A Study of the Performance of Three Asphalt Pavement Rehabilitation Strategies

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This study analyzes the performance of three common hot mix asphalt rehabilitation strategies on 149 pavements over a period of seven years. All three strategies place two-inch overlays on the pavement to be rehabilitated. The first strategy includes an overlay on the existing pavement after sweeping the surface and applying a tack coat. The second strategy places the overlay after removing two inches of the existing pavement by cold milling. The third strategy places the overlay after treating the existing pavement using the heater scarification process. Performance was evaluated with respect to PG binder temperature range, traffic volume, overlay nominal maximum aggregate size, and climate. Data analyzed in the study was obtained from a pavement management system that is updated annually with respect to pavement condition. Results of this analysis indicate that two of the rehabilitation strategies perform approximately equal with one performing slightly better than the other, and both performing significantly better than the third. Polymer modified asphalts enhanced pavement performance depending on which rehabilitation strategy was utilized. Pavements were generally rehabilitated before reaching the zero service life threshold. However, when fatigue cracking was present in the original pavements, this was not the case. These pavements were rehabilitated when the zero remaining service life threshold had been reached or when pavement condition exceeded this threshold. This indicates rehabilitation would have been warranted earlier in the life of these pavements. As a result, the expected life of the rehabilitation strategies utilized on these pavements may be shorter than could be expected had rehabilitation been done before distress reached this high level.

Keywords: Asphalt pavement rehabilitation, pavement performance, zero remaining service life

Literature Review

A review of the literature did not reveal any studies specifically evaluating performance of the three rehabilitation strategies presented here. However, studies have been done to evaluate pavement performance over time including a Texas study (1) where reflective cracking of asphalt overlays on jointed concrete was done to evaluate six rehabilitation methods. Another study in Pennsylvania (2) evaluated techniques for selecting correct pavement rehabilitation strategies. They determined that understanding project history was most significant although assessment of traffic history, evaluation of materials used, general understanding of past construction practices, history of climate, and an understanding of the type of subgrade were also factors. A study for the Nevada Department of Transportation (3) developed a network optimization system to evaluate alternate rehabilitation techniques and then recommended the most efficient and cost effective technique for different sections of highway.

Background

Rehabilitation of asphalt pavements is done when pavement condition is below that where preventive maintenance treatments can restore serviceability. The cost of rehabilitation varies based on damage severity and the rehabilitation method. In addition, the length of time the rehabilitation method is effective is dependent on the method used, pavement condition prior to rehabilitation, traffic, climate and materials.

This study provides an evaluation of the performance of three common rehabilitation methods utilized to restore serviceability to hot mix asphalt pavements. It is believed that each of these rehabilitation methods performs differently depending on how and where the method is being utilized. However there has not been an extensive study examining the performance of each method, so relative performance and cost effectiveness of the rehabilitation strategies are not well understood.

Rehabilitation Methods Studied

Two-Inch Overlay

This process includes a dense graded hot mix asphalt overlay applied directly over the existing asphalt pavement. The only preparation of the existing surface includes sweeping and tack coat.

Cold Planing and Overlay

Cold planing and overlay involves removing the top two inches of the existing pavement with a milling machine at ambient temperatures. The milled pavement surface is then swept, a tack coat applied and a two inch dense graded hot mix overlay applied.

Heater Scarification and Overlay

Heater scarification and overlay begins with the process of heating the pavement with infrared or propane heaters, scarifying the heated pavement, and then spraying a rejuvenating agent on the scarified surface. The rejuvenating agent and the scarified asphalt pavement are mixed together and leveled using a screed. After this rejuvenated material is leveled and compacted a two-inch hot mix asphalt surface is placed.

Independent Variables Evaluated

Independent variables evaluated for each of the rehabilitation strategies were:

a. PG Binder Temperature Range
b. Traffic Volume
c. Overlay Nominal Maximum Aggregate Size
d. Climate

PG Binder Temperature Range

Asphalts used in this study were graded according to the Superpave PG system. The projects were analyzed based on PG temperature range of greater than 90C and less than 90C.

Traffic Volume

The highways are split into three different traffic volumes based on 20 year, 18 kip equivalent single axle loads (ESALs):

- Low Traffic   < 0.3 million ESALs
- Moderate Traffic   0.3 to 11 million ESALs
- High Traffic   > 11 million ESALs

Overlay Nominal Maximum Aggregate Size

Two hot mix aggregate gradations were evaluated in this study. The 'S' gradation has a nominal maximum aggregate size of 1 inch. The 'SX' gradation has a nominal maximum aggregate size of ¾ inch.

Climates

Four different temperature regimes were evaluated: a very cool environment has an average seven day high air temperature of less than 81F, a cool environment with a average high air temperature between 81 – 88F, a moderate environment that has an average high air temperature between 88 – 97F, and a hot environment that has an average high air temperature of greater than 97F (4).

Performance Evaluated

Performance was judged based on the condition of the pavements over time with respect to each of the following criteria:

1. Smoothness
2. Rutting
3. Fatigue Cracking
4. Transverse Cracking
5. Longitudinal Cracking

Experimental Method

Data analyzed in this study was obtained from the pavement management database of the Colorado Department of Transportation. This database houses the results of pavement condition surveys collected annually by automated photo survey and laser profilometer equipment. Data has been collected and stored in the database using this technology since 1999. Data from 1999 to 2006 were analyzed in this study. Pavement condition is recorded in increments of 0.10 mile for various lengths of highway ranging from one to six miles. Each of these 0.10-mile increments represents a data point. The condition of each roadway was represented by calculating a moving average from five of these data points for the length of roadway evaluated each year. The change in condition was then determined by comparing the average of the moving averages from year to year.

Each roadway in the study was evaluated this way for each year of condition surveys.

A total of 149 roadways were evaluated in this study separated by the three rehabilitation methods as shown in Table 1:

Table 1
Rehabilitation Methods for Roadways Studied

Rehabilitation Method	**Roadways Studied**
Two Inch Overlay	73
Cold Planing ad Overlay	57
Heater Scarification and Overlay	19
Total	**149**

The analysis was done from one year prior to rehabilitation to six years after rehabilitation. This way, the condition of the pavements prior to rehabilitation could be captured in the analysis so that the amount of time required to return the pavements to pre-rehabilitation condition could be determined. This allows calculating the service length of each of the rehabilitation strategies. That is, if a pavement had 500 square feet of fatigue cracking at the time of rehabilitation and fatigue cracking re-appears after rehabilitation at the rate of 100 square feet per year, then it will take five years for the pavement to return to the pre-rehabilitated condition with respect to fatigue cracking.
The cumulative change in smoothness with time can then be determined as shown in Table 2.

A linear regression of Change in Smoothness vs. Time from Year 0 to Year 6 results in:

$$\Delta \text{ IRI} = 8.42 \text{ T}$$

Where,

Δ IRI = Change in IRI in inches per mile
T = Time After Rehabilitation, yrs

Table 2
Cumulative Smoothness Change for Planing and Overlay Projects

Year	Smoothness Change, inches/mile/year (from Table 3)	Cumulative Smoothness Change, inches/mile/year
0	0	0
1	11.3	11.3
2	6.3	17.6
3	10.2	27.8
4	7.7	35.5
5	3.3	38.8
6	15.6	54.4

The same analysis was done for each of the other rehabilitation methods with respect to smoothness resulting in the following expressions when all projects are considered:

Overlay	Δ IRI = 8.20 T
Cold Planing	Δ IRI = 8.42 T
Heater Scarification	Δ IRI = 14.59 T

This analysis was also done for the other performance output variables for each rehabilitation method. The results are shown in Table 3 for all projects indicating coefficient of determination and number of projects utilized in the regression.

Zero Remaining Service Life (ZRSL) is the point at which the level of distress present in the roadway exceeds what is considered acceptable. Those values are shown below and will be indicated on the performance curves as bold horizontal lines to provide a reference regarding when the pavements were actually rehabilitated with respect to ZRSL.

- Smoothness, IRI 300 inches/mile
- Rutting 0.55 inches
- Fatigue 1,800 square feet
- Transverse Cracking 55 cracks per 0.1 mile
- Longitudinal Cracking 1,400 linear feet

Table 3
Linear Regression for Change in Performance for First Six Years

		Slope	**R^2**	**n, Avg**
Smoothness	Cold Planing	8.42	0.82	16
	Overlay	8.20	0.81	28
	Heater Scarification	14.59	0.83	11
	Average	10.26		
Rutting	Cold Planing	0.03	0.83	29
	Overlay	0.05	0.70	45
	Heater Scarification	0.06	0.79	10
	Average	0.04		
Fatigue Cracking	Cold Planing	86.42	0.50	28
	Overlay	191.35	0.42	44
	Heater Scarification	241.37	0.65	10
	Average	171.49		
Transverse Cracking	Cold Planing	2.38	0.71	40
	Overlay	3.72	0.64	57

	Heater Scarification Average	6.47 4.19	0.73	13
Longitudinal Cracking	Cold Planing Overlay Heater Scarification Average	53.14 55.01 96.79 68.31	0.66 0.61 0.68	28 37 10

Results

All of the pavement performance data is represented in Figures 1 through 5 for smoothness, rutting, fatigue, transverse and longitudinal cracking with respect to each rehabilitation method. Each of these figures represents the absolute value of the respective performance measure with the exception of smoothness, which is represented as the change in smoothness over time. This was done because the absolute value for smoothness is the only parameter that does not start from zero after rehabilitation. Therefore, to compare each project on an equal basis, the change in smoothness was represented in Figure 1, instead.

The results presented in Figures 1 through 5 indicate several things:

- Cold planing with an overlay and the simple overlay tend to outperform heater scarification with an overlay for each performance indicator
- Cold planing with an overlay outperforms the simple overlay for each performance indicator
- Pavement condition where heater scarification and overlay was the rehabilitation method tended to be poorer than the other two rehabilitation methods
- Pavement condition tended to be below the Zero Remaining Service Life Threshold for all performance indicators except fatigue cracking. The condition of the pavements where cold planing and heater scarification were utilized exceeded the ZRSL threshold.

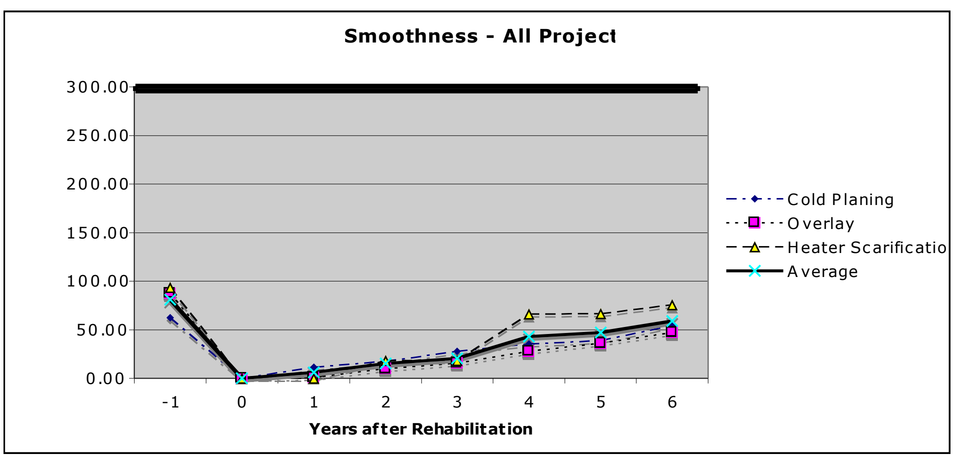

Figure 1: Smoothness With Respect to Rehabilitation Method Over Time

Figure 2: Rutting With Respect to Rehabilitation Method Over Time

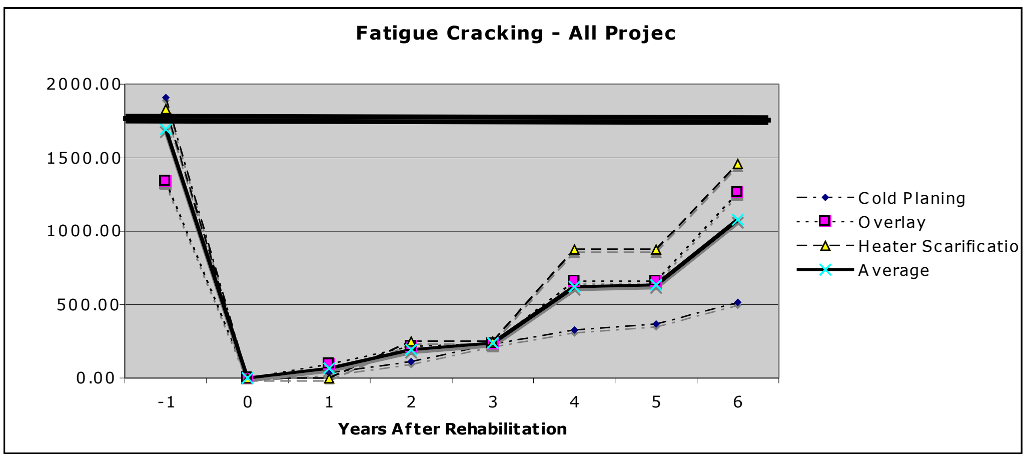

Figure 3: Fatigue Cracking With Respect to Rehabilitation Method Over Time

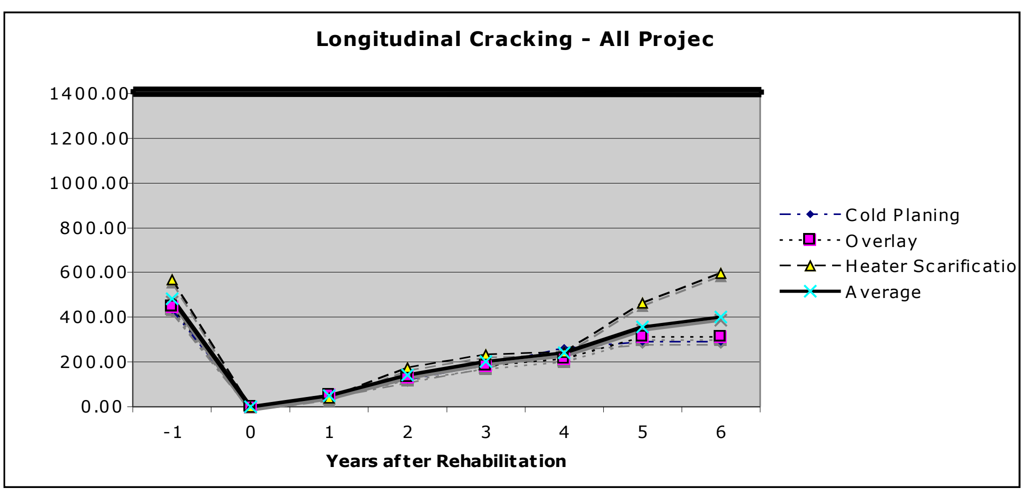

Figure 4: Longitudinal Cracking With Respect to Rehabilitation Method Over Time

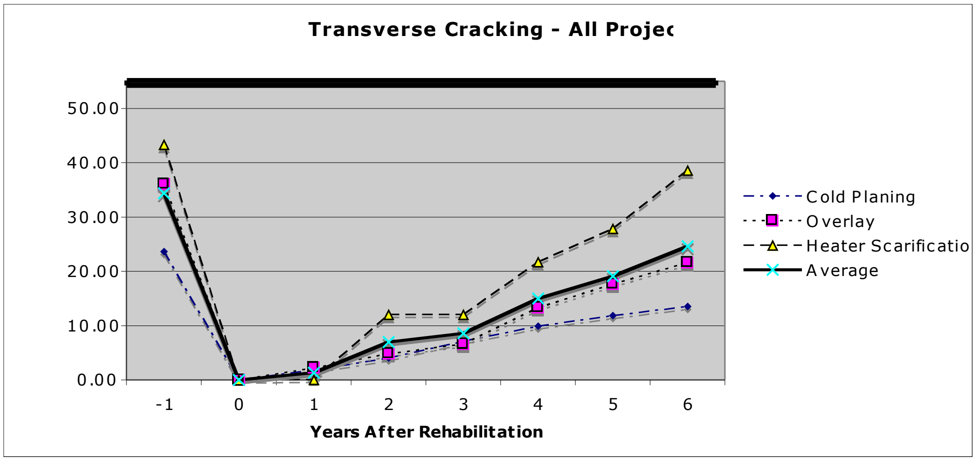

Figure 5: Transverse Cracking With Respect to Rehabilitation Method Over Time

Analysis

These preliminary results lead to further investigation to determine why the heater scarification rehabilitation process tended to under perform compared with cold planing and simple overlays.

For example, fatigue performance of the cold planing and overlay process significantly outperforms the heater scarification and overlay process although both methods are practiced on pavements with fatigue levels exceeding the ZRSL threshold prior to rehabilitation. To determine why this difference exists the data were further evaluated to determine if one process was used more on lower traffic roadways or with more polymer modified asphalts in the overlays compared with the other which might provide an advantage.

Neither method was utilized on low traffic pavements, but both methods were used on moderate (0.3 to 11M EALs) and high traffic (> 11M ESALs) pavements. The rate of change of fatigue cracking for moderate traffic pavements was 312 square feet per year for heater scarification compared with 82 square feet per year with cold planing. On high traffic pavements a similar result occurs with 202 square feet per year occurring with heater scarification and 77 square feet per year occurring with cold planing. A similar result is found when polymer (> 90C PG temperature range) and non-polymer (<90C PG temperature range) modified mixtures are compared. Polymer modified mixtures fatigue at the rate of 247 square feet per year when heater scarification is used as the rehabilitation method compared with 391 square feet per year for non-polymer modified mixtures. The cold planing process leads to 82 square feet per year when polymer modified mixtures are used as the overlay and 72 square feet per year when non-polymer modified mixtures are used.

The rate of change of transverse cracking for moderate traffic pavements was 7.3 cracks per year for heater scarification compared with 2.6 cracks per year with cold planing. On high traffic pavements a similar result occurs with 5.3 cracks per year occurring with heater scarification and 2.0 cracks per year occurring with cold planing. A similar result is found when polymer (> 90C PG temperature range) and non-polymer (<90C PG temperature range) modified mixtures are compared. Polymer modified mixtures crack at the rate of 5.0 cracks per year when heater scarification is used as the rehabilitation method compared with 14.0 cracks per year for non-polymer modified mixtures. The cold planing process leads to 2.5 cracks per year when polymer modified mixtures are used as the overlay and 2.3 cracks per year when non-polymer modified mixtures are used.

The rate of change of rutting for moderate traffic pavements was 0.08 inches per year for heater scarification compared with 2.6 cracks per year with cold planing. On high traffic pavements a similar result occurs with 5.3 cracks per year occurring with heater scarification and 2.0 cracks per year occurring with cold planing. A similar result is found when polymer (> 90C PG temperature range) and non-polymer (<90C PG temperature range) modified mixtures are compared. Polymer modified mixtures crack at the rate of 5.0 cracks per year when heater scarification is used as the rehabilitation method compared with 14.0 cracks per year for non-polymer modified mixtures. The cold planing process leads to 2.5 cracks per year when polymer modified mixtures are used as the overlay and 2.3 cracks per year when non-polymer modified mixtures are used.

Conclusions

1. Cold planing with an overlay and the simple overlay tend to outperform heater scarification with an overlay for each performance indicator.
2. Cold planing with an overlay outperforms the simple overlay for each performance indicator.
3. Pavement condition where heater scarification and overlay was the rehabilitation method tended to be poorer than the other two rehabilitation methods.
4. Heater scarification did not appear to have a disadvantage to the other rehabilitation strategies with respect to traffic volume or polymer modified asphalt.
5. A greater positive effect on performance occurred when polymer modified asphalt was used with heater scarification compared with cold planing.
6. Pavement condition tended to be below the Zero Remaining Service Life Threshold (ZRSL) for all performance indicators except fatigue cracking. The condition of the pavements where cold planing and heater scarification were utilized exceeded the ZRSL threshold.
7. Rehabilitation would have been warranted earlier in the life of the pavements which reached ZRSL at the time of rehabilitation. As a result, the expected life of the rehabilitation strategies utilized on these pavements may have been shorter than could be expected had rehabilitation been done before distress reached this high level.
8. Although a linear regression was used successfully to compare the rates of change of distress through time for the first six years' service for this research, it is likely a more complex model would be needed to predict performance beyond this time.

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