Cold Recycled Bituminous Pavement
Chester/Springfield, Vermont
Final Report

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Reporting on Work Plan 92-R-7

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16. Abstract

This report documents the evaluation of a cold recycled bituminous pavement (CRBP). The Vermont Agency of Transportation constructed this experimental treatment along VT Route 11 in the towns of Chester and Springfield in 1993. In addition, two control sections, consisting of a cold-plane–and-overlay or an overlay-only, were applied in conjunction with the project.

Cracking, rutting, and roughness were documented on an annual basis prior to and following construction to evaluate pavement condition. These results are presented herein with recommendations on possible further research studies on this topic.

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INTRODUCTION

With a growing number of pavements in need of reconstruction or rehabilitation and ever increasing construction costs, State Agencies are seeking out cost effective long-lasting treatments. A method known as cold recycled bituminous pavement, or CRBP, utilizes preexisting in-place bituminous pavement to construct a new bituminous layer during roadway rehabilitation. This varies from full reconstruction methods, which typically involve the removal and replacement of the existing pavement layer. The reuse of in-place materials reduces the overall cost of pavement rehabilitation by the preservation of aggregates and bitumen. Additionally, the construction of cold recycled bituminous pavement reduces the impact on the environment and preserves energy in comparison to traditional methods.

The standard CRBP process includes the reclamation of the existing pavement to a typical depth of 65 to 125 mm. The reclaimed materials are then crushed and mixed with a predetermined amount of asphalt emulsion or other binding agent. The mixed-composite material is reapplied and compacted to a specified density. The new pavement layer should be allowed to cure prior to the application of a wearing surface. In most cases, the reconstruction is carried out onsite continuously through the use of a recycling train. However, for this investigation, the material was removed to an offsite location for mixing purposes. As would be expected, the CRBP process has been shown to successfully retard reflective cracking, otherwise known as the propagation of cracks from the preexisting pavement.

In an effort to assess the performance and cost effectiveness of a cold recycled bituminous pavement in a cold weather climate, the Vermont Agency of Transportation constructed this experimental treatment along VT Route 11 in the towns of Chester and Springfield in 1993. In addition, two control sections, consisting of a cold-plane–and-overlay or an overlay-only, were applied in conjunction with the project. Pavement studies to characterize the current condition of the various treatments were conducted prior to and following construction on an annual basis. The following report summarizes the findings from annual data collection efforts and subsequent recommendations. With regards to a cost analysis, it is important to note that, unlike CRBP, a standard overlay only includes the application of a new wearing course but does not address the underlying pavement structure.

PROJECT DESCRIPTION

The CRBP reconstruction occurred in 1993 along a 6.657 mile segment of VT Route 11 in the towns of Chester and Springfield. This project was completed under five separate contracts, with the most westerly of these beginning at the intersection of VT Route 11 and 103 at MM 5.116 in Chester. This rehabilitation effort extended east to MM 3.528 in Springfield. All of these projects were executed as one contract for construction and research evaluation purposes. According to the construction plans, the work consisted of a 3 ½” cold plane, cold recycling, bituminous concrete resurfacing, signs, guardrails, drainage, pavement markings, safety upgrading, and other related items.

In order to establish a basis of comparison for the CRBP treatment, two control sections were incorporated into the project, a cold planed pavement and a standard bituminous overlay. The treatment within the cold planed sections included the removal of the preexisting pavement to a depth of 3.5” and subsequent application of 2” of VT Type II bituminous concrete binder course with a nominal aggregate size of 1” and 1.5” of VT Type III wearing course with a nominal aggregate size of ¾”. The standard overlay section consisted of the application of a leveling course and 1.5” of VT Type III wearing course. Both control sections were located on relatively flat and straight section of highway. The paving limits are listed in Table 1 below:

Chester-Springfield CRBP Project						
Section Type:	**Number of Test Sites:**	**Mile Marker:**	**Town:**	**Mile Marker:**	**Town:**	**Distance (mi.):**
Cold Plane	0	5.116	Chester	5.865	Chester	0.749
Cold Plane	2	5.865	Chester	6.065	Chester	0.200
Overlay	2	6.065	Chester	6.265	Chester	0.200
CRBP	4	6.265	Chester	3.560	Springfield	6.022

Table 1 – Project Paving Limits

The remainder of the project received the experimental CRBP treatment. This included the removal of 3 ½” of in-place pavement and then processing and recycling the material off-site. Following the addition of asphalt emulsion, the composite was trucked onsite, reapplied and compacted. A wearing course consisting of 1 ½“of VT Type III bituminous concrete was constructed directly on top of the CRBP. Please note that the wearing course is consistent throughout the length of the project.

The Vermont Agency of Transportation specification, Section 415, “Cold Recycled Bituminous Pavement”, dated 1993, was modified to accommodate this off-site recycling process. This process required the material to be hauled by truck to a pug mill located at an established site, 150 yards off the highway at approximately MM 1.50, on VT Route 11 in Springfield. The pug mill phase included crushing and screening the material to pass a ¾” sieve, and adding emulsified asphalt to the recycled mix. Asphalt emulsion rates averaged 1.78% of the weight of the mix and are provided in Appendix E. This process was a one-pass operation and oversized material was separated and used elsewhere off the project.

A summary of construction and compliance test results were previously published in VTrans report, 94-1, entitled, “Cold Recycled Bituminous Concrete Pavement” on VT Route 11. Minor problems associated with the construction of the CRBP were noted. Specifically, some quality control issues attributed to the specification resulted in unacceptable concentrations of asphalt emulsion in small areas. These were subsequently removed and replaced by Type II bituminous concrete pavement. At that time, the milling process was suspected to be the cause for this problem.

A total of eight test sites were established throughout the length of the project. Of these eight test sites, four sites were located within the control sections, and four sites were identified within the experimental sections as shown in Table 1. Each test site consisted of a length of 100’ in the direction of travel and were approximately 22’ wide encompassing both the east and westbound lanes. Generally, each test site was examined annually for cracking, rutting, and IRI. Figure 1 and 2 provided below depict a typical test site within a control and experimental treatment area 9 years following construction.

8/27/2002

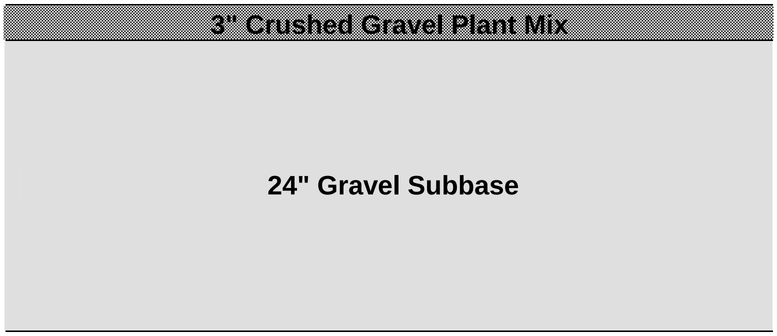
Figure 1 – Test Site 5.9 (Cold Plane)

8/27/2002

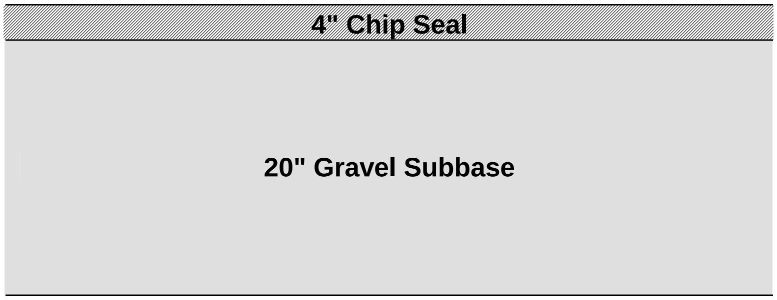
Figure 2 - Test Site 7.2 (CRB)

HISTORICAL INFORMATION

As with any surface treatment, the overall success of a pavement is often dictated by the underlying structure. Insufficient lateral support may cause fatigue cracking or rutting. An impervious media coupled with surface cracks, allows for further water infiltration leading to thermal cracking. According to historical data, the original construction of this highway varied throughout the project area. Figure 3, provided below, contains the profile of the original construction in the 1930s. Unfortunately there is no record of the original construction or rehabilitation efforts between MM 5.116 and MM 5.865 in Chester.



MM 5.865 in Chester to MM 1.162 in Springfield



MM 1.185 to MM 3.528 in Springfield

Figure 3 – Original Construction

As shown above, the first half of the project area was overlaid with a 3” crushed gravel plant mix in the 1930’s, with the second half receiving a 4” Macadam, a mixture of coal tars and aggregate, during the same period. The area was reconstructed twice more before 1993, once in the in the early 1960’s and again in the early 1980’s. In 1961, the 2.479 mile road section between MM 1.049 and MM 3.528 in Springfield was resurfaced. A 3” bituminous concrete surface course was applied to the preexisting pavement layer at a variable road width of 40’-43’. This section of road was again resurfaced with 1 ½” bituminous concrete layer in 1981. In 1965, the road section between MM 5.865 in Chester to MM 1.049 in Springfield was constructed using 8’-12’-12’-8’ typical road section. In this case a 2 ½” surface course of bituminous concrete was constructed. In 1983, this section of road was resurfaced with 1” bituminous concrete wearing surface.

PERFORMANCE

Cracking, rutting, and IRI values are often utilized to assess the performance and service life of pavement treatments or in this case differing rehabilitation efforts. It has been shown that the surface condition of a pavement is directly correlated to its structural condition and is a non-linear system that can be characterized by different rates of deterioration. The following is an examination of the surface condition of both the experimental and control pavements.

CRACKING

There are several causations for cracking in flexible pavements, including inadequate structural support such as the loss of base, subbase or subgrade support, an increase in loading, inadequate design, poor construction, or poor choice of materials. For this analysis, longitudinal, transverse and reflective cracking were examined. Longitudinal cracks run parallel to the laydown direction and are usually a type of fatigue or load associated failure. Transverse cracks run perpendicular to the pavement’s centerline and are usually a type of critical-temperature failure or thermal fatigue that may be induced by multiple freeze-thaw cycles. Reflection cracks occur from previous cracking that may exist within the base course, subbase or subgrade material and continue through the wearing course. In all cases, the cracks allow for moisture infiltration and can result in structural failure over time.

Pavement condition surveys of each test section were conducted throughout the study duration period in accordance with the "Distress Identification Manual for the Long-Term Pavement Performance Program" published in May of 1993 by the SHRP. Crack data is collected by locating the beginning of each test section, often keyed into mile markers or other identifiable land marks. The test section is then marked at intervals of ten feet from the beginning of the test section for a length of 100'. Pavement surveys start at the beginning of a test section and the locations and length of each crack are hand drawn onto a data collection sheet. Once in the office, the information is processed and the total length of transverse, longitudinal, centerline and miscellaneous cracking is determined and recorded into the associated field on the survey form. For this analysis, failure criterion is met when the amount of post construction cracking is equal to or greater than the amount of preconstruction cracking. Please note that all recorded crack data is provided in Attachment A.

I. Fatigue Cracking

The following assessment began with examining longitudinal or fatigue cracking. As indicated by the "Distress Identification Manual", fatigue cracking occurs in areas subjected to repeated traffic loading, or wheel paths, and may be a series of interconnected cracks in early stages of development that progresses into a series of chicken wire/alligator cracks in later stages. For this investigation, the wheel paths were determined to be three feet in width with the center of the left wheel path 3.5' from the centerline and 8.5' from the shoulder for the right wheel path on either side of the roadway. An important parameter considered during the pavement design process is a wheel load characterized as an ESAL, or equivalent single axle load. An ESAL is defined by Clemson University as "the effect on pavement performance of any combination of axle loads of varying magnitude equated to the number of 80-kN (18,000-lb.) single-axle loads that are required to produce an equivalent effect." Basically, pavements are designed to structurally support traffic loads which are often calculated by AADT or ESALs with regards to roadway use. ESAL information was not available for this investigation. Therefore a comparison between average cumulative fatigue cracking of the experimental and control sections vs. AADT is provided in Figure 4 below. Averages were calculated by adding up all of the recorded linear feet of cracking of each test section within one of the two mix types and dividing by the total number of test sections.

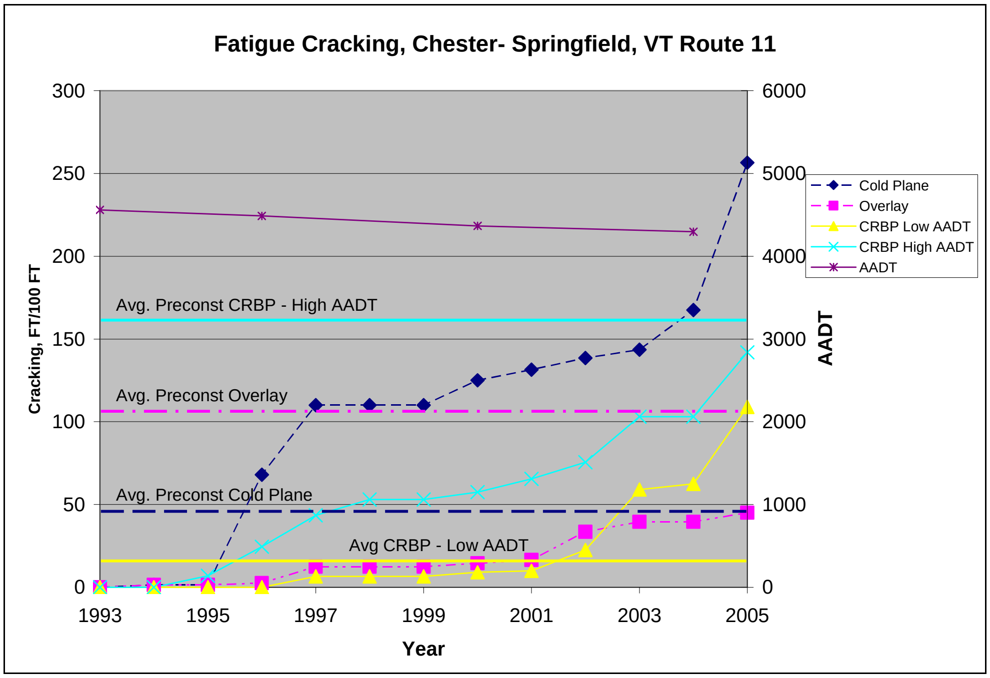


Figure 4 – Fatigue Cracking

A weighted average AADT was utilized in Figure 4, otherwise defined as an average of quantities that have been adjusted by the addition of a statistical value to allow for their relative importance in a data set. However, it is important to keep in mind that the AADT, provided in Appendix D, was not a constant variable across all test sites. The AADT did remain consistent across the control sections and the first two tests of the CRBP sections. However, the AADT within the last two test sites of the CRBP section was almost twice that of the other test sites. As previously discussed, AADT is an important parameter when defining the traffic loading across a pavement. While the AADT only describes the average number of vehicle passes a day, it may be surmised that additional vehicles will include additional truck traffic or heavier weighted vehicles resulting in an increase in fatigue cracking. In addition, local soil maps provided by the National Conservation Service, indicate that matrix below the lower and higher AADT sections consists of a stony or rocky subgrade and a sandy loam, respectively. Both should provide adequate subgrade support, although loams typically contain sand, silt and clay, resulting in slower rate of consolidation and a propensity to retain water.

However, the results from the graph do not confirm the theory that a greater amount of traffic contributes to a higher rate of fatigue cracking. Rather the test sections located within a lower AADT area returned to preconstruction levels earlier. In the case of the cold plane control section, preconstruction levels were met within two to three years following construction. Additionally, the CRPB section within the lower AADT area met preconstruction levels sometime between 2001 and 2002, nine to ten years following construction. Conversely, the standard overlay in the lower AADT area and the CRPB section in a higher AADT area have not yet encountered preconstruction levels.

It is interesting to note the consistency in the shape of the fatigue cracking rate, indicating similar pavement responses over time from all test sites. Additionally, the slope is not constant, with higher amplitudes resultant of increased failure rates. As expected, this may be attributed to the traffic stream during this time period.

II. Transverse (Thermal) Cracking

The formation of transverse cracking is largely due to climatic conditions and is often induced by freeze-thaw cycles or maximum low temperature shrinkage cracking. In addition to comparison of the cumulative transverse cracking between the experimental and control sections, monthly average minimum temperatures were attained from a weather station that resides in Burlington, VT, and are provided in Figure 5 below:

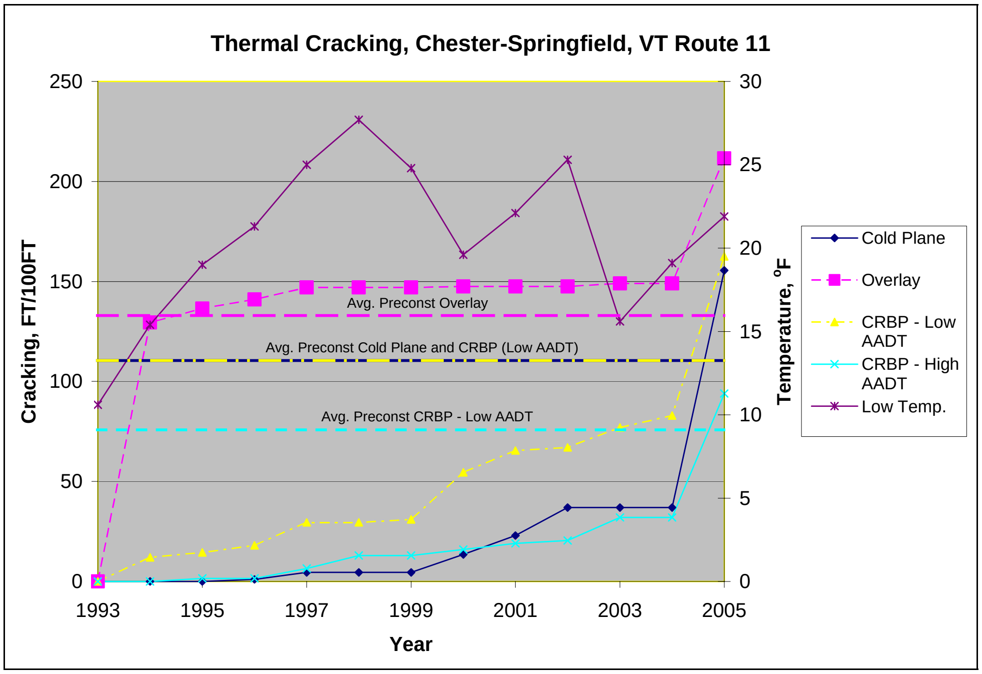


Figure 5 – Thermal Cracking

Unlike AADT, temperature remains a constant variable across all test sections. While the average amount of preconstruction cracking was variable across all sections, the minimum amount of thermal cracking was identified within the CRBP low AADT section at an average of 74 feet per 100 foot test section while the maximum amount of thermal cracking was found in the overlay section at an average of 132 feet per 100 foot test section. As would be expected, the standard overlay control section is the first to meet its preconstruction levels sometime between 1994 and 1995, only 1 to 2 years following construction. This is most likely due to reflective cracking from the underlying pavement and is further supported by the slope of the line. In examining 1997 through 2004, the amount of thermal cracking does not increase in this section. Surprisingly, all other treatments were found to meet preconstruction levels between 2004 and 2005, 11 to 12 years following construction. A reduction in the rate of thermal cracking may be expected within the CRBP areas due to the reclamation process. However, a greater amount of reflective thermal cracking was expected within the cold planed areas. It is important to note that construction plans specified the removal of 3.5” of preexisting pavement within the cold planed areas and the reclamation of 3.5” of preexisting pavement within the CRBP sections. The rate of thermal cracking within the CRBP sections and cold planed area appears to be relatively consistent with the exception of the period between 2004 and 2005 consistent with the colder temperatures shown in the graph.

III. Reflective Cracking

According to Dr. Beatriz Martin-Perez of the National Research Council of Canada, reflective cracking is defined as “the propagation of cracks from the existing pavement into the layer of pavement added (overlay) during rehabilitation.” As stated within the “Project Description” section above, the experimental section included the reclamation of preexisting pavement to a depth of 3.5”. Since this process involves the removal of the preexisting pavement it is less likely to observe reflective cracking with a reclaimed stabilized base as compared to a standard overlay.

An attempt was made to decipher the reflective cracking within all test sections. This is typically performed by overlaying the preconstruction data on top of the post construction data and counting the length of cracks that appear to be similar in location and overall length. However, there is a great deal of variability within the pavement surveys due to the nature of the data collection process, typically involving a large variation in field personnel, who may have differing personal interpretations. Therefore, reflective cracking could not be thoroughly examined.

RUTTING

Rutting is generally caused by permanent deformation within any of the pavements layers or subgrade and is usually caused by consolidation or lateral movement of the materials due to traffic loading. Throughout the duration of the investigation a rut gauge was utilized to quantify the overall depth of rut within each test section. This was done by collecting rut measurements at 50’ foot intervals from the beginning to the end of each test section. The measurement was collected by extending a string across the width of the road and measuring the vertical length between the string and the deepest depression within all wheel paths identified along the length of the string. All measurements were recorded onto a standard field form in 1/8” intervals. It is important to note that this procedure is highly subjective due to the nature of the data collection procedure. The following table displays the rut data that was collected throughout the duration of the investigation. All rut data is provided in Appendix B.

Average Rutting Readings for VT Route 11, Chester Springfield												
	WB Right WP			WB Left WP			EB Left WP			EB Right WP		
Year	Cold Plane	Overlay	CRBP	Cold Plane	Overlay	CRBP	Cold Plane	Overlay	CRBP	Cold Plane	Overlay	CRBP
1993 (pre)	0.19	0.19	0.27	0.25	0.27	0.37	0.21	0.30	0.45	0.19	0.34	0.33
1994	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00
1995	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1996	0.00	0.04	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1997	0.02	0.02	0.04	0.04	0.11	0.12	0.07	0.09	0.18	0.00	0.07	0.05
1998	0.00	0.04	0.05	0.02	0.11	0.11	0.04	0.17	0.19	0.00	0.07	0.05
1999	0.00	0.00	0.02	0.02	0.00	0.05	0.07	0.07	0.12	0.00	0.09	0.01
2000	0.04	0.06	0.13	0.07	0.04	0.16	0.17	0.19	0.28	0.04	0.21	0.15
2001	0.08	0.15	0.23	0.15	0.13	0.15	0.32	0.25	0.30	0.02	0.17	0.13
2002	0.07	0.17	0.12	0.09	0.13	0.16	0.31	0.23	0.29	0.04	0.26	0.09
2003	0.16	0.17	0.19	0.16	0.19	0.28	0.44	0.29	0.46	0.13	0.35	0.19
2004	0.17	0.17	0.19	0.16	0.15	0.24	0.46	0.19	0.43	0.08	0.35	0.19
2005	0.19	0.31	0.28	0.23	0.21	0.32	0.65	0.38	0.54	0.15	0.39	0.39
Precon. %	**100**	**163**	**103**	**92**	**78**	**86**	**310**	**127**	**120**	**79**	**115**	**118**

Table 2 – Rutting

In general, the overall depth of rutting increases throughout all test sections on an annual basis. However, some of the data from 2004 appears to be erroneous as the depth of rut decreases significantly in some of the test locations, without any known cause. According to the project history extracted from the “Pavement Management Database”, there was no record of a “rut fill” at any point during the investigation period. Therefore, this data was excluded from the subset.

In examining the data sets, the test sites in the cold plane section appear to have the least amount of rutting over the 13 year monitoring period (with one notable exception), closely followed by the CRBP. Regarding the standard overlay section, a leveling course was applied to the excessive pavement deformations prior to the application of the wearing course. In some cases, a single pass operation may result in inadequate compaction, which further consolidates under vehicle loading. The amount of rutting in this section exceeds preconstruction conditions, which may indicate some type of insufficient lateral support within the test sections. A similar pattern was identified within the CRBP sections possibly resulting from inadequate compaction or subgrade support. When the CRBP sections were separated by AADT, the high AADT section showed a greater amount of rutting than the lower AADT section which is to be expected.

IRI

IRI, or International Roughness Index, is utilized to characterize the longitudinal profile within wheel paths and constitutes a standardized measurement of smoothness. According to Better Roads Magazine, “the pavement’s IRI in inches per mile measures the cumulative movement of the suspension of the quarter-car system divided by the traveled distance. This simulates ride smoothness at 50 miles per hour.” IRI values were collected on an annual basis with the exception of 1999 through the Pavement Management Section of VTrans utilizing road profilers. Please note that the data was collected by different vendors through the investigation which resulted in poor correlation between collection events. The following figure provides a summary of the IRI data:

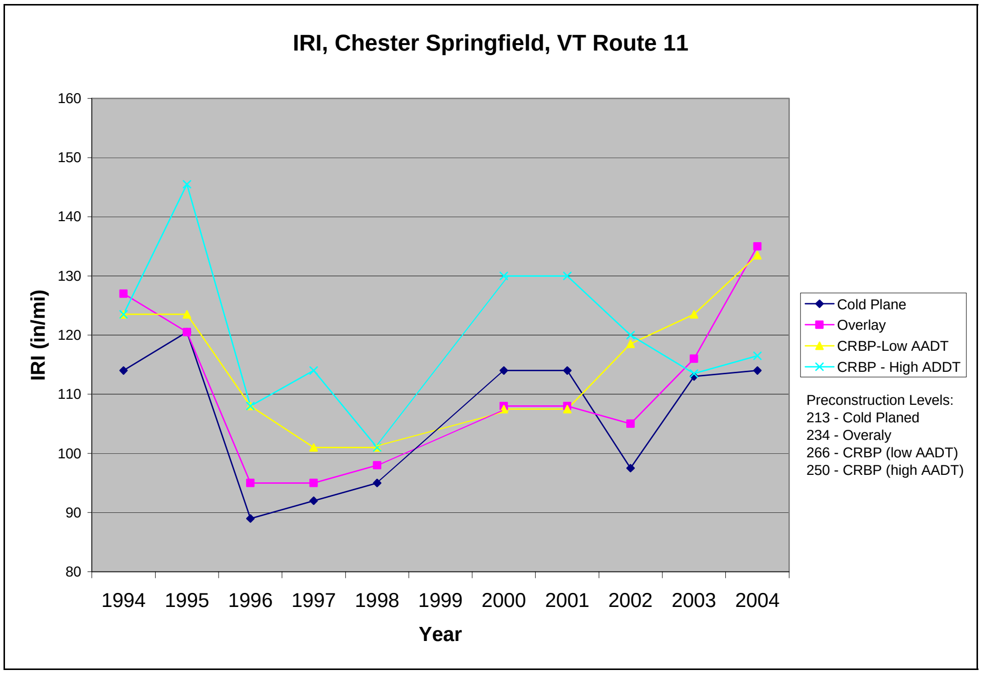


Figure 6 – IRI

There are some discontinuities within the data set. Usually IRI values are at a minimum immediately following construction as the pavement condition is optimum and will then degrade over time. Therefore, it was anticipated the there would be an upward trend throughout data collection. However the initial IRI values are greater than those from following years which is may be caused by the variation in testing equipment. There is a general upward trend between 1998 and 2004. In the latest data collected (2004), the IRI values for each pavement section were well below preconstruction values. This inference may not be accurate due to the variability of sampling equipment. It was documented that three different road profilers were utilized for the collection of the IRI values throughout the investing period. Each of the road profilers vary from one another which causes discontinuities between annual data sets. The ratio between the IRI data collected in 2004 as compared to preconstruction values are fairly consistent across all test sites and were found to range between 47 percent in the CRBP section with a high AADT to 57 percent in the overlay section. It is also important to keep in mind that IRI is directly related to all pavement distresses. It is recommended that all future IRI values are collected by the same profiling device for research projects evaluating various pavement treatments in order to provide consistency and accuracy. If there is a change in profiling device, there should be an effort to establish a correlation between data sets by selecting a number of reliable-data-value sites for measurement and verification.

COSTS

The costs associated with the project included emulsified asphalt at $1.00/hundred weight (CWT), bituminous concrete pavement at $28.10/ton, and cold recycling of bituminous concrete at $1.65/sy. In 2006, a similar project was let on VT 111 in Morgan and Brighton, with the costs for the items increasing to $65.00/ton for bituminous concrete, $8.00/sy for cold recycling and $45.00 per hundred weight for asphalt emulsion.

SUMMARY

In terms of pavement deformations, the overlay and CRBP sections outperformed the cold plane treatment in terms of fatigue cracking. Additionally, all CRBP and cold planed treatments outperformed the standard overlay section with regards to thermal cracking. The least amount of rutting was identified with the cold planed areas while IRI was relatively consistent throughout the length of the project. These results are quite interesting as a reduction in pavement deficiencies was expected within the CRBP and cold planed areas as compared to the standard overlay. Additionally, one of the reported advantages of the CRBP process is the mitigation of reflective cracking. However, due to the nature of data collection, reflective cracking could not be analyzed.

Generally, the CRBP performed well in the reduction of thermal and fatigue cracking, with mixed/inconclusive results in terms of rutting and IRI.A cost analysis could not be performed as the control pavement treatments are considered to be a surface remedy but does address the underlying structure as is the case for the CRBP process. Given the inconclusive results, it is difficult to make any type of recommendation with regards to the future use of cold recycled bituminous pavements. At this time another application of CRBP is suggested in association with annual pavement studies. This should include an adjacent control section constructed from standard rehabilitation efforts.

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Appendix A

Crack counts on VT 11

Cold Plane Section								
Year	Test Site 5.9 – Chester (ft/100ft)				Test Site 6.0 – Chester (ft/100ft)			
	All Transverse Cracking	All Longitudinal Cracking	Misc. Cracking	Centerline Cracking	All Transverse Cracking	All Longitudinal Cracking	Misc. Cracking	Centerline Cracking
1993 (Pre)	103	147	17	11	132	295	68	2
1993 (Post)	0	0	0	0	0	0	0	0
1994	0	4	0	0	0	0	0	0
1995	0	4	0	0	0	0	0	0
1996	2	129	6	0	0	31	0	0
1997	7	182	16	0	2	74	9	0
1998	7	182	16	0	2	74	9	0
1999	7	182	16	0	2	74	9	0
2000	13	219	37	0	14	168	18	0
2001	22	236	113	0	24	199	28	0
2002	35	253	118	0	39	202	38	0
2003	35	266	178	0	39	212	58	0
2004	35	253	118	0	39	212	58	0
2005	148	426	151	0	163	380	159	0

Overlay Section								
Year	Test Site 6.1 – Chester (ft/100ft)				Test Site 6.2 – Chester (ft/100ft)			
	All Transverse Cracking	All Longitudinal Cracking	Misc. Cracking	Centerline Cracking	All Transverse Cracking	All Longitudinal Cracking	Misc. Cracking	Centerline Cracking
1993 (Pre)	151	179	29	0	113	274	18	40
1993 (Post)	0	0	0	0	0	0	0	0
1994	140	13	0	14	119	68	16	27
1995	146	44	0	14	127	70	22	27
1996	146	85	7	14	136	77	40	27
1997	146	91	23	14	148	91	51	34
1998	146	91	23	14	148	91	51	34
1999	146	91	23	14	148	91	51	54
2000	146	100	23	14	149	109	53	54
2001	146	100	29	28	149	121	53	54
2002	146	113	33	28	149	147	53	54
2003	146	153	33	28	152	151	54	55
2004	146	153	33	28	152	151	54	58
2005	153	280	38	28	270	172	64	66

CRBP Section

Year	Test Site 7.2 – Chester (ft/100ft)				Test Site 1.0 – Springfield (ft/100ft)			
	All Transverse Cracking	All Longitudinal Cracking	Misc. Cracking	Centerline Cracking	All Transverse Cracking	All Longitudinal Cracking	Misc. Cracking	Centerline Cracking
Pre 1993 (pre)	134	252	2	0	103	206	17	99
1993 (post)	0	0	0	0	0	0	0	0
1994	13	0	0	0	11	0	0	0
1995	13	0	4	35	16	9	0	37
1996	15	0	42	59	21	9	4	51
1997	36	34	64	59	23	17	10	51
1998	36	38	64	66	23	19	10	51
1999	39	38	64	75	23	19	14	51
2000	53	89	70	75	56	46	20	51
2001	73	109	77	75	58	56	39	56
2002	76	126	77	75	58	78	39	56
2003	76	176	77	75	78	118	39	56
2004	76	180	77	75	90	118	39	56
2005	188	293	105	75	137	205	52	56

Year	Test Site 2.2 – Springfield ** (ft/100ft)				Test Site 3.4 – Springfield ** (ft/100ft)			
	All Transverse Cracking	All Longitudinal Cracking	Misc. Cracking	Centerline Cracking	All Transverse Cracking	All Longitudinal Cracking	Misc. Cracking	Centerline Cracking
1993 (Pre)	50	345	11	39	99	292	421	0
1993 (Post)	0	0	0	0	0	0	0	0
1994	0	51	0	0	0	51	0	0
1995	0	65	0	0	3	65	4	0
1996	0	72	2	0	3	116	9	0
1997	0	101	22	10	13	156	44	0
1998	0	101	22	10	26	218	54	0
1999	0	101	47	10	26	218	54	0
2000	0	121	51	10	32	251	54	0
2001	6	194	83	10	32	278	156	0
2002	9	236	89	13	32	293	165	0
2003					32	323	165	0
2004					32	323	165	0
2005					94	473	171	0

Definitions:

- All Transverse Cracking- this includes all cracks in the eastbound and westbound lanes, both partial and full width, perpendicular to the direction of the travel lanes.
- All Longitudinal Cracking- this includes all cracks parallel to the direction of travel for the eastbound and westbound lanes. This excludes cracking along the centerline construction joint.
- Miscellaneous Cracking- this includes all cracks other then those transverse, longitudinal, and along the centerline construction joint. This may include diagonal cracking and alligator cracking to name a few.
- Centerline Cracking- all cracking along the centerline construction joint.

Appendix B

Rut Readings

Cold Plane								
	Test Site 5.9 – Chester (in)				Test Site 6.0 – Chester (in)			
Year	Outer WB Wheel Path	Inner WB Wheel Path	Inner EB Wheel Path	Outer EB Wheel Path	Outer WB Wheel Path	Inner WB Wheel Path	Inner EB Wheel Path	Outer EB Wheel Path
1993 (Pre)	0.29	0.29	0.33	0.25	0.08	0.21	0.08	0.13
1993 (post)	0	0	0	0	0	0	0	0
1994	0	0	0	0	0	0	0	0
1995	0	0	0	0	0	0	0	0
1996	0	0	0	0	0	0	0	0
1997	0.04	0.04	0.13	0	0	0.04	0	0
1998	0	0	0.08	0	0	0.04	0	0
1999	0	0	0.13	0	0	0.04	0	0
2000	0.04	0.13	0.29	0.04	0.04	0	0.04	0.04
2001	0.08	0.21	0.5	0.04	0.08	0.08	0.13	0
2002	0.13	0.13	0.58	0.08	0	0.04	0.04	0
2003	0.2	0.2	0.667	0.13	0.125	0.125	0.21	0.125
2004	0.25	0.2	0.75	0.08	0.08	0.125	0.167	0.08
2005	0.292	0.292	0.96	0.167	0.08	0.167	0.333	0.125

Overlay								
	Test Site 6.1 – Chester (in)				Test Site 6.2 – Chester (in)			
Year	Outer WB Wheel Path	Inner WB Wheel Path	Inner EB Wheel Path	Outer EB Wheel Path	Outer WB Wheel Path	Inner WB Wheel Path	Inner EB Wheel Path	Outer EB Wheel Path
1993 (Pre)	0.17	0.17	0.13	0.13	0.21	0.37	0.46	0.54
1993 (Post)	0	0	0	0	0	0	0	0
1994	0	0	0	0	0	0	0.04	0
1995	0	0	0	0	0	0	0	0
1996	0	0	0	0	0.08	0.08	0	0
1997	0.04	0.08	0.04	0	0	0.13	0.13	0.13
1998	0.04	0.08	0.13	0	0.04	0.13	0.21	0.13
1999	0	0	0	0	0	0	0.13	0.17
2000	0.08	0.04	0.08	0.08	0.04	0.04	0.29	0.33
2001	0.13	0.08	0.17	0.04	0.17	0.17	0.33	0.29
2002	0.17	0.08	0.21	0.13	0.17	0.17	0.25	0.38
2003	0.167	0.167	0.21	0.167	0.167	0.208	0.375	0.541
2004	0.08	0.125	0	0.125	0.25	0.167	0.375	0.583
2005	0.25	0.125	0.25	0.08	0.375	0.292	0.5	0.708

	CRBP							
	Test Site 7.2 – Chester (in)				Test Site 1.0 – Springfield (in)			
Year	Outer WB Wheel Path	Inner WB Wheel Path	Inner EB Wheel Path	Outer EB Wheel Path	Outer WB Wheel Path	Inner WB Wheel Path	Inner EB Wheel Path	Outer EB Wheel Path
1993 (Pre)	0.21	0.17	0.17	0.13	0.13	0.21	0.21	0.21
1993 (post)	0	0	0	0	0	0	0	0
1994	0	0	0	0	0	0	0	0
1995	0	0	0	0	0	0	0	0
1996	0	0	0	0	0	0	0	0
1997	0	0	0.13	0.13	0	0.08	0.13	0
1998	0.04	0	0.13	0.08	0	0.04	0.17	0.04
1999	0	0	0	0.04	0	0	0	0
2000	0.13	0.08	0.21	0.08	0	0.08	0.17	0.13
2001	0.13	0.08	0.21	0.08	0.4	0.08	0.29	0.08
2002	0.04	0	0.17	0.04	0	0.08	0.21	0.08
2003	0.125	0.125	0.25	0.04	0.125	0.292	0.292	0.125
2004	0.04	0.04	0.293	0.208	0.208	0.25	0.167	0.04
2005	0.167	0.125	0.25	0.375	0.125	0.292	0.375	0.25

	Test Site 2.2 – Springfield (in)				Test Site 3.4 – Springfield (in)			
Year	Outer WB Wheel Path	Inner WB Wheel Path	Inner EB Wheel Path	Outer EB Wheel Path	Outer WB Wheel Path	Inner WB Wheel Path	Inner EB Wheel Path	Outer EB Wheel Path
1993 (pre)	0.42	0.33	0.5	0.25	0.33	0.75	0.92	0.71
1993 (post)	0	0	0	0	0	0	0	0
1994	0	0	0	0	0	0	0	0
1995	0	0	0	0	0	0	0	0
1996	0	0	0	0	0	0	0	0
1997	0.08	0.17	0.17	0.08	0.08	0.21	0.29	0
1998	0.08	0.17	0.17	0.08	0.08	0.21	0.29	0
1999	0	0.04	0.17	0	0.08	0.17	0.29	0
2000	0.13	0.17	0.25	0.13	0.25	0.29	0.5	0.25
2001	0.17	0.17	0.25	0.13	0.21	0.25	0.46	0.21
2002	0.17	0.17	0.25	0.013	0.25	0.375	0.542	0.208
2003					0.333	0.416	0.833	0.416
2004					0.333	0.416	0.833	0.333
2005					0.542	0.542	1	0.542

Appendix C

Ride Roughness Values for VT Route 11, Chester-Springfield

Cold Plane Section

(all values in inches/mile)

	Cold Plane					
	EB Lane			WB Lane		
Year/TS	5.9	6	Ave	5.9	6	Ave
1993 (post)	122		122	122		122
1994	119		119	102		102
1995	126		126		125	125
1996	109		109	65		65
1997	104		104		91	91
1998	103		103		88	88
1999						
2000	115		115	112		112
2001	112		112	100		100
2002	89		89	105		105
2003	142	98	120	96	76	86
2004	147	110	129	82	92	87

Overlay Section

(all values in inches/mile)

	Overlay					
	EB Lane			WB Lane		
Year/TS	6.1	6.2	Ave	6.1	6.2	Ave
1993 (post)	72		72	126		126
1994	111		111	138		138
1995	104		104		150	150
1996	63		63	109		109
1997	83		83		113	113
1998	80		80		106	106
1999						
2000	91		91	127		127
2001	74		74	120		120
2002	129		129	77		77
2003	96	144	120	88	136	112
2004	113	181	147	153	129	141

Cold Recycled Bituminous Concrete Sections

(all values in inches per mile)

	CRBP									
	EB Lane					WB Lane				
Year/TS	7.2	1	2.2	3.4	Ave	7.2	1	2.2	3.4	Ave.
1993 (post)	130	113	101	126	118	116	140	123	116	124
1994	132	109	92	164	124	111	147	135	135	132
1995	135	99	169	165	142	136	122	133	148	135
1996	85	100	69	151	101	108	120	87	226	135
1997	104	98	101	125	107	99	108	107	128	111
1998	86	89	97	110	96	86	104	90	109	97
1999										
2000	104	100	106	151	115	103	130	109	140	121
2001	106	100	88	157	113	96	120	102	120	110
2002	113	140	125	147	131	89	132	96	111	107
2003	130	138	120	137	131	93	132	88	108	105
2004	151	153	128	135	142	95	135	90	113	108

- All values were collected using the ‘Mays’ trailer.
- Due to the established interval of the data collection process, some values represented in the cold planed and standard overlay treatments may be based on one reading only.

Appendix D

Traffic Data

A summary of the average annual daily traffic (AADT) for the project area on VT Route 11 is presented in the table below

Town	Mile Marker		AADT			
	From To	Length	1992	1996	2000	2004
Chester	MM 5.63 - MM 8.25	2.62	3900	4000	4000	3900
Springfield	MM 0.00 – MM 1.88	1.88	3900	4000	4000	3900
Springfield	MM 1.88 – MM 2.67	0.79	5945	6000	6200	6100
Springfield	MM 2.67 – MM 3.56	0.89	6665	5600	4600	4700
Weighted AADT		6.18	4560	4486	4368	4296

Example Weighting Formula

$$1992 \text{ -- } \frac{(2.62)(3900)+(1.88)(3900)+(0.79)(5945)+(0.89)(6665)}{6.18} = 4560$$

Appendix E

Application Rates of Asphalt Emulsion

(percentage of weight of emulsified asphalt)

Date	Mile Marker	Location	Percentage
8-Jun-93	MM 6.272 – MM 7.031	Chester EB	1.96%
9-Jun-93	No Work		
10-Jun-93	MM 7.031 – MM 7.975	Chester EB	1.51% ***
11-Jun-93	MM 7.975 – MM 8.245	Chester EB	1.67%
11-Jun-93	MM 0.000 – MM 0.585	Springfield EB	1.67%
12-Jun-93	MM 0.585 – MM 1.277	Springfield EB	1.90%
14-Jun-93	MM 1.277 – MM 2.455	Springfield EB	1.90%
15-Jun-93	MM 2.455 – MM 3.450	Springfield EB	1.64%
16-Jun-93	MM 6.272 – MM 7.548	Chester WB	1.79%
17-Jun-93	MM 7.548 – MM 8.245	Chester WB	1.81%
17-Jun-93	MM 0.000 – MM 0.817	Springfield WB	1.81%
18-Jun-93	MM 0.817 – MM 2.101	Springfield WB	1.67%
19-Jun-93	MM 2.101 – MM 2.860	Springfield WB	1.91%
22-Jun-93	MM 2.860 – MM 3.528	Springfield WB	1.88%
22-Jun-93	MM 3.468 – MM 3.528	Springfield EB	1.88%
Average			**1.78%**

*** Some raveling detected the next day.