

Preventive Maintenance of Asphalt Concrete Pavements

E. R. BROWN

Preventive maintenance of asphalt concrete can often extend the pavement life for a number of years at relatively low costs. The types of preventive maintenance discussed in this report include rejuvenators, slurry seals, surface treatments, and crack sealing. The report's emphasis is directed toward the use of asphalt rejuvenators. The maintenance procedure should be selected for a specific project to be maintained, and the treatment should be designed for the project. Random selection of maintenance procedures may be ineffective, resulting in loss in performance and additional life-cycle costs. This report provides some guidance into the selection process for maintenance procedures, problem areas to consider, and expected performance of various procedures.

Maintenance of most asphalt pavements involves repairing localized problem areas, such as potholes or badly cracked pavement sections and sealing cracks. This type of maintenance is needed to prolong the pavement life and prevent rapid damage to the pavement from water penetration and other causes.

Some problems with asphalt pavements can be prevented or delayed by using good maintenance practices. Unfortunately, there is very little guidance available concerning when to perform maintenance, what type of maintenance to perform, and how long its benefit will last. All of these questions need to be addressed in order to set up an acceptable maintenance schedule.

The objective of this paper is to discuss preventive maintenance procedures used to prolong the life of asphalt concrete pavements. The procedures discussed include rejuvenators, slurry seals, surface treatments, and crack sealing. Emphasis is directed toward the use of asphalt rejuvenators.

The most important step in minimizing maintenance costs is to properly design and construct the pavement initially. To do this requires satisfactory specifications and adequate quality control procedures during construction. A little extra money spent during the construction process to ensure that quality is obtained will reduce the life-cycle cost of the pavement and reduce maintenance costs in subsequent years.

REJUVENATORS

There are a number of rejuvenators on the market today that are being used to seal and rejuvenate asphalt concrete. Most

of these rejuvenators are proprietary materials and, thus, are often difficult to specify using a generic specification. Very little information is available that describes the expected performance when using rejuvenators to maintain pavements.

The rate of oxidation of asphalt concrete is highly dependent on the voids in the total mixture (VTM). If the VTM is below 7 to 8 percent in place, then the effects of oxidation will be greatly minimized. Oxidation causes the asphalt mixture to stiffen and crack at low temperatures. The purpose of the rejuvenator is to penetrate into the asphalt concrete somewhat and soften (rejuvenate) the asphalt binder. The rejuvenator also helps to seal the pavement and minimize future oxidation.

For a rejuvenator to be effective, it must penetrate into the asphalt concrete. If it does not penetrate, it cannot soften the asphalt, and it will cause the surface to become slick, especially in wet weather. The VTM must be about 7 to 8 percent or more to provide sufficient permeability to allow for penetration of the rejuvenator into the asphalt mixture.

A study was conducted by the U. S. Army Corps of Engineers to evaluate the performance of pavement sections treated with rejuvenators (1). These treated sections were compared to untreated (control) sections to determine relative performance. Five rejuvenators were selected for this study. One rejuvenator was selected to be SS-1 asphalt emulsion, while the remaining four rejuvenators were proprietary materials. The rejuvenators are identified in this report as materials A, B, C, D, and E. Material E was the SS-1 asphalt emulsion.

The rejuvenators were evaluated to determine their ability to penetrate oxidized pavements, to soften the asphalt binder, to reduce the amount of surface cracking, to reduce the loss of surface fines, and to minimize reduction in skid resistance. Three locations in the United States were selected for application of the test sections. One was located in the Southeast, one in the Southwest, and one in the North to allow for evaluation in each of the three major climatic areas.

The amount of each rejuvenator to be applied was determined by covering a 1-square-yard section with various amounts of each rejuvenator. The amount that would penetrate into the pavement and cure within 24 hours was selected as the optimum amount. For purposes of comparison, two application rates were applied to the test sections—one at the selected optimum and one lower than optimum. In most cases, the application amount was approximately 0.05 gallons per square yard.

After the pavements were rejuvenated, cores were taken and observed to determine approximate penetration of rejuvenator. Materials A, B, and C appeared to penetrate the

TABLE 1 MTO-DESIGNATED SOURCES LIST FOR ENGINEERING MATERIALS:
PRODUCTS SUITABLE FOR USE IN ALL DISTRICTS

Material	Penetration at 77 Degrees Fahrenheit, 0.1 mm				
	48 Hour	6 Month	1 Year	2 Year	3 Year
A - Control	21	21	21	18	18
A - Treated	57	30	38	24	26
B - Control	21	21	21	18	18
B - Treated	31	30	29	22	22
C - Control	21	21	21	18	18
C - Treated	28	25	24	20	21
D - Control	27	27	27	21	22
D - Treated	18	19	18	18	18
E - Control	26	26	26	19	20
E - Treated	23	23	20	18	20

surface about $\frac{3}{8}$ inch on the average, while materials D and E showed no significant penetration. For this reason, the top $\frac{3}{8}$ inch of all cores was removed and evaluated during this study to determine the effect of rejuvenators.

The ability of the rejuvenator to soften asphalt was measured by extracting the asphalt from the top $\frac{3}{8}$ inch of each core and measuring the penetration and viscosity. The recovered asphalt from each treated area was compared with the asphalt recovered from an adjacent untreated area. The results of penetration at 77 degrees Fahrenheit during the three-year evaluation period are shown in Table 1. The results of viscosity tests at 275 degrees Fahrenheit for the same time period are shown in Table 2. The viscosity was measured at 275 degrees Fahrenheit since the viscosity at 140 degrees Fahrenheit was too high to be measured for some of the asphalts being tested.

The relative penetration (ratio of penetration of treated asphalt to untreated asphalt) of the five rejuvenated sections is shown in Figure 1. Materials A, B, and C provided some rejuvenation to the asphalt cement for the three-year evaluation period, while materials D and E actually stiffened the

asphalt during this evaluation time. The viscosity data in Figure 2 show the same relative results. These data clearly show that the application of the materials being evaluated modified the asphalt properties for at least three years.

The skid resistance can be significantly reduced for a substantial period of time when rejuvenators are applied, especially when the rejuvenators do not penetrate. A summary of skid tests as measured with a British Portable Skid Tester is shown in Table 3. The data show that most materials reduce the skid resistance for at least one year. The two- and three-year tests show that the skid resistance of the treated sections are approximately equal to the skid resistance of the untreated sections. This is shown in the summary of data presented in Figure 3. It is obvious from these data that judgment must be used when applying rejuvenators to ensure that a dangerous condition does not develop. Rejuvenators are most often used in areas of slow-moving traffic, such as parking lots.

When excess rejuvenator is applied or when the material does not penetrate the asphalt concrete, skid resistance can be greatly reduced. If excess rejuvenator remains on the surface after 24 to 48 hours, it should be sanded and removed.

TABLE 2 MTO-DESIGNATED SOURCES LIST FOR ENGINEERING MATERIALS:
PRODUCTS SUITABLE FOR USE IN DISTRICTS 1-8 ONLY

Material	Viscosity at 275 degrees Fahrenheit, Centistokes				
	48 Hour	6 Month	1 Year	2 Year	3 Year
A - Control	1930	1876	2008	2142	2697
A - Treated	562	959	766	1072	1522
B - Control	1930	1876	2008	2142	2697
B - Treated	1167	1288	1388	1606	2062
C - Control	1930	1876	2008	2142	2697
C - Treated	1374	1487	1523	1974	2978
D - Control	1909	1851	1987	2123	2648
D - Treated	2783	2713	2978	3300	4305
E - Control	2330	2396	2480	2652	3456
E - Treated	2330	1758	3325	3493	4850

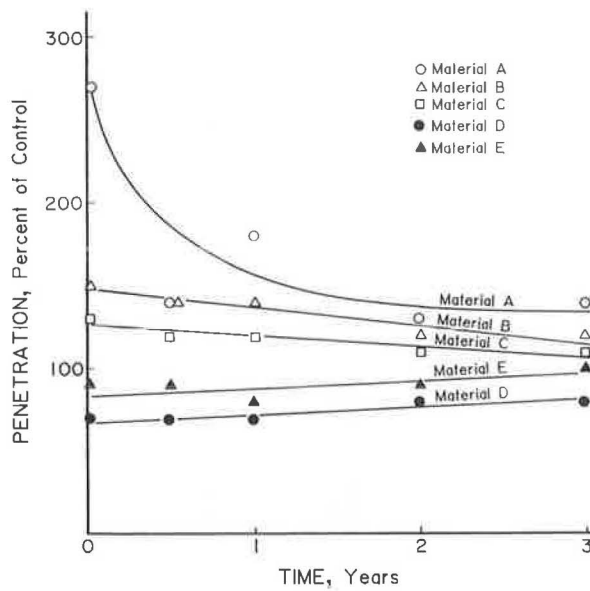


FIGURE 1 Relative penetration of asphalt recovered from sections treated with materials A-E during a three-year investigation.

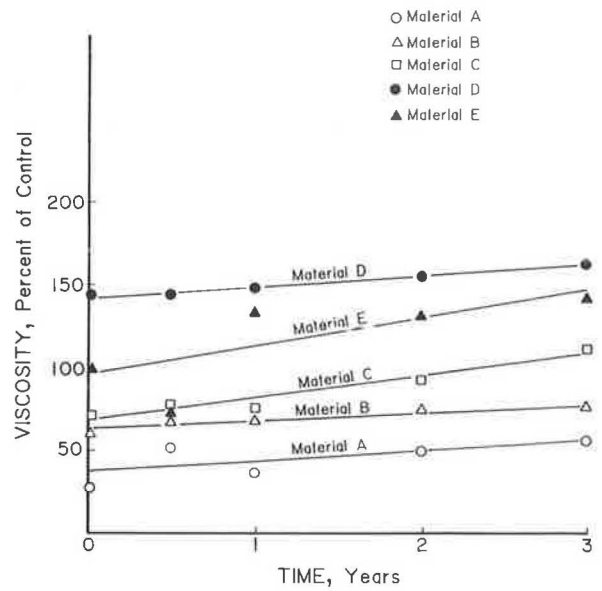


FIGURE 2 Relative viscosity of asphalt recovered from sections treated with materials A-E during a three-year investigation.

Rejuvenators should not normally be applied to a pavement surface, such as slurry seal or surface treatment, that has a large amount of asphalt near the surface. Applications of rejuvenator to these surface types may produce a sticky, soft surface.

After the rejuvenators had been in place for three years, the amount of cracking was evaluated. Results are presented in Table 4 and are shown graphically in Figures 4 and 5. Figure 4 shows that the total amount of cracking for each of the test sections is approximately equal to the total amount of cracking in the control sections. In most cases the cracking of the treated sections varied from 80 to 125 percent of the cracking in the control test sections. Figure 5 shows that the amount of cracking wider than 1/4 inch is lower for materials A, B, and C than for the control test sections. The amount of cracking is reduced more inside the traffic lane than outside the traffic lane. For instance, the cracking varies from 12 to 30 percent of control inside the traffic lane, while it varies from

25 to 100 percent of control outside the traffic lane. The amount of cracking in sections D and E was higher for the treated sections than for the untreated sections. The amount of data for large cracks was limited. The results indicate, however, that the rejuvenators that softened the asphalt binder (materials A, B, and C) also resulted in a smaller amount of large cracks after three years; the rejuvenators that stiffened the asphalt binder (materials D and E) resulted in a greater amount of large cracks after three years.

Another property that was observed when the rejuvenated test sections were being inspected was the surface texture. After three years, it was noted that the untreated sections, in some cases, had lost surface fines, while the treated sections appeared to perform better. The loss in surface fines was measured by quantifying the surface texture. This was done by spreading a known amount of sand into the surface voids. The area was measured, and the average penetration into the asphalt mixture was calculated. A higher penetration indi-

TABLE 3 AVERAGE SKID RESISTANCE VALUES FOR AVERAGE APPLICATION RATES OF APPROXIMATELY 0.05 GSY

Material	Skid Resistance (Wet), Percent of Control				
	48 Hour	6 Month	1 Year	2 Year	3 Year
A	97	87	88	96	100
B	76	100	93	99	103
C	90	91	98	99	103
D	76	80	89	100	103
E	118	94	86	95	98

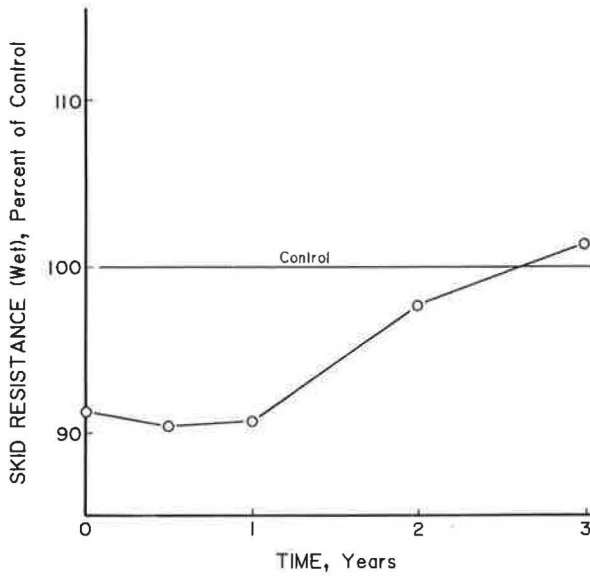


FIGURE 3 Average skid resistance of wet rejuvenated pavement during three years.

cated more loss in surface fines. The results of these tests are shown in Table 5. All five materials tested resulted in a reduction in sand penetration, which indicates that all five materials resulted in a reduction of fines being lost. At some locations, a difference in surface texture was noted visually. It was apparent in these areas that the untreated sections had lost some fines while the treated areas had not. The material that appeared to hold the surface fines best was material D, which did not penetrate but did seal the surface.

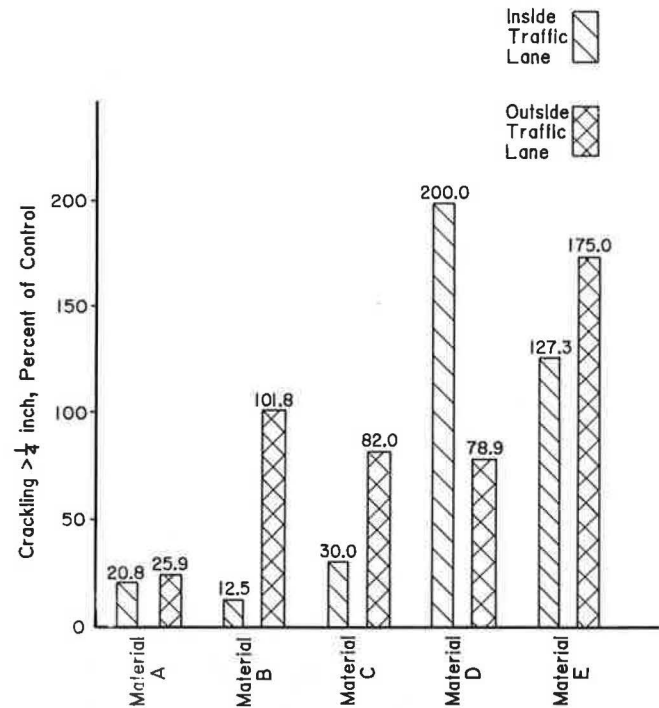


FIGURE 4 Relationship between material type and total cracking.

SLURRY SEALS

Slurry seal is a fluidlike mixture of fine aggregate, asphalt emulsion, and water. The slurry seal is used to seal an existing asphalt surface and to provide improved surface texture in

TABLE 4 EFFECT OF REJUVENATOR APPLICATION ON AMOUNT OF CRACKING (1)

Material	Amount of Traffic	Total Cracking	Total Cracking > 1/4 Inch Wide
A	Inside Traffic Lane	133	2.5
Control	Inside Traffic Lane	111	12
A	Outside Traffic Lane	157	14
Control	Outside Traffic Lane	148	54
B	Inside Traffic Lane	103	3
Control	Inside Traffic Lane	140	24
B	Outside Traffic Lane	82	57
Control	Outside Traffic Lane	92	56
C	Inside Traffic Lane	122	3
Control	Inside Traffic Lane	116	10
C	Outside Traffic Lane	101	41
Control	Outside Traffic Lane	120	50
D	Inside Traffic Lane	56	12
Control	Inside Traffic Lane	57	6
D	Outside Traffic Lane	62	30
Control	Outside Traffic Lane	61	38
E	Inside Traffic Lane	14	14
Control	Inside Traffic Lane	11	11
E	Outside Traffic Lane	14	14
Control	Outside Traffic Lane	8	8

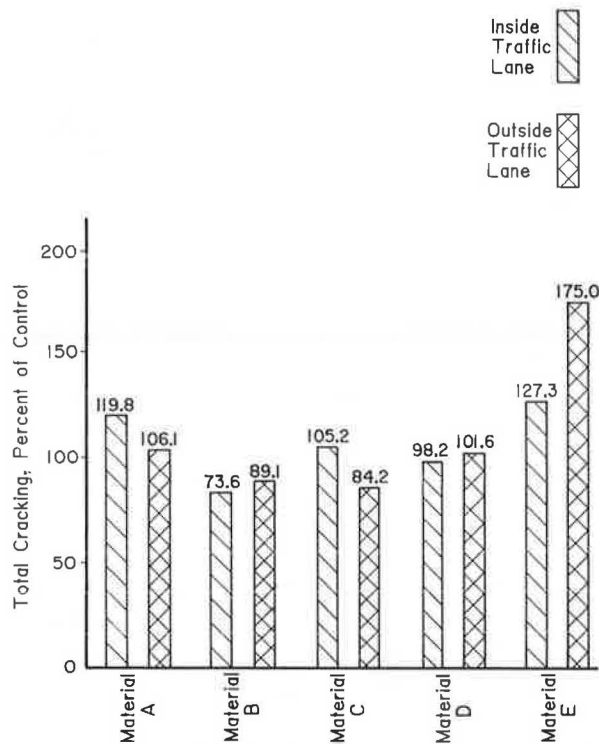


FIGURE 5 Relationship between material type and cracking wider than $\frac{1}{4}$ inch.

some cases. When properly applied, it prevents penetration of water into the pavement and, therefore, prolongs the pavement life.

For most projects, a special rapid-set asphalt emulsion that

has been specifically designed for slurry seals is used. The fine aggregate used should be crushed for best results.

Slurry seals are normally used on pavements subjected to low traffic volumes. When slurry seals are subjected to high traffic volumes, the life is greatly reduced. One of the biggest problems observed with slurry seals is the loss of bond between the slurry and the underlying asphalt mixture. This loss in bond can be a result of several factors that may occur simultaneously or separately. The underlying surface must be clean prior to application of a tack coat. Construction equipment operating on a pavement to be sealed can often track mud and other foreign material onto the pavement surface, preventing the development of a satisfactory bond. The tack coat is normally applied immediately before application of the slurry, so dust and other debris on top of the tack is not a problem. Many times the slurry is placed at a time when the temperature is relatively low, resulting in a poor bond. Slurry seal construction should be performed in hot weather. It generally should not be placed when the ambient temperature is below 50 or 60 degrees Fahrenheit. For best results, slurry seals should be rolled with a rubber tire roller after placement. A roller is often not required by the specifications, but failure to use one can result in a slurry seal that does not provide satisfactory performance. Another problem that sometimes affects the performance of slurry seals is water vapor. The slurry seal is watertight, preventing water from passing through the sealer and evaporating. Water that might be trapped in the existing pavement may vaporize during the hot summer months and exert sufficient pressure on the slurry to cause blisters or delamination.

Performance data determined from a number of Air Force bases has shown that slurry seals typically last from three to six years, depending on the construction quality and environ-

TABLE 5 SURFACE TEXTURE OF TREATED AND UNTREATED SECTIONS

Material	Amount of Traffic	Average Penetration of Sand Into Pavement (0.001 inches)
A	Inside Traffic Lane	18.7
Control	Inside Traffic Lane	24.5
A	Outside Traffic Lane	17.0
Control	Outside Traffic Lane	21.1
B	Inside Traffic Lane	20.6
Control	Inside Traffic Lane	24.8
B	Outside Traffic Lane	17.9
Control	Outside Traffic Lane	21.5
C	Inside Traffic Lane	20.1
Control	Inside Traffic Lane	24.3
C	Outside Traffic Lane	17.0
Control	Outside Traffic Lane	21.0
D	Inside Traffic Lane	22.3
Control	Inside Traffic Lane	28.8
D	Outside Traffic Lane	22.5
Control	Outside Traffic Lane	30.5
E	Inside Traffic Lane	24.8
Control	Inside Traffic Lane	25.9
E	Outside Traffic Lane	24.7
Control	Outside Traffic Lane	25.6

mental conditions (2). The cost for slurry seals based on 1985 data varies considerably but generally ranges from \$1.00 to \$3.00 per square yard.

SURFACE TREATMENT

Surface treatments are generally placed in one or two layers. A single bituminous surface treatment consists of one layer of asphalt followed by a layer of uniformly graded aggregate. The thickness of the surface treatment is controlled by the aggregate size. A double bituminous surface treatment consists of two layers of asphalt and two layers of aggregate. The top layer of aggregate is normally about one-half the size of the bottom aggregate layer.

All three types of asphalt (asphalt cement, cutback asphalt, and asphalt emulsion) can be used to construct surface treatments. The use of crushed aggregate provides better performance than that derived with uncrushed aggregate.

Surface treatments are normally used on existing pavements to improve skid resistance and to waterproof the underlying layers. When surface treatments are used in high-traffic-volume areas, surface life is relatively short. One of the biggest problems with surface treatments is the loose aggregate on the pavement surface that is often thrown into windshields, causing damage. Good design and construction techniques can minimize the loss of cover aggregate.

For best performance, construction should take place in warm weather, at least 50 to 60 degrees Fahrenheit. When asphalt cement is used, the aggregate must be placed immediately after the asphalt is placed and the surface must be rolled as soon as possible. Steel-wheel rollers are sometimes used, but they tend to break the aggregate and bridge over low spots. A rubber tire roller is desirable. The aggregate is often heated when asphalt cement is used.

The aggregate used in surface treatments must be clean to ensure a good bond between the asphalt and aggregate. The use of dirty aggregates will result in loss of aggregate and, hence, unsatisfactory performance.

Performance data from a number of Air Force bases has shown that surface treatments usually last for between three and six years, depending on quality and environmental conditions (2). Based on 1985 data, the cost for surface treatments varies from \$1.00 to \$3.00 per square yard, depending on location and other factors.

CRACK SEALING

When cracks occur in asphalt pavements, they must be sealed to prevent water infiltration and loss of load-carrying capacity.

A number of materials are available for sealing cracks. These materials include cutback asphalt, emulsified asphalt, joint sealing materials, and proprietary materials. On occasion, large cracks are sealed with sand-asphalt mixtures.

Small cracks (less than 1/4 inch) are difficult to seal. If these cracks are few, they may be routed and sealed or left unsealed. If there are many cracks, it is usually too expensive to route and seal them. In such cases, the entire area may be sealed with a slurry seal, surface treatment, or overlay. Liquid asphalt should not be painted on the surface over the cracks. This does not properly seal the cracks, and it can cause a skid problem, especially in areas with many cracks. This excess asphalt may also cause problems when overlaying the existing pavement. The asphalt on the surface often causes slippage of the overlay when it is rolled.

In 1985, the cost for crack sealing at a number of Air Force bases was \$0.75 to \$1.25 per linear foot (2). At that time, it was expected that crack sealing had to be performed every three to five years.

SUMMARY

There are a number of maintenance procedures, including rejuvenators, slurry seals, surface treatments, and crack sealing, that can be used to prolong the life of asphalt pavements. Construction quality will greatly decrease the need for maintenance and ensure years of satisfactory performance.

Preventive maintenance procedures can increase the pavement life significantly and reduce future reconstruction costs. Pavements to be maintained need to be investigated to allow the selection of the most appropriate maintenance procedures for optimizing performance and ensuring that the lowest life-cycle cost is obtained.

REFERENCES

1. E. R. Brown and R. R. Johnson. *Evaluation of Rejuvenators for Bituminous Pavements*. AFCEC-TR-76-3. Air Force Civil Engineering Center, Tyndall Air Force Base, Florida, 1976.
2. E. R. Brown. Maintenance of Asphalt Pavements. In *Proceedings of Flexible Pavement Workshop Sponsored by the U.S. Army Corps of Engineers and U.S. Air Force*, 1986, pp. 183-196.