
**EVALUATION of NEW
PAVEMENT
TECHNOLOGIES in
NEVADA**

(Interim Report)

May 2003

Prepared by Research Division
Nevada Department of Transportation
1263 South Stewart Street
Carson City, Nevada 89712



TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No. RDT-03-034		2. Government Accession No.	3. Recipient's Catalog No.
4. Report Title EVALUATION OF NEW PAVEMENT TECHNOLOGIES IN NEVADA		5. Report Date March 24, 2003	
		6. Performing Organization Code	
7. Author(s) Peter E. Sebaaly, Gabriel M. Bazi, and Yatheep Vivekanathan		8. Performing Organization Report No. 13AX-1	
9. Performing Organization Name and Address Western Regional Superpave Center Department of Civil Engineering/258 University of Nevada, Reno Reno, Nevada 89557		10. Work Unit No.	
		11. Contract or Grant No. P073-99-803	
12. Sponsoring Agency Name and Address Nevada Department of Transportation 1263 S. Stewart Street Carson City, NV 89712		13. Type of Report and Period Covered Interim	
		14. Sponsoring Agency Code	
15. Supplementary Notes			
16. Abstract This report documents the performance of new rehabilitation technologies of highway pavements in Nevada. A total of five new technologies were evaluated: four for flexible pavements and one for rigid pavements. The technologies evaluated include: cold in place recycling, crumb rubber modified mixtures, HMA overlays over concrete pavements, Hveem mixtures with PG-graded binders, and special asphalt binders. The performances of the various technologies were evaluated using the pavement management system (PMS) indicators as measured by the Nevada DOT on annual basis. The PMS performance indicators included: present serviceability index (PSI), rut depth (RD), fatigue cracking, thermal cracking, and block cracking. The performance indicators for each project were collected over its service life. The variations in the PSI, RD, and fatigue were then used to assess the successes or failures of the technology being evaluated. The data presented in this report showed that: a) the cold in place recycling is an effective rehabilitation technique for Nevada's low and medium volume roads, b) crumb rubber modified mixtures do not represent a cost effective rehabilitation technique under Nevada's environmental, materials, and traffic conditions, c) HMA overlay over a deteriorating concrete pavement is an effective rehabilitation technique as long as the effective action of the concrete slab is broken through crack/seat or rubblization, d) the Superpave PG binder grading system alone is insufficient is evaluating the asphalt binders most commonly used in Nevada, namely polymer-modified binders, therefore, it is necessary to impose additional requirements on the Superpave PG grading system, d) some special binders performed excellent under Nevada's conditions such as polymer modified binders while other special binders such the Trinidad Lake blended binder did not perform well.			
17. Key Words Pavement Rehabilitation Technologies, cold in place recycling, crumb rubber modified asphalt binder, Superpave PG grading system, Polymer-modified binders, Trinidad Lake asphalt.		18. Distribution Statement Unrestricted. This document is available through the National Technical Information Service, Springfield, VA 21161	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. Of Pages 50	22. Price

INTRODUCTION

For many years, state highway agencies (SHA) have been trying to assess which rehabilitation technology is best suited for their roadways. This research deals with the evaluation of field performance of new flexible pavement technologies in Nevada. The alternatives considered by an agency for rehabilitation usually represent current practice. However, they almost invariably continue to change as new technologies become available. Very often, successful and cost-effective technologies seem to become part of the long-term practice.

A pavement is a complex structure, which is subjected to many diverse combinations of loading and environmental conditions. Adding to this complexity are; materials behavior, varying pavement performance and their interrelationships.

Traffic loading and environmental factors cause hot mixed asphalt (HMA) pavements to degrade and eventually fail in various ways. The modes of failure are typically categorized as permanent deformation, cracking, surface defects, and potholes, commonly referred to as pavement distresses. Mixture design methods, structural design procedures, and construction specifications are designed to combat early failure of the HMA pavements. Fatigue cracking, rutting, and edge cracking are load related distresses (i.e., caused by traffic loads, principally trucks). Thermal cracking, block cracking, and reflection cracking are caused principally by environmental factors and thus are considered non-load related distresses (i.e., not caused by traffic loads, although traffic loading can accelerate these distresses in some cases). Bleeding, raveling, and potholes are caused by a combination of environmental factors and traffic loads.

In any given situation, the feasible set of pavement rehabilitation alternatives may be much smaller than the total available options because of costs, physical constraints, or the condition of the existing pavement. In this research, the Nevada Department of Transportation (NDOT) evaluated some technologies that were new to the state but have shown promise in other states such as the crumb rubber technology. In other cases, the research evaluated technologies that were new to the entire country such as the Superpave binder and mixture design system.

Objective

The objective of this research effort was to document the performance of new technologies in pavement rehabilitation, design and materials throughout the state of Nevada. Using the documented performance, the research can recommend changes to existing practices on pavement rehabilitation, design and materials.

Scope

This report documents Nevada's experience with flexible pavement rehabilitation techniques within the past 12 years. The state's experience is then used to implement changes to the current practice. The following list represents a summary of the various technologies that Nevada has experimented with during the past 12 years:

- Cold in place recycling
- Crumb rubber modified (CRM) binders and mixtures
- Rehabilitation of rigid pavements
- Hveem mixtures designed with PG- graded binders
- HMA mixtures with special binders

A number of projects were constructed under each category starting in 1990.

DATA COLLECTION AND PROCESSING

In order for a state highway agency (SHA) to implement new technologies and modify existing specifications and design procedures, it must establish a historical database on the performance of new and existing technologies. Such a database must include extensive information to effectively define the various technologies and the conditions under which the performance are being evaluated. It is well known that certain pavement technologies may perform successfully under a certain set of conditions while they may experience several distresses under a different set of conditions (i.e., traffic, environment, and materials).

The success of the development and implementation of a historical database is heavily dependent on the quality of the data that are being used. The data must be highly accurate and consistent. These two qualities are very difficult to achieve especially when dealing with long-term field performance data. This section describes the various groups of data that have been collected and techniques used to collect and process such data.

Project Related Data

Figure 1 shows the project information data form that was implemented in this research. The date of construction, location, construction, and information on existing pavement were available in the “Pavement Analysis Section” in the construction history database. The mix design information and the gradations for both dense and open graded layers and some of the information on field mixtures were obtained from the Bituminous Lab and the Binder Lab of the Materials Division. The date of construction is needed to define the age of the pavement and to locate the performance related data in the PMS database, it includes the award date and the completion date. The location of the project includes the route and the beginning and ending mileposts that are needed to locate the project within the system.

The construction information includes the type and the thickness of the layers being constructed. This also includes any activity done prior to the overlay (e.g. mill, RBM, rubblization, crack and seat,...). The mix design information was collected for the dense graded and wearing courses. It includes the binder, aggregate, and mix properties. The information on field mixtures includes testing of the materials during construction (behind the paver or cores). These data are part of the quality control process to check if the constructed material satisfies the mix design.

Finally, the information on the existing pavement is collected in terms of the type and thickness of the existing layers

Performance Related Data

Pavement performance data, collected over time, provides the basis for assessing the actual performance of a pavement technology. Pavement roughness, rutting, and cracking represent the major components of NDOT's pavement conditions survey program.

NDOT's philosophy on pavement performance can be summarized as: A "good" pavement provides a comfortable ride to its users, does not require extensive maintenance for the repair of distress, it is structurally adequate for the traffic loads, and provides sufficient friction to avoid skidding accidents.

The present serviceability index (PSI), rut depth and surface cracking will be used to assess the long-term performance of the various technologies in Nevada.

Present Serviceability Index

The PSI concept was developed during the AASHTO Road Test experiment to relate the ride conditions of the road with the opinion of the user. The original PSI equation has been modified throughout the years by state highway agencies in order to better describe the local conditions. Currently NDOT uses the following PSI equation for flexible pavements:

$$\text{PSI} =$$

If $\text{PSI} < 0$ then $\text{PSI} = 0.10$

Where:

IRI = international roughness index (in/mile)

RD = rut depth (in)

C = cracking ($\text{ft}^2/1000\text{ft}^2$)

P = patching ($\text{ft}^2/1000\text{ft}^2$)

The international roughness index (IRI) is the first widely used profile index where the analysis method is intended to work with different types of profilers. It is defined as a property of the true profile, and therefore it can be measured with any valid profilometer. The analysis equations were developed and tested to minimize the effects of some profilometer measurement parameters such as sampling rate.

Almost every automated road profilometer includes a software to calculate IRI. Since 1990, the Federal Highway Administration (FHWA) has required the states to report road roughness using the IRI scale for inclusion in the Highway Performance Monitoring System (HPMS) (1).

NDOT used the slope variance to measure the road roughness prior to 1992, then the ultrasonic profilometer was used

until 2000 followed by the laser profilometer thereafter. Both profilometers produced IRI measurements. Research showed that the laser sensors produce lower IRI (higher PSI) values than ultrasonic sensors. This is due to the better accuracy of the laser sensors (2).

NDOT conducts roughness measurements on an annual basis for all the interstates, many of the US routes and some of the state routes, and on a biannual basis for all others. The profilometer measurement is continuous, but an average roughness value for every mile is recorded unless otherwise specified.

Surface Cracking

For the purpose of this research, fatigue cracking, non-wheelpath longitudinal cracking, transverse cracking and block cracking monitored over the service life of the pavement were selected. The cracking classes, extent and severity are defined in reference 3.

Fatigue Cracking: Fatigue cracking is caused by repeated traffic loading on the pavement surface. These cracks initiate at the bottom of the HMA layer and slowly work their way to the top of the surface. Fatigue cracking usually start as a longitudinal crack in the wheelpath (Type A). Further weakening of HMA and base layers coupled with repeated traffic loading leads to the progression of the longitudinal crack and the formation of interconnected cracks referred to as alligator cracking since they resemble the shape of an alligator skin (Type B). An unstable base, inadequate drainage, insufficient pavement thickness, or moisture damage of the HMA layer combined with traffic loadings will accelerate this type of distress.

The extent of type A fatigue cracking is measured as the total linear feet of this type of cracking in the wheelpath of the pavement area being surveyed. The extent of type B fatigue cracking is measured as the total square feet of this type of cracking in the wheelpath of the pavement area being surveyed (10 feet by 100 feet area at every milepost).

Non-Wheelpath Longitudinal Cracking: This type of crack may occur at a poorly constructed lane joint or be reflective from an underlying joint or crack. This type of distress is not load related and is not located in the wheelpaths. The extent is measured as the total linear feet of cracking throughout the pavement area being surveyed (10 feet by 100 feet area at every milepost).

Transverse Cracking: This type of cracking is primarily caused by the contraction of the HMA layer due to temperature changes. Other causes include: age hardening, reflection cracking from portland cement concrete pavement joints or from transverse cracks below. The extent is measured as the total linear feet of cracking throughout the pavement area being surveyed (10 feet by 100 feet area at every milepost).

Block Cracking: Block cracking starts as a combination of transverse and non-wheelpath longitudinal cracking (Type A). It is caused by age hardening and shrinkage of the HMA layer. Although traffic loading is not the primary cause

of this type of distress, continued loading on the aged surface will accelerate this distress and break the larger pieces into smaller pieces progressing to Type B, and finally to Type C. The extent of type A is measured as the total linear feet of this type of cracking throughout the pavement area being surveyed. The extent of type B and C is measured as the total square feet of this type of cracking throughout the pavement area being surveyed (10 feet by 100 feet area at every milepost).

Rutting

Rutting is a load related failure of the pavement. Any one, or combination of the following factors may cause rutting:

- Soft pavement due to poor quality HMA mix
- Insufficient pavement thickness
- Unstable HMA mix
- Insufficient compaction during construction
- Stripping of the HMA mix
- Pavement wear or loss due to abrasive action of traffic

Rut depth can be measured manually using the straight edge or through the automated road profilometer. NDOT collects both types of rut depth data.

Traffic

Traffic data in terms of the 18-kip equivalent single axle load (ESAL) are collected over the service life of the pavement in order to relate the performance of a project to the traffic level since it is a key contributor to the overall pavement performance.

PERFORMANCE OF Cold in Place Recycling Projects

NDOT started using cold in place recycling (CIR) technology in 1995 to rehabilitate low to medium volume roads serving between 30 and 300 ESALs/day. CIR consists of milling, screening, and crushing the top 2"-3" of the existing HMA layer and remixing it with a low percentage of asphalt emulsion. The resulting compacted layer represents a flexible base that is resistant to fatigue cracking and moisture damage. A new surface layer consisting of a HMA mix or a seal coat is usually applied over the CIR layer. The CIR is believed to strengthen the existing pavement by treating many types and degrees of distresses. The following summarizes the long-term performance of CIR projects throughout the state of Nevada.

Contract 2808

This contract was constructed in August 1997 on US 50 in Eureka and White Pine Counties over 12.5 miles. The

construction consisted of CIR the top 2" of the existing HMA layer and overlaying it with 2" dense graded HMA and ¾" open grade.

Prior to the CIR process, the pavement section had a very low PSI and moderate rutting (0.20"). After the CIR process, the pavement experienced high and steady performance in terms of PSI as shown in figure 2 and no rutting was developed as shown in figure 3. In 2001, minor transverse cracking was observed at one milepost, which can be neglected due to its low extent, and since it is a local failure.

Contract 2819

This contract was constructed in September 1997 on US 95 in Nye County over 7.5 miles. The construction consisted of CIR the top 3" of the existing HMA layer and overlaying it with 3" dense graded HMA and ¾" open grade.

Prior to the CIR process, the pavement was experiencing moderate PSI (3.0) and moderate rutting (0.20"). The CIR process resulted in high and steady performance in terms of PSI as shown in figure 4 and no rutting was developed as shown in figure 5. No other distresses were observed during the four service years of this road.

Contract 2838

This contract was constructed in 1998 on SR 396 in Pershing County over 6 miles. The construction consisted of CIR the top 2" of the existing HMA and overlaying it with 2" dense graded HMA and ¾" open grade.

At present, the performance data included one year of PSI and two years of surface distresses. The pavement had 100% block cracking type B prior to rehabilitation. Based on the limited data presently available, this pavement showed good performance.

Contract 2961

This contract was constructed in 1999 on SR 376 in Nye County over 37 miles. The construction consisted of CIR the top 2" of the existing HMA and overlaying it with 1.5" dense graded HMA and a chip seal.

This is a long project that experienced several types of distresses prior to rehabilitation but none reappeared for the past two years.

CONCLUSIONS AND RECOMMENDATIONS

The long-term field performance of CIR projects throughout Nevada indicated that cold in place recycling is an effective rehabilitation treatment for roads with low-medium traffic levels. Both laboratory testing and field performance proved that the CIR process produces a more flexible and stable base course a greater tendency to resist fatigue and thermal cracking and significantly reduces rutting. Also the use lime in the CIR mix has made it more resistant to moisture damage, which greatly improved the mixture's long-term durability. Based on the performance of

the CIR projects in Nevada, it is recommended that NDOT continues to use CIR for rehabilitating low-medium traffic volume roads. Each project should be designed using the standard mix design procedure for CIR mixtures in Nevada established an earlier research effort and documented in reference 4. In addition, any new products should always be evaluated against the performance of the more established products through both laboratory mix design and analysis and field test sections.

PERFORMANCE OF CRM PROJECTS

It is believed that asphalt pavements containing rubber are more flexible under heavy loads, which results in fewer cracking and durability problems. It has also been observed that asphalt-containing rubber is more resistant to cold weather cracking and warm weather rutting.

In general, Nevada can be divided into two distinct environmental regions: southern and northern regions. The southern region is characterized by a dry and hot environment while the northern region is characterized by a cold-warm and dry environment. Both regions receive low-medium amount of precipitation. Pavements constructed in the southern region are subjected to excessive rutting potential during the hot summer days while pavements in the northern region are threatened with rutting during the warm summer and thermal cracking during the cold winter. The majority of Nevada's aggregate sources are highly susceptible to moisture damage, which is accelerated in the northern region due to the occurrence of freeze-thaw cycling.

Based on a large amount of field performance data throughout California, Caltrans recommends that rubber modified mixtures could be designed at half the thickness of conventional mixtures. This led to the construction of thin overlays on most of Nevada's CRM projects. The following represents a discussion of the performance of the various CRM projects in Nevada.

Performance of Contract 2585

This contract was constructed in 1993 on SR 223 in Elko County over 2 miles. The construction consisted of placing ¾" asphalt rubber concrete (ARC) overlay. Figures 6 and 7 show the performance of this project. The ¾" ARC overlay did not show significant improvement in the PSI which kept on decreasing with time. No rutting occurred over the service life of the ARC overlay. The pavement started showing reflective cracking within one year of construction, which kept on progressing until its rehabilitation in 2000.

Performance of Contract 2623

This contract was constructed in 1994 on SR 225 in Elko County over 13 miles. The construction consisted of placing ¾" ARC overlay with SAMI seal. Figures 8 and 9 show the performance of this project. The ¾" ARC overlay with

SAMI maintained a constant but low PSI level with rutting increasing after the third year. Surface cracking showed up one year after construction and continued to progress until 2001 at which time a new rehabilitation was required.

A conventional HMA overlay was constructed on the same route (SR 225 Elko) in 1996 under contract #2693 following NDOT's standard practice of 2" conventional dense graded HMA mix with ¾" open graded mix. Both the CRM and conventional overlays were subjected to the same environmental and traffic conditions. As shown in figure 10, the conventional HMA overlay experienced higher and steadier PSI performance than the ARC overlay. The Conventional HMA overlay started showing minor transverse cracking five years after construction

Performance of Contract 2505

This contract was constructed in 1992 on US 95 in Mineral County over 6 miles. The construction consisted of placing 1.5" ARC overlay with SAMI. Figures 11 and 12 show the performance of this project in terms of PSI and rut depth, respectively. It should be noted that the first performance survey of the ARC overlay occurs one year after construction. The PSI shows an immediate and continuous drop after construction until rehabilitation in 1999. The rutting data showed a return to the same pre-rehabilitation level in five years after construction. In term of surface cracking, the pavement was highly cracked prior to overlay construction in 1992 but it didn't show any cracking until 1998 when it experienced medium fatigue cracking. In summary, the useful life of this ARC overlay was around five years.

Another project was constructed on the same route (US95 Mineral) under contract #2426 following NDOT's standard practice of 2" conventional dense graded HMA mix with ¾" open graded mix. This project was subjected to the same environmental and traffic loading as the AR overlay on project 2505. Figure 13 show the PSI of the conventional HMA project. The conventional HMA project performed very well throughout its service life. It started showing minor cracking after 8 years of construction which is significantly longer than the useful life of the ARC overlay.

Performance of Contract 2513

This contract was constructed in 1994 on US 93 in Lincoln County over 9 miles. The construction consisted of placing 1.5" ARC overlay with SAMI seal. Figures 14 and 15 show the PSI and rutting performance of this project. This project showed a steady PSI and no rutting was developed. The pavement was highly distressed with block cracking (40–80%) prior to the construction of the ARC overlay, but no cracking was observed for the first five years of its service life. However, the pavement became highly distressed in the sixth and seventh year of its service life. The performance of this project was excellent in terms of roughness and rutting but its resistance to cracking was unsatisfactory.

Performance of Contract 2680

This contract was constructed in 1995 on US 95 in Clark County over 1.5 miles. The construction consisted of placing a 2" ARC overlay with a ¾" open graded course. Figures 16 and 17 present the performance of the ARC overlay which showed good and steady PSI without any rutting. No surface cracking was present until six years after construction where medium extent transverse cracking was observed.

Performance of Contract 2697

This contract was constructed in 1995 on US 50 in Churchill County over 7 miles. The construction consisted of placing 2" ARC overlay. The PSI showed a steady decrease with time (Figure 18). No significant rutting was observed until 2001 (Figure 19). The pavement started showing minor cracking after one year of construction until it became highly cracked in 2001.

CONCLUSIONS AND RECOMMENDATIONS

This section of the report documents the long-term performance of six CRM projects in Nevada. The performance of two CRM projects was compared with conventional HMA overlays that were constructed on the same route during the same time period. On all six CRM projects, the NDOT standard practice would have been to place a 2" dense graded conventional HMA layer and a ¾" open graded course. However, because of the increase in cost of the CRM mixtures, it was necessary to reduce the thickness of the ARC overlays while anticipating similar long-term performance. The following represents the conclusions drawn from Nevada's experience with CRM mixtures.

- On projects 2585 and 2623 NDOT started experimenting with a very thin ARC overlays with and without SAMI in an effort to offset the additional cost of CRM mixtures. The performance of both projects was very unsatisfactory with the SAMI being in-effective in retarding reflective cracking.
- The next step was for NDOT to increase the thickness of the ARC overlay. Projects 2503 and 2513 used a 1.5" ARC overlay with SAMI. The long term performance of the two projects were unsatisfactory indicating that doubling the thickness of the ARC overlay and including a SAMI is still in-effective.
- Finally, NDOT decided to increase the thickness of the ARC overlay to the same thickness as the conventional HMA overlay with and without an open grade. Project 2680 used a 2" ARC overlay with open grade and project 2697 used a 2" ARC overlay. The 2" ARC overlay with the ¾" open grade showed comparable performance to the conventional HMA overlay but the 2" ARC overlay without the open grade showed unsatisfactory performance.
- It has been hypothesized that the un-satisfactory performance of the reduced thickness ARC overlays in Nevada is due to the following reasons: a) the majority of Nevada's aggregate are classified as highly susceptible to moisture damage and b) most of Nevada's low-medium volume roads suffer from extensive age-related cracking which lead to high potential for reflective cracking through thin overlays.

In summary, NDOT's experience with CRM mixtures indicated that for ARC overlays to be effective under Nevada's

materials, traffic, environmental, and pavement conditions, they must be constructed similar to the conventional HMA overlay with a minimum thickness of 2" and a ¾" open graded course. This requirement made ARC overlays too expensive to be considered as a rehabilitation alternative in Nevada.

PERFORMANCE OF HMA Overlays Over Rigid Pavements

When a concrete pavement reaches the end of its serviceable life, there are essentially two rehabilitation alternatives: removing/replacing it or overlaying it with HMA. When removal and replacement proves too costly, the traditional approach has been to use the crack/seat or the rubblization methods before overlaying it with HMA.

The main concern of overlaying rigid pavements with HMA overlays is reflective cracking through the HMA layer. The rubblization provides a total destruction of the existing slab action whereas in the crack/seat method, large pieces (1-3 feet) of the PCC are still present which may lead to a reflection problem. In both techniques, heavy impact loads are used to crack the concrete slabs followed by a heavy rolling to compact the broken concrete pieces firmly into the base/subgrade.

During the 1990s, NDOT had constructed couple PCCP rehabilitation projects. The following represents the performance of these projects.

Contract 2544

This contract was constructed in June 1995 on IR080 in Elko County over 15.5 miles. Two sections were constructed; the first using the rubblization technique and the second using the crack/seat technique. The first section consisted of rubblizing the existing PCC pavement, placing 2" leveling course and 5" HMA overlay with ¾" open grade. The second section consisted of crack/seat the existing PCC, placing 2" leveling course and 4" HMA overlay with ¾" open grade. The two sections had a steady and high PSI as shown in figure 20 and no rutting was developed as shown in figure 21.

No cracking were observed for the first six years. The rubblized section started showing medium extent type A fatigue cracking in the east bound in 2001 and new construction was planned for 2002. In 2001, the crack/seat section started showing medium extent type B fatigue cracking at one milepost, non-wheelpath longitudinal cracking at three mileposts, and medium extent transverse cracking at one milepost. The non-wheelpath and transverse cracking showed up only in the crack/seat section, which could have been reflected from the underlying PCC pavement. The rubblized section did experience such distresses.

Contract 2901

This contract was constructed in 1999 on IR 80 in Humboldt County over 5.5 miles. The section consisted of rubblizing the existing PCC pavement, placing 1.5" dense graded HMA overlay with ¾" open grade.

The pavement section had a steady performance since construction as shown in figure 22 and no rutting was developed as shown in figure 23. No distresses were observed since construction but close monitoring is recommended since this project is still new.

CONCLUSIONS AND RECOMMENDATIONS

Rubblization followed by a HMA overlay seems to be an effective rehabilitation technique for Nevada's rigid pavements. The rehabilitated pavement offers 6-7 years of good service life. It is recommended that close monitoring of performance be continued to establish a larger database.

Performance of Hveem Mixtures Designed with PG-Graded Binders

The objective of this experiment was to identify the PG grade of the binders supplied into Nevada and how they will perform when designed with the Hveem method. By knowing the Superpave PG grades of the binders used on Hveem projects, NDOT can assess the applicability of the PG grading system for Nevada's binders prior to fully adopting it along with the Superpave mix design and analysis methods.

There are total of 24 projects that were designed using the Hveem method while their binders were graded using the Superpave PG-grading system. It should be noted that the binders for these projects were specified using NDOT's AC grading system while during construction the binders were graded using the PG system. Projects that are one to seven years old are currently still in service while older projects have been overlaid as part of NDOT's preventive rehabilitation program.

Table 1 shows the various binder grades that were used on these projects. The AC-20P binder represents the single most common binder among all projects. The great majority of the binders used did not satisfy the PG grade requirements for the project location. Mainly the high temperature PG grade of the AC-20P binders did not satisfy the projects requirements. This should have affected the rutting resistance of the HMA mixtures used on these projects. However, none of these projects experienced any rutting failures. These observations led to the conclusion that the Superpave PG grading system alone is not capable of fully assessing the performance characteristics of polymer-modified binders.

Due to the large number of projects in this category, only a selected number of projects are discussed below.

Contract 2480

This contract was constructed in April 1993 on US 95 in Clark County over 11 miles. The construction consisted of placing 2" dense graded HMA overlay with ¾" open grade. The binder used was an AC-20P graded as PG 58-28. The PSI level was high and steady over its eight years in service as shown in figure 24 and no rutting was developed as shown in figure 25. The section was highly distressed prior to rehabilitation in 1993, but none of these distresses reflected through the overlay until year 2001 when fatigue cracking and transverse cracking were observed in the northbound. New rehabilitation was planned in 2001.

Contract 2491

This contract was constructed in October 1992 on IR 80 in Lander and Eureka Counties over 14 miles. The construction consisted of 8" roadbed modification, a 5" dense graded HMA overlay, and a ¾" open grade. The binder used was an AC-20P and it was graded as PG 52-16.

This contract had an outstanding performance in terms of PSI and no cracking. The PSI level was high and steady throughout the service life as shown in figure 26 and no rutting was seen as shown in figure 27. The section was highly distressed prior to rehabilitation in 1992 but no cracking was observed throughout its 8 years of service.

Contract 2552

This contract was constructed in April 1994 on IR 15 in Clark County over 7 miles. The construction consisted of placing 4" dense graded HMA overlay with ¾" open grade over 1.5" leveling course. The binder used was an AC-20P graded as PG 58-28.

This contract showed a high and steady PSI as shown in figure 28 and no rutting was developed as shown in figure 29. The section was highly distressed prior to rehabilitation in 1994 but no cracking was observed until 2001 where minor fatigue cracking appeared on two mileposts in the north bound.

Contract 2615

This contract was constructed in September 1996 on IR 80 in Elko County over 9 miles. The construction consisted of 8" roadbed modification, 1.5" leveling course, 4" dense graded HMA overlay, and ¾" open grade. The binder used was an AC-20P graded as PG 58-28.

The section experienced a high and steady PSI as it is shown in figure 30 and no rutting was observed as shown in figure 31. No cracking were observed since its construction.

Contract 2622

This contract was constructed in March 1995 on US 95 in Clark County over 4 miles. The construction consisted of placing 3.5" dense graded HMA overlay and ¾" open grade over 1" leveling course. The binder used was an AC-30. The section experienced a high and steady PSI as shown in figure 32 and no rutting was observed as shown in figure

33. The section was severely distressed prior to the 1995 rehabilitation but no cracking was reflected until the present.

Contract 2825

This contract was constructed in September 1998 on SR 651 in Washoe County over 4.5 miles. The construction consisted of cold milling 2" of the existing pavement and replacing it with 2" dense graded HMA overlay and ¾" open grade. The binder used was a PG 70-28.

This section experienced steady and high PSI as shown in figure 34 and no rutting was developed as shown in figure 35. The section was cracked prior to the 1998 overlay but none reflected until the present.

Predicted Performance of Polymer Modified Binders

Table 2 shows the Superpave PG grades for the polymer modified binders used on 12 projects. The Superpave weather database (LTPPBIND) was used to determine the required PG grade for every project (98% Reliability, depth = 0, traffic load = 0, traffic speed = fast). The measured PG grade of the AC-20P binders didn't satisfy the grade requirement identified by the LTPPBind software. However, these projects showed a steady and high performance without any appreciable distresses. The AC-20P binders didn't mainly satisfy the high temperature PG grade that should affect the rutting resistance of these pavements. However, no rutting was observed on any of these projects. This may suggest that the PG grading doesn't work well with polymer-modified binders.

The actual versus the required PG grades of 5 projects are shown in table 3. Table 4 summarizes the conformance of the actual PG grades with the requirements of the project as identified by through the LTPPbind Software.

Contract 2480 was distressed in block cracking type A over the entire section and fatigue cracking in few mileposts prior to construction. After rehabilitation, transverse and fatigue cracking were observed in the 6th year. Pre-rehabilitation data indicate that the transverse cracking may have been due to reflection of the old cracks while fatigue cracking was developed in the overlay.

Contract 2552 started showing low extent fatigue cracking after 7 years on two mileposts. The fatigue cracking cannot be due to reflection since these two mileposts didn't have any fatigue cracking prior to rehabilitation and a leveling course was placed.

Table 5 shows the actual performance of the five projects in terms of rutting, thermal cracking and fatigue cracking.

Table 6 shows the ability of the PG grading system to predict the performance of the mix in the field. As it is shown in table 6, the PG grade was not able to predict the performance of the mix in terms of rutting, whereas for fatigue cracking and low temperature (thermal) cracking, the PG grade was sometimes able to predict the field performance

since these properties are, to a certain extent, dependent on the binder.

CONCLUSIONS AND RECOMMENDATIONS

The performance of the PG-graded binders with Hveem mixtures throughout Nevada indicated that in the majority of the cases the Superpave PG grading system alone is not fully capable of accurately identifying the potential performance of polymer-modified binders under Nevada's traffic, materials, and environmental conditions. On several cases the PG grading system indicated that a potential problem may arise from the use of the polymer-modified binder in the HMA mixture while field performance proved otherwise.

In light of the field performance data that have been developed on the use of PG grading system with Hveem mixtures, it is recommended that any implementation of the Superpave PG grading system in Nevada should be accompanied with specific requirements on the use of polymer modification process. These requirements can be in terms of dictating the percent and/or type of polymer to be used. Recognizing that the Superpave PG grading system was originally developed for neat asphalt binders, this approach will allow NDOT to implement the Superpave PG grading while other research efforts are being conducted to make it more compatible with polymer-modified binders.

PERFORMANCE OF Projects using Special Binders

This experiment was performed to monitor the behavior of some contracts that were constructed with non conventional binders. Two contracts were placed using special binders; the first consisting of five different types of polymers and the second using certain percent of the Trinidad Lake Asphalt (TLA).

The polymer modified binders experiment showed an outstanding performance in all aspects; whereas the one constructed using the TLA binder was very stiff and showed a very high percent of cracking.

Contract 2344

This contract was constructed in March 1990 on IR 15 in Clark County over 1.5 miles in the Northbound. The objective was to evaluate the performance of HMA mixtures designed with five different polymer modifiers. The construction consisted of 8" roadbed modification overlaid with 6.5" dense graded HMA and ¾" open grade.

The five polymer modified binders used are listed below:

1. Witco AR 4000 AW
2. Witco AC 20 PM
3. Dupont/Conoco AR 4000 R
4. Sahuaro/Shell AC 20 HP
5. Sahuaro/Shell AC 20 LR

The sections showed high and steady PSI as shown in figure 36 and the maximum rut depth was 0.3" for test section # 2 (AC-20PM) as shown in figure 37. The pavement sections were rehabilitated after nine years in service as part of

preventive rehabilitation program on the interstate system. The distresses at the time of rehabilitation were minimal under high interstate traffic levels. The full analysis of this project was documented in a recent NDOT report entitled: "Performance of Polymer-Modified HMA Mixtures in Nevada," Report #13Ap-3, August, 2001.

Contract 2603

This contract was constructed in August 1994 on SR 159 in Clark County over 2 miles. The objective was to evaluate the performance of a HMA mixture designed with an AC-20 + 25% TLA binder. The construction consisted of cold milling 3" from the existing pavement and replacing it with 3" dense graded HMA overlay and ¾" open grade.

This project didn't show a significant improvement in the PSI after construction as shown in figure 38. It had a steady and low PSI level for the first five years after which it started to drop. No rutting was observed throughout its service life as shown in figure 39. The roadway became highly distressed especially in the last three years. In 2001, 100% transverse cracking, 80% block cracking type A and 50% non-wheelpath longitudinal cracking were observed at different mileposts.

A post-mortem evaluation of the mix indicated that the binder has experienced significant aging, which led to the extensive cracking and minimal reduction in the in-place air voids.

CONCLUSIONS AND RECOMMENDATIONS

The long term field performance data indicated that polymer-modified binders lead to superior performing HMA mixtures under Nevada's traffic, materials, and environmental conditions. On the other hand, the use of relatively stiff asphalt binder such as the TLA blended binders may cause significant performance problems. Therefore, it is recommended that NDOT continues to use polymer-modified binders throughout the state while any new product be subjected to extensive laboratory and field evaluation prior to adaptation.

REFERENCES

1. "International Roughness Index (IRI)," The University of Michigan Transportation Research Institute (UMTRI).
2. Ksaibati, k., McNamara, R., Armaghani, J., "A Comparison of Roughness Measurements from Laser and Ultrasonic Road Profilers," Florida DOT, Research report FL/DOT/SMO/98-425, August, 1998.
3. "Flexible Pavements Distress Identification Manual," Nevada DOT, Materials Division, Carson City, Nevada.
4. Sebaaly, P.E., Tabet, W., Epps, J.A., and Rahman M., "Evaluation of Rehabilitation Techniques for Flexible Pavements in Nevada," Research report 1276-2, Nevada DOT, Carson City, Nevada, March, 2001.

Table 1. Hveem Mixtures with PG Graded Binders.

Number	Contract	Route	Binder Grade	PG-Grade	LTPPBIND PG Grade	PSI	Distress
1	2480	US095	AC-20P	58-22	70-16	S,H	D8
2	2491	IR080	AC-20P	52-16	64-34	S,H	N
3	2501	IR015	AC-20P	58-28	70-10	S,H	D6
4	2530	IR015	AC-20P	58-28	70-10	S,H	MD5
5	2545	IR080	AC-20P	58-22	64-22	S,H	MD6
6	2552	IR015	AC-20P	58-28	70-10	S,H	MD7
7	2558	IR080	AC-20P	58-16	58-34	S,M	MD7
8	2594	SR163	AC-20P	58-28	70-10	S,M	N
9	2604	IR015	AC-30	70-22	64-16	S,H	N
10	2611	US093	AC-20P AC-20	64-28 64-16	64-28	US	MD4
11	2615	IR080	AC-20P	58-28	64-28	S,H	N
12	2617	US095	AC-20P	52-22	64-28	S,H	N
13	2622	US095	AC-30		70-16	S,H	N
14	2629	SR278	AC-20P		64-34	S,M	MD5
15	2704	IR080	AC-20P	58-28	64-28	S,H	MD5
16	2726	SR160	AC-30P	70-22	70-16	S,M	MD3
17	2742	IR080	AC-20P	58-28	64-28	S,H	MD3
18	2775	SR647		64-28	64-22	L	MD5
19	2784	SR146		70-16	70-10	M	N
20	2785	SR160		70-16	70-16	S,H	MD3
21	2803	SR160		70-16	70-16	L	MD1
22	2825	SR651		70-28	64-22	S,H	N
23	2852	SR593		76-16	70-16	M	MD3
24	2874	US093	AC-20P & PG64-34		58-28	M	MD3

In PSI:

S = steady performance

H = High PSI level: > 3.8

M = Medium PSI level: 3.2 – 3.8

L = Low PSI level: < 3.2

US = Unsteady PSI level

In Distress:

Dx = Distressed in Year x

N = No Distresses

MDx = Medium Distresses in Year x

Table 2. Polymer Modified Binder Performance

Contract	Binder Grade	PG-Grade	LTPPBIND PG Grade	PSI	Distress
2480	AC-20P	58-22	70-16	S,H	D8
2491	AC-20P	52-16	64-34	S,H	N
2501	AC-20P	58-28	70-10	S,H	D6
2530	AC-20P	58-28	70-10	S,H	MD5
2545	AC-20P	58-22	64-22	S,H	MD6
2552	AC-20P	58-28	70-10	S,H	MD7
2558	AC-20P	58-16	58-34	S,M	MD7

2594	AC-20P	58-28	70-10	S,M	N
2615	AC-20P	58-28	64-28	S,H	N
2617	AC-20P	52-22	64-28	S,H	MD6
2704	AC-20P	58-28	64-28	S,H	MD5
2742	AC-20P	58-28	64-28	S,H	MD3

Table 3. Actual vs. Required PG Grade

Contract	Actual		Required	
	PG-Grade	Interm. Temp	LTPPBIND PG Grade	Interm. Temp
2480	58-22	22	70-16	31
2491	52-16	22	64-34	19
2552	58-28	19	70-16	31
2615	58-28	19	64-34	19
2825	70-28	25	64-22	25

Table 4. Satisfaction of Actual vs. Required PG Grade

Contract	High Temp. Satisfaction	Low Temp. Satisfaction	Inter. Temp. Satisfaction
2480	No	Yes	Yes
2491	No	No	No
2552	No	Yes	Yes
2615	No	No	Yes
2825	Yes	Yes	Yes

Table 5. Actual Performance

Contract	Rutting	Low Temp. Cracking	Fatigue Cracking
2480	No (< 0.17")	Transverse after 6 years (Reflection) None	Fatigue after 9 years
2491	No (<0.12")	None	None
2552	No (<0.15")	None	Fatigue after 7 years
2615	No (<0.24")	None	None
2825	No (< 0.05")	None	None

Table 6. Ability of the PG Grade to Predict Performance

Contract	Rutting Performance	Low Temp. Cracking Performance	Fatigue Cracking Performance
2480	No	Yes	No
2491	No	No	No
2552	No	Yes	No
2615	No	No	Yes
2825	Yes	Yes	Yes

NDOT RESEARCH IMPLEMENTATION

PROJECT INFORMATION DATA FORM

CONTRACT NO.

Date of Construction:

Award Date:

Completion Date:

Location of the Project:

Route:

Beginning and Ending Mile Post:

Beginning and Ending Cum. Mile:

Objective of the Project:

Construction:

Type of Construction:

Thickness of designed layer:

Wearing Course:

Type:

Thickness:

Mix Design Information:

Dense Graded Course:

Design Method:

Mix Type:

Binder Grade:

Refinery Test Report: Table

Gradation: Table

Aggregate Properties: Table

Mix Design Data at Optimum:

Optimum Binder Content:

Additives:

Air voids:

Stability:

VMA:

Moisture Sensitivity:

Mr at 77⁰F

Mr ratio

TS Dry (psi)

TS Ratio (%)

Wearing Course:

Design Method:

Mix Type

Binder Grade:
Refinery Test Report: Table
Gradation: Table
Aggregate Properties: Table
Mix Design Table at Optimum:
Optimum binder content:
Additives:
% Durability Loss:

Information on Field Mixtures:

Binder Compliance:

Binder Content:

Stability: Range:

Air Voids: Range:

Moisture Sensitivity:
Dry TS: Range:
Ratio: Range:
Dry Mr:
Ratio:
Air Voids: Range:

In-place Air Voids: Range:

Information on Existing Pavement:

Types of Layers:

Thickness of Layers:

Figure 1. Information Data Form

Figure 2. Contract 2808 PSI Performance

Figure 3. Contract 2808 RD Performance

Figure 4. Contract 2819 PSI Performance

Figure 5. Contract 2819 RD Performance

Figure 6. Contract 2585 PSI Performance

Figure 7. Contract 2585 RD Performance

Figure 8. Contract 2623 PSI Performance

Figure 9. Contract 2623 RD Performance

Figure 10. Contract 2693 PSI Performance

Figure 11. Contract 2505 PSI Performance

Figure 12. Contract 2505 RD Performance

Figure 13. Contract 2426 PSI Performance

Figure 14. Contract 2513 PSI Performance

Figure 15. Contract 2513 RD Performance

Figure 16. Contract 2680 PSI Performance

Figure 17. Contract 2680 RD Performance

Figure 18. Contract 2697 PSI Performance

Figure 19. Contract 2697 RD Performance

Figure 20. Contract 2544 PSI Performance

Figure 21. Contract 2544 RD Performance

Figure 22. Contract 2901 PSI Performance

Figure 23. Contract 2901 RD Performance

Figure 24. Contract 2480 PSI Performance

Figure 25. Contract 2480 RD Performance

Figure 26. Contract 2491 PSI Performance

Figure 27. Contract 2491 RD Performance

Figure 28. Contract 2552 PSI Performance

Figure 29. Contract 2552 RD Performance

Figure 30. Contract 2615 PSI Performance

Figure 31. Contract 2615 RD Performance

Figure 32. Contract 2622 PSI Performance

Figure 33. Contract 2622 RD Performance

Figure 34. Contract 2825 PSI Performance

Figure 35. Contract 2825 RD Performance

Figure 36. Contract 2344 PSI Performance

Figure 37. Contract 2344 RD Performance

Figure 38. Contract 2603 PSI Performance

Figure 39. Contract 2603 RD Performance



Kenny C. Guinn, Governor

Jeff Fontaine, P.E. Director
Prepared by Research Division
Tie He, Research Division Chief
(775) 888-7803
the@dot.state.nv.us
1263 South Stewart Street
Carson City, Nevada 89712