Maintenance and Longevity of Longitudinal Joints

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Above: Since completing a successful micro surfacing project, the Minnesota Department of Transportation has used the treatment—a mixture of water, asphalt emulsion, aggregate, and chemical additives applied to an existing composite pavement surface—to maintain and preserve longitudinal joints along other roadways. Years of project evaluations have led to better ways of slowing deterioration of U.S. roads, like this centerline and fog line joint maintenance project on Interstate 77 in Jackson County, West Virginia.

Many highway agencies have discovered that significant safety issues often occur when longitudinal pavement joints deteriorate. This deterioration can appear in both asphalt and concrete pavements and is typically visible at longitudinal lane joints and shoulder joints (Figure 1).

Joint deterioration in asphalt pavements is a consequence of improper bonding of a new mix to the adjacent pavement surface or the result of lower densities at the joint due to poor compaction during paving. The lower density results in higher air-void levels at the joint, leaving it permeable and susceptible to the intrusion of water that accelerates deterioration. In time,

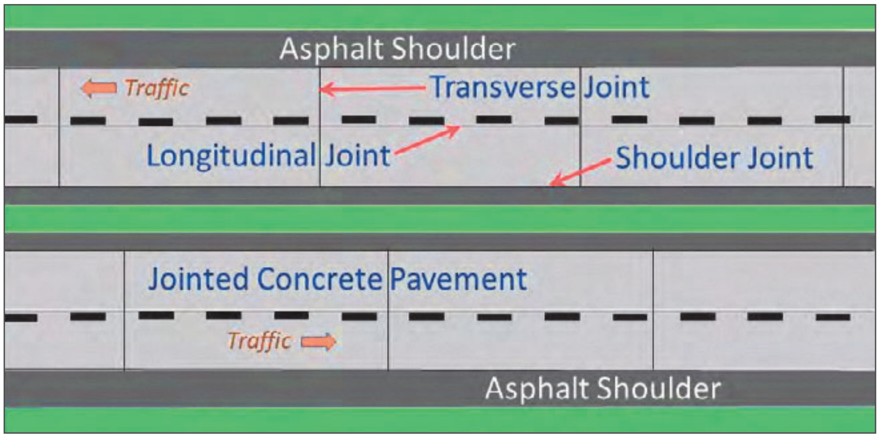

FIGURE 1 Typical pavement joint configuration.

the joint tends to ravel under traffic and material is then lost.

Generally, infiltration of surface water into the pavement structure at traverse and longitudinal joints is the cause of concrete pavement deterioration. Filling joints with an engineered sealant will eliminate the intrusion of water and reduce the potential of future pavement degradation.

When the longitudinal joint deterioration is unattended, a potential hazard can develop. Loose pavement material from the joint will eventually find its way onto the travel lanes, leading to possible vehicle damage from flying debris and injury risks to motorcyclists. Severely deteriorated joints present an even greater risk for motorcycles and small vehicles when changing lanes. Their narrow tires drop into the open joint, causing a momentary loss of control and greater potential for a serious accident. Therefore, it is important not only to maintain longitudinal joints but also to design longitudinal joints to have a long service life.

Background on Longitudinal Joint Maintenance

Every highway agency has a mission to save lives, prevent injuries, and reduce economic costs due to accidents. When the Minnesota Department of Transportation (DOT) faced serious deterioration of longitudinal joints on a major highway, maintenance forces needed to find a quick and cost-effective solution. In the past, they tried different patching methods without success. These approaches were expensive, left a poor driving surface, and deteriorated rapidly under heavy traffic.

Interstate 494 is an urban freeway in Minneapolis that consists of three to four lanes in each direction, with average daily traffic between 140,000 to 150,000 vehicles. The extremely high average daily traffic limited Minnesota DOT from performing most repair options, since they would endanger maintenance personnel. Longitudinal joint deterioration was evident throughout both directions of the 5.3-mile section, with some areas exhibiting joints that had opened as much as three inches wide and four inches deep.

Minnesota DOT

Before repair, the ride was rough—and potentially dangerous—along a stretch of Interstate 35 in Minnesota, where, in some spots, cracks along longitudinal joints were inches deep and several inches wide.

The freeway is like many urban composite pavements seen today: an older concrete pavement covered with numerous hot-mix asphalt overlays. The most recent overlay was a 1.5-inch-thick Superpave® mix using a PG (performance grade) 64-28 binder.

Approach to Longitudinal Joint Maintenance

The Minnesota DOT Metro District worked closely with Tom Wood and Paul Nolan of the Minnesota DOT Office of Materials to consider several possible solutions to the joint deterioration on I-494. In identifying solutions, the group was constrained by available funding and the need to minimize traffic disruptions. They discussed milling the joint one foot wide and four inches deep, tacking the milled area, and filling the joint with hot-mix asphalt. Contractor estimates varied from $4.83 to $9.66 per linear foot, which exceeded the planned budget. They then decided to try micro surfacing technology to fill the joints and leave a smooth durable surface. A St. Joseph, Minnesota, company was awarded the project contract.

Together, they devised a plan to apply micro surfacing over two longitudinal lane joints and a shoulder joint, with each application totaling more than 28,000 feet in length. The entire project in both directions totaled nearly 167,000 linear feet of needed repair. The quantity of micro surfacing to fill the joints was estimated at 2.5 pounds per linear foot. The micro surfacing used International Slurry Surfacing Association Type II gradation, containing granite from a St. Cloud quarry. The haul distance to the job site was more than 80 miles, which increased the trucking delivery cost.

The project mix design called for 13 percent Ralumac micro surfacing emulsion and 1 percent portland cement.

Field Implementation of Longitudinal Joint Maintenance

Due to high traffic volume, the contractor's daily work window was restricted to six hours, which began at 11 p.m. and ended at 5 a.m. In addition, the Metro District stipulated that no more than two lanes could be closed at any time.

The contractor fabricated a rut-filling spreader box to accommodate the narrow placement width of two feet. The spreader box was fitted with flexible seals on the sides to control the mixture application and a rear adjustable strike-off plate that allowed the operator to feather the mixture to align with the existing pavement cross-section. Crews removed loose debris from the longitudinal joints by using compressed air before the micro surfacing operation began.

The entire project was finished in six nights, and Minnesota DOT received many positive comments about the smooth ride. Maintenance crews installed new permanent pavement markings one week after completing joint filling. Public comments regarding the increased visibility of new white markings over the black micro surfacing also were positive.

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Creative engineering came into play when contractors fabricated a spreader box to distribute the micro surfacing mixture on Interstate 494.

Minnesota DOT

Repaired and ready for white paint, the fog line joint (*at left*) marks the boundary between the shoulder and the legally driveable road surface. Open to traffic after less than a week of undergoing maintenance, the finished section of Interstate 494 offered motorists a much smoother ride.

Conclusions on Longitudinal Joint Maintenance

The final yield of micro surfacing was 3.6 pounds per linear foot, surpassing the original estimate of 2.5 pounds per linear foot. The final project cost of micro surfacing was $.50 per linear foot.

The use of micro surfacing to fill the deteriorated joints proved to be a cost-effective, durable treatment that is performing well under high traffic volumes. After three years, the micro surfacing was performing well with only a few small cracks appearing where transverse joints intersected with longitudinal joints. Due to the successful outcome of the I-494 project, Minnesota DOT maintenance forces are continuing to use micro surfacing in other locations to repair deteriorated longitudinal joints.

As discussed before, just as it is important to maintain longitudinal joints in asphalt pavement, it is important to design them to last a long time. The following case examples explore how to establish concrete pavement joint sealant longevity.

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Interstate 94 near St. Cloud is one of several Minnesota roadways benefiting from micro surfacing as a practical—and affordable—solution for deteriorating longitudinal joints.

Background on Joint Sealant Longevity

The processes for sealing and resealing concrete pavements are the same, except the latter requires removal of the existing sealants. As such, performance of either type of sealant installation can be evaluated in the same manner. The following case examples in Arizona, Washington State, and Illinois demonstrate the benefits of establishing field-test sections in selected locations to define sealant performance.

Sealant test sections are relatively easy and inexpensive to install on construction projects or with maintenance forces. The most difficult aspect is documenting the necessary performance factors and maintaining the data and evaluations over a long time. Placement of sealant test sections in selected areas that represent different climate, traffic, and aggregate conditions can significantly benefit the selection of material types and joint design. The case examples also illustrate this concept.

Arizona LTPP SPS-2 20-Year Sealant Evaluation

The SHRP Long-Term Pavement Performance (LTPP) program Strategic Pavement Study 2 (SPS-2) experiment, *Strategic Study of Structural Factors of Jointed Plain Concrete Pavements*, consisted of constructing 12 test sections in each of 14 selected states in a designed experiment between 1992 and 2000. The FHWA LTPP has continued to evaluate these test sections to this day. It is the largest and longest monitored concrete pavement research ever conducted.

The takeaway from the Arizona SPS-2 experiment is that silicone joint sealant had exceptional performance and lasted more than 20 years with no maintenance. At the other SPS-2 locations, the silicone sealant was not as effective and did not have as significant a life span. This suggests that the best information for a particular location may not be the range of results found on the overall SPS-2 experiment (or the average life), but rather determined in specific areas where the same aggregate, mix designs, construction procedures, and so on are used (*1*).

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Standing up to the test of time—and daily use, the silicon joint sealant applied during the Arizona SPS-2 experiment has lasted more than 20 years without maintenance.

Fairchild Air Force Base, Washington, 21-Year Sealant Evaluation

In 1989, the U.S. Army's Construction Productivity Advancement Research Program constructed a joint sealant experiment at Fairchild Air Force Base in Washington State. It was evaluated for 10 years.

Many years after the final report, researchers conducted another evaluation and reported the results at the 2013 Transportation Research Board Annual Meeting (*2*). Two important findings resulted from this 21-year evaluation: First, joints flush-filled with hot-pour sealants (i.e., filled until flush with the pavement surface) had about twice the service life as the recessed installations with the same sealant. Second, one of the sections exhibited moisture bubbles in the hot pour during installation. This occurs if moisture is present when installing the hot-pour sealant; the water vaporizes and rises to the surface, resulting in small cavities or bubbles in the surface. Typically, this condition is a construction problem, but it is difficult to avoid in high-humidity environments. However, after 21 years in service the hot pour with bubbles was still performing well.

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During the hot-pour sealant installation at Washington's Fairchild Air Force Base, moisture bubbles formed in the mix. Still, after 21 years, the sealant performed well.

Illinois SR-59 Joint Sealant Experiment

In 2009, a new concrete pavement roadway was constructed on SR-59 in Cook County. Nine test sections were constructed to evaluate the impact of transverse joint sealant width and material type on sealant performance. Silicone and hot-pour materials were installed in both a narrow (0.2-inch) and standard (0.375-inch) width joint configuration. To achieve this, contraction joints are sawed into concrete pavement to control the location of shrinkage cracking. Often, these joints are widened to allow installation of joint sealants. The pavement structural section consisted of a dowelled 9.75-inch-thick jointed plain concrete pavement on a 12-inch-thick aggregate base with 15-foot joint spacing. Researchers then conducted three evaluations of the test sections.

The first evaluation in 2010 established the range of transverse joint widths, creating a baseline for comparing future sealant and pavement performance to joint width and movement (*3*). Most specifications require a single joint width, but many factors affect the final opening width. Often, every third to fifth joint opens significantly wider and exhibits more problematic sealant performance.

The second evaluation—conducted in 2013—was a visual determination of sealant performance and baseline pavement performance (*4*). Researchers removed sealant samples to determine the installed sealant shape factors that are width-to-depth ratio. For example, if the sealant thickness in the joint is twice as large as the width of the joint, it has a shape factor of 0.5. Conversely, if the sealant thickness is half as large as the width of the joint, then the shape factor is 2. Researchers compared joint opening widths to those obtained in 2010 and noted that joint opening widths increased between May 2010 and September 2013 from approximately .04 inch to .09 inch. Temperatures ranged from 75°F to 90°F in the 2010 test and from 53°F to 75°F in the 2013 test.

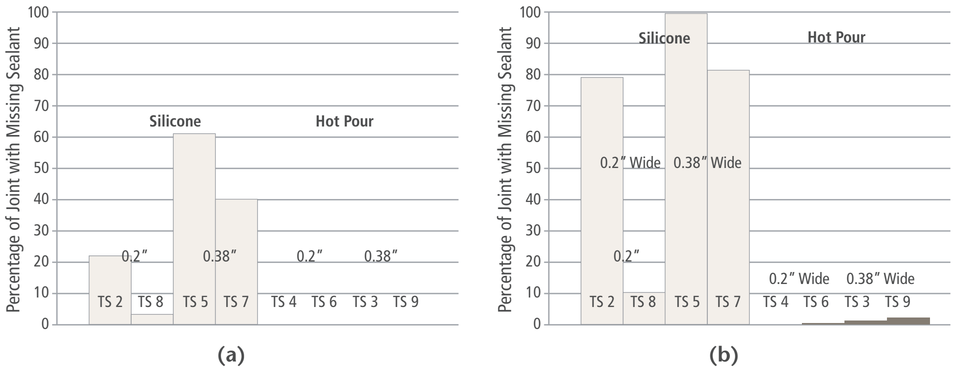

FIGURE 2 Percentage of joint sealant missing from transverse joint with (*a*) 2013 and (*b*) 2021 data (TS = test section).

The third evaluation took place in 2021 and was a visual assessment of the percentage of missing sealant (i.e., sealant loss) (*5*). Although not a research-level evaluation, some interesting findings regarding shape factor were discovered.

Figure 2 presents the results from the 2013 and 2021 visual assessments of missing sealant. The 2013 results indicate that material type was already a factor in performance. That is, hot-pour sealant was outperforming silicone sealant after just four years in service. The silicone sections indicated the effect of joint width, specifically that the narrow joint width was outperforming the wider joint width. The value of having replicate test sections also was evident, as Test Section 2 and Test Section 8 were performing differently but should have had similar performance.

The 2021 test results continue to support the 2013 test conclusions: Hot-pour sealants significantly outperformed silicone sealants. Narrow width joints outperformed wider width joints, and Test Section 2 and Test Section 8 exhibited even larger performance disparities.

Sealant shape factor had a dominant impact on sealant performance at this location but opposite that of conventional wisdom where sealants placed with shape factors of less than 1 should not perform.

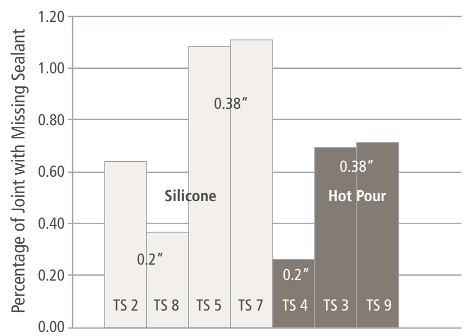

FIGURE 3 Shape factor of test section sealant installations.

However, as indicated in Figure 3, the narrow sealant installations had the worst shape factor by far, yet the best performance. This is true for hot pour, as well as silicone installations.

One explanation for this is the possible impact of vertical forces on the sealant surface. For silicone sealants, a flush-filled condition will fail quickly in the wheelpaths due to contact with tires. This is why silicone sealant should be installed in a recessed condition. In situations that involve snow, ice, or high rainfall, vertical forces also may be transferred to the sealant surface through snow and ice or hydrostatic pressures beneath the tire. If this assumption is true, there may be an optimum shape factor for these conditions, and it may favor narrow joints—the opposite of conventional wisdom on shape factor.

Recommendations and Conclusions for Sealing Jointed Plain Concrete Pavement

Case examples have shown how construction of sealant test sections can and should be used to establish sealant performance and to select the sealant types and joint configurations for new installation and resealing strategies. Through evaluation of these cases, several important points were established:

- Long-life joint sealants are possible (Arizona SPS-2 and Fairchild Air Force Base).
- Test section construction is the most effective means of establishing project sealant performance (i.e., case examples).
- Although research-grade sealant test section construction and evaluation are recommended, researchers demonstrated that more-limited studies also can provide useful results (SR-59).
- The success of field sealant performance may not coincide with conventional wisdom (SR-59).

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