Effective Timing for Two Sequential Applications of Slurry Seal on Asphalt Pavement

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Abstract: This study evaluated the field performance of asphalt pavements with two sequential slurry seal applications, developed performance models for asphalt pavements without slurry seals and asphalt pavements receiving slurry seals at various times following construction, and identified the optimum time for the application of two slurry seals on asphalt pavements within the Washoe County, Nevada, region. This is a continuation of a previous study in which a single application of slurry seal was investigated. The *MicroPAVER* system was used to evaluate the long-term pavement performance data collected for the last 15 years and the cost-effectiveness of slurry seals applied to new and existing flexible pavements at 0, 1, 3, 5, 7, and 9 years after construction. The data generated in this study clearly reveal an optimum time window for slurry seal application. The optimum times and highest relative benefit of application of slurry seals for both overlaid and newly constructed pavements were when the first slurry seal was applied at 3 years after construction, followed by a second slurry seal at year 7 or 9. Accordingly, it was recommended to apply the first slurry seal for newly constructed and overlaid pavements, respectively, when the pavement condition index (PCI) is 90 and 87, followed by a second slurry seal when the PCI reaches a value of 86 and 77. **DOI: 10.1061/(ASCE)TE.1943-5436.0000521.** © *2013 American Society of Civil Engineers.*

CE Database subject headings: Slurries; Asphalt pavements; Maintenance; Benefit cost ratios.

Author keywords: Slurry seal; Optimum time of application; Pavement preservation; Maintenance; Performance model; Pavement condition index; Cost-benefit ratio.

Introduction

Pavement preservation has been proven to reduce local and state agencies' overall transportation costs. Pavement preservation addresses pavements that are still in good condition or have minor distress. It restores the function of the existing roadway, but does not increase its capacity or strength. With timely pavement preservation, the occurrence of more costly, time-consuming rehabilitation and reconstruction techniques can be reduced. The process also provides users with safer and more comfortable rides. Although the selection of the appropriate pavement-preservation technique is critical for a long-lasting pavement, this study focuses on one of the treatments: the slurry seal.

A slurry seal is a mixture of slow-setting emulsified asphalt, well-graded fine aggregate, mineral filler, and water. It is used to fill cracks and seal areas of old pavements, to restore a uniform surface texture, to seal the surface to prevent moisture and air intrusion into the pavement, and to improve skid resistance (Peshkin et al. 2004).

This study is a continuation of a project conducted by the Pavements/Materials Program at the University of Nevada in Reno, Nevada (UNR), for the Washoe Regional Transportation Commission (RTC) to evaluate the field performance of slurry seals on asphalt pavements. The optimum time for the application of a single slurry seal has already been determined (Hajj et al. 2011), and this study focuses on the optimum time for two sequential applications of slurry seals on asphalt pavements.

Objective

The overall objectives of this study are (1) to evaluate the field performance of asphalt pavements with sequential slurry seal applications, (2) to develop performance models for asphalt pavements without slurry seals and asphalt pavements receiving sequential slurry seals at various times following construction, and (3) to identify the optimum time for the application of sequential slurry seals on asphalt pavements within the RTC region in northern Nevada. The third objective was achieved by evaluating the long-term pavement performance and the cost-effectiveness of sequential slurry seals applied to new and existing flexible pavements with respect to the time of slurry seal application.

Background

Pavement performance is defined as the serviceability trend of the pavement over a design period, with serviceability indicating the ability of the pavement to serve the demand of the traffic in

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the existing condition (Highway Research Board 1962). A pavement performance model can be described as an equation that relates a pavement performance index to time. It serves as a valuable tool to aid in predicting the future condition of the pavement on the basis of current pavement condition data. Additionally, pavement performance models are critical to the pavement-management process because the scheduling of maintenance and rehabilitation (M&R) activities is based on present pavement serviceability conditions measured in the field and future pavement serviceability conditions predicted with pavement performance models (Li and Zhang 2004).

It has been noted that a valuable method to prioritize and justify transportation infrastructure expenditures is the use of road surface condition ratings such as the pavement condition index (PCI) (Hein and Watt 2005). By utilizing road surface ratings in conjunction with construction and maintenance histories, pavement condition prediction models, which are imperative for the development of a complete pavement-management system, can be developed.

It is a fundamental tenet of treatment performance that the same treatment performs differently when applied at different times in the life of the pavement (Peshkin et al. 2004). Highway agencies have realized that the timely application of multiple, sequential treatments throughout the life span of the pavement saves money and provides users with safer and more comfortable rides. There are very few studies in the literature that have addressed the optimal timing of sequential application of surface treatments. Peshkin et al. (2004) investigated the timing of surface treatments by reviewing more than 200 references, among which only a handful of studies that specifically addressed the timing of treatment applications was found (Marasteanu et al. 2008). Most of the studies conducted analyzed the optimal time for a single application of surface treatment. This study addresses the lack of knowledge on optimal time for the application of two sequential slurry seals.

As discussed, this project is a continuation of a slurry seal study by Hajj et al. (2011) in which the optimum time to place a single slurry seal on northern Nevada roads was determined. From their study, it was concluded that the optimum time for application of slurry seal for newly constructed flexible pavements was 3 years after construction. For pavements subjected to overlays, the optimum time to apply slurry seal was between 3 and 5 years after construction. The application of the slurry seal immediately after or 1 year after construction of the asphalt layer was not effective in terms of both the benefit to the users and the cost-benefit ratio for the agency. Similarly, previous work has demonstrated the cost-effectiveness of modified slurry seals (Liu et al. 2010).

Furthermore, Hajj et al. (2011) determined the slurry seal performance lives and the extensions in pavement service life for the various single slurry seal applications. The slurry seal performance life was defined as the number of years for the slurry sealed pavement to reach the PCI of the existing pavement before the treatment application. In other words, the slurry seal performance life is the number of years for the treated pavement section that provides higher user satisfaction before returning to the serviceability condition before treatment. whereas the extension in pavement service life is the number of additional years the pavement will have at the end of its service life (e.g., PCI = 40) owing to the application of the slurry seal. That is, the extension in pavement service life is the number of years for which pavement reconstruction is delayed. Typically, the slurry seal performance life ranged from 2.0–4.0 years; however, when applied in years 0 and 1, it ranged from 0.0–1.0 years. Except in very few cases, the pavement service life was not extended by the application of the single slurry seal.

The performance-modeling process in this study was used to identify the effectiveness with respect to time of a slurry seal application to a flexible pavement within the Washoe County region. To document pavement performance, the Washoe County Engineering Department (WCED) uses the *MicroPAVER* pavement-management software system [American Public Works Association (APWA) 2012] that is supported, maintained, and periodically updated by the Construction Engineering Research Laboratories (CERL) of the U.S. Army Engineer Research and Development Center (Shahin 2010).

The *MicroPAVER* system works in conjunction with the ASTM D6433 (ASTM 2011) inspection standard to determine and monitor the PCI of a given roadway section. The PCI rating of a roadway is based on the observed surface distresses. The PCI rating is not a direct measure of structural capacity, skid resistance, or road roughness; however, it is an objective tool for assessing the M&R needs of roadway section with respect to an entire pavement system.

The environmental conditions of the Washoe County region can be characterized as high desert, which generally indicates relatively low annual precipitation rates, usually approximately 250 mm; nearly all locations in the county have annual precipitation rates below 500 mm except for the mountainous regions surrounding Lake Tahoe (NV Energy 2012). Being a high desert, the area is subjected to relatively high summer temperatures, periodically over 38°C, and generally mild winters, usually not below −18°C. However, the region is subjected to significant daily temperature fluctuations varying by 17–22°C, but may exceed 25°C between consecutive day and night temperatures throughout the year (National Oceanic and Atmospheric Administration 2012).

Evaluated Pavement Sections

All asphalt pavement sections identified for this study were within the jurisdictions of Washoe County, the city of Reno, and the city of Sparks. The evaluation covered two pavement types: newly constructed pavements and pavements that received overlays. Only residential roads within the three jurisdictions experienced sequential slurry seal applications. There were no projects found for arterial or collector roads. The Washoe County regional functional classification for residential roads defines residential roads as having an approximate average daily traffic (ADT) of less than 6,000, with a high percentage of trucks (>4%), and lower-volume roads that provide direct access to commercial and industrial lands. As shown in Table 1, 2,866 pavement sections were evaluated for this study. Pavement sections that had only one slurry seal received the treatment at the age of 0 years whereas pavement sections that had two sequential slurry seals received the first treatment at the age of 0, 1, 3, or 5 years and the second slurry seal at the age of 7 or 9 years.

Materials Used in Evaluated Pavement Sections

The asphalt mixtures used in the evaluated pavement sections were generally dense-graded hot-mix asphalt (HMA) with a 12.5- or 19.0-mm nominal maximum aggregate size with AC-20, AR4000, or PG64-22 unmodified asphalt binders. Emulsion

Table 1. Number of Pavement Sections Identified for Study

Treatment	Newly constructed pavement sections	Overlaid pavement sections	Total number of sections
Nothing	525	1,848	2,373
Single slurry seal	85	236	321
Two sequential slurry seals	82	90	172

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asphalts used in the production of slurry seal consisted of latex-modified cationic quick set with a minimum of 3% latex rubber by weight of the binder following agency requirements. Slurry seals were designed in accordance with guidelines contained in International Slurry Surfacing Association (ISSA) Publication A105 (ISSA 2001).

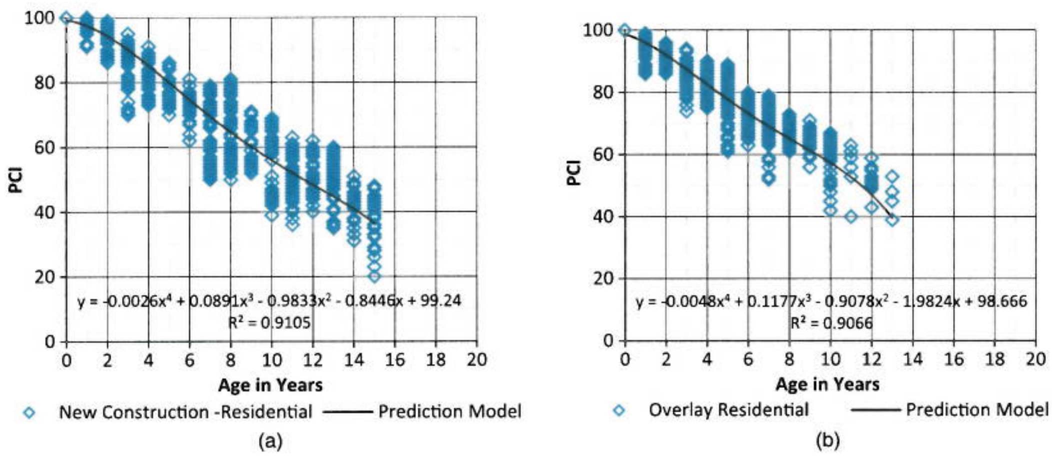

Fig. 1. Developed performance curves for do-nothing condition: (a) new construction; (b) overlay sections

Table 2. Performance Models for Newly Constructed and Overlaid Pavements

ID	Number of sections	Year of treatment application	Age range (years)	Performance models regression parameters[a] a_4	a_3	a_2	a_1	a_0	R^2
OL	1,848	Do nothing	0 ≤ Age ≤ 16	−0.0048	0.1177	−0.9078	−1.9824	98.666	0.907
OL-0[b]	236	0	0 ≤ Age ≤ 16	−0.0041	0.1056	−0.8448	−2.2707	99.849	0.973
NC	525	Do nothing	0 ≤ Age ≤ 19	−0.0026	0.0891	−0.9833	−0.8446	99.240	0.911
NC-0[c]	85	0	0 ≤ Age ≤ 19	−0.0023	0.0805	−0.8721	−1.4712	99.924	0.977
		0	0 ≤ Age ≤ 7	−0.0165	0.2949	−1.7736	−1.5027	100.030	0.989
OL-0-7[d]	15	7	7 ≤ Age ≤ 16	−0.0395	1.6286	−24.5130	153.7300	−260.280	0.959
		0	0 ≤ Age ≤ 9	−0.0244	0.4825	−3.0234	1.4635	98.752	0.976
OL-0-9	17	9	9 ≤ Age ≤ 15	−0.0853	3.6414	−56.6280	371.1100	−772.950	0.936
		1	1 ≤ Age ≤ 7	0.0025	−0.0636	0.3471	−4.8768	104.340	0.992
OL-1-7	13	7	7 ≤ Age ≤ 16	−0.0318	1.2850	−19.1690	120.2100	−187.490	0.951
		1	1 ≤ Age ≤ 9	−0.0046	0.1310	−1.1386	−1.1760	101.900	0.993
OL-1-9	10	9	9 ≤ Age ≤ 17	−0.0119	0.4477	−5.5291	14.5360	150.440	0.983
		3	3 ≤ Age ≤ 7	−0.0625	1.3750	−11.6880	38.8750	56.500	0.944
OL-3-7	17	7	7 ≤ Age ≤ 21	0.0076	−0.4031	7.3648	−59.8090	267.210	0.988
		3	3 ≤ Age ≤ 9	−0.0457	1.1416	−10.5400	37.2020	55.974	0.990
OL-3-9	12	9	9 ≤ Age ≤ 20	−0.0005	−0.0233	1.2645	−21.4950	193.060	0.988
		5	5 ≤ Age ≤ 9	0.1167	−2.9250	26.1580	−104.8000	262.500	0.979
OL-5-9	6	9	9 ≤ Age ≤ 18	−0.0308	1.5823	−30.3100	249.1400	−654.220	0.983
		0	0 ≤ Age ≤ 7	−0.0248	0.3615	−1.9867	−0.5081	100.090	0.990
NC-0-7[e]	10	7	7 ≤ Age ≤ 17	−0.0401	1.8221	−30.0140	204.8100	−402.300	0.991
		0	0 ≤ Age ≤ 9	−0.0145	0.3004	−2.0051	−0.4084	99.452	0.979
NC-0-9	12	9	9 ≤ Age ≤ 15	−0.2215	10.2580	−176.8200	1335.5000	−3637.300	0.980
		1	1 ≤ Age ≤ 7	0.0025	−0.0636	0.3471	−4.8768	104.340	0.992
NC-1-7	15	7	7 ≤ Age ≤ 17	−0.0214	0.9241	−14.6520	95.9820	−140.610	0.956
		1	1 ≤ Age ≤ 9	0.0166	−0.3062	1.7789	−7.9927	106.320	0.977
NC-1-9	12	9	9 ≤ Age ≤ 15	−0.1279	6.0189	−105.9500	819.1900	−2257.700	0.995
		3	3 ≤ Age ≤ 7	0.1597	−3.1528	22.5900	−72.9310	187.670	0.948
NC-3-7	15	7	7 ≤ Age ≤ 19	−0.0032	0.1351	−2.4789	17.5430	56.590	0.983
		3	3 ≤ Age ≤ 9	−0.0519	1.2266	−10.5740	36.1500	57.839	0.856
NC-3-9	11	9	9 ≤ Age ≤ 19	0.0224	−1.2347	24.5770	−215.9000	799.080	0.993
		5	5 ≤ Age ≤ 9	0.3417	−9.4083	95.1330	−424.1200	804.500	0.989
NC-5-9	7	9	9 ≤ Age ≤ 18	−0.0308	1.5823	−30.3100	249.1600	−654.220	0.990

[a]$PCI = a_4 \times Age^4 + a_3 \times Age^3 + a_2 \times Age^2 + a_1 \times Age + a_0$.

[b]Overlaid pavement subjected to a single slurry seal at year 0.

[c]Newly constructed pavement subjected to a single slurry seal at year 0.

[d]Overlaid pavement subjected to a first slurry seal at year 0 followed by a second slurry seal at year 7.

[e]Newly constructed pavement subjected to a first slurry seal at year 0 followed by a second slurry seal at year 7.

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Evaluation Method

The performance of the various pavement sections was measured in terms of the PCI that the agencies collected using the *MicroPAVER* system. All three local agencies use the same pavement-evaluation procedures and scored their pavements on the same cycle (i.e., every other year). A joint refresher meeting is held every year to ensure that all pavement survey teams are conducting similar survey procedures. Additionally, a portion of the network is periodically cross-scored by an independent rating source to make sure that ratings among agencies are comparable (RTC of Washoe County 2004).

The *MicroPAVER* system divides the road network into sections on the basis of uniform properties of the pavement and traffic conditions. Each pavement section is further divided into units, and the units to be surveyed within a given section are identified randomly. The average PCI value of the surveyed units within each section is used to represent the condition of the entire section for the specific survey date.

Performance Models

The PCI data collected by the owner agencies were used to develop the performance prediction models. Figs. 1(a and b) present individual PCI measurements for the do-nothing condition for both new construction and overlay sections; Eqs. (1*a*) and (1*b*) show the developed fourth-degree polynomial family performance prediction model for the graphs shown in Figs. 1(a and b), respectively. Performance prediction models for the various sequential slurry seal conditions were developed in a similar fashion:

$$\mathrm{PCI} = -0.0026\ \mathrm{Age}^4 + 0.0891\ \mathrm{Age}^3 - 0.9833\ \mathrm{Age}^2 - 0.8446\ \mathrm{Age} + 99.24 \tag{1a}$$

$$\mathrm{PCI} = -0.0048\ \mathrm{Age}^4 + 0.1177\ \mathrm{Age}^3 - 0.9078\ \mathrm{Age}^2 - 1.9824\ \mathrm{Age} + 98.67 \tag{1b}$$

The do-nothing performance prediction model and the performance prediction model for sections that only had one slurry seal applied at year 0 throughout their pavement lives were used to help determine the improvement in performance of the various sequential slurry application conditions. To forecast the performance prediction model after a first or second slurry seal is applied, the models need to be shifted to a present PCI/age point. Once this shift is applied, it is assumed that the deterioration of all pavement sections in a family is similar and is a function of only their present condition, regardless of age (Shahin 2010). It must be stated that the performance prediction models were not shifted further than 1.2 years.

Table 2 presents all the various performance prediction models used for the project. The number of sections reported in Table 2 represents the number of sections identified by the *MicroPAVER* system. This indicates that multiple sections may have been located on the same road. The section-identification nomenclature was organized as follows: OL-0-7, for example, would indicate overlaid (OL) pavements that received the first slurry seal at year 0 and the second slurry seal at year 7. Similarly, NC-0-7 would indicate newly constructed (NC) pavements that received the first slurry seal at year 0 and the second slurry seal at year 7.

As indicated in the Table 2 column indicating age range, the performance models are only valid over certain pavement age ranges. For example, the performance model for OL-0-9 has two models; one of them can only be used to predict PCI values when pavement is less than 9 years old, whereas the other one can only be used when the pavement is 9 years or older.

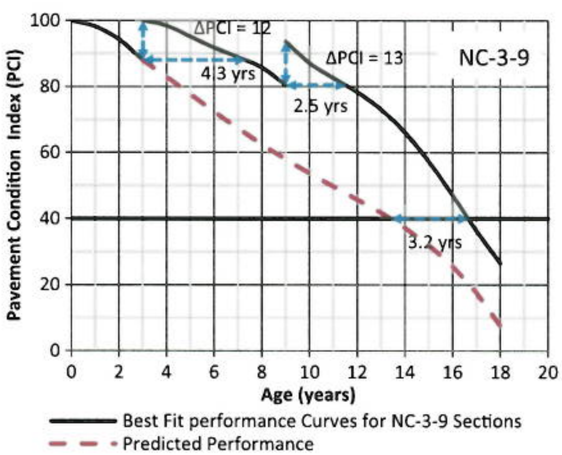

Fig. 2. Performance curves for newly constructed residential section for do-nothing condition and slurry seals applied in years 3 and 9

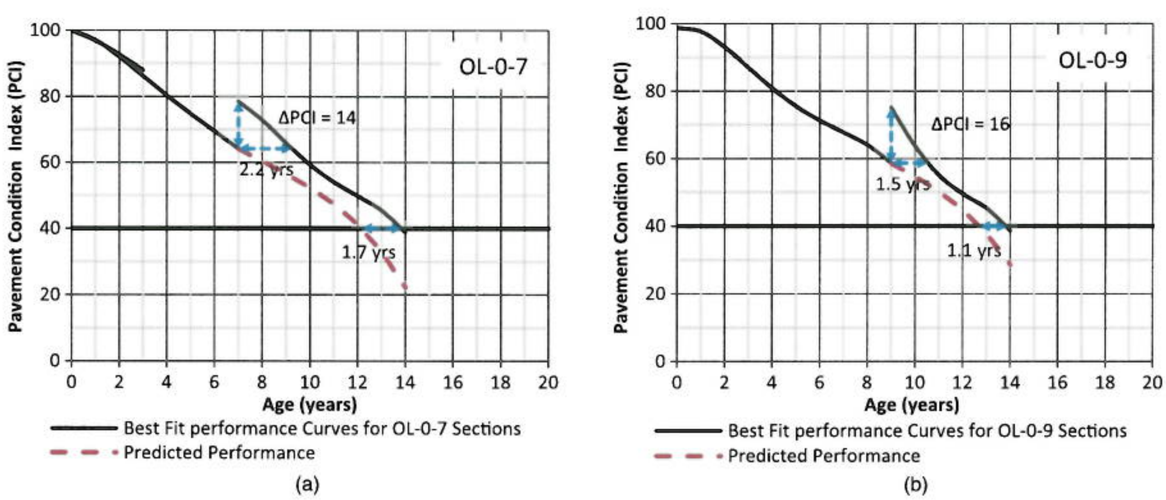

Fig. 3. Do-nothing and slurry seal performance models for overlay: (a) years 0 and 7; (b) years 0 and 9

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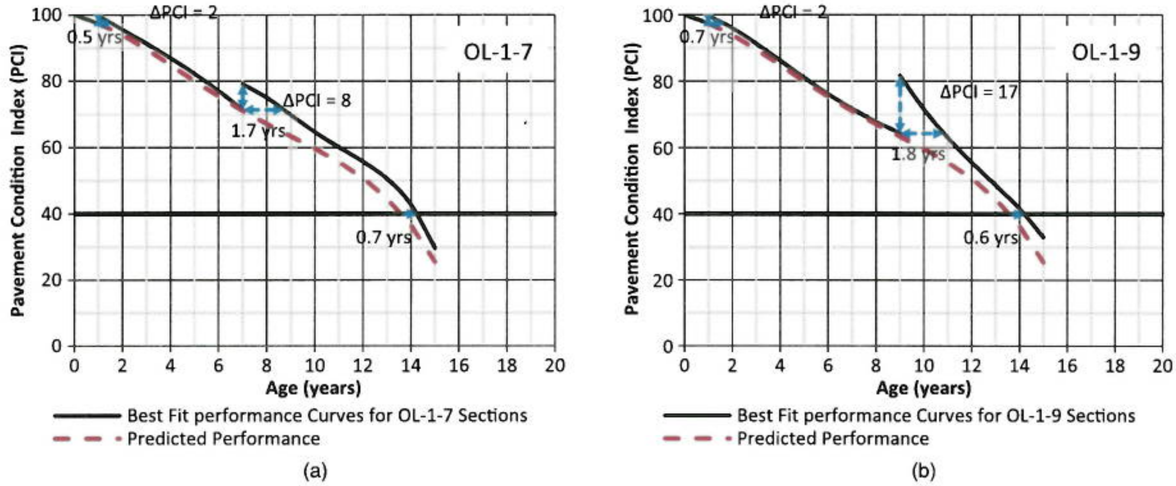

Fig. 4. Do-nothing and slurry seal performance models for overlay: (a) years 1 and 7; (b) years 1 and 9

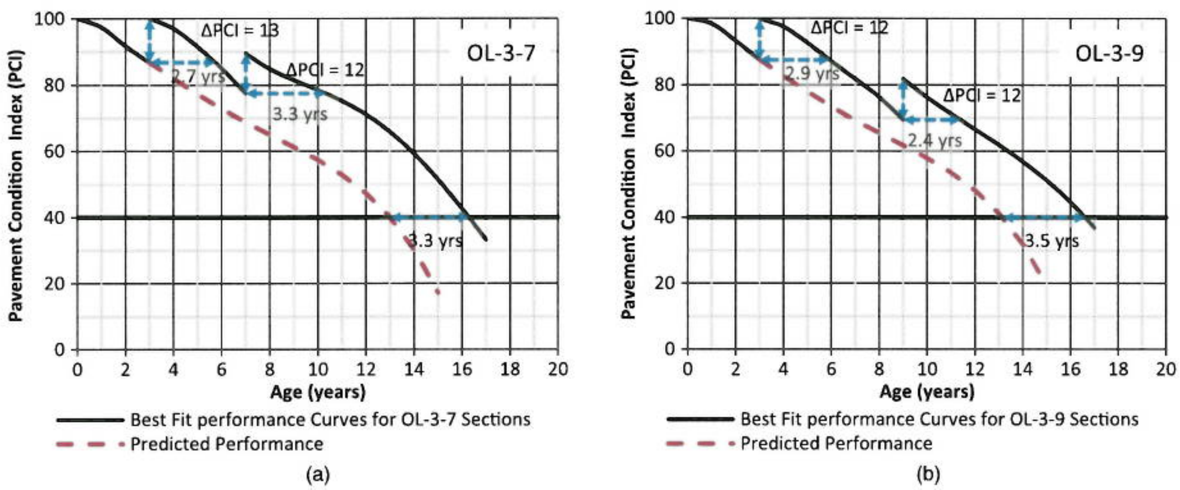

Fig. 5. Do-nothing and slurry seal performance models for overlay: (a) years 3 and 7; (b) years 3 and 9

The R^2 value indicates the coefficient of determination between the model and the actual data. An R^2 value of 1.00 indicates a perfect fit between the model and the data, and an R^2 value of 0.00 indicates a very poor fit.

Fig. 2 shows a typical performance curve for the do-nothing condition, the first slurry seal, and the second slurry seal superimposed on a PCI-versus-time plot. The slurry seal performance life and the extensions it causes in pavement service life can be determined for slurry seal at various times of applications. As discussed previously, the slurry seal performance life is defined as the number of years for the slurry seal performance curve to reach the PCI of the existing pavement before treatment application, whereas the extension in pavement service life is the number of additional years the pavement will have at the end of its service life (i.e., PCI = 40) owing to the application of the slurry seal. For example, it took 4.3 years for the first slurry seal applied on year 3 of service to the newly constructed residential road to deteriorate from a PCI of 100 right after treatment to the pretreatment PCI of 88 (□ PCI = 12) (Fig. 2). Furthermore, it took 2.5 years for the second

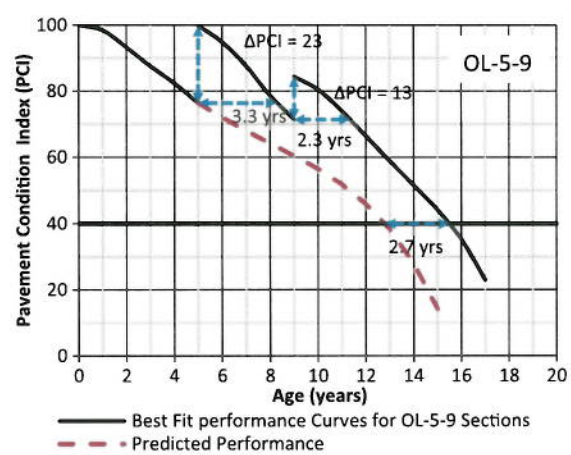

Fig. 6. Do-nothing and slurry seal performance models for overlay at years 5 and 9

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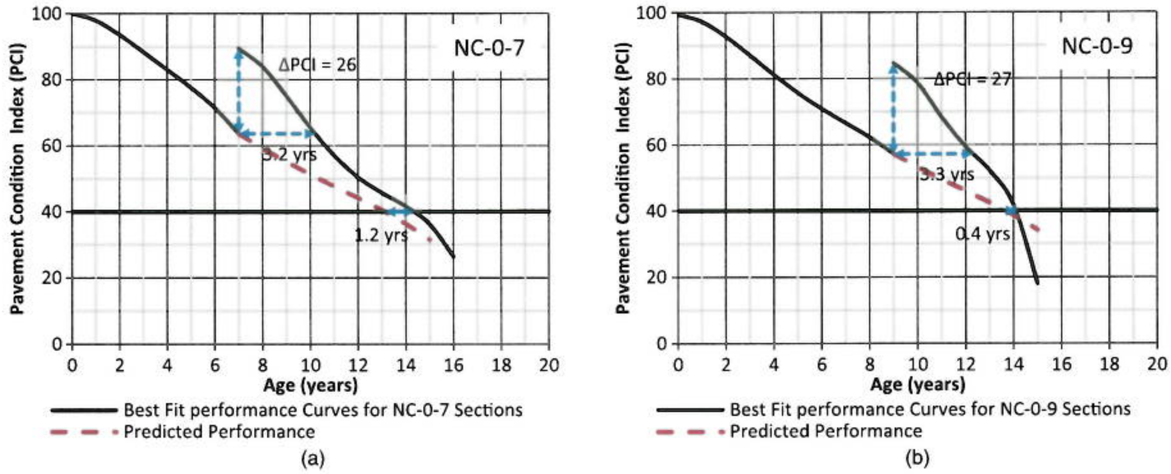

Fig. 7. Do-nothing and slurry seal performance models for new construction: (a) years 0 and 7; (b) years 0 and 9

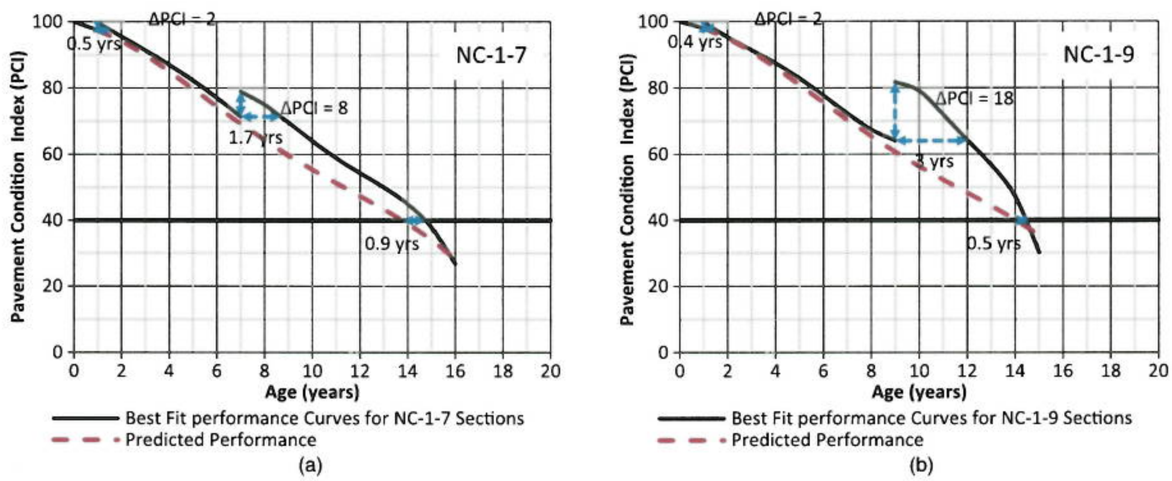

Fig. 8. Do-nothing and slurry seal performance models for new construction: (a) years 1 and 7; (b) years 1 and 9

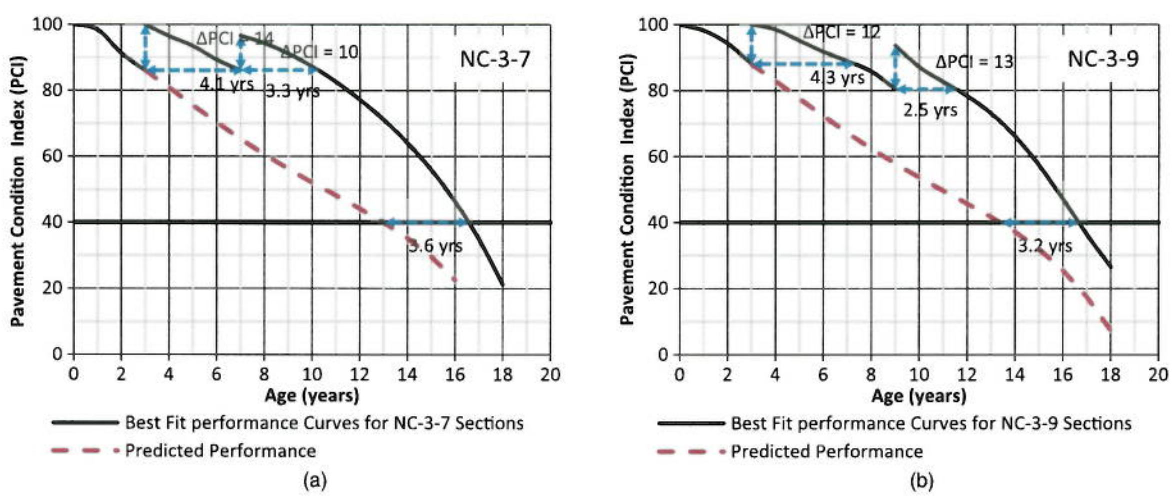

Fig. 9. Do-nothing and slurry seal performance models for new construction: (a) years 3 and 7; (b) years 3 and 9

slurry seal applied on year 9 of service to deteriorate from a PCI of 93 right after treatment to the pretreatment PCI of 80 (ΔPCI = 13). Therefore, the performance life for the first slurry seal is 4.3 years, whereas the performance life for the second slurry seal is 2.5 years. For the same example, the two treatments of slurry seal extended the pavement service life and delayed the time until a PCI of 40 was reached by 3.2 years (see Fig. 2).

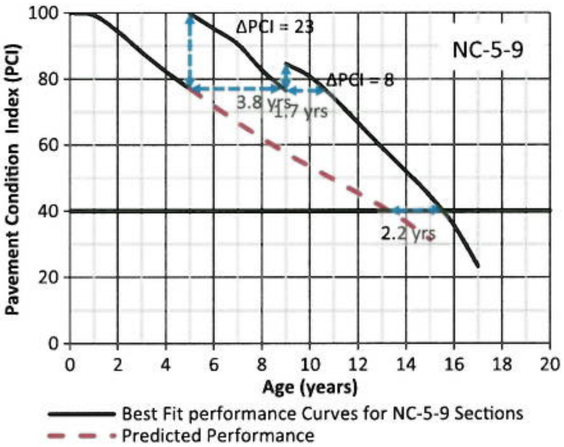

Fig. 10. Do-nothing and slurry seal performance models for new construction at years 5 and 9

Figs. 3–10 present all the various cases of sequential application of slurry seals for overlays and newly constructed pavements. The performance model for pavements without slurry seals (do-nothing case) is superimposed on the performance models for the first slurry seal application and the performance models for the second slurry seal application. From the figures, the following general trends can be observed:

- The application of the first slurry seal at years 0 and 1 shows a significant change in neither the shape of the performance curve nor the initial PCI value for both overlays and newly-constructed pavements (Figs. 3, 4, 7, and 8);
- The application of the first slurry seal at years 3 and 5 shows significant jumps in the PCI value at the time of application and in the shape of the performance curve for future years—in fact, the PCI value jumps back up to nearly 100 (Figs. 2, 5, 6, 9, and 10);
- The shape of the performance curve of the second slurry seal and the magnitude in the jump of the PCI values are greatly affected by time of application of the first slurry seal; for both overlay and newly constructed pavements, the second slurry seal

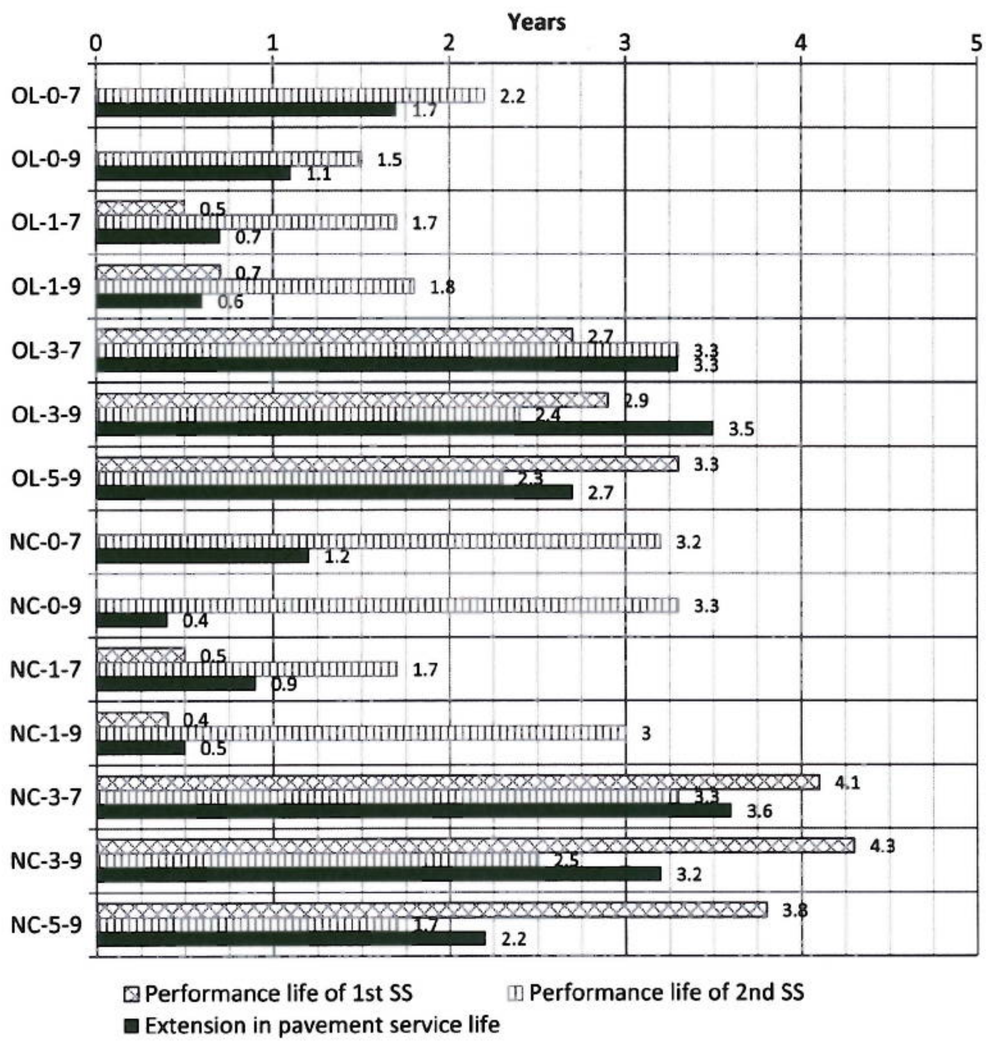

Fig. 11. Performance lives of first and second slurry seals (SS) and extension in pavement service life for both newly constructed pavements and pavements with overlays

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extends the serviceability life of the pavements most when the first slurry seal is applied in year 3 or 5.

From the performance models in Figs. 3–10, the slurry seal performance lives and extensions in pavement service life can be determined. Fig. 11 summarizes the various performance lives and extensions for all pavement types and shows clearly that the highest performance life for the first slurry seal is when it is applied in years 3 and 5. This does not necessarily mean that this higher performance life for the first slurry seal carries over to the second slurry seal. In fact, the performance life of the second slurry seal for NC-0-9 is higher than the performance lives of both NC-3-9 and NC-5-9. Regardless of this fact, the extension in pavements lives was found to be the highest with the first slurry seal applied in year 3 or 5 and the second slurry seal in either year 7 or 9.

Cost-Benefit Analysis

The relative benefit is defined as the ratio of the slurry seal's performance benefit (B) to the area under the performance curve of the pavement without slurry seal (A) up to the terminal PCI of 40 (i.e., $B/A \times 100$) (Fig. 12). The relative benefit can thus be viewed as the percent improvement in the serviceability of the pavement, which is directly related to users' satisfaction.

Fig. 13 presents relative benefit values for sequential slurry seals applied at various combinations for both newly constructed and overlaid pavements. For both pavement types, it is clear that the pavements that received the highest relative benefit were those that had the first slurry seal applied in year 3 and the second slurry seal applied in year 7 or 9. The highest relative benefit was achieved when both pavement types had the first slurry seal applied in year 3 and the second slurry seal applied in year 7.

The cost of the slurry seal (C) was estimated on the basis of 2009 cost figures (i.e., 0 years after construction) at $6,880/lane-km. A discount rate of 3%, determined on the basis of historical 15-year records (1991–2005) for the region, was used to estimate the cost figures for the various years of slurry seal applications. For example, the cost of slurry seal applied at year 3 after construction will be $\$6,880 \times (1 + 0.03)^4 = \$7,742$/lane-km. In general, the longer a slurry seal is postponed, the higher the present cost of the slurry seal will become. The costs presented in Table 3 are total costs of both the first and second slurry seals.

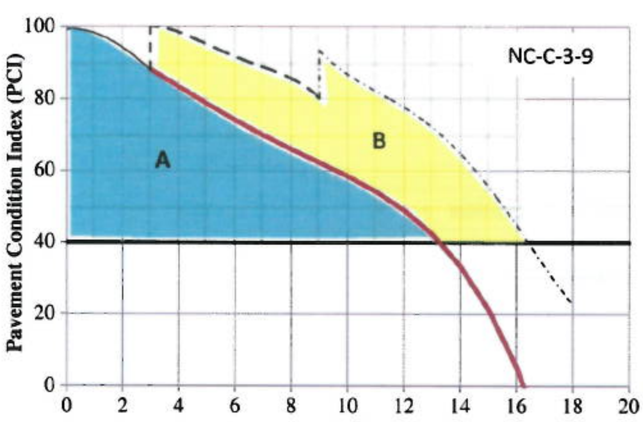

Fig. 12. Benefit determination of do-nothing condition and sequential slurry seal application

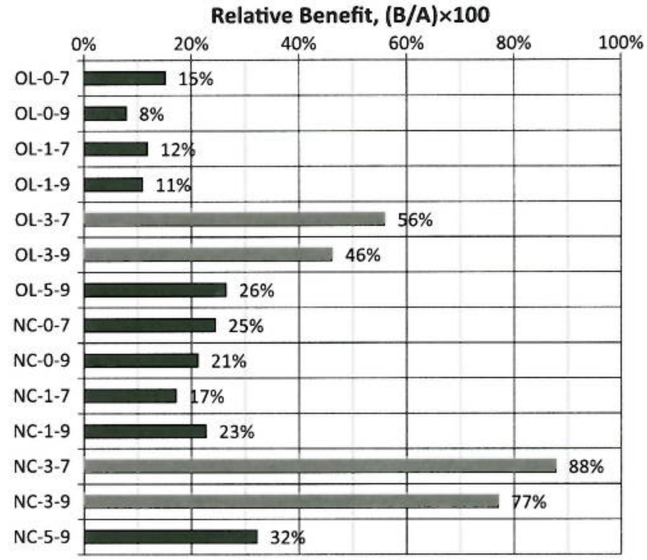

Fig. 13. Relative benefit for newly constructed pavements and pavements with overlays

The cost-benefit ratio is defined as the benefit (B) divided by the cost (C) of the application of the slurry seal. The cost-benefit ratio was used to determine the relative cost-effectiveness of the slurry seal treatment with respect to various times of application. Table 2 summarizes the benefit and cost figures for the application of slurry seals at various years after construction for the new construction and overlay.

For overlays, the highest cost-benefit ratio (12.4) from a sequential slurry seal application occurs when the first slurry seal is applied in year 3 followed by the second slurry seal in year 7. The second highest cost-benefit ratio (11.8) for overlays occurs when the first slurry seal is applied in year 3 followed by the second slurry seal in year 9. Similarly, for new construction, the highest cost-benefit ratio (20.9) from a sequential slurry seal application occurs when the first and second slurry seals are applied in years 3 and 7, respectively. The second highest cost-benefit ratio (18.8) for new construction occurs when the first slurry seal is applied in year 3 followed by a second slurry seal in year 7.

Table 3. Cost-Effectiveness of Sequential Slurry Seals for Newly Constructed and Overlaid Asphalt Pavements

Sample ID	Benefit (area)	Cost (U.S. dollars/lane-km)	Cost-benefit ratio[a]
OL-0-7	56.7	15,339	3.7
OL-0-9	31.6	15,854	2.0
OL-1-7	52.7	15,545	3.4
OL-1-9	48.7	16,060	3.0
OL-3-7	229.6	18,561	12.4
OL-3-9	194.5	16,491	11.8
OL-5-9	124.4	16,949	7.3
NC-0-7	94.2	15,339	6.1
NC-0-9	83.5	15,854	5.3
NC-1-7	72.5	15,545	4.7
NC-1-9	99.2	16,060	6.2
NC-3-7	333.4	15,976	20.9
NC-3-9	310.4	16,491	18.8
NC-5-9	148.2	16,949	8.7

[a] $B/C \times 1,000$.

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Conclusions and Recommendations

Review of the pavement performance data and cost-benefit ratio of two slurry seal applications as a function of the years of application leads to the following conclusions:

- The application of the first slurry seal immediately after or 1 year after construction of the asphalt layer is not effective in terms of both the benefit to the users and the cost-benefit ratio for the agency.
- Regardless of construction activity, optimum time for a sequential slurry seal is when the first slurry seal is applied in year 3 and the second slurry seal is applied in year 7. Consequently, on the basis of the developed performance models, the optimum time for sequential slurry seals of newly constructed pavement is when the first slurry seal is applied at PCI of 90 and the second slurry seal is applied at PCI of 86. However, the optimum time for sequential slurry seals of overlaid pavement is when the first slurry seal is applied at PCI of 87 and the second slurry seal is applied at PCI of 77.
- The pavement service life was extended by 2.0 to nearly 4.0 years when the slurry seals were applied at optimum time. For such application conditions, the sequential slurry seal was effective in delaying the time until reconstruction.

In summary, for newly constructed pavement, it is recommended that agencies apply the first slurry seal when PCI reaches 90 and the second slurry seal when PCI reaches 86. For overlaid pavement, it is recommended that agencies apply the first slurry seal when PCI reaches 87 and the second slurry seal when PCI reaches 77. It should be stated that the conclusions and recommendations in this section were based on the analysis of asphalt pavement sections that received a sequential application of slurry seal during their intended performance lives. The optimum time for a single slurry seal application has already been studied for this region and was consistently found to be at 3 years after construction or when the PCI reaches values of 90 and 87 for newly constructed and overlaid pavements, respectively.

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