Performance analysis of an experimental field project utilizing asphalt modifiers
by David Richard Johnson

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Civil Engineering
Montana State University

Abstract:
Utilization of a mix design that will resist rutting is crucial to the life expectancy of a pavement. Drainage problems associated with rutting distress contribute to safety problems and accelerate pavement deterioration. In an effort to combat rutting in Montana, a series of experimental test sections utilizing polymer modifiers were installed along Interstate 94 Prairie County Line West Project, in eastern Montana. These sections were monitored for a period of five years by Montana State University - Bozeman.

Monitoring of the test sections consisted of annual evaluations of the test sections via the use of a visual distress survey and the production of transverse pavement profiles at set locations. In addition to the annual evaluations, laboratory testing was performed on pavement cores acquired before construction of the existing pavement and after placement of the overlays to determine if a correlation existed between Marshall pavement properties and rutting.

This thesis focuses on results of the five-year monitoring of the polymer-modified test sections and the results of the laboratory testing of the pavement cores. The findings of this study indicate that utilization of polymer modifiers has quantifiable benefits in rut resistance for an asphalt pavement. These benefits extend beyond improvements in resistance to rutting, and into resistance to raveling, weathering, and bleeding. The core study indicated that the air void property of a pavement was inversely related to the level of rutting witnessed in these test sections. Moreover, the benefits were found to be economically valuable. It was concluded, therefore, that polymer utilization was advisable for Montana highway construction and rehabilitation.

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APPROVAL

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David Richard Johnson

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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ABSTRACT

Utilization of a mix design that will resist rutting is crucial to the life expectancy of a pavement. Drainage problems associated with rutting distress contribute to safety problems and accelerate pavement deterioration. In an effort to combat rutting in Montana, a series of experimental test sections utilizing polymer modifiers were installed along Interstate 94 Prairie County Line West Project, in eastern Montana. These sections were monitored for a period of five years by Montana State University - Bozeman.

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CHAPTER 1

INTRODUCTION

In pursuit of solutions to problems with the rutting of asphalt pavements, the Montana Department of Transportation (MDT) contracted with the Department of Civil Engineering of Montana State University - Bozeman (MSU) in 1988 to investigate asphalt modifiers. Laboratory testing of 120/150 penetration grade samples from four Montana refineries, incorporating six separate commercial modifiers, were evaluated during the interval July 1, 1988 to April 1, 1989. A direct consequence of the positive results from the laboratory work was the implementation of this field study. All of the modified asphalts tested by the 1988 study outperformed their unmodified counterparts. Based on their performance in the lab study, two of those modifiers were selected for inclusion in the field study. Those modifiers were Kraton D4141G from Shell Chemical Company, and Exxon's Polybilt X-1. (*1*)

The primary objective of the field study was to quantify differences in rutting and economic costs of polymer-modified versus unmodified asphalt concretes in Montana. The primary deliverable for MDT would be detailed recommendations for the construction of pavement sections incorporating polymers within the asphalt, emphasizing normal construction practices to the extent possible. Information was collected on pre-construction conditions, the overlay construction process, the original condition of the completed overlay, and on their subsequent performance for a period of five years.

The pre-construction pavement surface condition survey included the selection of the profilograph test stations, profilograph data collection at those stations, and pavement crack surveys about those stations. A Rainhart Transverse Profilograph was used for the surveying and monitoring of the pavement.

The existing pavement surface in the test section exhibited visible rutting, cracking, and bleeding (Figure 1). Most of the thermal transverse cracks ran the full width of the pavement. The crack maintenance was apparent from sealed cracks (Figure 1). The driving and passing lanes each displayed contrasting appearances. The driving lane was black from recent maintenance activities, including chip sealing and thin lift overlays to cover the ruts in the original pavement surface (Figure 1). The surface was worn, exposing coarse aggregates which were glossy in appearance and smooth to the touch. Most driving lane wheel paths were bleeding, and isolated patches of bleeding in the passing lanes were noticed. During an observed rain, water ran in the ruts along the pavement surface in a longitudinal direction exhibiting poor drainage characteristics. In addition, some water pools were noticed on the pavement.

Figure 1. Pre-construction pavement condition.

Monitoring of construction activities consisted of documenting the production of the modified asphalt, recording asphalt-aggregate mix temperatures, recording placement and rolling performance of the mix, and photographing all operations. Equipment utilization was noted, and any special deviations from normal paving operations were detailed (i.e., mixing requirements, lay-down temperatures, rolling effort and patterns).

Following construction, initial conditions were surveyed to determine pre-traffic rutting and surface conditions. Overall conditions were noted and rutting measurements were done at test stations. String-line and leveling techniques were used at referenced transect locations. The number of transects were sufficient to adequately represent the condition of the test sections. Again, photographs were utilized as well as established pavement management techniques for assessing surface conditions.

For a five year period after construction, monitoring of the experimental project was done at a fixed time each year, in the summer. Rutting measurements were taken at this time. A distress survey was also completed as part of the evaluation.

CHAPTER 2

EXISTING BODY OF KNOWLEDGE

The concept of using modifiers, including polymers, within asphalt road surfaces is not new. It has long been known that modified asphalt cements offer advantages over their unmodified counterparts. In general, modifiers are used to increase a pavement's ability to resist permanent deformations, or rutting, and/or to reduce the occurrence of low temperature cracking. The drawback to modifiers is that while improving a pavement's performance, they were not considered cost effective. Increasing traffic loading and tire pressures have lead to reevaluations into the use of modifiers over the last 20 to 25 years. Today modifiers are an integral and common component of many pavements.

The earliest reference to the use of polymers within an asphalt aggregate matrix was associated with some minor experiments done by the state of Arizona. This work was done in the 1930s, and the cost of incorporating polymers could not be justified. (*4*) The economic viability of polymers did not change for at least the next 35 years. In fact, the 1965 edition of The Asphalt Handbook, the Asphalt Institute makes no mention of modifying asphalt. (*5*)

Extensive research into the use of modifiers began in the late 1960s and accelerated through the 1980s. Following the Arab oil embargo of 1973, the quality of the crude available to produce asphalt was believed to have decreased. One of the ways producers attempted to rectify this perceived situation was to modify the asphalt base. Various forms of polymers, manganese, and recycled rubber products were tried as asphalt modifiers. The performance of these materials as modifiers varied primarily as a result of practitioners learning and developing effective means for their use. (*6 - 14*)

Research into the benefits of asphalt modification has continued into this decade. The emphasis has been on polymers and recycled rubber products as modifiers. By the mid-1980s, proper means of modifying and placing these mixes had been developed. Research has focused on trying to quantify the benefits from modification, in addition to showing that it is beneficial.

In 1990, English researchers demonstrated that within the confines of their research, polymers improved the fatigue characteristics of the asphalt binders used. (*15*) Namely, they found greater resistance to fatigue, low temperature, cracking in modified test specimens.

Oregon researchers expounded in 1990 on the need to classify asphalt cements based on their expected in-place performance. (*16*) This research was part of the Strategic Highway Research Project (SHRP) program that, among other things, helped develop a performance grading system for asphalt. This development is particularly important for modified asphalt, as their field performance was poorly correlated with traditional grading methods (penetration or viscosity).

Research had progressed in 1993 to the point that differences in performance of modified mixtures were noted dependent on the type of recycled tires used and the size of the rubber particles. When mixed with asphalt, recycled passenger car tires yielded properties that differed from recycled commercial tires. (*17*) These researchers also found that passenger car tires tended to produce more consistent modification results than were seen with commercial tires. The effect of rubber particle size produced mixed results in an investigation of traditional material properties (penetration, specific gravity, ductility, softening point, and flash point) of modified mixes. (*18*)

By 1996 researchers were reporting on the proper tests that should be conducted to determine which modifier may be best for a particular application. (*19*) A mixture of traditional (softening point and penetration) and SHRP (dynamic shear rheometer) tests were found useful in assisting engineers n choosing which modifier is best for their particular application.

An Ontario study in the early 1990s was remarkably similar to that reported herein. (*20*) These investigators evaluated two test sections incorporating a total of nine modified materials and one unmodified 85/100 penetration graded asphalt control section. Conclusions of note from Ontario include that many of the modified mixtures seemed to offer superior resistance to thermal cracking than their unmodified counterpart. Rutting resistance was improved through the introduction of modifiers. A life-cycle cost analysis found that modified mixtures were cost-effective in these installations.

CHAPTER 3

TEST SECTION

A section of Interstate Highway I-94 was selected as the experimental test section and identified by Federal Aid Project No. IR 94-5(25)185, Plant Mix Overlay, Prairie County Line-West, Prairie County. The total length of the project was 6.7 miles, consisting of 3.35 miles in the eastbound direction and 3.35 miles in the westbound direction. The test sections in each direction included a section of Kraton D4141G modified asphalt, a control section, and a section of Polybilt X-1 modified asphalt. Asphalt type for the control, as found in Table 1, was selected by the contractor.

Table 1. Station, Length, and Asphalt Binder on East and Westbound Lanes

Station	Length (feet)	Binder on Eastbound Lane	Binder on Westbound Lane
2126+92 to 2174+73	4781	Polybilt Modified Asphalt	Kraton Modified Asphalt
2174+73 to 2204+73	3000	85/100 Exxon Asphalt	85/100 Exxon Asphalt
2204+73 to 2264+25	5952	Kraton Modified Asphalt	Polybilt Modified Asphalt

The test section, near Fallon, Montana, experiences diverse climatic conditions annually. Temperatures in this area exceed 90°F for an average of 44 days annually. Monthly highs average 81.1°F, 89.4°F, and 88.5°F for June, July and August, respectively. Daily lows fall below 0°F for an average of thirty-five days annually. Average lows in December, January and February are 21.4°F, 13.5°F, and 21.8°F, respectively. The annual precipitation is about ten inches. The elevation of the area is about 2200 feet. (*2*)

Traffic loadings for this section of Montana Interstate highway average about 300,000 equivalent single axle loads (ESALs) per year, with commercial trucks accounting for approximately 25 percent of the traffic. (*3*) The average daily traffic (ADT) on this section of I-94 over the test period ranged between 2210 vehicles per day (vpd) and 3128 vpd, with a mean of 2628 vpd and a standard deviation of 318. It should also be noted that the ADT counts during the months of June, July, and August were approximately 135 percent of the ADT calculated using annual data. (*3*) This situation is significant as the majority of rutting occurs during the warmest months, which in this case also corresponds to the period of highest usage.

Table 1 shows the lengths and locations of the highway overlays and the utilized binder within each section for both the eastbound and westbound lanes. The detail of the layout of the test section and the location of the test sections with different binders are shown in Figure 2.

Mile Post 188.0	Mile Post 188.9	Mile Post 189.5	Mile Post 190.6
SBS Modified (4781 ft.)	Unmodified 85/100 (3000 ft.)	EVA Modified (5952 ft.)	

Westbound Field Experimental Test Sections

Median

Mile Post 188.0	Mile Post 188.9	Mile Post 189.5	Mile Post 190.6
EVA Modified (4781 ft.)	Unmodified 85/100 (3000 ft.)	SBS Modified (5952 ft.)	

Eastbound Field Experimental Test Sections

Figure 2. Layout of Test Sections - Interstate Highway I-94

The existing pavement consisted of 0.50 feet of plant mix bituminous base and 0.40 feet of plant mix bituminous surface (PMBS). Twenty-hundredths (0.20) feet of the driving lane was trenched by a cold milling machine and was back-filled with the respective PMBS as the overlay material. A final overlay of 0.35 feet with the respective PMBS was then placed in two lifts. Figure 3 shows the typical cross section of the pavement following the placement of the overlays.

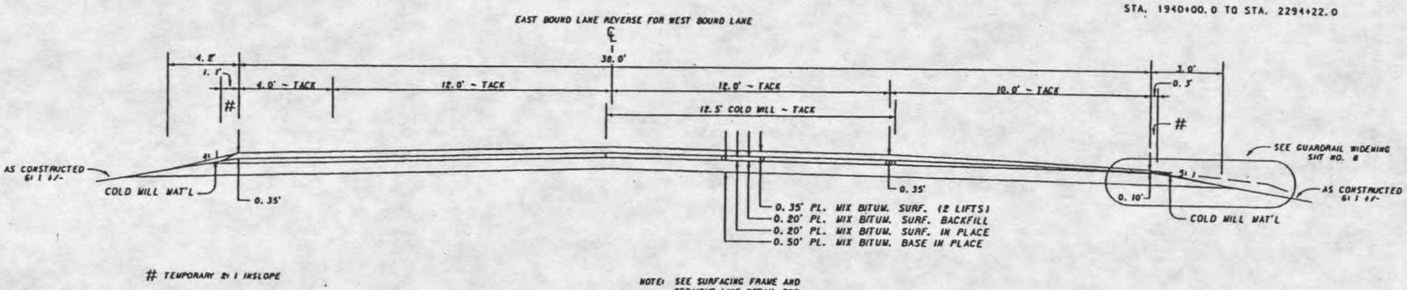
LINEAR AND LEVEL DATA

LENGTH OF ROADWAY IR 94-5(25)185	34,177.85 FEET	= 6.473 MILES
LENGTH OF BRIDGES IR 94-5(25)185	1,398.95 FEET	= 0.265 MILES
TOTAL LENGTH OF IR 94-5(25)185	35,576.80 FEET	= 6.738 MILES

BEARING SOURCE

TAKEN FROM PROJECT: I - IG 94-5(14)181

TYPICAL SECTION NO. 1



NOTE: SEE SURFACING FRAME AND STRAIGHT LINE DETAIL FOR MODIFIED ASPHALT LOCATIONS

QUANTITIES

UNIT	GRAVEL				UNIT	BITUMINOUS MATERIAL					
		PLANT MIX OVERLAY	PLANT MIX BACKFILL	△ COLD MILL MAT'L		TACK	PL. MIX OVERLAY OIL	PL. MIX BACKFILL OIL			
AREA SQUARE FEET		12.3	2.5	1.4	AREA SQUARE YARDS	903.3					
CU. YARDS PER STATION		45.6	9.3	5.2	TONS PER STATION		5.27	1.07			
TONS PER STATION		87.9	17.9	10.0	GALLONS PER STATION	49.2					

△ QUANTITY DOUBLED FOR INSLOPES

Figure 3. Typical cross-section.

Pre-Construction Pavement Surface Condition

The condition of the existing pavement could substantially effect the performance of the overlays, and thus the pre-overlay pavement surface was closely documented. Cracking and rutting were visually documented, supplementing transverse pavement profiles measured at stations established by MSU.

Cracking. Both transverse and longitudinal cracks were studied with reference to the MSU stations. The distance of the closest transverse crack, both ahead of and behind each MSU station, were measured and recorded. The severity levels of the cracks were classified according to the Strategic Highway Research Project's (SHRP) Distress Identification Manual for the Long Term Pavement Performance Project. (*21*) The majority of these were found to be of moderate or high severity cracks. (*2*) The longitudinal cracks found in the vicinity of the station were also classified according to the manual. These too were mostly moderate or high severity cracks. (*2*)

Rutting. Rutting is described in the Distress Identification Manual for the Long Term Pavement Performance Project as longitudinal surface depressions in the wheel path. Severity levels can be defined in relation to inches of rut depth. Rut depths were measured to the nearest 1/10-inch at set stations. (*21*) For the field study, 52 stations were chosen randomly at distances ranging from 200 to 600 feet.

A summary of the pre-construction rutting is found in Table 2. The maximum rut depths at each station's wheel paths for the westbound driving and passing lanes were measured from the transverse profilograph record provided by the Rainhart Profilograph. It was observed that the rut depth on the driving lane was greater than that in the passing lane, even though the driving lane had undergone several maintenance activities to fill the ruts on the original pavement surface. The average rut depths on the left and right wheel paths were 0.26 and 0.18 inches for the passing lane, and 0.31 and 0.29 inches for the driving lane. The maximum rut depths on left and right wheel paths were 0.45 and 0.55 inches for the driving lane, and were 0.55 and 0.45 inches for the passing lane.

Similarly, the rut depths of the pre-construction pavement on the eastbound driving and passing lanes were obtained from the profilograph output. Again, the rut depths on the driving lane were higher than those on the passing lane, even though the eastbound driving lane also had been subjected to overlays and chip seals to reduce the rutting on the original pavement surface. The average rut depths on the left and right wheel paths of the passing lane were 0.20 and 0.12 inches, with maximum rut depths of 0.30 and 0.20 inches, respectively. The average rut depths on the left and right wheel paths of the driving lane were 0.39 inches for both wheel paths, with maximum rut depths of 0.60 and 0.70 inches for the respective wheel paths.

Transverse Pavement Profile. The profilograph records illustrate the actual profile of the pavement surface referenced to the straight profilograph beam. The output of the profilograph was electronically reproduced by taking the coordinates of the profile at intervals of four inches. The results of the differential leveling survey gave the elevation of the profilograph legs' positions.

The transverse slope of the pavement no longer matched the original intended shape. The distortions were so excessive that the pavement no longer drained as intended in the design. This situation could affect the stability of vehicles and reduce the performance of the pavement. In general, the distortion of the driving lanes was more extensive than that of the passing lanes.

Table 2. Pre-Construction Rutting

Direction	**Driving Lane**		**Passing Lane**	
	LWP (Inches)	RWP (Inches)	LWP (Inches)	RWP (Inches)
Westbound				
Average Depths	0.31	0.29	0.26	0.18
Maximum	0.45	0.55	0.55	0.45
Standard Deviation	0.12	0.08	0.07	0.10
Eastbound				
Average Depths	0.39	0.39	0.20	0.12
Maximum	0.60	0.70	0.30	0.20
Standard Deviation	0.12	0.16	0.04	0.03