 95% can be assumed. For example, if 1-1/2 gallons of sand are added to a gallon of epoxy, the resulting mixture of sealant will measure 1.95 gallons. These findings should be directly applicable to field experience.

5. A fine sand should be used as a filler in the epoxy loop sealant systems. Fine sands mix better than the coarse sands which rapidly settle out of the mixture.

6. An epoxy system is completely "filled" when 1-1/2 parts of sand are added to 1 part of epoxy. Better utilization of the epoxy is obtained at this mix ratio than at the 1 part sand to 1 part epoxy now specified by the Department.

   Although pourability of the 1-1/2:1 mix was satisfactory in the laboratory, it is unknown how well this sand will work in a practical field application.

Implications of Laboratory Results on Specifications and Procedures

The results of the laboratory tests have direct implications for the Department's current sealant specifications and procurement and loop installation procedures. These are discussed below.

1. Laboratory results suggest that the sand to epoxy mix ratio be changed from 1:1 to 1-1/2:1. A field demonstration of this mix ratio is necessary to verify its validity in field applications.

2. Laboratory results suggest that a fine sand should be used as a filler in epoxy systems. The use of a fine sand should also be subjected to a field demonstration and, if still acceptable, consideration should be given to specifying limits on the gradation of the sand.

1861

3. Laboratory results are mixed as to whether soft, pliable sealants or hard, rigid sealants are best. Hard sealants, which are currently specified, performed well except for a tendency to crack under repeated loading. Soft sealants performed poorly when subjected to freezing and thawing. These facts suggest that the current specifications are appropriate; however, because of the uncertainty as to the parallel between laboratory results and field experience, it is believed that decisions should await the final evaluation of the field test sites.

4. Laboratory results suggest that the width of the saw cut in the body of the loop should be 3/8" rather than the currently allowed 1/4". Since slots for the lead-in wire must be 3/8", a requirement of 3/8" for the loop slots would be reasonable and not create an unnecessary burden in installation.

5. Laboratory results indicate that the addition of 1 part sand to the currently specified epoxy system results in a 60% expansion to the sealant mix. This factor should be used in determining low bid in the procurement procedure. Similarly, should a 1-1/2:1 ratio of sand to epoxy be specified, an expansion factor of 95% should be used.

DESCRIPTION OF DEMONSTRATION 3

A third demonstration was undertaken primarily to determine if the use of a sand to epoxy mix ratio of 1-1/2:1 and a fine sand were practical in field applications. A secondary purpose was to determine if allowing the mixed parts A and B of the epoxy to sit for a short period prior to adding the sand and pouring the mixture would improve cold weather application. When the epoxy is cold, it is very viscous and hard to mix and pour. When parts A and B react and begin to heat, the mix should become less viscous. Thus, the addition of sand and subsequent pouring into the saw cut should be facilitied. Further, more rapid curing due to the accelerated reaction should enable earlier opening of the roadway to traffic.

Procedure and Results

On November 15, 1984, the coauthors met at a job site on Route 33 east of Richmond where a loop was being installed in a left-turn lane. It was sunny and windy with temperatures between 50° and 60°F. Three combinations of sand to epoxy mix and premixing of parts A and B were tried and subjectively evaluated. A fine sand was used in an epoxy system by Futura. It is noted that the epoxy had sat in the back of an open truck all day and was relatively viscous.

Mix 1

One-half gallon of part A was mixed with 1/2 gallon of part B and allowed to sit with periodic stirring until the mixing can became very slightly warm to the touch, which took more than 10 minutes. At that point, 1-1/2 gallons of sand were added and mixed with the epoxy. The resulting mixture was very stiff and coarse and became unworkable after being poured into only about 4' of saw cut. Thus, almost all of the mixture was discarded.

Mix 2

A second mix using 1/2 gallon each of parts A and B was allowed to sit for 7 minutes before 1 gallon of sand was added. After mixing for 2 more minutes, the mixture was poured into the saw cut. The mixture poured very slowly; however, all of it poured out of the bucket.

Mix 3

A final mix was prepared according to the current specifications and procedures; that is, 1 gallon of sand was mixed with the combined 1 gallon of parts A and B and immediately poured into the saw cut. The mixture was much more pourable and workable than the previous mixtures and the bucket was emptied.

Conclusions from Demonstration 3

Based on the above mixing experiences, it is concluded that the addition of 1-1/2 parts of sand to epoxy systems is not practical in field applications. Subjective evaluation by the coauthors and by field personnel performing the mixing operation indicated that the addition of 1-1/2 parts of sand result in an epoxy mixture that is much too stiff and coarse to be mixable and is not pourable and workable when applied. It is speculated that a 1-1/2:1 mix may be more acceptable in hot weather, as the epoxy is less viscous; however, it is not desirable to maintain separate specifications and separate procedures for different categories of temperature.

Further, preheating parts A and B of the epoxy by allowing the mix to sit for a period of time in order to facilitate cold weather application is not practical. The process is apparently very sensitive to both

1863

timing and the outside temperature. The establishment of a simple field procedure for preheating the mixed components through induction which accounts for both timing and outside temperature is not feasible.

Finally, the use of a fine sand is satisfactory in field applications. As observed above, the ease of mixing, pourability, and workability of the mix using fine sand and current procedures were satisfactory.

RECOMMENDATIONS

Based on the results of the laboratory testing, on the current status of the first two field demonstrations, and on the third demonstration, the following recommendations are made:

1. When comparing the purchase price of an epoxy loop sealant to which sand is added to a polyester sealant to which no sand is added, expansion factors of 60% and 95% should be assumed for a 1:1 sand to sealant ratio and a 1-1/2:1 sand to sealant ratio, respectively. In other words, when one part sand is added, the resulting mixture is 1.6 times the amount of sealant by volume. Likewise, if 1-1/2 parts of sand are added, the resulting mixture is 1.95 times the amount of sealant by volume.

2. The specification for traffic loop sealants found in Section 213.13 of the Road and Bridge Specifications should be modified to require the use of a fine sand as a filler in the epoxy system. The use of the following limits on the gradation is suggested. The percent passing the no. 16 screen should be a minimum of 100%, no. 30 -- minimum of 90%, no. 100 -- maximum of 10%, and no. 200 -- maximum of 3%.

   The current requirement for epoxy and polyester sealants should be maintained. There is no evidence that sealants falling within these specifications perform poorly.

   Finally, the current requirement of a 1:1 mix ratio of sand to epoxy should be maintained. Although laboratory tests indicated that a 1-1/2:1 mix ratio would result in a better system, a field demonstration showed that the addition of 1-1/2 parts of sand is not practical.

3. The Department's Road and Bridge Standards for the installation of loop detectors should be changed to require that the width of saw cut in the body of the loop be 3/8". A 1/4" width is now allowed;

1864

however, there was substantial evidence in the laboratory testing that the larger saw cut performed better.

FUTURE EVALUATION

The field demonstration site on Broad Street where different types of sealants are being evaluated will continue to be monitored. Conclusions regarding the sealants will be made as appropriate and forwarded to the proper divisions; however, a formal report is not anticipated.

1865

ACKNOWLEDGEMENTS

A number of individuals were helpful to the authors during this study. Thanks go to John Shelor, Steve Blackwell, Bobby Marshall, Buddy Wood, Clyde Giannini, and Mike Burton for their help in the laboratory testing; to Bill Maupin and Celik Ozyildirim for their technical assistance in evaluating the lab results; to Ben Cottrell, Neal Robertson, and Ed Galloway for their review of the draft report; to Susan Kane and Jan Kennedy for typing the draft report; and to Harry Craft and his staff for editing and producing the final report.

1866