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Rigid Pavement Joint Resealing: Field Application, State of the Art

JOHN W. BUGLER

ABSTRACT

In the 1970s the New York State Department of Transportation initiated and executed field performance studies of formed-in-place sealant for future use in a statewide joint resealing program. It was determined after 3 years of service that of the six formed-in-place sealants tested, hot-poured polyvinyl chloride, conforming to ASTM D3406, performed best. A joint resealing program was initiated in Region 10 (Nassau and Suffolk counties) in 1979. There were initial field application problems. The problems are described, and the solutions used are explained.

Until 1958 New York State constructed concrete pavements with transverse expansion joints generally spaced every 100 ft. At that time the state amended the specifications to include the use of contraction joints spaced every 60 ft 10 in. The width of the joint was 0.375 in. and remained so until 1968.

Liquid formed-in-place sealants were in use until 1963, at which time the specifications were amended to require the exclusive use of 0.8125-in. (uncompressed width) preformed compression seals.

BACKGROUND

Performance of 0.8125-in. Preformed Compression Seals

The service life of the 0.8125-in. preformed compression seals was from 2 to 3 years (1). An explanation for the seal having such a short service life is as follows (2):

> Past experience had shown that due to slab contraction, transverse joints might open an additional 3/8-in. In other words, joints might be as wide as 3/4-in. during cold periods in winter. State specifications require preformed sealers to be 13/16-in. wide--1/16-in. wider than the anticipated maximum joint opening. This was in an effort to ensure that pressure against the joint faces would be maintained throughout the winter months. To consistently construct transverse joints exactly 3/8-in. wide was, of course, difficult if not impossible. Many joints were constructed slightly wider or narrower. Joints wider than 3/8-in. sometimes opened beyond 13/16-in. during winter, and thus the sealer was not in compression. When joints were too narrow, it was difficult to install the preformed sealer without stretching it. Also, in narrow joints it sometimes was subjected to more compressive stress than it was designed to withstand.

In March 1968 the specifications were amended to increase the joint width to 0.625 in. The uncompressed width of the preformed sealer was increased to 1.25 in.

This was an improvement, in that the 1.25-in. seal had to recover only 80 percent of its uncompressed width to be able to effectively seal the joint in the dead of winter, whereas the 0.8125-in. seal had to recover 92 percent.

Performance of 1.25-in. Preformed Compression Seals

After 7 years of service, 65 percent of the seals examined in the field were found to have taken a compression set of 0.375 in. (3). Also 51 percent of the joints examined were found to have moderate bottom-of-joint infiltration (3).

FIELD RESEARCH

For the purpose of effectively resealing pavement joints as the need arose, a field study involving the application and performance evaluation of six different formed-in-place sealers was initiated by the New York State Department of Transportation (NYSDOT) (1).

A research report by Bryden et al. (1) stated that "polyvinyl chloride coal tar performed best of any liquid sealer, and the material itself is in excellent condition after three winters."

Maintenance Resealing Program

Regarding the limits on the effective service life of preformed compression seals, NYSDOT advised all regions to initiate condition surveys in the sixth year of service; and as the need arose, they should initiate a maintenance joint resealing program (4).

Results of Regional Survey

The survey of preformed compression seals was conducted in the tenth year of their service. It was found that, although the seals appeared to be doing their job at moderate temperatures, a high percentage of those examined in winter were not sealing the joints.

Initiation

Following department guidelines (4), a small joint resealing contract (5,000 linear feet) was executed by using liquid polyvinyl chloride coal tar, which conformed to ASTM D3406. This first joint resealing contract was actually supplementary to a larger rehabilitation contract, and department personnel believed that it should limit the quantity of materials used, because there was limited experience with formed-in-place sealers.

In writing the original specification, an intensive literature search was performed and correspondence was made with both industry and other jurisdictions, all of which resulted in an inclusive specification. There were, however, some field application problems.

FIELD APPLICATION PROBLEMS AND SOLUTIONS

Problem: Joint Overfilling

The first maintenance joint resealing contract experienced problems with joint overfilling. The specification called for sealing the joint to a level no higher than 0.25 in. from the road profile. More than 50 percent of the joints sealed failed by an unacceptable margin to meet that design criterion.

The solution was as follows. The industry was contacted about the problem (Posh Chemical, Inc., of Port Washington, New York). The manufacturer responded by designing and manufacturing a new applicator wand (Figure 1, left).

The cutoff valve on the original applicator wand was located 4 ft from the discharge tip (Figure 1, right). This made it difficult for the operator to judge when to close it as he approached the end of his pass. He would invariably overfill the last 2 ft of the joint.

The operator had the problem of having to hold the wand up over the joint as he made his pass. It was difficult to keep the elevation of the wand tip constant. These problems were eliminated with the introduction of the new applicator wand:

1. The cut-off valve was located 6 in. from the discharge tip, and
2. The applicator wand discharge tip was redesigned to include a set of wings (Figures 2-4), thereby allowing the operator to glide the applicator wand along the joint as he made his pass.

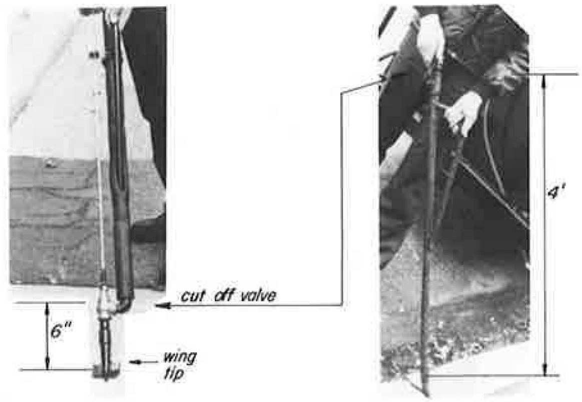

FIGURE 1 Applicator wand: new (left) and original (right).

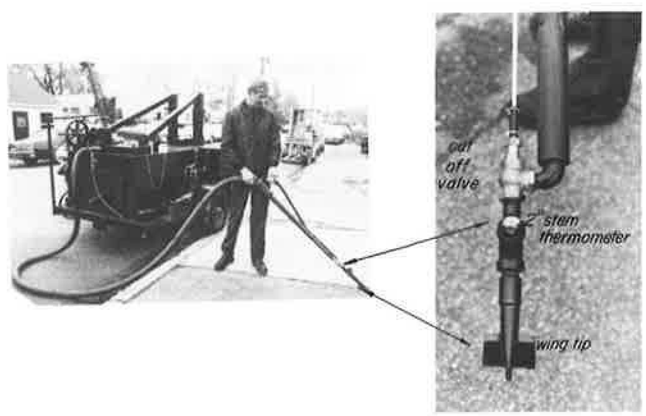

FIGURE 2 Posh field extruder with insulated hose and insulated applicator wand.

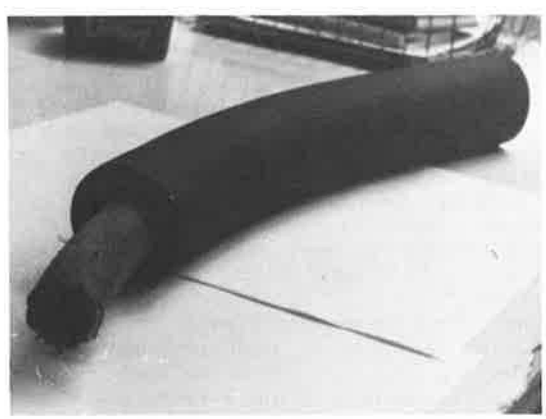

FIGURE 3 Section of insulated hose.

FIGURE 4 Wing tip.

These improvements gave one additional benefit: time. The time needed to seal a 12-ft joint was reduced by one-half.

Since introduction of this new applicator, Region 10 has resealed an additional 300,000 linear feet of contraction joints, and no additional problems with joint reservoir overfilling have been noted.

Problem: Incomplete Sandblasting of Joint Face, Leading to Intermittent Bond Adhesion Failure

The first large maintenance resealing contract (92,000 linear feet) executed in Region 10 experienced problems. These were 2- to 4-in. bond adhesion failures for the full depth of the seal.

Representatives from the industry and the Materials Bureau of NYSDOT were called. It was the conclusion of all concerned that the heart of the problem was improper and incomplete joint sandblasting.

Field investigation of another joint resealing project in progress revealed faulty sandblasting. Some of the joint faces examined after sandblasting were found to have less than 50 percent of the joint face thoroughly clean.

Many contractors have little experience in sandblasting highway pavement joints. Their approach and methods are more applicable to plane surfaces (i.e., bridge decks, structural steel).

Figure 5 shows a method used by an out-of-state contractor with some success. Other jurisdictions (Iowa and Pennsylvania) were contacted and they confirmed that they also had experienced similar problems with sandblasting pavement joints.

The original specification for sandblasting was as follows: "Both faces of the joint shall be throughly cleaned by sandblasting or high pressure water blaster, to a depth of the bottom of the proposed sealer."

The specification was modified by adding the following: "The sandblast or high pressure waterblast joint cleaning operation shall be such that when completed the concrete joint surface which is to receive the new joint sealant shall be free of all constituents of the lubricant adhesive used to place the original preformed compressive seals; all tar and asphalt; all discoloration and stain; as well as any and all other forms of contamination, leaving a clean, newly exposed concrete surface."

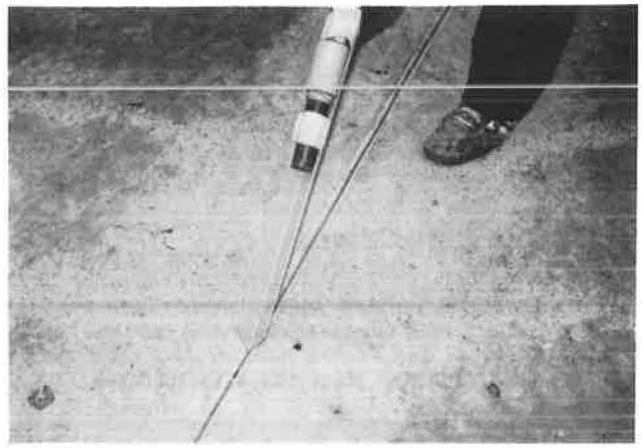

FIGURE 5 Sandblasting equipment.

This upgrading was done to preclude such inquiries as, "What do you mean by clean?"

Field inspection forces were advised to assign one inspector to oversee the sandblast operation at all times. Previously, one inspector was used to cover both the sandblast and the joint sealing operations.

Sandblast operators have been observed holding the nozzle several feet above the joint and walking the length of the joint, moving the nozzle from left to right as they walked. On the return pass they would airblast the joint. To the undiscerning it would appear that they executed two separate sandblast passes; such was not the case.

To properly sandblast the joint face it is necessary that the operator hold the sandblast nozzle very close to the pavement. This is unpleasant but necessary.

There is also the problem of the joint seal apparatus catching up with the sandblast operation in about the fourth hour of operation. This is because the joint seal operation is 4 to 6 times faster than the sandblast operation (using one sandblast operator).

Therefore, it is recommended that contractors consider using high-capacity compressor-sandblast units; thus they would be able to operate two or more sandblast units simultaneously. It is also recommended that contractors execute their sandblast operations far ahead of the joint seal operation, so as to preclude their coming together before the day's end. Finally, it is recommended that there should be correspondence with the sandblast equipment industry, urging them to consider development of a sandblast nozzle more applicable to the needs of pavement joint sandblasting.

Inspectors were advised to use their clipboards or other similar device to cast a shadow on the pavement surface near the joint reservoir when inspecting the quality of the sandblasting. This was necessary because sunlight reflecting off the pavement surface will close the eye's pupil, such that it will be difficult to see into the joint reservoir with any discernment.

Some inspectors have reported that, by using a Sear's "inspection mirror" (similar to a dental mirror), they are able to successfully expedite the inspection of the joint reservoir after sandblasting.

Problem: Some Joints Were Not Sandblasted at All

The problem of some joints not being sandblasted is unique to joint faces that had their pore structure impregnated with constituents of the lubricant adhesive used in the placing of the original preformed compression seals.

With the passing of time the preformed compression seals take a compression set. Often in such cases the seal slips down into the joint reservoir, leaving the top 0.5 in. of the joint face exposed (Figure 6). With the passing of time the exposed surface weathers and, as a result, appears to be clean. It is not sandblast clean. It is, however, clean enough to give the appearance of having been sandblasted. Field investigation has revealed instances of cursory joint sandblasting, such that the area under the exposed 0.5 in. had not been touched by the sandblast. Looking down from a standing position, however, the joint appears to have been sandblasted. This apparent condition is reinforced by the fact that the sandblast operator invariably leaves his signature (sandblast abrasions) on the pavement area around the pavement joint.

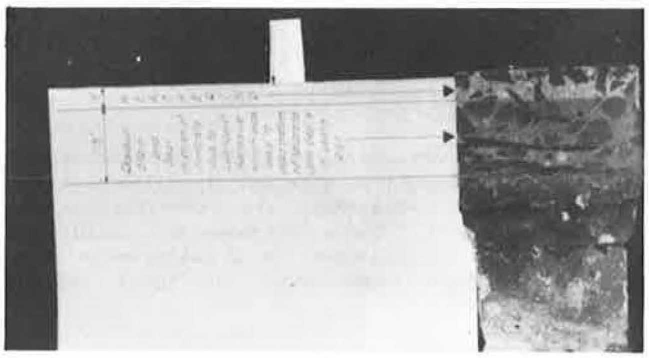

FIGURE 6 Seal slippage.

The constituents of the lubricant adhesive are such that bonding of the formed-in-place sealant to the joint face is impossible. The problem is compounded by the fact that unless the inspector physically inspects the joint (close up), he will fail to discern the problem.

The solution to this problem is closer inspection.

Proper sandblasting is the most critical part of the joint sealing operation. The failures in the field were bond adhesion failures, basically because of improper sandblasting. According to Tons (5), "if there is a true bond between the sealant and the concrete, the sealant should fail in cohesion rather than in adhesion."

Another point of consideration is the joint face surface area. A sandblasted joint face has a much greater surface area for bonding when compared with a sawcut joint face without sandblasting. A sandblasted joint face enables a properly constituted formed-in-place sealant to achieve a significant increase in net bonding force at the joint face. Also, by doing this, the performance of the sealant is optimized during periods of extension.

Problem: Failure to Maintain the Design Shape Factor

The shape factor (depth-to-width ratio) of formed-in-place sealants has a decided effect on the amount of tensile stress induced into the sealant during periods of extension (6). The amount of strain imposed on the extreme fiber of the sealant is largely determined by the shape factor (6).

Adhesion failure occurs when the tensile stress in the sealant exceeds the bonding force exerted at the concrete joint face, thus causing the sealant to pull away from the joint face. Figure 7 shows the strain imposed on the extreme fiber of a sealant (being extended 0.5 in.) at different joint design shape factors.

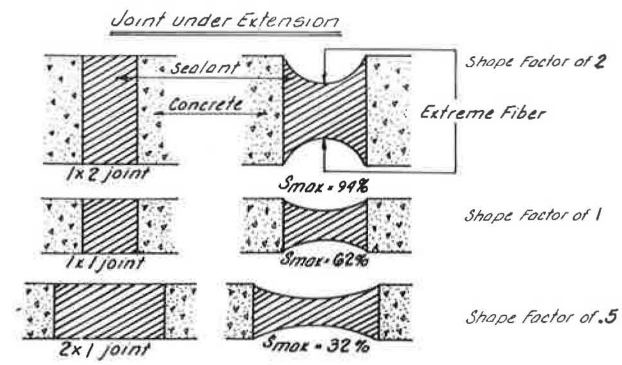

FIGURE 7 Strain on extreme fiber of sealant for a 0.5-in. extension of different joint designs (shape factors).

A joint with a shape factor of 2, when extended 0.5 in., will increase the length of the extreme fiber by 94 percent of its original length (7). A joint with a shape factor of 1, when extended 0.5 in., will increase the length of the extreme fiber by 62 percent of its original length (7). By simply reducing the depth of the sealant to 1 in., the strain is decreased by 50 percent.

There are advantages in keeping the strain concentration to a minimum. Therefore the specifications call for a deformable bondbreaker to be inserted in the joint reservoir, thus creating a formed joint geometry that will keep stress concentrations within the performance limits of the sealant. However, if insufficient compression is exerted on the deformable bondbreaker, the sealant will make its way around it, resulting in a depth-to-width ratio outside the limits of design.

Figure 8 (left) shows a deformable 1-in.-diameter bondbreaker placed inside a 1-in.-wide joint reservoir. There is virtually no compressive force being exerted on the bondbreaker. Field inspection revealed that the sealant had passed around the periphery, resulting in a depth-to-width ratio outside the limits of design.

Figure 8 (right) also shows a 1-in.-diameter bondbreaker. However, this time it is inserted into a 0.75-in.-wide joint reservoir. Therefore, it is in compression. Field inspection revealed the sealant to be contained within the limits of design.

The solution to this problem is closer inspec-

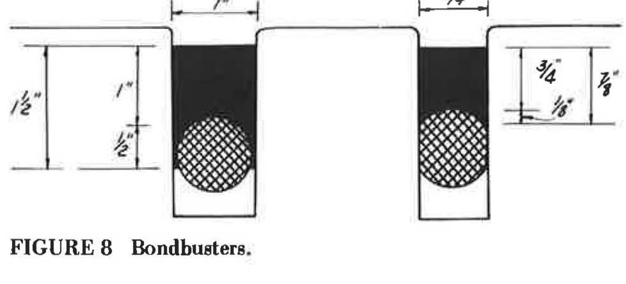

FIGURE 8 Bondbusters.

tion. Inspectors were advised to check the diameter of the stitched cotton piping cord used in the joint and compare it with the width of the joint. They were also advised that the diameter of the cord should be approximately 25 percent greater than the width of the joint.

Because joint widths vary due to moisture, temperature, and degree of infiltrated incompressibilities, it may be necessary to have on hand cord, the diameter of which is not readily available; thus the contractor may have to make a special order. The readily available cord diameters are 0.375, 0.5, 0.625, 1, and 2 in. Special orders take 3 weeks to execute. Figures 9 and 10 show how the cord is inserted and how it should look when it is in place.

FIGURE 9 Placing stitched cotton piping cord.

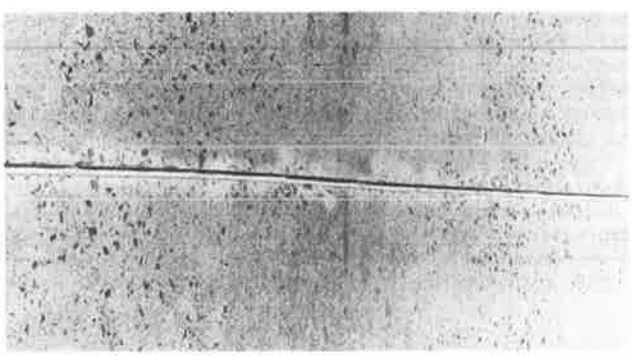

FIGURE 10 Cord in place.

Problem: Heat Losses Endemic to the System

Unless equipment operators are experienced (and very often they are not), they will find it difficult to achieve the recommended pouring temperature at the start of the work day. To preclude this condition, the specification has been amended to include the following: "At the start of the day's operations special procedures may be necessary in order to achieve a sealant temperature consistent with specification. The contractor shall ascertain from the manufacturer of the apparatus he is using the procedures necessary and be able to so execute these procedures prior to his commencement of joint sealing operations."

Problem: Heat Losses Endemic to the Hoses and Applicator Wand

The hoses are usually 15 ft long, and the applicator wand is 4 ft long. The heat losses from the hoses and the wand are significant if they are not insulated. In the field heat losses of 20°F, at ambient temperatures near 70°F, have been experienced.

The problem was solved by amending the specification to read: "The hoses and the applicator wand shall at all times be insulated. The material and method of insulation shall be in compliance with the recommendations of the joint seal apparatus manufacturer and meet with the approval of the Engineer. The material and methods shall be submitted to the Engineer for his approval, two weeks prior to the commencement of joint sealing operations."

Problem: Joint Seal Apparatus Thermometers Out of Calibration

On occasion it was noted that the thermometers of the joint seal apparatus were out of calibration by as much as 25°F. Therefore the specification was amended to read: "These thermometers...shall be turned over to the Engineer for a calibration check two weeks before commencement of joint sealing operations."

Problem: Oil Residue

One final problem noted was failure to purge the flush oil residue (remaining from the previous day's flushing of the system on completion of work) from the hoses and applicator wand at the start of the work day. Therefore the specification was amended to read: "The first gallon of material to flow out of the applicator wand at the start of the day shall be considered spoil and as such be discarded into a container so designated."

IMPORTANCE OF TEMPERATURE OF MATERIAL AT TIME OF PLACEMENT

Barksdale and Hicks (8), working with ASTM D3406 at a time when the industry recommended a pouring temperature of 250°F, reported that "polyvinyl chloride...when poured at a temperature 40°F above the recommended pouring temperature, was found to perform significantly better (in bond adhesion) than specimens poured at the recommended pouring temperature."

The industry has since amended its recommended pouring temperature to the 290°F range. The reason for the significant improvement in bond adhesion is because the surface tension of the material is significantly lower at the temperature range of 290°F, and as such it better penetrates the pore structure of the concrete joint face.

CONCLUSION

Formed-in-place sealants conforming to ASTM D3406, when applied in conformance with the specifications, have performed satisfactorily. With the exception of one section on the first contract in Region 10, there have been virtually no failures in bond adhesion, material cohesion, or extrusion. It would appear that rigorous inspection with regard to field application is the key to successful performance.

(Editor's note: A rigorous specification is currently in force and is working well in Region 10 in New York State. A copy of the specifications is available from the author.)

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Materials and Methods for Sealing Cracks in Asphalt Concrete Pavements

JIM CHEHOVITS and MARK MANNING

ABSTRACT

In recent years significant advances in both materials and methods for sealing cracks in asphalt concrete pavements have been made. Crack sealing has been transformed from a poorly performing and many times ineffective fill-in type of maintenance task to a viable and cost-effective preventive maintenance technique that can extend the life expectancy of roadways. Many aspects of the maintenance technique of sealing cracks in asphalt concrete pavements are examined herein. The subject is covered by qualitatively examining the cracking mechanism and the consequences of not maintaining adequately sealed cracks. The influences of climatic conditions and traffic on crack formation and subsequent movements are discussed. Physical characteristics of sealant materials required for application and acceptable performance are discussed, as well as testing methods for determining these characteristics. Physical properties and specification conformance of materials that are currently used as crack sealants are presented. Advantages and disadvantages of two basic types of sealant application configurations are discussed along with equipment and application methods that are used in crack sealing.

Asphalt concrete highways comprise approximately 1.9 million miles or 93 percent of the surfaced roadways in the United States, with portland cement concrete roadways comprising the remaining 7 percent (1). Asphalt concrete roadways range in type from low traffic volume seal-coated roads and subdivision streets to high traffic volume full-depth asphalt concrete Interstate highways. The majority of asphalt concrete roadways are at least several years old and are exhibiting cracking of varying types and extents.

Crack sealing in asphalt concrete pavements is thought by many to be an ineffective, low-priority pavement maintenance task that is performed only after other pavement maintenance activities such as overlays, seal coats, and fog seals are completed, and only if time, budgets, and manpower are sufficient. Because of this belief, cracks in many miles