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Methods for Maintenance of flexible Asphalt Pavements and Preventative life time

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ABSTRACT
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 that are discussed in this study include rejuvenators, slurry seals, surface treatments, and crack sealing. The emphasis of this study is directed towards 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 study provides some guidance into the selection process for maintenance procedures, problem areas to consider, and expected performance of the various procedures.
Keywords: *pavement, rejuvenate, slurry seals, surface treatments, crack sealing*

INTRODUCTION

Maintenance of most asphalt pavements involves repairing localized problem areas such as potholes or badly cracked pavement sections and sealing cracks. This type maintenance is needed to prolong the pavement life and to prevent rapid damage to the pavement due to 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 maintenance to perform, and how long it 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 that will be discussed include rejuvenators, slurry seals, surface treatments, and crack sealing. Emphasis will be directed towards 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 insure 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, often difficult to specify with 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 7-8 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 somewhat into the asphalt concrete and soften (rejuvenate) the asphalt binder. The rejuvenator also helps to seal the pavement and minimize future oxidation. In order 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 approximately 7-8 percent or more to provide sufficient permeability to allow for penetration of the rejuvenator into the asphalt mixture. A study was 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 study 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 were selected in the United States to apply 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 0.840 m^2 section with various rates 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 rate was approximately 0.05 gallons per 0.840 $m^{2,}$, After the pavements were rejuvenated, cores were taken and observed to determine approximate penetration of rejuvenator. Materials A, B, and C appeared to penetrate into the surface approximately 0.925 on the average while materials D and E showed no significant penetration. For this reason, the top 0.925 cm of all cores were removed and evaluated during conduct of this study to determine effect of rejuvenators. The ability of the rejuvenator to soften asphalt was measured by extracting the asphalt from the top 0.925 cm 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 25°C during the three-year evaluation period are shown in "Table 1".

Table 1- Penetration of Asphalt Recovered from Asphalt Sections During Three-Years After Being Rejuvenated

Penetration at 25°C, 0.1 mm					
Material	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	18	18	19	18
E -Control	26	26	26	19	20
E -Treated	23	23	20	18	20

The results of viscosity tests at 135°C for the same time period are shown in "Table 2". The viscosity was measured at 135°C since the viscosity at 60°C 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" shows the same relative results. This data clearly shows 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 shows 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 is 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 this data that judgment must be used when applying rejuvenators to insure that a dangerous condition does not develop. Rejuvenators are most often used in areas of slow moving traffic such as parking lots.

Table 2- Viscosity of Asphalt Recovered from Asphalt Sections During Three-Years After Being Rejuvenated

Viscosity at 135°C, Centistokes					
Material	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	1176	1288	1388	1606	2062
C -Control	1930	1876	2008	2142	2697
C -Treated	1374	1587	1523	1974	2978
D -Control	1909	1851	1987	2123	2658
D -Treated	2783	2713	2978	3300	4305
E -Control	2330	2396	2480	2652	3456
E -Treated	2330	1758	3325	3493	4850

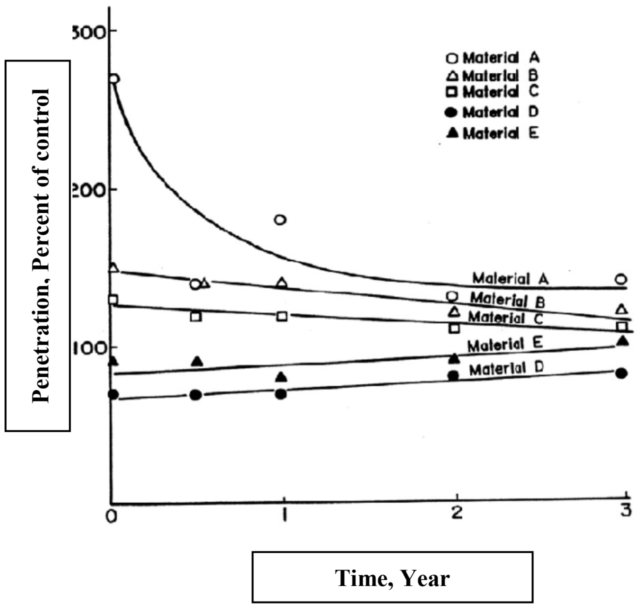

Figure 1. Relative Penetration of Asphalt Recovered from Sections Treated with Materials A-E During a Three-Year Investigation

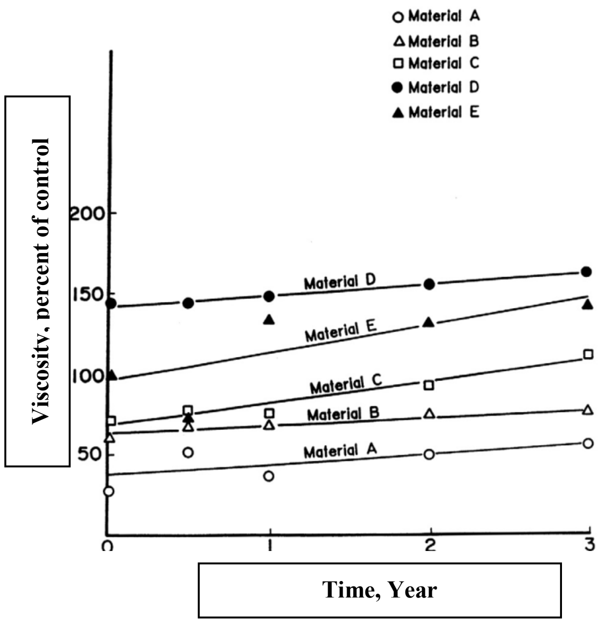

Figure 2. Relative Viscosity of Asphalt Recovered from Sections Treated with Materials AE During a Three-Year Investigation

Table 3. Average Skid Resistance Values for Average Application Rates of Approximately 0.05 GSY

Skid Resistance (Wet), Percent of Control					
material	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

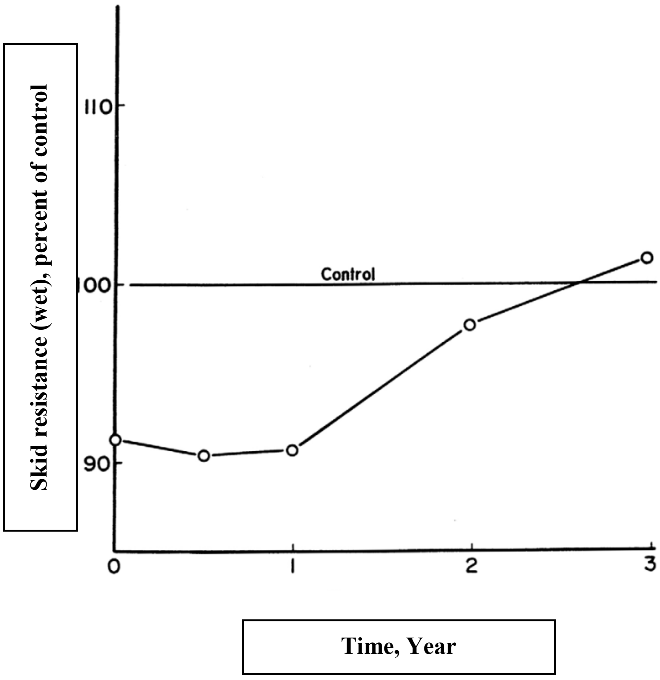

Figure 3. Average Skid Resistance of Wet Rejuvenated Pavement during Three Years

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

Table 4. Effect of Rejuvenator Application on Amount of Cracking (*1*)

Material	Amount of Traffic	Total Cracking	Total Cracking > 0.635 cm 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

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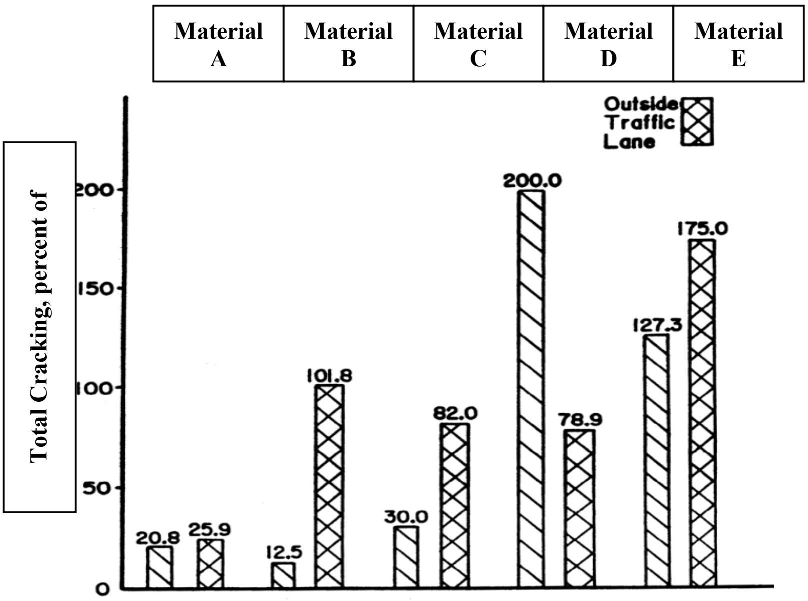

Figure 4. Relationship between Material Type and Total Cracking

"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 80-125 percent of the cracking in the control test sections. "Figure 5" shows that the amount of cracking wider than 0.635 cm 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 12-30 percent of control inside the traffic lane while it varies from 25-100 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; however, the results indicate 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 and the rejuvenators that stiffened the asphalt binder (materials D and E) resulted in a larger amount of large cracks after three years.

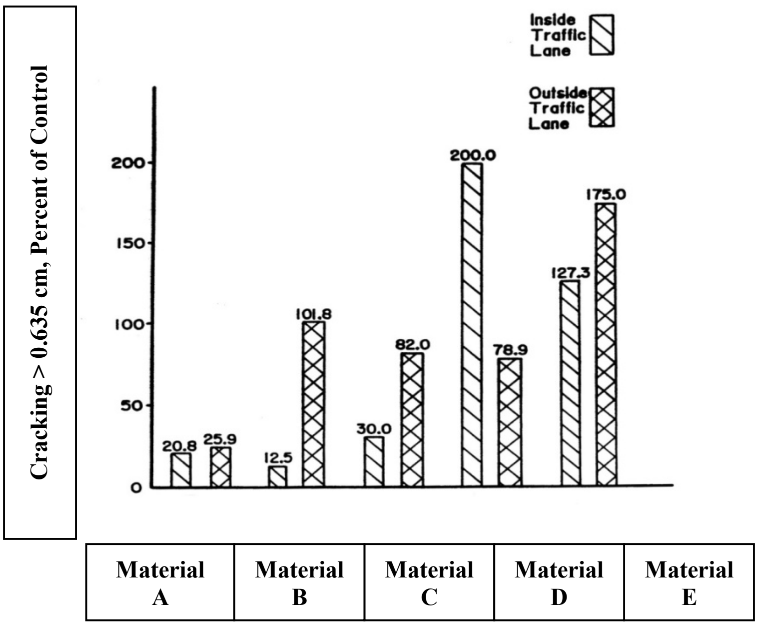

Figure 5. Relationship between Material Type and Cracking Wider Than 0.635 cm

Another property that was observed when inspecting the rejuvenated test sections was the surface texture. After three years, it was observed 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 indicated 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 visually observed. It was apparent in these areas that the untreated sections had lost some fines, while the treated areas had not. The material which appeared to hold the surface fines the best was material D, which did not penetrate but did seal the surface.

Table 5. Surface Texture of Treated and Untreated Sections

Material	Amount of Traffic	Average Penetration of Sand In Pavement (0.00254 cm)
A	Inside Traffic Lane	18.7
control	Inside Traffic Lane	24.5
A	Outside Traffic Lane	17
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
control	Outside Traffic Lane	21
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

Slurry Seals

Slurry seal is a fluid-like 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 some cases. When properly applied, it will prevent penetration of water into the pavement and, therefore, prolong the pavement life. For most projects, a special rapid-set asphalt emulsion which 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 which 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 prior to applying the slurry so dust or 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 poor bond. Slurry seal construction should be performed in hot Weather. It generally should not be placed when the ambient temperature is below 10 or 15° C. 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 this can result in a slurry seal which 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 which 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 delaminating.
Performance data determined from a number of Air Force Bases has shown that slurry seals typically last for 3-6 years depending upon the construction quality and environmental conditions [*2*].

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 approximately 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 provided 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, the life is relatively short. One of the biggest problems with surface treatments is the loose aggregate on the pavement surface which is often thrown into windshields causing damage. Good design and construction techniques will minimize the loss of cover aggregate. For best performance, construction should take place in warm weather, at least 10-15° C. 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 insure 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 typically last for 3-6 years depending on quality and environmental conditions [*2*].
Crack Sealing
When cracks occur in asphalt pavements, these cracks must be sealed to prevent water infiltration and loss of load-carrying capacity [4]. A number of materials are available for sealing cracks. These materials include cutback asphalt, emulsified asphalt, joint sealing materials, and proprietary materials. On occasions, large cracks are sealed with sand-asphalt mixtures. Small cracks (less than 0.635 cm) are difficult to seal. If there are few of these cracks, they may be routed and sealed or they may be left unsealed. If there are many of these cracks, it is usually too expensive to route and seal. In this case, 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 having 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 being rolled.

CONCLUSIONS
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 insure years of satisfactory performance. Preventive maintenance procedures can increase the pavement life significantly and reduce future reconstruction costs. The pavements to be maintained need to be investigated to select the most appropriate maintenance procedures to optimize performance and insure that the lowest life-cycle cost is obtained.

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