



COLORADO

Department of Transportation

**Applied Research and Innovation
Branch**

FINAL REPORT

Effectiveness of Two Reflection Crack Attenuation Techniques

Scott Shuler

Report No. CDOT-2015-10

September 2015

The contents of this report reflect the views of the author, who is responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views of the Colorado Department of Transportation or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

1. Report No. CDOT-2015-10		2. Government Accession No.		3. Recipient's Catalog No.	
4. Title and Subtitle Effectiveness of Two Reflection Crack Attenuation Techniques			5. Report Date September 2015		
			6. Performing Organization Code		
7. Author(s) Scott Shuler			8. Performing Organization Report No. CDOT-DTD-R-2015-10		
9. Performing Organization Name and Address Colorado Department of Transportation - Research 4201 E. Arkansas Ave. Denver, CO 80222 Colorado State University Ft. Collins, CO 80523-1584			10. Work Unit No. (TRAIS)		
			11. Contract or Grant No. Performed internally by CDOT-Research Office and Colorado State University		
12. Sponsoring Agency Name and Address Colorado Department of Transportation - Research 4201 E. Arkansas Ave. Denver, CO 80222			13. Type of Report and Period Covered Final Report, September 2015		
			14. Sponsoring Agency Code Study #11.50		
15. Supplementary Notes Prepared in cooperation with the US Department of Transportation, Federal Highway Administration					
16. Abstract <p>Asphalt overlays are one of the most common tools for rehabilitating existing asphalt and concrete pavements. However, the performance of new overlays is often jeopardized by the cracking distress in the existing pavement. This existing cracking propagates, or reflects, through the new overlay to the surface of the new overlay. The rate at which this reflection cracking propagates to the surface is a function of overlay thickness, crack severity, traffic loading and subgrade or subbase support. Once reflection cracks appear on the surface of the new pavement, water and debris can enter the subbase and subgrade which can affect pavement strength and reduce the life of the overlay. Therefore, reducing the rate at which these reflection cracks propagate to the surface of the pavement is desirable in order to lengthen the time between rehabilitation projects or crack sealing operations.</p> <p>Various methods have been used in past decades in an attempt to reduce the rate of reflection crack propagation. These include geosynthetic membranes and asphalt stress absorbing interlayers.</p> <p>This study compares performance of a grid reinforcing system, a polymer modified asphalt-rich interlayer system and control pavement test sections.</p> <p>After five years of performance monitoring differences between the attenuation systems and the controls have appeared.</p>					
17. Keywords: Reflection crack attenuation, asphalt overlay reflection cracking, reflection crack interlayers			18. Distribution Statement No restrictions. This document is available to the public through the National Technical Information Service Springfield, VA 22161; www.ntis.gov		
19. Security Classif. (of this report) Unclassified		20. Security Classif. (of this page) Unclassified		21. No. of Pages	22. Price

ACKNOWLEDGEMENTS

Many thanks to study panel members Gary DeWitt, CDOT Region 4 Materials, Skip Outcalt, Research Branch, Richard Griffin, Research Branch, Michael Stanford, CDOT Materials and Geotechnical Laboratory, Shamshad Hussain, CDOT Region 1 Materials, Donna Harmelink, CO. Div. of FHWA, and Robert Shanks, R-5 Materials.

EXECUTIVE SUMMARY

Asphalt overlays are one of the most common tools for rehabilitating existing asphalt and concrete pavements. Rehabilitation of existing pavements is often necessary after several years due to distress such as cracking, moisture damage and permanent deformation. However, the performance of new overlays is often jeopardized by the cracking distress in the existing pavement. This existing cracking will propagate, or reflect, through the new overlay to the surface of the new overlay. The rate at which this reflection cracking propagates to the surface is a function of overlay thickness, crack severity, traffic loading and subgrade or subbase support. Once reflection cracks appear on the surface of the new pavement, water and debris can enter the subbase and subgrade which can affect pavement strength and reduce the life of the overlay. Therefore, reducing the rate at which these reflection cracks propagate to the surface of the pavement is desirable in order to lengthen the time between rehabilitation projects.

Various methods have been used in past decades in an attempt to reduce the rate of reflection crack propagation. These include geosynthetic interlayers and asphalt stress absorbing interlayers between existing pavements and relatively thin overlays.

Two reflection crack attenuation techniques have been installed by CDOT: Tensar, a grid reinforcing system, and a polymer modified asphalt-rich interlayer system called Reflection Crack Interlayer or RCI. Locations where these systems were installed with control sections are on I-70 at M.P. 255/256 (Tensar) and on US85 in Greeley and on US34 east of Kersey (RCI).

This study presents the differences in performance after five years' service for the two reflection crack attenuation systems and the comparable control pavement test sections.

CONTENTS

ACKNOWLEDGEMENTS	1
EXECUTIVE SUMMARY	1
INTRODUCTION	3
BACKGROUND	3
EXPERIMENTAL METHOD	4
REFLECTION CRACK ATTENUATING METHODS	4
GlasGrid®	4
Reflective Crack Interlayer (RCI)	5
PAVEMENT TEST SECTIONS	6
I-70 Golden.....	6
US85-Greeley	8
US34-Kersey East.....	9
PERFORMANCE	9
I-70 GlasGrid	9
Eastbound Right (Driving) Lane.....	10
Westbound Right (Driving) Lane	11
Eastbound Center Lane	13
Eastbound Median Lane	14
US 85 - Greeley	14
US 34 – Kersey East.....	16
ANALYSIS	17
I-70 Golden.....	17
US85-Greeley	17
US34-Kersey East.....	17
CONCLUSIONS	18
REFERENCES	19

INTRODUCTION

Asphalt overlays are one of the most common tools for rehabilitating existing asphalt and concrete pavements. Rehabilitation of existing pavements is often necessary after several years due to distress such as cracking, moisture damage and permanent deformation. However, the performance of new overlays is often jeopardized by the cracking distress in the existing pavement. This existing cracking will propagate, or reflect, through the new overlay to the surface of the new overlay. The rate at which this reflection cracking propagates to the surface is a function of overlay thickness, crack severity, traffic loading and subgrade or subbase support. Once reflection cracks appear on the surface of the new pavement, water and debris can enter the subbase and subgrade which can affect pavement strength and reduce the life of the overlay. Therefore, reducing the rate at which these reflection cracks propagate to the surface of the pavement is desirable in order to lengthen the time between rehabilitation projects.

Various methods have been used in past decades in an attempt to reduce the rate of reflection crack propagation. These include geosynthetic interlayers and asphalt stress absorbing interlayers between existing pavements and relatively thin overlays.

Two reflection crack attenuation techniques have been installed by CDOT: Tensar, a grid reinforcing system, and a polymer modified asphalt-rich interlayer system called Reflection Crack Interlayer or RCI. Tensar was installed on I-70 at M.P. 255/256 while RCI was installed on US85 in Greeley and on US34 east of Kersey. For each location a control section was set aside where no reflective crack reduction treatment was used.

This study presents the differences in performance after five years' service for these two reflection crack attenuation systems and the comparable control pavement test sections.

BACKGROUND

When asphalt overlays are placed on substrate surfaces containing cracks the anecdotal rule-of-thumb regarding the rate the cracks will appear in the new surface is usually considered to be one inch per year. So, a two inch thick asphalt overlay placed on top of a cracked substrate pavement should display cracks reflected through from below in two years. As stated above there are many factors that affect this leading to either faster or slower crack growth than predicted. However, the underlying cracks almost always reappear unless the overlay thickness is substantial.

Many different techniques have been attempted to reduce or even eliminate these so-called reflection cracks. These include stress-absorbing membrane interlayers (SAMI) (Epps, Heitzman, Shuler), geotextiles (Bush et al, Button et al, Buttlar et al, Cleveland et al, Hutter), large aggregate layers, cracking and seating, rubblizing and, most recently, low modulus hot mix asphalt (Makowski et al) and fiber glass reinforced grid systems (Vespa et al). Fracture mechanics indicates that if a material of low stiffness modulus is sandwiched between two layers of higher modulus, energy generated at the tip of a crack during propagation will be

dissipated in the low modulus layer and further movement of the crack will cease (Sanford 1997). Although this theory is sound for homogeneous, linear elastic materials it has been less successful when predicting crack growth in non-homogeneous, viscoelastic and thermoplastic materials (Germann and Lytton).

Various reflection crack attenuation techniques have demonstrated varying degrees of success over the past 40 years, none of which, to the knowledge of this writer, and after reviewing the literature completely halt reflection cracking. Indeed, most suppliers of reflection crack attenuation materials or methods would agree the materials and methods are intended to slow the progression of the reflection cracks, not stop progression. However, the economics of reflection crack interlayers can work if the interlayer slows crack progression enough to postpone maintenance activities.

EXPERIMENTAL METHOD

This report summarizes the performance of two types of reflection crack attenuation systems over a five year period of service. These systems were installed in three different pavements as test sections with corresponding control sections. One system was placed on one pavement and the other placed on two pavements. Performance of the test sections was evaluated using visual condition survey methods (SHRP 1990) for five years in the case of one system and two years in the case of the other.

REFLECTION CRACK ATTENUATING METHODS

Two types of reflection crack attenuation processes were evaluated in this research study. These are described below.

GlasGrid[®]

This is a patented product of Saint-Gobain ADFORS, distributed for use in the U.S. by Tensar International Corporation. Saint-Gobain describes this product as a “Pavement Reinforcement System composed of fiberglass strands coated with an elastomeric polymer and formed into a grid structure” as shown in Figure 1.



Figure 1. GlasGrid®

The theory behind attenuation of reflection cracks using this type of system regards the mechanics of crack tip energy. The idea is that when GlasGrid is sandwiched between a leveling course and the surface course in an asphalt overlay the energy at the tip of a vertical crack in the substrate is dissipated horizontally at the GlasGrid interface, causing the crack to stop propagating upward to the surface of the new overlay.

The test sections placed in this section consisted of removal by milling of 3.0 inches of the existing asphalt pavement, a tack coat, then a one inch leveling course of SX(75) PG(64-22), then GlasGrid followed by a 2.0 inch lift of SMA (1/2 in NMS).

Reflective Crack Interlayer (RCI)

This system was originally developed by SEM Materials, later known as RoadScience, and branded as ‘Strata’. The process was not proprietary and several states including Colorado developed their own specifications for the use of RCI. The material is a hot mixed asphalt concrete with relatively small 3/8-inch nominal maximum aggregate size, gap grading, high asphalt content, and high VMA as shown in Table 1.

Table 1. Properties of RCI

Sieve	Passing, %
3/8-inch	100
4	94
8	75
16	53
30	33
50	12
100	5
200	2.9
Stability	18

VTM, %	4.5
VMA, %	23.5
AC, %	9.5
PG Grade	70-28
Compaction, gyrations	50

The material is placed as a 1-inch interlayer sandwiched between the cracked substrate pavement and the new overlay. The idea of RCI systems is to create a lower modulus layer between the substrate and the overlay that will cause crack tip energy to dissipate in the RCI and not propagate upward to the pavement surface.

PAVEMENT TEST SECTIONS

Test sites are located on I-70 east of Golden, on US85 in Greeley and on US34 east of Kersey. The vicinity of these sites are shown in Figures 2, 3, and 4.

I-70 Golden

The first project constructed is on I-70 east of Golden. Test sections containing two types of GlasGrid and installed using two methods are located in the east and westbound lanes as shown on Figure 5. The two types of GladGrid installed are identified as 8511 and 8512. Both types of GlasGrid were installed the full width of the pavement lane except between milemarker 255 and 255.5 in the center and left (median) lane where it was installed only over the transverse cracks.

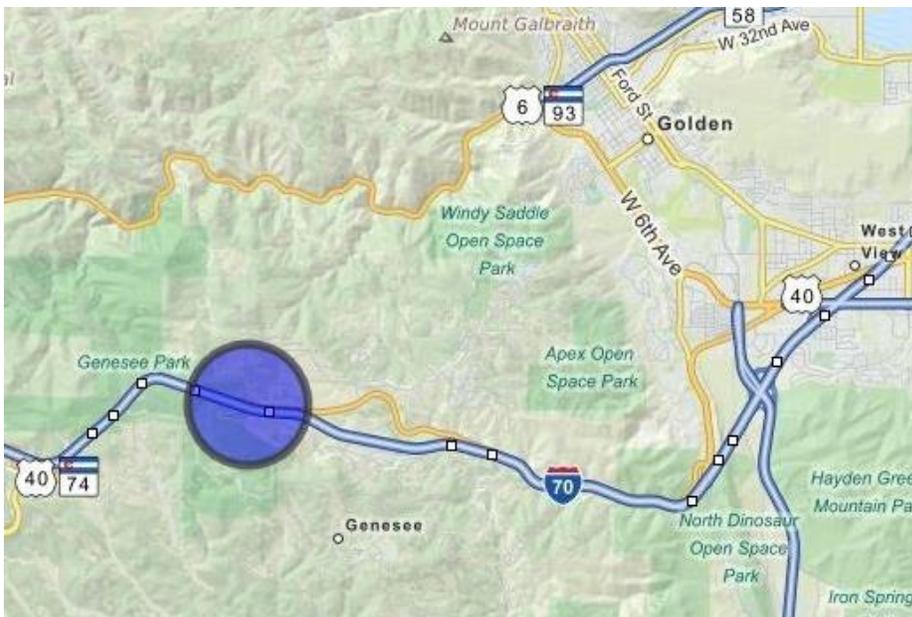


Figure 2. I-70 Test Site

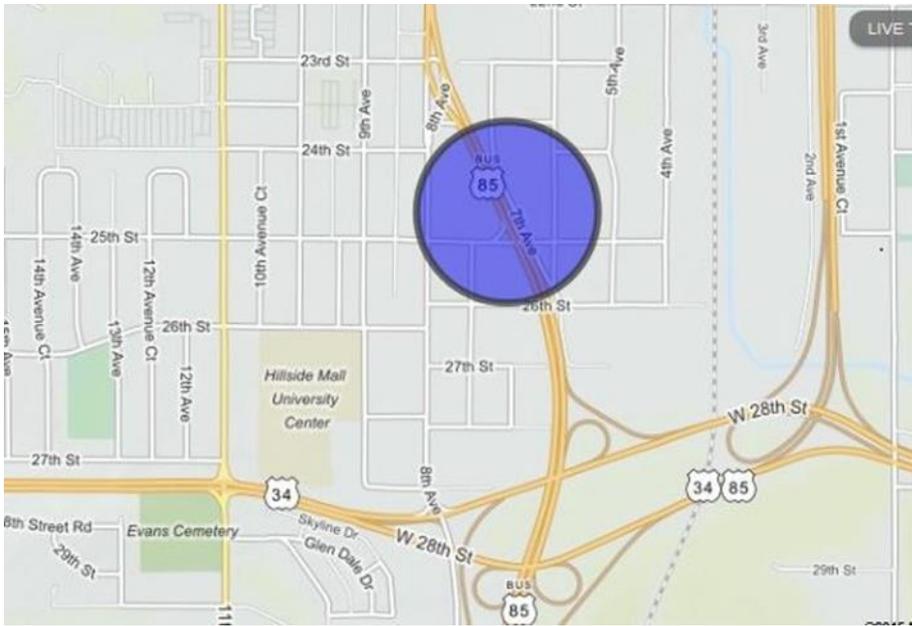


Figure 3. US85 Test Site



Figure 4. US34 Test Site

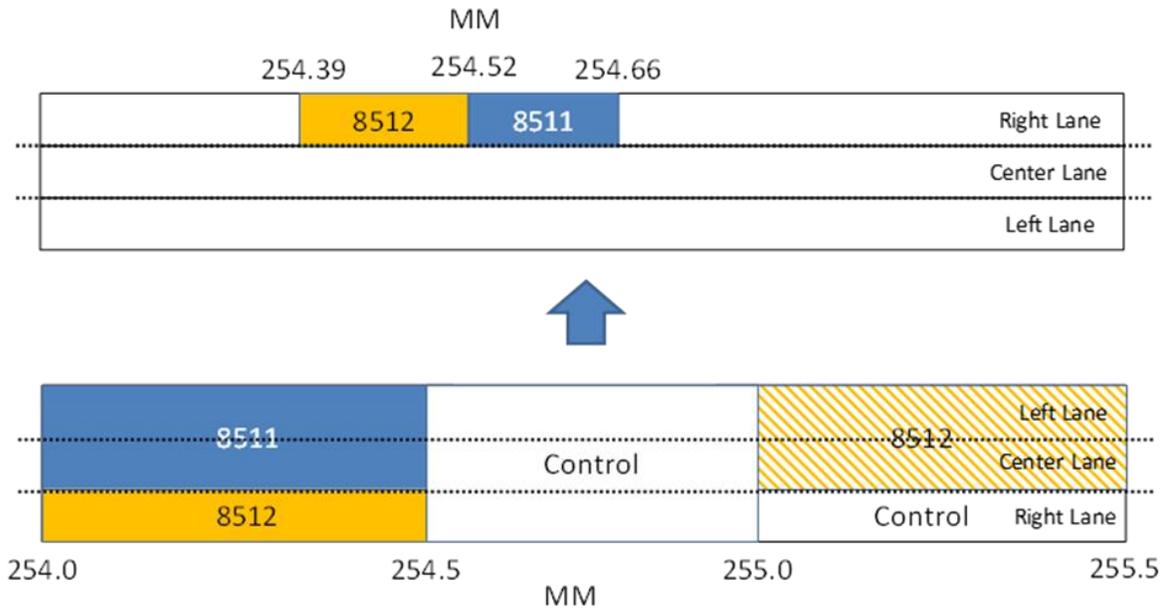


Figure 5. I-70 Test Section Locations

US85-Greeley

The second test sections were constructed on US85 in Greeley as shown in Figure 6. These test sections were constructed with an RCI system in the northbound lanes between 24th and 26th Streets, in the southbound driving lane, and in the passing lane from 25th to 26th Streets. A control section was included in the southbound passing lane from 24th to 25th Streets.

This section consists of a 3.0 inch hot mixed asphalt surface course and a 1.0 inch RCI layer placed over the original jointed concrete pavement.

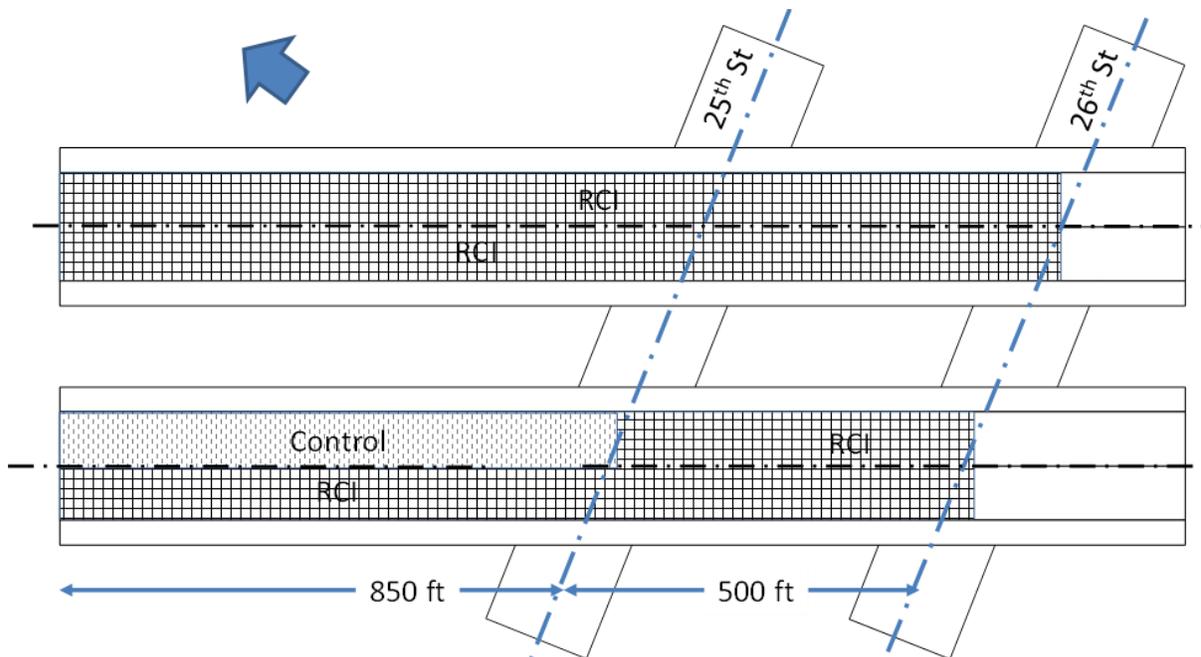


Figure 6. US85 Test Section Locations

US34-Kersey East

The third experimental location was constructed on US34 east of Kersey as shown in Figure 7.

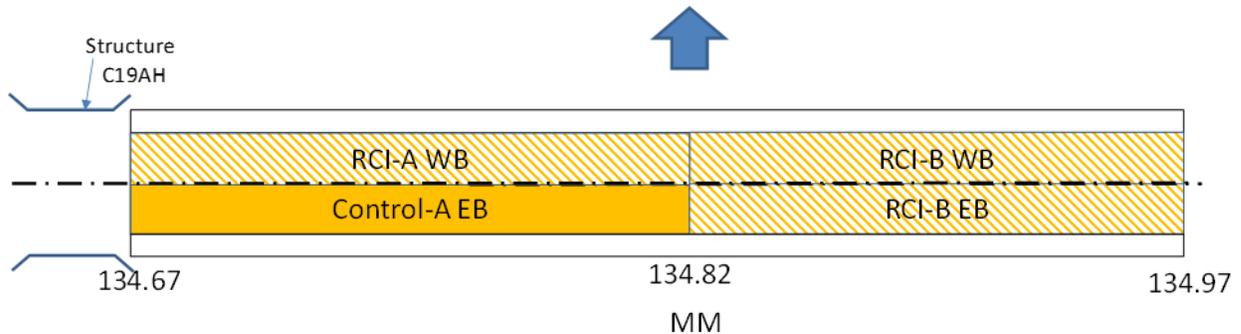


Figure 7. US34 Test Section Locations

These test sections were constructed with RCI in the westbound direction from milemarker 134.97 to the east edge of the C19AH bridge structure and in the eastbound direction from milemarker 134.82 to 134.97. The control section was placed in the eastbound direction from the C19AH bridge structure to milemarker 134.82.

This section consists of a 1.0 inch hot mix asphalt levelling course followed by the 1.0 inch RCI layer, followed by 3.0 inches of SX surface course.

PERFORMANCE

The three test sites were chosen for this research because they all included control sections where no experimental treatment was included. This is important so that relative performance of the experimental feature can be evaluated. Visual condition surveys were conducted from the beginning of construction in 2009 for the GlasGrid sections and in 2014 and 2015 for the RCI sections. The surveys followed the protocols established by SHRP (SHRP, 1990).

I-70 GlasGrid

Test and control sections are located as shown in Figure 5. Performance is presented based on the lanes and traffic direction where the sections are located. This is done to eliminate variability associated with traffic direction and traffic volume between lanes.

Comparisons to follow will be done for each lane in each direction in accordance with the materials constructed in each location as follows:

- Eastbound Driving Lane – Control vs 8512 (Full Width)
- Westbound Driving Lane – 8511 vs 8512 (Full Width)

- Eastbound Center Lane – 8511 vs 8512 (Cracks Only) vs Control
- Eastbound Median Lane - 8511 vs 8512 (Cracks Only) vs Control

Distress in these test sections consists of longitudinal, transverse and alligator cracking. Results are presented as a percentage of the original cracking when that form of distress was present in the original pavement. However, when no distress was present in the original pavement, results are shown as the amount of cracking observed in square feet or linear feet for alligator and longitudinal, respectively, for the length of the evaluation sections.

Eastbound Right (Driving) Lane

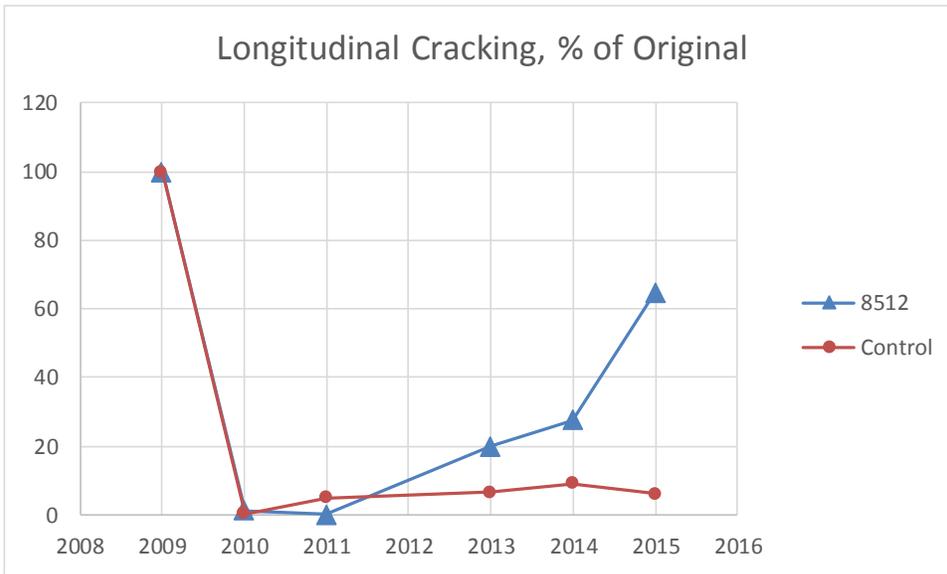


Figure 8. Longitudinal Cracking in Eastbound Driving Lane

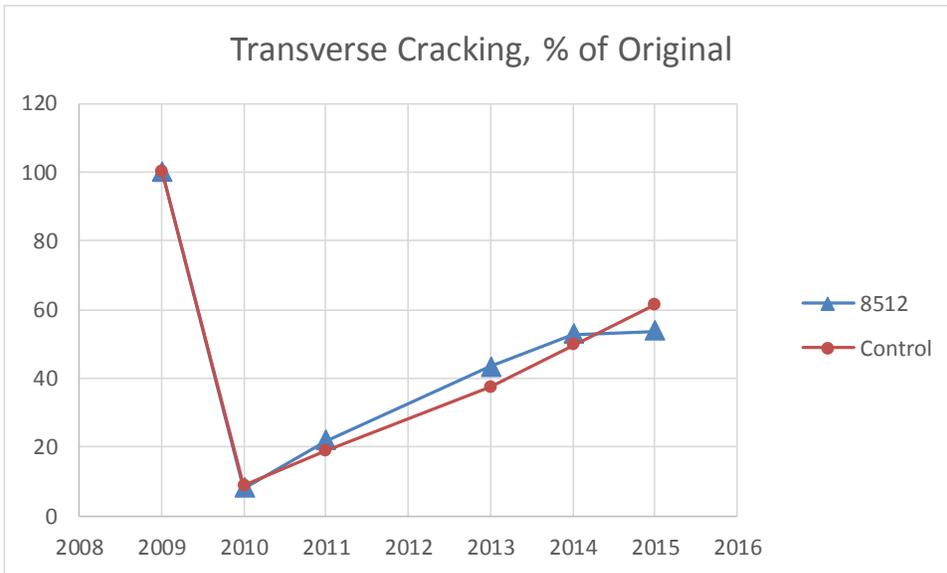


Figure 9. Transverse Cracking in Eastbound Driving Lane

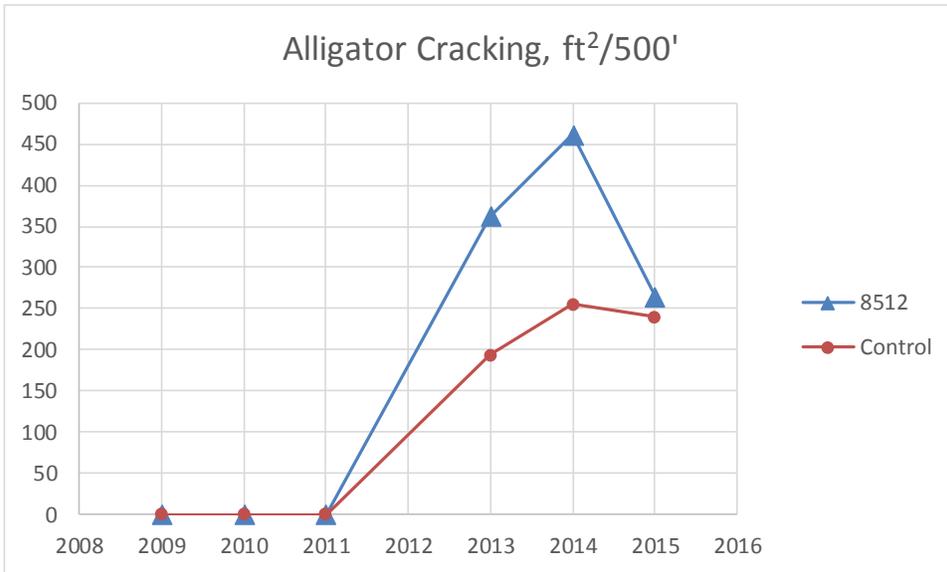


Figure 10. Alligator Cracking in Eastbound Driving Lane

Westbound Right (Driving) Lane

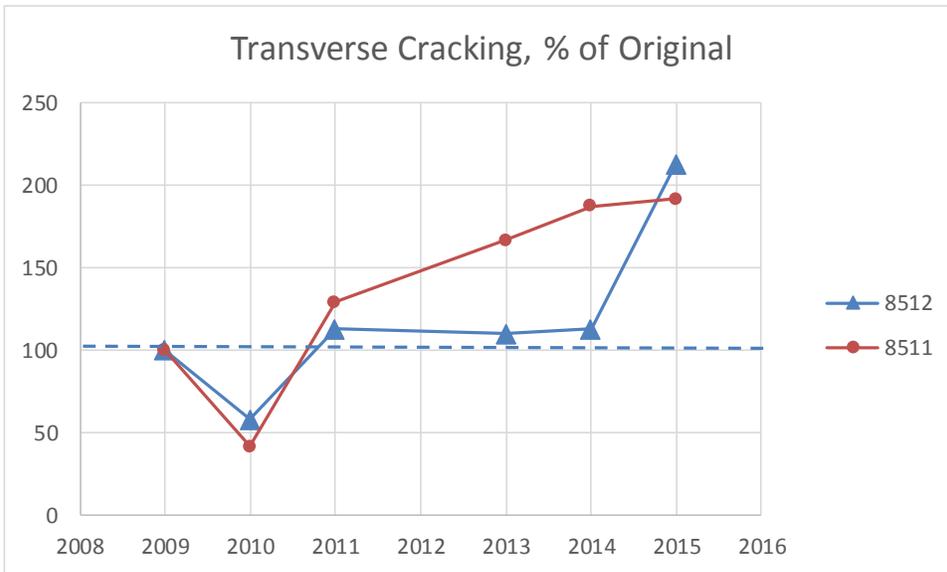


Figure 11. Transverse Cracking in Westbound Driving Lane

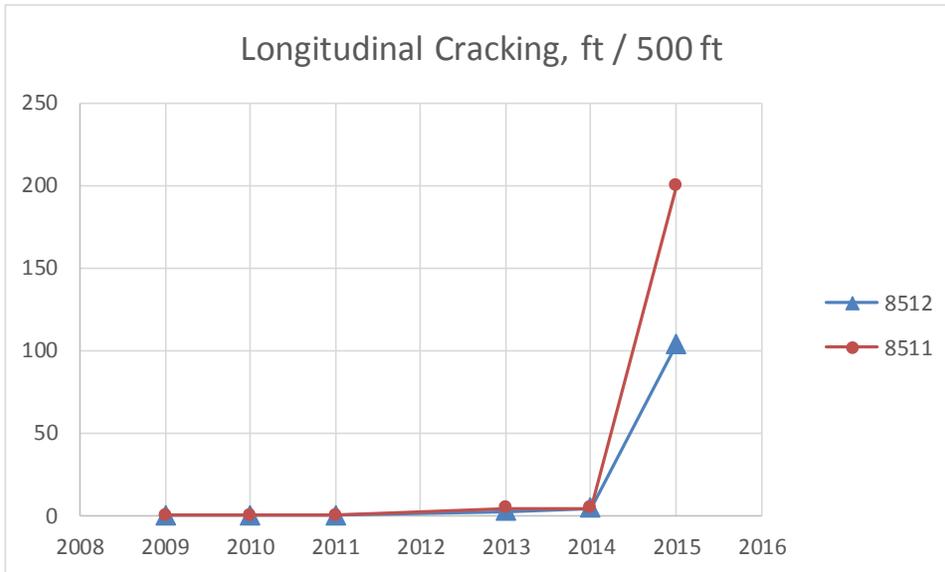


Figure 12. Longitudinal Cracking in Westbound Driving Lane

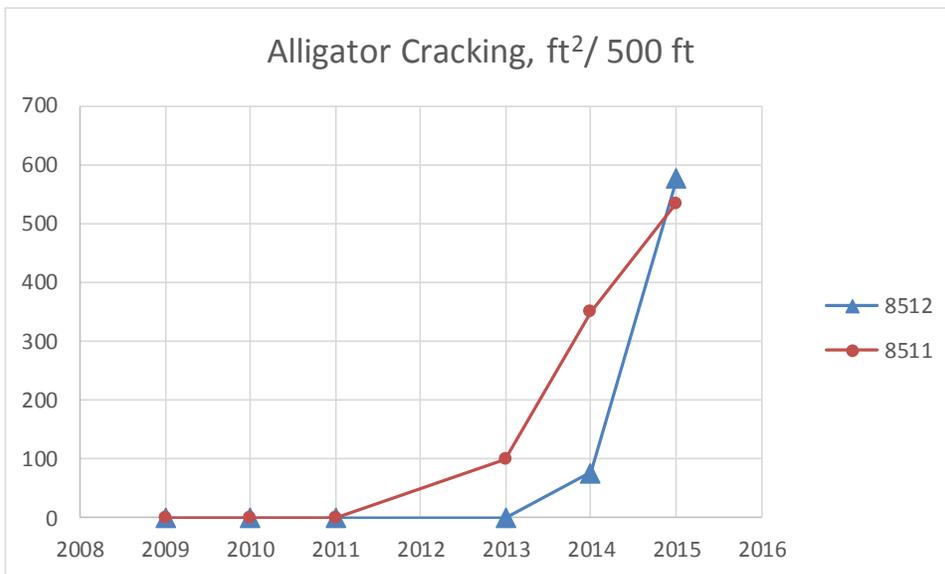


Figure 13. Alligator Cracking in Westbound Driving Lane

Eastbound Center Lane

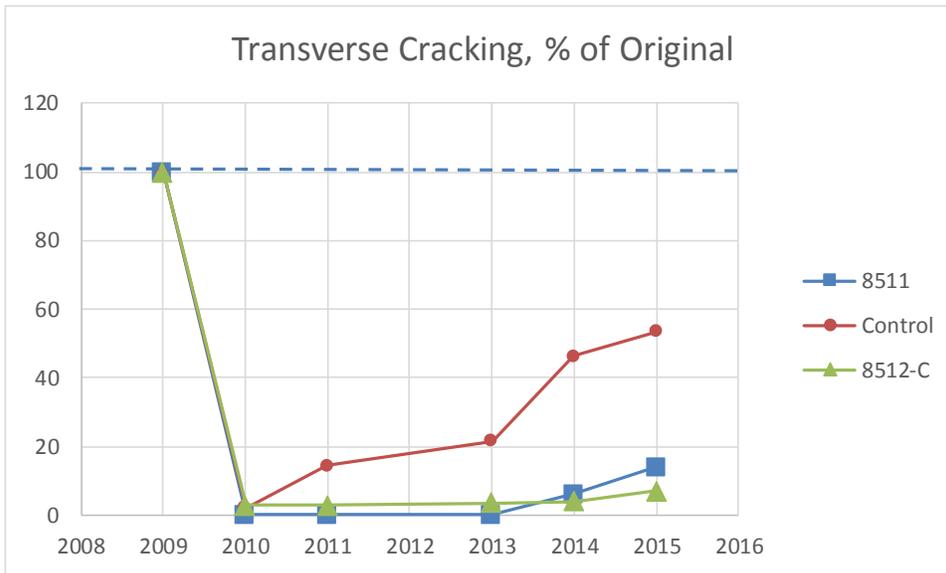


Figure 14. Transverse Cracking in Eastbound Center Lane

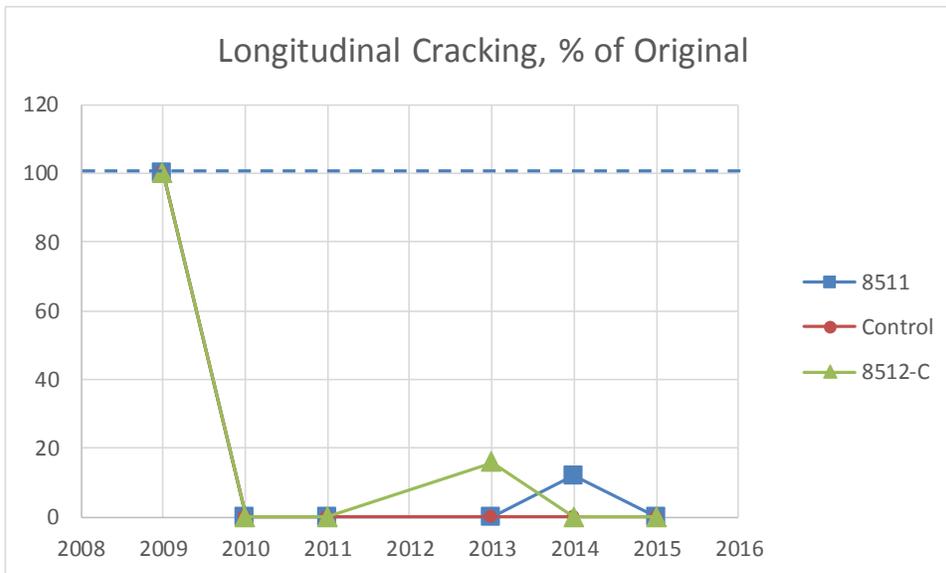


Figure 15. Longitudinal Cracking in Eastbound Center Lane

Eastbound Median Lane

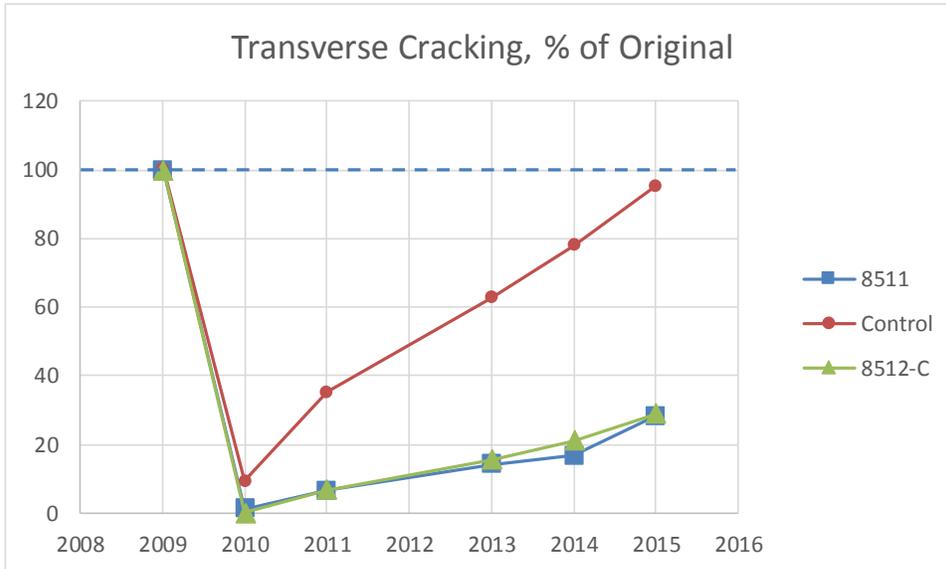


Figure 16. Transverse Cracking in Eastbound Median Lane

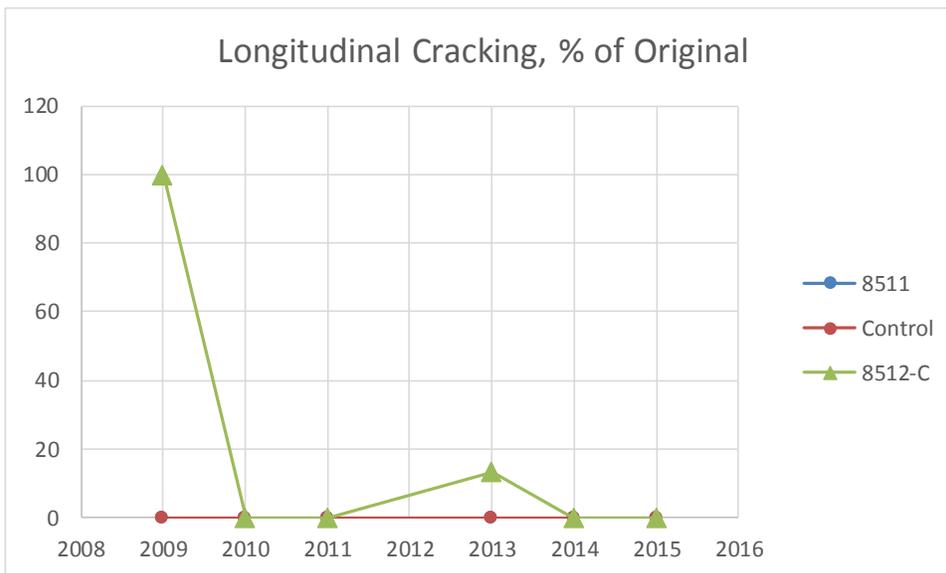


Figure 17. Longitudinal Cracking in Eastbound Median Lane

US85 - Greeley

This site has been subdivided into five segments for analysis. These segments are based on the direction of travel and the lane. For example, three segments are in the southbound lanes. One segment is the control which is in the southbound median (left) lane. The corresponding RCI segment is in the same lane. The third segment is the RCI constructed in the southbound driving lane. The other two segments are in the northbound driving and median lanes, respectively. Performance of these test sections are presented normalized with respect to the

length of the test sections. That is, the total length of cracking observed is normalized relative to the length of the test section. For example, the control section is 850 feet in length while the corresponding RCI section in the same lane is 500 feet in length. So, the length of cracks observed for each test section is divided by the length of the test section to provide an index represented as length of cracks per foot of test section. The only distress observed at this site was transverse cracking.

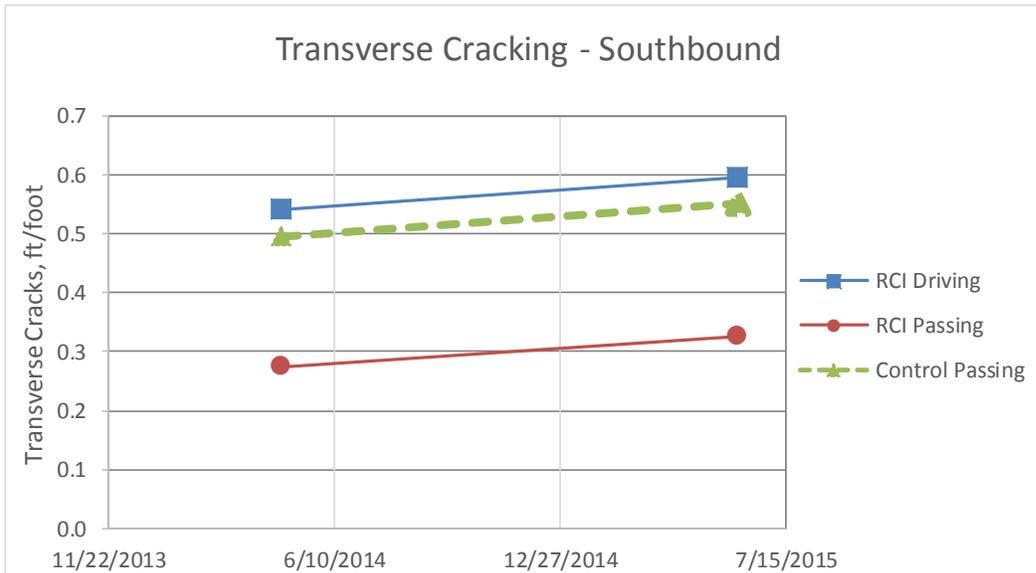


Figure 18. Transverse Cracking in Southbound Lanes of US85

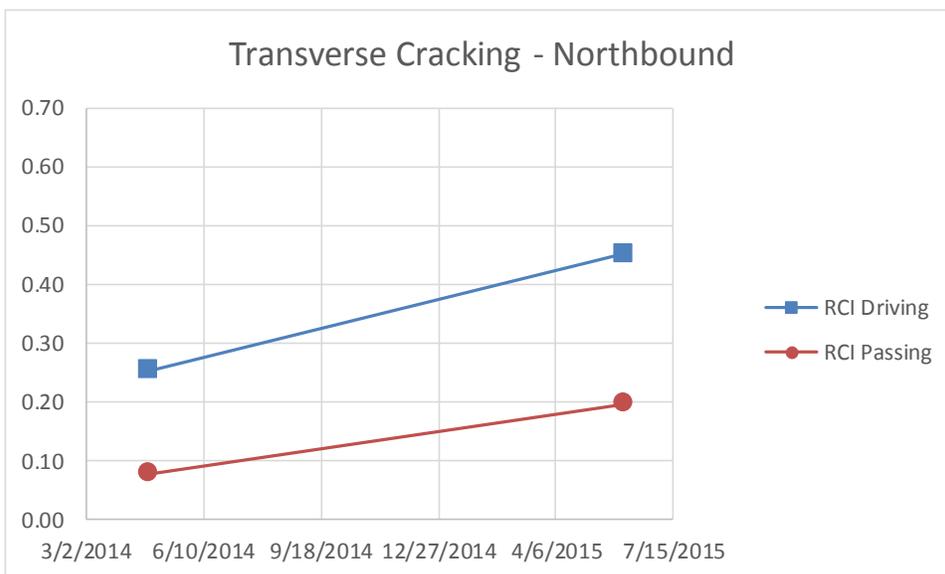


Figure 19. Transverse Cracking in Northbound Lanes of US85

US34 – Kersey East

This site has been subdivided into four segments for analysis. These segments are based on the direction of travel and whether east or west of the center of the evaluation area. Each segment is the same length, so normalization of data was not required as for US85. Transverse cracking and alligator cracking are the only distresses present, to date. Since the amount of cracking seemed to be significantly lower near the east end of the test area, the analysis has been divided into two portions labelled ‘A’ and ‘B’ for the west and east portions, respectively. The control section in the eastbound lane and the corresponding RCI section in the opposite lane is the ‘A’ portion immediately east of the bridge structure. The RCI sections to the east of the control are the ‘B’ portions. Performance of these sections are shown in Figures 20 and 21.

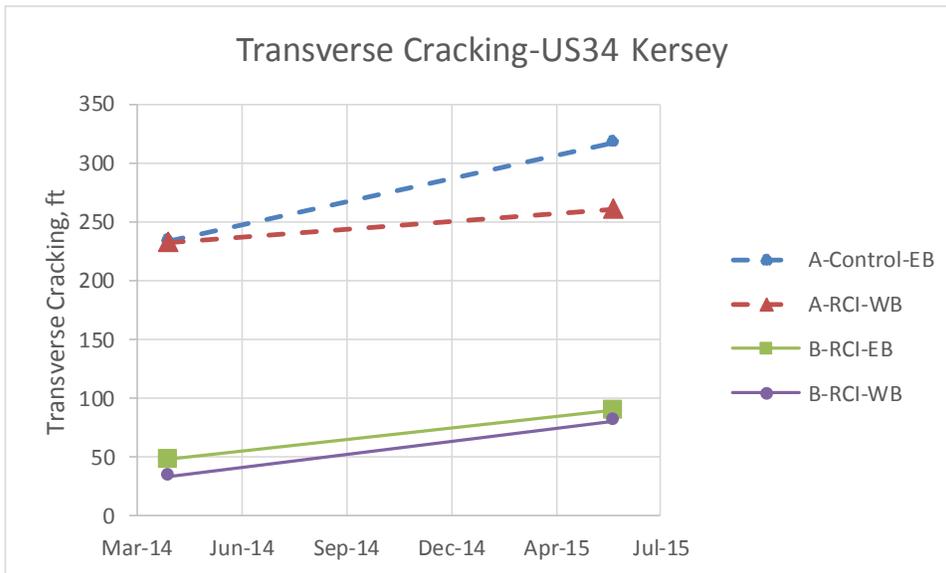


Figure 20. Transverse Cracking on US34

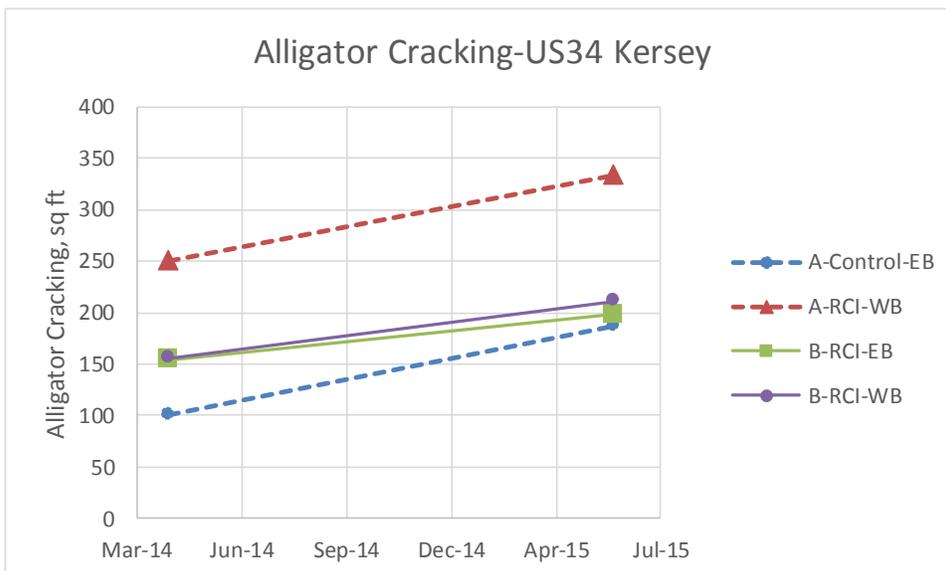


Figure 21. Alligator Cracking on US34

ANALYSIS

I-70 Golden

Performance of the GlasGrid compared with the control sections varies depending on the lane and the form of distress. Transverse cracking in the eastbound driving lane is about equal for both the control and the 8512 GlasGrid. However, the control is outperforming the GlasGrid with respect to longitudinal cracking, and possibly alligator cracking in this lane.

Both GlasGrid products are outperforming the control in the eastbound center and median lane with respect to transverse cracking, showing only 10 to 20 percent of the original cracking in the center lane and about 30 percent in the median lane. This is compared with about 60 percent and 100 percent of the original cracks for the control in these lanes. Both GlasGrid and the control show little evidence of longitudinal cracking and no evidence of alligator cracking.

Although there was no control section in the westbound driving lane for comparison the GlasGrid sections in this lane are performing poorer than the GlasGrid in the eastbound driving lane. All of the original transverse cracking had returned after two years and after six years both sections have approximately two times the original transverse cracking.

US85-Greeley

The RCI on US85 is outperforming the control in the southbound passing lane by approximately a factor of 2. That is, there are approximately half the number of reflected transverse cracks in the RCI section as there are in the control. However, the RCI in the driving lane southbound is performing approximately equal or slightly poorer than the control in the passing lane. A similar conclusion can be drawn regarding the RCI in both northbound lanes. The passing lane is performing more than two times as well as the driving lane, but both northbound lanes are performing better than their counterparts in the southbound direction.

US34-Kersey East

The RCI on US34 is outperforming the control with respect to transverse cracking but is performing poorer with respect to alligator cracking. However, the rate of increase in alligator cracking from 2014 to 2015 was about the same for the RCI as for the control, while the rate of increase in transverse cracking was approximately flat for the RCI during this period but increasing for the control.

CONCLUSIONS

1. The GlasGrid on I-70 is performing approximately equal to the control section with respect to transverse cracking in the eastbound driving lane; both sections having approximately 60 percent of the original transverse cracks present after six years. However, the two GlasGrid sections in the westbound driving lane are performing significantly poorer; with approximately two times the original transverse cracking.
2. The control section is performing better than the GlasGrid in the eastbound driving lane with respect to longitudinal and alligator cracking.
3. The GlasGrid in the center and left (median) lane is performing better than the control section with respect to transverse cracking.
4. The RCI on US85 in the southbound direction is outperforming the control section in the passing lane by a factor of two. However, the RCI in the driving lane adjacent to the control is performing slightly poorer than the control. RCI in the northbound passing lane is performing more than two times as well as the RCI in the driving lane, but both northbound lanes are performing better than their counterparts in the southbound direction.
5. The RCI on US34 is outperforming the control with respect to transverse cracking but is performing poorer with respect to alligator cracking.

REFERENCES

1. Bush, A.J. and E.W. Brooks. Geosynthetic Materials in Reflective Crack Prevention. Research Report No. SR 537, Research Unit, Oregon Department of Transportation, Salem, Oregon, 2007.
2. Buttlar, W.G., D. Bozkurt, and B.J. Dempsey. Cost-Effectiveness of Paving Fabrics Used to Control Reflective Cracking. *Transportation Research Record 1730*, Transportation Research Board, National Academy of Sciences, 2000, pp. 139–149.
3. Button, J. W. and A. Chowdhury. Field Tests Using Geosynthetics in Flexible and Rigid Pavements to Reduce Reflection Cracking. Research Report No. FHWA/TX-06/1777-2, Texas Transportation Institute, Texas A&M University, College Station, Texas, 2006.
4. Cleveland, G.S., J.W. Button, and R.L. Lytton. Geosynthetics in Flexible and Rigid Pavement Overlay Systems to Reduce Reflection Cracking. Research Report No. FHWA/TX-02/1777-1, Texas Transportation Institute, Texas A&M University, College Station, Texas, 2002.
5. Epps, Jon A., “Uses of Recycled Rubber Tires in Highways,” *NCHRP Synthesis 198*, Transportation Research Board, 1994.
6. Germann, F.P. and R.L. Lytton. Methodology for Predicting the Reflection Cracking Life of Asphalt Concrete Overlays. Research Report FHWA/TX-79/09+207-5, Texas Transportation Institute, Texas A&M University, College Station, Texas, 1979.
7. Heitzman, M., “State of the Practice – Design and Construction of Asphalt Paving Materials with Crumb Rubber Modifier,” *FHWA-SA-92-202*, Federal Highway Administration, May 1992.
8. Sanford, R. J., “Selected Papers on Crack Tip Stress Fields”, Society for Experimental Mechanics (SEM). See also MS 137, a companion volume of Selected Papers on Foundations of Linear Elastic Fracture Mechanics, R.J. Sanford, Editor, University of Maryland, College Park, Dept. of Mechanical Engineering, 676 pages/61 papers, Published 1997.
9. Hutter, W. Crack Reduction Strategies on a Pavement Warranty Project (Interstate 25 at Fountain, Colorado). Report No. CDOT-DTD-R-2003-5, Colorado Department of Transportation, Denver, Colorado, 2003.
10. Makowski, L., D.L. Bischoff, P. Blankenship, D. Sobczak, and F. Haulter. Wisconsin Experiences with Reflective Crack Relief Projects. *Transportation Research Record 1905*, Transportation Research Board, National Academy of Sciences, Washington, D.C., 2005, pp. 44–55.
11. Distress Identification Manual for the Long-Term Pavement Performance Studies. Report No. SHRP-LTPP/FR-90-001, Strategic Highway Research Program, National Research Council, Washington, D.C., 1990.
12. Vespa, J.W. An Evaluation of Interlayer Stress Absorbing Composite (ISAC) Reflective Crack Relief System. Report No. FHWA/IL/PRR 150, Illinois Department of Transportation, Bureau of Materials and Physical Research, Springfield, Illinois, 2005.