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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

Interim Report - Fourth Year, May 2003

Transportation Research Division

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Introduction

Rehabilitation of deteriorated asphalt pavements has become one of the primary tools utilized by the Maine Department of Transportation (MDOT). 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 this 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 Route #2 and begins 0.42 km northerly of Beaver Brook Bridge #2059 in Passadumkeag and extends 20.4 km to the Access Road in Lincoln.

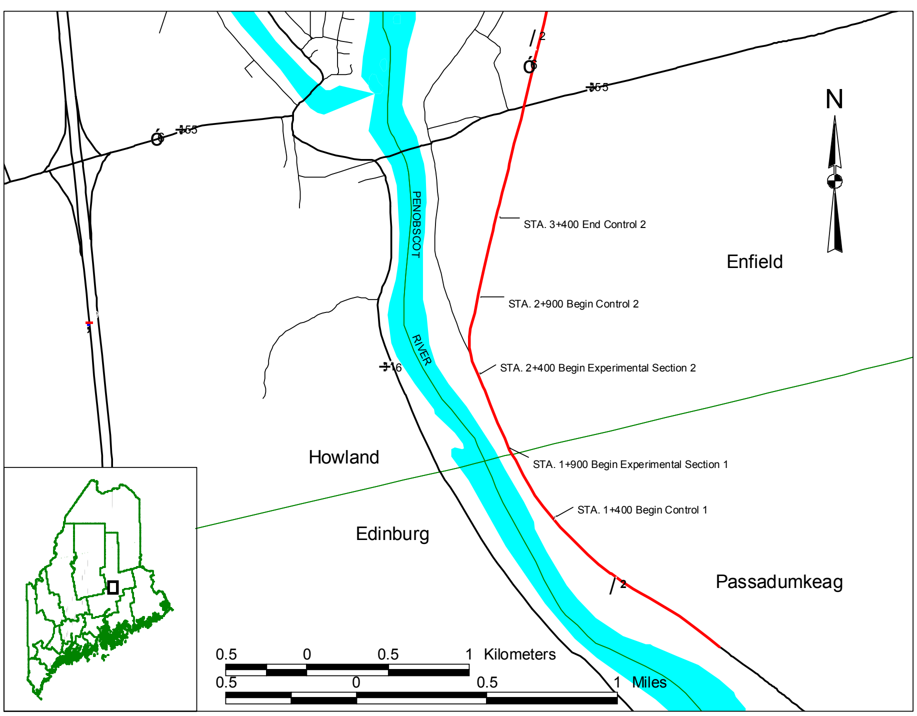

Figure 1. Experimental Area Location Map

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 and introducing an MS-2 emulsified asphalt at a rate of 6.0 liters per square meter. 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 150mm to 300 mm. As is common practice with MDOT pavement reclamation projects, 25 mm of existing gravel base was also reclaimed. Each section was overlaid with 45 mm of 19.0 mm NMAS Superpave and 30 mm of 12.5 mm NMAS Superpave.

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 the 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 the 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 pass was sufficient to cover the entire 7.3 meter 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 the emulsion throughout the width of the reclaimed base.

Construction of the section from station 2+400 to 2+900 went 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.

Field Inspection Summary

As discussed in the First Year Interim Report, 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 three inches of macadam, five inches of crushed stone base, and 18 inches of gravel. The second section from station 2+300 to the end of the project was treated with two inches of asphalt treated gravel and 24 inches 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 compare Control section #1, from station 1+400 to 1+900, with Experimental section #1, from station 1+900 to 2+400, and Experimental section #2 from station 2+400 to 2+900, with Control section #2, from station 2+900 to 3+400.

Structural Analysis

In September of 2001, Falling Weight Deflectometer (FWD) data was collected on each of the four sections at 50-meter intervals in each lane. A series of four drops, each at 9000 pounds 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 drop location. The Subgrade Resilient Modulus value is a measure of subgrade layer strength and elasticity. The Pavement Modulus value represents the pavement and gravel layer above subgrade and the Effective Structural Number is a value of the overall roadway strength.

Table 1 contains a summary of processed FWD data comparing Control Section 1 with Experimental Section 1 and Control Section 2 with Experimental Section 2 from 1998 to 2001.

TABLE 1

Summary of FWD Data
1998-2001 Comparison

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

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.

Average Subgrade Modulus values are very stable 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 2001. Although the Experimental 1 section has greater stability than the Control 1 section, the graph indicates that Experimental 1 section decreased at a higher rate than Control 1 section, 2.02 percent compared to 1.37 percent respectively. This indicates the sections may have peaked in 2000 and may be stabilizing.

A statistical comparison of the Control 1 and Experimental 1 Structural Numbers is displayed in Table 2. A high two tailed P value of 0.568470331 indicates no significant difference between the two means.

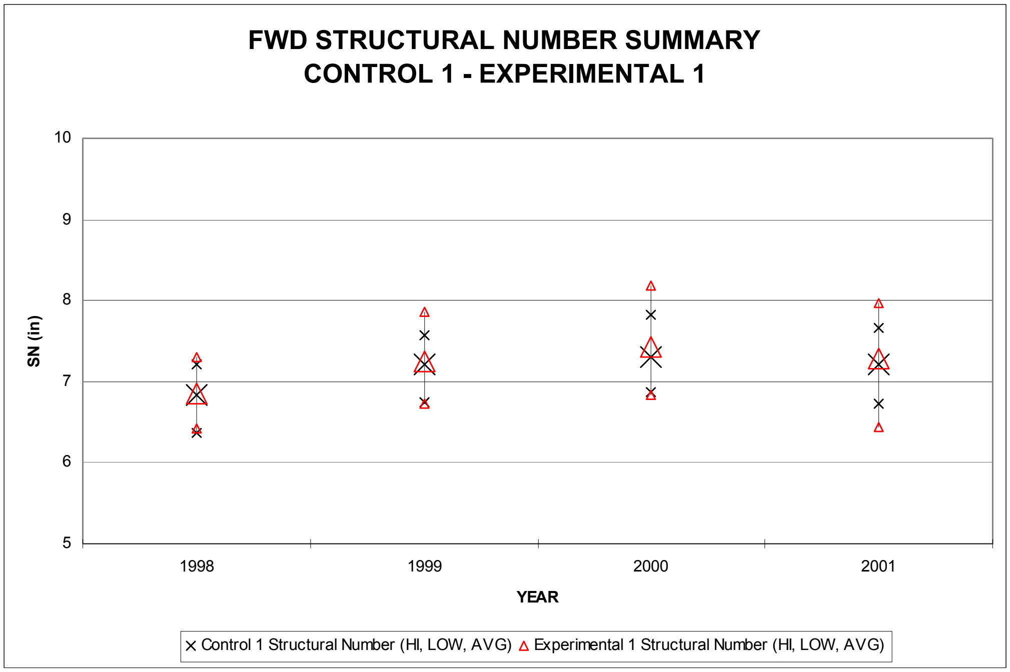

Figure 2. Control 1 and Experimental 1 Structural Number Comparison

TABLE 2

F and t-Test Statistical Analysis Results
'2001' Control 1 and Experimental 1 Structural Numbers

F-Test Two-Sample for Variances		
	Control 1	Experimental 1
Mean	7.211053	7.275263
Variance	0.059554	0.175837
Observations	19	19
P(F<=f) one-tail	0.013420	
Alpha	0.5	
t-Test: Two-Sample Assuming Unequal Variances		
	Control 1	Experimental 1
Mean	7.211053	7.275263
Variance	0.059554	0.175837
Observations	19	19
P(T<=t) two-tail	0.568470	
Alpha	0.5	

Control 2 and Experimental 2 Structural Number Comparison

Control 2 Pavement Modulus and Structural Number values have increased slightly this year whereas the Experimental 2 Pavement Modulus increased but the Structural Number has declined. The change is very slight indicating the sections may have stabilized.

Figure 3 contains high, low and average Structural Numbers for Experimental 2 and Control 2 sections from 1998 to 2001. Although stability has increased in the Control 2 section, Experimental 2 Structural Numbers continue to outperform the Control 2 section.

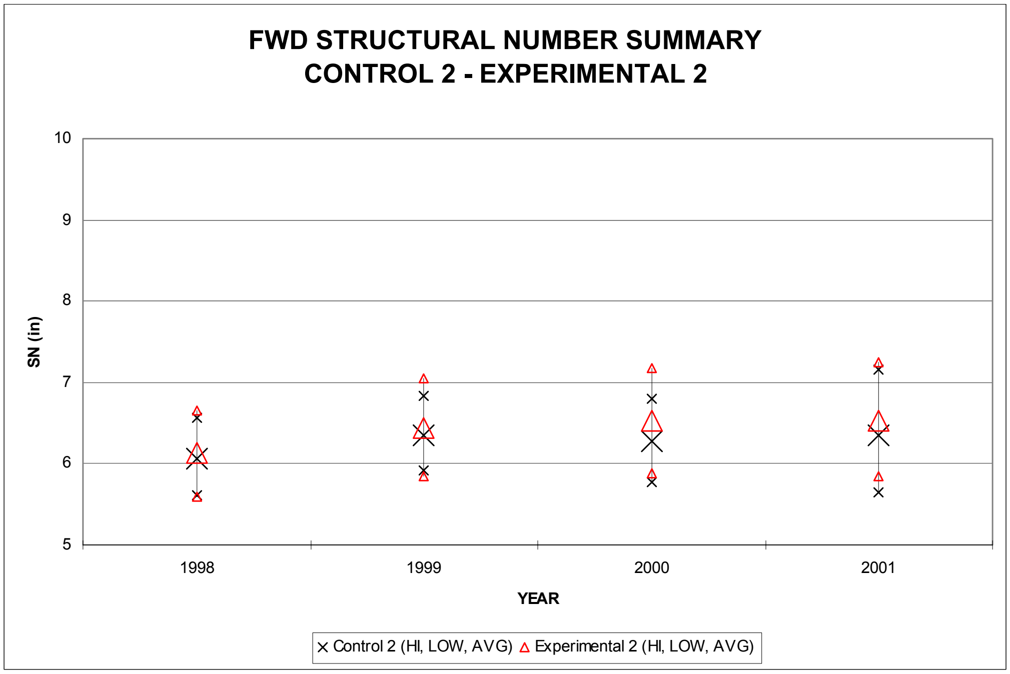

Figure 3. Control 2 and Experimental 2 Structural Number Comparison

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.

TABLE 3

F and t-Test Statistical Analysis Results
'2001' Control 2 and Experimental 2 Structural Numbers

F-Test Two-Sample for Variances		
	Control 2	Experimental 2
Mean	6.342105	6.521053
Variance	0.186018	0.173621
Observations	19	19
P(F<=f) one-tail	0.442644	
Alpha	0.05	
t-Test: Two-Sample Assuming Equal Variances		
	Control 2	Experimental 2
Mean	6.342105	6.521053
Variance	0.186018	0.173621
Observations	19	19
P(T<=t) two-tail	0.201634	
Alpha	0.05	

Ride Quality Analysis

Ride quality data was collected on November 8, 2001 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 4 contains verbal descriptions for IRI values.

TABLE 4

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 5 displays a comparative view of 2000/2001 ride data. Roughness has increased in all sections. Control 1 and Experimental 1 sections have a smoother ride possibly due to the macadam base. The rate of increase is greater in the Control sections than the Experimental Sections. Experimental 1 section has the smoothest ride and lower percentage of change, possibly due to a combination of emulsified reclaim base and macadam base providing greater stability for the roadway.

TABLE 5

Roughness Summary

Section	Average IRI (meters/kilometer) 2000	Average IRI (meters/kilometer) 2001	% Change
Control 1	1.06	1.13	6.6
Experimental 1	1.04	1.07	2.9
Control 2	1.34	1.45	8.2
Experimental 2	1.12	1.18	5.4

Control 1 and Experimental 1 Ride Quality Comparison

A statistical comparison of Control 1 and Experimental 1 sections is displayed in Table 6. F and t test results show no significant difference between the means.

TABLE 6

F and t-Test Statistical Analysis Results
2001 Control 1 and Experimental 1 IRI

F-Test Two-Sample for Variances		
	Control 1	Experimental 1
Mean	1.1332	1.0702
Variance	0.049634	0.04312
Observations	50	50
P(F<=f) one-tail	0.31217	
Alpha	0.05	
t-Test: Two-Sample Assuming Equal Variances		
	Control 1	Experimental 1
Mean	1.1332	1.0702
Variance	0.049634	0.04312
Observations	50	50
P(T<=t) two-tail	0.146747	
Alpha	0.05	

Control 2 and Experimental 2 Ride Quality Comparison

F and t-test results comparing the means for Control 2 and Experimental 2 sections are displayed in Table 7. Results show a significant difference between the means.

TABLE 7

F and t-Test Statistical Analysis Results
2001 Control 2 and Experimental 2 IRI

F-Test Two-Sample for Variances		
	Control 1	Experimental 1
Mean	1.1818	1.4518
Variance	0.120717	0.549607
Observations	50	50
P(F<=f) one-tail	2.15E-07	
Alpha	0.05	
t-Test: Two-Sample Assuming Unequal Variances		
	Control 1	Experimental 1
Mean	1.1818	1.4518
Variance	0.120717	0.549607
Observations	50	50
P(T<=t) two-tail	0.02259	
Alpha	0.05	

Rut Depth Analysis

The ARAN was also utilized to measure rut depths. Table 8 contains a summary of rut depths. Rutting has increased in all sections. Rut depths are lower 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 is similar in all sections ranging from 23.1 to 31.1 percent. All sections are resisting rutting very well after four years of traffic. A statistical comparison of Control 1 to Experimental 1 and Control 2 to Experimental 2 is displayed in Table 9 and 10 to determine if there is a significant difference between sections.

TABLE 8

Rut Depth Summary

Section	Average Rut Depth (millimeters)		% Change
	2000	2001	
Control 1	4.68	5.76	23.1
Experimental 1	4.15	5.44	31.1
Control 2	6.07	7.58	26.0
Experimental 2	4.84	6.08	25.6

Control1 and Experimental 1 Rut Depth Comparison

F and t-Test results displayed in Table 9 show no significant difference between the means.

TABLE 9

F and t-Test Statistical Analysis Results
2001 Control 1 and Experimental 1 Rut Depth

F-Test Two-Sample for Variances		
	Control 1	Experimental 1
Mean	5.76	5.44
Variance	1.196327	0.833061224
Observations	50	50
P(F<=f) one-tail	0.104409	
Alpha	0.05	
t-Test: Two-Sample Assuming Equal Variances		
	Control 1	Experimental 1
Mean	5.76	5.44
Variance	1.196327	0.833061224
Observations	50	50
P(T<=t) two-tail	0.115423	
Alpha	0.05	

Control 2 and Experimental 2 Rut Depth Comparison

F and t-Test results in Table 10 show a significant difference between the means.

TABLE 10

F and t-Test Statistical Analysis Results
2001 Control 2 and Experimental 2 Rut Depth

F-Test Two-Sample for Variances		
	Control 2	Experimental 2
Mean	6.08	7.58
Variance	4.126122	19.56489796
Observations	50	50
P(F<=f) one-tail	1.11E-07	
Alpha	0.05	
t-Test: Two-Sample Assuming Unequal Variances		
	Control 2	Experimental 2
Mean	6.08	7.58
Variance	4.126122	19.56489796
Observations	50	50
P(T<=t) two-tail	0.032739	
Alpha	0.05	

Visual Evaluation

A visual inspection of the project was completed on October 11, 2001. Table 11 contains results of that inspection. Centerline joint cracking and transverse cracking as well as the amount and severity of load cracking were recorded.

TABLE 11

Pavement Cracking Summary

Section	Centerline Joint Cracking (linear meters)	Transverse Cracking (number of cracks)	Load Associated Cracking (linear meters)		
			Initial	Moderate	Severe
Control 1	339.5	0.5	162.9	20.8	
Experimental 1	240	0.3	76.9		
Control 2	282	1.75	145.3	45	
Experimental 2	156	1.75	108.6	13	

There is very little transverse cracking throughout the project. Centerline joint cracking is much more prominent in the Control 1 section and less severe in the Experimental 2 section.

Load cracking is a key indicator of roadway performance. Both Experimental sections are outperforming there respective control counterparts. Experimental 1 section has the lowest amount of load cracking at 76.9 linear meters with no moderate or severe cracking. Experimental 2 has the second lowest amount of load cracking at 108.6 linear meters of initial and 13 linear meters of moderate. Control 2 section has the greatest amount of moderate load cracking.

A majority of load cracking in Control 2 section is located beyond a 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 12 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.

TABLE 12
Sieve Analysis Summary
12.5 mm Bituminous Concrete Mix

Sieve	Percent Passing		Specification Limits
	Reference # 43367	Reference # 43368	
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 performing well after fours years of exposure to traffic and the environment.

Statistical analysis of FWD, Ride, and Rut Depth data for Control 1 and Experimental 1 sections show no significant difference between sections. Structural numbers are higher in these sections possibly due to the macadam base.

The Control 2 and Experimental 2 structural numbers are not significantly different, but the Experimental 2 Ride 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.

In addition, 2002 FWD structural numbers have decreased as compared to 2001 data in all sections indicating the experimental area may have peaked structurally and is beginning to settle.

Additional tests will be collected in 2002 and a final report will be generated in 2003.

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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

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