Report No. UT-04.07

LIFE CYCLE OF PAVEMENT PRESERVATION SEAL COATS

Final Report

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UDOT RESEARCH & DEVELOPMENT REPORT ABSTRACT

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16. Abstract

The use of preservation seals on asphalt pavements is a crucial part of any effective pavement management program. It is important to optimize the use of available budgets to extend the life of our pavements as much as possible. The nation's highway system is one of our most valuable assets.

Analysis of the performance of surface treatments on Utah pavements indicates that Open Graded Surface Courses (OGSC) have an average life, based on skid resistance of almost 9 years and that Chip Seal Courses (CSC) have a significantly longer life.

Out of all the factors analyzed, traffic has the most significant effect on the performance of the treatment. Factors such as aggregate source and asphalt supplier were also investigated but lack of data prevented from reaching any significant conclusion.

Based on the relative cost of both treatments and the performance observed through this study, it is recommended that Utah Department of Transportation expand the use of CSC to certain roads with AADTs up to 20,000 vehicles and continue the existing procedure of using CSC in highway sections with AADTs below 5,000.

It is also recommended that UDOT modified the existing policies and limit the use of OGSC where the running speeds are 55 mph or greater and AADTs are in excess of 25,000 vehicles. Medium volume facilities (5,000 to 25,000 AADT) should be sealed with treatments new to UDOT but proven in other states.

An initial cost analysis showed that the implementation of the changes suggested as part of this report will results in savings of over $2 million per year in the maintenance budget. Thus allowing for better use of resources while still serving the traveling public.

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Background

Utah Department of Transportation (UDOT) expends approximately $40 million each year on pavement preservation strategies. A major portion of this program is dedicated to bituminous seal coats.

Seal coats are intended to extend the life of bituminous pavements by accomplishing the following:

- Protect the pavement surface from solar radiation
- Prevent the intrusion of water
- Seal narrow cracks
- Provide adequate resistance to skidding
- Open graded treatments reduce hydroplaning by limiting surface water during storms

It is well documented that preventive maintenance activities, such as bituminous seal coats, extend the life of highway and airport pavements more efficiently that any other activity. Studies done nationally and in Utah have estimated dramatic increase in the useful life of pavement structures were sound and timely surface seals have been placed. However, the cost-effectiveness of this strategy is very dependant on the quality and effective life of the seal coats themselves. If the seal coat fails prematurely, this has a corresponding negative effect on the life of the underlying pavement. Good performing seal coats are a crucial piece of any pavement management program. UDOT should fully fund the Preventive Maintenance Program.

Unfortunately, shrinking budgets and expanding highway systems have had a negative impact on UDOT's Preventive Maintenance Program. The recommended cycle to place chip seals and open graded surface courses on flexible pavements cannot be fully funded with the current budget. Under current guidelines, an increased budget would be needed to complete the current treatment cycles.

An alternative to current strategies would be to utilize less expensive treatments to make the existing budget go further while still treating the needed number of surface areas. Replacing the OGSC with chip seals on some selected sections of high volume pavement is one way to accomplish this. Traditional chip seals however, are not accepted well in high volume or urbanized corridors. Loose chips draw complaints and broken windshields, problems with curb and gutter, sidewalks, and driveways are an issue. Furthermore, reduced speeds during construction result in congestion and accidents. Enhancements in the chip seal design and construction practices would be needed to allow UDOT to utilize the less expensive strategy on more routes. By doing so, significant benefits can be realized by UDOT and the traveling public.

Study Objectives

The objective of this study was to compile performance data on Open Graded Surface Courses (OGSC) and Chip Seal Coats (CSC) in an attempt to measure the life of these seal coats. In addition other variables that are available will be analyzed to determine their relative impact on seal coat performance. Other preservation activities such as rejuvenation, fog seals, slurry seals, etc. were not included in the scope of this study.

The main objectives of the study were:

1. Determine the life of Open Graded Surface Courses (OGSC) and Chip Seal Coats (CSC) on pavements for the range of highway types and conditions in Utah.
2. Develop relationships using available data to predict the life of a seal coat for the various materials used, environmental conditions, and traffic loadings.
3. Recommend how the study results can be used to better plan the placement of future seal coats on UDOT's pavements.

Performance factors that were collected over the years, and available in a database, were analyzed as a function of time to determine which of them had a significant influence in the life of the seal coat

Technical Advisory Committee

A team of experts in the operations and maintenance area were organized into the Technical Advisory Committee (TAC) for this study. The TAC reviewed and approved the detailed work plan, set direction for the study, and reviewed the final report. The TAC members are end users of the project findings, and will play a major role in the implementation of the study results.

The TAC members for the study were:

John Gunderson, Region 1 Operations
Shana Lindsey, Region 2 Operations
Lloyd Neeley, Central Pavement Management
Nathan Lee, Region 1 Pavement Management Engineer
Greg Punske, Federal Highway Administration

Literature Review

SPS Studies

The effectiveness of preventive maintenance treatments was studied in the Strategic Highway Research Program project H-101; experiments SPS-3 and SPS-4 for flexible and rigid pavements, respectively. During the SPS-3 experiments, test sections were constructed with chip seals, crack seals, slurry seals, and thin hot-mix asphalt overlays. State supplemental sections were also constructed including microsurfacing, plant mix seals, open-graded friction courses, and chip seals constructed to state specifications. Sections were selected to represent a range of traffic, environment, and pavement conditions. Three levels of pavement conditions were included in the experiment: good, fair and poor.

Some general performance-related findings were:

1. The pavement sections on which preventive maintenance treatments had been applied generally out-performed the associated control sections (i.e., sections that received no treatment).
2. A specific treatment's performance is generally related to the condition of the pavement at the time the treatment was applied. Treatments applied to pavements in good condition have good results.
3. Both traffic level and pavement structural adequacy did not appear to have an effect on maintenance treatment performance.
4. The SHRP preventive maintenance research indicates that preventive maintenance treatments can be effectively applied to high-volume roads. Success depends on:
    a. Proper selection of pavements to receive the treatment, based on the amount and type of distress.
    b. Proper materials and specifications for the treatments
    c. Good construction practices.

Selection of Preventive Maintenance Treatments

The preventive maintenance treatment selected for a section of pavement should consider: the condition of the existing pavement, the traffic volumes using the pavement, and the environmental conditions. Other factors, to consider include, experience with treatments, budget constraints, political reality, etc. Research to date has not produced detailed rules for selecting one treatment over another for high-volume, high-speed highways.

Effect of Surface Treatments on Pavement Distresses

In the literature, distress propagation and performance curves have been developed that show how each of the treatments have performed. However, all of these curves have the confounding effect that they do not separate those sections where the quantity of an existing distress is increasing from sections where the distress was constant or no distress was present. Ideally, a surface treatment should be applied *before* any significant distress is present. Nevertheless, all studies conclude that in general the treatments had a positive impact on reducing the occurrence of distresses, except for bleeding.

Alligator cracking plus patching

All treatments decreased the quantity of alligator cracking plus patching except for the fog seal, which had little impact. Patching was added to alligator cracking to account for large areas of alligator cracking that had recently been patched. Without this correction some treatments would show an increase of alligator cracking for a time and then the quantity would drop dramatically as the area was patched.

Other cracking

All treatments showed a decrease in the total quantity of other cracking except for the fog-seal, which had little impact. The reduction in other cracking due to the microsurfacing treatment was minimal after forty-eight months. Other cracking is composed of longitudinal cracking in the wheel path, non-wheel path longitudinal cracking, a correction for block cracking, edge and transverse cracking.

Bleeding

Microsurfacing was the only treatment that reduced bleeding relative to the control section. All other treatments increased the quantity of bleeding although not all effects were immediate.

Raveling and Weathering

All treatments decreased the total quantity of raveling and weathering except for the fog seal, which had little impact. The total quantity of raveling and weathering was quite low, so these results are not considered reliable. A small increase or reclassification can cause the analysis curves to shift dramatically. In the analysis, no attempt was made to include the severity of the distress. While the analysis of progression of distress from low to high is very important, there was not enough data to support this type of analysis.

Summary of Findings from SPS-3 Analysis

Based on the analysis of SPS-3 sections, the following observations were made:

- Pavements in good and fair initial condition performed approximately the same when chip seals were applied, except for the asphalt rubber modified chip seal where good out-performed fair.
- Pavements in good and fair initial condition generally out-performed those in poor initial condition.
- The fog seal showed little or no impact on the performance of the pavements studied. However, to be effective the fog seal should have been applied on a routine basis which was not done.

Performance Evaluation Models

The following have been suggested to evaluate the performance history of a pavement and ascertain whether it is satisfactory.

1. *Level of service.* The controlling level of service will vary with the type of facility. For example, an interstate highway will require a much higher level of service than is required on a secondary road with low traffic volumes. Therefore, the rehabilitation requirements will vary considerably depending on the facility type.
2. *Riding quality*. The riding quality is a judgment item that expresses a user's opinion as to how well the pavement is serving traffic. Generally, some minimum level can be specified for a given facility, to represent a minimum tolerable value accepted by the public.
3. *Safety*. Although safety may be evaluated to a degree by accident statistics, it is also a judgment value that encompasses a wide variety of conditions. For example, the pavement width of an existing facility may be increased to provide lane widths required for safe movement of increased traffic. Skid resistance and hydroplaning are also pertinent features of safety.
4. *Structural adequacy*. Structural adequacy expresses a pavements capability to carry the wheel loads of the present and future traffic.
5. *Surface condition*. The appearance of the pavement (for e.g. cracking, patching, raveling) is not necessarily related to the structural adequacy, although an inadequate, load-carrying capacity will ultimately lead to a poor appearance. Many detrimental surface conditions may be rectified by the practices and procedures, but those due to structural inadequacies must be corrected by the appropriate procedure.
6. *Cost*. The total cost required to keep the pavement adequately serving traffic is a primary decision criterion. This involves not only construction costs, but also maintenance costs and user costs. User costs may be incurred due to accidents or traffic delays. These are not direct costs from

the construction fund, but they represent a real cost to the traveling public. If a high-traffic-volume facility is subject to delays because of frequent maintenance, high user costs will be experienced; hence, a major rehabilitation will be required.

7. *Surface condition ratings and/or structural adequacy ratings.* These are used to evaluate pavement structure. Surface condition ratings can be used to quantify the decision criteria items of riding quality, safety, and structural adequacy. It is emphasized that these factors give only an indication of how well the facility is serving the traveling public at that time, although the data are very useful in providing a criterion for allocation of funds to those areas with the greatest need. For a long-term prediction, the structural adequacy of the pavement structure must be ascertained.

Modeling pavement performance after treatment

To predict the performance of the treatments, models need to be develop of the change in certain distress (e.g., roughness) due to the treatment and the rate of distress development over time. The conceptual forms of the models are

$$R_0 - R_a = f\,(D, R_0, F_c) \pm e$$
$$dR = f\,(D, T, R_a, dR_b, SN, RF) \pm e$$

Where

- dR = Rate of development of roughness (in./mile/year),
- D = thickness of the treatment,
- R_0 = roughness before treatment (in/mile),
- R_a = initial roughness after treatment (in./mile),
- F_c = indicator for the presence of a friction course,
- T = average daily traffic loadings,
- dR_b = rate of change in roughness before the treatment (in/mile/year),
- SN = structural number,
- RF = regional factor, and
- e = error term.

The roughness model development was stratified into six cases based on the highway type and treatment. The highway types used in the analysis were Interstate, state, and U.S. routes. The treatment types were conventional overlays and milled sections.

After developing the regression equations and analyzing them, following conclusions were made:

a) The change in roughness due to the surface treatment was not sensitive to the thickness of the treatment but was sensitive to the roughness before the treatment.

b) In developing the conceptual model, it was thought that thick overlays, constructed in multiple lifts, would have greater reduction in roughness than thin overlays. The amount of reduction of roughness is not sensitive to overlay thickness. There are many cases in which relatively thin overlays produced dramatic reduction in roughness. This indicates that quality control during construction is extremely important in determining the initial roughness.

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Description of Data

The data set used in this analysis was available as part of UDOT's pavement condition survey and pavement management system. The format and content of the data was not always consistent with the needs of this project. Furthermore, the data was located in different files, sometimes organized by year and sometimes organized by project. Before any analysis could be done, the data had to be combined into useable files. Several attempts were made to develop a single MS Excel file, however the large quantity of data did not allow for data manipulation. The data was finally organized into two main files using MS Access. The first file contained pavement condition data. This file included over 80,000 lines each with about 20 records, while this format did not allow data analysis it simplify the data manipulation. The following data was organized in this file for every mile of the road:

Identifying Data

- Year of data collection
- Route number
- Direction
- Beginning and end mile post

Performance Data

- Ride index
- Skid Number
- FWD data for five sensors
- Pavement condition survey (i.e., cracking, rutting, etc.)
- Yearly traffic
- IRI

A second file was created with the maintenance data. Since this file contained a lower number of entries, it could be created in MS Excel. The following data was organized in this second file:

- Project number
- Type of treatment
- Contractor
- Region
- Asphalt binder vendor
- Asphalt binder grade
- Aggregate source
- Route number
- Beginning and ending mile post
- Construction date

The entries between the two files were related based on route number, milepost and year. Initially, data was available from 1988 to 1994; later more information was obtained with data from 1995 to 1999. However, due to differences in format, this last set of data had to manually be added to the original data.

Unfortunately, as in any project were large amounts of data exists, there was some missing information. Some data was not usable because it was not consistent with the rest of the data. As technology has improved over the years, data collection methods have change, thus giving different results. The following data was not readily available and hence is not included in the analysis.

- Ride-Index data for year 92, 93 and 94.
- Binder-grade for many projects.
- Actual traffic data for some routes

Traffic is, perhaps, the most important variable to study. To supplement existing data, traffic counts for each milepost were obtained from the *Traffic on Utah Highways, 2002 edition*. It is understood that the traffic counts obtained from this publication will not directly correspond to the traffic that was applied to the treatment. However, this trade off was needed to maximize the use of the data provided.

In summary, the data consisted of 72 projects totaling 484 miles of road surface. Twenty-one of those project consisted of CSC while the rest consisted of OGSC. The list of routes, the project length, and the treatment applied is shown in the appendix section.

Analysis of Data

Once the data was organized, graphs were made to represent the different conditions being evaluated. This section includes an analysis of Open Graded Surface Courses (OGFC) and Chip Seal Course (CSC) based on the data available to the investigators.

Performance Variables

To properly evaluate the surface treatments, it was necessary to determine which factors should be used to measure failure, and the appropriate level that indicates the end of the useful life of the seal.

While many valid arguments can be made regarding the selection of performance variables, it was decided that the variables used to measure performance should relate to the intended use of the seal coat as described in the background section and in the literature review. Variables that relate exclusively to the structural condition of the pavement, such as falling weight deflectometer measurements, were not considered for the analysis. The surface condition of the pavement was also considered, however, no significant changes were recorded during the years covered by the study. This implies that the seal coat, for the most part, performed as design or that the data collection method was not consistent. Furthermore, as discussed in the literature review, to consider these variables, the condition and rate of deterioration of the pavement surface before the treatment was applied needs to be known. Other variables, such as roughness index, were not available for a complete analysis and some could not be related to specific section (milepost) of pavement.

With these constraints, two variables were selected to evaluate the performance of the seal coat. These variables relate to ride quality and safety in the form of roughness (International Roughness Index) and Skid Number, respectively. The values were taken from the year the treatment was applied until the last year where data was available for that section.

Data Analysis

To determine the performance of surface treatments, both OGSC and CSC were plotted in one graph as a function of time. While a direct comparison is, perhaps, difficult to justify given that both treatments are used in different conditions, it is still of interest to compare both treatments side by side. Figure 1 shows the results based on skid number (SN) and figure 2 shows the results based on roughness (IRI). The skid number of the road was expected to decrease with time as a result of the normal wear of the surface caused by the traffic. The roughness index was expected to increase as the surface deteriorates.

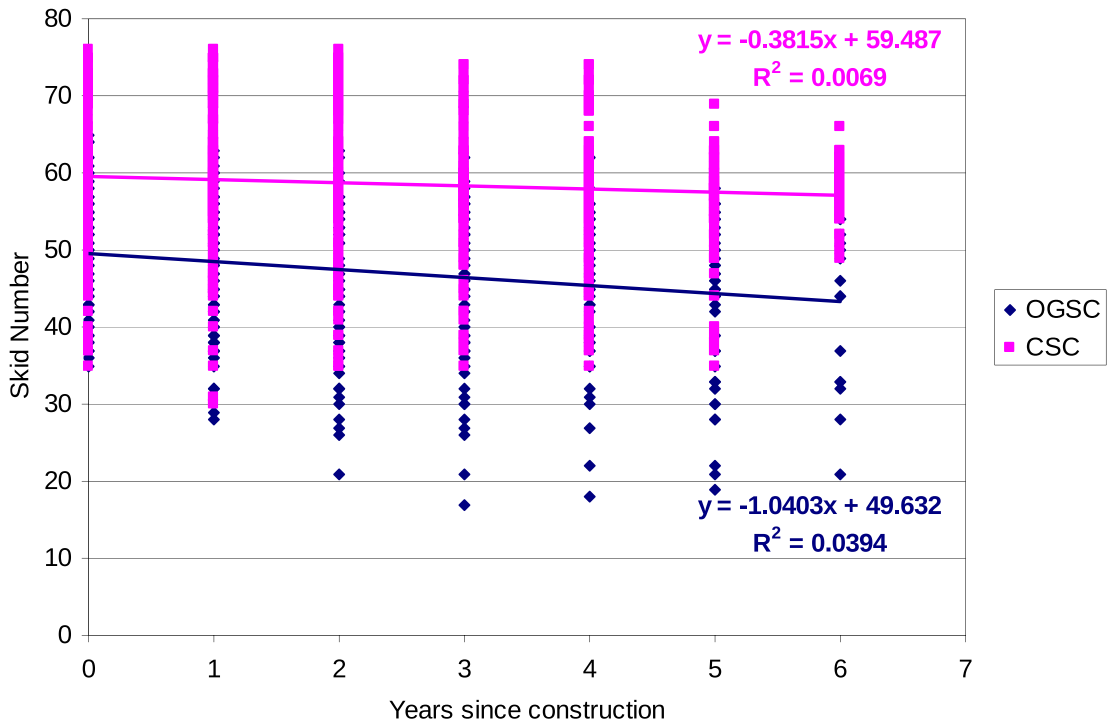

Figure 1. Skid Number for all sections evaluated

Figure 1 shows a significant variation in the data leading to a trend-line with a coefficient of determination (r-squared) close to zero. It is believed that the poor relationship is due to the great number of variables influencing surface resistance to skidding. Traditionally UDOT has used aggregates with many fractured faces in the CSC program. Figure 1 clearly shows that sections in which CSC have been applied have higher skid numbers than sections where OGSC was applied.

Similar variation in data is seen in Figure 2 with regard to the roughness index as measured by the IRI.

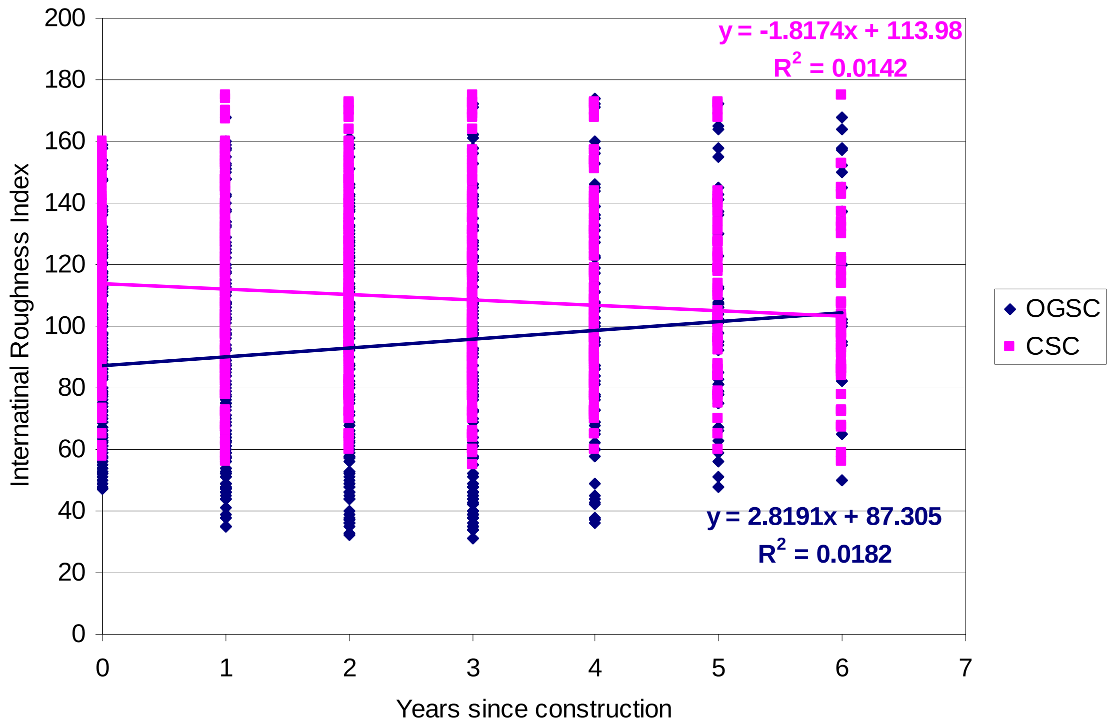

Figure 2. Roughness index for all sections evaluated

Upon discussion with maintenance personnel, as well as interpretation of the data, it was found that the method to measure roughness has changed within the timeframe of this study. This might also explain the unusual trend of decreased roughness with time for CSC observed in Figure 2. It must be noted, however, that the trends shown in Figures 1 and 2 are not statistically significant.

After discussing the trends observed in Figures 1 and 2, it was decided that Skid Number would be the primary parameter used in this study to measure the performance of seal coats. Further analysis will be based mostly on Skid Number.

Figure 3 shows a different approach in the analysis of the data. Rather than analyze the actual Skid Number for all projects combined and then try to determine a trend-line, the application of the treatment was evaluated independently. Within each year after construction, the number of miles, express as a percent of total miles, that had a skid number less than 40 was determine as an indication of the treatment life. The specific value of skid number below 40 was selected because this value is likely to trigger some corrective action on the road. Accident rates have been shown to increase on many highways when skid numbers drop below 40. Other values can also be selected with very similar results.

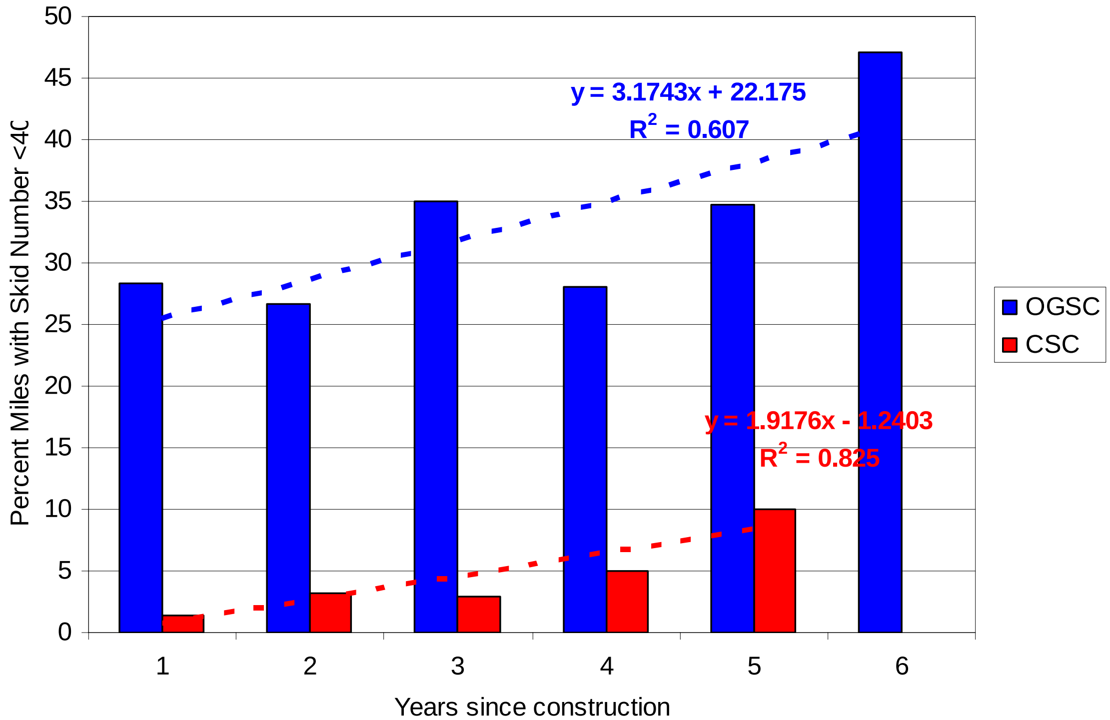

Figure 3. Percent of miles with skid number less than 40

Figure 3 shows an increase in percent miles that have a skid number below 40 with increasing years. In other words, the skid resistance decreases with time. The trends observed for OGSC and CSC are more reasonable than those shown in Figures 1 and 2. The data indicates a faster deterioration of OGSC as compared to CSC from the standpoint of skid resistance.

Within any given surface treatment, there are going to be some projects that show premature failure while others are going to exceed their design life. The results obtained from the data analysis, shown in Figure 3, can be used to determine the probability that some corrective action is needed on any given year after construction of a specific surface treatment using the current loading conditions. If we use a skid number of 40 as the trigger value, the probability that some corrective action is needed for OGSC and CSC can be summarized in Table 1. This gives an idea of the expected life performance of the specific surface treatment.

Table 1. Performance of Surface Treatments

	OGSC	CSC
Percent of miles requiring corrective action*	Time	
10	n/a	6 years
25	2 years	14 years
50	9 years	27 years
75	17 years	40 years

* based on a skid number less than 40

Life of Surface Treatments

Based on the analysis of the data shown in Table 1, it is possible to determine the life of different surface treatments based on their skid resistance and the probability that some corrective action is needed. The average life of a treatment represents the condition where 50% of miles require some corrective action. Using the values shown above, the average life of the OGSC is approximately 9 years while the average life of the CSC is 27 years. CSC are apply in places were there is less traffic (AADT less than 5,000), if traffic is a significant factor in the performance of these surface treatments, this data indicates that CSC are underutilized in the state as they could be applied in places were traffic demands are higher.

The predicted life of OGSC using the above analysis is similar to the average life of 9 years determine from the survey of different state highway agencies shown later on this report. The predicted life of chip seals is significant longer using the above analysis in comparison to the survey (7 years). It must be emphasized that the analysis is based on skid number only. It is likely that failure of some chip seals occur in another mode not considered in the study.

Factors Affecting the Performance of Surface Treatments

Several factors believed to have an effect on the performance of surface treatments were analyzed. However, only those factors in which there was a reasonable number of data points available for analysis are discussed here.

<u>Traffic</u>

The effect of traffic, as measured using the average annual daily traffic (AADT) in 2001 on each milepost was evaluated on both OGSC and CSC. The AADT shown is for the specific milepost, so each section can have more than one AADT value.

Since the application of each treatment is determined based on traffic, the treatments were not compared to each other but divided into categories of low, medium and high traffic. For OGSC AADT's less than 10,000 vehicles were considered low, between 10,000 and 40,000 were considered medium, and more than 40,000 vehicles were considered high. For chip seals AADT's values of less than 1,000 were considered low, between 1,000 and 5,000 were considered medium, and greater than 5,000 vehicles were considered high values. These values were selected based on the availability of data so that each category had even number of miles.

To determine the effect of traffic on the performance of surface treatments, the skid number measured at years three and five was used as an indicator. The percent of miles with skid numbers less than 40 was used for OGSC and is shown in the following figure.

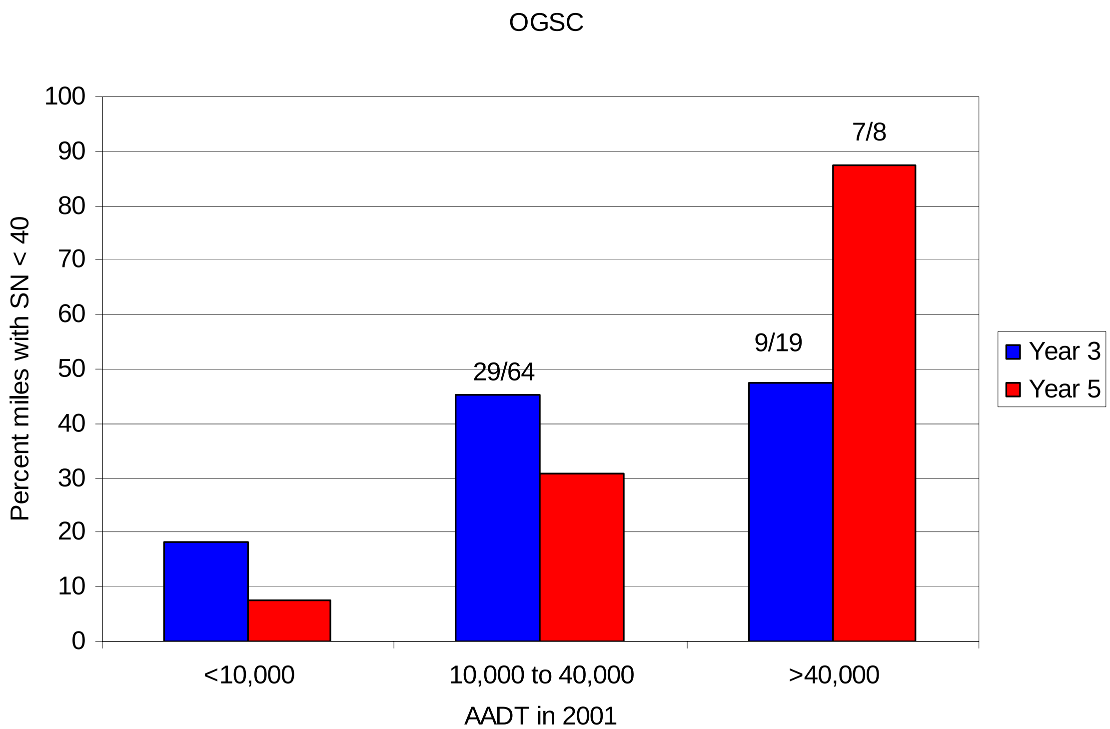

Figure 4. Effect of traffic on the skid resistance of OGSC. (The number above the columns represent the number of miles available for analysis)

Figure 4 shows that the performance of OGSC is dependent on traffic. As the traffic increases, the performance level decreases. The plot seems to indicate that there is less probability of failure at year 5 than at year 3 for low and medium traffic levels. This is actually a reflection of the number of data points used in the analysis. There are fewer miles in year 5 than in year 3, because those sections that showed severe early failures are not included in the data set at year 5.

A similar analysis was done for chip seals. However, given that traffic levels are lower; fewer sections with low skid number are expected.

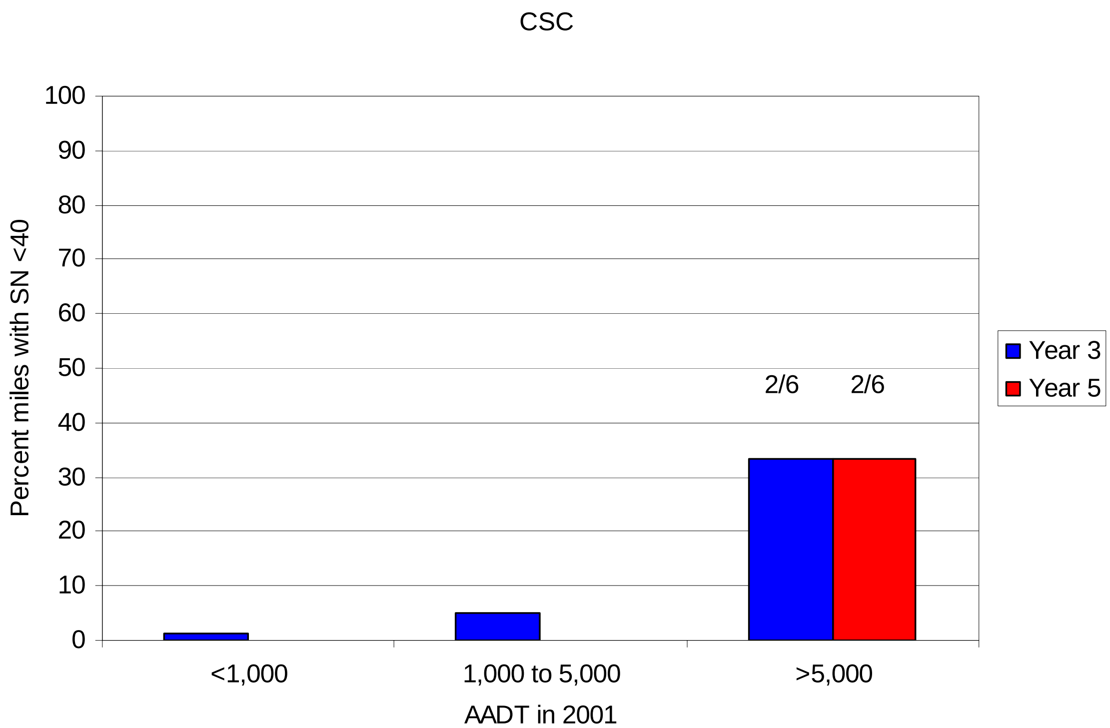

Figure 5. Effect of traffic on the skid resistance of CSC. (The number above the columns represent the number of miles available for analysis)

Figure 5 shows similar results to Figure 4 in that traffic has an effect in the performance of the treatment. The data shows that once the AADT exceeds 5,000 the number of miles with low skid number increases, reducing the life of the CSC. However, caution must be used since there are only six sections with AADT greater than 5,000. It can be speculated that the AADT can be increased beyond the 5,000 value while still having more than 50 percent of miles with adequate skid resistance. This is shown next.

In order to analyze the effect of traffic on CSC, a simple model was developed by separating AADT into equal categories and then determining a trendline. Using the equation of this trendline, it is possible to extrapolate and determine the traffic level that would cause 50% of miles to have a SN <40 in three years. Obviously, this analysis is only a rough guideline since the assumptions that are associated with regression analysis are not met and the regression has low coefficient of determination.

This type of analysis is shown in Figure 6 and discussed in the following paragraph.

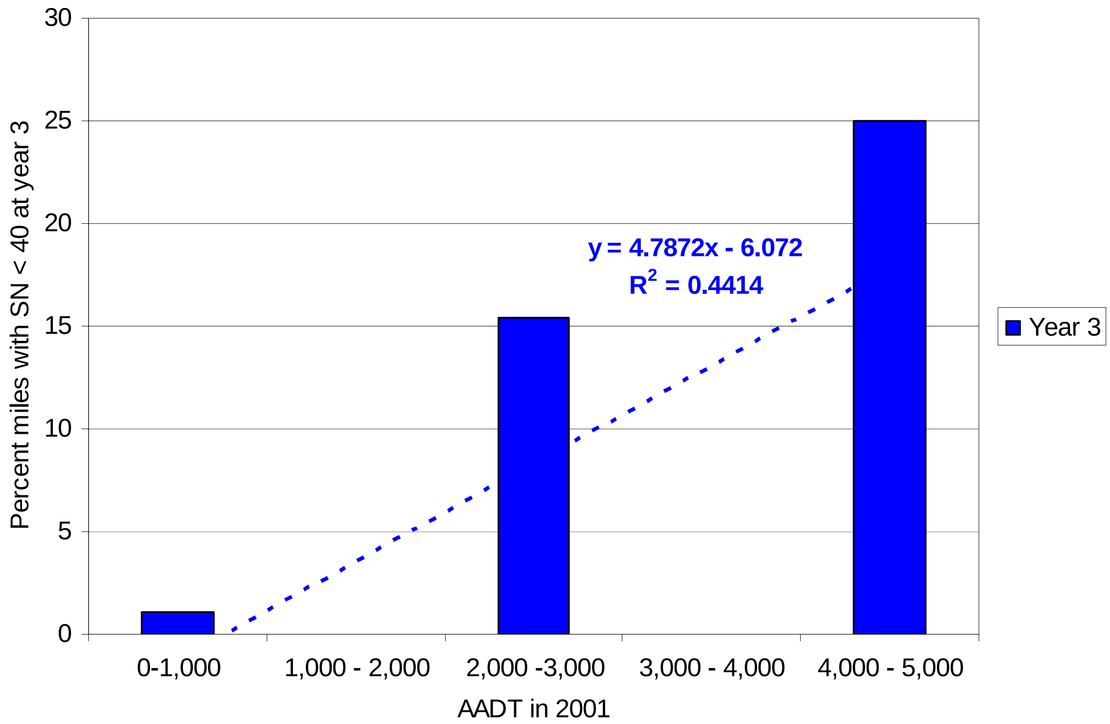

Figure 6. Model of traffic effects on CSC at year 3

The equation shown in Figure 5 can be simplified and used to predict the approximate traffic level that CSC can support

%Miles with Sn3 < 40 = 4.8x – 6

If we consider 50% as the point that triggers maintenance activitites, then solving for x, gives a value of 11.6, which indicates that, based on this simple trendline and using year 3 as a baseline, the upper limit of application of CSC is in roads with 11,000 to 12,000 AADT.

Construction Materials

The aggregate and asphalt binder source used in the surface treatment was evaluated when data was available. In this analysis, data was separated into three groups, skid number greater than 45 which indicates no problem, skid numbers between 40 and 45 still adequate but closer to the trigger value, and skid number below 40 which, as previously discussed, might trigger some corrective action.

Aggregate Source

The effect of aggregate source is shown in Figures 7 and 8 for OGSC and CSC, respective. These figures are based on the 6-year duration of the treatment, therefore, the figures do not separate early failure from late failures nor do they take into account traffic.

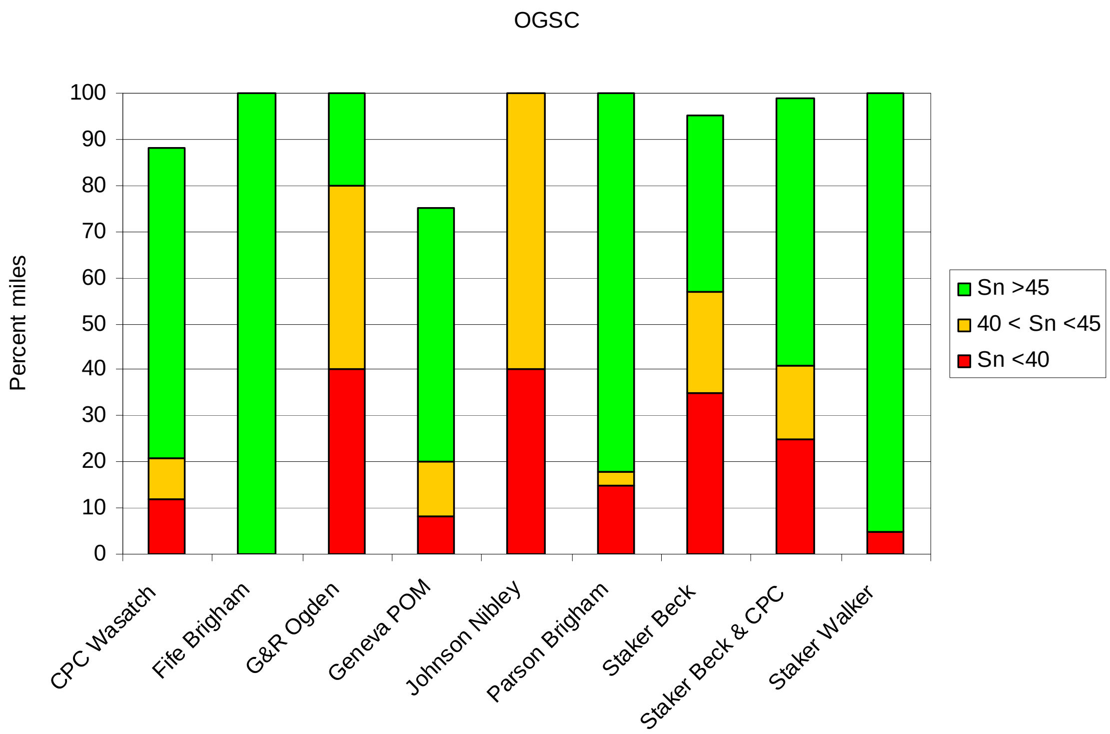

Figure 7. Effect of aggregate source on skid resistance of OGSC (Note that columns do not add up to 100 due to missing data)

Perhaps a more realistic way to measure aggregate performance in OGSC is to look at year 3 only and separate each aggregate source by traffic, when possible. Unfortunately when this is done, the number of miles available for analysis is significantly reduced. To increase the number of points available for analysis, the threshold for Sn was increased to 50. This is based on the recommendations provided by the TAC. The results for OGSC and CSC are shown in the Tables 2 and 3, respectively.

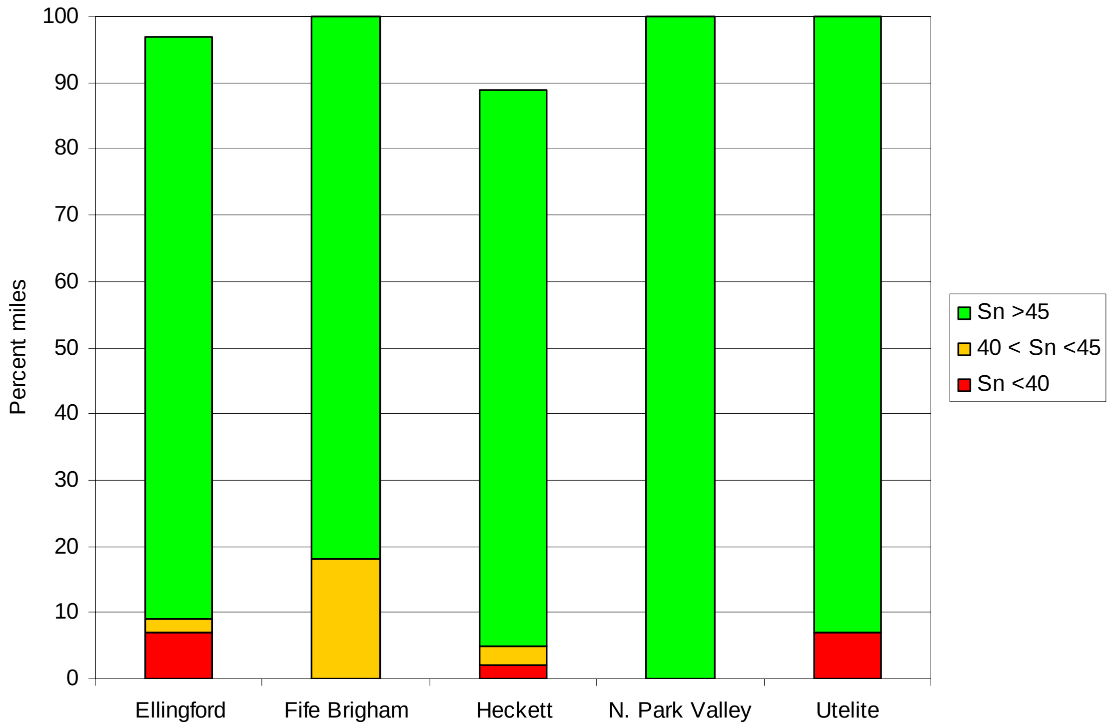

Figure 8. Effect of aggregate source on skid resistance of CSC
(Note that columns do not add up to 100 due to missing data)

Figures 6 and 7 show that the durability of surface treatments is dependent on aggregate source as not all aggregates performed the same. As expected, some aggregates seem to provide greater skid resistance than others. In some cases, this was well known to maintenance personnel.

The reasons for the differences in performance are not known. It is suspected that the texture of some aggregates can lead to a decrease in the skid resistance due to mix design issues like bleeding, or simply aggregate abrasion and polishing.

Table 2. Effect of aggregate source on the performance at year 3 of OGSC

Aggregate source	**Miles with SN < 50**	**Total Miles**	**AADT**
CPC Wasatch	0	7	5,530
G&R Ogden	1	1	7,095
Geneva POM	0	1	9,445
Parsons Brigham	0	2	7,445
Staker Beck	6	6	4,225

Table 3. Effect of aggregate source on the performance at year 3 of CSC

Aggregate source	Miles with SN < 50	Total Miles	AADT
	1	9	370
Ellingford	0	6	590
	2	8	3,620
Fife Brigham	2	2	>5,000
	1	4	270
Heckett	0	11	750
	2	7	920
	1	3	1,320
	0	27	<500
North Park Valley	2	7	565
	0	2	828
	0	4	970

Tables 2 and 3 have limited data for a complete analysis. There are few distinctions in the aggregate with the exception of Staker Beck source, which stands out as an aggregate source that is prone to low skid resistance. In the case of Fife Brigham, it shows that as AADT increases, so does the possibility of failure.

Asphalt Source

A more difficult task was to separate the data into different asphalt sources for evaluation. This data was not complete and some of the refineries have merged or changed names since the data was collected. Furthermore, the data represents the binder source without any consideration to future modifications that might have occurred. Different suppliers also produce different grades of asphalt binder and emulsions used in surface treatments.

An attempt to look at binder sources is shown in Figures 9 and 10. Again, these figures are based on the 6-year duration of the treatment. They do not separate early failure from late failures nor do they consider traffic.

In general, Figures 9 and 10 show only small differences between the asphalt suppliers in terms of performance. This is not surprising given that almost all asphalt used in OGSC had the same grade (AC-20) and all the emulsions used in CSC were CRS-2. Not enough data is available to separate the different asphalt suppliers into traffic categories.

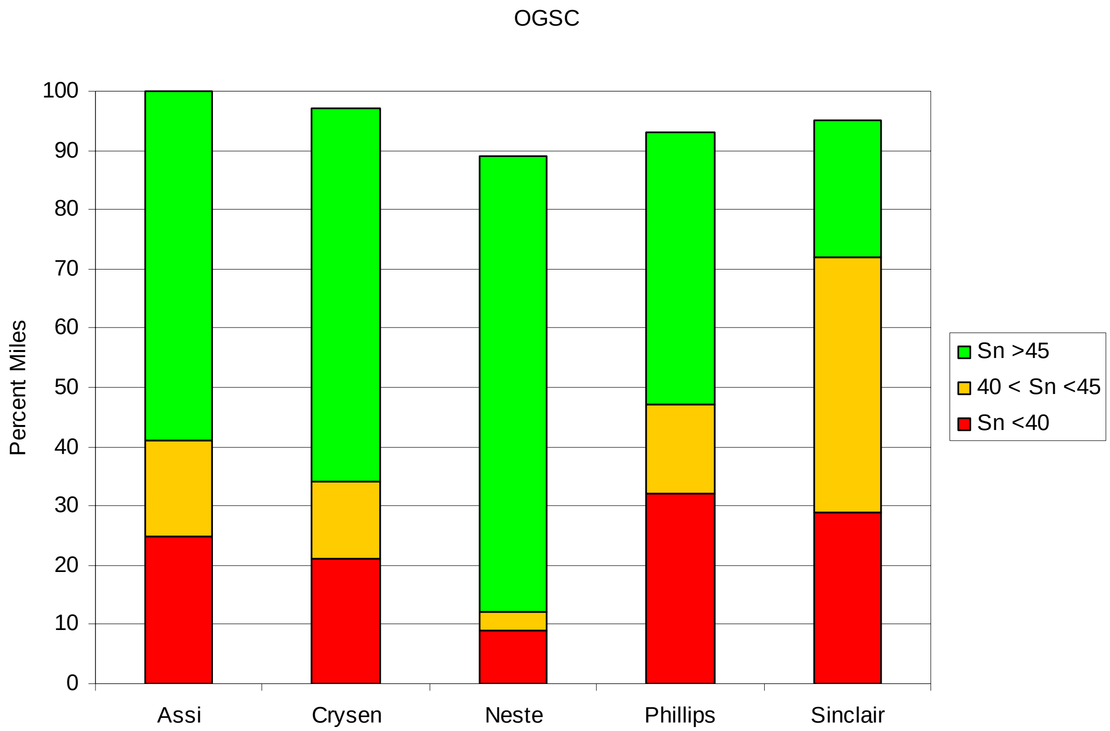

Figure 9. Effect of asphalt binder source on the skid number of OGSC

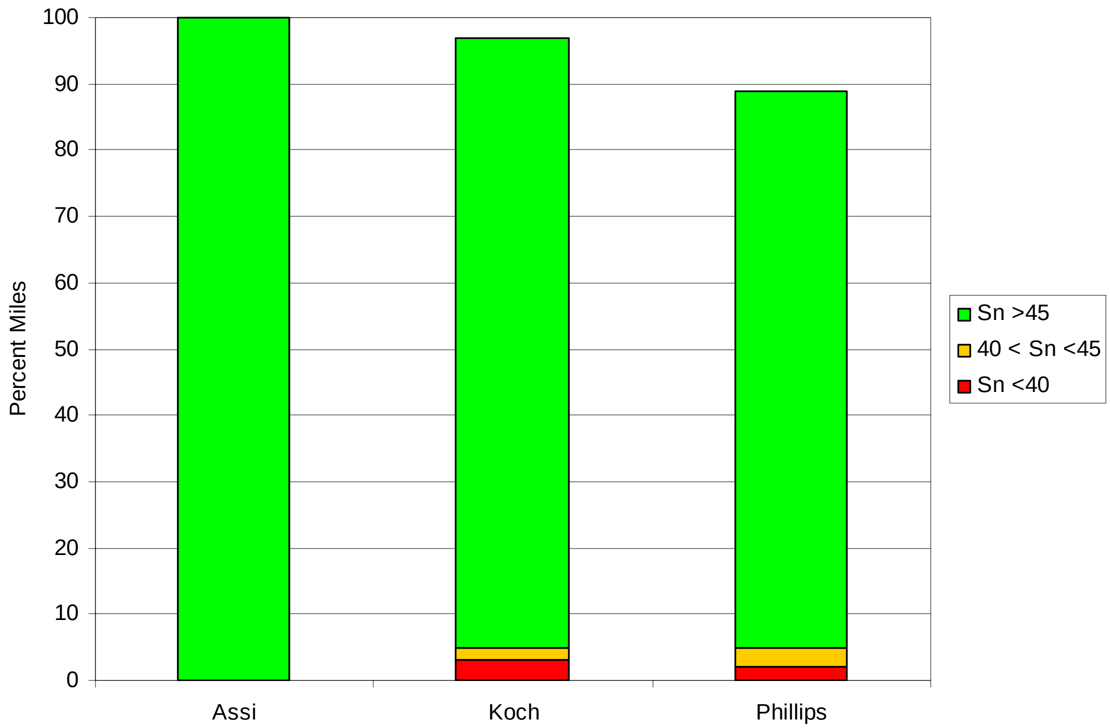

Figure 10. Effect of asphalt binder source on the skid number of CSC

Survey

As part of this work, a survey was send to maintenance and materials personnel to obtain information on the failure modes and failure levels of OGSC and CSC. This information was compared with the result obtained in Utah.

Twenty-two state DOTs responded to this questionnaire. Surveys were also completed by the Asphalt Institute, the Foundation for Pavement Preservation, and San Diego County. A summary of the results is included next.

Open Grade Surface Course

Agencies Using OGSC:

Georgia DOT	Greater that 25,000 AADT
Nevada DOT	High volume and high ESAL corridors
Oklahoma DOT	Interstate and high volume corridors
Wisconsin DOT	Preventive maintenance treatment

Limited Use of OGSC:

California DOT	To reduce truck spray only
Connecticut DOT	Very limited use since 1993- significant failures
Missouri DOT	Based on traffic, cost, pavement type, spray, friction needs
Nebraska DOT	Trying their first at this time
Rhode Island DOT	To reduce hydroplaning, spray, and noise
South Carolina DOT	Interstate and other high volume controlled access
Texas DOT	Discontinued in 1994. Use a Permeable Friction Coarse (PFC) with fibers and PG-76

Agencies Not Using OGSC:

Alaska DOT	
Colorado DOT	
Illinois DOT	Some poor performance, abandoned use in 1980's
Louisiana DOT	
Maine DOT	
Michigan DOT	Tried but discontinued
Minnesota DOT	
Montana DOT	
North Dakota DOT	
San Diego County	
Tennessee DOT	Nova Chip only
Washington DOT	Discontinued due to raveling

The average life of an OGSC: 9 years, with a range 5 to 12 years

Few states had knowledge of the reduction in life of an OGSC on top of a previous OGSC. Two states estimated a 3 or 4 year reduction. Many mill off the OGSC prior to placing the new surface.

An extreme variance was reported in the estimated OGSCs failing prior to replacement. The average is 27%, with a range of 1 to 80% failing.

Agencies use OGSCs for:

Hydroplaning	13 states	57%
Spray	13 states	57%
Friction	7 states	30%
Noise	3 states	13%

The average rating of reducing hydroplaning/spray of OGSC is 4.4 high, 4.0 medium, 3.5 low volume.

The Asphalt Institute recommends OGSCs on high volume roadways. They believe an OGSC is generally very effective to reduce hydroplaning and spray on high and medium volume highways.

The Foundation for Pavement Preservation indicates that an OGSC should last 10 years if a fog seal is placed on it every 3 or 4 years. They believe that the life of an OGSC placed on top of an existing OGSC will not be reduced. The foundation estimates that 20% of the OGSC placed fails prior to replacement. They indicate that an OGSC is very effective in reducing hydroplaning, spray, and noise.

Texas DOT has implemented an Permeable Friction Coarse (PFC) that contains fiber, and utilizes PG-76 as the binder to reduce spalling. They have a somewhat more open gradation than a traditional OGSC. Three years of service have been observed with good performance.

Five agencies (23%) report that they are using Nova Chip. This product was developed in Europe and introduced in the U. S. in 1992. A layer of heavily-modified emulsion is applied to the road surface, and within three seconds, a layer of HMA is place with a screed onto the emulsion. Nova Chip is designed around an average 0.5 inch material depth with a maximum depth of 1.5 inches. The material is compacted with a static 8 to 10 ton roller.

Chip Seals

Agencies Using Chip Seals:

Alaska DOT	With high float asphalt in single and double layers
California DOT	Less than 30,000 AADT
Colorado DOT	
Louisiana DOT	Less than 7,000 AADT
Michigan DOT	Single & double course applications. Also Nova Chip.
Montana DOT	
Nebraska DOT	
North Dakota DOT	
Oklahoma DOT	
Rhode Island DOT	
San Diego County	
Texas DOT	Nova Chip
Washington DOT	
Wisconsin DOT	

Limited Use of Chip Seals:

Connecticut DOT	Rural roads with AADT less than 3,000
Georgia DOT	County roads with a few hundred AADT
Nevada DOT	
South Carolina DOT	

Agencies Not Using Chip Seals:

Illinois DOT	
Maine DOT	Experimenting with microsurfacing
Minnesota DOT	Use Nova Chip
Missouri DOT	Nova Chip
Tennessee DOT	Nova Chip only

The reported average life of a chip seal is 6.5 years. The range is 3 to 15 years.

Most states believe that there is no reduction in life for a chip seal placed on top of a previous chip seal. Only three states listed any loss in life, with none over three years. Some states indicated that there is a benefit from multiple chip seal layers.

Chip seals failing prior to replacement estimated at 27% on average with a full range of 1 to 100%. This wide range is no doubt due to a range in designs, materials, underlying pavement condition, time between replacement, definition of failure, etc.

The Asphalt Institute recommends that chip seals be used on low volume roadways with AADTs less than 2,000.

The Foundation for Pavement Preservation indicates that if chip seals are used as a preventive maintenance application they will extend the life of a pavement system. They report that a chip seal lasts about six years, and that placing chips on top of previous applications is beneficial. They estimate that 15% of chip seals fail prior to replacement.

Comments

The data available for this report, while limited, shows that there are significant differences in performance between OGSC and CSC. The degree to which these differences can affect the decision to apply one treatment or another is a subject that deserves a more rigorous analysis than what has been done with the available dataset.

Out of all variables analyzed, traffic stands out as having the most significant effect on the performance of the treatment based on skid resistance. This indicates that the decisions to apply any given treatment should carefully consider traffic conditions. Construction materials such as aggregates and asphalt also seem to have an effect on the performance of the treatment. However, without the ability to perform a cost analysis, it is difficult to comment on the applicability of one aggregate or asphalt source over another.

Cost Analysis

As stated in the background, one of the reasons for this study was to determine if replacing OGSC with CSC on selected sections was a viable alternative so that the number of surface areas in need of treatment can be covered with existing budgets. The data shows that the use of CSC can be expanded while still maintaining the needed level of skid resistance. With this in mind, a cost analysis is presented that shows how the use of CSC can be expanded and the corresponding savings associated with this change.

Utah's highway system is made up of the following AADT breakdown:

AADT	Surface Areas	Miles
Less than 5,000	11,020	3,975
5,000 to 10,000	2,500	630
10,000 to 25,000	3,740	780
Greater than 25,000	2,390	395

Most of the lane miles under the jurisdiction of Utah DOT have AADT less than 10,000 vehicles. Thus, CSC represents the majority of surface treatments. The data presented shows that CSC can perform at an acceptable level within this traffic range. A national survey shows that most state agencies either do not use OGSCs, or the use of OGSC is limited to high volume, high speed facilities. Only 4 states reported that they use OGSC on a large portion of their system. They are used only where spray and hydroplaning are a problem or are not used at all. National experts indicate that OGSCs are more costly than other seals, and durability problems have led them away from extensive use.

The current maintenance policies can be changed and the use of CSC expanded based on the following percentage of State Highways receiving the listed seal types.

Seal Type	Surface Areas	Percentage
CSCs	11,020 to 13,520	55 to 70%
Dense Seals or CSCs	3,740 to 6,240	20 to 30%
OGSCs	2,390 to 2,750	12 to 14%

Previously about 30 to 45% of the surface areas in the State received OGSCs as the routine maintenance treatment. Reducing this to the recommended level of 12 to 14% will result in a significant savings for the Department in routine maintenance costs.

Costs

Preservation Seal Coats In Utah

Cost Analysis

AADT	*Surface areas*	*Miles*
< 5,000	**11,020 (56%)**	**3,975 (69%)**
5-10,000	**2,500 (13%)**	**630 (11%)**
10-25,000	**3,740 (19%)**	**780 (13%)**
>25,000	**2,390 (12%)**	**395 (7%)**
Total	**19,650**	**5,780**

Current program cost estimate:

Open Graded SC:

$21,000 x 6,130 =	$128.7 million
Annual expenditure =	$14.3 million (9 year life)

Chip Seals:

$6,200 x 13,520 areas =	$83.8 million
Annual expenditure =	$12.0 million (7 year life)

Total Seal Program = *$26.3 million per year**

Proposed program cost estimate:

Open Graded SC:

$21,000 x 2,390 =	$50.2 million
Annual expenditure =	$5.6 million (9 year life)

Dense Seal: Eliminate first cycle

$21,000 x 3,740 =	$78.5 million
Annual expenditure =	$8.7 million (9 year life)
Eliminate first cycle =	$6.5 million

Chip Seals:

$6,200 x 13,520 areas =	$83.8 million
Annual expenditure =	$12.0 million (7 year life)

Total Seal Program = *$24.1 million per year**

* Does not include pavement marking, traffic control, etc.

Difference **$2,2 million per year**

Conclusions and Recommendations

Chip Seals have served UDOT well. The use of Chip Seals on low volume highways has shown good performance. Premature failures are rare, and are usually a result of construction problems or failure of the underlying pavement.

Open Graded Surface Courses (OGSC) have had a mixed performance record in Utah. The average life of OGSCs has been shown to be 7 years. Early failures are related to raveling, stripping, and the development of potholes.

It is recommended that UDOT modify the existing policies on seal coats. OGSC should be limited to high volume, high speed facilities. This would be sections where the running speeds are 55 mph or greater, and AADTs are in excess of 25,000 AADT. The added safety of reduced spray and hydroplaning justify their use and the increased cost.

The Department should continue to use Chip Seals with the existing policies and procedures. Highway sections with AADTs below 5,000 should still be candidates for Chip Seals. Highways with certain characteristics could be treated with Chip Seals up to AADT levels of about 10,000.

Many medium volume facilities (5,000 to 25,000 AADT) should be sealed with treatments new to UDOT, but proven in other states. These include Nova Chip, Road Armor or other tested products that provide preventive maintenance attributes. These products are less costly than OGSCs, while providing good durability and performance. A series of experimental features is recommended to place test sections with these products for evaluation to give UDOT pavement and materials personnel exposure to these products. Where roughness or significant distress is observed, a thicker dense-graded maintenance overlay should be considered for our medium volume highways.

UDOT should consider modifying the existing polishing test criteria. Some poor performing aggregates are being placed on Utah’s flexible pavement surfaces. The Region Material Engineers or a Department QIT should review this issue.

Implementation of the changes suggested as part of this report will result in savings of over $2 million per year in the maintenance budget.

Appendix

List of project analyzed as part of this report

Route No.	Miles	Treatment
80	8	OGSC
89	3	OGSC
106	2	OGSC
210	9	OGSC
91	2	OGSC
37	2	OGSC
89	1	OGSC
26	1	OGSC
15	3	OGSC
71	2	OGSC
111	3	OGSC
171	3	OGSC
173	1	OGSC
181	1	OGSC
186	1	OGSC
248	1	OGSC
91	4	OGSC
102	2	OGSC
15	14	OGSC
89	2	OGSC
15	1	OGSC
36	3	OGSC
48	2	OGSC
89	4	OGSC
106	4	OGSC
171	1	OGSC
173	2	OGSC
181	2	OGSC
186	3	OGSC
190	6	OGSC
201	3	OGSC
201	4	OGSC
209	3	OGSC
215	2	OGSC
266	3	OGSC
270	1	OGSC
84	5	OGSC
89	4	OGSC
89	3	OGSC
89	3	OGSC
13	1	OGSC
15	16	OGSC
39	5	OGSC
83	12	OGSC

84	16	OGSC
89	2	OGSC
90	1	OGSC
91	1	OGSC
227	1	OGSC
235	3	OGSC
239	1	OGSC
201	2	CSC
36	17	CSC
65	5	CSC
150	15	CSC
150	7	CSC
199	8	CSC
202	1	CSC
232	2	CSC
30	48	CSC
32	2	CSC
150	8	CSC
16	29	CSC
30	49	CSC
30	13	CSC
30	14	CSC
30	21	CSC
39	9	CSC
84	17	CSC
84	18	CSC
89	12	CSC
129	4	CSC