New York State Experience with Concrete Pavement Joint Sealers

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The primary method of evaluating sealer performance at test sites in New York State has been to make frequent periodic observations with a special effort to observe the sealers during subzero temperatures. In a test area established in 1963, time-lapse movie photography is being employed to obtain visual records of sealer performance.

Observations of joint sealing materials installed during 1959 indicate that extruded neoprene has given excellent service. However, the appropriate width tubing must be installed without stretching in joints of a consistent and predictable width. Thiokol with extenders performed well for approximately 18 months when cracks began to appear over air bubbles formed during installation and some adhesion failures developed. Polysulfide with tar extenders gave excellent service for 1 year, after which surface cracks appeared and progressed through the material. The ability of hot-poured rubber asphalt to seal joints varied, depending on the season installed. Materials placed during hot summer weather failed in less than 4 months; material poured in the fall performed well for about 1 year, when adhesion failures developed. Rubber asphalt, cold-poured with solvent, gave very poor performance and failed entirely within 4 months. Observations on polyurethane with tar extenders and other recently developed sealers are continuing.

•TRANSVERSE JOINTS in concrete pavement are constructed to prevent random cracking due to stresses caused by the contraction of the concrete. These joints, if left unsealed, afford an excellent collection point for water and incompressible materials. Water running through the joints can cause corrosion of the load-transfer devices, weaken the subgrade and possibly cause pumping. Incompressible materials in the joint create localized stresses in the concrete when the joint attempts to close; these stresses usually result in spalling. To prevent such occurrences, a sealer is placed in the joint.

The difficulty of maintaining a sealed joint is primarily caused by the opening and closing of the joint. Ideally, to perform its intended function, a joint sealer must remain in contact with the joint face as the joint opens and closes. The sealer material should remain pliable and resilient at all temperatures which might be encountered; it should become neither excessively soft during hot weather nor hard and brittle during cold weather. If a sealer softens appreciably at high temperatures, it is susceptible to the intrusion of foreign material and may sag deeper into the joint or be tracked out onto the pavement by the action of traffic. At low temperatures, the sealer must be ductile

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enough to withstand elongation and flexure without separating from the joint face or tearing internally.

As early as 1910, asphalt and pitch were used to seal joints in concrete pavements. However, continued use of these materials showed their inadequateness. Attempts were made by some states to modify the asphalt by adding a mineral or diatomaceous earth filler. However, little if any improvement was observed. Until 1958 the New York State Department of Public Works specified a 50-60 penetration grade asphalt cement to seal joints in concrete pavements. However, in hot weather the sealer became soft, was incapable of resisting penetration by foreign material, and was often tracked onto the pavement. In cold weather it became brittle and cracked, permitting the infiltration of water and foreign materials.

INVESTIGATION

Recognizing this problem, Deputy Chief Engineer B. A. Lefeve with the cooperation and support of the district engineers arranged for experimental installations of new sealers as they became available. This work was started about 1955 and when the Bureau of Physical Research was formed in 1958 a project dealing with joint seal materials was initiated. Locations of all previous and current field experiments were recorded and an attempt at a uniform observation survey was made. However, it soon became apparent that these materials were very difficult to compare because of the different ages and preparation of the joints, and it was decided to establish a field test where different types of sealers would be placed at the same time under the same conditions.

A field test area was established on I-87 just north of Albany. The six types of sealers under test in this area can be described as: (a) rubber asphalt, cold-poured, with solvent; (b) rubber asphalt, hot-poured; (c) latex with extenders, premixed, cold-poured; (d) polysulfide tar (Thiokol), nozzle-mixed, cold-poured; (e) polysulfide tar, hand-mixed, cold-poured; and (f) polysulfide with extenders, premixed, cold-poured. These materials were placed in transverse contraction joints spaced at 60 ft 10 in. All joints were hand formed and measured about $\frac{3}{4}$ in. wide at the pavement surface when sealed. The joints were cleaned with a power wire brush and then blown out with compressed air. A styrofoam filler was placed in the lower portion of the joint and the sealers were installed by manufacturers' representatives using their own equipment.

Observations and measurements of the joints were conducted approximately every 3 months for 2 years. The air temperature, determined during each observation, varied from 90 to 5 F. As a result of these temperature variations, the maximum change in width of all test joints was found to be approximately the same, amounting to an annual movement of about $\frac{1}{4}$ in . during this particular 2-year period.

In the fall of 1960, Mr. Lefeve arranged for two test installations of a new preformed neoprene sealer, one on Fuller Road in Albany and the other on the Sunrise Highway near Babylon, Long Island. He then asked the Bureau of Physical Research to observe these seals. The experimental installations and observation of this type of material in contraction joints spaced at 60 ft 10 in. continued during 1961.

Installation of the neoprene sealer is accomplished by first coating the joint faces with a lubricant adhesive and then forcing the tubing into the joint. When first placed experimentally, this type of sealer was inserted with putty knives and screwdrivers. At present, a flanged roller is usually used as shown in Figure 1.

Neoprene and urethane tapes were also installed experimentally near Albany during the fall of 1962. This material was $1\frac{1}{2}$ and $2\frac{1}{2}$ in. wide and 0.040 and 0.050 in. thick, respectively. The tape was fastened with epoxy resin to the surface of the concrete on either side of the joint. To minimize damage to the tape, the pavement surface near the joint was ground down to a depth of 0.060 in. on 17 of the 19 experimental joints. Curing of the epoxy resin was extremely difficult since the air temperature was near 40 F and the weather was windy, cloudy and damp. These conditions necessitated heating the joint during the installation.

Development of new sealers during the early 1960's prompted a new field test in 1963. Manufacturers of joint sealers who expressed an interest in a field test were

Figure 1. Installing preformed neoprene sealer.

invited to install their products in a new concrete pavement on the Delmar Bypass south of Albany. In this field test, 21 companies installed 37 products, representing nine different categories of sealers: (a) polysulfide with extenders; (b) polysulfide tar; (c) polyurethane foam impregnated with asphalt; (d) polyurethane with extenders; (e) rubber asphalt, cold-poured, with solvent; (f) rubber asphalt, hot-poured; (g) neoprene, preformed; (h) latex with extenders; and (i) adduct rubber. All sealers were placed in transverse contraction joints formed with $^3/_8$-in. wide plastic inserts. These joints were spaced at 60 ft 10 in. Before sealing, the joint faces were etched with a 20 percent solution of hydrochloric acid and the residue was flushed out with clean water. It was requested that the participating companies place a filler in the lower portion of the joint groove which would be compatible with their sealer. Most commonly used fillers were polyurethane foam strips and butyl rod stock, although a few companies elected to use upholsterers' cord and jute rope. Each product was installed in five joints by the manufacturers' representative after the filler was placed and the concrete had thoroughly dried.

Time-lapse movies of the pavement joints are being used to evaluated the performance of the sealers. For this purpose, a 16-mm magazine-loading movie camera is mounted on a wooden jig. The jig is positioned in the same location for each exposure by aligning two sets of guide wires directly above a pair of brass pins set in the concrete (Fig. 2). A film magazine for each joint to be photographed is exposed for 2 seconds every other week. The film when projected will show an accelerated movie of the life of the sealer.

RESULTS AND DISCUSSION

Observations of the liquid joint sealers revealed three typical failures: adhesion, cohesion and extrusion. Figure 3 shows adhesion failure which occurs when the tensile stress in the sealer exceeds the bonding force available at the joint face. The tearing of the sealer in Figure 4 illustrates cohesion failure which occurs when the bonding force at the joint face is greater than the sealer tensile strength. An extruded joint sealer is shown in Figure 5. The sealer is forced from the joint when the joint closes to a point where there is not enough volume to contain it. The extrusion is aggravated when depressions in the sealer become filled with incompressible material. This action can progressively entrap sand and small stones until the joint is nearly filled.

The rubber-asphalt, cold-poured with solvent type of sealer solidifies by the evaporation of the solvent. Initially, it is easily "tracked" onto the pavement and is capable of absorbing large quantities of sand and stones. A condition survey, 4 months after installation, indicated practically 100 percent failure in adhesion or cohesion. Many stones had penetrated the surface of the sealer and in some instances, pieces of the sealer were missing. In cold weather, the sealer became extremely hard and brittle.

The rubber-asphalt, hot-poured sealers gave variable performance in the test areas, depending on the season installed. The material poured during hot summer weather failed in less than 4 months, whereas that poured in the fall performed satisfactorily for an average of approximately 1 year at which time adhesion failures developed. During hot weather the material was soft and where extruded was easily smeared on

Figure 2. Time-lapse movie camera.

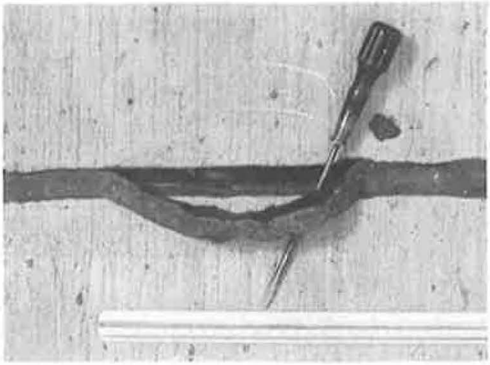

Figure 3. Adhesion failure.

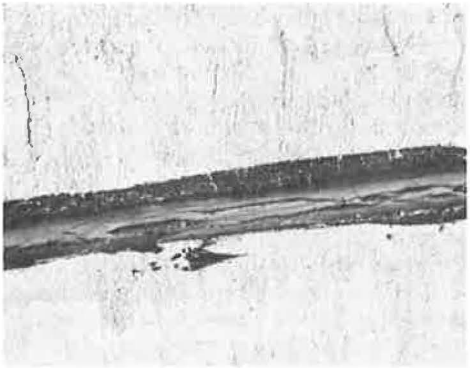

Figure 4. Cohesion failure.

Figure 5. Extruded sealer.

the pavement. Stones and sand were easily pressed into the sealer in this condition and in cold weather the sealer became hard, usually failing in adhesion.

The latex with extenders was the consistency of caulking compound when installed and appeared to form an effective seal for approximately 5 months. However, during the winter the surface of the sealer hardened and became checked with small shallow cracks. On close examination it proved to be saturated with water. Although little adhesion failure was apparent after 12 months, it was easy to either puncture the sealer or pull it from the concrete. The ease with which the sealer could be displaced seems to leave its effectiveness as a joint sealer open to question. After 18 months, this material hardened and failed in adhesion.

All polysulfide-tar sealers were cold-poured; the two components were either combined by hand mixing or in a nozzle-mixing machine. Some difficulty was encountered with the proportioning pumps. Mechanically driven pumps proportioned the components more satisfactorily than those driven by compressed air. Unfortunately, since both components are black and essentially the same consistency, it is difficult visually to detect an improperly proportioned mixture until it fails to cure. Polysulfide tar gave excellent performance for about 1 year. As it aged, the surface became cracked. These cracks progressed until they extended completely through the material.

The polysulfides with extenders are two-component sealers which are pre-mixed and then placed in the joint without heating. Judging from the bubbles that form in the material, air is easily entrapped during installation or the curing reaction releases a gas.

As long as these bubbles remain intact they pose no problem; however, when they become punctured, they afford an excellent pocket for the collection of water and incompressible materials. This material remained resilient during cold weather and was not easily punctured by stones. After about 18 months, cracks appeared over the bubbles and adhesion failures developed. These adhesion failures progressed, rendering the sealer ineffective after 2 years.

The adduct-rubber sealer exhibited a gradual hardening during the first 5 months and began to tear away from the concrete as the cold weather started. On close examination it was discovered that only a thin skin or web extended between the top of the two slabs in the places that were not yet torn. This skin was dry and brittle and was easily punctured.

Because polyurethane liquid sealers were comparatively new, they were under observation for about 5 months. Some tearing of the sealer along the joint face was encountered as soon as the weather became cold.

Polyurethane foam impregnated with asphalt was supplied eight times as wide as the joint (8 by $\frac{3}{8}$ or 3 in.) so that it remained compressed to 25 percent of its initial width at maximum joint opening ($\frac{3}{4}$ in.). This was recommended by the manufacturer to prevent infiltration of water. For installation, the material was compressed between rollers to one-quarter its initial width and then with a hydraulic press to a width of $\frac{3}{8}$ in. It was extremely difficult to place the material before it had expanded to a width greater than the joint opening. The material performed well during the summer months, although heat and pressure from the expanding slabs squeezed the asphalt from some of the foam. The uncoated polyurethane foam then appeared to dry out and lose some of its strength or toughness. As colder weather widened the joint openings, the sealer failed to recover and remain tight against the slabs in the places where the asphalt had been forced out.

The preformed tape sealers, both neoprene and urethane, failed rapidly and 3 months after installation only two of the original 19 tapes remained. The primary cause of this rapid failure was a break in the bond between the tape and concrete. An epoxy-resin compound was used to fasten the tape edges, but low temperatures (40 F) the day the sealing was done may have contributed to the weakening of the epoxy. In addition, several of the tapes were severely chewed by snowplow blades and by the blade of a grader working along the shoulders of the highway. Some or all of this damage could have been eliminated had the tapes been recessed in the pavement to make them flush. Recessing was attempted, but it was improperly done and did not allow the tape to be set deep enough. Many of the tapes were also punctured by small stones, mostly at the corners of the slabs, indicating a high stress concentration at these points.

Preformed neoprene has given excellent service for 3 years with no apparent failures where the appropriate section was properly installed. The material remained flexible during the coldest weather, maintaining contact with the joint faces. It was capable of resisting puncture and has not exhibited any evidence of deterioration from weathering. The use of this material has disclosed that certain precautions must be exercised in designing the joint, specifying the width of sealer, and installing the material. The joints must be constructed to provide a predictable and consistent width to hold the neoprene sealer in compression throughout the year. Initially, the joint must be wide enough to allow placement of the sealer and the uncompressed width of the sealer tube must be at least $\frac{1}{16}$ in. greater than the as-constructed joint width plus the anticipated annual change in opening.

Figure 6 illustrates a section of preformed neoprene sealer before and after installation. The shape pictured is the presently accepted cross-section; however, other configurations may perform as well or better. In designing different cross-sections it should be remembered that the center of the top of the sealer must fold down when compressed into the joint so that it does not protrude above the pavement surface.

During the winter of 1961-62, observations of the neoprene sealer installed on two contracts the previous summer revealed that the sealer was not in compression and in some instances was loose enough to drop to the bottom of the joint. This prompted a review of the data available on annual change in joint opening which revealed that 90 percent of the joints spaced at 61 ft experienced an annual change in opening of $\frac{5}{16}$ in. or less. As a result, the Department presently specifies that the neoprene gasket

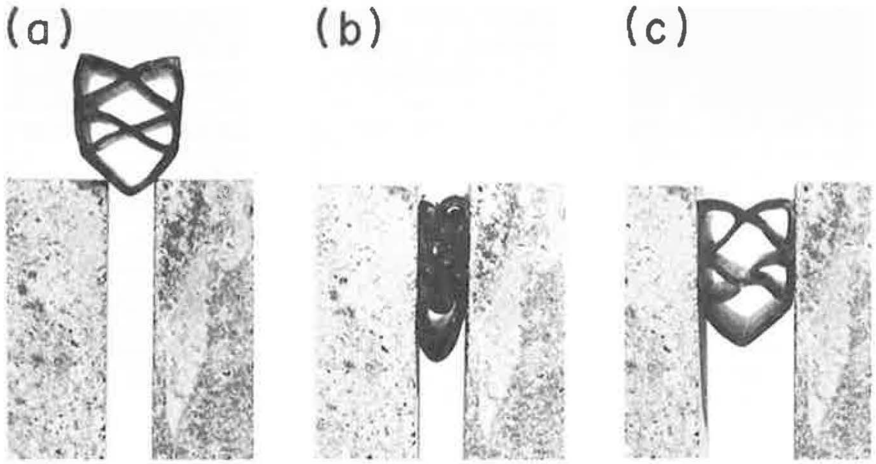

Figure 6. Preformed neoprene: (a) before installation; (b) installed in $^3/_8$-in. joint; and (c) after joint opens to $^3/_4$-in. in cold weather.

for transverse contraction joints must be at least $^3/_8$ in. wider than the initial joint width.

Spalls along the joint permit this sealer to lose some, if not all, of its compression. At present, the Department requires that the spalls be repaired with epoxy resin before installing the neoprene gasket. It is also important that the sealer tube not be placed too low in the joint. If the top of the tube is more than $^1/_4$ in. below the pavement, it is probable that stones will become wedged in the joint, thereby causing spalls when the joint closes. Therefore, the Department specifications state that the sealer shall at all times be not less than $^1/_{16}$ in. or more than $^1/_4$ in. below the level of the pavement surface. These are maximum dimensions, the intent being to have the sealer approximately $^1/_8$ in. below the pavement surface.

Installation of the neoprene tube is preceded by an application of lubricant adhesive to the joint faces. This liquid facilitates the insertion of the sealer tube and fills slight irregularities in the joint face which might otherwise remain open. Observation of instances where the joint opening has exceeded the initial width of the sealer tube revealed that the lubricant adhesive had torn and was, therefore, not capable of stretching the neoprene. However, the adhesive is beneficial in that it does prevent the sealer from being forced to the bottom of the joint in the winter when compression in the sealer is minimal.

Since the sealer cross-section is reduced when the tube is stretched, it is very tempting for the installer to do so when placing the sealer. The sealed joint may appear satisfactory but the neoprene under continued tension may tear, or when the joint opens, the sealer tube will contract, leaving a portion of the joint unsealed.

Considering the outstanding service which this material appears capable of providing and being aware of the problems associated with its use, the Department has recently amended the specifications to permit only preformed neoprene joint sealer on new construction.

CONCLUSIONS

Installation of joint sealers in transverse contraction joints ($^3/_8$ in. wide, spaced at 61 ft) throughout the state and in two special test areas near Albany has provided the basis for appraising their performance. Observations of the test area installed in 1963 are not complete; however, there are no indications that the results will be substantially different from those of the earlier field tests. Therefore, based on field observations of joint seal materials for 5 years, the following conclusions appear warranted:

1. Preformed neoprene has given excellent service for 3 years. There have been no apparent failures where the appropriate section was properly installed.
2. Polysulfide with extenders and polysulfide tar performed well for about 18 months and 12 months, respectively, before beginning to deteriorate. Polyurethane-based liquid materials exhibit a rate of deterioration similar to polysulfide tar after 6 months of observations in the Delmar test area.
3. Hot-poured rubber asphalt gave variable performance, never maintaining an adequate seal for more than 1 year and usually failing in adhesion during the first winter.
4. Latex with extenders, rubber asphalt cold-poured with solvent, and adduct rubber have provided very poor service, failing when the weather first turned cold.
5. Polyurethane foam impregnated with asphalt sealed the joints until cold weather when the sealer failed to recover as the joint opened.
6. The neoprene and urethane tapes were punctured and pulled from the pavement by traffic or snowplows after 2 months. However, the lack of adhesion can probably be attributed to the adverse weather conditions during installation.