

CONCRETE PAVEMENT JOINTING AND SEALING METHODS

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A comprehensive program to study the performance of concrete pavement joint sealing materials and related practices is being conducted in Pennsylvania. The experimental pavement consisted of combinations of various sealant materials, joint shapes, and slab lengths; a total of 1,020 transverse joints were involved. The materials include conventional "improved" rubberized asphalt, cold-poured, 2-component polymers, and preformed neoprene seals. Various sizes of step-cut joints were tried. These joints have a wider cut at the top to improve the width-to-depth ratio of the sealant. Shorter-than-normal slab lengths were also tested. Preliminary observations indicate that the improved rubberized-asphalt sealant performs better than the conventional-grade material. The cold-poured polymers were found to require careful mixing and handling to obtain satisfactory results. When properly placed, these materials also appear to provide good sealing qualities. The neoprene seals are also performing very well. Preliminary results indicate that the shorter slab lengths offer better joint seal performance and the $\frac{1}{2}$ -in. wide \times $\frac{3}{4}$ -in. deep joint cut is more satisfactory than the method conventionally used.

•MANY concrete pavement failures can be attributed in some way to poor joint functioning. It is generally necessary to provide joints in a conventional concrete pavement to control shrinkage cracking and allow for thermal changes. For the joint to function properly throughout the life of the pavement, it should be properly sealed to prevent the intrusion of water and debris. Problems that may arise from poorly sealed joints often reduce the life of the pavement and lead to costly maintenance procedures.

The intrusion of incompressible materials into the joint opening is a primary cause of pavement blowups in hot weather (1). This incompressible material restricts pavement slab expansion, resulting in excessive stresses in the slab and eventual buckling or crushing of the slabs at a joint. Slab migration, or translation in a longitudinal direction, has also been attributed partially to joint intrusion. This phenomenon is often called pavement growth and has led to severe damage to structure abutments.

Water intrusion is considered another major cause of deterioration at joints (1). A degradation of subbase support due to infiltration of water may lead to pumping and frost heaving. In the winter, deicing chemicals are also carried into the joint by this water, leading to corrosion of the steel load-transfer devices.

Conventional methods of sealing concrete pavement joints, using hot-poured asphalt sealant, have never been really effective. Bond and cohesion failures generally occur in cold weather, and excessive extrusion of sealant takes place in summer. Annual resealing maintenance is necessary to replace sealant lost by extrusion and snowplowing. Sealant material in the past simply consisted of asphalt with a mineral filler; it

is still used for resealing in some areas. The most popular material in use at the present time is the hot-poured, rubberized-asphalt sealant. Initially, it gives somewhat better performance than plain asphalt, but it still suffers from the same faults.

Achieving a satisfactory seal of concrete pavement joints has been the goal of many past research projects. Many states have had success with preformed neoprene seals, and their performance has generally been better than other types of joint sealers (2). A variety of cold-poured elastomeric sealers are also available. These more sophisticated materials are generally 2-component mixtures of either the polysulfide or urethane type. A recent summary report of joint seal research in Pennsylvania (3) showed a need for further investigation of improved, hot-poured sealants, neoprene seals, and cold-poured elastomers. Some initial evidence, on the basis of limited research, has also indicated that shorter slab lengths and an improved joint width-to-depth ratio contribute to better performance.

OBJECTIVE

The purpose of this project is to perform a comprehensive evaluation of various types of sealing materials, joint shapes, and slab lengths by using methods that have indicated good results during previous research (4). It is expected that an extensive project such as this will provide meaningful results that may lead to better sealing techniques and performance of the sealed joint. A minimum of 7 years of study is anticipated; interim reports will be prepared as results become apparent.

SCOPE

The test site is located in Pike County on Interstate 84 between Pennsylvania routes 507 and 390. A total of 1,020 joints are involved in the study. Various combinations of material, joint shape, and slab length were used to obtain 51 different test sections consisting of 20 joints each.

Five different types of sealant materials were used:

1. Control—hot-poured rubberized asphalt;
2. Improved—hot-poured rubberized asphalt with upgraded specifications;
3. Urethane—2-component, cold-poured urethane elastomer;
4. Polysulfide—2-component, cold-poured polysulfide elastomer; and
5. Neoprene—preformed, elastomeric seals.

In addition to the normal $\frac{3}{8}$ -in. (9.5-mm) joint width, three sizes of step-cut joints were used (Figure 1). A fifth size of joint was used for neoprene only. The joint sizes were as follows:

1. Control, $2\frac{1}{2} \times \frac{3}{8}$ in. (63.5 \times 9.5 mm);
2. Step-cut, (A) $2\frac{1}{2} \times \frac{1}{8}$ in. (63.5 \times 3.2 mm), (B) $\frac{1}{2}$ in. w \times $\frac{3}{4}$ in. d (12.7 mm w \times 19 mm d);
3. Step-cut, (A) $2\frac{1}{2} \times \frac{1}{8}$ in. (63.5 \times 3.2 mm), (B) $\frac{3}{4}$ in. w \times $\frac{3}{4}$ in. d (19 mm w \times 19 mm d);
4. Step-cut, (A) $2\frac{1}{2} \times \frac{1}{8}$ in. (63.5 \times 3.2 mm), (B) 1 in. w \times 1 in. d (25.4 mm w \times 25.4 mm d); and
5. Step-cut, (A) $2\frac{1}{2} \times \frac{1}{8}$ in. (63.5 \times 3.2 mm), (B) $\frac{1}{2}$ in. (12.7 mm) w \times seal depth + $\frac{1}{4}$ in. (6.4 mm) (neoprene only).

There were 2 shorter slab lengths utilized in addition to the conventional 46.5-ft (14.1-m) joint spacing. They were 38.5 ft (11.7 m) and 31.5 ft (9.6 m).

Figure 1. Step-cut joints.

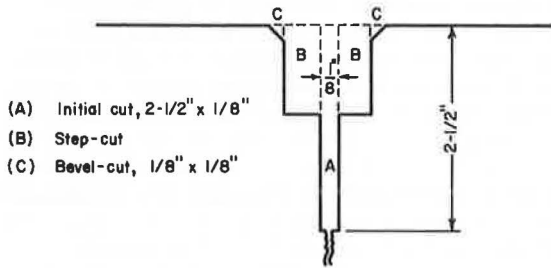
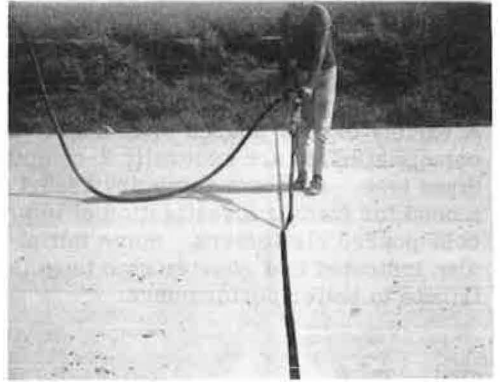


Figure 2. Sealing joint with rubberized asphalt.



CONSTRUCTION PROCEDURES AND EQUIPMENT

Pavement Construction

The concrete pavement was constructed with accepted conventional equipment and procedures. The compacted subbase material was fine-graded with a CMI Autograder that followed alignment and grade set by the offset stringline. The concrete pavement slab was placed on the compacted subbase by a CMI slipform paving train.

Concrete, with an average slump of 1.5 in. (38.1 mm), was placed in slabs 10 in. (254 mm) thick and 24 ft (7.2 m) wide. Pavement slab reinforcement, consisting of wire mesh, was placed in the plastic concrete prior to final strike-off at a depth of $3 \pm \frac{1}{2}$ in. (76.2 ± 12.7 mm). Basket units of slip-bar dowels were staked in place at each transverse joint location for the purpose of load transfer. White membrane curing compound was sprayed on the slab immediately after final finishing of the concrete.

Joint Sawing

All transverse joints were sawed to a depth of $2\frac{1}{2}$ in. (63.5 mm) between 4 and 24 hours after the concrete was placed. The control joints were cut $\frac{3}{8}$ in. (9.3 mm) wide and the step-cut joints were initially sawed $\frac{1}{8}$ in. (3.2 mm) wide. After the joint was sawed, it was immediately flushed with clean water and a roving material was placed in the saw cut. The longitudinal joint between lanes was sawed within 72 hours after placing the concrete. This joint had a width of $\frac{3}{16}$ in. (4.6 mm) and a depth of $2\frac{3}{4}$ in. (69.9 mm).

The experimental transverse joints consisting of a step-cut joint were sawed in a 2-stage operation. Initially, the step-cut section of the joint was to be sawed immediately after the initial $\frac{1}{8}$ -in. (3.2-mm) cut; however, the concrete was too green and spalled excessively. The second cut was therefore made after the concrete was allowed to cure for at least 3 days. The wider saw cuts were made with conventional concrete saws. A pair of blades was spaced the required width and centered over the initial cut. All joints of the eastbound lanes had beveled edges, whereas the joints on the westbound lanes were square-cut. These saw cuts were flushed with water and again filled with roving material to keep the joint clean and the joint area moist during the curing period.

Joint Sealing

The joints on the eastbound lanes were sealed within 3 to 7 days after they were sawed. This was done to permit the contractor to use the pavement as a haul road. The joints on the westbound lanes were sealed after the entire section of pavement was placed, because the contractor did not need to use the pavement.

Every joint was cleaned prior to sealing by the following method: First, the saturated rope was extracted from the joint, and any stones, concrete chips, and other debris were removed with a metal-bladed scraper. Next, the joint was blown clean by compressed air, and the saturated rope was returned to most of the $\frac{3}{8}$ -in. (9.5-mm) joints where the cold-poured sealants were used. The step joints had a bond breaker inserted at the bottom of the channel consisting of either an adhesive-backed sponge-rubber tape or common masking tape. Joint-sealing material was poured immediately after the bond breaker was placed.

Three different types of equipment were used to place the materials in the joints. The control material (hot) and the improved material (hot) were heated in a conventional truck-mounted kettle. This kettle was equipped with a motor-driven pump that forced the material through a hose and hand-held nozzle into the joint (Figure 2).

The 2-component, cold-pour material (polysulfide and urethane) was mixed in a device that blended the material in equal proportions by volume. After the material was mixed, it was pumped through a hand-held nozzle into the joint.

Neoprene seals were installed with a hand-operated machine. Two rollers compressed the seal in front of a third roller that forced the seal into the joint. This third roller was adjustable to any desired depth. Prior to the installation of the seal a lubricant was painted on the edges of the joints.

Instrumentation

Expansion and contraction of the joints are being measured with an Invar bar gauge. Brass plugs were inserted in the plastic concrete on each side of 10 joints in each of 15 test sections. They were spaced 10 in. (254 mm) apart across the joint and 10 in. (254 mm) in from the edge of the pavement.

MATERIALS

Five joint sealers are being evaluated in this project. The conventional, rubberized-asphalt joint sealer conformed to ASTM designations D 1190 and D 1191 and Federal Specifications SS-S-164. The ductility test was performed using molds as described in ASTM D 113 at 77 F and applied at a rate of extension of 5 centimeters per minute.

An "improved", rubberized-asphalt sealer having a higher latex content was used to evaluate material conforming to more stringent specifications. This specification followed ASTM D 1190, with additional requirements and modifications relating to composition and physical properties. The composition was specified as a mixture of virgin synthetic rubber, devulcanized reclaimed rubber, or a combination of the two, with asphalt, plasticizers, and taciifiers that excluded ground cured rubber. The impact test consisted of a swinging hammer that delivered 10 ft-lb of force (13.56 J) to the side of the upper concrete block of a bond specimen turned on its side. This test was performed after the bond test, or, if the specimen failed, a new specimen was conditioned at 0 F for 24 hours and immediately tested. The resiliency test was performed on a sample contained in a 3-oz tin at ambient temperature, 74 ± 2 F (23.3 ± 1.1 C). A steel ball, $\frac{5}{8}$ in. (15.8 mm) in diameter, was pushed to a depth of 10 mm and the pressure held for 15 seconds before being released. A new reading was recorded after 30 seconds and subtracted from 100 for the penetration value. The bond test was modified to a $\frac{1}{2}$ -in. (12.7-mm) spacing.

Cold-poured, 2-component polymers, one a polysulfide and the other a urethane, were installed to evaluate the performance of these types of materials. The sealants

were subjected to the requirements of Federal Specifications SS-S-159b and modified to include water soaking and oven aging. The polysulfide was a thixotropic, nonflowing compound cured with an accelerator introduced and blended into the base compound. The urethane consisted of 2 nonvolatile bitumen-extended elastomers.

Preformed neoprene compression seals $1\frac{1}{4}$ in. (31.8 mm) deep were also installed. The neoprene seals were tested against and conformed to ASTM D 2628.

MATERIAL COST DATA

The costs of the material for a 24-ft lane width are as follows (in dollars):

Material	Joint Size, in.				
	$\frac{3}{8} \times 2\frac{1}{2}$	$\frac{1}{2} \times \frac{3}{4}$	$\frac{3}{4} \times \frac{3}{4}$	1 × 1	$\frac{1}{2} \times 1\frac{3}{4}$
Control	2.27	0.90	1.32	2.38	—
Improved	3.15	1.24	1.83	3.29	—
Polysulfide	12.07	4.72	7.12	12.63	—
Urethane	5.47	2.14	3.24	5.74	—
Neoprene	—	—	—	—	24.19

These are the costs of the sealant material only. Labor costs involved in the construction of the joints would be additional. Joint cutting and bevel cutting would add to the cost of the step-cut and neoprene joints due to the added sawing operations involved. Another cost involved with the step-cut joints would be the labor required to place the bond-breaker tape in each joint prior to sealing. Cost data for these operations were not available. The primer for the polysulfide sealant and the lubricant-adhesive for the neoprene seals are included in the cost data but not the labor to apply them.

FIELD OBSERVATIONS

Control Material

The control sealant was very susceptible to the intrusion of debris, especially in the step-cut joints. A bond breaker of either masking tape or sponge-rubber tape was used in the bottom of all wide joints.

Improved Material

The improved material was much less susceptible to the intrusion of debris. The installation procedure was the same as for the control. Bond breakers were again used in the wider joints.

Polysulfide Material

The primer was applied by hand with an ordinary paint brush. Occasionally the primer turned white and powdery because of excessive moisture in the concrete and repriming was necessary. The mixing procedure for the polysulfide sealer was critical and required a positive means of thoroughly blending on a 1:1 ratio to ensure proper curing. Some joints with partial cure did result from poor mixing, and these required removal

and replacement. The mixing and placing equipment was less than ideal and required close attention to maintain a uniform mixture through the application nozzle. A mechanical failure occurred after the first 3 joints were completed, requiring manual operation of the machine. The proportioning was not satisfactory until a replacement part was obtained. A bond breaker of either masking tape or sponge tape was used in the bottom of the wider joints. In several instances the masking tape turned or became embedded in the sealer and did not provide the necessary seal at the bottom of the joint. This allowed the uncured material to flow under or around the bond breaker and required additional applications to obtain the proper level and seal. The use of masking tape was discontinued in favor of the sponge-rubber tape, which performed satisfactorily when installed correctly. The consistency of the material allowed placement on superelevation with a minimum of flow before "set" occurred (Figure 3). The cure time varied from 10 minutes at 95 F (35 C) to 24 hours at 60 F (15.6 C). Where additional applications were required, the material bonded to itself satisfactorily.

Urethane Material

The mixing of the urethane material appeared to be more critical than with the polysulfide. This judgment was based on the wide range of curing times observed. Some joints had not achieved permanent set even after 3 months. The appearance would indicate that set had occurred, but when the surface film was broken the material underneath was in a semicured condition.

The first portion of the test application was completed with the same equipment used for the polysulfide sealer. After the first half of the project was completed and many of the joints remained in a semicured condition, further use of the machine was discontinued. A concerted effort was made by the supplier of the sealant to determine why the material did not cure. One possibility suggested was that moisture had contaminated the stored material, because it was allowed to remain exposed to the elements. The remainder of the shipment was therefore replaced with new material. A portable mixing device, consisting of a motorized turntable with a mixing paddle to blend the 2 components, was also supplied with this new shipment. This operation, which required hand-proportioning and pouring from "watering cans", gave decidedly poor results. The joints were characterized by a wide range of curing time and excessive bubbling of the sealant. Again, further use of the material was suspended. Another effort was undertaken to determine why the variations had occurred. The supplier felt that the problem was caused by improper mixing and procured another machine.

A small, portable, air-operated machine was supplied. It was capable of high-speed, airless mixing and proportioned the materials prior to application through a small hose and nozzle. A fast cleaning method was also possible if the operation should be halted for any period of time.

The remaining joints were completed with a uniform range of curing time. Sealant placed with this machine was characteristic of typical urethane materials (Figure 4). The sponge bond breaker was again used in most of the wider joints. Roving material was placed in the bottom of the conventional joints and a light application of sealer was applied and allowed to cure partially before the joint was fully sealed. Areas that required resealing did not bond as well as expected to the previously placed material. The urethane material flowed slightly on superelevated sections.

Neoprene Material

The lubricant-adhesive machine was inoperative and hand application was required. The machine used to place the seal was fast, efficient, and provided a uniformly placed seal (Figure 5). When a problem occurred, such as a twisted or deeply placed seal, the machine could be backed up and the nonuniform area could be extracted and reinserted with a minimum of effort. The ease of installation was superior to all other sealers placed during this evaluation (Figure 6).

Figure 3. Polysulfide sealant ($\frac{1}{2} \times \frac{3}{4}$ in.).

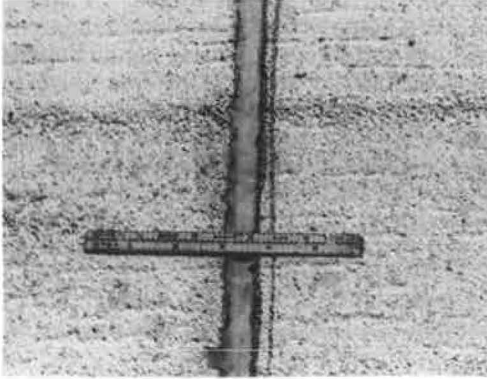


Figure 4. Urethane sealant ($\frac{3}{4} \times \frac{3}{4}$ in.).

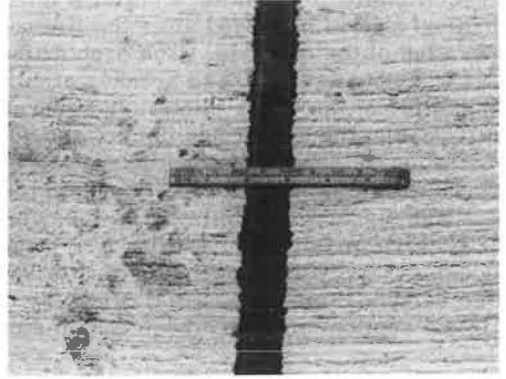


Figure 5. Preformed neoprene seal installer.

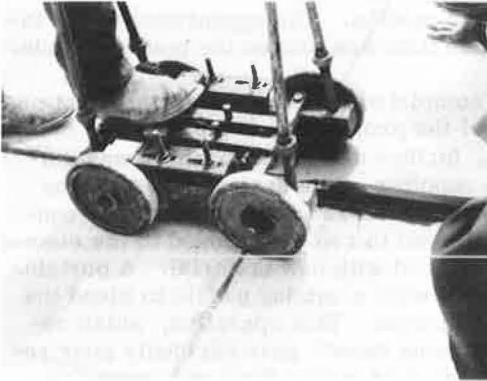


Figure 6. Completed preformed neoprene seal.

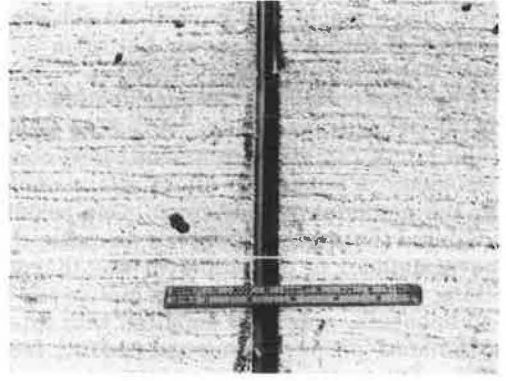


Table 1. Rating levels.

Rating	Degree	Description
Sealing		
5	None	Seal is intact and in the condition as constructed.
4	Slight	Seal has experienced adhesion, cohesion, and/or spalling defects in less than 5 percent of the joint area.
3	Moderate	Seal has experienced adhesion, cohesion, and/or spalling defects in less than 50 percent but more than 5 percent of the joint area.
2	Severe	Seal has experienced adhesion, cohesion, and/or spalling defects in less than 50 percent but more than 25 percent of the joint area.
1	Deteriorated	Seal has experienced adhesion, cohesion, and/or spalling defects in more than 50 percent of the joint area.
Weathering		
5	None	Seal is intact and in the condition as constructed.
4	Slight	Seal surface aged or oxidized.
3	Moderate	Seal surface has weather checking.
2	Severe	Seal surface has alligator cracking.
1	Deteriorated	Seal surface has eroded.
Debris Intrusion		
5	None	Seal is intact and in the condition as constructed.
4	Slight	Seal is intact and in the condition as constructed with debris accumulated but no intrusion.
3	Moderate	Seal has accumulated debris with scattered intrusion.
2	Severe	Seal has accumulated debris with much intrusion.
1	Deteriorated	Seal is broken and eroded by excessive intrusion of debris.

CONDITION SURVEY

A rating system was devised to evaluate the performance of the joint sealing materials. The method requires that each joint be appraised for its sealing, weathering, and debris-resistant characteristics. The level of performance is rated on a scale of 1 to 5, with 5 as maximum, as described in Table 1.

The first field performance evaluation was accomplished on November 15-16, 1973. A summary of the data accumulated is given in Table 2. Each value shown is the average obtained for 20 joints (Figure 7).

The control material was performing poorly in all joint size configurations and in all 3 pavement slab lengths (Figure 8). There was an excessive intrusion of debris into the material in the wider joint openings. Bond failure is prevalent between pavement joint and sealant (adhesion) and to some extent within the material itself (cohesion).

The improved rubberized-asphalt material was much better in appearance. It sealed the joints and rejected the intrusion of debris better than the control material (Figures 9 and 10). There was a minimal amount of debris even in the $\frac{3}{4}$ - and 1-in. joints.

Both of the poured sealants, polysulfide and urethane, are performing significantly better than the improved rubberized-asphalt material. The polysulfide has a very slight edge over the urethane material in overall performance. The sealing, weathering, and debris-resistant characteristics of these materials are excellent thus far. As mentioned earlier, some difficulty was experienced with curing in some of the urethane joints. These joints will not be discarded from the test, but they have been identified in Table 2 with an explanation of their lower-than-normal performance.

The overall performance of the preformed neoprene seals was rated as superior at this time. Although some intrusion of debris was apparent between the neoprene seal and the joint face, this was attributed to a poor construction practice.

The practice of allowing construction equipment and traffic to use the pavement after the joints are sealed has led to poor joint performance. The shoulder placement and final clean-up operations have spalled the joint walls as a result of aggregate being "bladed" across or from the pavement surface (Figure 11). At the same time, debris is forced into the joint opening, and, if the sealer lacks characteristics to repel this intrusion, "solid" contamination occurs. A high joint failure rate can be expected from this practice. The occurrence of such damage on this job has served to lower the overall performance ratings.

The initial condition survey has indicated the following levels of performance (in decreasing order):

<u>Material</u>	<u>Joint Spacing</u>	<u>Configuration</u>
Neoprene	31.5 ft	$\frac{1}{2} \times \frac{3}{4}$ in.
Polysulfide	38.5 ft	$\frac{3}{4} \times \frac{3}{4}$ in.
Improved	46.5 ft	1 × 1 in.
Urethane		$\frac{3}{8} \times 2\frac{1}{2}$ in.
Control		

RECOMMENDATIONS

The data collected and observations made thus far would seem to justify the following statements:

1. The specification for joint sealing material should be upgraded to require the use of a sealer equivalent to the improved rubberized-asphalt material.
2. Consideration should be given to the potential savings that might be achieved in going from the conventional joint (\$2.27 to fill a $2\frac{1}{2} \times \frac{3}{8}$ -in. joint with conventional hot-pour sealer) to a $\frac{1}{2} \times \frac{3}{4}$ -in. joint (\$1.24 to fill with improved rubberized material). It would require some additional cost to make the second step-cut.

Table 2. Summary of joint ratings.

Section	31.5-ft Joints				38.5-ft Joints				46.5-ft Joints			
	Seal	Weather	Debris	Average	Seal	Weather	Debris	Average	Seal	Weather	Debris	Average
C-1	3.7	3.0	3.0	3.2	3.2	3.0	3.0	3.1	1.4	2.1	1.8	1.8
C-2	3.0	3.0	2.1	2.7	2.3	1.9	2.0	2.1	3.2	3.0	3.0	3.1
C-3	2.0	3.0	1.4	2.1	3.5	3.0	3.0	3.2	2.8	2.0	1.7	2.2
C-4	3.0	2.0	1.4	2.1	2.7	3.0	2.4	2.7	3.8	2.0	2.4	2.7
I-1	3.9	3.0	3.0	3.3	3.4	3.0	3.1	3.2	2.7	3.0	3.1	2.9
I-2	3.5	3.0	3.0	3.2	3.5	3.0	3.0	3.2	3.5	3.0	3.0	3.2
I-3	3.5	3.0	2.9	3.1	3.4	3.1	3.0	3.2	3.9	3.0	2.9	3.3
I-4	4.0	3.0	3.0	3.3	3.3	3.0	3.0	3.1	3.7	3.0	3.0	3.2
P-1	4.1	4.0	4.7	4.3	3.3	4.0	3.8	3.7	2.6	4.0	4.2	3.6
P-2	4.3	4.0	5.0	4.4	3.3	4.0	5.0	4.1	3.1	4.0	4.7	3.9
P-3	4.2	4.0	5.0	4.4	3.7	4.0	5.0	4.2	4.0	3.7	4.0	3.9
P-4	4.2	4.0	4.4	4.2	3.5	4.0	4.9	4.1	3.6	4.0	3.9	3.8
U-1	4.1	4.0	4.4	4.2	3.1	4.0	4.4	3.8	1.7	2.9	2.2	2.3 ^a
U-2	3.1	3.5	4.9	3.8	1.5	2.2	2.0	1.9 ^a	1.0	3.0	3.0	2.3 ^a
U-3	1.9	2.0	2.2	2.0 ^a	3.1	4.0	5.0	4.0	4.4	3.0	4.6	4.0
U-4	2.7	2.7	2.1	2.5 ^a	1.9	2.1	1.6	1.9 ^a	3.7	3.0	3.1	3.3 ^a
N-5	5.0	5.0	3.5	4.5	5.0	5.0	3.5	4.5	5.0	5.0	3.3	4.4

^aEither part or all of the joints in this section suffered from improper curing due to poor mixing of the two components.

Figure 7. Field rating sheet.

46.5-Ft. Joints

Rating	Joint	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Sealing																					
Weathering																					
Debris																					
Average Rating _____																					

Section _____
Date _____

38.5-Ft. Joints

Rating	Joint	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Sealing																					
Weathering																					
Debris																					
Average Rating _____																					

31.5-Ft. Joints

Rating	Joint	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Sealing																					
Weathering																					
Debris																					
Average Rating _____																					

Figure 8. Control joint showing early failure.

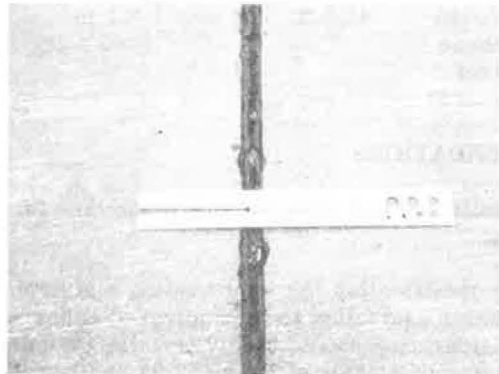


Figure 9. Debris intrusion in control material (1 x 1 in.).

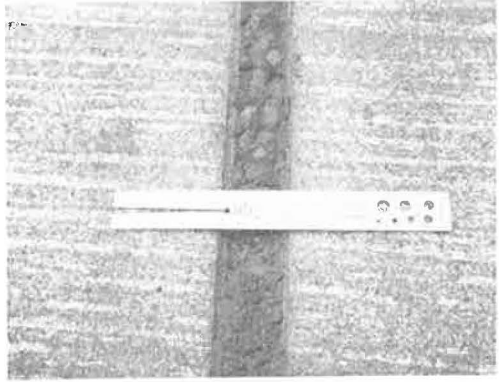


Figure 10. Minimal intrusion in improved rubberized-asphalt material (1 x 1 in.).

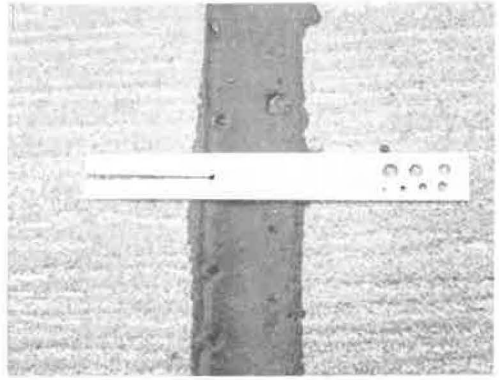


Figure 11. Construction damage to completed urethane sealant.



3. Consideration should be given to specifying the joint sealing operation as the last construction operation on a new project. The use of step cutting would allow the first cut to be made at the required time and roving material could be maintained until the second cut is completed.

4. Inspection of the joint sealing operation should receive a high priority to ensure the construction of a quality joint seal.

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