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Resealing Joints and Cracks In Concrete Pavement (Minnesota)

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Resealing Joints and Cracks In Concrete Pavement (Minnesota)

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Resealing Joints and Cracks in Concrete Pavments With Hot-Poured Rubber-Asphalt

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SYNOPSIS

IN view of the obvious need for a major program of resealing joints and cracks in concrete pavements, the Maintenance Division of the Minnesota Highway Department, in cooperation with the Division of Materials and Research, initiated an experimental project in 1949 to study the cutting, cleaning, and resealing of joints and cracks. The study included methods, equipment, materials and costs.

In view of the apparently successful results obtained on the experimental project, the Maintenance Division awarded contracts for sealing approximately 85 mi. of pavement with hot-poured rubber-asphalt in the 1950 season. The principal bid item was for joint cleaning and resealing, the bid price per pound to include "all material furnished, and all operations necessary for, or incidental to cutting, cleaning and filling" joints and cracks. The overall results obtained were so satisfactory that the department decided to continue the program of rehabilitation of its old concrete pavements and 333 mi. were placed under contract for 1951. The contemplated program for 1952 is approximately 390 mi.

This paper describes the experimental project and the materials, methods and equipment developed to accomplish economically the work under contract.

IN the early years of concrete highway construction, pavements were laid without joints, either transverse or longitudinal. The inevitable result, of course, was the development of cracks of indefinite and irregular pattern varying in spacing as well as pattern and depending on such factors as subgrade soil, strength of the concrete, temperature at time of placing, subsequent curing and others. With the objective in mind of controlling the cracking, joints, both longitudinal and transverse, were introduced. Much has been done and written in connection with the development of satisfactory joint design, and it can be said that such design and practice have largely eliminated the former promiscuous cracking. In recent years the trend appears to be, at least in several states, to eliminate the expansion joints, except at such places where the pavement abuts against a bridge or other structure. The joints are thus limited to longitudinal joints and transverse contraction joints, the spacing of the latter being relatively close, depending upon such factors as amount of steel reinforcement, if any, climate, experience of the engineer, and other factors.

Although the use of joints has largely eliminated the cracking problem, other problems have arisen, the solution of which are among the most serious related to the maintenance of concrete pavements. Pavements, like people, require continual maintenance, and as with people, the maintenance problem becomes more acute with increasing age. It has been our observation that, for the most part, deterioration of pavements starts at the cracks and joints and progresses from there. If not caught in the early stages the maintenance can become a very costly item. Figure 1 shows the development of cracking adjacent to a joint and Figure 2 shows the advanced stage of similar deterioration at a nearby joint intersection. What appears to be adequate joint maintenance in Figure 1 is a case of "too much too late."

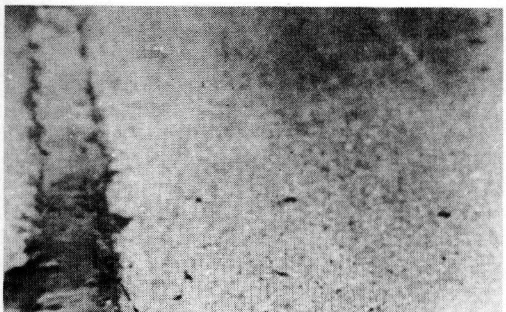

Figure 1. Development of cracking adjacent to a joint intersection.

Figure 2. Advanced stage of deterioration at a joint intersection.

In addition to the prevention or retarding of deterioration, the maintenance of joints is particularly important in those areas where high joints can develop because of the effect of moisture on the subgrade soil. Proper joint maintenance can also contribute to the reduction of the likelihood of pumping where the combination of soils, moisture, and traffic may be such as to permit or cause pumping.

NEED OF MAJOR RESEALING PROGRAM IN MINNESOTA

It has been apparent for some time that a major resealing of joints and cracks was long past due in Minnesota. Deterioration of the concrete (as evidenced by D-cracking), which we believe is aggravated by lack of adequate joint maintenance, was becoming a very serious maintenance problem. High joints have also been a problem on a number of projects, and it is believed that these, to a degree, can be attributed to the joints not being sufficiently well sealed to prevent the entry of water. The prevention of pumping was also a factor deserving of consideration. With the usual joint-filling materials and practices, the field maintenance forces were unable to cope satisfactorily with the problem, and it became evident that a major program was in order.

THE 1949 EXPERIMENTAL PROJECT

Prior to entering upon a resealing program of statewide proportions it was felt that some preliminary studies should be made. An experimental project was set up in 1949 with a three fold objective to: (1) study the behavior and performance of rubber-asphalt and other joint-and-crack-filling materials and the equipment necessary to properly heat and place them into the joints and cracks; (2) study mechanical methods and equipment for the proper cleaning of joints prior to resealing; and (3) develop data which would serve as a guide to the state and potential contractors in the matter of suitable methods, equipment, and cost estimates.

With the above objectives in mind the Maintenance Division, with the technical assistance of the Division of Materials and Research, set up an experimental project approximately 6.6 mi., net, in length. This project consisted of cutting, cleaning, and resealing the joints and cracks on US 8 through Ramsey County. The pavement consisted of three lanes, each 9 ft. in width, and was built in 1927 and 1928. The coarse aggregate consisted of gravel and limestone, each separately in various sections. Expansion joints of premolded filler were spaced at 201-ft. intervals and contraction joints using steel divider plates were spaced at 40-ft. intervals. The longitudinal joints were also constructed with steel divider plates. The pavement was in good condition, except for some sections where limestone aggregate had been used, and pitting had occurred rather severely in some sections. The joints and cracks were generally in need of filling.

The resealing work was done with maintenance forces and equipment, except for the joint-cutting machine, which was rented. The sealing compounds were purchased except in some cases where manufacturers donated the material so that it might be included in the experiment. The work was started on August 9 and the last pouring was completed on October 27, 1949.

Cutting and Cleaning Operations

The cutting or grooving was done with a concrete-grooving-and-joint-cleaning machine. This machine was used for the cutting of all joints and cracks. A general view of the machine as well as a typical view of the pavement is shown in Figure 3. Typical arrangements of the cutters on the cutter head are shown in Figures 4 and 5.

Figure 3. Concrete-grooving-and-joint-cleaning machine.

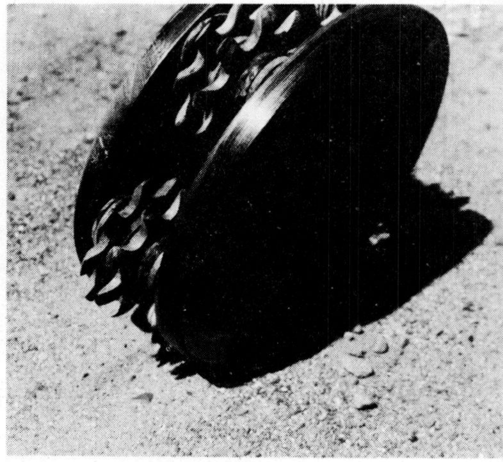

Figure 4. Arrangement of cutters for transverse joints.

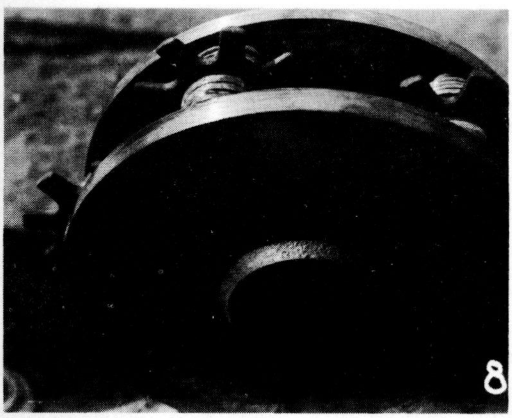

Figure 5. Arrangement of cutters for longitudinal joints.

Original joint size, shape, and condition determine to a great extent what the dimensions of the cleaned cut will be. Degree of wear of the cutters, hardness of the concrete, and the amount of old joint-sealing material are also factors. The cuts are not square shouldered, the resultant cross section being dependent on the shape of the original joint and the degree of wear on the cutters. The cuts vary from a rounded shoulder nearly square to a V-shaped cut. On wide and irregular joints as many as three passes were required to thoroughly clean the sides of the joint. On uniform, unspalled, average-sized expansion joints only one pass was required. Cracks were cut in one operation. A typical joint after cutting is shown in Figure 6.

Heating of Hot-Poured Fillers

Among the important lessons learned on the project was that concerned with the heating equipment. The heating kettle was new, of the oil-jacketed type with automatic temperature control and hand-actuated agitator. The effect of the agitator was purely local and of doubtful effectiveness

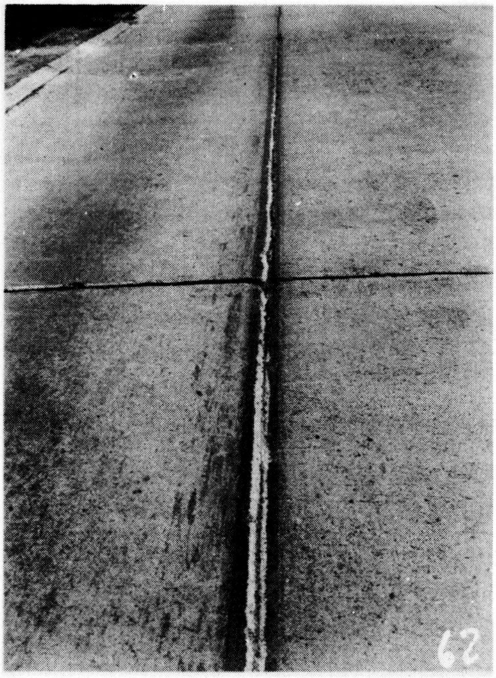

Figure 6. Typical joint after cutting with concrete-grooving-and-joint-cleaning machine.

even there. Regardless of the efficiency of the hand-operated agitator it should not be permitted. Rubber-asphalt joint filler requires continuous agitation and this cannot be positively assured with hand operation.

Because of the inadequate agitator and other factors, heating of the filler was a slow and costly process. Its shortcomings contributed substantially to slow progress and high cost of the work. The maximum quantity of filler heated and poured in one day was 1,400 lb. and this required 13 hr. The experience proved invaluable in that it was learned that to make satisfactory progress and insure uniformity in temperature and consistency--and this is vital to efficient and satisfactory work--mechanically agitated kettles must be specified.

Pouring Filler

All pouring was done with pouring pots, but this was not satisfactory. As pouring progressed, the pour pots built up with filler material and it was necessary to burn them out from time to time. For this and other reasons, including uniformity and neatness of pour, it was concluded that for future work mechanical applicators would be required.

A hand-operated squeegee was used with some success at a sacrifice of speed. From the standpoint of joint appearance it was of benefit, although it became sticky and could not be easily cleaned.

Pouring was commenced on all rubber-asphalt fillers at temperatures from 400 F. to 430 F. As the pour progressed the filler became increasingly more viscous with little drop in temperature to the point where discontinuation of pouring operations was indicated. It would appear that something similar to latent heat of fusion requires time as well as adequate temperature to convert this type of filler into a fluid state. Subsequent experience has taught us that there is a difference in the heating properties and most-suitable pouring temperatures for various fillers.

Fillers Used

The major portion of the filler material used in this investigation consisted of the hot-poured rubber-asphalt type conforming to Federal Specification SS-F-336a. Five other fillers were used in relatively small quantities.

Observations and Conclusions

Following the completion of the experimental project the following observations concerning the methods were noted:

The joints and cracks can be readily cut with the cutting or grooving machine, although the joints did not always have as vertical a shoulder as would seem to be desirable. More-frequent changing of cutter heads would, to a large extent, improve this condition. The matter of cutter replacements amounts to a rather substantial item of cost.

Specifications for future work should definitely require that the melting unit have a mechanically operated agitator to provide continuous and effective agitation of the melting filler material. Positive control of temperature is also a necessary requirement.

Filling of joints should be done with a mechanical applicator and pouring pots should not be permitted.

The joints should be dry and free of dust. An adequate amount of brushing and air equipment of sufficient air pressure and volume should be required.

Traffic can be satisfactorily handled without too much interference to operations if properly coordinated.

On the basis of this experimental project, it was recommended that serious consideration be given to setting up joint-and-crack-filling projects of such magnitude that they could be done by contract. It would be expected that if contracts were of sufficient size, contractors would be interested in such work and would purchase the equipment necessary to do the work efficiently to the mutual benefit of the state and the contractor. It was stated that there were many miles of concrete pavements seriously in need of joint-and-crack maintenance. Prior to the later setting up of projects for 1950, it was recommended that the work be done using fillers of the hot-poured rubber-asphalt type.

1950 MAINTENANCE CONTRACTS

Location of Projects

From the study of methods used and the results obtained in the 1949 experimental project, the department early in 1950 decided to prepare specifications for the performance of this type of work by contract. Initially, two projects were selected, one of 33 mi. of 20-ft. pavement located between South St. Paul through Hastings and southerly to Cannon Falls, the second a 42-mi. section of 20-ft. pavement located between McGregor and Carlton, near Duluth. A third project consisting of about 10 mi. in length of 40- to 57-ft. pavement in Duluth was selected and designed for contracting in the late summer months.

Estimate of Requirements

An estimate of the requirements was based on a representative crack survey. For 20-ft. pavement 10,000 lin. ft. per mile was used as the estimated total footage of joints and cracks. For the work in Duluth, 26,000 ft. per mi. was used as this pavement was over 40 ft. wide and therefore had additional longitudinal joints. This was estimated at 0.5 lb. (average) of rubber-asphalt material per lineal foot of all joints and cracks. An accurate record was subsequently kept of actual footage of joints and cracks cleaned and resealed on these three contracts, to be used as a basis for estimating requirements and costs on future work. The contract on Highway 210 actually required 0.566 lb. per lineal foot (average) and the average total footage of joints and cracks was 10,134 ft. per mi. (20-ft. pavement). The work in the city of Duluth required an average of 0.559 lb. of material per lineal foot and the average total footage of all joints and cracks was 27,780 ft. per mi.

1950 Specification Synopsis

The specifications and special provisions for these projects contained only three bid items. The principal item was for joint cleaning and resealing, the bid price per pound to include "all material furnished, and for all operations necessary for, or incidental to cutting, cleaning and filling" of joints and cracks. The other two bid items covered cleaning of any pavement area outside of the joints and cracks, and the furnishing of flagmen as required by the engineer (both on a man-hour basis). The latter two items were exempted from the standard contract clause which permits an adjustment in unit bid price when such items are more than 20 percent over or under the contract quantity.

For the removal of the old joint filler and the cleaning of the joints and cracks, the specifications required the following equipment:

1. Cutting or Grooving Machine. A self-powered machine operating a rotary cutter or revolving cutting tool capable of completely removing the old joint material and roughening or refacing each side wall of the joint or crack without excessive spalling or otherwise unduly damaging the edges.

2. Power Brush. A mechanically-powered rotary wire brush, either as a separate unit or as a part of the cutting or grooving machine.

3. Air Compressor. A portable air compressor capable of continuously furnishing not less than 60 cu. ft. of air per minute at a pressure of not less than 90 lb. per sq. in.

4. Wire Brush and Air Nozzle. A manually operated push-type wire brush with air-nozzle attachment for final cleaning of joints and cracks, immediately in advance of the joint-and-crack-filling operations.

The joint-sealing compound to be furnished by the contractor was required to be of the rubber-asphalt, hot-poured type, conforming to Federal Specification SS-F-336a.

For the melting and pouring of the rubber-asphalt material, the specifications required:

5. <u>Melting Kettle</u>. The melting kettle shall be of the double-boiler, indirect-heating type, utilizing hot or other material as the heat-transfer medium. The kettle shall have an effective mechanically operated agitator and shall be equipped with positive temperature control to prevent overheating of the filler material.

6. <u>Pouring Equipment</u>. The pouring equipment shall consist of a mechanical applicator equipped with satisfactory means of keeping the sealing compound heated, with adequate temperature control and manual agitator to facilitate pouring.

Hand-pouring pots will be permitted only to complete the filling of joints or cracks inadequately filled by the mechanical applicator.

A suitable squeegee or shoe shall be used to remove excess material at the joint or crack so as to obtain a fully filled joint, neat in appearance and without excess of joint material. The squeegee or shoe may be a part of the pouring kettle or a separate tool.

7. <u>Construction Requirements</u>. The construction requirements of the 1950 specifications provided that "the joints and cracks shall be thoroughly cleaned of all loose scale, dirt, dust, and other foreign matter, that the cutting and cleaning of the joint shall be such that a clean joint surface will be obtained on each wall of the joint to a depth of not less than 3/4 in." Following the cutting operation, the joints were to be further "cleaned by means of a mechanically operated, rotary wire brush", and immediately before the pouring of the hot rubber-asphalt material, the joints were to be "again thoroughly cleaned with compressed air and a manually operated wire brush."

The specifications provided that "the rubber-asphalt material shall be heated to the temperature recommended by the manufacturer, but not to exceed 450 F. at any stage in the melting or pouring operations; that it shall be subject to continuous and positive mechanical agitation; that it shall be maintained at an even temperature until placed in the joint; and that the contractor shall, in the event of circumstances beyond his control which prevent him from pouring the sealing compound, reduce the temperature to from 275 F. to 325 F., and maintain that temperature until just prior to the time pouring operations are resumed."

Pouring of the sealing compound was permitted only when the pavement surface and the joints were dry, and when the air temperature was above 40 F.

Half-width construction was required at all times, and all old joint material and other debris removed from the joint was required to be immediately removed from the pavement surface.

<u>Preliminary Information to the Contractors</u>

As none of the contracting firms of this area had had experience in the performance of work of this nature, the department made available to them complete information on the construction methods, equipment and costs obtained in its experimental work of 1949.

When the contractors were first approached on the proposed work, some of them seriously questioned the proposed basis for payment, which was to be on the basis of pounds of sealing material placed instead of the customary lineal feet of joint. However this method of payment was adopted in the belief that it would be fair to all parties. The contractor would not be encouraged to skimp the work, as might be the case with a per-foot payment basis. Nor would he be tempted to widen joints and cracks unnecessarily, since widening is a costly procedure. The per-pound method has worked excellently, in our opinion, and the contractors are believed to be entirely satisfied with it.

Spirited bidding for the first two projects developed and both contracts were awarded on July 7, 1950. The project in Duluth was awarded on August 11. The unit prices bid for rubber-asphalt joint filler on these three projects ranged from $0.216 to $0.298 per lb. in place.

Development of Equipment

It was discovered during the first few days of operations that if the letter of the specifications was strictly adhered to requiring the use of a self-powered machine operating a rotary cutter or revolving cutting tool, the amount of sealing compound required to fill the grooved and cleaned joints would be considerably in excess of the 0.50 lb. per ft. originally estimated. If permitted to continue, this would have resulted in a prohibitive cost per mile, and the death of the future program for this type of work. Therefore, the contractors were permitted and encouraged to devise equipment that would groove and clean the joints to the extent required by the specifications, even though such equipment might not conform to specification requirements. Figures 7 to 9 illustrate equipment developed by the contractors to accomplish the desired results. The results obtained with such equipment have been reasonably satisfactory.

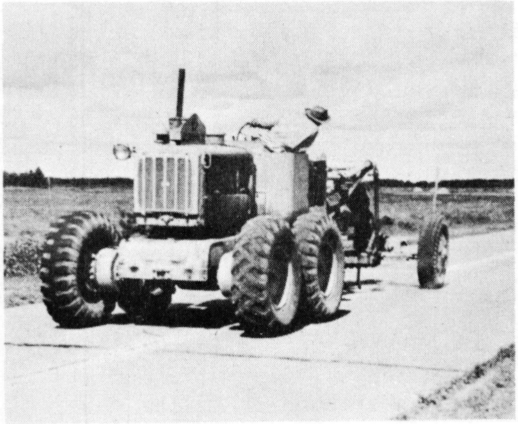

Figure 7. Motor grader with special cutter mounted on scarifier teeth. This machine used for cleaning, roughening, and refacing longitudinal joints only.

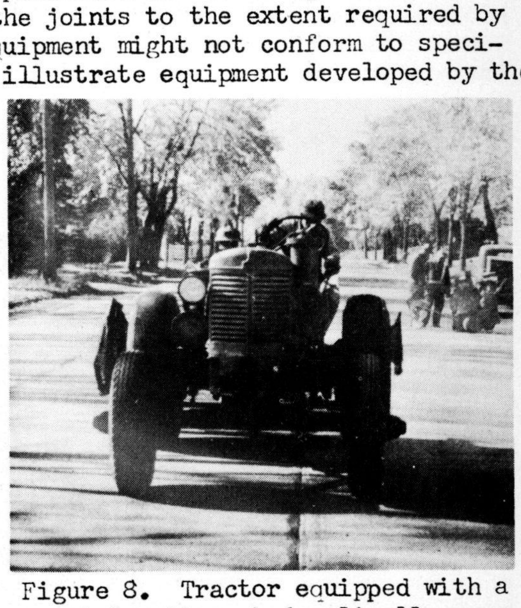

Figure 8. Tractor equipped with a special cutter, hydraulically controlled by operator. This machine is in operation, cleaning, roughening, and refacing longitudinal joints in Duluth, Minnesota. It can also be used for transverse joints.

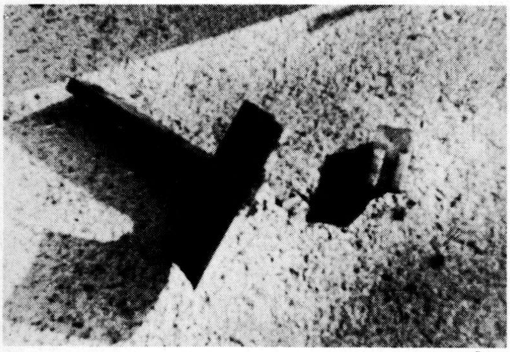

Figure 9. The small cutter is $2\frac{1}{2}$ in. wide and was used for cleaning, roughening, and refacing longitudinal joints. The wide cutter was used for the removal of old, extruded joint-filling materials from the pavement surface adjacent to the crack or joint.

Progress

Overall progress was, at first, relatively slow, but with development of equipment, experience with such equipment and familiarity with the material and its behavior, rate of progress gradually improved until as much as 5,000 lb. of filler were poured per day.

Costs

The average cost per mile for the 85 mi. constructed under the three 1950 contracts was $1,621 for the 20-ft. width of pavement and $4,685 for the Duluth project, which costs included all engineering, inspection and maintenance cleanup, and disposal of all debris removed from the joints and pavement surface.

Observations and Conclusions

So successful was the experience with the performance of this type of work by contract methods that the department decided to continue its program of pavement rehabilitation with a considerably enlarged program in 1951.

1951 PROGRAM

Location of Projects

Early in January of 1951, three projects were advertised for a letting in February. The pavements selected were built between 1929 and 1933, all of a 20-ft. minimum width, structurally sound, and not programmed for reconstruction, widening or resurfacing within the next 10-year period. The length of each project and the estimated requirements of hot-poured type of rubber-asphalt compound were as follows:

Project One	91 mi.	550,000 lb.
Project Two	125 mi.	750,000 lb.
Project Three	117 mi.	714,000 lb.

A fourth project was selected for a letting on May 18th. This project was located in Duluth and was 4.10 mi. in length, minimum of 60 ft. in width, requiring an estimated 57,465 lb. of rubber-asphalt filler material.

Bid prices for the 1951 work for the item of rubber-asphalt joint filler in place ranged from $0.248 to $0.290 per lb.

Specification Revisions

Prior to the preparation of the bid proposals for these projects, an exhaustive review was made of the construction difficulties encountered in the 1950 work, the machinery and equipment developed by the contractors, the reports and recommendations of the engineers and inspectors assigned to this work, all of which revealed the necessity of only minor revisions in the 1950 specifications. The changes adopted were as follows:

1. Cutting or Grooving Equipment. Any rubber-tired equipment capable of completely removing old joint materials and roughening or refacing each sidewall of the joint without excessive spalling or otherwise unduly damaging the joint edges and the pavement surface. Such equipment shall be capable of positive depth (not less than 3/4 in. nor more than 1 in.) and width control and shall further produce clean joint sidewalls. The width will be specified by the engineer.

The machine shall be suitable for operation to the edge of the pavement.

The use of any equipment which results in damage to the pavement will not be permitted.

2. Restricted Operations. Half-width construction will be required at all times for the placement of joint-sealing compound.

At the discretion of the engineer, permission may be granted for the operations of cutting, grooving and cleaning transverse joints over the full width of pavement.

3. Flagmen. Flagmen shall be placed in such number and at such locations as designated by the engineer to facilitate the safe movement of traffic through the zone of joint-cleaning-and-sealing operations, and for the protection of the completed work during the curing period.

Progress

Due to an abnormally cold and wet construction season, the contractor on Project 1 worked only 91 days, on Project 2, 95 days, and on Project 3, 84 days. As a result, none of these projects were completed, but the daily average of sealing compound poured on each project exceeded the estimate of 5,000 lb.

Equipment

1. Joint Cleaning. In the cleaning of the joints and cracks all three contractors used the concrete-cleaning-and-grooving machine for cracks, a large tractor or motor grader for the longitudinal joints, and small tractors for transverse joints (see illustrations).

The type of joint filler in place had much to do with the number of passes required to obtain a clean longitudinal joint. As many as 10 passes were required at times to obtain a clean joint meeting specification requirements. In a normal day, these machines could clean 6,500 lin. ft.

Figure 10. This garden-type tractor with concrete weights was used on two of the 1961 contracts for the cleaning of tranverse joints. The pail shown hanging from the tractor was used for carrying extra cutters and tools.

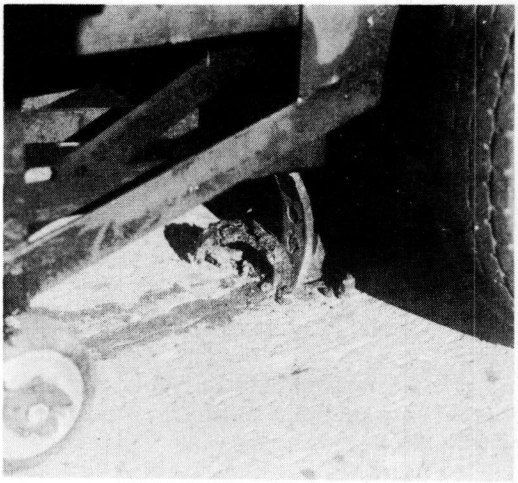

Figure 11. Close-up of cutter tooth and assembly mounted on machine shown in Figure 10.

Figure 12. A power patrol used by one of the contractors for longitudinal joint cutting and cleaning.

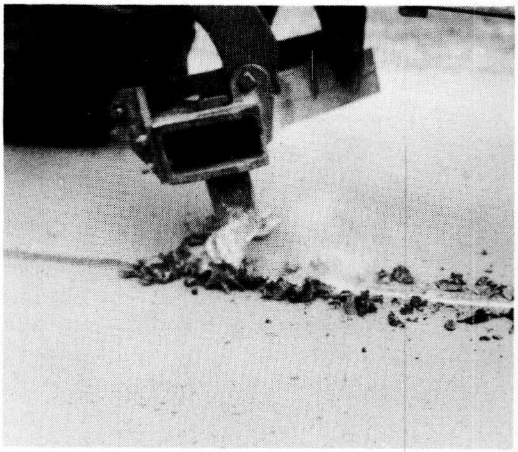

Figure 13. A close-up view of the cutter and depth-control shoe in action.

By continuous experimenting with various small farm tractors and many different shapes and sizes of cutting tools, the machines, previously mentioned and illustrated, were developed. These machines were able to clean all transverse joints of the old joint-filler material without excessive spalling. The walls of the joint were cut vertically, which insured a better bond than obtained by the V joint left by cutting and cleaning with the cutting-and-grooving machine. The amount of rubber-asphalt material required for filling was reduced by the use of such machines.

All machines used in 1951 for cleaning joints were equipped with positive-depth-control devices.

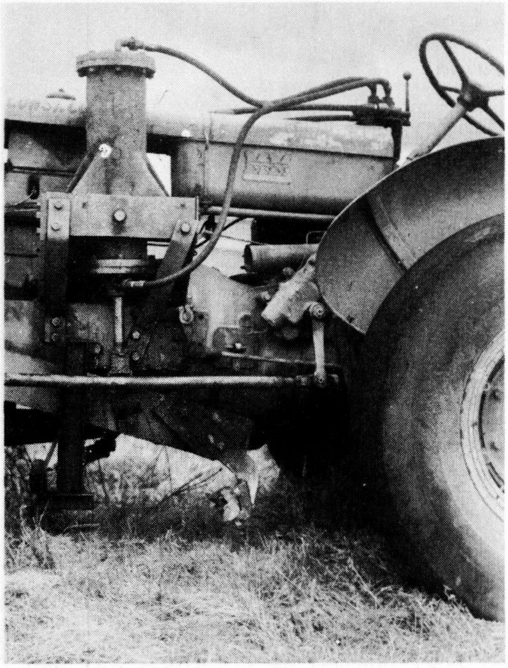

Figure 14. Same machine as shown in Figure 8, equipped with hydraulic ram and depth control arrangement.

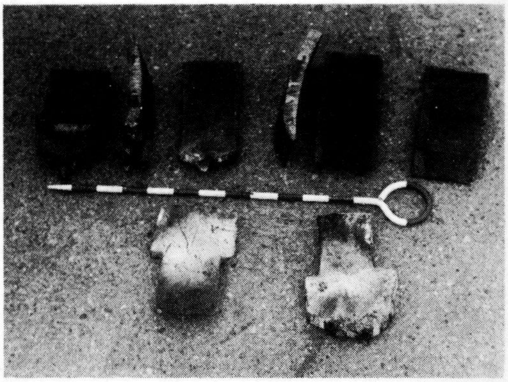

Figure 15. Longitudinal joint cutters used on 1951 projects.

Figure 16. Cutters developed and used for cleaning transverse joints.

Figure 17. Concrete-grooving-and-joint-cleaning machine used for cutting cracks.

Thorough brushing out of the joint is a very important and critical operation. Dust left on the walls of the joint to be filled will cause bond failure, requiring costly removal of the filler, recleaning of the joint, and repouring with new filler material. Very diligent inspection of this operation is most necessary to be certain of good results. The best results were obtained with motor-driven brushes, powered by at least a 7 hp. motor, similar to the machine shown in Figure 18.

Immediately prior to filling with the hot rubber-asphalt, all joints and cracks were hand brushed and blown clean with compressed air. Such a device is illustrated in Figure 19.

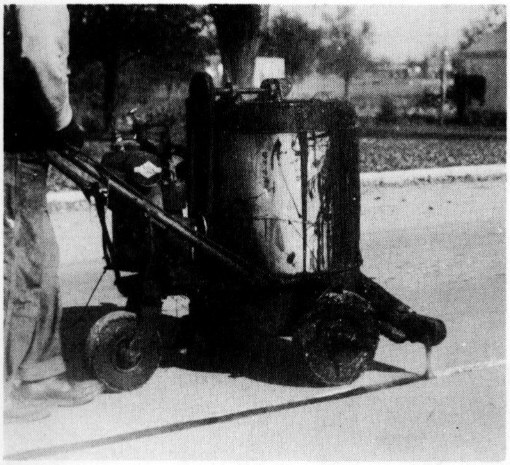

Figure 23. One method used in mounting a small gasoline motor for continuous agitation of the hot rubber asphalt.

inspectors on each project, one of whom was in overall charge, one on pouring, one on cutting and cleaning joints, and the fourth on joint inspection directly in advance of pouring operations.

THE 1952 PROGRAM

The approved program for 1952 will approximate 390 mi., requiring an estimated 2,348,000 lb. of rubber-asphalt material. The pavements selected were built between 1930 and 1943 to a width of 20 ft., are structurally sound, and are not in the next 10-year program for widening, resurfacing, or reconstruction.

SPECIFICATION REVISIONS FOR THE 1952 PROGRAM

An exhaustive review has been made of the construction difficulties encountered in the 1951 work, the improvements in equipment and technique developed by the contractors and manufacturers, the recommendations of our engineers and inspectors assigned to these projects, and the behavior of field and laboratory experiments. The following revisions have been made in the specifications:

1. Equipment. Only indirect, gas-heated-type melting kettles with positive thermostatic control will be permitted under the revised specifications.

Likewise, the pouring equipment must be equipped with positive thermostatic control and continuous mechanical agitation.

Hand-pouring pots will only be permitted for the filling of joints inaccessible to the mechanical applicator. It has been found that hand-pouring pots are not satisfactory and their use will be further restricted.

2. Construction Requirements. In the 1951 specifications there was no limitation on the extent of the contractor's operations, and as a result, his cutting, grooving, and cleaning operations were as far as 30 mi. ahead of his pouring. The revised specifications limit the overall extent of all operations to a length of 5 mi. He will be further limited in that the joints shall not be poured on half of the pavement more than one day's pour ahead of that poured on the adjacent half.

The drying of the joints by the use of heat will be permitted, provided that this operation is accomplished without damage to the concrete faces of the joint. It is further specified that compressed air shall be used concurrently with the operation of heating.

3. Preparation of the Joints. The depth of cutting and cleaning has been changed from a minimum of 3/4 in. to a minimum of $\frac{1}{2}$ in. The maximum depth remains at 1 in.

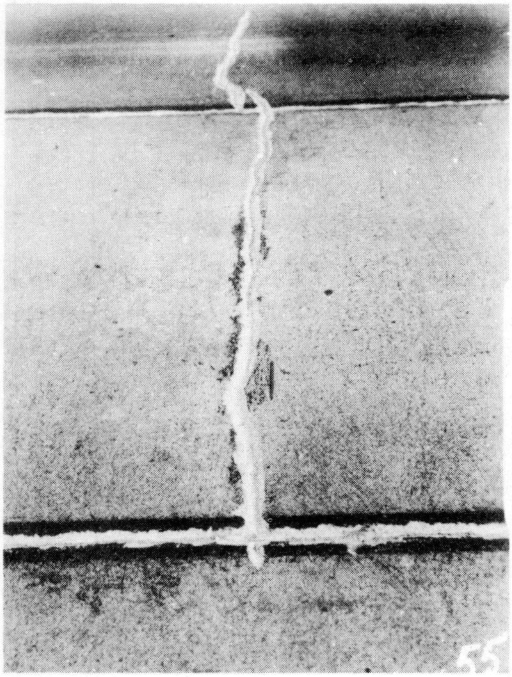

Figure 24. Transverse crack after cutting.

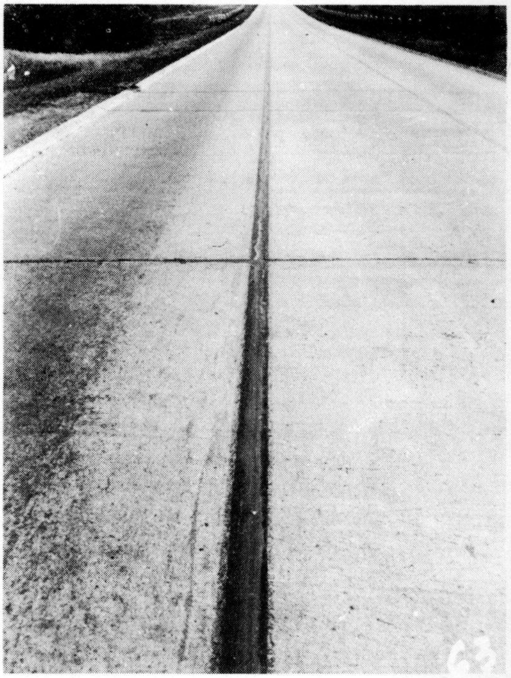

Figure 25. Longitudinal joint after filling.

Recognizing that dust is the greatest enemy to good adhesion the revised specifications will require that: "Immediately before the pouring of the filler, the joints shall be thoroughly cleaned by means of a mechanically-operated, rotary wire brush, and the manually operated wire brush with air-nozzle attachment. The air pressure for these operations shall not be less than 90 lb. per sq. in. In conjunction with this operation, the entire width of pavement, or such area designated by the engineer, shall be cleaned by means of compressed air."

4. Melting of Joint Sealing Compound. The sealing-compound melting temperature will be designated by the engineer instead of by the manufacturer.

In the event of circumstances beyond the control of the contractor which prevent him from pouring sealing compound already melted, he shall reduce the temperature to from 275 to 325 F. and maintain that temperature until just prior to the time filling operations are resumed. However, at the end of the day, any material remaining in the melter and applicators shall be drawn off, and may be salvaged if resacked in approved containers.

Estimated Cost Per Mile

For the 1952 approved program it is estimated that the cost of sealing a 20-ft. pavement will be between $2,100 and $2,200 per mi., such estimated costs to include field supervision, inspection, final cleanup and overhead, as well as contract costs.

LABORATORY TESTING AND CONTROL

It was required that the fillers of the hot-poured rubber-asphalt type conform to the requirements of the Federal Specification SS-F-336a dated May 19, 1947. For the detailed requirements the reader is referred to that specification. Suffice it to say that the specification includes requirements for pour point, penetration, flow and bond.

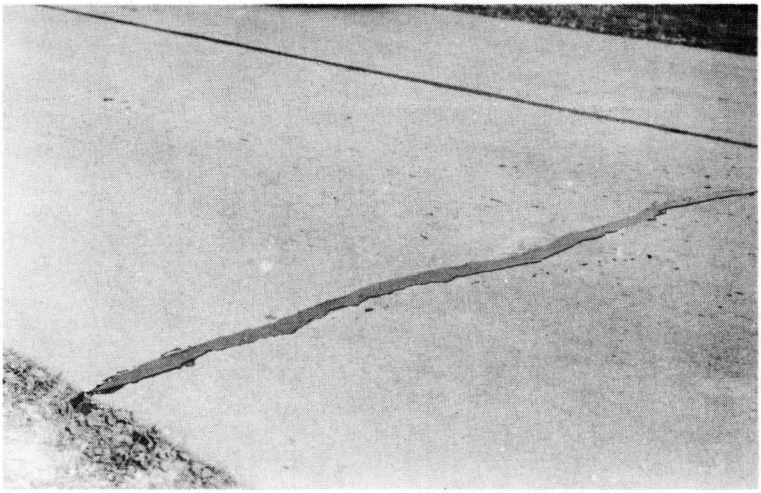

Figure 26. Transverse crack after filling.

During the 1951 season approximately 75 carloads of rubber-asphalt joint filler were sampled and tested. Unless failures were encountered the sampling procedure involved the taking of nine samples at random from different batches of each 40-ton car and 13 samples from the 60-ton cars. Of these samples, three were tested completely and for the other six the bond test was omitted. If any of the samples failed in bond test, more tests were made to determine if failure was confined to one batch or several. The number of tests run and the number of failures are shown in Table 1.

TABLE 1.

Test	Number of Samples	Number of Failures
Bond	220	25
Flow	684	4
Penetration	690	3

It would appear that the testing procedures are still in the pioneering stage and this also applies, at least in part, to the specification requirements. Testing and heating techniques are sensitive to variations, particularly in temperature. Indicative of the difficulties encountered in the testing of this material are the data obtained in 1950 by a group of nine cooperating laboratories of Group IV AASHO. On presumably identical samples the determined pouring temperature varied from 370 to 440 F. The range of penetration results was from 0.64 to 0.94 cm. Penetration and flow may vary with the pouring temperature and the bond test is quite critical as related to pouring temperature. Temperature and time of heating have considerable effect on all of the specified test requirements. A limited number of tests in this laboratory indicates a change of penetration of from 0.07 to 0.13 cm. per 10 F. change in pouring temperature.

The penetration test involves a procedure similar to that for penetration of asphalt cement except for the substitution of the grease cone for the needle and appears to be a bit crude for the measurement being made. It would appear that perhaps the test could be better made using the standard asphalt needle (see Fig. 27).

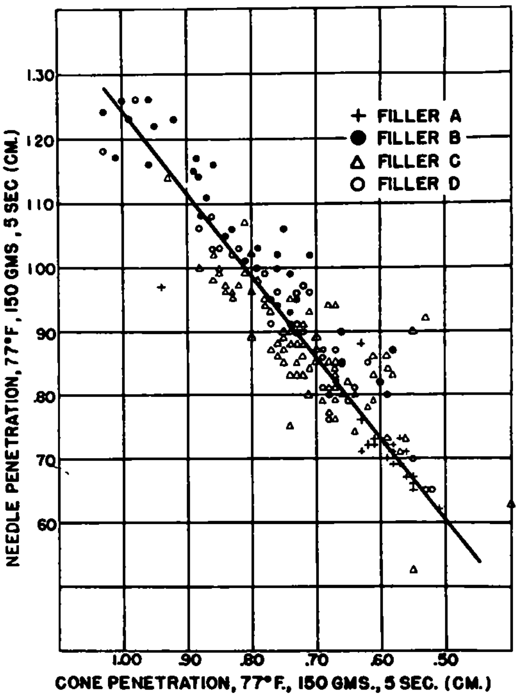

Figure 27. Relationship between cone and needle penetration.

The bond test presumably simulates the behavior of the filler in the joint at low temperatures and under stress induced by contraction of the pavement. It is a difficult and unsatisfactory test and may or may not represent service conditions. The degree of polish of the block surfaces is extremely critical. The higher the degree of polish the better the adhesion appears to be. Failure may occur at the filler-block interface or within the filler itself. This test deserves further study as to its significance and idiosyncrasies and the test procedure warrants clarification.

CONCLUSIONS

The results obtained to date in the above program of sealing joints and cracks with hot-poured rubber-asphalt joint filler appears to justify the following conclusions: (1) joints and cracks can be effectively sealed with hot-poured rubber-asphalt under proper placement conditions; (2) mechanical agitation and positive temperature control must be provided on the melting and applicator units; (3) all dust and loose concrete must be thoroughly removed prior to the placement of the filler material; (4) overheating of the filler material must not be permitted; (5) this type of work lends itself to being done under contract; and (6) a satisfactory method of payment for the major items is on the basis of unit price of filler material in place, including cutting, cleaning, material, and placement.

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