Application of Cracking and Seating and Use of Fibers To Control Reflective Cracking

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Two methods for reducing pavement cracking on asphalt overlays over concrete pavement on I-74 in Indiana—cracking and seating before overlay and fiber reinforcement in the overlay mixture—were evaluated. The project was constructed in 1984 and 1985 and divided into several experimental sections and control sections. As a performance comparison with the experimental sections, the control sections were overlaid by the conventional method. The study results based on the 7-year pavement performance data indicated that the cracking and seating technique was successful in this project: it delayed most of the transverse cracks for 5 years. The majority of the transverse cracks on the cracked and seated sections were thermal cracks, which were narrower and less severe than the reflective cracks on the control section. It was also found that the type of hammers used for cracking the concrete slabs had strong effects on pavement performance. The use of fibers in the overlay mixture further reduced transverse cracks on cracked and seated sections but did not improve the cracking resistance of the control sections. Fibers improved rutting resistance on both control and cracked and seated sections. However, the sections with fibers exhibited quick decreases in pavement strength and rideability. Thicker overlays increased the construction costs significantly but did not reduce the transverse crack intensities. According to the pavement performance and the cost analyses, it is recommended that the thickness of asphalt overlay be determined only by the pavement strength requirement and not be increased as a means of cracking control.

This study evaluated two methods for reducing reflective cracking of an asphalt overlay over a 12.5-mi (20.1-km) section of reinforced jointed concrete pavement on I-74 in Indiana from the Montgomery/Boone County Line to State Route 39. The first method, cracking and seating, breaks the existing concrete pavement slabs into smaller pieces and then seats these pieces by rolling to achieve uniform contact between the individual slab pieces and the base layer before placement of the asphalt overlay. This process reduces the effective slab length and therefore reduces the slab's horizontal movement caused by temperature or moisture changes, or both. The vertical movements of slabs are also limited because the small pieces of the slabs are in uniform and tight contact with the subbase and there exists some degree of aggregate interlock between the slab pieces. The second method involves the addition of polypropylene fibers to the asphalt overlay to increase the tensile strength of the asphalt mixture.

The project was constructed in 1984 and 1985. The pavement condition has been monitored since then by performing deflection tests, roughness tests, visual inspections, and rutting measurements. This paper presents the study results based on the 7-year pavement condition data. In this paper, pavement performance in the experimental and control sections in the 7-year period is discussed and the effectiveness of the techniques is determined. The results of a life cycle analysis are also presented to determine the cost-effectiveness of the cracking and seating technique.

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SCOPE OF THE STUDY

The concrete pavement in place before rehabilitation was 19 years old. It consisted of concrete slabs 10-in. (25.4 cm) thick over a 6-in.-thick granular subbase. The concrete slabs were 40 ft (12.2 m) long with joints connected by dowel bars. The traffic volume is over 10,000 vehicles per day with about 30 percent trucks. The following eight different treatments were applied on this project:

A—Asphalt underseal with 4.25-in. (11.4-cm) asphalt overlay
- Surface: 70 lb/yd^2 (38 kg/m^2)
- Binder: 150 lb/yd^2 (81 kg/m^2)
- Base: 250 lb/yd^2 (135 kg/m^2)

A1—Same as A with fiber-reinforced asphalt base layer

A2—Same as A with fiber-reinforced asphalt base and binder layers

B—Cracked and seated slab with 5-in. (12.7-cm) asphalt overlay
- Surface: 70 lb/yd^2 (38 kg/m^2)
- Binder: 150 lb/yd^2 (81 kg/m^2)
- Base: 330 lb/yd^2 (179 kg/m^2)

B1—Same as B with fiber-reinforced asphalt base layer

B2—Same as B with fiber-reinforced asphalt base and binder layers

C—Cracked and seated slab with 6.5-in. (16.5-cm) asphalt overlay
- Surface: 70 lb/yd^2 (38 kg/m^2)
- Binder: 150 lb/yd^2 (81 kg/m^2)
- Base: 510 lb/yd^2 (276 kg/m^2)

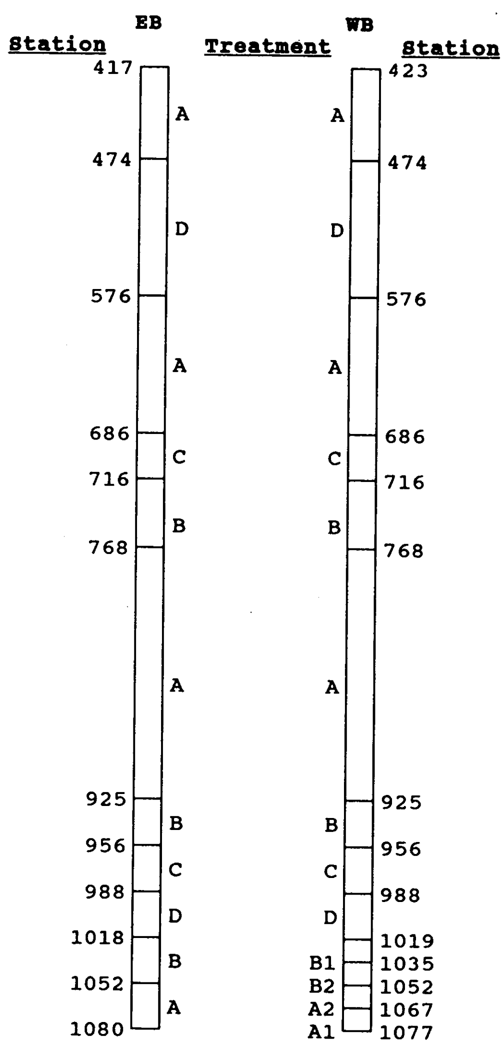
D—Cracked and seated slab with 8.5-in. (21.6-cm) asphalt overlay
- Surface: 70 lb/yd^2 (38 kg/m^2)
- Binder: 150 lb/yd^2 (81 kg/m^2)
- Base: 700 lb/yd^2 (380 kg/m^2)

Figure 1 shows the layout of the sections of various treatments along the roadway. Treatments A, A1, and A2 were designated as control sections of this study. Treatments B, B1, B2, C, and D were required to be cracked transversely at 18- to 24-in. spaces. No longitudinal cracks were allowed to develop during the cracking and seating process. Polypropylene fibers were added to the base layer or base and binder layers in sections of treatments A1, A2, B1, and B2. All the rehabilitation work, except for laying the 70-lb/yd² (38-kg/m²) surface layer, were carried out in the summer and fall of 1984. The surface layer was laid the following summer in 1985.

CONSTRUCTION

The cracking process was started in the section between Stations 474 and 576 with a whip hammer manufactured by Wolverine Technology. A number of hammer head shapes and blow patterns were tried and it was found that six to eight blows in a large semicircular pattern produced the required transverse cracks. This was verified by removing a portion of a slab with a crane and taking cores at the location of the surface. Two methods were used to detect the presence of cracks at the surface. The first method used water sprinkled on the surface of the slab. As the water evaporated, the water in the location of the cracks could be seen. The second method used flour sprinkled on the surface of the slab. When the slab was struck by the hammer, the flour moved from the cracks showing the locations of the cracks.

Cracking the pavement with the whip hammer was relatively time consuming, since it required approximately six blows across the width of the 12-foot (3.66-m) lane. Also, it did not always produce the desired cracking pattern. Therefore, a second type of cracker was used for other experimental



Treatments:
A: Underseal, 41/4 Inch Overlay
B: Crack & Seat, 5 Inch Overlay
C: Crack & Seat, 61/2 Inch Overlay
D: Crack & Seat, 81/2 Inch Overlay

1: Fiber Reinforced Base
2: Fiber Reinforced Base & Binder

FIGURE 1 Location of various treatments.

sections. The new cracker was a 7-ton guillotine-type drop hammer manufactured by Wirtgen. With the drop hammer, only one blow was required to produce a crack across the full width of the lane, and the cracks were more consistent in pattern than those produced by the whip hammer. The drop hammer needed only about one-sixth of the time required by the whip hammer to produce a transverse crack of full lane width.

After cracking the slabs, a 50-ton rubber-tired roller pulled by a rubber-tired tractor was used to seat the pavement. The seating process was intended to reduce the voids between the cracked slabs and the subbase. The Dynaflect was used to test the pavement deflection before and after cracking of some selected sections in the travel lane. The Dynaflect has five sensors for deflection measurements. Sensor 1 is located between the two loading wheels of the Dynaflect, and Sensors 2 through 5 are spaced at 1-ft (30.5-cm) increments from Sensor 1, with Sensor 5 being the farthest (4 ft or 122 cm) from Sensor 1. In practice, sensor 1 is used as an indicator of slab strength, and sensor 5 is used as an indicator of the base and subbase support strength. To compare the changes of slab and subbase strength, the deflection values before cracking and after cracking and three passes of the roller are plotted in Figures 2 and 3. The two figures show that the sections cracked with the whip hammer (Figure 3) lost more strength than those cracked with the drop hammer (Figure 2). This indicates that the cracking process with the whip hammer may have disturbed the consolidation of the subbase and damaged the aggregate interlock between the produced small slab pieces. This was evidently related to the fact that too many blows were required for the whip hammer to produce each transverse crack.

The deflections after a various number of roller passes on the whip hammer cracked sections are plotted in Figure 4. Because the seating process was to impress the slab pieces onto the subbase, it was expected that the deflections would decrease with each pass of the roller. However, as shown in Figure 4, the deflections under both sensors did not decrease but increased with the number of passes. That is, both the concrete slabs and the subbase lost, instead of gained, strength in the seating process. The possible reason for this strength decrease was that the heavy roller further weakened the very little remaining aggregate interlock between slab pieces produced by the whip hammer. The rolling process then caused

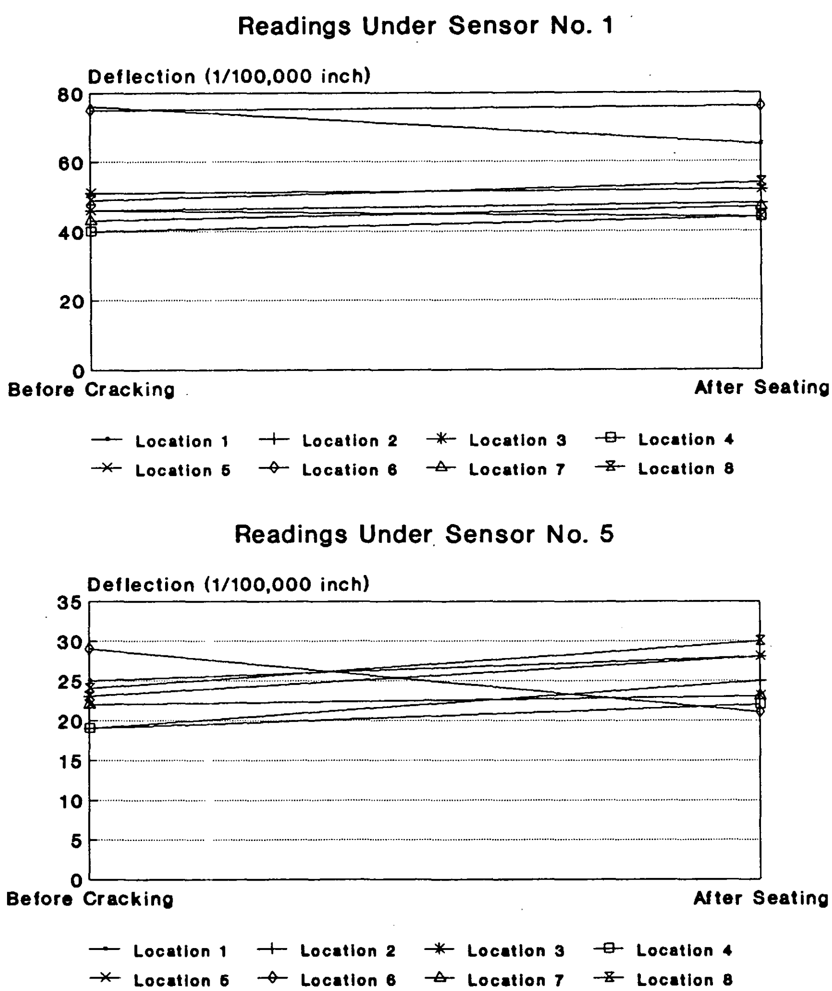


FIGURE 2 Deflections before and after cracking and seating at various locations (on drop hammer-cracked sections).

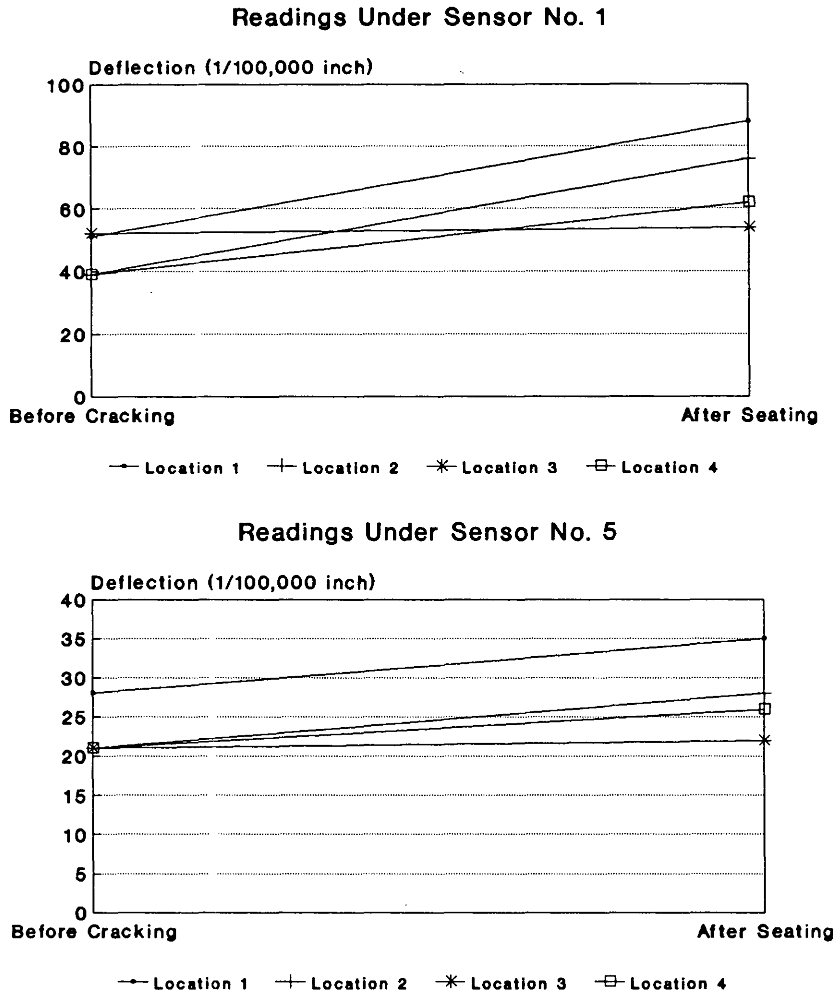


FIGURE 3 Deflections before and after cracking and seating at various locations (on whip hammer-cracked sections).

the slab pieces to rock on the subbase. The slab pieces were unseated instead of seated as was intended. Therefore, the whip hammer was not suitable for the cracking and seating process because it was not only time consuming to use, it also caused significant strength decrease of slabs and subbase support. The drop hammer, however, proved to be efficient and produced the required cracks and maintained aggregate interlock between the slab pieces as desired.

As control sections, treatments A, A1, and A2 were overlaid by the conventional method. Before they were overlaid, the concrete slabs were first undersealed in areas showing high deflections with oxidized asphalt to improve the strength and the uniformity of the subbase support.

The polypropylene fibers were 0.4 in. (1.0 cm) long and were added at the rate of 0.3 percent by weight of the asphalt mixture (approximately 6 lb of fibers per ton of asphalt mixture) to the base layer of sections A1 and B1 and to the base and binder layers of section A2 and B2. The effects of the fibers on the asphalt mixture were assessed by visual inspections of the mixture during construction. The fibers appeared to decrease the segregation of the mixture at the plant and during placement on the roadway, especially for the larger maximum aggregate size base.

PAVEMENT PERFORMANCE

The pavement condition has been monitored for 7 years since the rehabilitation. The Dynaflect deflection test, a visual survey of reflective cracks, rutting measurements, and roughness tests, was conducted each year. These pavement condition data are summarized in this section to study the performance of each rehabilitation treatment. To examine the effects of cracking equipment, Treatment D is divided into the following two groups:

1. D(drop)—Treatment D cracked with the drop hammer and
2. D(whip)—Treatment D cracked with the whip hammer.

Pavement Strength

Table 1 shows the average deflection values for 6 of the 7 years of the study period (1987 data are missing) for all the treatments. The deflection data were adjusted to the standard temperature of 70°F (21°C) according to the manual for Dynaflect operation (*1*). Sensor 1 is used as an indicator of pave-

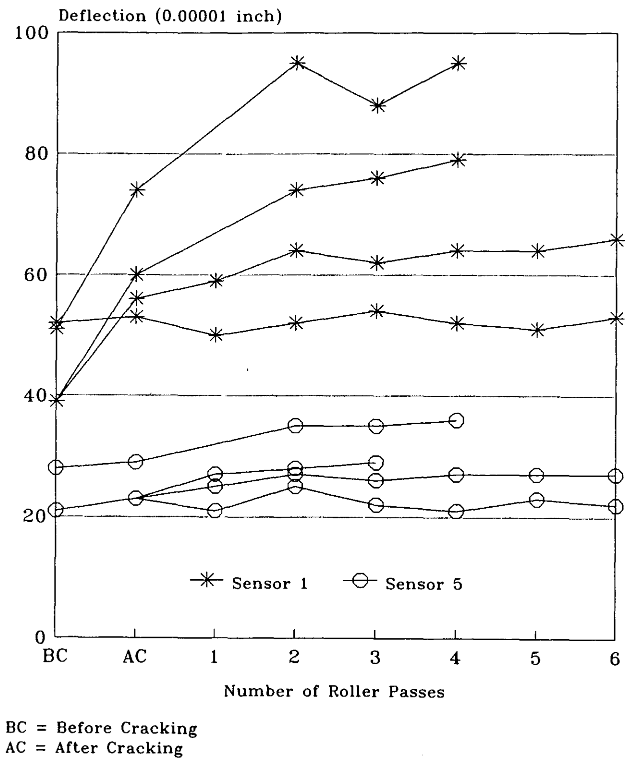


FIGURE 4 Slab deflections for various numbers of roller passes (on whip hammer-cracked sections).

ment strength, and Sensor 5 is used as an indicator of the base and subbase support strength. Readings of 50×10^{-5} in. (0.0127 mm) or less by Sensor 1 and 30×10^{-5} in. (0.00762 mm) or less by Sensor 5 are indications of adequate pavement strength and good subbase support, respectively.

The data in Table 1 indicate that all the sections have undergone some decrease in strength during the 7-year period. However, the data show that all the sections still had good pavement strength and subbase support after 7 years in service. To compare the strengths and the strength changes of the treatments, the deflection values under Sensor 1 in 1991 and the percent changes of these values are listed below.

Treatment	*Deflection (1991)*	*Change (1991 Versus 1985) (%)*
D(drop)	28	16.7
D(whip)	30	7.1
C	32	10.3
A	32	18.5
B	33	13.8
A1	34	21.4
A2	35	45.8
B1	36	38.5
B2	39	39.3

Because the deflection values are listed in ascending order, it is easy to observe the following:

1. All the sections still had adequate pavement strength with deflection values lower than 50.
2. Comparing Treatments D, C, and B for the cracked and seated sections, the thicker the overlay was, the higher was the pavement strength (or the lower was the deflection value). However, the differences were not significant.
3. The strength of Treatment A (4.25-in. conventional overlay) was equivalent to the strength of Treatment C (6.5-in. cracked and seated overlay).
4. The sections of Treatments A1, A2, B1, and B2 experienced greater loss of strength (with higher percent changes of deflection values) than other sections.

Because it was known that the use of fibers could increase the stiffness and tensile strength of the asphalt mixtures, it was expected that the sections with fibers would have a somewhat higher pavement strength. The deflection data, however, do not support this. The reason for this could not be known without further study of the mixture material, but the

TABLE 1 Average Pavement Dynaflect Deflection Values by Treatments (10^{-5} in.)

Treatment	Year											
	1985		1986		1988		1989		1990		1991	
	S1	S5	S1	S5	S1	S5	S1	S5	S1	S5	S1	S5
A	27	16	30	18	34	18	-	-	33	18	32	17
A1	28	18	36	22	36	22	36	21	37	21	34	18
A2	24	15	32	19	-	-	29	15	32	17	35	19
B	29	17	32	18	34	18	33	18	38	20	33	15
B1	26	15	32	17	-	-	27	15	32	17	36	19
B2	28	16	35	20	-	-	30	16	33	17	39	20
C	29	18	29	19	32	19	30	18	34	20	32	16
D(whip)	28	16	28	18	27	16	-	-	32	17	30	14
D(drop)	24	14	26	16	27	15	25	14	28	17	28	15

Note: S1 -- Sensor No. 1
S5 -- Sensor No. 5
D(whip) -- Sections of Treatment D Cracked with Whip Hammer
D(drop) -- Sections of Treatment D Cracked with Drop Hammer

loss of strength may have been caused by the decrease in bonding between the fiber and the asphalt mixture as the asphalt hardens with time. As the bond in the interface between the fiber and asphalt reduced or disappeared, the fiber could no longer reinforce the mixture but became detrimental to the integrity and the strength of the mixture. This issue should be investigated further.

Pavement Roughness

Pavement roughness testing was performed annually with a PCA Roadmeter. Table 2 gives the average roughness numbers (RN) and the corresponding present serviceability indexes (PSI) for each treatment from 1985 to 1991. A roughness number is a measure of the square of the number of ⅛-in. (3.2-mm) movements of the automobile body with respect to the rear axle. The lower the roughness number is, the better is the rideability of the pavement. The roughness numbers have been correlated to PSI values ranging from 0 to 5. A PSI of 2.5 or less is considered unsatisfactory on interstate pavements. Table 2 shows that the PSI values for all treatments were fairly high except in 1988. However, the PSI values for 1988 are suspiciously low compared with the data for the other 6 years. Because no significant changes in pavement condition were observed during the visual inspection in 1988, it is believed that the roughness data for 1988 are not accurate because of some equipment or operational problem.

The PSI values for the other 6 years indicate that the pavement rideability for all sections was good during the study period. The data for 1991 indicate that the pavement was still in good condition with respect to roughness or rideability after 7 years in service. There were no significant differences in pavement roughness between either the control sections and the cracked and seated sections or the sections with and without fibers.

Transverse Cracks

General Observations and Comparisons

Figure 5 illustrates the average transverse crack intensities for various treatments over the 7-year study period. The crack intensities are expressed as the number of transverse cracks per 1,000 ft of pavement section. Each transverse crack across the whole width of the pavement (24 ft or 7.3 m) is counted as one transverse crack, and a crack of a lane width (12 ft or 3.7 m) is counted as one-half transverse crack. This figure shows that the cracked and seated sections had fewer transverse cracks than the control sections in the first 5 years, even though the crack intensities on these sections were not significantly different in the last 2 years. Therefore, the crack-and-seat technique successfully delayed the crack development for 5 years. This deferment of crack development is very desirable because it can prolong the service life of the pavement and reduce maintenance activities.

It was observed that the transverse cracks were spaced in regular intervals of about 40 ft (12.2 m) on control sections but spaced randomly on the cracked and seated sections. The cracks on the control sections apparently developed over the joints of the underlying concrete pavement because the spaces between joints are 40 ft (12.2 m). This indicates that these transverse cracks on the control sections are truly reflective cracks, or they were caused mainly by movement of the concrete slabs beneath the asphalt overlay because of the thermal and moisture changes. However, it is believed that the transverse cracks on the cracked and seated sections were mainly caused by the contraction of the asphalt overlay as a result of low temperatures or hardening of the asphalt mixture.

The difference in crack severity between the control sections and the cracked and seated sections was also noticed during the annual visual inspections. Most of the transverse cracks on the control sections were in the categories of medium and high severities, whereas the cracks on the cracked and seated sections were of low severity. The widths of the

TABLE 2 Roughness Number and Present Serviceability Index Data by Treatments

Treatment	Year													
	1985		1986		1987		1988		1989		1990		1991	
	RN	PSI	RN	PSI	RN	PSI	RN	PSI	RN	PSI	RN	PSI	RN	PSI
A	272	3.96	396	3.64	431	3.54	721	3.10	523	3.38	431	3.54	318	3.80
A1	-	-	-	-	452	3.50	1434	2.51	634	3.21	452	3.50	345	3.73
A2	320	3.79	-	-	-	-	1676	2.34	502	3.41	353	3.71	260	3.97
B	235	4.06	403	3.60	426	3.55	721	3.10	514	3.39	402	3.60	307	3.83
B1	290	3.88	327	3.80	-	-	1390	2.54	446	3.51	397	3.61	260	3.97
B2	251	4.00	398	3.61	584	3.28	1841	2.30	538	3.35	379	3.65	260	3.97
C	181	4.28	330	3.77	426	3.55	730	3.09	457	3.49	379	3.65	314	3.81
D(whip)	251	4.00	388	3.12	386	3.63	2175	2.16	554	3.33	465	3.48	363	3.68
D(drop)	197	4.21	342	3.74	390	3.63	666	3.17	492	3.43	360	3.69	288	3.88

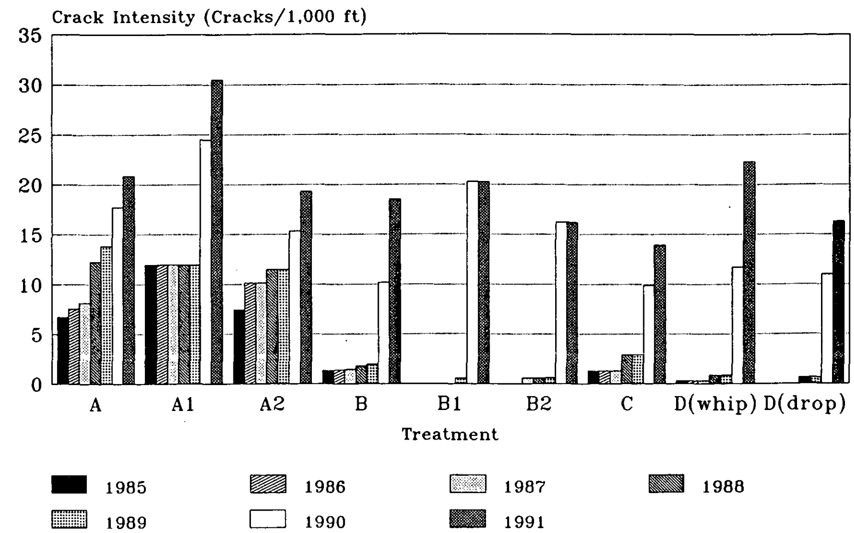


FIGURE 5 Development of transverse cracks with time for all treatments.

crack openings ranged from 0.25 to 2 in. (0.6 to 5.1 cm) on the control sections, but from 0.04 to 0.25 in. (0.1 to 0.6 cm) on the cracked and seated sections. The wide openings of the reflective cracks on the control sections served as entrances for water to get into the pavement and therefore caused the asphalt mixture near the cracks and the concrete joints underneath to deteriorate. The deterioration of the joints then in turn further accelerated the deterioration of the asphalt overlay. On the other hand, the transverse cracks on the cracked and seated sections had much less deterioration, lower severity, and narrower opening. Figure 6 presents a picture of deteriorated pavement around a reflective crack in Treatment A and a picture of a typical transverse crack on a cracked and seated section. Picture A shows that raveling (dislodging of aggregate particles) and weathering (loss of asphalt binder) have occurred on the pavement around the reflective crack on the control section, and a pothole has also developed in the area. Picture B shows that the transverse crack on the cracked and seated section has a much lower severity.

The better conditions of cracks on the cracked and seated sections can be explained as follows. First, the cracking and seating technique reduced the size of concrete slabs and impressed the small pieces onto the subbase, which limited the horizontal and vertical slab movements and, therefore, the reflective cracking. Second, most of the transverse cracks (thermal cracks instead of reflective cracks) emerged 5 years later than the reflective cracks on the control sections. This delay of crack occurrence allowed less time for water penetration and other detrimental effects to damage the pavement through the cracks than on the control sections. Third, the thermal cracks were generally narrower and less than the reflective cracks.

As can be seen in Figure 5, the crack intensities on the cracked and seated sections increased more quickly than those on the control sections during the last 2 years. On the cracked and seated sections, the final crack intensities were almost the same as or even higher than those on the control sections.

It was found during the visual inspections that most of those cracks that did emerge on the control sections in the last 2 years were similar to those on cracked and seated sections—that is, they were most likely thermal instead of reflective cracks. The reason that the control sections did not develop as many transverse cracks in the last 2 years as the cracked and seated sections was probably because many reflective cracks developed in the first 5 years, reducing the effective contraction size of the asphalt overlay. In other words, the reflective cracks on control sections worked as contraction joints to relieve pavement tensile stress and, therefore, limited the development of thermal cracks in the last 2 years.

Effects of Cracking and Seating, Overlay Thickness, and Types of Crackers

The changes in crack intensities with time for Treatments A, B, C, D(whip) and D(drop) are shown in Figure 7. The differences in crack intensities between Treatment A and cracked and seated treatments are clearly illustrated by the figure. Treatment A had much higher crack intensity values consistently during the 7-year period, except for the last year when it had a slightly lower value than Treatment D(whip). In 1989 or the year before the crack intensity values jumped, the crack intensity value for Treatment A was about 5 to 21 times as high as the values for other treatments. It is apparent that the cracking and seating technique was successful in reducing the transverse cracks. In addition, as discussed earlier, this technique also significantly alleviated the severity of cracks and the deterioration of the pavement around the cracks.

Among the cracked and seated treatments, Figure 7 indicates that during the first 5 years the thickest overlay, Treatments D(whip) and D(drop), had lower crack intensities than the thinner overlays. However, comparing Treatments B (5-in. overlay) and C (6.5-in. overlay), the differences in crack intensities were not significant, and Treatment C even had higher crack intensity values in 1988 and 1989. Furthermore, according to the figure, in 1991 Treatment C (6.5 in.), but not D(drop) or D(whip) (8.5 in.), had the lowest final intensity value. These results indicate that the increase of overlay

FIGURE 6 Examples of transverse cracks: *left*, deteriorated pavement around a reflective crack on control section; *right*, typical transverse crack on cracked and seated section.

thickness on cracked and seated sections indeed reduced pavement cracking for a while, but the reduction was not consistent or significant. Considering the cost involved, the option of using a thicker overlay to control pavement cracks is not recommended.

As indicated in Figure 7, the crack intensity values for Treatment D(whip) were slightly higher than those for Treatment D(drop) in the first 6 years. However, in 1991, Treatment D(whip) increased its crack intensity at a much greater rate than did D(drop). It has been shown in the previous section that the whip hammer was time consuming to use and caused a significant decrease in strength of the original concrete pavement. With the intensity values, D(whip) once again proved its relative weakness compared with D(drop). It is therefore strongly recommended that whip hammers not be used in the cracking operation.

Effects of Fibers

The crack intensities for Treatments A and B and their corresponding sections with fibers (A1, A2, B1, and B2) are plotted in Figure 8. The figure shows that the control sections (A, A1, and A2) were in much worse condition with respect to crack intensities for most of the time. Comparing the curves for treatments A, A1, and A2, it can be concluded that use of the fibers in the base layer (Treatment A1) or in both base and binder layers (Treatment A2) did not delay or reduce transverse cracking on the control sections. This is because the majority of the transverse cracks in these sections were reflective cracks caused mainly by the horizontal and vertical movements of the concrete slabs. The movements of the uncracked concrete slabs were significant because of the large slab size and the existence of joints. They produced too great a stress in the asphalt overlay to be offset by the bonding between asphalt and fibers.

On the other hand, Figure 8 also shows that use of fibers further reduced or delayed the transverse cracking on cracked and seated sections (B1 and B2) as compared with Treatment B. Treatments B1 and B2 were not significantly different in crack intensities during the study period, but for most of the time Treatment B1 had the same or lower crack intensities than Treatment B2. This indicates, although contrary to what was expected, that the use of fibers in the binder layer in addition to in the base layer did not provide further help in reducing transverse cracks in this project. It appears that the option of cracking and seating in combination with adding fibers in the base layer should be most appropriate for cracking control.

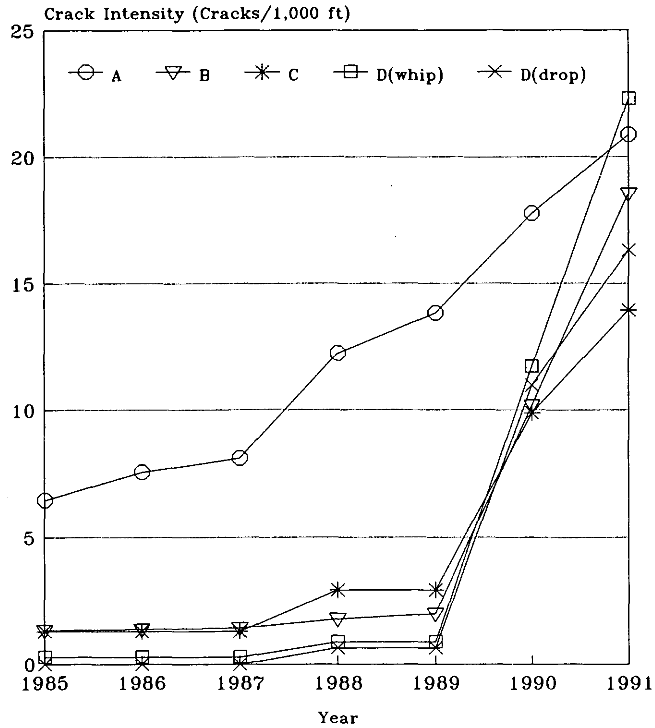


FIGURE 7 Comparison of crack intensities on control and experimental sections.

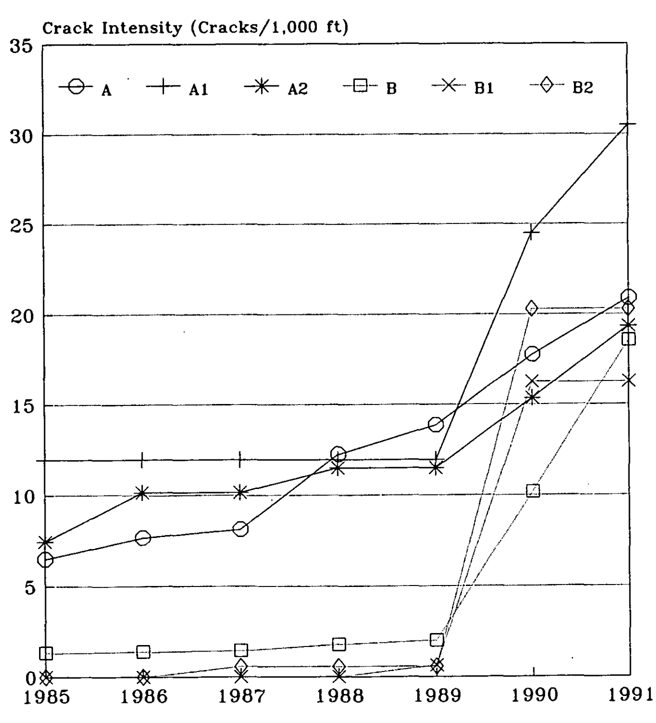


FIGURE 8 Comparison of crack intensities on sections with and without fibers.

Rutting

Ruts were measured in the wheelpath using a 4-ft (1.2-m) straightedge. Rutting on this project was negligible in 1985 and 1986. In 1987 ruts were approximately 1/16 in. (1.6 mm) for all sections with fiber and 1/8 in. (3.2 mm) for all other sections. These ruts did not develop further according to the measurements taken between 1988 and 1991. The slightly reduced rutting in fiber sections was the result of fiber reinforcement. The measurements showed that the cracking and seating technique did not affect pavement rutting.

COST ANALYSIS

The construction cost per mile for each treatment is listed as follows:

Treatment	*Cost ($/mi)*
A	247,974
B	272,998
C	340,838
D	431,290

The data show that the increase of overlay thicknesses significantly increased the construction costs on the cracked and seated sections. Because various thicknesses and techniques were involved, the pavement service lives for the treatments are expected to be different. To compensate for the higher costs on the cracked and seated sections, these sections must have longer service lives than the control sections. A life-cycle analysis was conducted on the basis of an interest rate of 7 percent to compare the control sections and the cracked and seated sections. The life-cycle cost of a pavement depends on the service life of the pavement (*2*). The construction costs for all treatments were converted to equivalent uniform annual costs for different service lives between 10 and 20 years, as shown in Figure 9. The maintenance costs were not available and therefore were not included in the analysis.

A 10-year service life is a reasonable estimation for a conventional asphalt overlay such as Treatment A. If treatment A has a service life of 10 years, then Treatments B, C, and D should have service lives of longer than 10 years to have the same life-cycle cost as that of Treatment A. A dashed horizontal line is drawn in Figure 9 to determine that the minimum service lives for these treatments are as cost-effective as Treatment A with a service life of 10 years. The intersections of the horizontal line and the cost curves indicate that the minimum service life required is about 11.5 for Treatment B, and 16.7 for Treatment C. That is, Treatments A, B, and C would have the same uniform annual costs if their service lives were 10, 11.5, and 16.7 years, respectively. The uniform annual cost for Treatment D was so high that even at the 20-year service life it is still much higher than that for Treatment A with a 10-year life. Because the thicker overlays did not improve pavement performance considerably but greatly increased construction costs, it is recommended that the thickness of asphalt overlay be determined only by the pavement strength requirement, but not be increased as a means of cracking control. Considering the cost as well as the performance, Treatment B should be the best choice for this project.

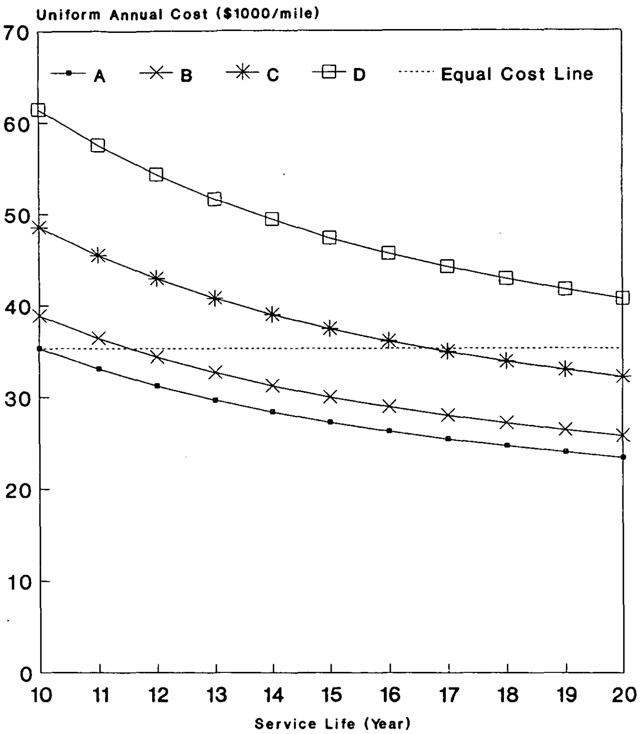


FIGURE 9 Equivalent uniform annual costs with various service lives.

CONCLUSIONS AND RECOMMENDATIONS

This study evaluated two methods for reducing pavement cracking on asphalt overlay over concrete pavement: cracking and seating before overlay and fiber reinforcement in the overlay mixture. On the basis of the analysis of the 7-year data, the following conclusions and recommendations are made.

1. The cracking and seating technique was successful in this project. It delayed most of the transverse cracks for 5 years. The majority of the transverse cracks on the cracked and seated sections were thermal cracks, which were narrower and less severe than the reflective cracks on the control section.
2. The type of hammers used for cracking concrete slabs had strong effects on pavement strength. The sections cracked with the whip hammer developed more transverse cracks than did the sections cracked with the drop hammer. It is recommended that the whip hammer not be used for cracking and seating projects.
3. Use of fibers in the overlay mixtures further reduced transverse cracks on cracked and seated sections, but did not improve the cracking resistance of the control sections. Adding fibers in the base layer of the asphalt overlay on cracked and seated sections proved to be as effective for cracking control as adding fibers in both base and binder layers.
4. Use of fibers improved rutting resistance on both the control and the cracked and seated sections.
5. Sections including fibers exhibited quicker decreases of pavement strength than did other sections.
6. The increase of overlay thickness improved pavement strength, as expected. However, thicker overlays increased the construction costs significantly but did not reduce the transverse crack intensities. The pavement performance and the cost analysis indicate that Treatment B, the thinnest cracked and seated overlay, should be the best choice for this project. It is recommended that the thickness of asphalt overlay be determined only by the pavement strength requirement and not be increased as a means of cracking control.

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