EVALUATION OF PAVEMENT CRACK TREATMENTS

February 2006

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Connecticut Advanced Pavement Lab – Connecticut Transportation Institute
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16. Abstract

This research effort conducted field evaluations of previously placed emulsified and hot pour crack treatment materials on Connecticut secondary roads and limited access highways. Crack sealing and crack filling consist of the placement of specialized materials into the cracks in pavement surfaces in order to prevent the intrusion of water and foreign objects. The field evaluations consisted of visual determinations of the crack treatment's ability to prevent water or foreign objects from entering the crack. The results of the field evaluations indicate that the hot pour materials performed better than the emulsified crack treatment material in working transverse cracks. These results are supported by the findings of a literature review that was conducted by the research team concurrently with this research project.

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METRIC CONVERSION PAGE

SI* (MODERN METRIC) CONVERSION FACTORS				
APPROXIMATE CONVERSIONS TO SI UNITS				
SYMBOL	**WHEN YOU KNOW**	**MULTIPLY BY**	**TO FIND**	**SYMBOL**
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa
APPROXIMATE CONVERSIONS FROM SI UNITS				
SYMBOL	**WHEN YOU KNOW**	**MULTIPLY BY**	**TO FIND**	**SYMBOL**
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised March 2003)

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INTRODUCTION

There are two primary types of crack treatment materials currently in use: hot pour and emulsified (sometimes referred to as cold pour). Hot pour materials require heating prior to application and cold pour materials generally pour at ambient temperature because they have been emulsified with water and do not require heating prior to application. Both materials are asphaltic in nature and may contain polymer, rubber, fibers as well as other proprietary additives.

Crack treatment is the placement of materials into the cracks of pavement surfaces in order to prevent the intrusion of water and foreign objects that may damage the pavement structure. Crack treatment involves two types of action: crack sealing and crack filling. The Federal Highway Administration (FHWA) *Materials and Procedures for Sealing and Filling Cracks in Asphalt-Surfaced Pavements,* Manual of Practice (1) identifies the distinct difference between crack filling and crack sealing. Crack sealing is "the placement of specialized treatment materials above or into *working* cracks using unique configurations to prevent the intrusion of water and incompressibles into the crack." The Manual further defines crack filling as "the placement of ordinary treatment materials into *non-working* cracks to substantially reduce infiltration of water and to reinforce the adjacent pavement." Working cracks require a material that has a greater capacity for adhesion and cohesion failure due to the increased pavement movement. (1)

A working crack is defined as having movement in excess of 3 millimeters. Transverse cracks, cracks perpendicular to the direction of traffic, are typically considered to be working cracks and are often targeted for crack sealing. Non-working cracks are defined by *Materials and Procedures for Sealing and Filling Cracks in Asphalt Surfaced Pavements, FHWA Manual of Practice* (1) as "cracks where little movement is occurring between crack edges." Most longitudinal cracks, cracks parallel to the direction of traffic, are typically considered to be non-working cracks and are often targeted for crack filling.

PROJECT OBJECTIVE AND SCOPE

This project's objective was to evaluate the effectiveness of the hot and cold pour material's ability to maintain its seal of cracks within asphalt pavements to prevent the intrusion of water and incompressibles.

The original scope of this project was to conduct a multi-year performance evaluation of hot and cold pour crack treatment materials placed in highly controlled conditions and test sections. The project was also intended to evaluate the performance of previously placed hot and cold pour crack treatment materials. Due to changes within the Connecticut Department of Transportation's contracting process, the research project's scope was altered to include only the evaluation of the previously placed crack treatment materials.

SUMMARY OF REVIEWED LITERATURE

(This section was excerpted from a separate CAP Lab research project conducted concurrently with this project to generate a literature review of pertinent information. This literature review project was funded jointly by ConnDOT and FHWA. The complete reference for this document can be found under Reference 6)

The literature that has been reviewed indicates a general assumption that cracks in pavements facilitate the intrusion of water into the pavement structure and that this intrusion has detrimental and unfavorable effects. These effects include secondary cracking, spalling, edge deterioration and potholes as well as other distresses. It is generally accepted that crack treatment inhibits the intrusion of water and thus slows the deterioration and further distress of the pavement.

The FHWA Manual of Practice (1) has established guidelines for evaluating a road or highway for potential treatment. ConnDOT conducts preliminary evaluations based on the PSR (pavement serviceability rating) system. The PSR system assigns a serviceability rating based on five performance conditions. These conditions are cracking, distortion, disintegration, drainage and ride. Each condition carries a weighted percentage of the overall serviceability rating.

The FHWA Manual of Practice (1) also offers guidelines for evaluating the performance of in place treatment materials. The treatment conditions examined in determining performance are loss of full depth adhesion, cohesion loss, material pull out, spalling, secondary cracks and potholes. Smith and Romine (2) have developed a failure rating procedure based on failure of treatment as a percentage of crack length.

Review of experiments and investigations conducted by several agencies and organizations present discrepancies as to the cost effectiveness of treating cracks. Hall et al. (9) express that while the intrusion of water into cracks is hindered by treatment, there is no significant benefit of treating cracks with respect to the overall long term quality of the structure. Most states in the U.S. simply assume that crack treatment contributes to the life of the pavement structure and thus their roads and highways receive crack treatment. A study conducted by the Ministry of Transportation, Ontario (MTO), Canada, (6) indicates that crack treatment can extend the service life of the structure by 2 years. This cost effectiveness discrepancy is the subject of ongoing research. A study conducted in Indiana by Purdue University in cooperation with Indiana Department of Transportation and Federal Highway Administration (25) collected data on 19 test sites in Indiana. The objective of the project was: *"… to provide adequate evidence to determine if joint and crack sealing is cost effective and under what conditions."*

Only one year of data was collected by Purdue on the performance of the treatments, and the authors were able to draw no conclusions regarding material performance or cost effectiveness of crack and joint treatment.

There are two major categories of crack treatment materials, namely hot and cold. The available treatment materials are standardized by several ASTM tests. Some products are subject to additional tests by their manufacturer. ConnDOT accepts hot applied crack treatment materials that conform to the AASHTO M301 (ASTM D 3405). This standard was discontinued in the 24th edition of the AASHTO *Standard Specifications for Transportation Materials and Methods of Sampling and Testing* and replaced by M324 (ASTM D 6690) in the year 2004. Current ConnDOT specifications do not reflect these changes. Several investigated experiments and documents indicate that hot applied materials perform better than those of cold applied materials (6,7,8,9) and that cold applied materials have other negative impacts to the safety of the roadway (10). Contrarily, there is also a reviewed internal ConnDOT document that indicates better performance from cold applied than hot applied materials (12).

CRACK TREATMENT FIELD EVALUATIONS

Evaluations were made of previously placed crack treatment materials during the late winter and early spring months of 2005. Materials placed during the 2004 construction season were not included in the evaluations. The intent of these evaluations was to determine the crack treatment's ability to prevent water infiltration as well as incompressibles from entering the crack. Safety issues associated with the different types of crack treatments were not investigated as part of the field evaluations, nor were the effects of the crack treatments on the service life of the pavement. It was assumed that all materials evaluated were placed in accordance with Connecticut Department of Transportation specifications.

METHODOLOGY

The Connecticut Department of Transportation provided the research team with a list of projects that were constructed in Districts 1, 2 and 4. The projects were divided into limited access highways and secondary roads. The projects used for the evaluation were placed between 1999 and 2003. Crack treatments placed during the 2004 construction season were not considered for the field evaluations as it was assumed that all the new materials should be in very good condition and would provide very little useful information regarding the longevity of the performance of the treatment material. The evaluations were conducted during the late winter-early spring of 2005. Projects where known problems with the placement of the materials were conveyed to the research team were excluded from the evaluations. Examples of sections excluded from the evaluation included a roadway where material had been in storage for a couple of years and then applied by DOT forces as well as an area where the sealant was pulling out of the cracks and it had been determined that the material was placed while the road was damp.

Attempts were made to include a minimum of two projects per District for each type of crack treatment and type of roadway. This was difficult to achieve with the hot-pour material as the number of projects constructed with this material were very limited in recent years. Each of these projects was driven through to ensure that the pavement had not been overlaid since the crack treatment was placed. Several sections were disregarded and replaced with another location as they had been overlaid since the treatment material was placed. This process was repeated for the limited access highways but the number of candidates for evaluation was considerably smaller so all of the existing crack treatments on limited access highways were included.

In total, there were 24 field evaluations conducted for this project. For secondary roadways there were 6 evaluations conducted on hot-pour materials and there were 11 evaluations conducted on cold-pour materials. For the limited access roadways, there were 4 evaluations conducted on hot-pour materials and 3 evaluations conducted on cold-pour materials.

The field evaluations were conducted on sections of roads that were 500 feet long. These 500 foot sections were placed in their respective locations in order to maximize the safety of the research team as well as minimize the impact on the motoring public. The crack treatment materials were only evaluated in the travel lane to avoid potential differences that could occur in the shoulders. The primary focus of the evaluations was on transverse cracks as they are considered to be working cracks. Working cracks are more demanding on the crack treatment materials.

At each evaluation section, the total length of each transverse crack in the travel lane was measured with a measuring wheel accurate to 1 inch. Each crack that was evaluated was assigned a unique number that was marked on the pavement. The crack was then photographed at a distance as well as photographed up close. The evaluation of failure was conducted by the same member of the research team for all of the secondary roads evaluated. Scheduling difficulties prohibited the same person from evaluating failure on the limited access highways. Therefore, a different member of the research team conducted the failure evaluations for the limited access highways.

Failure was assessed as those areas in which the crack treatments were no longer able to prevent the intrusion of water and incompressibles into the crack. The areas within the treated crack deemed to be failed were marked on the pavement and the total length of failure was measured for each crack. All of the data gathered from these evaluations was entered into a Filemaker® database and each crack was assigned its own individual record.

FAILURE CRITERIA

The SHRP H-106 crack treatment study performed by Smith and Romine (1) examined the performance of many different crack treatment materials as well as methods of placement in several locations in the United States and Canada. During the study Smith and Romine (1) developed criteria for deciphering material distress from material distress failure and used the established guidelines while performing their evaluations. The following paragraph was extracted from Smith and Romine (1) page 47:

"*Most of the distresses represented a reduction in a treatment's ability to perform its function (i.e., to keep water and incompressibles out of the crack channel). Examples of these distresses include partial-depth adhesion and cohesion loss, and overband wear. On the other hand, some distresses, such as full-depth pull-outs and full-depth adhesion and cohesion loss, signified a treatment's failure to perform its function. These distresses were termed "failure distresses." The total amount of failure distress observed in a treatment formed the basis for performance comparison.*"

A working definition of crack treatment failure is when the crack treatment is no longer capable of preventing water and incompressibles from entering the crack. This research team determined visually when failure had occurred. If the sealant material had pulled away from the wall of the crack (adhesion failure) then water and incompressibles could enter the crack and thus the material had failed. If the sealant material itself had cracked or opened (cohesion failure) thus allowing the intrusion of water and incompressibles into the crack, then the material was deemed to have failed. Additionally, if there was no material present in portions of a crack that was at one time sealed (full-depth pullout), clearly, water and incompressibles would be able to enter the crack and this was deemed as failure.

For the purposes of our study the percent of failure will be calculated by measuring the total length of failed material within a section and dividing it by the total length of crack originally sealed within that section multiplied by 100

The percentages calculated for each section and crack type will then be assigned a rating per the SHRP-H-106 (2) experiment.

- 0 to 10 percent failure, excellent;
- 11 to 20 percent failure, good;
- 21 to 35 percent failure, fair;
- 36 to 50 percent failure, poor; and
- 51 to 100 percent failure, very poor.

Figures 1 and 2, show adhesion/cohesion failure on cracks that were treated with hot material while figures 3 and 4, show adhesion/cohesion failures on cracks that were treated with cold materials.

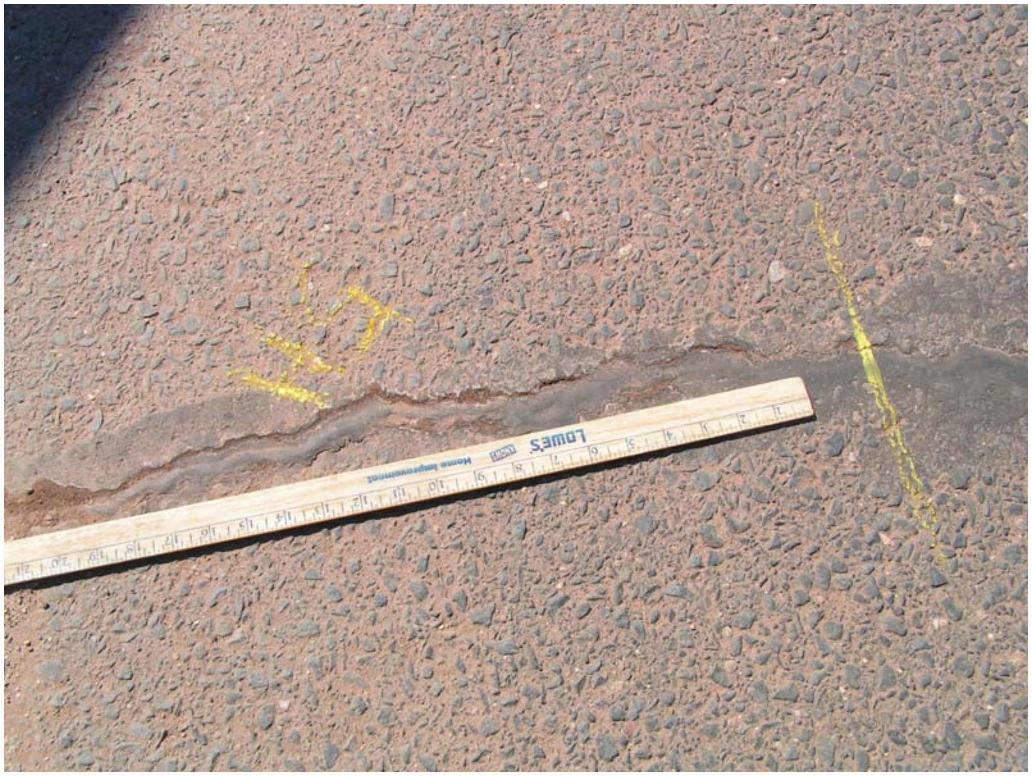

Figure 1: Failure of hot material (cohesion/adhesion)

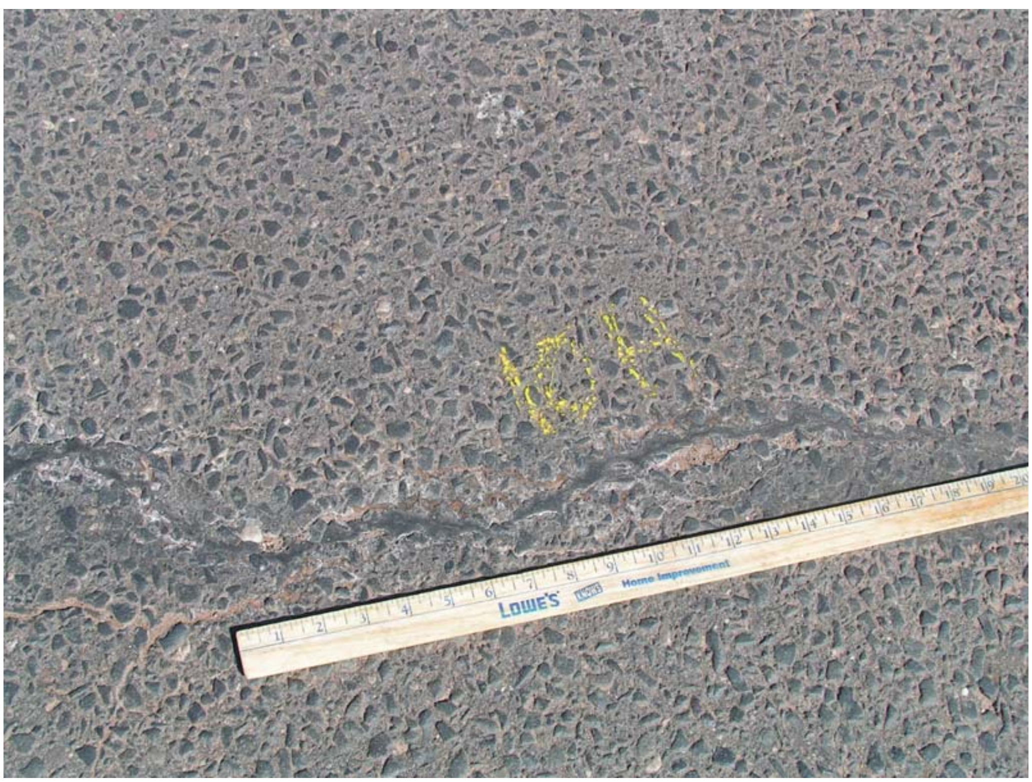

Figure 2: Failure of hot material (cohesion/adhesion)

Figure 3: Failure of cold material (cohesion/adhesion)

Figure 4: Failure of cold material (cohesion/adhesion)

RESULTS – TRANSVERSE CRACKS

The results in Tables 1 and 2 indicate that the performance of the crack treatment materials in transverse cracks is very similar between limited access highways and secondary roads. The results in Table 3 also show that the hot-pour crack treatments are performing on average better than the cold-pour materials even though the hot-pour's average age was approximately two years older than the cold-pour material. Graphical depictions of the failure percentages are given in Figures 5 and 6:

TABLE 1

SUMMARY OF RESULTS FOR EVALUATIONS ON SECONDARY ROADS

Town	Route Number	Year Placed	Number of Transverse Cracks	Sealant Type	Average Percent Failure
Granby	189	1999	3	Cold	87
Somers	83	1999	14	Cold	99
Sherman	39	1999	2	Cold	100
Hebron	85	2000	6	Cold	85
Ellington	30	2001	12	Cold	94
Washington	45	2002	7	Cold	93
Groton	215	2002	21	Cold	100
Colebrook	183	2002	12	Cold	100
Windham	14	2002	7	Cold	100
Stafford	190	2003	12	Cold	94
Cromwell	99	2003	7	Cold	100
Southington	10	1999	12	Hot	68
Farmington	71	1999	10	Hot	73
Groton	12	2000	5	Hot	57
Stonington	184	2000	10	Hot	57
Stonington	216	2000	19	Hot	52
Marlborough	66	2000	17	Hot	99

Figure 5: Percent Failure on Secondary Roadways

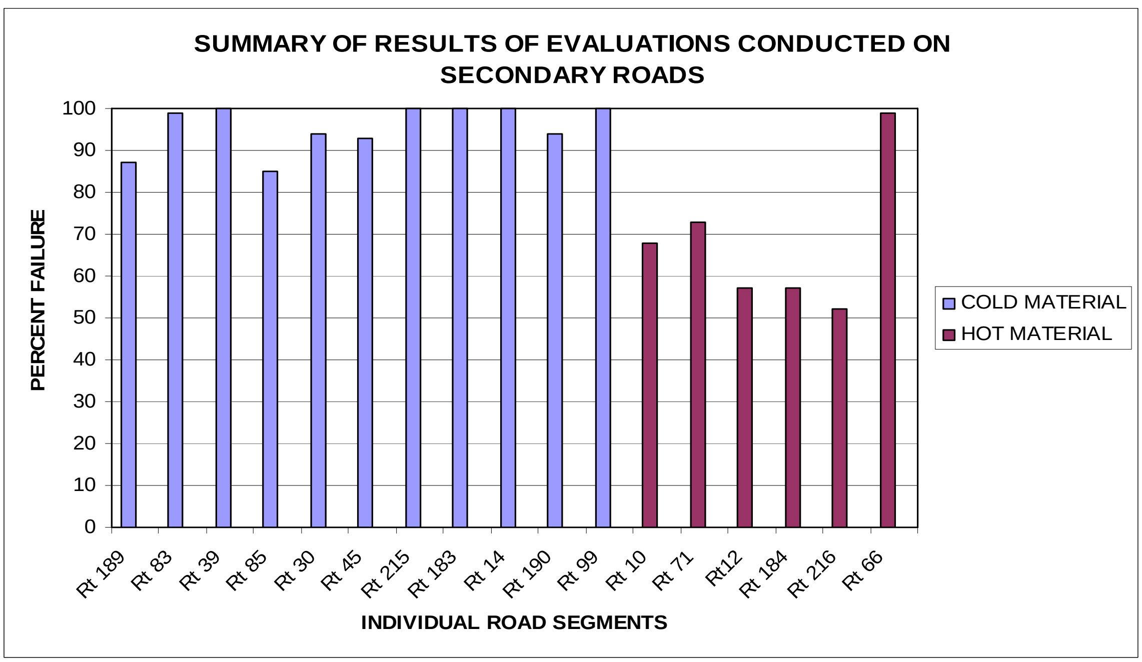

TABLE 2

SUMMARY OF EVALUATIONS ON LIMITED ACCESS HIGHWAYS

Town	Route Number	Year Placed	Number of Transverse Cracks	Sealant Type	Average Percent Failure
Southbury	84	2001	11	Cold	100
Waterford	395	2002	13	Cold	100
Tolland	84	2003	4	Cold	87
Salem	11	1999	11	Hot	93
Colchester	2	1999	6	Hot	25
Haddam	9	1999	4	Hot	52
Meriden	91	2003	6	Hot	81

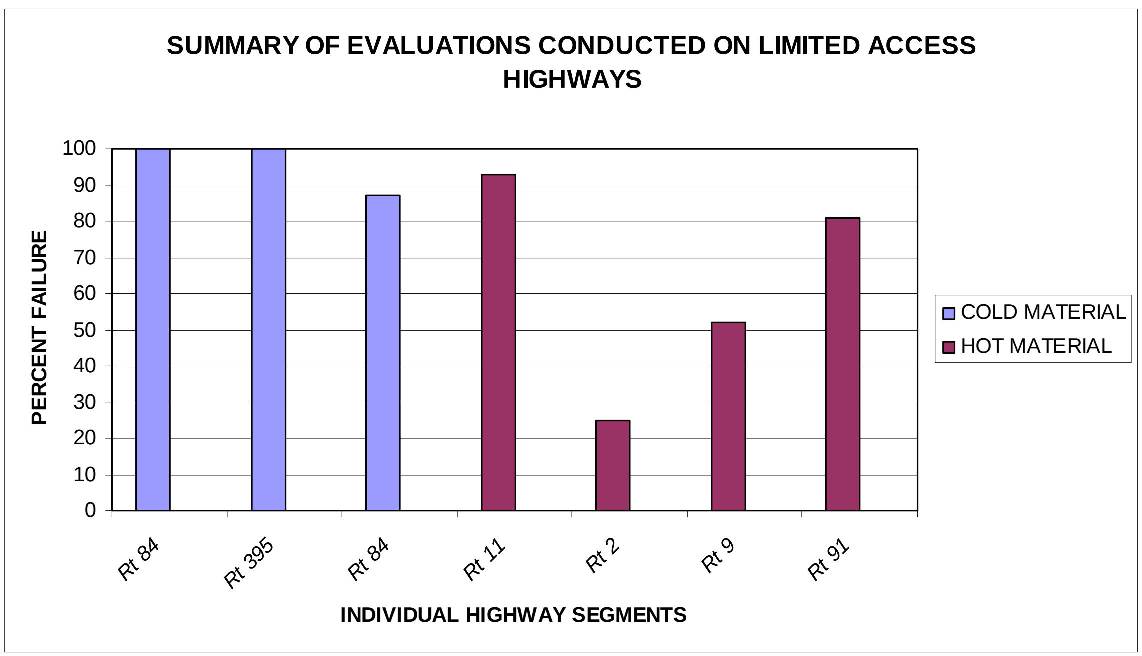

Figure 6: Percent Failure on Limited Access Highways

TABLE 3

SUMMARY OF MATERIAL PERFORMANCE ON TRANSVERSE CRACKS

	Hot-Pour Materials			Cold-Pour Materials		
	Number of Transverse Cracks	Avg. Year of Placement	Overall Average % Failure	Number of Transverse Cracks	Avg. Year of Placement	Overall Average % Failure
Limited Access	27	2000	70	28	2002	99
Secondary Roads	73	2000	73	102	2001	97
Overall	100	2000	72	130	2002	97

RESULTS – LONGITUDINAL CRACKS

The results for longitudinal cracks, as seen in Table 4, indicate that both materials perform better in longitudinal cracks than in transverse cracks. The data set for longitudinal cracks is limited, due to the focus of the field evaluations being placed on transverse cracks, but the improved performance in the longitudinal cracks should be expected as the amount of longitudinal crack movement is typically less than for transverse cracks. **Note the sample sizes for longitudinal crack data in Table 4 are not statistically valid.** This data is presented for informational purposes and to better illustrate that materials used in longitudinal cracks will tend to perform better than in transverse cracks due to the limited amount of movement inherent in longitudinal cracks as opposed to transverse cracks.

TABLE 4: SUMMARY OF PERFORMANCE ON LONGITUDINAL CRACKS

	Hot-Pour Materials			Cold-Pour Materials		
	Number of Longitudinal Cracks	Avg. Year of Placement	Overall Average % Failure	Number of Longitudinal Cracks	Avg. Year of Placement	Overall Average % Failure
Limited Access	4	2000	43	2	2003	33
Secondary Roads	6	2000	51	10	2001	69
Combined	10	2000	46	12	2002	58

CONCLUSIONS

Based upon the observations and data from the field evaluations, hot-pour crack treatments used on the projects evaluated by the research team outperformed the cold-pour products even though the hot-pour products were approximately two years older than the cold pour products. As the field evaluations were just a snapshot of the performance of the crack treatment material performance, it is difficult to establish the exact rate of decline in performance for either product. The decline in performance may have occurred immediately after the first winter or it could have occurred in a gradual and steady decline.

It was difficult to locate projects treated with a hot-pour product in the 2002 timeframe as ConnDOT was primarily using the cold-pour crack treatment materials at that time. Therefore, it was very difficult to directly compare the performance of the two different types of materials at the same age. The comparison of the two products with different ages actually places the older hot-pour material at a disadvantage because it is being compared with cold pour material that was more recently placed. Even so, the hot-pour material still outperformed the cold pour material.

RECOMMENDATIONS

Based upon the findings of the field evaluations as well as the concurrent literature review, the following recommendations regarding crack treatments are made.

- ConnDOT specifications should be updated to reflect the current state of the practice in regards to materials and application processes according to the current version of the FHWA Manual of Practice (1).
- Additional research needs to be conducted to explore the performance differences between the various hot-pour products available for sealing and filling of cracks in asphalt pavements.
- Research also needs to be conducted to quantify the amount that crack treatment extends the pavement life or improves the pavement condition of overlays.

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