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Maine Department of Transportation

Transportation Research Division

Technical Report 98-3

Potential Benefits of Adding Emulsion to Full Depth Reclamation Material

Final Report - September 2004

Transportation Research Division

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Introduction

Roughly 40% of MaineDOT's highway network is not built to state standards and is in need of reconstruction or rehabilitation. To maintain these highways the Department has been utilizing lower cost improvements until funding is available to rebuild them to state standards. One method used to achieve this task is the use of full depth reclamation (FDR).

In an effort to improve the benefits of reclaiming, a study was undertaken to compare the properties of FDR material treated with emulsified asphalt, to material without emulsion treatment.

Project Location/Description

Two projects were originally selected for construction in 1997 as part of this study, STP-6666(00)X in Winslow-Benton, and STP-7697(00)X in Passadumkeag-Lincoln. Problems encountered during the construction process necessitated the exclusion of the Winslow-Benton project. The Passadumkeag-Lincoln project is located on US Route #2 and begins 0.4 km (0.2 mi) northerly of Beaver Brook Bridge #2059 in Passadumkeag and extends 20.4 km (12.7 mi) to the Access Road in Lincoln.

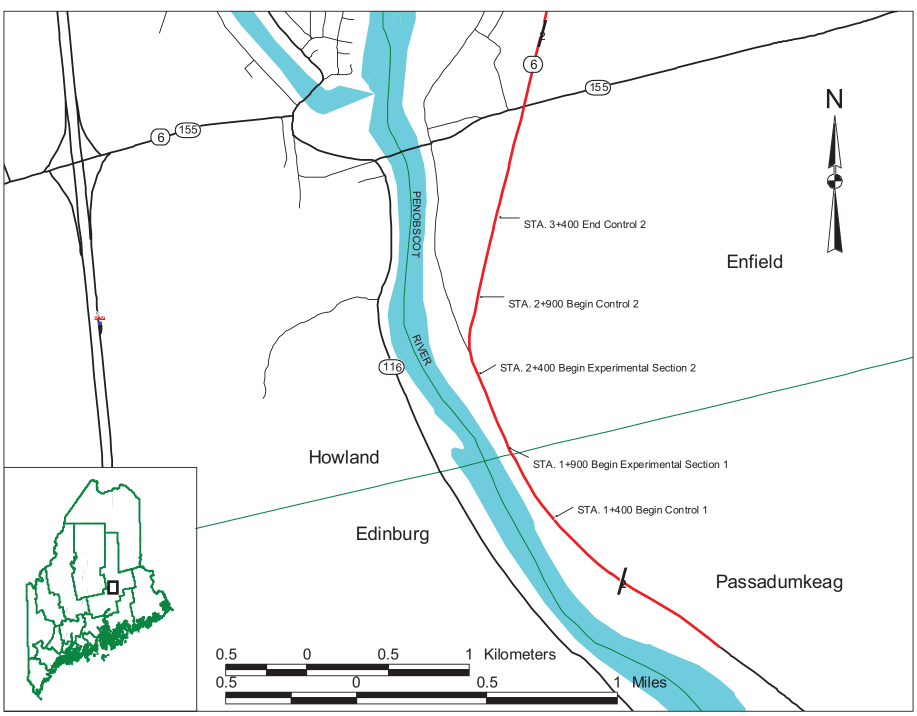

Figure 1. Experimental Area Location Map

The original experimental feature for this project included three sections; the experimental section from station 1+900 to station 2+900 and two control sections from station 1+400 to 1+900 and station 2+900 to 3+400 respectively. The experimental sections consisted of full depth reclamation of the existing pavement then introducing an MS-2 emulsified asphalt at a rate of 6.0 liters/meter^2 (1.3 gallons/yard^2). Treatment of the two control sections included full depth reclamation of the existing pavement with no emulsified asphalt added. Existing pavement depths throughout the experimental and control sections varied from 150 to 300 mm (6 to 12 in). As is common practice with MDOT pavement reclamation projects, 25 mm (1 in) of existing gravel base was also reclaimed. Each section was overlaid with 45 mm (1.75 in) of 19.0 mm (0.75 in) NMAS Superpave base and 30 mm (1.25 in) of 12.5 mm (0.5 in) NMAS Superpave surface.

Construction

Reclaiming was performed using a CMI reclaimer. The MS-2 emulsified asphalt was incorporated into the reclaimed material by pumping the liquid directly from a tank truck to the reclaimer's spraybar.

A first pass was completed with the reclaimer to pulverize the existing pavement. A second pass was then made to add and mix emulsion with the reclaimed base material. This material was then compacted using a Caterpillar vibratory roller. Density measurements were taken using a Troxler 3430 nuclear moisture-density gauge.

During placement of emulsified asphalt between stations 1+900 and 2+400, the contractor experienced problems with the emulsion metering system that caused an excess of emulsified asphalt to be added to the reclaimed base material. The amount added to the first 2.4 meter (8 ft) pass was sufficient to cover the entire 7.3 meter (24 ft) roadway width. To correct this, the contractor used a grader to blend the material containing excess emulsion into the remaining roadway width. MDOT personnel monitoring the operation were comfortable that this provided adequate distribution of emulsion throughout the experimental area.

Construction of the section from station 2+400 to 2+900 proceeded as planned. The spraybar delivered the proper amount of emulsion during each of the three passes to provide a uniform application.

It was noted during construction, that there appeared to be several different existing roadway structure types within the experimental and control areas. Different pavement thickness, gravel depths, and subbase materials, including penetration macadam, were encountered. It is believed that this may be the result of a previous research effort by MDOT.

A review of the original construction plans (dated late 1940's), identified two significantly different construction procedures in the experimental area. The first section, which began at approximately station 0+100 and ended at station 2+300, was treated with 76 mm (3 in) of macadam, 127 mm (5 in) of crushed stone base, and 457 mm (18 in) of gravel. The second section from station 2+300 to the end of the project was treated with 51 mm (2 in) of asphalt treated gravel and 610 mm (24 in) of gravel. Considering these subgrade differences and the emulsion distribution difficulties mentioned earlier that occurred during construction of the emulsion portion of this project, two subsections were created within the emulsion treated area. Data presented in this report will compare Control 1 section from station 1+400 to 1+900 with Experimental 1 section from station 1+900 to 2+400, and Experimental 2 section from station 2+400 to 2+900 with Control 2 section from station 2+900 to 3+400.

Field Inspection Summary

Structural Analysis

Falling Weight Deflectometer (FWD) readings were collected on August 28, 2002. Data was collected at 50-meter (164-foot) intervals in both lanes on each of the four sections. A series of four drops, each at 40 kN (9000 lb) was completed at each test point. This data was then analyzed using AASHTO pavement design software "DARWin 3.01". Subgrade Resilient Modulus, Pavement Modulus and Effective Structural Number values were calculated for each test. The Subgrade Resilient Modulus value is a measure of subgrade layer strength and elasticity. The Pavement Modulus value represents layer strength and elasticity of the combined pavement and gravel layer above subgrade and the Effective Structural Number is a value of overall roadway strength.

Table 1 contains a summary of processed FWD data comparing Control 1 section with Experimental 1 section and Control 2 section with Experimental 2 section from 1998 to 2002.

Table 1: FWD data analysis summary

	Average Subgrade Modulus (psi)					Average Pavement Modulus (psi)					Average Structural Number				
Section	1998	1999	2000	2001	2002	1998	1999	2000	2001	2002	1998	1999	2000	2001	2002
Control 1	10037	10935	10167	10708	9945	98347	115374	119833	114882	107285	6.84	7.22	7.31	7.21	7.05
Exp. 1	9425	10953	10203	11362	10048	98640	116941	125824	118671	119732	6.85	7.25	7.43	7.28	7.30
% Diff.	-6.10%	0.17%	0.36%	6.11%	1.04%	0.30%	1.36%	5.00%	3.30%	11.60%	0.25%	0.39%	1.62%	0.89%	3.52%
Control 2	5597	6607	6105	6617	6370	68457	78314	76282	78916	75752	6.06	6.34	6.28	6.34	6.26
Exp. 2	6752	7437	7095	7472	7094	70739	77417	85492	85674	86184	6.13	6.44	6.53	6.52	6.52
% Diff.	20.63%	12.57%	16.21%	12.91%	11.37%	3.33%	-1.14%	12.07%	8.56%	13.77%	1.11%	1.50%	3.84%	2.82%	4.19%

Subgrade Modulus, Pavement Modulus, and Structural Number values in the Control 1 and Experimental 1 sections continue to be higher than the Control 2 and Experimental 2 sections possibly due to the penetration macadam base and crushed stone.

Average Subgrade Modulus values are very stable from 1998 to 2002 for all four sections. This ensures reliable Pavement Modulus and Structural Number values that will not be influenced by fluctuating subgrade modulus readings.

Control 1 and Experimental 1 Structural Number Comparison

Figure 2 contains a graphical display of the high, low and average Structural Number for Experimental 1 and Control 1 sections from 1998 to 2002. Control 1 Structural Numbers peaked in year 2000 and has decreased since then. Experimental 1 Structural Numbers also peaked in 2000 then decreased and stabilized at 7.28 and 7.30 for 2001 and 2002 respectively. As mentioned in the Fourth Interim Report, Experimental 1 Structural Numbers decreased at a greater rate than Control 1 section during year 2001 tests. In 2002, Control 1 section continues to decline whereas Experimental 1 section increased slightly.

A statistical comparison of 2002 Control 1 and Experimental 1 Structural Numbers is displayed in Table 2. A low two tailed P value of 0.0287 indicates a significant difference between the two means. Analysis of 2001 data indicated no significant difference, suggesting that Experimental 1 section is effectively stabilizing the roadway after five years exposure to traffic.

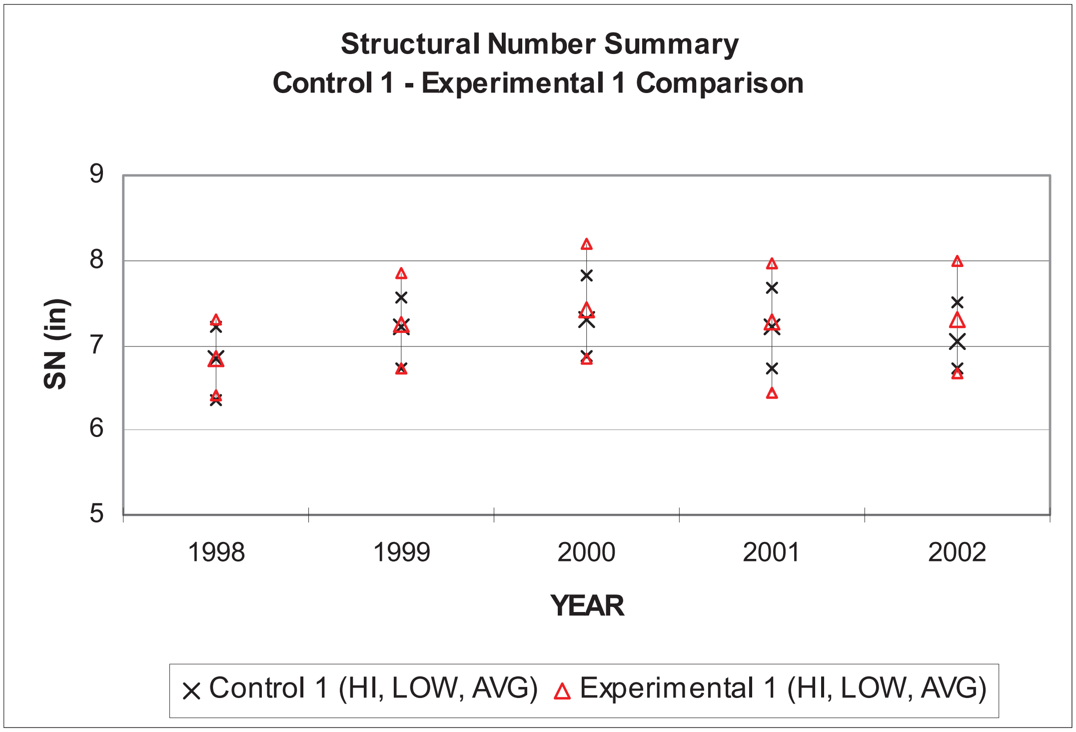

Figure 2. Control 1 and Experimental 1 Structural Number Comparison

Table 2. 2002 Control 1 and Experimental 1 Structural Number Analysis Results using the F and t-Test

Control 1 2002 SN	Exp. 1 2002 SN	F-Test Two-Sample for Variances	Variable 1	Variable 2
6.92	8	Mean	7.049474	7.297368
6.95	7.21	Variance	0.045327	0.173276
7.29	7.96	Observations	19	19
6.86	7.23	df	18	18
7.24	7.35	F	0.261591	
6.77	7.11	P(F<=f) one-tail	0.003353	
7.49	7.75	F Critical one-tail	0.45102	
7.09	6.78	t-Test: Two-Sample Assuming Unequal Variances		
7.06	7.53		Variable 1	Variable 2
6.94	7.67	Mean	7.049474	7.297368
7.15	6.84	Variance	0.045327	0.173276
7.15	6.9	Observations	19	19
7.03	6.86	Hypothesized Mean Difference	0	
6.89	7.74	df	27	
6.9	7.48	t Stat	-2.311083	
6.73	7.1	P(T<=t) one-tail	0.01435	
7.47	7.58	t Critical one-tail	1.703288	
6.9	6.9	P(T<=t) two-tail	0.0287	
7.11	6.66	t Critical two-tail	2.051829	

Control 2 and Experimental 2 Structural Number Comparison

Figure 3 contains high, low and average Structural Numbers for Experimental 2 and Control 2 sections from 1998 to 2002. Control 2 Structural Numbers have fluctuated from year to year, increasing in strength one year then decreasing the next. This year stability has decreased 1.26 percent. The Experimental 2 section has remained stable since year 2000, indicating greater load carrying capacity. Experimental 2

Structural Numbers continue to outperform the Control 2 section. Experimental 2 section also has a wider range of values indicating the stabilized base is not uniform.

A statistical comparison of the two sections is presented in Table 3. The two tailed P value is high indicating no significant difference between the two means.

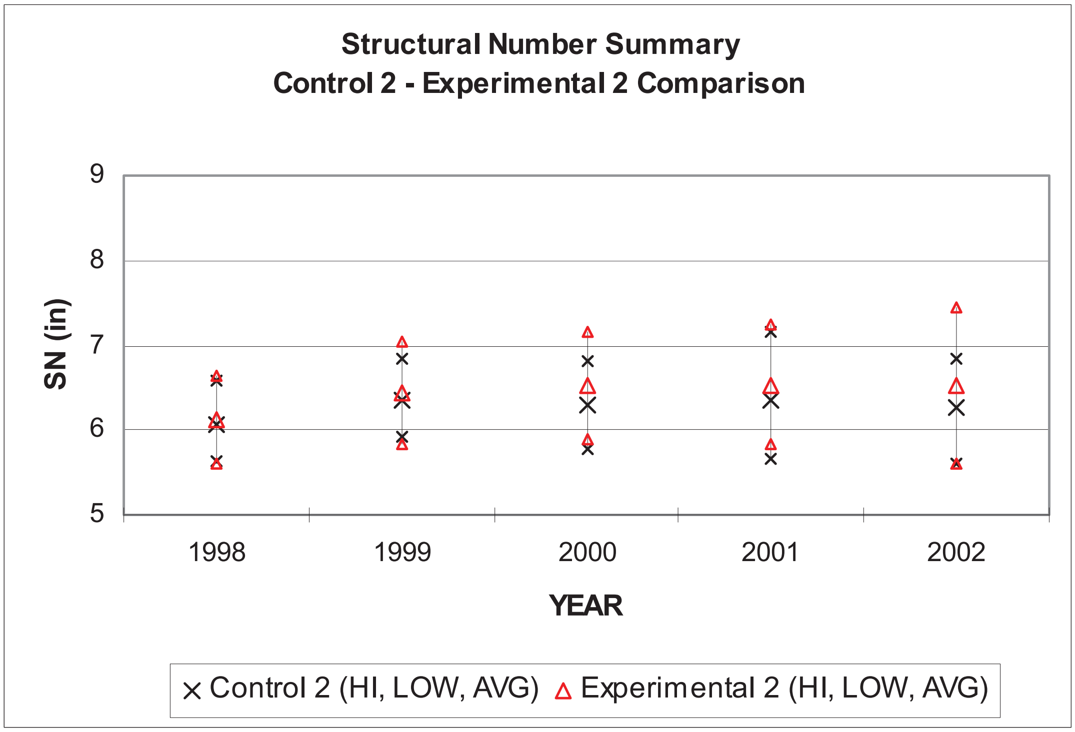

Figure 3. Control 2 and Experimental 2 Structural Number Comparison

Table 3. 2002 Control 2 and Experimental 2 Structural Number Analysis Results using the F and t-Test

Control 2	Exp. 2	F-Test Two-Sample for Variances		
2002 SN	2002 SN		*Variable 1*	*Variable 2*
6.82	6.88	Mean	6.262632	6.524737
6.65	6.38	Variance	0.143665	0.237237
6.85	7.18	Observations	19	19
6.37	6.69	df	18	18
6.21	7.46	F	0.605574	
6.14	6.69	P(F<=f) one-tail	0.148244	
5.99	7.36	F Critical one-tail	0.45102	
6.04	6.48	t-Test: Two-Sample Assuming Equal Variances		
5.81	6.43		*Variable 1*	*Variable 2*
5.71	5.75	Mean	6.262632	6.524737
6.09	6.38	Variance	0.143665	0.237237
5.6	6.13	Observations	19	19
6.39	6.71	Pooled Variance	0.190451	
5.77	5.95	Hypothesized Mean Difference	0	
6.66	6.55	df	36	
6.49	5.61	t Stat	-1.851168	
6.47	6.25	P(T<=t) one-tail	0.036182	
6.3	6.53	t Critical one-tail	1.688297	
6.63	6.56	P(T<=t) two-tail	0.072363	
		t Critical two-tail	2.028091	

Section Uniformity

Section Uniformity is a pavement performance measurement utilizing FWD data to determine the "uniformity" of a section. This procedure was developed by William Phang using LTPP pavement data collected on sections of roadways in North America. The results of Mr. Phangs initial efforts can be reviewed in the FHWA report titled "LTPP Data Insight – Section Uniformity Using FWD", Report No. FHWA-LTPP-NAR-96-01. The report states that the more uniform a section is, relative to its pavement deflection, the longer it will last. If a pavement is non-uniform the pavement response to load leads to larger tensile and shear stress in the adjacent elements in pavement layers resulting in particle rotation and volume expansion in unbound or loosely bound materials. Section Uniformity is determined from pavement deflections recorded from the number one sensor located at the falling weight. The deflections are "normalized" to a force of 40kN (9000 lbs) then temperature corrected to 20° C (68° F). An average and standard deviation are then calculated for each pavement section and the standard deviation is divided by the average to get a Coefficient of Variation (COV) as a percent.
Section Uniformity is classified as follows:

COV < 10 %	Excellent
COV ≥ 10 % and < 15 %	Good
COV ≥ 15 % and < 20 %	Fair
COV ≥ 20 % and < 25 %	Fair – Poor
COV ≥ 25 %	Poor

COV results are displayed in Table 4. Control 1, Experimental 1 and Control 2 sections have a Fair classification. Experimental 2 section is classified as Poor. Although the mean deflection is lower than the Control 2 section, the standard deviation is high resulting in a non-uniform pavement. This is further supported by the range of Structural Number data in Figures 2 and 3. Experimental 2 has a greater range of data than Experimental 1 section.

Table 4. Coefficient of Variation Summary

Section	# Samples	Standard Deviation	Mean	COV	Classification
Control 1	21	1.37	7.10	19%	Fair
Exp. 1	20	1.23	6.86	18%	Fair
Control 2	20	1.98	10.85	18%	Fair
Exp. 2	20	2.50	9.19	27%	Poor

Ride Quality Analysis

Ride quality data was collected on October 15, 2002 utilizing the Department's Automatic Road Analyzer (ARAN) test vehicle. The Department began collecting ride data on this project in 2000. Roughness data is presented as International Roughness Index (IRI) in meters per kilometer units. Table 5 contains verbal descriptions for a range of IRI values.

A comparative view of ride data from 2000 to 2002 is displayed in Table 6. Both experimental sections have smoother roadways than their respective control sections indicating the stabilized reclaim base is providing greater stability for the roadway. Experimental 1 section continues to have the smoothest ride, possibly due to a combination of emulsified reclaim base and macadam base. Control 1 and Experimental 1 sections have smoother readings than last year and are smoother than the Control 2 and Experimental 2 sections. This may also be attributed to the macadam base.

Table 5. International Roughness Index (IRI) Verbal Descriptions

IRI (Meters/Kilometer)	IRI (Inches/Mile)	Verbal Description
Less than 1.02	Less than 65	Extremely comfortable ride at 105/65 kph/mph. No potholes, distortions or rutting. Extremely high quality pavement. Typically new or near new pavement.
1.02 – 1.57	65 – 99	Comfortable ride at 105/65 kph/mph. No noticeable potholes, distortions, or rutting. High quality pavement.
1.58 – 3.15	100 – 199	Comfortable ride at 88/55 kph/mph. Moderately perceptible movements induced by occasional patches, distortions, or rutting.
3.16 – 4.73	200 – 299	Comfortable ride at 72/45 kph/mph. Noticeable movements and swaying induced by frequent patches and occasional potholes. Some distortion and rutting.
Greater than 4.73	Greater than 299	Frequent abrupt movements induced by many patches, distortions, potholes, and rutting. Ride quality greatly diminished.

Table 6. Roughness Summary

Section	Average IRI (meters/kilometer) 2000	2001	2002
Control 1	1.06	1.13	1.11
Experimental 1	1.04	1.07	1.02
Control 2	1.34	1.45	1.52
Experimental 2	1.12	1.18	1.19

Control 1 and Experimental 1 Ride Quality Comparison

A comparative graphical display of hi, low, and average IRI values for Control 1 and Experimental 1 sections is presented in Figure 4. IRI values are very similar for both sections and the range of values is also very similar. This could be attributed to the penetration macadam base.

A statistical comparison of Control 1 and Experimental 1 sections is displayed in Table 7. F and t test results show no significant difference between the means at a 5 % significance level.

Control 2 and Experimental 2 Ride Quality Comparison

Figure 5 contains a graphical display comparing Control 2 and Experimental 2 hi, low, and average IRI readings. Experimental 2 section has a smoother ride than Control 2 section and a narrow range of IRI values.

F and t-test results comparing the means for Control 2 and Experimental 2 sections are displayed in Table 8. A low two tailed P value (<0.05) indicates a significant difference between the means at a 5 % significance level.

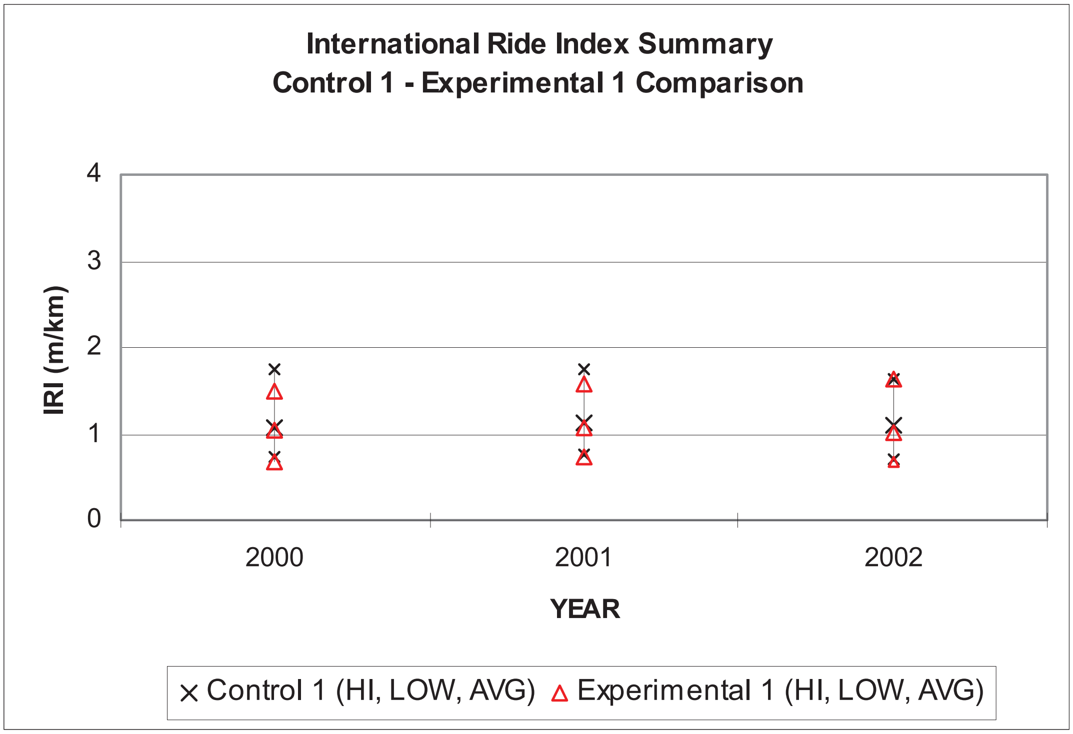

Figure 4. Control 1 and Experimental 1 International Ride Index Comparison

Table 7. F and t-Test Ride Quality Analysis Results, 2002 Control 1 and Experimental 1 Sections

F-Test Two-Sample for Variances		
	Variable 1	*Variable 2*
Mean	1.106	1.0232
Variance	0.047061	0.044141
Observations	50	50
df	49	49
F	1.066167	
P(F<=f) one-tail	0.411735	
F Critical one-tail	1.60729	

t-Test: Two-Sample Assuming Equal Variances		
	Variable 1	*Variable 2*
Mean	1.106	1.0232
Variance	0.047061	0.044141
Observations	50	50
Pooled Variance	0.045601	
Hypothesized Mean Difference	0	
df	98	
t Stat	1.938714	
P(T<=t) one-tail	0.027707	
t Critical one-tail	1.660551	
P(T<=t) two-tail	0.055413	
t Critical two-tail	1.984467	

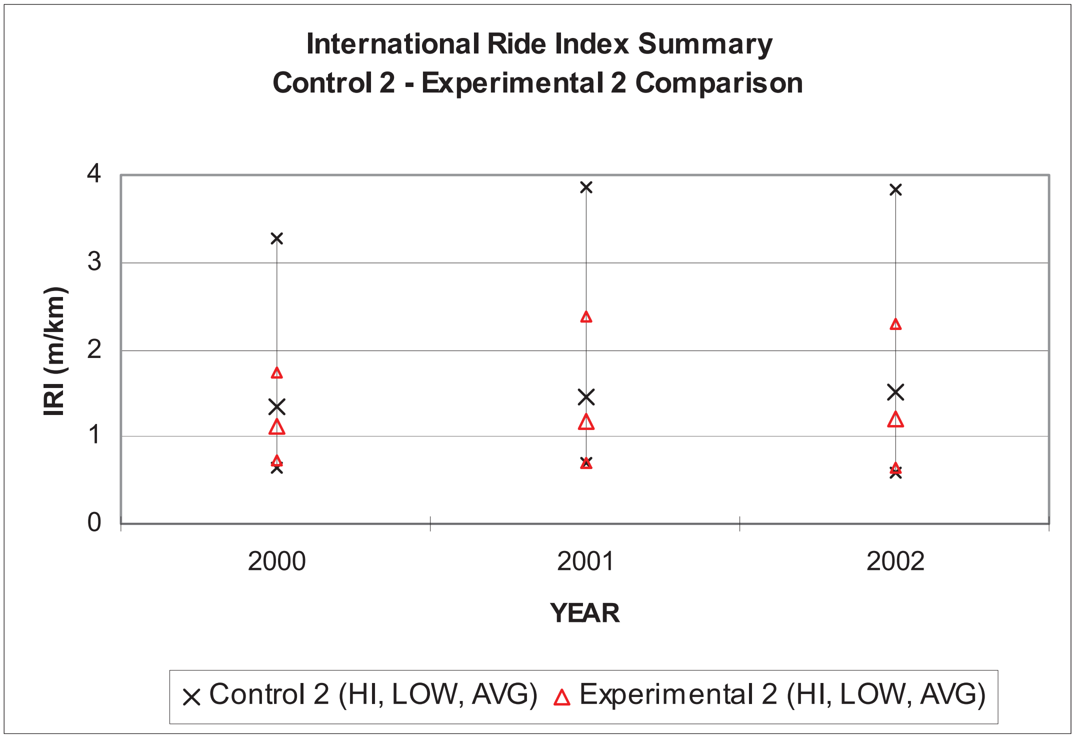

Figure 5. Control 2 and Experimental 2 International Ride Index Comparison

Table 8. F and t-Test Ride Quality Analysis Results, 2002 Control 2 and Experimental 2 Sections

F-Test Two-Sample for Variances		
	Variable 1	*Variable 2*
Mean	1.52	1.1942
Variance	0.634539	0.150013
Observations	50	50
df	49	49
F	4.229903	
P(F<=f) one-tail	6.91E-07	
F Critical one-tail	1.60729	
t-Test: Two-Sample Assuming Unequal Variances		
	Variable 1	*Variable 2*
Mean	1.52	1.1942
Variance	0.634539	0.150013
Observations	50	50
Hypothesized Mean Difference	0	
df	71	
t Stat	2.60091	
P(T<=t) one-tail	0.005653	
t Critical one-tail	1.666599	
P(T<=t) two-tail	0.011306	
t Critical two-tail	1.993944	

Rut Depth Analysis

The ARAN was also utilized to measure rut depths. Table 9 contains a summary of rut depths from 2000 to 2002. Rut depths have increased in all sections. Rut depths are less severe in the Control 1 and Experimental 1 sections as compared to the remaining sections, indicating greater stability possible due to the macadam base. The rate of change between 2001 and 2002 measurements are similar for Control 1, Control 2, and Experimental 2 sections at 9.9 %, 11.9 %, and 10.2 % respectively. Experimental 1 section had a smaller change of 5.1 % indicating the macadam base combined with the stabilized base may be supporting the roadway more efficiently. All sections are resisting rutting very well after five years of traffic.

Table 9. Rut Depth Summary

	Average Rut Depth (millimeters)		
Section	2000	2001	2002
Control 1	4.68	5.76	6.33
Experimental 1	4.15	5.44	5.72
Control 2	6.07	7.58	8.48
Experimental 2	4.84	6.08	6.70

Control 1 and Experimental 1 Rut Depth Comparison

Figure 6 shows the range of rut depth data. The spread of data is greater for the Control 1 section than the Experimental 1 section.

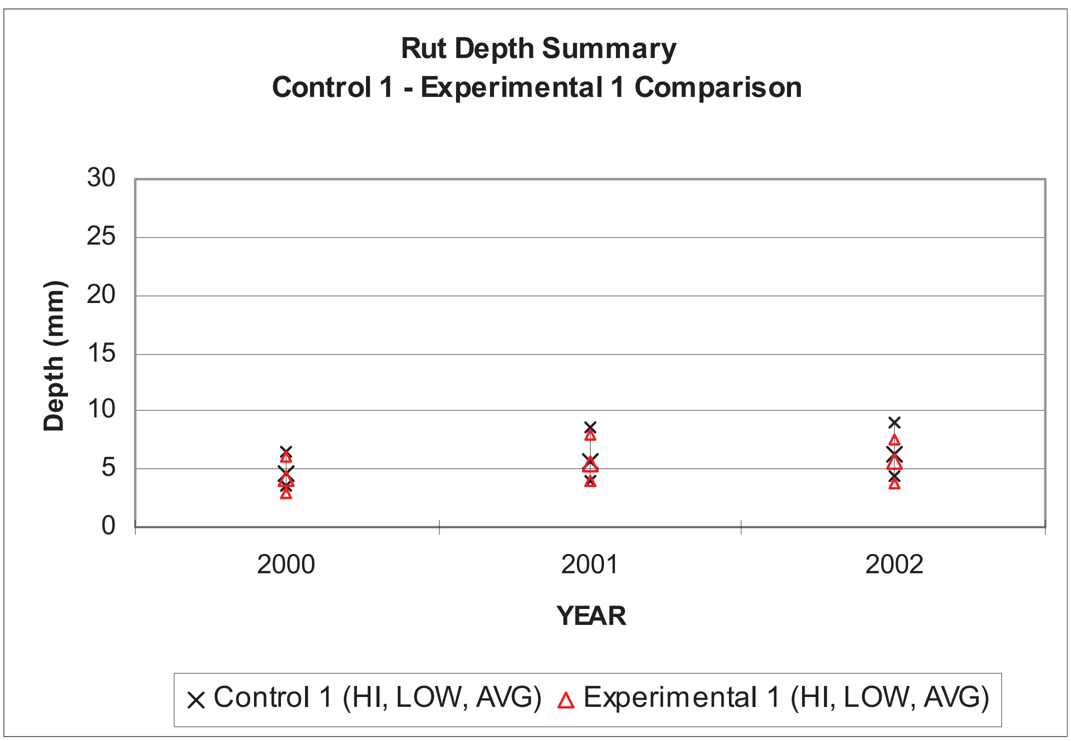

Figure 6. Control 1 and Experimental 1 Rut Depth Comparison

A statistical comparison of Control 1 to Experimental 1 sections is displayed in Table 10. The F and t-Test results show a significant difference between means at a 5 % significance level.

Table 10. F and t-Test Rut Depth Analysis Results, 2002 Control 1 and Experimental 1 Sections

F-Test Two-Sample for Variances		
	Variable 1	*Variable 2*
Mean	6.33	5.715
Variance	1.138878	1.033189
Observations	50	50
df	49	49
F	1.102294	
P(F<=f) one-tail	0.367277	
F Critical one-tail	1.60729	
t-Test: Two-Sample Assuming Equal Variances		
	Variable 1	*Variable 2*
Mean	6.33	5.715
Variance	1.138878	1.033189
Observations	50	50
Pooled Variance	1.086033	
Hypothesized Mean Difference	0	
df	98	
t Stat	2.95069	
P(T<=t) one-tail	0.001983	
t Critical one-tail	1.660551	
P(T<=t) two-tail	0.003966	
t Critical two-tail	1.984467	

Control 2 and Experimental 2 Rut Depth Comparison

Rutting is greater and the spread of data is greater in this portion of the project. Figure 7 contains mean, hi, and low rut depth values. The Experimental 2 section has less severe rutting and the range of data is smaller than the Control 2 section. Control 2 section has a butt joint at station 3+093 where paving ended and started the next day. The mix is visually dissimilar north of the joint and bituminous tests, summarized later in the report, confirm the difference. Severity of rutting is greater north of this joint where paving continued the next day indicating a possible pavement failure and increasing the range of rut data.

A statistical comparison of Control 2 to Experimental 2 sections is displayed in Table 10. F and t-Test results show a significant difference between means.

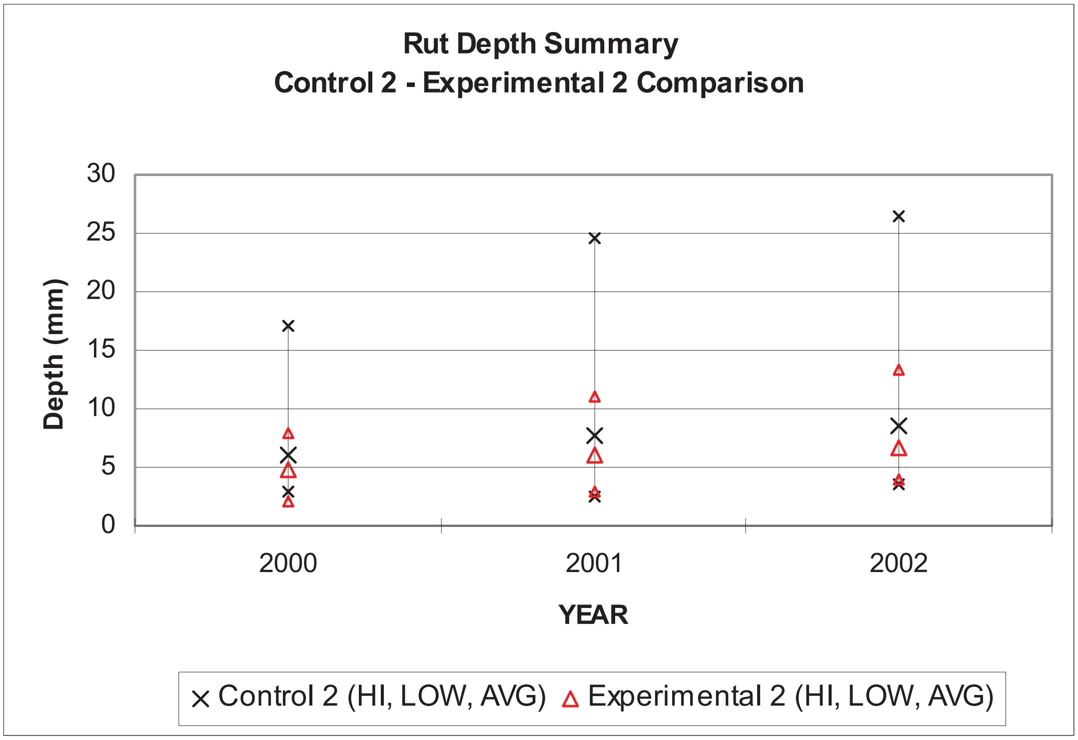

Figure 7. Control 2 and Experimental 2 Rut Depth Comparison

Table 11. F and t-Test Rut Depth Analysis Results, 2002 Control 2 and Experimental 2 Sections

F-Test Two-Sample for Variances		
	Variable 1	*Variable 2*
Mean	8.475	6.695
Variance	27.76849	6.023699
Observations	50	50
df	49	49
F	4.609874	
P(F<=f) one-tail	1.76E-07	
F Critical one-tail	1.60729	
t-Test: Two-Sample Assuming Unequal Variances		
	Variable 1	*Variable 2*
Mean	8.475	6.695
Variance	27.76849	6.023699
Observations	50	50
Hypothesized Mean Difference	0	
df	69	
t Stat	2.165194	
P(T<=t) one-tail	0.016917	
t Critical one-tail	1.667238	
P(T<=t) two-tail	0.033833	
t Critical two-tail	1.994945	

Visual Evaluation

A visual inspection of the project was completed on September 23, 2002. Table 12 contains a summary of that inspection. Centerline joint cracking, transverse cracking, and load cracking were recorded.

Table 12. 2002 Pavement Crack Summary

Section	Centerline Joint Cracking (linear meters)	Transverse Cracking (number of full width cracks)	Load Associated Cracking (linear meters)		
			Initial	Moderate	Severe
Control 1	375.8	0.5	286.7	106.9	
Experimental 1	308.4	0.5	240.2	7.1	
Control 2	302.8	3.5	214.9	56.9	
Experimental 2	233.1	2.25	194.0	50.4	

Control 1 section continues to have the majority of centerline joint cracking (Photo 1) and Experimental 2 section has the least amount. Centerline joint separation is not as severe in Experimental 1 section as compared to Control 1 section. Joint separation is also less severe in Experimental 2 section as compared to Control 2 section.

After five years of traffic there is very little transverse cracking throughout the project. Control 1 has three small cracks that equal a half width crack. Experimental 1 section has one transverse crack halfway across the roadway. Control 2 section has the greatest amount of transverse cracking with one full width crack and six small cracks which amount to a total of three and a half full width cracks. Experimental 2 section has five transverse cracks that equal two and a quarter full width cracks.

Load cracking is a key indicator of roadway performance. All sections experienced an increase in initial and moderate load cracking with no severe load cracking. Both Experimental sections have less initial and moderate cracking than their respective Control sections. Control 1 has the greatest amount of initial load cracking at 286.7 m (940.6 ft), an increase of 76 %. Moderate cracking in this section increased from 20.8 to 106.9 m (68.2 to 350.7 ft) an increase of 414 %. Experimental 1 section has the second highest amount of initial load cracking at 240.2 m (788.1 ft), an increase of 212 %, and the least amount of moderate load cracking at 7.1 m (23.3 ft) (Photo 2). Control 2 section has the second lowest amount of initial load cracking at 214.9 m (705.1 ft), an increase of 48 % and the lowest increase of all sections. Moderate load cracking in this section increased 26 % from 45.0 to 56.9 m (147.6 to 186.7 ft) (Photo 3). Experimental 2 section has the lesser amount of initial cracking at 194.0 m (636.5 ft), an increase of 79 %, and the second lowest amount of moderate cracking at 50.4 m (165.3 ft) (Photo 4), an increase of 288 %.

The majority of load cracking in Control 2 section is located beyond the butt joint at station 3+093. When the control and experimental sections were surfaced in 1997, the first day of paving ended at station 3+093 and the second day completed the experimental area. Beyond the butt joint at station 3+093 it appears that the surface mix is coarse with less asphalt. A review of the aggregate and asphalt content reports for this area is included in Table 13 and confirms the coarse aggregate observation. Reference number 43367 was sampled on August 20, 1997 and had sieve analysis tests only. Reference number 43368 had sieve and asphalt content tests and was sampled on August 21, 1997. It’s possible that the bituminous mix change may be contributing to the additional cracking in this area of Control 2 section.

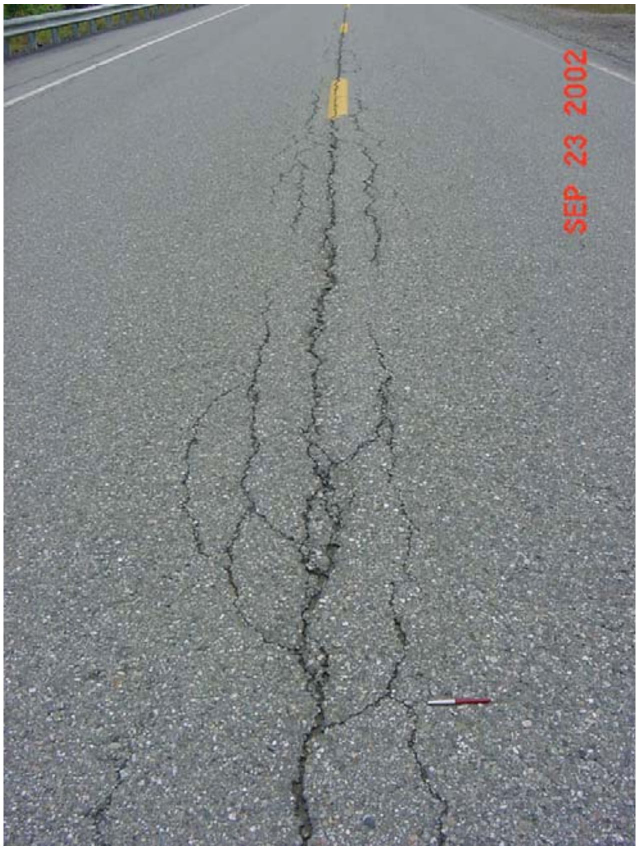

Photo 1. Control 1 Centerline Separation

Photo 2. Experimental 1 Centerline & Load Cracking

Photo 3. Control 2 Moderate Load Cracking

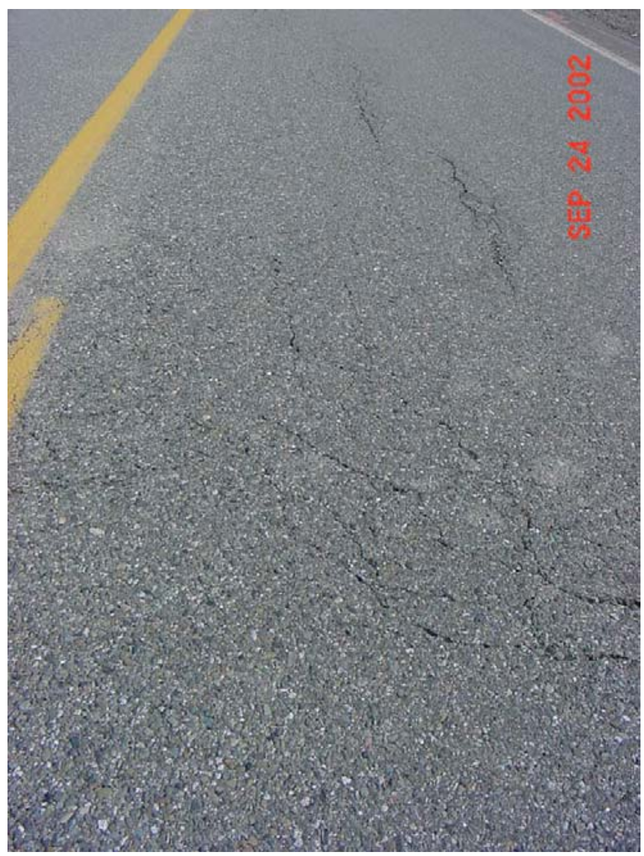

Photo 4. Experimental 2 Moderate Load Cracking

Table 13. Sieve Analysis Summary

12.5 mm Bituminous Concrete Mix			
	Percent Passing		
Sieve	Reference # 43367	Reference # 43368	Specification Limits
19 mm (3/4 in)	100.0	100.0	100
12.5 mm (1/2 in)	96.8	89.5	80 – 100
9.5 mm (3/8 in)	86.6	75.4	65 – 100
6.35 mm (1/4 in)	67.1	57.9	
4.75 mm (# 4)	58.8	49.5	40 – 70
2.36 mm (# 8)	44.7	37.1	26 – 52
1.18 mm (# 16)	31.2	25.9	17 – 40
600 µm (# 30)	18.9	15.0	10 – 30
300 µm (# 50)	10.3	8.4	7 – 22
150 µm (# 100)	6.0	5.1	4 – 14
75 µm (# 200)	4.03	3.56	2.0 – 7.0
Asphalt Content	NA	5.44 %	5.2 – 5.8

Summary

The project is supporting traffic as expected after five years exposure to traffic and the environment.

Both experimental sections have higher structural numbers, lower ride numbers and a smaller amount of cracking than their respective control sections.

Experimental 1 and Control 1 Comparison

This portion of the experimental project was partitioned due to the penetration macadam base beneath the emulsified asphalt treated base. The macadam base is of uniform thickness making it ideal to make a comparison between the treated and control sections. Section Uniformity tests resulted in a “Fair” classification for both sections with COV’s of 19 and 18 percent for the Control 1 and Experimental 1 sections respectively. Ride quality is nearly identical but structural numbers and rutting is statistically better in the Experimental 1 section. In addition, structural numbers have leveled off in the experimental section whereas they continue to decline in the control section. The treated base in Experimental 1 section is also reducing the amount and severity of load associated cracking. Load cracking and rutting is a very good indicator of the roadways ability to support traffic. Full depth reclamation with emulsified asphalt appears to have significantly reduced the occurrence of load cracks and rutting and as mentioned earlier has significantly increased the structural capacity of the roadway making it a good stabilizing agent for full depth reclaimed material over penetration macadam base.

Experimental 2 and Control 2 Comparison

Section Uniformity for this portion of the experimental project is quite different than the penetration macadam base portion. Section COV’s are 18 and 27 percent, a classification of “Fair” and “Poor”, for the Control 2 and Experimental 2 sections respectively. A “Poor” rating indicates the emulsion was not distributed evenly or compaction efforts were not uniform throughout the section resulting in a wide range of deflections. The Control 2 and Experimental 2 structural numbers are not significantly different but the experimental section results have been holding steady for the past three years while the control section has been fluctuating. Experimental 2 ride quality and rut depth data is significantly different than the Control

2 section indicating emulsion has improved the roadways ability to support traffic with less distortion. The Experimental 2 section has slightly reduced the number of transverse cracks and amount of initial and moderate load cracking. Although Section Uniformity is rated as “Poor”, possibly due to construction efforts, Experimental 2 section is outperforming the Control 2 section after five years of traffic and should be considered as a viable stabilizing agent. In general the use of emulsion in full depth reclamation has improved overall performance. When using full depth reclamation it is important to conduct preliminary investigations of the existing roadway materials in order to select the best alternative for stabilization and to avoid problems during construction.

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Additional available documents:
Potential Benefits of Adding Emulsion to Reclaimed Base Material, Experimental Construction Report #98-3, January 1998
Potential Benefits of Adding Emulsion to Reclaimed Base Material, Experimental Construction Report #98-3, Interim Report – First Year, March 1999
Potential Benefits of Adding Emulsion to Reclaimed Base Material, Experimental Construction Report #98-3, Interim Report – Second Year, September 1999
Potential Benefits of Adding Emulsion to Reclaimed Base Material, Experimental Construction Report #98-3, Interim Report – Third Year, February 2001
Potential Benefits of Adding Emulsion to Reclaimed Base Material, Experimental Construction Report #98-3, Interim Report – Forth Year, May 2003

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