PAPER 124

Comparative Field Testing of Asphalt and Concrete Pavement Preservation Treatments in Oklahoma

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ABSTRACT

This paper reviews and discusses the interim results from the first year of a three-year pavement preservation research project. The project builds on research done in Australia and New Zealand by conducting a long-term study of 23 methods to restore pavement skid resistance by retexturing the existing surface with either a surface treatment, chemical treatment, or a mechanical process and furnish the Oklahoma Department of Transportation (ODOT) with the technical engineering data for each treatment coupled with an economic analysis of the costs and benefits associated with each treatment. The project is designed to furnish ODOT pavement managers the required information to make rational engineering decisions based on both physical and financial data for the use of potential pavement preservation tools, evaluated in the field under identical traffic and environmental conditions, over the same period by an impartial investigator. The paper concludes that the combination of skid resistance, macrotexture, and financial data provide a powerful tool to assist pavement preservation engineers in selecting the appropriate treatment for a given road.

INTRODUCTION

With the decline in the condition of the nation's transportation infrastructure, pavement preservation has become an essential component to every state Department of Transportation's (DOT) program. Small states, like Oklahoma, have annual construction budgets that far less than larger states and as a result, preserving the state's infrastructure is doubly important. Unfortunately, true pavement maintenance/preservation research has been limited to investigatory material science across the US, which while valuable, does not usually provide the technical and more importantly, financial information that pavement managers need to make informed decisions. In fact, the majority of the research is done by the commercial entities that manufacture and sell the various pavement preservation products, leaving DOTs with no choice but to experiment with different means and methods by trial and error. Luckily, this has not been the case overseas where a robust pavement preservation research program has existed for the past three decades.

Maintaining Skid Resistance as a Preservation Activity

Pavement skid resistance is perhaps the most important engineering component of the road from a safety standpoint. During the period 1995-2001, nearly a half a million injuries and over 6,000 fatalities were attributed to roadway accidents caused by slippery pavements (Noyce et al. 2005). Slippery pavements are the result of several causes chief of which is the loss of both pavement surface micro and macrotexture. A European study found that increasing the pavement's macrotexture not only reduced total accidents under both wet and dry conditions but also reduced low speed accidents (Roe et al. 1998). Another author found the following: "The safety of a pavement surface is related to both the surface friction and the texture of the pavement. It is imperative that pavement surfaces provide adequate friction and drainage ability to minimize the number of accidents that occur as a result of frictional deficiencies" (Flintsch et al 2003). As a result, pavement managers must not only manage the structural condition of their roads but also their skid resistance (NCHRP 1989). In fact it is possible for a structurally sound pavement to be rendered unsafe from a loss of skid resistance due to polishing of the surface or in the case of chip seals, flushing of the binder in the wheel paths (Patrick et al 2000). This results in a safety requirement to modify the pavement surface to restore skid resistance. Many of the possible tools for restoring skid resistance, like chip seals, are also used for pavement preservation. Thus, it seems that maintaining adequate pavement skid resistance is also a pavement preservation activity (Moulthrop 2003). This intersection of two requirements creates a technical synergy that a state like Oklahoma can leverage to stretch its pavement maintenance budget if it has the necessary technical and financial information to assist decision-makers in selecting the appropriate surface treatment tool for a given situation.

There is a wealth of information on skid resistance in the literature (Henry 2000). However, most of the previous research has been in the safety realm developing the relationship between skid resistance and crashes. There is also a wealth of information on pavement surface treatments (NCHRP 1989). However, the majority of the research has been in the laboratory and is focused on the material science. Very little substantive work has been done in the field regarding surface treatment performance, and most of the research in this area is focused on short-term performance (Owen 1999). The FHWA Long Term Pavement Performance Program (LTPP) collects friction data as part of its standard protocol (Titus-Glover and Tayabji 1999). However, the LTPP data largely relates to pavement mix design criteria and while it includes data for chip seals, it does not collect data for any of the other potential pavement preservation treatments. Additionally, the research typically only studies a single surface treatment. Also making it more difficult for DOT pavement managers, much of the published research is commercial in nature and while completely valid, contains a strong inherent bias toward showing the given product in its best light (ARRB 2001; Vercoe 2002; Bennett 2007). Finally, with a couple of exceptions, both completed by the authors of this paper (Gransberg and Pidwerbesky 2007; Gransberg and Zaman 2005), virtually no research in this area has addressed the economic aspects of pavement retexturing in conjunction with the engineering aspects. Thus, the gap in the body of knowledge is the lack of engineering data correlated with a comparative economic analysis of different alternatives to restore skid resistance on a long-term basis. It must be noted that pavement preservation involves more than just the monitoring of skid resistance and macrotexture. However, those are the primary variables of interest in this research.

International Pavement Preservation Research

Transportation agencies in the United States have procedures in place to identify and rectify skid resistance problems. However, the procedures are often empirical and tend to be reactive rather than proactive in nature. This is not the case in some overseas countries. For example, Austroads, the Australia/New Zealand equivalent to AASHTO, developed and has been successfully using a set of procedures to literally manage pavement macrotexture for the past three decades (Austroads 2005). Austroads sees macrotexture as furnishing enhanced drainage to combat hydroplaning during wet periods as well as enhancing skid resistance and as such implemented an aggressive macrotexture-oriented program as part of their pavement management system. Therefore, it is not necessary to develop new procedures for the industry and the transportation agencies in the US. Americans can customize the Austroads model to suit US needs. The Austroads "Procedure to Identify and Treat Sites with Skidding Resistance Problems" uses the following five steps:

1. "Identify [possible] treatment [alternatives]
2. Cost works and carry out economic evaluation
3. Shortlist schemes in priority order
4. Carry out short-term measures, if required
5. Program longer term measures" (Austroads 2005).

From the aforementioned discussion, it is evident that pavement managers in Australia and New Zealand have not only the engineering technical data that they need to generate a set of technically feasible options for rectifying a loss of skid resistance, but they also have the economic data required to be able to place those alternatives in the context of a limited maintenance budget. It should be noted that this approach does not merely involve selecting the lowest cost alternative. Instead Austroads requires a life cycle cost analysis to accompany all public works and as a result, selects treatment alternatives on a basis of the lowest life cycle cost not the lowest construction cost. As a result, a treatment alternative with a higher initial cost but which effectively extends the service life of a pavement for a longer time period can be selected and the long-term benefits to the agency's multi-year budgets can be accrued. Additionally, Austroads advocates the use of both short and long-term measures. For example, a given pavement may lose its skid resistance during the winter months where it is climatically impossible to install a surface treatment due to low ambient air temperatures. Agencies in Australia and New Zealand have a machine called the ultra-high pressure watercutter that can literally go out in a limited area such as a super-elevated curve or a ramp and restore pavement macrotexture in any weather. This is considered a short-term measure. The long-term measure might involve installing microsurfacing or a new chip seal in the summer when the climatic conditions allow it. Both treatments would be included in the life cycle cost analysis used to justify the retexturing project.

In 2005, the Federal Highway Administration issued a memorandum that standardized the terminology for pavement preservation projects (Geiger 2005). This document described those practices that are eligible for federal funding. The essence of that document was to restrict pavement preservation treatments to those that do not enhance or restore structural integrity. Subsequent guidance refined the definition to allow thin overlays up to 1.5 inches (3.7 cm) thick (Gee 2007). Thus, pavement preservation ranges from treatments by shotblasting that merely restore microtexture through fog seals to reduce aging up to thin overlays on asphalt pavements. A similar range of possible treatments exists in concrete pavements which run from shotblasting through grinding and grooving to white-topping.

Therefore, the objective of the study is to build on the research done in Australia (ARRB 2001) and New Zealand (Transit 2002) and conduct a comparative field evaluation of various methods used to restore pavement skid resistance by retexturing the existing surface with either a surface treatment, chemical treatment or a mechanical process. The goal is to assemble the technical engineering data for each treatment coupled with an economic analysis of the costs and benefits associated with each treatment. This will allow pavement managers to have the required information to be able to make rational engineering design decisions based on both physical and financial data for a suite of potential pavement preservation tools. Each treatment alternative will have been evaluated under the same conditions over the same period of time by an impartial research team.

METHODOLOGY

In a nutshell, the research project established a series of asphalt and concrete test sections on State Highway 77H (Sooner Road) between Norman and Oklahoma City, Oklahoma. Each test section is ¼ miles (400 meters) long and one lane wide. Each section has been retextured with a different type of pavement preservation process. Table 1 shows the different pavement preservation treatments that are included in this research. It shows the 23 different treatments that are covered in the research. Of these, 14 were installed during the summer of 2008. These have 12 months worth of data. The remaining sections were installed during the summer of 2009 as a part of a project extension requested by ODOT and members of the pavement preservation industry who donated test sections.

Table 1. Oklahoma Pavement Preservation Test Sections

<table>
<tr><th colspan="3">Asphalt Test Sections</th></tr>
<tr><th>Surface Treatment</th><th>Chemical Treatment</th><th>Mechanical Treatment</th></tr>
<tr><td>• Fog seal
• Microsurfacing
• ODOT Standard 3/8” chip seal
• ODOT Standard 5/8” chip seal
• ODOT Standard 5/8” chip seal with a fog seal
• Single size ½” chip seal
• Novachip
• Open Graded Friction Course
• Open Graded Friction Course with a fog seal
• Permeable friction course
• 1” Hotmix Asphalt mill-inlay</td><td>• E-Krete pavement surface stabilizer
• Asphalt penetrating conditioner with crack seal</td><td>• Pavement retexturing using shotblasting (48” width)
• Pavement retexturing using abrading (72” width)
• Pavement retexturing using abrading (72” width) with fog seal
• Pavement retexturing using a flat headed planing (milling) technique with asphalt penetrating conditioner
• Asphalt diamond grinding</td></tr>
<tr><th colspan="3">Concrete Test Sections</th></tr>
<tr><th>Surface Treatment</th><th>Chemical Treatment</th><th>Mechanical Treatment</th></tr>
<tr><td></td><td>• Pavement retexturing using shotblasting treated (48” width) with Nanolithium densifier</td><td>• Pavement retexturing using shotblasting (48” width)
• Pavement retexturing using abrading (72” width)
• Diamond grinding
• “Next Generation” diamond grinding</td></tr>
</table>

The project features a unique partnership between the Oklahoma Transportation Center, the University of Oklahoma, ODOT, and members of the pavement preservation industry from six states. It will seek to demonstrate the benefits of their pavement preservation materials, means and methods in a manner that will not only be of value to ODOT and other Oklahoma public agencies but also to the rest of the nation. All the test sections were donated by either ODOT or the pavement preservation industry.

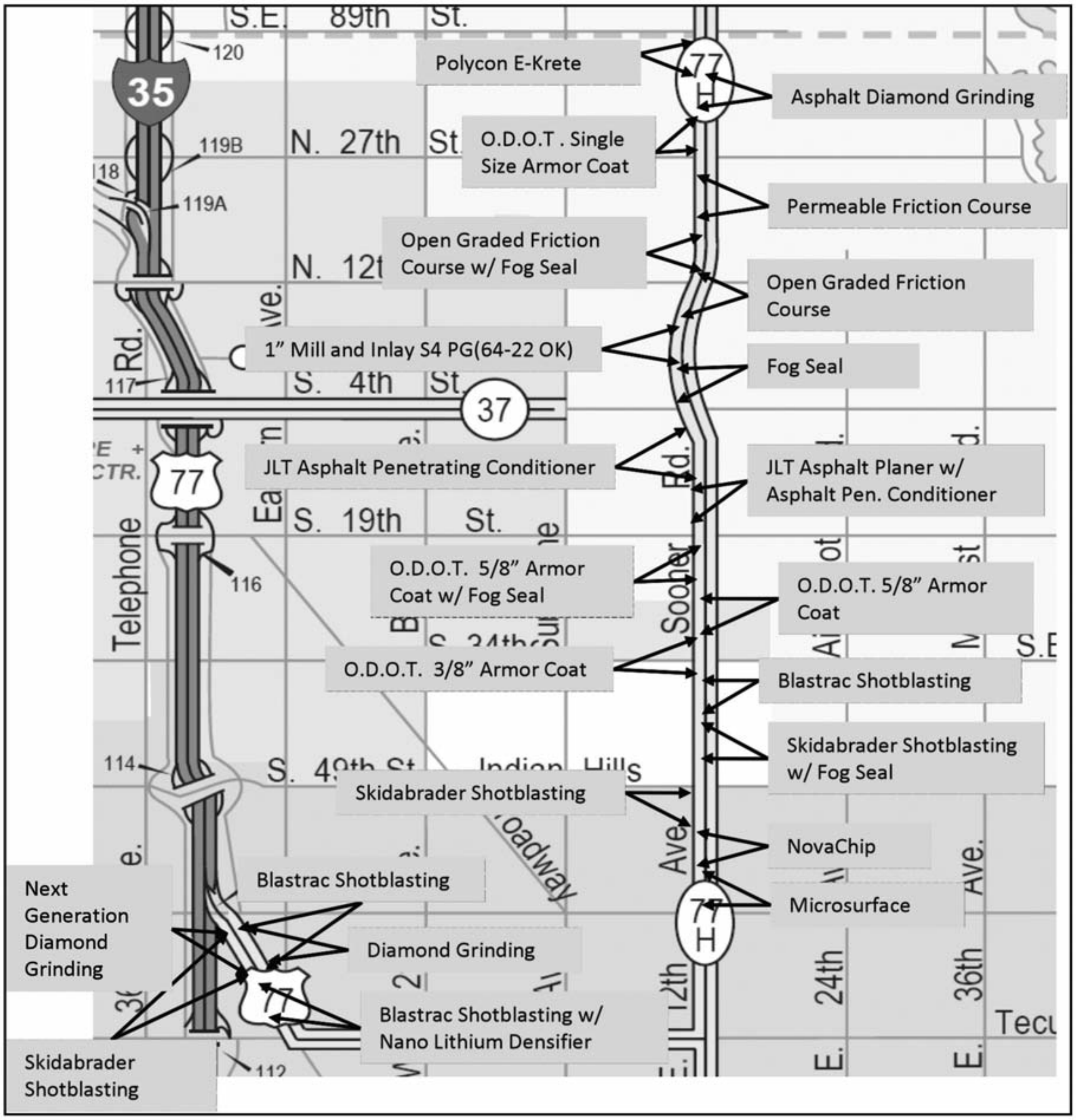

Figure 1. Oklahoma Pavement Preservation Test Site Map

Surface friction and pavement macrotexture were measured on each test section before the treatments and continue to be measured on a monthly basis for three years after application. Thus, changes in both skid resistance and pavement macrotexture will be recorded over time, and each treatment's performance can then be compared to all other treatments in the same traffic, environment, and time period. The project's major deliverable is a pavement surface texture maintenance guide that can be used by ODOT pavement managers to restore surface texture and skid resistance to various types of pavements throughout the state. This will constitute a surface retexturing "toolbox" that contains both the technical engineering information as well as the economic analysis of each treatment's efficacy. The idea is not to identify the "best" method but rather to quantify the benefits of all the treatments in a manner that then allows a pavement engineer to select the right pavement preservation “tool” for the specific issue that they need to address and satisfy the fundamental definition of pavement preservation: “put the right treatment, on the right road, at the right time” (Galehouse et al 2003)

Test Protocol

The first step is to mark the individual test sections. Quarter mile asphalt test sections were selected along the south-bound, outside lane of SH 77H at locations where the alignment was as straight as possible. Additionally, areas at intersections and turn-outs were avoided to the greatest extent possible. Concrete test sections were located in all four lanes of SH 77 using the same standard for actual siting as the asphalt sections. A specific test location roughly in the middle of the test section was marked to ensure that measurements are taken in the same location each month. Finally, untreated control sections were established between the test sections on the existing pavement surface.

Once the test sections were properly marked and the field testing protocol was finalized, the pre-treatment condition of the existing pavement surface at each test section was characterized using the same tests used after the treatments are applied This furnishes a benchmark against which to measure the change in surface friction and macrotexture before and after the treatments for each test section before traffic and environmental conditions begin to impact the treatments.

The aggregate used in each of the treatments was restricted to the same source. Abrasion resistance and aggregate microtexture are the two characteristics that have the greatest impact on skid resistance. Therefore, prior to installation, aggregate samples were collected and characterized in the laboratory using both the Micro-Deval method to test for abrasion resistance as recommended by a FHWA report on pavement preservation (Beatty et al 2002) and the Aggregate Imaging System (AIMS) (Bathina 2005). The Aggregate Imaging System (AIMS) is used to provide a quantitative evaluation of the form, angularity and texture of coarse aggregates and angularity and form of fine aggregates used in surface treatment methods. All aggregates used in the research have been characterized in the same manner.

The field test section data will consist of friction measurements using the ODOT skid trailer and two types of macrotexture measurements (Outflow meter ASTM STP 583 and the Transit New Zealand TNZ T/3 Sand Circle). The TNZ T/3 testing procedure feeds the TNZ P/17 performance specification which can then be used as a metric to judge the success or failure of the surface treatments in their first 12 months based on a field-proven standard (Transit 2002 and 1981). A recently completed pavement surface texture research project in Texas proved the validity of both the test procedure and the performance specification for use in the US (Gransberg 2007). The purpose of taking two different types of measurements of pavement surface macrotexture is to allow a back-check by relative readings to be conducted and thus improve the accuracy of the discrete engineering property data collected as well as to enhance reproducibility. Figure 2 shows the skid trailer and the two field macrotexture tests being conducted in the field.

Figure 2. ODOT Skid Trailer, Outflow meter ASTM STP 583 and the Transit New Zealand TNZ T/3 Sand Circle Testing

EMERGING OUTPUT FROM YEAR I

It would be physically impossible to report on the performance of all the test sections in this paper. So, a few examples are provided that illustrate the emerging findings of the project. The fundamental objective involves measuring the change in macrotexture and skid number over time. A previous study found that “the skid number gradient with speed is inversely proportional to the pavement macrotexture” (Flintsch et al 2003). Thus, as this study is focused on pavement preservation, it is important to be able observe the change over time for each measurement on each test section treatment. Figure 3 shows the observed change to date (11 months) for a concrete pavement retextured using the Blastrac shotblasting technology and an asphalt pavement that was covered with an open-graded friction course (OGFC). The concrete pavement is one with very low macrotexture but high microtexture which produces a high skid number. Figure 3 shows that this test section’s macrotexture remained virtually constant over the year. The skid dropped from the initial value but since then has remained basically constant. It must be noted that the test protocol was established to reduce as much variation in test locations as possible. However, all three tests are inherently variable as it is functionally impossible to take the measurements in exactly the same spot. Thus, it is the trends over time that are important rather than the individual measurements.

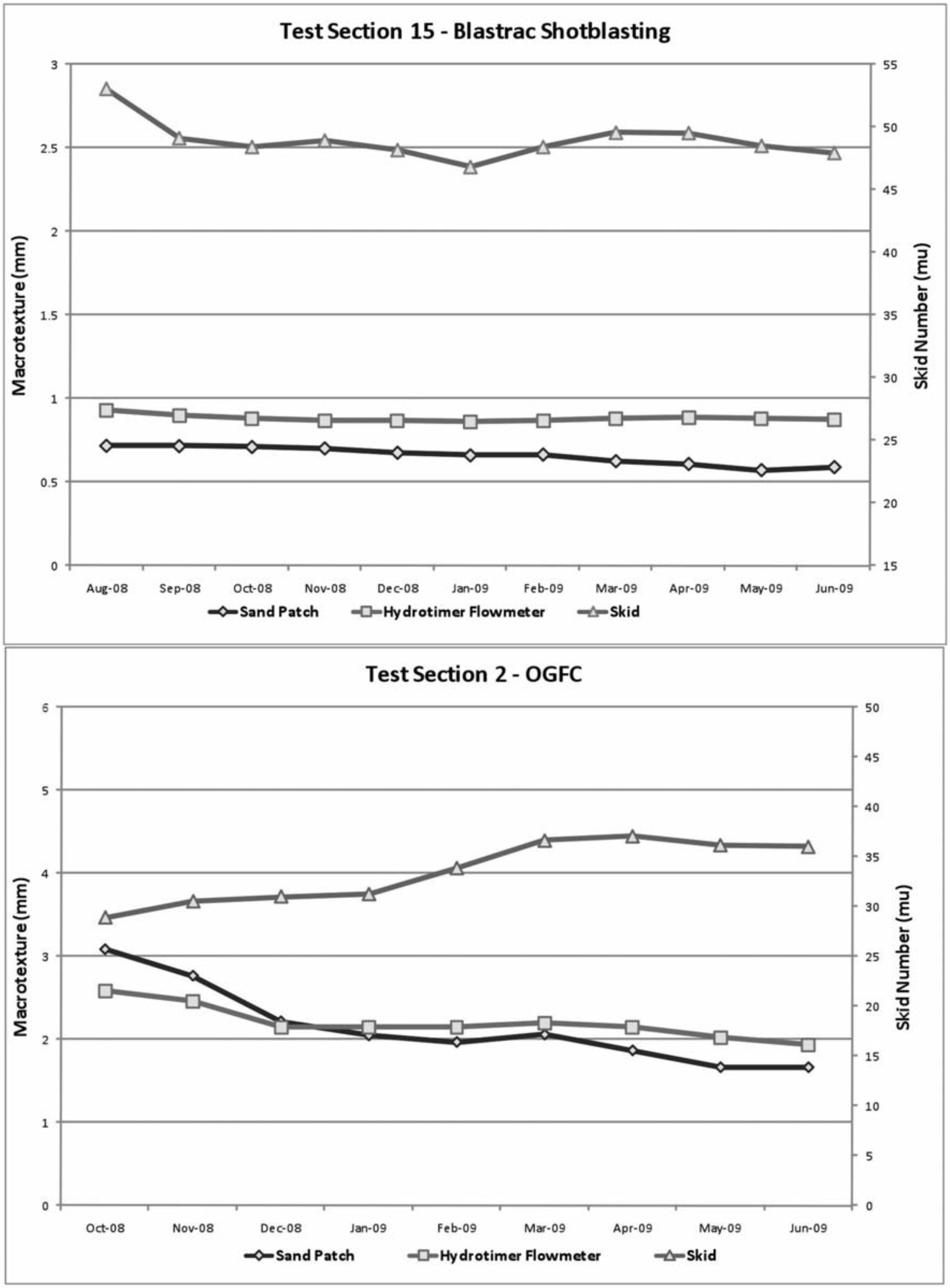

Figure 3. Test Sections 2 and 15, Skid Number and Macrotexture Measurements for Year-1

The next example is a test section that was treated with an asphalt penetrating pavement conditioner (i.e. one of the chemical treatments). This treatment was recommended as a pavement preservation treatment for structurally sound asphalt pavements whose primary distress is oxidation. No surface retexturing was done on this section, and this is seen in the two macrotexture test measurements remaining relatively constant in Figure 4. However, the conditioner had an initial negative impact on skid number. However, this immediate loss in skid resistance dissipated as the surface film was worn away by traffic. The project has a second test section that used the same product after milling 1/8 inch off the surface. It too suffered a short-term loss of skid but it had increased macrotexture. This is the type of information that is currently missing in the body of knowledge. This shows that while there is a loss in skid number initially, it takes roughly 3 months to reach a level of 35 and then stays above that level for at least the remainder of the year. A maintenance engineer can now make a rational decision as to the viability of this pavement preservation treatment.

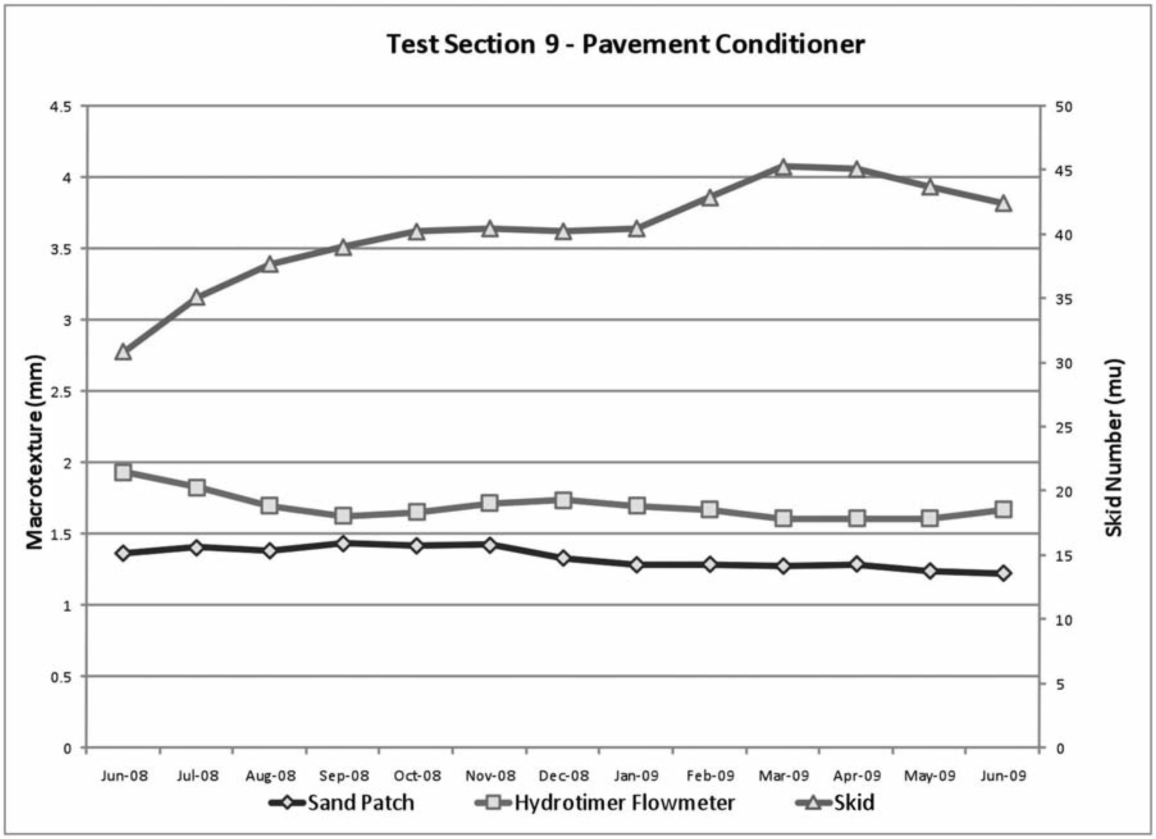

Figure 4. Test Section 9 Skid Number and Macrotexture Measurements for Year-1

Figure 5 shows an example of a thin (1 inch/2.5 cm) hot-mix asphalt overlay that has very low macrotexture by high skid numbers. This is the most expensive of the pavement preservation treatments. It is also the one with the least macrotexture, note that its initial skid numbers are quite high. Given the research by Flentsch et al (2003) that shows that macrotexture is important to pavement drainage and the reduction of hydroplaning, this treatment would be best used in areas where climatic conditions and pavement geometry do not lend themselves to periods of wet pavement. If this does not apply to the problem at hand then a treatment such as a chip seal would be a better choice.

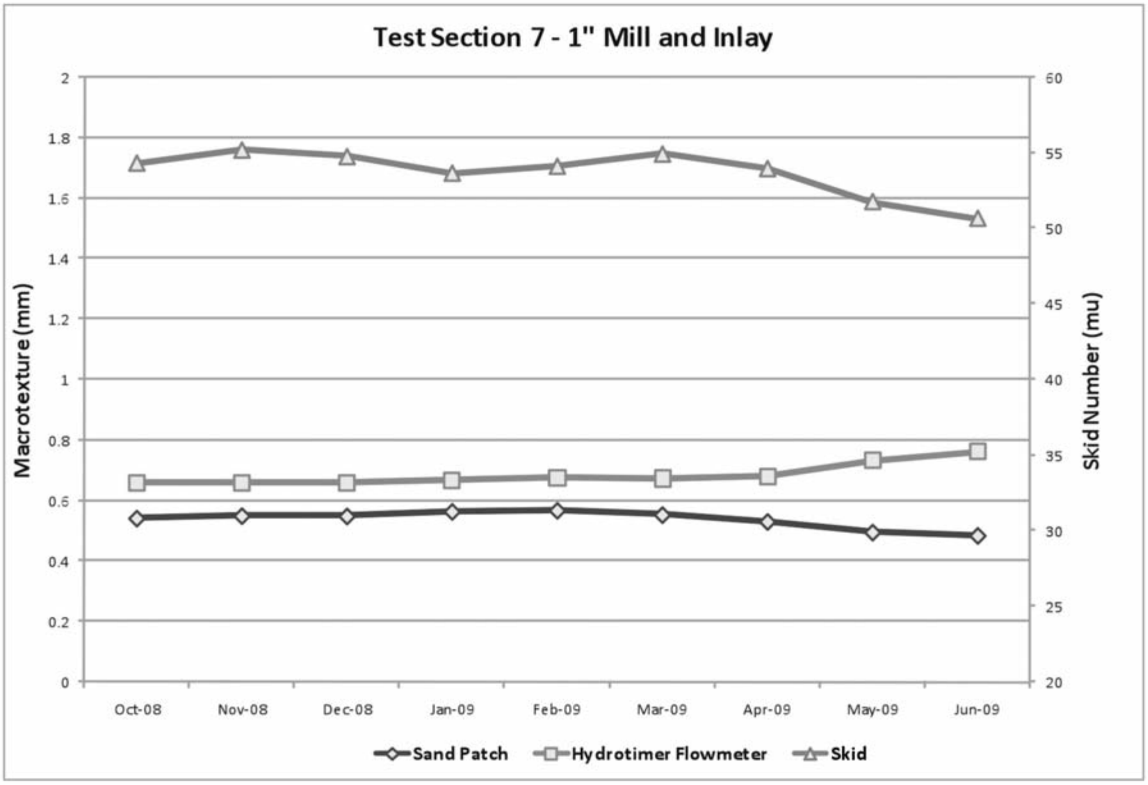

Figure 5. Test Section 7 Skid Number and Macrotexture Measurements for Year-1

Figure 6 shows the comparison with the above mill and inlay test section and a chip seal test section. First it should be noted that the inlay test section was constructed 2 months after the chip seal test section, hence the different periods shown in the graph. This example graphically shows the trade-off that must be made by a maintenance engineer when deciding to which pavement preservation treatment is most appropriate for a given problem on the highway. A later phase of this research project will set to measuring cost effectiveness based on actual field performance. The technique that will be used will be cost index number theory (West and Riggs 1986). This technique allows the analyst to measure the "bang for the buck." In this case, the following equation can be used to calculate the Skid Number Cost Index for each treatment alternative (Gransberg and Zaman .

$$\mathrm{SNCI}_i = \frac{\mathrm{TC}_i}{\mathrm{Ave\ SN}_i} \qquad \text{Equation 1}$$

Where: SNCI_i = Skid Number Cost Index of Treatment "i"
$\mathrm{Ave\ SN}_i$ = Average Skid Number of Treatment "i"
TC_i = Total Cost per Lane-mile of Treatment "i"

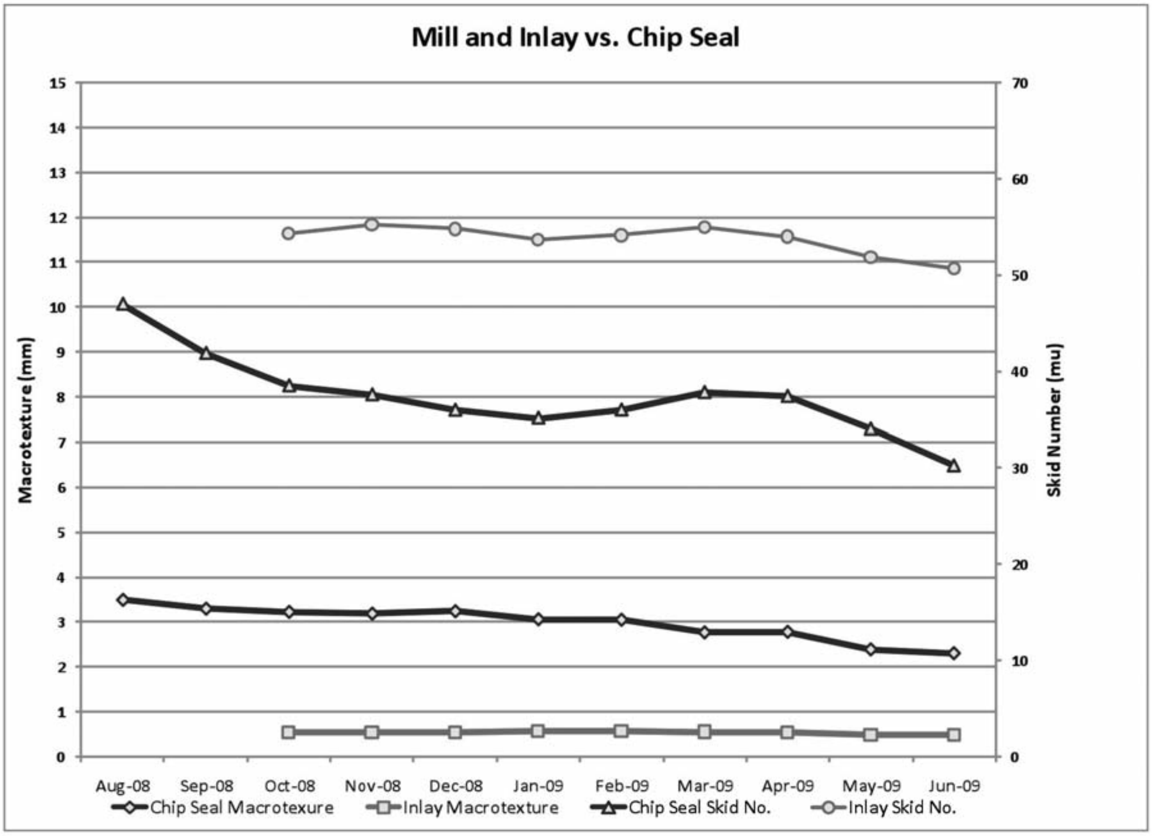

Figure 6. Comparison of Skid Number and Macrotexture Measurements
Hotmix Mill and Inlay versus a Chip Seal

Using the July 2008 prices from the Oklahoma Department of Transportation, which is the period in which these two treatments were installed, the results are obtained and shown in Table 2. The alternative with the lower cost index number is the more cost effective option. So given the information on skid change, macrotexture and the financial facts, the maintenance engineer can now determine if spending six times as much per lane mile is justified by a 40% increase in skid number. The location and traffic level of the road in question would also play into this decision. The idea is to change the decision criterion from "minimize cost" to "maximize value" by having all the necessary decision-making information in one place.

Table 2. Skid Number Cost Index Analysis of Treatment Alternatives

Treatment	Unit Price (July 2009)	Total Cost per Lane-Mile	Average Skid Number	Skid Number Cost Index
1" Mill and Inlay	$8.52/SY	$59,981	52.6	1,141.28
Emulsion Chip Seal	$1.51/SY	$10,630	37.6	282.45
1 SY = 0.84 SM; 1 Lane-mile = 5,890 SM				

CONCLUSIONS

This study shows that the value of long-term pavement preservation field research. It also shows the need to have the combination of both skid resistance and macrotexture available to the maintenance engineer when pavement preservation treatments are selected. The combination of these two measurements with financial information and cost analysis provides all the tools that are necessary to permit an informed engineering and management decision to be made.

This project demonstrates a robust partnership between government, academia, and industry. The fact that over $400,000 worth of pavement preservation treatments were donated as well as the in-kind donations of ODOT in providing traffic control, skid testing, and engineer's time, shows the importance of research in pavement preservation. This project is not a competition between products. It is the start of an encyclopedia of pavement preservation comparative analysis, and projects of this nature should be instituted throughout the US to provide the unique local performance information that only long-term filed testing can generate.

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