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Field Studies of Methods and Materials for Joint and Crack Sealing

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Contents

A Field Study of Joint and Crack Resealing Methods and Materials

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During August and September of 1953, the joints and cracks in a 19-year old, 5-mile stretch of concrete pavement on US 16 between Nunica and Fruitport, Michigan, were resealed under contract on a force account basis. Six different brands of hot-pour joint sealer were used. In addition to the resealing work, experimental concrete repairs were made in several places where corners were broken from slabs at the junction of the joint and pavement edge.

Various methods of cleaning and resealing the joints and cracks were investigated until a practical, efficient procedure was developed. This procedure included sandblasting of joints and cracks prior to sealing and the use of thermostatically controlled pouring equipment for applying the sealer.

After two and one-half years of service, the various maintenance repairs have held up very well with the exception of material failures in two of the six brands of joint sealer used. The results of this work indicate that the widespread failure of joint seals in Michigan has been due partly to deficiencies in the sealing material and partly to inadequate cleaning and sealing operations. An extensive experimental project involving both field and laboratory tests has been initiated in order to study these factors quantitatively and to develop better materials and methods.

● WITH the advent of hot-poured rubber-asphalt joint sealing compounds, the problem of sealing joints in concrete pavements appeared to have been solved. Postwar pavements in Michigan, however, have shown widespread failure of the seal in joints containing such materials. Examination of these failures indicated that in most cases they were of the adhesive type and were probably due to inadequate cleaning and sealing methods although the possibility existed that at least part of the trouble could be attributed to some deficiency in the sealing compounds themselves. As a result, steps were taken to inaugurate a general program directed toward improvement in materials and methods for sealing joints in concrete pavements, both in new construction and in maintenance operations.

As one phase of this program, a project was set up in July 1953, for experimental contract resealing of joints and cracks in an old pavement with hot-pour, rubber-asphalt joint sealers. The project had three main objectives: (1) to evaluate current rubber-asphalt joint sealing materials; (2) to develop the most effective sealing procedures possible; and (3) to determine whether the workmanship and cost of such an operation would warrant adoption of contract resealing as a future maintenance policy on concrete pavements in such good physical condition that resurfacing would not be anticipated for at least 10 years. The work was to be done by a contractor specially qualified in this field and the contract drawn up on a cost-plus basis so that effective procedures could be developed as the work progressed.

This paper gives the location and a general description of the pavement, tells what materials and equipment were used, and what methods of cleaning and resealing were tried. It also contains a summary of the procedures finally adopted and a brief discussion of four condition surveys made since the work was completed, together with a cost analysis of the entire operation.

In conjunction with the joint and crack resealing, a few experimental concrete repairs were made in places where slab corners were broken at the junction of the joint and pavement edge. Because of its close relationship to the joint sealing operation, a brief description and cost analysis of this phase of the work is also included.

LOCATION AND DESCRIPTION OF THE PAVEMENT

A 5-mile section of US 16 between Nunica and Fruitport was selected for the project and a condition survey made on July 22, 1953. This pavement was built in 1933-34 on a sand subgrade and is of 9-7-9 cross-section containing 60 lb of reinforcing steel mat per 100 sq ft, with 100-ft expansion joints and no intermediate joints. No load transfer devices were used and the joints were all slightly faulted. The joints were about 1 in. wide and most of them had accumulated a considerable quantity of infiltrated sand and gravel which had forced the filler downward through the compacting action of traffic.

The longitudinal joint contained a premolded filler as a divider strip in the plane of weakness at the top. In many places this filler was partly gone and in some cases a section of concrete between a transverse joint and a nearby transverse crack had become laterally displaced, causing the adjacent longitudinal joint to open excessively.

Cracks in the pavement were almost entirely transverse and were of two distinct types—open ¼ in. or more, and closed tight. Although the closed cracks were tight enough to prevent infiltration of dirt and gravel, many of them were becoming badly

TABLE 1

LABORATORY DATA ON JOINT SEALING MATERIALS

Brand	Pour Temp., Deg. F.	Penetration, 77 F., 150 g., 5 Sec., cm.	Flow, cm.	Bond
A	401	0.53	0.40	Passes
B	401	0.64	0.20	Passes
C	401	0.70	0.20	Passes
D	401	0.70	0.10	Passes
E	401	0.65	0.20	Passes
F	425	0.84	0.30	Passes

spalled at the edges and needed sealing.

MATERIALS AND EQUIPMENT

Six brands of hot-pour rubber-asphalt joint sealer were used in this project and were tested in the laboratory with the results given in Table 1. Locations of these six materials in the project are given in Table 2 and the schematic drawing of Figure 1.

The joint sealing materials were melted in a melter of the double boiler type using oil as the heat transfer medium. This melter had thermostatically controlled gas heat, constant agitation, and a thermometer to indicate the temperature of the oil bath. Temperatures of the sealing material were taken at frequent intervals with a hand thermometer. A temperature differential of 50 F was maintained between the temperature of the oil bath and that of the sealing material.

The sealing materials were poured from a mechanical pour pot, also of the double boiler type (Figure 2) using oil as the heat transfer medium, with thermostatically controlled gas heat and a thermometer to indicate the oil temperature. The pour pot was mounted on rubber tired wheels and was provided with a mechanical agitator. Temperatures of the materials in the pour pot were also taken at frequent intervals with a hand thermometer. A temperature differential of 50 F was maintained between the oil and the sealing material in the pour pot.

It should be noted here that, while indication of the oil bath temperature is useful for proper control of the heating and melting process, an indicating thermometer to mea-

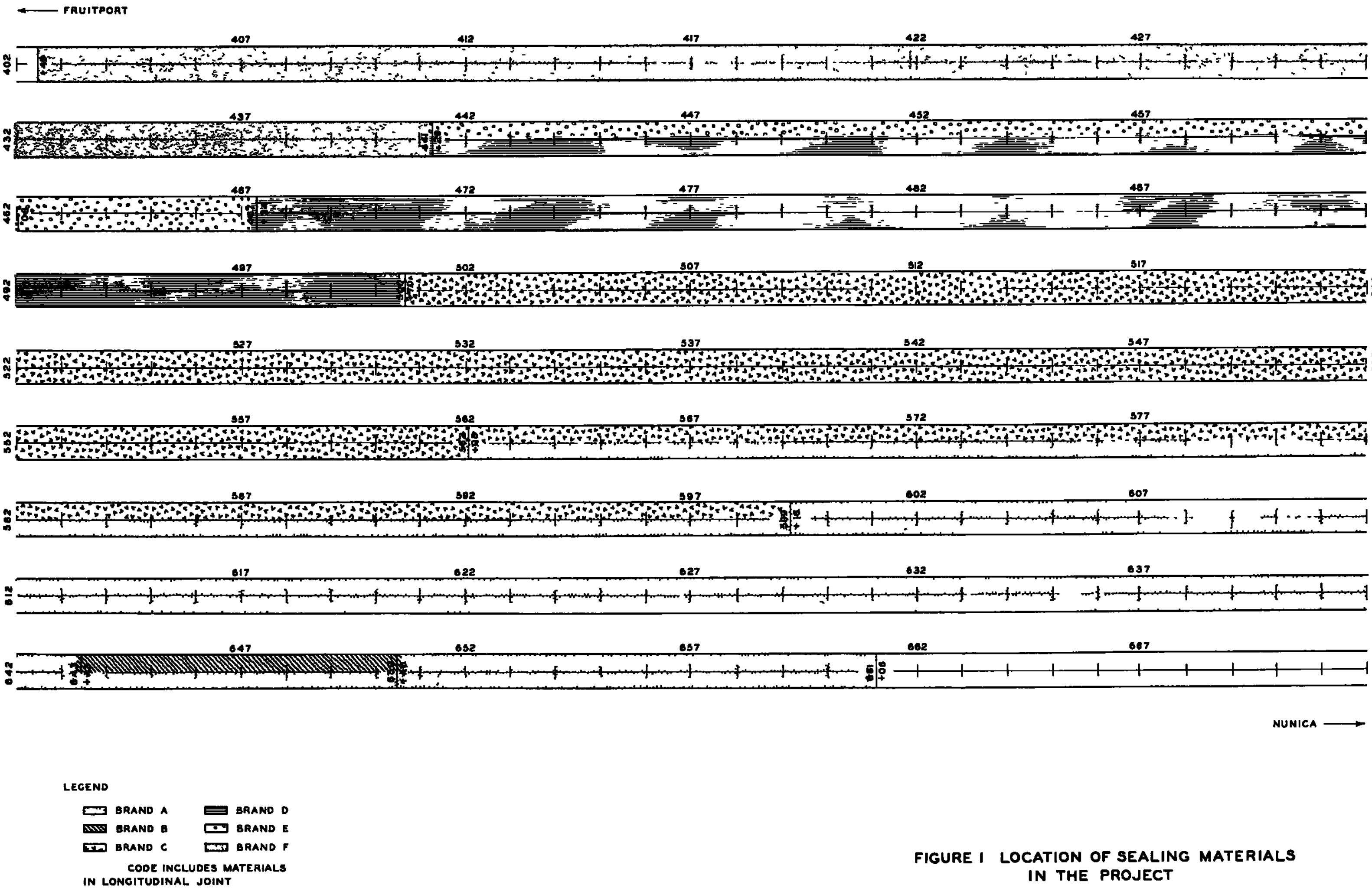


FIGURE I LOCATION OF SEALING MATERIALS IN THE PROJECT

FIGURE 2. SEALING LONGITUDINAL JOINT WITH MECHANICAL POURPOT.

FIGURE 3. CONTRACTOR'S JOINT - CLEANING MACHINE IN OPERATION.

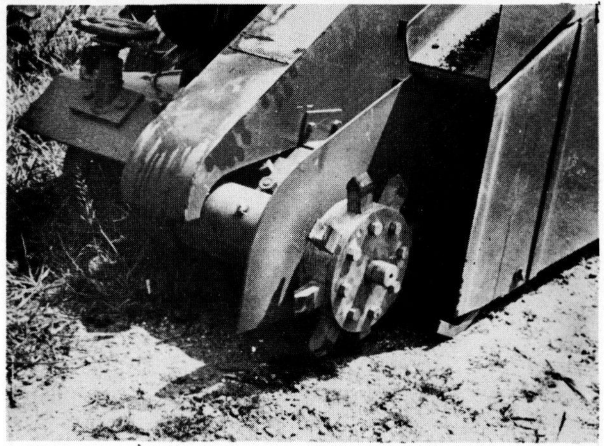


FIGURE 4. CUTTING HEAD OF CONTRACTOR'S JOINT - CLEANING MACHINE.

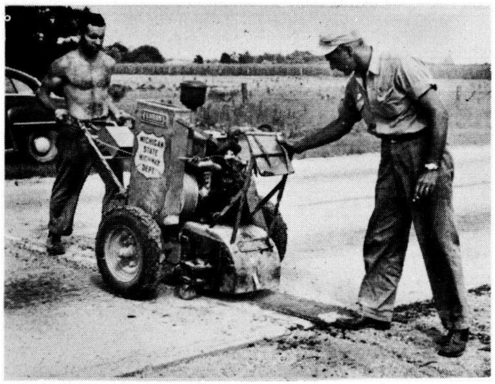


FIGURE 5. MSHD JOINT CLEANING MACHINE IN OPERATION.

FIGURE 6. GARDEN TRACTOR WITH PLOW ATTACHMENT REMOVING OLD JOINT SEALER.

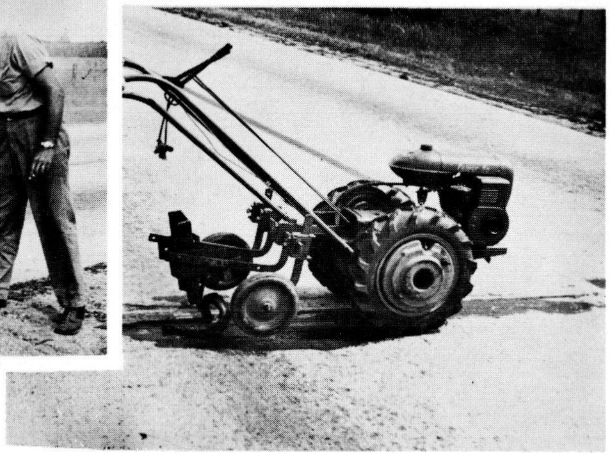
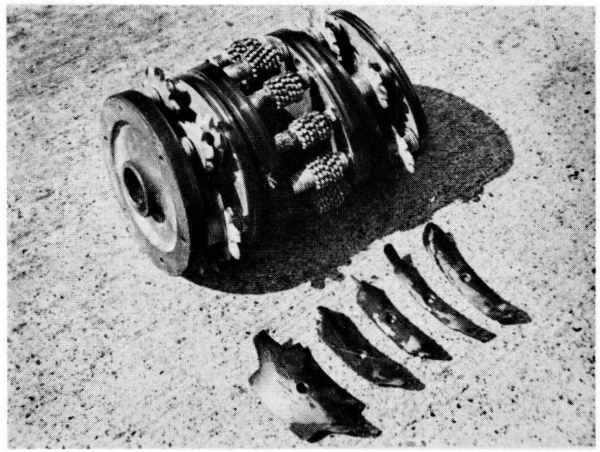


FIGURE 7. MSHD CUTTER HEADS AND TRACTOR PLOW BLADES USED FOR CLEANING JOINTS.



sure the temperature of the melted joint sealing material should be installed on all heating equipment to insure that the compound is heated and poured in the specified temperature range. In this connection it should also be emphasized that the thermostatically controlled pour pot prevents pouring at too low a temperature, which could result in poor adhesion of the sealer to the joint faces.

Two types of mechanical joint cleaning equipment were used for cleaning joints: one, a machine furnished by the contractor, Figures 3 and 4, and the other, a commercial joint cleaning machine owned by the Michigan State Highway Department, Figure 5.

A small garden tractor with a plow attachment was used to remove the bulk of old materials from joints, Figure 6. Plow blades of various shapes are shown in Figure 7.

The sandblast and air blowing operations on joints and cracks were accomplished with a portable air compressor capable of maintaining a pressure of 90 psi, and a sandblast machine mounted in a pickup truck.

A mechanical wire brush was used in some of the earlier joint cleaning operations but was abandoned later when better plowing techniques were developed.

TABLE 2

LOCATION OF SEALING MATERIALS USED IN THE PROJECT

Brand	Station Location			Pouring Temp. Deg. F.
	Cracks and Transverse Joints		Longitudinal Joint	
	North Lane	South Lane		
A	661+06 to 650+46 643+43 to 599+16	661+06 to 562+08	661+06 to 560+46 643+43 to 562+08	425
B	650+46 to 643+43		640+46 to 643+43	425
C	599+16 to 500+70	562+08 to 500+70	599+16 to 500+70	395
D	500+70 to 467+34	500+70 to 467+34 462+03 to 441+29	500+70 to 467+34	425
E	467+34 to 441+29	467+34 to 462+03	467+34 to 441+29	425
F	441+29 to 402+49	441+29 to 402+49	441+29 to 402+49	425

METHODS OF CLEANING AND RESEALING

The first experiments in cleaning old materials from joints involved the use of both the Highway Department's (MSHD) and the contractor's joint cleaning machines. In cleaning transverse joints, old sealer and filler were first removed with the contractor's new machine and then the pavement surface at each side of the joint was freed from the old sealer and other materials, using the MSHD machine equipped with a surface scarifying head. Adjustments of various depths and cutters of various widths were tried with the contractor's machine, and a satisfactory cut was finally obtained with cutters 1 in. wide set to clean the sides of the joint to a 1-in. depth. The head of this machine equipped with 1-in. cutters is shown in Figure 4.

Because the transverse joints were faulted, scarifying operations with the MSHD machine required a pass on each side of each joint. In Figure 7, the center head is the type used for scarifying operations. The MSHD machine with a single row of 4-in. cutters (Figure 7, upper right), was tried for routing old material from the transverse joints but failed to perform as well as the contractor's machine.

At first the contractor's machine was used to clean the old filler from the longitudinal joint, using cutters ⅜ or ½ in. wide, depending on the width of the joint. Trouble was encountered on the second day of operations with the carboloy tips which broke

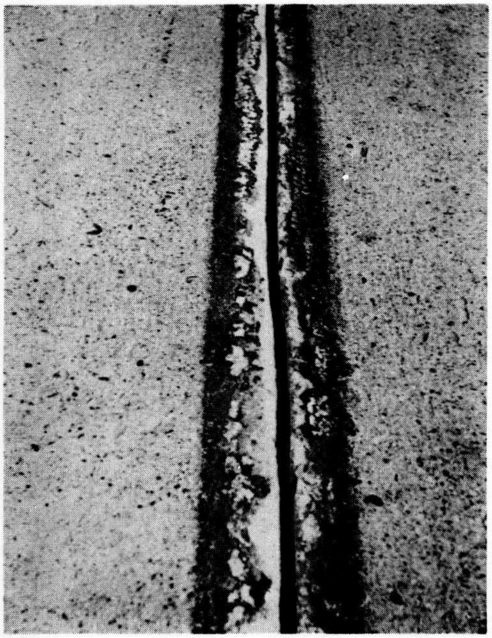


FIGURE 8. LONGITUDINAL JOINT CLEANED AND READY FOR SEALING.

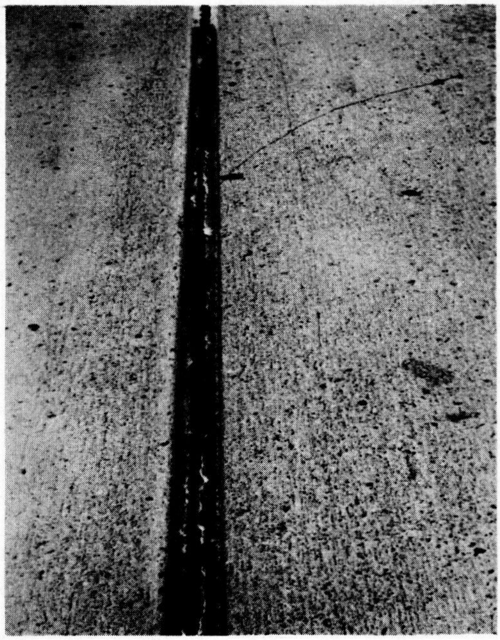


FIGURE 9. LONGITUDINAL JOINT AFTER SEALING.

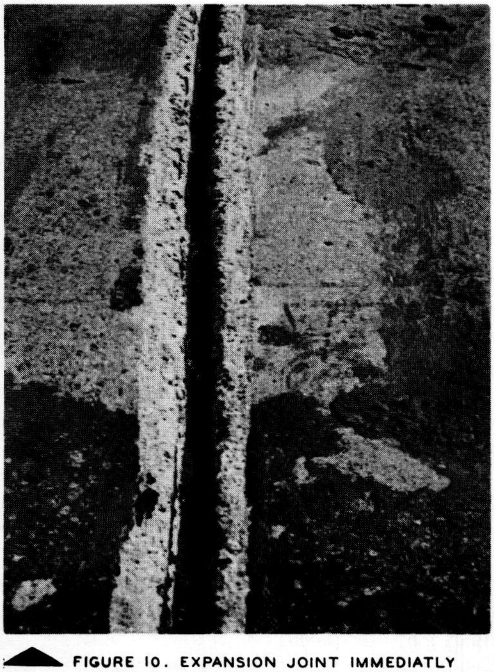


FIGURE 10. EXPANSION JOINT IMMEDIATLY BEFORE SEALING.

FIGURE 11. EXPANSION JOINT AFTER SEALING.

frequently on these narrower cutters. After ruining several sets of cutters, this machine was abandoned in favor of the MSHD machine using a head with a single row of 4-in. cutters. The MSHD machine produced a longitudinal joint as clean as that prepared by the contractor's machine. Where the longitudinal joint was excessively wide, a lateral swinging movement by the operator served to clean the joint faces satisfactorily.

The MSHD machine was again tried for removing old material from the transverse joints, but this time single and double cutters were alternated around the head (Figure 7, upper left). Since this operation left a cleaner joint than routing with the contractor's machine, the MSHD machine was adopted for this purpose.

Even after routing out both types of joints with the MSHD machine, small pieces of sealer and sections of filler still remained in greater quantities than were considered desirable or could be easily removed in the final operation of sandblasting and blowing with compressed air. To remedy this, a mechanical wire brush was used in the longitudinal joint, which took out sections of filler left by the MSHD machine in a fairly satisfactory manner. Pieces of old sealer left by the cleaning machine on the transverse joint corner were thinned enough by the brush to be removed later by sandblasting.

From the start of the project, experiments in plowing out old materials from the joints were run daily with a small garden tractor and plow attachments. The problem was one of developing a plow blade properly shaped to remove maximum material to a sufficient depth. After six days of experimental work, the plow was put into permanent operation on transverse joints, and by the twelfth day it was in use for the longitudinal joint. Plow blades of several typical shapes are shown in the lower portion of Figure 7. Since none of the several shapes developed was considered completely satisfactory, this operation is open to further experimentation.

In all of this earlier work the plowing operation was followed by use of the MSHD machine and then by the wire brush. It was soon noted, however, that the introduction of the plowing operation made the use of the brush unnecessary so this brush was eliminated from the procedure, speeding up the work. Both longitudinal and transverse joints before and after sealing are shown in Figures 8 through 11.

One open crack was cut out with the contractor's machine using ½ in. cutters at a depth of ⅞ in. Another open crack was routed out with the MSHD machine using a single row of 4-in. cutters. The crack prepared with the contractor's machine was satisfactory in appearance but did not look much different than one treated with sandblast only. The crack routed with the MSHD machine was opened much wider than necessary at the top. As a result of these two experiments it was decided to prepare all open cracks with sandblast only, followed by a final blowing out with air.

As soon as a decision had been made to seal closed cracks, two such cracks were sandblasted until a shallow groove was formed along the crack. The groove was 3/16 to ¼ in. deep and ½ to ¾ in. wide at the top. The pavement surface was cleaned with sandblast about ½ in. each side of the groove, blown out with air, and the crack sealed. Sealing material was applied in one pour to a level sufficient to allow an overlap on the pavement surface of about ⅛ in. This allowed the top surface of the sealer to be slightly higher than the pavement surface. After traffic had crossed these two cracks for 24 hr it appeared that the sealing material tended to become even more firmly wedged down into the groove and seemed to form a very tight seal. As a result, all closed cracks from station 581+65 to the west end of the project were treated in this manner. A crack of this type is shown ready for sealing in Figure 12 and after sealing, in Figure 13.

FINAL PROCEDURES

The most satisfactory procedure arrived at for joints and cracks is outlined below:

Longitudinal joint:

1. Plow out old filler to a depth of ¾ to 1 in., preferably making one pass each way.
2. Make one pass with MSHD machine, using a single row of 4-in. cutters in the

head to clean the vertical faces of the joint and to further remove the filler.

3. Sandblast vertical faces of the pavement surface to a distance of about 1 in. each side of the joint to remove traffic paint. If necessary, use hand tools to remove any filler left in the top inch of the joint.

4. Blow out with compressed air at pressure of at least 90 psi and seal in two pours.

Transverse Joints:

1. Plow out old joint materials to a depth of at least 1 in. preferably making at least one pass each way.

2. Make one pass on each side of the joint with the MSHD machine using a 2-in. row of 2-in. cutters in the head to remove all foreign materials from the pavement surface to a distance of at least 1 in. each side of the joint.

3. Make one pass with the MSHD machine, using alternate single and double 4-in. cutters in the head to clean vertical faces of the joint and to assure removal of all old joint material to a depth of at least 1 in.

4. Sandblast vertical faces of the joint and the pavement surface to a distance of 1 in. each side of joint. Use hand tools to remove any traces of old sealer that might be left.

5. Blow out with compressed air at a pressure of at least 90 psi and seal in two pours. Outer ends of joints must be dammed to prevent sealing material from running out onto the shoulder.

Open Cracks:

1. Sandblast vertical faces of the crack to a depth of at least 1 in. and the pavement surface to a distance of at least 1 in. each side of crack.

2. Blow out with compressed air and seal in at least two pours.

Closed Cracks:

1. Sandblast until a shallow groove is formed along the crack. The groove should be 3/16 to 1/2 in. deep and 1/2 to 3/4 in. wide. The pavement surface should be sandblasted for about 1/2 in. each side of the groove.

2. Blow out with compressed air and seal in one pour. Fill until sealer overlaps pavement surface about 1/8 in.

The old joint materials in almost all of the transverse joints had been displaced by gravel and dirt for all or most of the pavement depth for about two feet from each edge of the pavement. This necessitated extra sandblasting, blowing and hand raking in these sections to remove as much of the foreign material as practicable.

EXPERIMENTAL CONCRETE REPAIRS

In a number of places, corners were broken from slabs at the junction of the transverse joint and the pavement edge. Since the pavement was in very good general condition, and resealing of joints and cracks had eliminated the necessity of resurfacing, it was felt that an investigation should be made into the practicability of repairing such corner breaks. This work was started immediately after completion of resealing operations and was done by the contractor on a force account basis.

It was found that usually only one corner break was apparent at the pavement edge. Removal of a section of the shoulder always indicated, however, that the other corner was also broken. It appeared that compressive stress at the joint caused the upper corner of one slab and the lower corner of the other to shear off at an angle of about 30 deg to the horizontal. This condition is apparent in Figure 14 and is typical of all corner breaks examined in detail.

Figures 14 through 17 show the various steps used in making these repairs. The loose and unsound concrete was removed with an air hammer and the joint filler and groove form set in place. A wide board was used as a form for the pavement edge. A very thin water slurry of cement containing 10 percent by weight of a well known anti-shrink admixture was brushed into the faces of the old concrete for a bond coat. A grout made of 60 volumes of gravel of 1-in. maximum size, 40 volumes of No. 8 sand,

FIGURE 12. CLOSED CRACK AFTER SANDBLASTING SHALLOW GROOVE ALONG CRACK.

FIGURE 13. SAME CRACK AS IN FIGURE 12 AFTER SEALING.

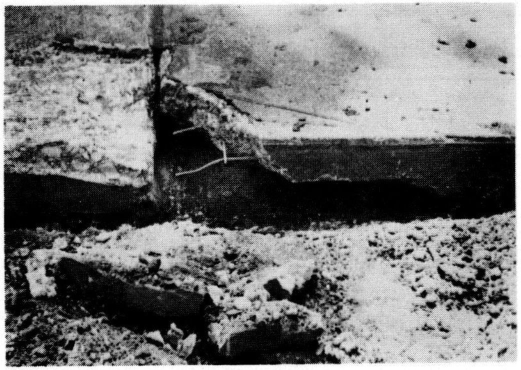


FIGURE 14. CORNER BREAK WITH LOOSE AND UN SOUND MATERIAL REMOVED.

FIGURE 15. ADDING GROUTING MIXTURE.

FIGURE 16. READY FOR FINISH COAT.

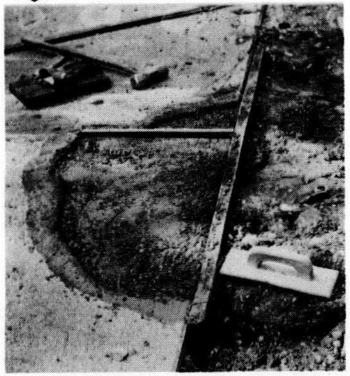


FIGURE 17. A TYPICAL REPAIRED CORNER BREAK.

and 33⅓ volumes of cement containing 10 percent by weight of the same admixture was then packed into the cavity by hand and consolidated by tamping in with the end of a small board, Figure 15. This grout mixture was unusually dry, containing just enough water to retain its shape when squeezed into a ball in the hand, and was consolidated on the surface patches simply by tramping on it with the feet. Figure 16 shows a patch at this stage and ready for the finish coat. A ½-in. surface coat, in which the gravel was replaced by No. 8 sand, was used to finish off the patch. The patch was covered overnight with curing paper and then alternately wetted and dried for several hours in order to rust the iron in the admixture. Figure 17 shows a typical finished patch.

Breaks at the north end of 13 different expansion joints were repaired at an average cost of $124.46 per patch. The area of the patchwork at each joint end averaged about 5 sq ft which means a cost of about $24.90 per sq ft. Within very wide limits, however, the cost per patch is somewhat independent of the size of the patch since about the same amount of time was required to repair each of the 13 corner breaks.

SUBSEQUENT CONDITION SURVEYS

Four detailed condition surveys of the experimental resealing of joints and cracks as well as the experimental patching of the broken concrete have been made to determine the effect of weathering and traffic on the repair work. These surveys were made on February 18, 1954, March 16, 1955, March 19, 1956 and October 1, 1956. The four surveys indicate the condition of the sealed cracks, the resealed joints and the concrete patches after 5 mo., 1½ yr, 2½ yr, and 3 yr of service under varying weather conditions.

The 5-mo. survey showed that the various maintenance repairs had held up very well with the exception of most of the transverse joints and open cracks which had been sealed with Brand A joint sealer. This material was badly cracked and separated from the joint or crackfaces and in some cases had worked entirely out of the open cracks.

After 1½ yr of service the Brand A material had continued to deteriorate to the point where in all transverse joints it was badly cracked and separated from the joint faces. In addition, Brand B had also started to deteriorate. In about half of the transverse joints and all of the open cracks containing this sealer, failures occurred in both cohesion and adhesion, while in the remainder of the transverse joints the seal was still intact. A few of the transverse joints containing Brand C sealer showed adhesion failures in which adhesion to one joint face was lost but most of the joints containing Brand C were in very good condition.

In the 2½ yr survey it was found that the only major changes since the previous survey had occurred with Brands A and B sealers in transverse joints. With the exception of a few adhesion failures, all of the Brand A failures had now become manifested as cohesion failures. The deterioration of Brand B sealer had continued to a point where all transverse joints containing this material had failed in adhesion. The remainder of the maintenance repairs appeared to be in exactly the same condition as they were at the time of the previous survey one year earlier. The Brand C sealer still showed adhesion failures in only a few transverse joints with most of them in good condition. Transverse joints and open cracks containing Brands D, E and F were still well sealed with no apparent failures of any kind, while the longitudinal joint and the closed cracks were still maintaining an excellent seal regardless of the brand of sealer used. Typical condition of joints sealed with the six different brands of material are shown in the photographs of Figures 18 through 23, taken during the third survey in March, 1956.

There was little change in the condition of the project when the fourth survey was made in October 1956, except what appeared to be a progression of failure in the Brand C material, Figure 24. On closer examination, however, it was found that the visible cracking and wrinkling of the sealer extended only slightly below the surface, with the seal still intact.

The concrete patches still remained bonded to the old concrete after 2½ yr and appeared to be sound, although some surface scaling was apparent (Figure 25).

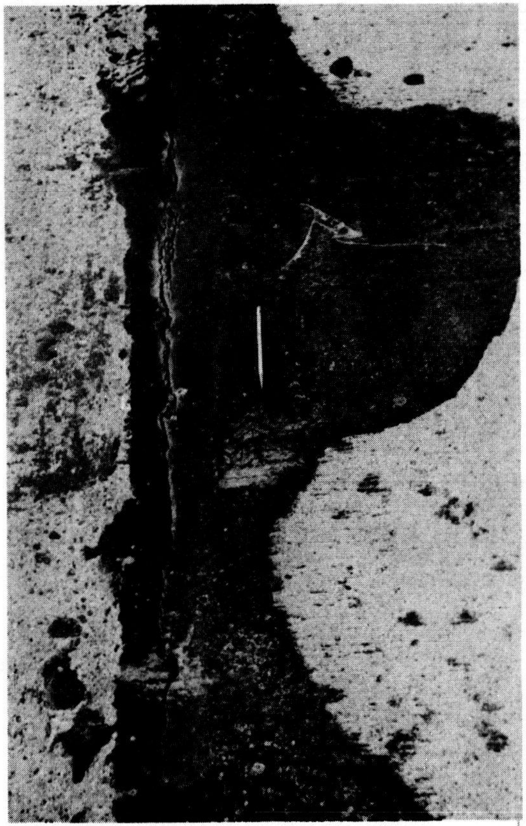


FIGURE 18. FAILURE MAINLY IN COHESION; TYPICAL OF BRAND A FAILURES AT 2 1/2 YEARS.

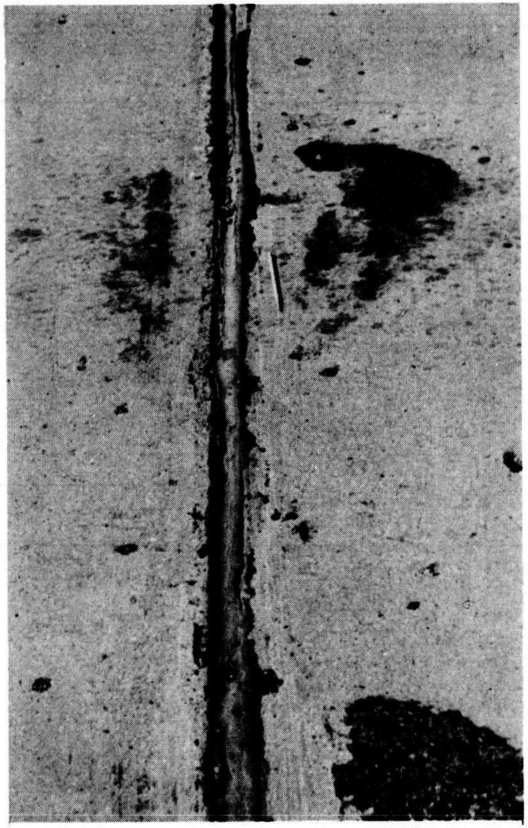


FIGURE 19. ADHESION FAILURE; TYPICAL OF JOINTS RESEALED WITH BRAND B AT 2 1/2 YEARS.

FIGURE 20. SEAL STILL INTACT. TYPICAL OF JOINTS CONTAINING BRAND C AT 2 1/2 YEARS.

FIGURE 21. BRAND D; IN GOOD CONDITION AT 2 1/2 YEARS.

FIGURE 22. BRAND E; IN GOOD CONDITION AT 2 1/2 YEARS.

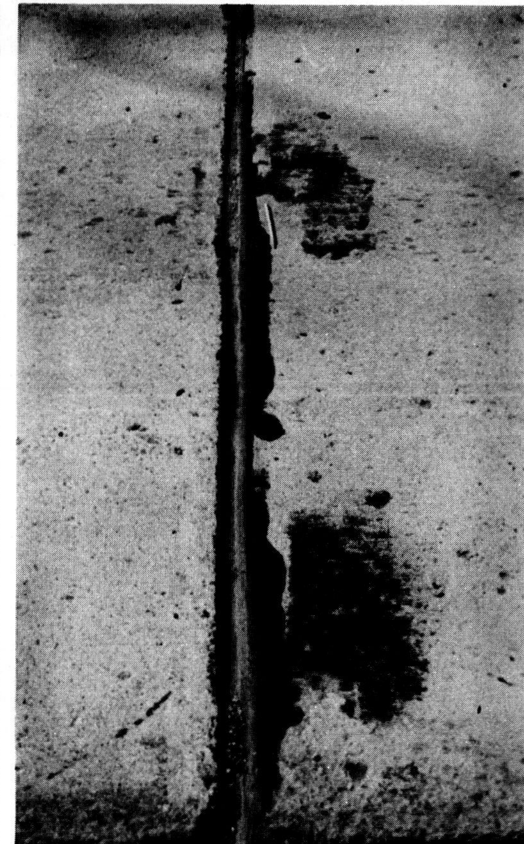


FIGURE 23. BRAND F; IN GOOD CONDITION AT 2 1/2 YEARS.

FIGURE 24. TYPICAL OF SURFACE CRACKING AND WRINKLING OF BRAND C AT 3 YEARS. SEAL STILL INTACT.

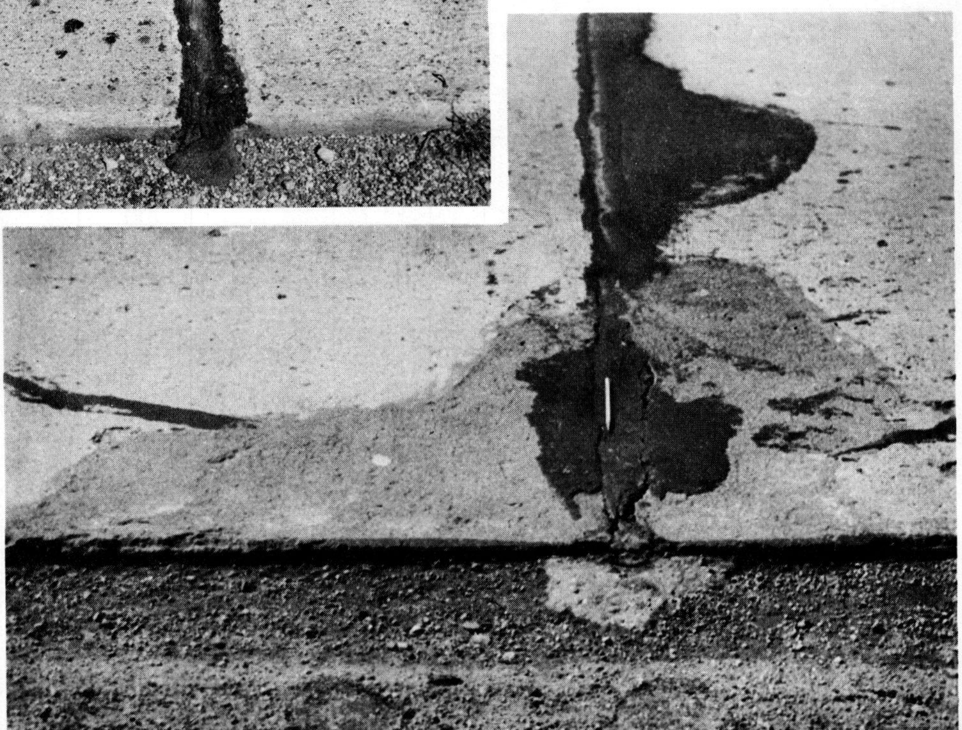


FIGURE 25. REPAIRED CORNER BREAK AFTER 2 1/2 YEARS.

CONCLUDING REMARKS

This study has shown that the extra care exercised in cleaning and preparing the joints has been justified by the results obtained, and that the use of sandblasting for the final cleaning operation is the most effective method tried thus far for this purpose. Furthermore, experience with the thermostatically controlled pouring pot with mechanical agitator supports the conclusion of Robbers and Swanberg[1] that this type of equipment should be used exclusively for all accessible joints.

It is also apparent that there is considerable difference in the performance of different brands of rubber-asphalt joint sealers, all meeting the same specifications. In this project, three of the six materials are still performing well after three years of service, while two brands definitely failed to survive the first winter. The other, Brand C, is intermediate between the two extremes. Even though three of the materials are maintaining a satisfactory seal after three years, they do not look as good, or as though they would last as long, as some of the earlier rubber-asphalt sealers at the same age in projects sealed more than fifteen years ago.

Finally, it is becoming increasingly evident that more significant, discriminating, and reproducible tests for joint sealing materials are sorely needed. Such tests can be developed effectively only in conjunction with field tests to enable a comparison of laboratory results with performance in service. Several new tests have been proposed, but none has been specifically related to performance.

In order to evaluate present materials and to stimulate the development of better products, Michigan has undertaken an experimental joint sealing project with the cooperation of the Joint Sealer Manufacturers' Association, with all six member companies participating. During the past summer the joints of a 24-ft, two-lane concrete roadway about ten miles long were sealed with six different makes of each of two types of hot-pour rubber-asphalt sealer, and five brands of cold-applied material, as well as several products developed especially for the project by the various manufacturers. These special products included both hot-pour and two-component cold materials of the jet fuel resistant type. Standard tests and several new tests are being performed on these materials in an attempt to relate laboratory tests with field performance. A report will be made on this project as soon as significant results appear.

APPENDIX A

DATA ON JOINT SEALING MATERIALS

Brand	Price per lb.		Quantity Used, lb.	Cost
A	$.1623		4,000	$ 649.20
B	.12		1,150	138.00
C	.128		4,000	512.00
D	.14		2,000	280.00
E	.135		2,000	270.00
F	.125		2,000	250.00
		Totals	15,150	$2,099.20

[1] Robbers, J.C., and Swanberg, J.H., "Resealing Joints and Cracks in Concrete Pavements with Hot-Poured Rubber-Asphalt," Highway Research Board, Bulletin 63, Washington, D.C., 1952.

APPENDIX B

COST ANALYSIS OF PROJECT

Total Materials, sealer, cutting tools, sand, etc.	$3,461.55	
15 % for profit, overhead, supervision and general	519.24	
		$3,980.79
Total Labor	4,969.62	
20 % for profit, overhead, etc.	993.93	
		5,963.55
Workmen's compensation, .0429 %	213.58	
Social Security tax, 1.5 %	74.55	
Michigan Unemployment Compensation 2.09 %	103.87	
	392.00	
15 % for overhead, profit, etc.	58.80	
		450.80
Employee's travel expense allowance, $.05 per mi.	376.25	
15 % for overhead, profit, etc.	56.45	
		432.70
Equipment rental for equipment furnished by contractor	1,572.35	
15 % for profit, overhead, etc.	235.86	
		1,808.21
Operating charges for Michigan State Highway equipment		93.10
Joint cleaning machine and sealing compound melter		
Total of Invoices		$12,729.15
1 % for bonds		127.29
Total due contractor		$12,856.44

Lineal feet of joints and cracks sealed in project:

Longitudinal joint	25,857
Transverse joints	5,340
Open cracks	403
Closed cracks	4,000
Total combined	35,600

Weight of sealing material per lineal foot of crack plus joint:

$$\frac{15,150}{35,600} = 0.593 \text{ lb per ft}$$

Cost per lineal foot of crack plus joint for total operation:

$$\frac{12,856.44}{35,600} = \$0.361 \text{ per ft}$$

Cost per pound to apply joint sealing material:

$$\frac{12,856.44}{15,150} = \$0.849 \text{ per lb}$$

Field Testing of Materials for Sealing Cracks and Joints in Bituminous Concrete Resurfacings

EGONS TONS, Research Engineer and
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Joint Highway Research Project, Massachusetts Institute of Technology and
Massachusetts Department of Public Works

Reflection cracking, its causes and possible means of prevention of treatment, have been under study for several years by the staff of the Joint Highway Research Project of the Massachusetts Institute of Technology and the Massachusetts Department of Public Works. This research has already been reported on in several Highway Research Board papers and Project reports (see References).

The authors have previously described their work on laboratory testing of materials for sealing cracks in bituminous concrete pavements (7). In this paper they outlined the physical requirements that appear to be necessary for a successful reflection crack sealer, basing these on previous Project research on the causes and development of reflection cracking. They then described a series of tests designed to measure whether a sealing material would meet these requirements and finally reported on the results obtained from the testing of 26 compounds.

Their conclusions were that the physical requirements needed for a sealer for ⅛-in. reflection cracks are such that an adequate material might be difficult to develop and that none of the materials tested were satisfactory. Four sealers subjected to the laboratory tests appeared promising for successfully sealing ¼-in. cracks.

The research on crack sealers has continued during the past two years both in the laboratory and in several field installations. Considerable outside interest has developed in knowing about the results achieved; this paper is a progress report on the work.

SEALING MATERIALS UNDER STUDY

●SEVERAL manufacturers have cooperated closely with the authors both in trying to improve their materials and in developing new ones which would better meet the severe requirements for a successful reflection crack sealer. All new compounds were of course subjected to the laboratory tests.

As a result of the investigation eight sealers appeared to offer sufficient promise to merit field testing. A ninth conventional sealer was included in one of the tests as a control. The materials can be summarized briefly as follows:

Sealer Number	Applied Cold or Hot	Basic Components	Tested at Randolph	Tested at Walpole	Number in Previous Paper
1	Cold	Rubber-Asphalt Emulsion	X	X	Developed since previous paper
2	Cold	Rubber-Asphalt Emulsion	X	X	
3	Cold	Rubber-Asphalt Emulsion	X	X	
4	Cold	Two synthetic compounds mixed just prior to application	X	X	C-24
5	Hot	Rubber-Asphalt	X	X	H-8
6	Hot	Rubber-Asphalt		X	H-9
7	Hot	Rubber-Asphalt		X	H-6
8	Hot	Rubber-Asphalt		X	H-3
9	Hot	Rubber-Asphalt plus mineral filler (control)		X	H-2

Only the first five could be placed in reflection cracks ⅛ in. or wider with the equipment available at the time.

All nine could be used in straight sawed grooves ¼ in. wide.

FIELD TEST PLANNING

It was decided to test these materials under a variety of field conditions. Extensive condition surveys of bituminous resurfacings have shown that typical reflection cracks are usually quite ragged and vary in width along their total length from fine hair cracks to ½-in. openings (11). These dimensions change continuously with changes in temperature.

Laboratory results indicated that sealers often fail due to insufficient adhesion to the crack walls, and that cleaning of these walls would improve the bond. It was hoped that air blowing might satisfactorily accomplish this cleaning in the field.

It was therefore decided to test each of the first five sealers in a series of reflection cracks, typically ragged and variable in width, with equal lengths being sealed as is and after being cleaned by air-blowing.

Another of the laboratory conclusions was that it should be possible to seal ¼-in. natural cracks, particularly so if the cracks were uniformly wide, smooth and clean, and in fresh asphaltic surfaces.

Coupling this finding with the fact that in resurfaced Massachusetts pavements reflection cracking develops over 80 percent of total joint length in four years (11), the idea evolved of sawing ¼-in. wide grooves in a new resurfacing directly over the underlying joints before cracks appear and then sealing them immediately. In this way, wide straight grooves would be substituted for ragged irregular cracks. These grooves might be able to hold a sufficient volume of sealing material to function properly and also, since groove surfaces would be fresh and clean, the conditions for adhesion of the sealer to the pavement would be at their best. It was assumed that such grooves would only need to be sawed about ⅓ of the total resurfacing depth, or roughly one inch deep, to be effective.

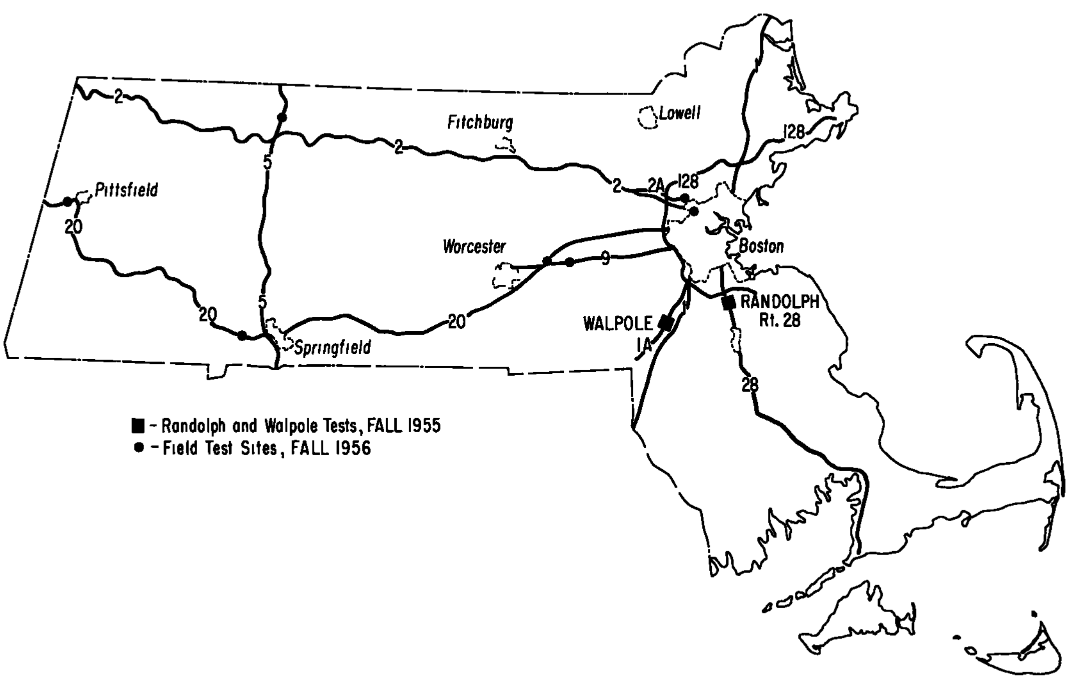


Figure 1. Location of experimental crack and sawed groove sealing sections in Massachusetts.

Figure 2. Air blowing a crack before sealing.

Figure 3. Sealing a crack with a hot-poured material.

DESCRIPTION OF TEST SITES

Two sites that offered a wide variety of test conditions were selected in the Fall of 1955 for field trials for the nine materials (Fig. 1).

Randolph Test Section

A four-year-old resurfacing in which almost all underlying transverse expansion joints were reflected by cracks varying in width from a hair to about ½ in. (See Appendix).

Walpole Test Section

A section with three-week-old resurfacing in which ¼-in. grooves were sawed directly over the underlying transverse joints (See Appendix).

SEALING OPERATIONS

Detailed condition surveys were made of the resurfacing in Randolph and the cement concrete pavement at Walpole prior to resurfacing. At the latter site the location of pavement joints was referenced with stakes. The information obtained was used as a guide for test section planning, the objective being to get as similar a condition as possible for each sealing material.

On the old resurfacing at Randolph there were two subsections for each of the five sealer tests:

1. About 180 ft of transverse cracks sealed without any pretreatment.
2. About 180 ft of transverse cracks airblown with a compressor before applying sealer (Fig. 2).

No longitudinal cracks were sealed as they were very narrow in width. The experiment covered about ¾ mi of roadway.

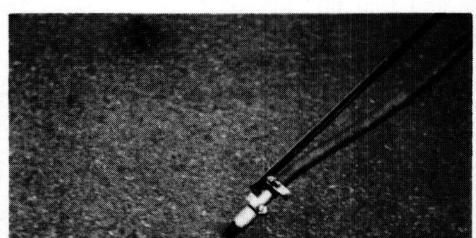
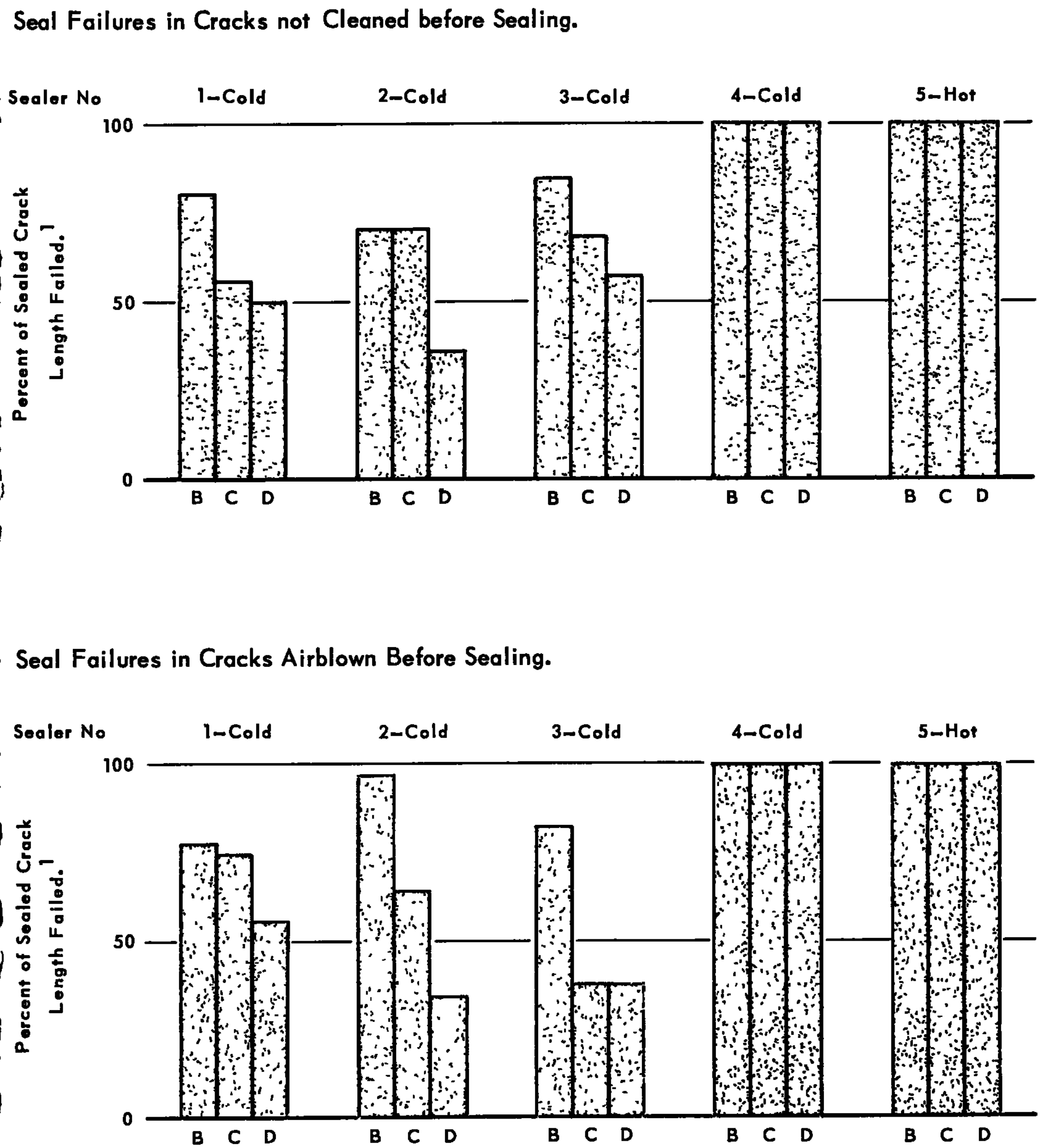


Figure 4. Sealing a crack with a cold-applied material.



1. All failures were primarily in adhesion, except for sealer 3 which failed in cohesion.
2. "B" cracks are 1/8 inch or less in width.
3. "C" cracks are 1/8 inch to 1/4 inch wide.
4. "D" cracks are 1/4 inch or more in width.

Figure 5. Randolph crack sealing, October 1955. Results after one year.

Figure 6. Crack $\frac{1}{4}$ inch or wider with Sealer 1 in good condition.

Figure 7. Crack below $\frac{1}{4}$ inch width was not well sealed.

In the new resurfacing at Walpole ¼ in. wide one inch deep straight grooves were sawed in the new resurfacing directly over the underlying concrete joints using a concrete saw and two ⅛-in. diamond blades side by side (Fig. 10). The cuts were allowed to dry out from the cooling water overnight, then were airblown and sealed. About 120 ft of grooves were prepared for each of the nine sealers; the experimental section extended about ⅔ of a mile.

The sealing work was done in the Fall, when cracks and joints open wider than in the summertime, but when it is still warm and dry enough to use the materials. The cracks at Randolph were sealed between October 19 and 24, 1955 (Fig. 2 to 4). The weather was fair with temperatures around 50 F during the day and in the low thirties at night. The work at Walpole was done between November 17 and December 8, 1955 (Fig. 10 to 12). Temperatures were much colder, below 40 F the entire time.

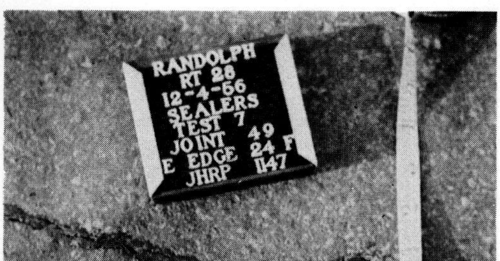


Figure 8. Sealer failed in adhesion.

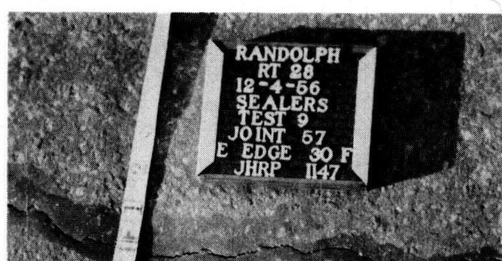


Figure 9. Sealer failed in cohesion.

SEALER APPLICATION MACHINES

There appeared to be no satisfactory equipment available for applying the four cold-applied sealers, which had the consistency of toothpaste. An improvised pressure applicator was therefore devised, consisting of a 2½-gal pressure tank on a dolly, a hose and 3/16-in. nozzle (Fig. 4 and 12). The nozzle was guided by a handle along the crack filling it flush with the sealer. None of the sealers required sanding except for Sealer 4, which was dusted with a limestone filler before traffic resumed.

Two commercially available machines for applying the hot-poured materials were lent by one manufacturer. The double boiler applicator used for Sealer 5 at Randolph had to be modified because the applicator shoe was designed for sealing straight smooth joints in cement concrete pavements and would not work in a reflection crack. This was done by attaching an adapter and then a nozzle similar to the one on the cold application apparatus (Fig. 3).

The same double boiler did not work smoothly at Walpole either, when used for ¼-in. straight groove sealing (Fig. 11). The hot shoe tended to grab into the asphaltic concrete as it was sliding along its surface. Hand labor was necessary to finish the work. Sealers 5, 6 and 7 were applied with this machine. For Sealers 8 and 9 a gravity flow machine was used with a squeegee attachment sliding along the top of the pavement. Some flow difficulties developed with Sealer 8 which was a relatively viscous material.

Figure 10. Grooves were sawed ¼ inch wide, one inch deep above the concrete expansion joints.

Figure 11. Hot-poured materials were applied with double boiler applicator.

In the opinion of the authors some modification would make the double boiler applicator suitable for sealing both cracks and grooves. At the same time field experience demonstrates that it takes less skill, time and effort and it is safer to work with cold-applied materials.

RESULTS TO DATE

Both test sections have been periodically observed and surveyed since sealing and after thirteen months show some significant results.

As in previous laboratory tests sealer failures were classified into:

Adhesion failure - separation of the sealer from the crack or groove wall.

Cohesion failure - the sealer sticks well to the crack or groove wall, but fails within itself.

Pavement failure - the pavement in the vicinity of the sealed crack fails.

All sealing materials performed well during the cold winter of 1955-56 except for a few spots of adhesion failure in the narrow cracks at Randolph.

Sealer failure to date, expressed as a percentage of total crack or groove length, is shown in Figures 5 and 13.

In the natural reflection cracks at Randolph Sealers 1 to 4 had frequent adhesion failures (Fig. 8). This occurred especially in cracks under ¼ in. in width. The only hot-poured sealer used there, Sealer 5, had an almost 100 percent failure in cohesion even in cracks ¼ in. or more wide (Fig. 9).

There was no marked improvement in performance of the sealers in airblown cracks at Randolph (Fig. 5). It was observed, however, that the sealing compounds had penetrated deeper into them than into cracks that had not been cleaned.

Figure 12. Cold-applied materials were placed under pressure.

In the ¼-in. grooves at Walpole there has been little sealer failure so far (Fig. 14), with one exception.

Four grooves containing Sealer 6 were adjacent to a traffic light. A recent survey showed them to have been narrowed considerably by braking and accelerating forces, thus displacing some sealing compound. When the grooves opened due to cold weather the narrow seal apparently could not stand the relatively severe extension and shear with the result that there was cohesion failure (Fig. 15).

Inadvertently one groove at Walpole was not sawed directly over the underlying joint and a parallel reflection crack has developed about a foot away (Fig. 17).

On both test sections the sealing is still very neat in appearance, particularly at Walpole with its straight uniformly wide sealed grooves.

DISCUSSION OF RESULTS TO DATE

The sealed grooves at Walpole have so far performed much better than the sealed cracks at Randolph, and have a neat appearance which should appeal to the traveling public. The tests have demonstrated that a neat seal can be achieved when the right equipment and materials are used. The uniformly wide and deep ¼-in. grooves at Walpole hold more sealer than do narrow ragged cracks. Greater sealer volume means

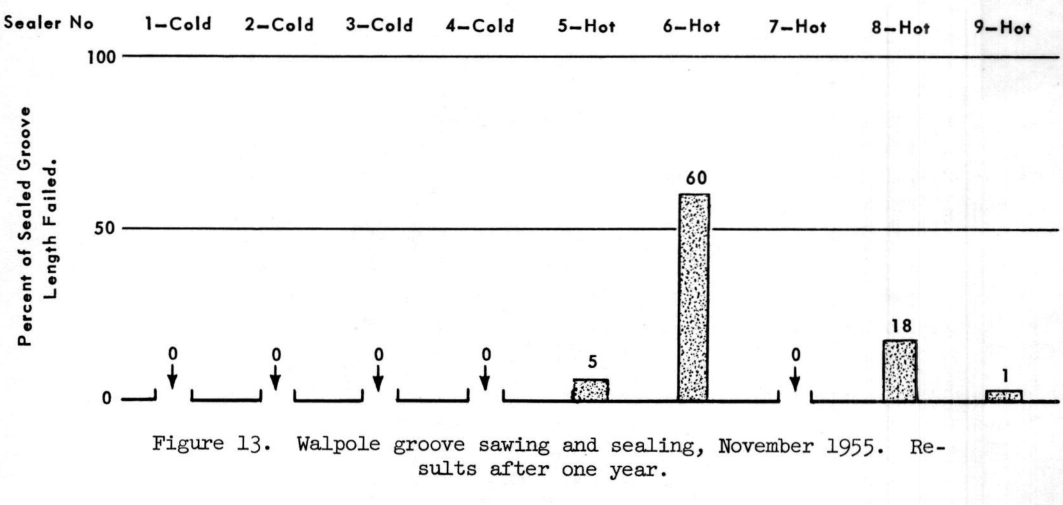


Figure 13. Walpole groove sawing and sealing, November 1955. Results after one year.

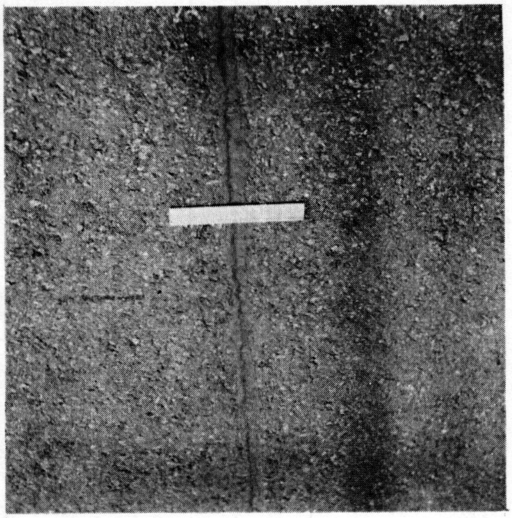


Figure 14. Typical joint with a good seal.

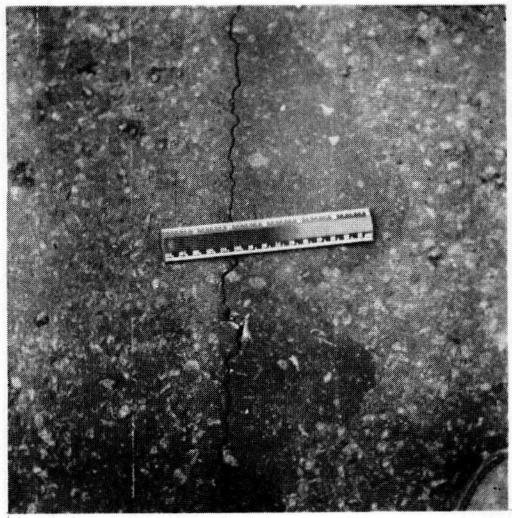


Figure 15. Sawed groove partially closed by traffic. Cohesion and pavement failure resulted.

less shear and tension stresses within as the adjacent pavement moves vertically and horizontally due to temperature and load changes.

Adhesion Failure

Achieving proper adhesion of the sealer to the crack walls is a major problem. Sealers 1, 2, 3 and 4 showed numerous adhesion failures in Randolph though these materials performed almost perfectly in Walpole. As the age of the two resurfacings is not the same, numerical results should be compared with caution.

A significant difference that would affect adhesion is apparently the difference in the condition of the crack walls. Probably in Randolph the dust layer which was not blown off the crack walls acted as a separator and was the primary cause of failure among several possible factors.

Further research on cleaning cracks and improving bond between sealer and pavement appears indicated. Two approaches might be possible:

1. Clean the crack before sealing by some mechanical means, thus removing the dust along with some of the pavement and getting a smooth fresh surface for the sealer to adhere to similar to that in the sawed joints.
2. Air-blow and prime the dusty crack with a compound that penetrates and wets the dust, dissolves some of the bituminous pavement binder along the crack wall and helps the dust layer become an integral part of the pavement and sealer after curing.

Work on the latter approach is described later in this paper.

Cohesion Failure

So far, except in the two cases discussed below, there has been little cohesion failure on either test section indicating that most of the materials that successfully passed the laboratory tests are living up to expectations in the field as well.

LARGE SCALE PILOT TEST 1956

Regardless of the effectiveness of grooving and sealing as a solution to the reflection crack problem there already exist in Massachusetts many miles of cracked resurfacings similar to the Randolph test site that need maintenance. Even if the ideal material cannot be developed, the best possible sealer is badly needed. At the request of the

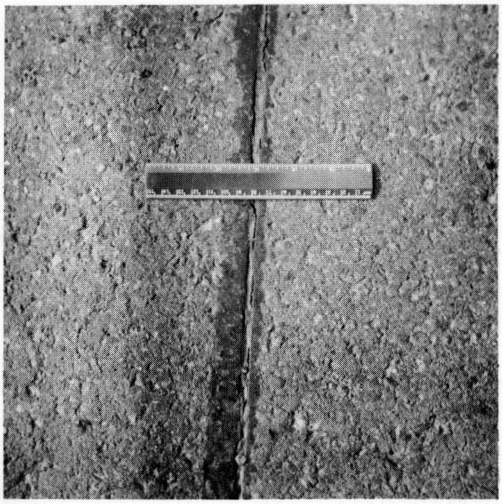


Figure 16. Very few adhesion failures were found.

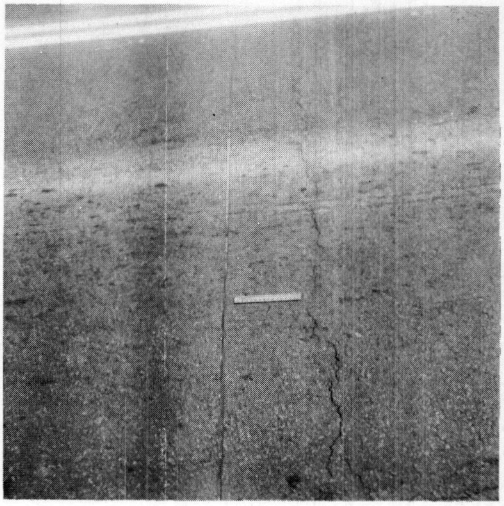


Figure 17. Groove was not sawed directly above underlying joint.

sponsor, the Massachusetts Department of Public Works, it was decided to further improve the most promising materials and equipment used at Randolph and Walpole and undertake larger scale pilot testing in the Fall of 1956.

IMPROVEMENT OF ADHESION

Therefore, during 1956 the three best materials from the Randolph experiment, Sealers 1, 2 and 3 were studied again in the laboratory with the object of improving their adhesion.

The manufacturer developed a new sample using softer asphalt and an additive. This compound was tried in the field and showed a slight but still inadequate improvement in adhesion.

Attention was focused again on preparing the crack for the sealer. Air blowing alone

Figure 18. Experimental sealing, general view.

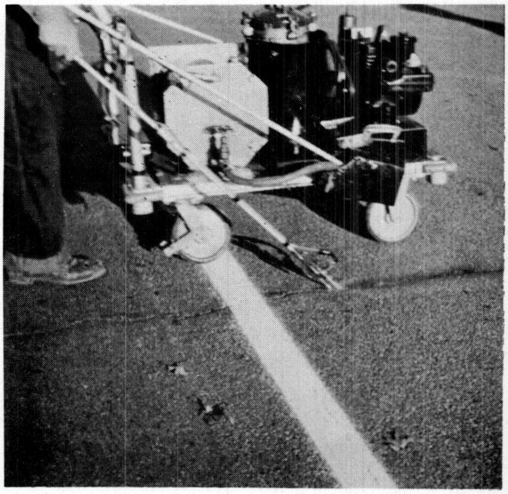


Figure 19. Experimental sealing machine. Primer-Sprayer in operation.

had not proved to be the solution. As already discussed, it was thought that perhaps priming of the crack wall after blowing might help. In the laboratory old dirty crack walls obtained from torn-up pavement were treated with a thin (50-50) asphaltic emulsion, kerosene and creosote, and then sealed. Kerosene appeared to be the most effective primer.

IMPROVEMENT OF SEALER APPLICATOR MACHINE

The small pressure applicator for cold applied materials used the previous fall was obviously inadequate for production work. A more elaborate experimental machine was therefore designed, built and tested by the authors (Fig. 18 to 20). It is designed to first blow out the crack, then prime it with kerosene and finally seal it, using successive passes of the machine (Fig. 21).

Its basic components are as follows: a three cu ft per minute compressor driven by a one horsepower gasoline engine, a 2½-gal steel container for primer able to take pressures up to 60 psi, a clamp-on device to hold a five-gallon can of sealer, a dust gun, a spray gun, a sealing stick and interchangeable nozzles, a magnesium dolly, clamps, hose, connectors, valves, etc.

Field trials with it proved satisfactory enough that a duplicate machine was constructed to increase sealing capacity in the field.

EXPERIMENTAL SEALING NOVEMBER 1956

The Maintenance Division of the Massachusetts Department of Public Works in cooperation with the Joint Highway Research Project sealed reflection cracks during November 1956, using the new material and machines. About 400 gal of sealer were used in seven different test locations (Fig. 1). It is planned to continue work with about 600 gal more in the Spring of 1957. Sealing operations proceeded satisfactorily except that the relatively cold weather this fall caused frequent interruptions and some difficulties. Test results will be reported at a later date.

CONCLUSIONS

After thirteen months the field tests have in general confirmed laboratory predictions.

1. Most of the materials tested in the field do give promise of being better than

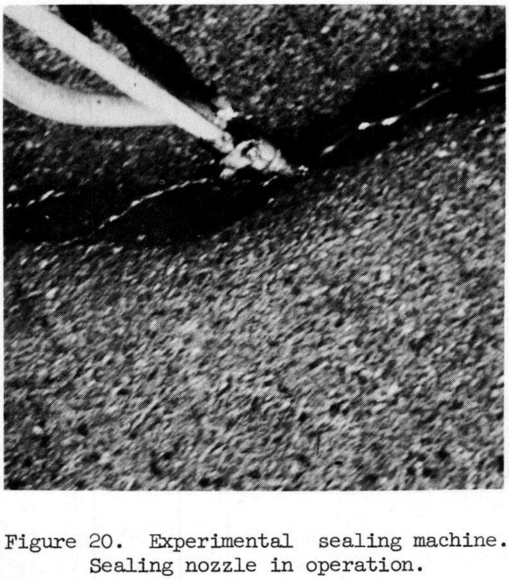


Figure 20. Experimental sealing machine. Sealing nozzle in operation.

Figure 21. Sealed $\frac{1}{4}$ inch wide crack.

presently used materials for sealing reflection cracks.

2. In the crack sealing test (Randolph) the most frequent failures were in adhesion; there were very few failures of this kind in the groove sealing test (Walpole) so far.

3. Sealers in ¼-in. or wider cracks showed considerably less failure than sealers in cracks under ¼ in. in width.

4. Sealers in grooves ¼ in. wide cut in bituminous resurfacing before reflection cracking starts have performed excellently so far.

5. Airblowing of cracks has not noticeably helped to improve adhesion. The sealers do, however, penetrate deeper into a blown crack.

6. Priming of cracks before sealing may promote better adhesion of a sealer to the crack walls.

7. A slight overlap of the sealer on the surface along the crack edges seems to help prevent adhesion failures.

8. Adequate machinery can be devised to properly place sealing material in a reflection crack or groove. The cold-applied materials require simpler equipment which is easier and safer to operate than the hot-applied sealer machinery.

9. Groove sawing and sealing in fresh bituminous resurfacing should not begin until the overlay has been subjected to stabilizing effect of traffic.

10. Grooves have to be sawed exactly above the existing concrete slab joints.

11. The appearance of a sawed and sealed groove is neater than that of a crack.

ACKNOWLEDGMENTS

The research described in this paper is part of the study of reflection cracking being conducted by the Joint Highway Research Project, established at the Massachusetts Institute of Technology by a grant from the Massachusetts Department of Public Works for research in the field of highway engineering.

The authors wish to express their sincere appreciation to the staff of the Maintenance Division of the Department of Public Works for their cooperation and assistance. Mr. G. Gordon Love, Maintenance Engineer, provided steady encouragement and help for the work ever since its inception. His assistants, Robert E. Lee, J.A. McCarthy and the District Maintenance Engineers, especially John Freeman, have been most helpful. Mr. Ralph P. Joslyn, Chief of the Asphalt Section of the Department of Public Works Laboratory, contributed both advice and assistance.

Thanks are extended to the numerous manufacturers who submitted samples of sealer for test, and particularly to those manufacturers who are working closely with the Project to develop better materials.

The Joint Equipment Company of Des Moines, Iowa, arranged for their machinery for applying hot-poured sealer to be made available for our use.

Finally, thanks are due to the members of the M.I.T. staff, particularly Professor A.J. Bone, for their many helpful suggestions.

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Appendix

TEST SECTION DESCRIPTIONS

Randolph

The experimental reflection crack sealing section is located on Route 28 about one mile north of Randolph, Massachusetts (See Fig. 1). The underlying pavement consists of three lanes of reinforced portland cement concrete. Slabs are ten feet wide, 57 ft long and eight inches thick. There are no contraction joints. Expansion joints have load transfer devices.

In the Spring of 1951 this pavement was resurfaced and widened to 45 ft with 2½ to 3 in. of Massachusetts Type I bituminous concrete. (Binder course - Specifications call for one inch maximum size aggregate, 1 to 6 percent filler, 4 to 6 percent asphalt cement. Top course - ½-in. maximum size aggregate, 4 to 9 percent filler, 5 to 8 percent asphalt cement.)

By the autumn of 1954 all underlying transverse expansion joints were reflected in the bituminous concrete overlay, the width of crack varying from a hair crack to about ½ in. and the length of crack extending usually beyond the 30 ft width of underlying pavement into the widening strip beyond.

Walpole

This test section is located on Route 1A immediately south of the center of Walpole, Massachusetts. Two lanes of reinforced portland cement concrete, each slab being 10 ft wide, 57 ft long and 8 in. thick form the underlying pavement. Only expansion joints with load transfer devices were used. This old pavement was resurfaced and widened in early November, 1955, with three inches of Massachusetts Type I bituminous concrete (see preceding note). The resurfacing was about three weeks old when the grooves were sawed and sealed.

THE NATIONAL ACADEMY OF SCIENCES—NATIONAL RESEARCH COUNCIL is a private, nonprofit organization of scientists, dedicated to the furtherance of science and to its use for the general welfare. The ACADEMY itself was established in 1863 under a congressional charter signed by President Lincoln. Empowered to provide for all activities appropriate to academies of science, it was also required by its charter to act as an adviser to the federal government in scientific matters. This provision accounts for the close ties that have always existed between the ACADEMY and the government, although the ACADEMY is not a governmental agency.

The NATIONAL RESEARCH COUNCIL was established by the ACADEMY in 1916, at the request of President Wilson, to enable scientists generally to associate their efforts with those of the limited membership of the ACADEMY in service to the nation, to society, and to science at home and abroad. Members of the NATIONAL RESEARCH COUNCIL receive their appointments from the president of the ACADEMY. They include representatives nominated by the major scientific and technical societies, representatives of the federal government, and a number of members at large. In addition, several thousand scientists and engineers take part in the activities of the research council through membership on its various boards and committees.

Receiving funds from both public and private sources, by contribution, grant, or contract, the ACADEMY and its RESEARCH COUNCIL thus work to stimulate research and its applications, to survey the broad possibilities of science, to promote effective utilization of the scientific and technical resources of the country, to serve the government, and to further the general interests of science.

The HIGHWAY RESEARCH BOARD was organized November 11, 1920, as an agency of the Division of Engineering and Industrial Research, one of the eight functional divisions of the NATIONAL RESEARCH COUNCIL. The BOARD is a cooperative organization of the highway technologists of America operating under the auspices of the ACADEMY–COUNCIL and with the support of the several highway departments, the Bureau of Public Roads, and many other organizations interested in the development of highway transportation. The purposes of the BOARD are to encourage research and to provide a national clearinghouse and correlation service for research activities and information on highway administration and technology.